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FACULTY OF HEALTH, ENGINEERING AND SCIENCE
SCHOOL OF NATURAL SCIENCES

An Appraisal of Experiences of Climate Change and Adaptive Response to Heat Stress by Farmers in Rural Ghana

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USE OF THESIS

ABSTRACT

With the increase in average global temperatures, heat-related illnesses and deaths have unfolded as occupational and health issues. Periods of high to extreme temperatures are becoming more common and are a leading cause of weather-related deaths in many countries. In agricultural settings of African countries, heat stress is a major concern as many smallholder farmers work outdoors with limited access to cooling systems even in their resting and living environments. This study, conducted in the Bawku East part of Northern-East Ghana in 2013, examines, in the context of climate change, the trends and impacts of heat stress on smallholder farmers, as well as their responses to heat stress and the barriers to adaptation they face. The study used qualitative and quantitative research approaches, including survey questionnaires, focus groups discussions, policy reviews and measurements of environmental heat exposure. The study identifies that heat exposure is prevalent at the household level and on the field of cultivation. Many farmers reported very hot conditions, in both their resting places and working environment, which were conducive to heat stress and other heat-related illnesses. The situation is further exacerbated by their weak adaptive capacity due to poverty and the usage of low technological equipment which requires the expenditure of many hours in hot conditions to conduct their farming businesses. Farmers employed coping strategies instead of long-term adaptive methods. This situation is particularly manifested by farmers who grow legumes, vegetables and cereals. Farmers' dwellings are designed using local architectural styles with limited ventilation. On farms, apart from high heat exposure in the range of WBGT 33-36^{0}C, the situation is worsened by the use of primitive equipment such as cutlasses and holes that require high physical input. The nature of heat at farmers resting places during the day falls within the threshold of 29-34^{0}C in WBGT, while night the time is 19-30.5^{0}C. Further to this, farmers have inadequate knowledge about precautionary health measures to avoid or minimize heat-stress related health effects and specifically the need to rest when tired. Generally, farmers' day to day activities are underpinned by the dictates of their human energy with little cognizance of health effects of hot environmental conditions. The practical measures enshrined in the Ghanaian National Social Protection and Climate Change Policies do not recognize and address heat stress as an occupational issue. The study recommends the need for government-led intervention to tackle farmers' accommodation and improve manual farming by incorporating mechanical methods. Also, based on one rainy season throughout the year, it will be necessary for government to provide more irrigation schemes for farmers. This will

prevent them from using their manual energy to draw water from hand dug boreholes, which requires a farmer to spend many hours in hot and humid conditions.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

i. Incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;
ii. contain any material previously published or written by another person except where due reference is made in the text of this thesis;
iii. contain any defamatory material; or
iv. contain data that have not been collected in a manner consistent with ethics approval.

I also grant permission for the library at Edith Cowan University to make duplicate copies of my thesis as required.

ACKNOWLEDGEMENTS

This thesis is dedicated to my father, Mr Emmanuel Kwaku Adu and my mother, Ms Cecilia Attaa Abena, Who have always supported me in heaven in all my endeavours. Rock of ages shields them in your bosom as you guide and protect my siblings and me.

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I therefore thank my wife Ewurama and my son Emmanuel, for their patients towards this academic journey. I wholeheartedly appreciate the constant support of my brothers Kwame, kwaku, kwabena and Duodu for prayers towards a successful completion of this academic venture. I thank my sisters Dora and Bertha for their prayers as well.

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CHAPTER 1

GENERAL INTRODUCTION

This chapter introduces the background and scope of the research problem that was investigated. Key methods of the research are summarized and a series of published papers are introduced as separate chapters of the thesis.

1.1 GENERAL NATURE OF CLIMATE CHANGE AND HEAT STRESS

A basic issue of global warming is a universal scale surge in absolute humidity (Manabe & Wetherald, 1975; Manabe & Stouffer, 1979) and increase in average temperatures (IPCC, 2007). As global warming continues, the response of integration of temperature and air humidity can pose elevated setbacks on human activity in tropical environments, especially in the time of increased heat stress (Delworth et al., 1999; Kjellstom 2009).

In spite of the rise in global average temperatures (of 0.74^{0}C) over the last century, it is envisaged that further increases of $1.8\text{-}4.0^{0}$C will occur within and beyond this century (IPCC, 2007). In the Conference of Party meeting (COP 17) of the United Nations Framework Convention on Climate Change (UNFCCC), climate change impacts on health and its associated adaptation measures to reduce health impacts were stressed as priority issues (WHO, 2011).

It is imperative to note that human health issues aligned to climate change are predominantly downscaled to concerns of heat stress, respiratory diseases, food insecurity, malnutrition, spread in infectious diseases and health repercussion of extreme weather events (McMichael, 2003; IPCC, 2007). Although climate change is expected to result in global-scale health effects, the poorest populations are likely to experience the worse impacts due to their poverty and low adaptive capacity (Parry, 2007). It cannot be gainsaid that the repercussion of global warming is the rise in global average temperatures with its corresponding occurrence of extreme heat events in many parts of the tropical world (Hales et al., 2003; Meehl & Tebaldi, 2004; Fischer & Schär, 2010). Heat stress and heat extremes are projected to have serious consequences on human populations in tropical regions where such effects are already frequently experienced (McMichael et al., 2008). In line with this perspective, global comprehension on the ways heat stress can affect population health is not only necessary, but timely and appropriate (Ebi, 2008), particularly since heat is the leading cause of weather-related deaths in countries like USA (Luber & McGeehin, 2008). Respiratory and cerebrovascular diseases are known to be exacerbated by heat extremes

(Langkulsen et al., 2010). For these reasons, it is necessary to conduct more research into the impacts of heat stress in the context of climate change. As climate change is intensified, areas with both frequent and minimal issues of heat exposure are likely to incur greater incidence of heat stress among the population. The level of adaptive capacity and awareness of heat stress in a given population can influence their risk to heat exposure (Haines et al., 2006).

In heat-prone environments, such as the tropical developing world, adaptation measures encompass acclimatization, frequent and routine use of air conditioning, adjustment of human behavior and improved architectural style of the workplace and home (Luber & McGeehin, 2008; Younger et al., 2008; Huang et al., 2011). Behavioral forms of adaptation, such as regular fluid intake, are known to prevent or minimize heat-related impacts among outdoor workers. Adaptation research is predominantly carried out in the developed world and some successful measures to offset heat stress in these regions have included health education, early warning systems of heat waves, proper home ventilation and urban shade (Kovats et al., 2006). In spite of improved adaptation to reduce heat stress effects on populationsin the developed world, there is even still the need for further research on how to improve adaptation to heat stress in the more vulnerable groups, such as the elderly, in the lightof climate change.

In the tropical developing world, and especially in Africa, rain-fed farming, subsistence fishing, and hunting are directly impacted by climate change (Adger et al., 2003), especially exposure of heat stress on the working people (Kjellstrom, 2009). Even though the African contribution to emissions of greenhouse gases is marginal, the effects of climate change in this region can be acute and is manifested as food insecurity, drought, flood, heat weaves and heat-related diseases (Africa Partnership forum, 2007; Ziervogel et al., 2008). As a result, it is clear that the efforts to achieve the set objectives of Millennium Development Goals are being undermined (African Development Bank Group, 2012). To this effect, climate change adaptation has been identified as the complementaryapproachto keep tropical developing countries on track to achieve sustainable development goals. Therefore, assessment of current adaptation strategiesis crucial as a prelude to determine how humans can adapt to future impacts of climate change (Ziervogel et al., 2008).

Studies on heat stress in the developing world has received marginal research attention (Kjellstrom, 2009) in the wake of confirmed but erratic increases in average temperatures across African region (Collins, 2011), although there has been sustained increases in atmospheric temperatures across West Africa over the last few decades (New et al., 2006). In a continent where a large number of the people are outdoor farmers (Ziervogel et al., 2008),

productivity will be reduced if frequent breaks are observed as a form of adaptation to environmental heat exposure, which is known form of coping strategy in the agricultural setting within Africa (Kjellstrom, 2009).This create the need for assessment of the level of heat that farmers are exposed, their general experience of climate change, barriers of adaptation and levels of response to heat exposure. These are key stepsin assessing climate change impacts on a given population (Kjellstrom, 2000; Byass et al., 2010).

1.2 HEAT STRESS AS HEALTH AND OCCUPATIONAL ISSUES IN DEVELOPING COUNTRIES

Heat exposure is a health, environmental and occupational issue. It is predicted that increases in average global temperatures will have corresponding impacts especially on people working in outdoor environments (Kjellstrom, 2009). The greater part of such impacts is projected to occur in developing countries (Holmer, 2009; Byass et al., 2010). A large number of these workplaces are devoid of any cooling system (Hyatt et al., 2010). A largenumber people worldwide are smallholder farmers (Nagayet O, 2005) who work under the direct exposure of sun and heat (Kjellstrom, 2009). Over two billion farmers are exposed to heat stress and climate change with a large number of them found in the African region (Nilsson & Kjellstrom, 2010). Heat-induced illnesses occur when the body is not able to maintainnormal body temperature resulting in excess heat in the body. Also, when there is a decrease in bodily heat dissipation to the environment, heat-related illnesses can occur. The body is able to maintain a heat threshold of 37-39 $^{\circ}$C depending on individual physiological capabilities. Over this threshold heat-related injuries, like heat stroke and hyperpyrexia, can emerge (Leithead & Lind, 1964). Heat-related illnesses can occur in various forms. Dehydration can causedizziness to fainting and sometimes heat stress can predispose people to cardiovascular and respiratory diseases (Parsons, 2003).

Exposure of farmers to heat stress is a threat to food security and theirhealth. A farmer’s exposure to heat stress is regulated by air temperature, humidity, mean temperature of theirworking environment and air movement (Srivastava et al., 2000). Radiant heat from the sun is an additional contributory factor indetermining farmers’ exposure to heat stress (Parsons, 2003; Parsons, 2006). When there is intensive workload in hot working environments, there is the tendency forthe farmer’s core body temperature to rise above 38 $^{\circ}$C, which is likely to diminish work capacity (Kerslake, 1972; Bridger, 2003). Depending on individual physiological responses to heat exposure, core body temperature above 39 $^{\circ}$C can affect the ability of humans to effectively perform mental task (Ramsey, 1995) which may

increase the rate of accidents in a given working environment (Ramsey et al., 1983) and can ultimately generate heat stroke and heat exhaustion (Hales & Richards, 1987). Apart from the elevation of the human core body temperature responsible for increasing the threat ofheat stress conditions, dehydration is also a consequenceespecially where there is inadequate fluid consumption. This can lead to clinical diseases such kidney malfunctioning (Cortez, 2009; Crowe, 2010).

Costello et al (2009) indicates that outdoor heat research has not been prominent in the African region. This has happened at the time when Africa is predicted to have low adaptive capacity to combat climate change due to poverty and low technological know-how (Parry, 2007). People living in low and middle income countries in the tropical world engaged in outdoor activities are most vulnerable to heat stress (Hanna et al., 2011). This is due to robust dependence on physical labour under intense sunlight and little or no cooling systems (Kjellstrom, 2009). The most prominent heat indexcommonly used in outdoor heat measurement is the Wet Bulb Globe Temperature (WBGT). It is clear that as WBGT increases above 26 °C in a hot working environment, work capacity reduces, which paves the way for estimating the impact of heat during climate change (Kjellstrom, 2009).

This index is substantiated internationally and widely measuredin both outdoor and indoor environments (Holmér, 2010). In the Africa region, a large number of the population obtain their living from outdoor farming which implies that increases in outdoor heat can have significant effects on the livelihood of smallholder farmers. Increases in WBGT values have caused excessive heat in many parts of the world especially south-east Asia indicating that climate change can affects levels of heat exposure in tropical regions with low adaptive capacity (Hyatt et al., 2010).

Apart from occupational concerns of heat stress in tropical developing countries (Kjellström, 2009), it is also unquestionable that heat stress is increasingly creating public health problems in these regions (Luber & McGeehin, 2008; Kjellström, 2009; Hyatt et al., 2010; Hanna et al., 2011). There are a lot of studies presenting the relationship between heat stress and productivity suppression worldwide. However, it is intimated, that there is a great room for investigating impacts of heat exposure on workers who work outdoor especially in low-income tropical countries (Nag & Ashtekar, 2007; Kovats & Hajat, 2008; Langkulsen et al., 2010; Nilsson & Kjellstrom, 2010). Although there is a growing amount of research on the effects of heat stress and heat exposure on both indoor and outdoor workersin Asian developing countries (Srivastava et al., 2000; Cortez, 2009; Langkulsen et al., 2001), there is a lacuna in heat stress research in Africa.

In Ghana, there is no significant research on heat exposure on outdoor workers even though many Ghanaians are engaged in outdoor farming and working in hot conditions. As climate change is envisaged to increase heat stress, it is timely for studies to estimate the health and occupational impacts associated with heat exposure, and also the comfort of workers at the household level where they rest. The reduction of health impacts of heat is contingent on effectiveness of adaptation methods.

1.3 RESEARCH SCOPE AND BACKGROUND OF THE STUDY

Ghana is divided into ten regions and located on the west coast of Africa. The land area is 238,537 km^2. The northern part of the country shares a border with Burkina Faso and the southern part bordersthe Gulf of Guinea. The eastern part of the country shares a border with Togo, while the western part borders with Ivory Coast. Ghana was selected for this study because it shares many of the environmental and demographic features of the African continent (World Bank, 2015).

Climate change is having significant impacts on the Ghanaian population with average temperature increasing by 1°C in the southern sector while the northern part of Ghana has experienced an average surge over 1 °C in the last fifty years (Agyeman-Bonsu et al., 2008; McSweeney, 2012). Moreover, the country is expected to sustain an increase in temperatures between 2-3 °C with the northern sector likely to experience 2.5-3 °C by the year 2050 (EPA, 2007). The people usually work under the exposure of heat stress with minimal cooling systems in place at both the household and farm levels (Frimpong et al., 2014).

The specific area in Ghana for the study is Bawku East. This area is encompassed by latitude 11° 11' and 10° 50' north and longitude 0° 18' west and 0° 6' east in north-eastern part of Upper East region. The study area shares borders with Burkina Faso in the north, and the Republic of Togo on the eastern side of the study area. Bawku West district borders the western side of the study area and Garu-Tampane district is at the southern part of the study area.

The area is about 120-150 meters above sea level (Ministry of Food and Agriculture, 2014) and has a population of 205, 000 with 65% being farmers who may also be involved in petty trade activities. For the purpose of this study the geographical definition of Bawku East include the villages of Binduri, Pusiga, Manga and Garu among others. Based on expert advice from the Ministry of Agriculture in Ghana with regard to selecting rural communities, Binduri, Pusiga, Manga and Garu were the key areas that are involved in the geographical

specification of Bawku East. Meteorological data is also readily available from Binduri, Manga and Garu.

Environmental heat measurements were conducted in Pusiga. The reason for selecting Pusiga for this measurement is that the farmers were prepared to protect the heat measuring instruments from being stolen and the climate shares the features of the other villages. This was important for the success of the study. Household survey and focus group discussion were conducted in Binduri, Manga and Pusiga. The three key villages for the household survey had an estimated 15,000 small holder farmers who do not engage in any other activity. These villages were selected in that they are severely exposed to extreme temperatures while smallholder farming is the predominant occupation.

The area is projected to incur temperature surge at 2.5-3°C within this century and beyond (EPA, 2007). The area is characterized by Sahel savannah woodland agro-ecology (Ministry of Food and Agriculture, 2014). Rainfall in the area averages 800-850 mm per year. Uni-modal patterns of rainfall allowa single main season for farming activities starting from May/June to September/October (Antwi-Agyei et al., 2014; Ministry of Food and Agriculture, 2014). The main type of crops grown in these areas is cereals, legumes and vegetables (Ministry of Food and Agriculture, 2014). As a result of fewer rains in most part of the year, hand-dug bole holes arethe predominant form of irrigating farmers' crops. This form of outdoor work is very hard and labour intensive in hot and humid environments (Frimpong et al., 2014). In Ghana there is no or little regulation of outdoor heat exposure. People rest when they feel hot and tired and work at any time. The north east part of Ghana is poorly developed while a large number of residents are engaged in outdoor subsistent farming (Webber, 1996; Whitehead, 2006; Laube et al., 2008). Temperature analysis indicates an increasing trend of temperature since 1931.

1.4 PROBLEM STATEMENT, AIMS AND SPECIFIC OBJECTIVES OF THE RESEARCH

Bawku East was selected in the present study because previous studies have identified the area as the poorest in Ghana (Whitehead, 2002, 2006) with the highest average temperatures in the country (EPA, 2007). Moreover, over 65% of the residents there are engaged in outdoor farming in hot and humid environment (Ministry of Agriculture, 2012). Generally, research reports have identified that heat stress has both food insecurity implications and public health significance (Ziervogel et al., 2008; Kjellstrom, 2009; WHO,

2011) and that people who are largely reliant on outdoor farming need to improve their adaptive capacity in terms of their livelihood patterns so that they can be more climate resilient (Kjellstrom, 2009).

As climate change, specifically temperature rises, is predicted to worsen in this part of northern Ghana (Luber & McGeehin, 2008), it is imperative for a comprehensive assessment to be conducted on the trends and impacts of climate change and heat stress on smallholder farmers' health, productivity and coping responses. The ultimate goal of this study is to provide effective mechanisms for improved working and living conditions so as to alleviate food insecurity known in this part of Ghana.

Therefore, the broad aim of this study is to assess farmers in Bawku East for their experiences of climate change, heat exposure and adaptive responses inboth their home and work environments, as well as assessing the impacts of heat stress on their capacity to work. To achieve the above aim, the following specific objectives are addressed:

1. Identify key government policies on climate change, heat stress and social protection that enhance or reduce adaptive capacity of smallholder farmers.
2. Quantify the recent trends in temperature and relative humidity in order to confirm an increase in temperatures over the past fifty years.
3. Determine the extent of heat exposure on farmers in their working and living environments and to determine the effectiveness of adaptation strategies to deal with climate change and heat stress.
4. Identify yearly trends of heat exposure and the effectiveness of using Lascar EL-USB temperature and humidity sensors to measure heat exposure in a remote setting
5. Determine the experiences and awareness of climate change and heat stress risks among farmers in both their working and living environments
6. Establish the impacts and coping mechanisms of farmers to heat exposure and climate change
7. Identify the barriers to heat stress adaptation at household and farm level

1.5 OVERVIEW OF RESEARCH METHODS AND DATA COLLECTION

The study commenced with trend analysis of temperature and relative humidity collected from the nearest three weather stations in Bawku East. The purpose was to establish if there had been a trend of increasing temperature since 1961. Data was obtained from 1961-

2012 and analysed using regression to establish rate of change for yearly mean maximum and minimum temperatures and relative humidity at 6am and 3pm**.**

A mixed method research approach consisting of quantitative and qualitative data with the aim achieving triangulation and complementarities was used. The purpose of adopting triangulation is to collect, analyse and seek consistency between quantitative and qualitative approach. The use of complementarities in the sphere of quantitative and qualitative methodology of research was aimed at measuring overlapping but different facts of association and distinction between experiences of heat stress and climate change vulnerability on farmers in a single study (Caracelli & Greene, 1993; Creswell, 2003).The adoption of varied sources of evidence in a single study exposes the researcher to adequate comprehension of the study problem by bridging the gap of numeric pattern emanating from quantitative data and salient information from qualitative data (Marten, 2003).

Famers were the study population. These included farmers who produced cereals, vegetables and legumes from the three selected farming communities at Bawku East of Northeast Ghana. Both males and female farmers were included in the study. A combination of purposive and simple random sampling techniques was used in selecting 385 participants for the study. Purposive sampling was used in selecting head farmers, community leaders and agricultural extension officers for Focus Group Discussion. Consequently, four persons were purposively sampled while fifteen farmers were randomly sampled based on their indicated interest to participate in the Focus Group Discussion (FGD).The use of purposive sampling was to specifically include experienced persons with regard to farming, heat stress and climate change. Random sampling was used to select 385 participants for the survey (questionnaire), out of which the nineteen were selected for focus group discussion. The sampling of 385 participants out of estimated farming population of 15000 was based on the sample size determination method of Krejcie and Morgan (1970), and was confirmed by the Australian Government online method for determining a sample size (NSS, 2012). In each of the farming community in Binduri, Manga and Pusiga simple random sampling was used to select 128 farmers for the study. In the statistical analysis of the selected sample size, 77 farmers were excluded after identifying that they were engaged in other businesses apart from farming, leaving 308 farmers for the analysis.

The methods of data collection were primarily centred on surveys, interviews and focus group discussion. Questionnaires, interview guides, and focus group discussions were the instrumentation involved in the collecting of primary data in this study (Sarantakos, 1998; McBurney & White, 2007). Questionnaires were used for farmers, agriculture extension

officers, chief farmers, and community heads. Focus group discussion (FGD) was conducted for key persons like chief farmers, community heads and agriculture officers.

The analysis of the study involved the use of descriptive statistics and inferential deduction for both qualitative and quantitative data. Primarily, Statistical Product and Service solution (SPSS) was the statistical program used toanalyse the data.Chi square tests wereused to determine the association between variables such as education, age, gender and experiences of heat stress and climate change.

Apart from the focus groups and survey questionnaires, and to fulfil triangulation, environmental heat measurements using two different instruments were conducted to gaugethe level of heat exposure faced by farmers in Bawku East. To achieve this objective, Lascar EL USB temperature and humidity sensors were placed in the outdoor working environment of farmers and intheir homes and resting places where they cool down.Six of these sensors were deployed to both resting and working environments. Three were placed in a shade at the working environment of farmers while two were placed in resting and living environment of farmers. One was placed closed to a weather station to compare temperature and relative humidity readings.

Data from these instruments were entered into Excel spread sheetsemploying Lemeke's (2013) formula for calculating heat stress from Lascar El USB data, represented as follows:

WBGT(indoors) = 0.67*Tnwb+0.33*Ta-0.048*log(ws) *(Ta-Tnwb) using the Bernard Method and for indoor wind speed (ws) up to 3m/s, and where Tnwb (Natural Wet Bulb Temperature) is calculated from Tg(globe temperature) by iteration, and Ta is ambient temperature.

WBGT (Outdoor) =0.7*Tnwb+0.2*Tg+0.1*Ta using the Liljegren method to calculate Tg and Tnwb, where Tnwb is (Natural Wet Bulb Temperature) and is calculated from Td by iteration.

Moreover, content analysis and descriptive research designs were employed in the review of the thesis. Over 400 articles related to the concept of social protection, climate change policies, climate change adaptation strategies, heat stress vulnerability and smallholder farmers in developed and developing countries were reviewed. About 300 key articles were then purposely selectedin order to obtain more specificinformation for the review. Climate change, heat stress, social protection and smallholder farmers are multidisciplinary issues that demand scholarly facts and articles from different sources.

Hence, different databases were carefully examined using a variety of search engines. Prominent among the search engines were: Google Scholar, ‘One Search’ (the search engine of Edith Cowan University’s library) and Web of Science, among others. The key words fundamentally used in the search were “trend of temperature in Ghana”, “occupational heat stress”, “climate change policy in Ghana”, “national social protection strategies”, “climate change”, “social protection” and “smallholder farming”. These presented series of information encompassing a wide range of scholarly peer reviewed journals, making available the relevant articles on climate change, heat stress and smallholder farmers.

1.6 PUBLICATIONS BASED ON THE THESIS

The study is organized in chapters as stand-alone research papers submitted to peer-reviewed journals for publication. Three of the papers have been published; two have been accepted and are under preparation for publication, while two papers are under review. Below are the details of published, accepted and submitted papers to international peer-reviewed journals.

1. Frimpong, K., Oosthuizen, J., & Van Etten, E.J (2015). A review of climate change adaptation and social protection policies in Ghana: An evaluation of the extent of the policies in reducing impacts of climate change and heat stress on smallholder farmers in Ghana. *Climate and Development*, (Published by Taylor and Francis Publishing Group), under review
2. Frimpong, K., Oosthuizen, J., & Van Etten, E.J (2015). Impacts and Adaptation of Heat Exposure by Rural Farmers in Northeast Ghana. *Climate and Development,* (Published by Taylor and Francis Publishing Group). Accepted and in press.
3. Frimpong, K., Oosthuizen, J., & Van Etten, E.J (2015). Global Warning and the yearly trend of heat exposure on farmers in North-East Ghana. *International Journal of Biometeorology*, (Published by Springer for the International Society of Biometeorology) Under review
4. Frimpong, K., Oosthuizen, J., & Van Etten, E.J (2014). The Extent of Heat on Health and Sustainable Farming in Ghana–Bawku East. *Sustainable Agriculture Research, 3*(3), p56. (Published by Canadian Centre for Science and Education DOI:10.5539/sar.v3n3p56, URLhttp://dx.doi.org/10.5539/sar.v3n3p56
5. Frimpong, K., Oosthuizen, J., & Van Etten, E.J (2014). Recent Trends in Temperature and Relative Humidity in Bawku East, Northern Ghana. *Journal of Geography and*

Geology, *6*(2), p69. (Published by Canadian Centre for Science and Education URL: http://dx.doi.org/10.5539/jgg

6. Frimpong, K., Oosthuizen, J., & Van Etten, E. J. (2014). The Barriers of Adaptation to Heat Stress in Ghana. *International Journal of Social Ecology and Sustainable Development*, (Published by IGI Global) Accepted for publication and in Press.
7. Frimpong, K., Oosthuizen, J., & Van Etten, E. J. (2014). Experiences of Heat Stress Vulnerability and Climate Change among Farmers in Ghana. *Journal of Environment and Earth Science*, *4*(17), 100-110.

1.7 STRUCTURE AND ORGANISATION OF THE THESIS

This study is organised into chapters, with this chapter (chapter 1) consisting of the introduction to the study. This includes general overview of climate change and heat stress with respect to heat stress as a health and occupational issue. It explains the background of the study and outlines the statement of the problem, aims and justification of the study. It presents the status of the papers involved in this study and finally concludes with the structure of the thesis.

Chapter 2 involves extensive analyses of key government policies on climate change, heat stress and social protection to identify if it has a bearing on reducing heat stress on smallholder farmers as climate change will intensify the impact of heat stress on the vulnerable groups like outdoor farmers. It integrates a literature review of climate change and heat stress and develops a conceptual framework to explorethe interaction between climate change adaptation and social protection policies that can either aggravate or reduce the impact of heat stress and climate change on smallholder farmers, which underpin the entire study. The results of this analysis expose the gaps in policies directly relevant to vulnerable smallholder farmers and what need to be done to improve their livelihood. This chapter addresses objective one of the study and is submitted for publication in the Journal of Climate and Development, published by Taylor and Francis, and is under review.

Chapter 3 quantifies the recent trends in temperature and relative humidity in order to either confirm or refute that there has been an increasing temperature over the last fifty years in Bawku East. This chapter also investigatesthe trend in relative humidity over the last fifty years, since temperature and humidity combined largely determines the level of heat exposure. The chapter is published in the Journal of Geography and Geology published by Canadian Center of Science and Education. This chapter addressesobjective number two.

Chapter 4 gives a preliminary overview onthe extent of heat stress that farmers in the study communities are exposed. It reports the result of oneLascar temperature and humidity sensors thatexaminedlevels of heat stress over a period of six months. This initial assessment of heat stress concurrently propelled a longer and more intensive study of the yearly trend of heat using several instruments of Lascar sensors to measure heat stress. The chapter has beenaccepted and published in the Journal of Sustainable Agriculture Research, published by the Canadian Center of Science and Education, and addresses objective three of the research aims. This initial assessment was presented at the annual conference of Australian Institute of Occupational health and was judged to be submitted for publication.

Chapter 5 consists of an extensive quantification of heat stress using six Lascar USB temperature and humidity sensors to capture yearly trend of heat exposure in the study area. It further tested the efficacy of the instrument lascar EL Temperature and Humidity Sensor by using Questemp instrument that accurately capturedWet Bulb Globe Temperature (WBGT). The results of the study depicts that farmers were exposed to heat stress that require remedial measures. There was a strong correlation between the two instruments which indicates that Lascar EL Temperature and Humidity sensor can conveniently capture heat stress in a given environment. This chapter is submitted for publication to International Journal of Biometeorology and is under review. This chapter addresses objective number four.

Chapter 6 consists of farmers self-reported experiences of heat stress and climate change vulnerability at both on the field of cultivation and on the household level. The paper used logistic regression to explore the relationships between age, gender and duration of residence, with their self-reported experiences of increasing heat stress and climate change. General experiences of farmers' exposure to heat and climate change are also presented in this chapter. This chapter is accepted and published in International Journal of Earth and Environment and addressesobjective five of the research.

Chapter 7 consists of farmers' self-reported impacts and adaptation to heat stress and climate change. A comprehensive assessment of impacts of heat and climate change and responses to heat both at the outdoor farming environment and at household level was undertaken. The study found different levels of heat stress and coping strategies among farmers. This chapter is submitted for publication to Journal of Climate and Development and has beenaccepted and is being prepared for publication. This forms study objective six of the research.

Chapter 8 reports on farmers self-reported barriers of adaptation to heat stress both at the farm level and in the field of cultivation. Basically, the study used focused group

discussion to elicit socioeconomic and cultural barriers of adaptation while household survey was used to identify farmers' level of effectiveness to heat adaptation. This chapter has beensubmitted and accepted for publication in International Journal of Social Ecology and sustainable Development. It forms objective seven of the study.

Chapter 9 consists of synthesis of the study. It integrates the study elements and presents the summary, conclusions, findings and recommendation of the study. This is the final chapter of the thesis.

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CHAPTER 2

REVIEW OF CLIMATE CHANGE ADAPTATION AND SOCIAL PROTECTION POLICIES OF GHANA: THE EXTENT OF REDUCING IMPACTS OF CLIMATE CHANGE AND HEAT STRESS VULNERABILITY OF SMALLHOLDER FARMERS

This chapter is submitted to journal of climate and development published by Tailors and Francis publishing group and is under review. The prelude to proper investigation of farmers exposure to heat stress and climate change and the level of their adaptation is contigent to identification of heat stress and climate change as a development issue and current policies of government to adress them in the context of sustaianable development. By virtue of that the first chapter was dedicated to a comprehensive examination of Ghana's climate and energy policies as well as the current social protections policies and their relevance to enhance identify climate change and heat stress as both health and occupational issue.Moreover,the content examniation of the the policies was to identify the existing measures by the government of Ghana to enhance the adaptation of smallholder farmers to heat stress and climate change both at the household level and on the field of cultivation. The study further construct a model to depict the significance of the integration of adequate climate change adaptation and social protection policies to enhance the resilience of smallholder farmers who form the bulk of the labour force in Ghana in order to achieve sustaianble developmen. The appraisal of the policy documents of social protection and climate change adaptation did not locate in these two policy documents of any pragmatic effort by government to address heat stress as both health and occuapational issue. Moreover, drought, flood vagaries in rainfall and temperature were the key areas the government has identified as climate change issues in the context of achieving sustainable development.Primarily, heat waves was noticed to be misrepresented as heat stress eventhogh the former can aggravate the occurence of heat stress.

2.1 ABSTRACT

Smallholder farming has become a significant livelihood coping strategy of the population in Ghana. However, in the last decade the upsurge of climate change and the effect

of heat stress vulnerability on smallholder farmers in Northern Ghana are alarming. This article investigates the chances of using social protection and climate change adaptation policies towards the management of risks associated with heat stress emanating from climate change. It reviews salient literature on heat stress, social protection, and climate change policies and develops a model upon which both domestic and international interest in climate and social protection policies of Ghana and Sub-Sahara Africa can reduce or aggravate heat stress impacts on smallholder farmers both at their working environment and at household level. It exemplifies the efficacy of the strength of social protection and climate change adaptation policies in Ghana and its impacts on vulnerable rural smallholder farmers and how such situation is replicated in many parts of Africa. It outlines further measures that can be undertaken by governments and international donor agencies to revamp the destitution of smallholder farmers to climate change and heat stress in African region.

2.2 INTRODUCTION

The development agenda and target of the world as encapsulated in the Millennium Development Goals (MDGs) is to ensure environmental sustainability and eradication of extreme poverty and hunger by 2015 and beyond. However, these goals may prove unattainable where exposure to vulnerabilities of climate change and heat stress which exacerbate poverty are not contained and well managed. Available information indicates that climate change is increasingly affecting socioeconomic and cultural lives of people within and beyond this century. It is recognised that the greatest impact of climate change will occur in tropical developing countries because of their geographic disposition, predominantly living on climate sensitive sectors, with marginal income and low adaptive capacity (IPCC, 2007; Stern, 2007; IPCC, 2014). Adaptation is identified as a major way to reduce vulnerability of climate change impact on poor people (Adger et al., 2003).

As adaptation is examined, it is necessary to identify the degree of risk of climate change that vulnerable communities are faced, the level of impacts on farmers both at household level and on the field of cultivation, and how to significantly reduce the level of vulnerability on the affected people such as smallholder farmers. Social protection and climate change adaptation have been identified as the key mechanism to offset the impact of climate change on vulnerable communities. As adaptation interventions, these policies have been identified as cardinal in protecting vulnerable communities and building resilience against climate change (Davies et al., 2008). While climate change adaptation seeks to reduce

underlying vulnerabilities and manage risks and impacts of climate change, social protection seeks to transform, prevent, promote and protect vulnerability to risks, shocks and impacts of climate change (Matin et al., 2008; Sabates et al., 2004; Slater & McCord, 2009). These measures have much in common the potential to create resilience and reduce vulnerability against environmental risk.

This article investigates the prospects of employing social protection and climate change adaptation policies to reduce the impact of heat stress and other predictors of climate change on smallholder farmers in African region. In cognisance of the robust threat that climate change create, the authors construct a model to depict the role of social protection and climate change adaptation policies to improve resilience and reduce the vulnerability of heat stress and other predictors of climate change on smallholder farmers. In this regard, the article purposes to inform the ongoing social protection and climate change policy debates in African countries, particularly, on external funding interest and its impacts on domestic policies with the goal of reducing vulnerability to heat stress as a result of climate change.

The paper is organised into five sections as follows. Section one consists of the introduction to the paper. It highlights the current trend of development goals, vulnerability to climate change, climate change adaptation and social protection, as well as the objective and organisation of the paper. Section two presents vulnerability to heat stress and climate change and accentuate how heat stress is an issue for domestic and international attention. Section three illustrates a model depicting the conceptual linkages between social protections, heat stress and climate change adaptation for smallholder farmers. Section four outlines current focus of climate change adaptation and social protection policies exemplifying the situation in Ghana. The last section highlights the implication of the current policies and the need to adjust programmes and policies by government and external organisation in Africa to ensure food security and sustainable development.

2.3 VULNERABILITY TO HEAT STRESS AND CLIMATE CHANGE

The root and pivot of vulnerability to environmental risks can be traced to research in natural hazards. The growing recognition of vulnerability in climate change issues has been widely embraced (Wisner, 2004). The concept of human vulnerability relates to the prospects of eroding people's capabilities and choices. It is the risk of an individual, household or a community experiencing a decline in well-being due to limited capacity to adapt, location, sensitive periods in life cycle, low social cohesion, insensitive institutions and policies,

position in society and poor governance (Adger et al., 2004; Malik, 2014). Vulnerability in the context of this review is described as the degree of exposure of a person or group of people to climate change impacts or other natural hazards and their capability to recover (Blaikie et al 1994).

There is a scientific resolution that the earth climate is changing as a result of human emissions of greenhouse gas leading to varied forms of vulnerability and impacts such as extreme temperature, heat episode, and profound precipitation (Trenberth et al., 2006; IPCC, 2007). In African region the most vulnerable people to climate change impacts are the poor, smallholder farmers, elderly, women and children among others (Morton, 2007; Malik, 2014). Consequently, issues of sustainable development with regard to food security, employment, incomes, livelihood, education, housing and assets of the population especially the poor smallholder farmer in rural areas of developing countries are likely to be negatively affected by climate variability and change (Morton, 2007). As a key source of food, income, employment and livelihood in developing countries, smallholder farmers are more likely to be grievously affected by the negative impact of climate change (Morton, 2007; Ziervogel et al., 2008) and heat stress without adequate adaptation as it can stifle productivity in outdoor farming (Kjellstrom, 2009; Lundgren et al., 2013).

Agriculture is one of the significant economic activities in Africa. For instance, over 70 percent of the population in African region earn their livelihood through farming (Ziervogel et al., 2008) and such activities are done under the exposure of full sunshine with its attendant hazards of occupational heat stress (Kjellstrom, 2009). In addition, the emergence of climate change and increase in temperature will obstruct outdoor farming in Africa which predominantly requires the use of physical human energy for work capacity and productivity (Kjellstrom et al., 2009).

Though farming is the largest employable sector in African region, it is argued that the precarious nature of occupational heat stress has not been given adequate research, funding and policy attention by local governments and international bodies (Kjellstrom, 2012). This is perceived to increase the vulnerability of smallholder farmers and affect livelihood and food security. This assertion of heat stress vulnerability on farmers' livelihood at both household and field of cultivation is buttressed by the fact that there is no single study on heat stress as occupational and livelihood hazard to farming in African region, even though scanty study has been done in Asia (Costello et al., 2009). In fact, frequent breaks will be needed to cool down the body temperature during high physically demanded outdoor farming activity,

which in itself slows work pace and eventually affect productivity (Kjellstrom, 2000; Kjellstrom, 2009). It will be difficult for farmers to respond to the maximum recommended heat exposure for a continuous work with high physical intensity per international standard (ISO, 1989) either through inadequate knowledge of the impact of heat on health or shear ignorance of the impact of heat stress.

The repercussion of heat stress on health is enormous. Common environmental heat exposure is likely to impair human physiology, state of health as well as work capacity and productivity (Bridger, 2003; Parsons, 2003). There is a strong association between future projection of increased temperature due to climate change and its impact on regular occurrence of heat episodes which is likely to have health effects on outdoor working people (Jendritzky & Tinz, 2009). Considerably, there seem to be an upsurge in human vulnerability as a result of financial instability and mounting environmental pressures such as heat stress and climate change with the growing potential to undermine progress in human development and post-2015 MDGs.

2.4. CONCEPTUAL FRAMEWORK FOR HEAT STRESS AND CLIMATE CHANGE ADAPTATION AND SOCIAL PROTECTION

This framework outlines the conceptual linkage between heat stress and climate change policy and social protection for smallholder farmers. The distinction between heat stress and extreme heat events need to be clarified. While heat stress is a daily physiological condition irrespective of the occurrence of extreme heat events, heat wave is exacerbated by extreme heat event which can intensify heat stress in an area (Kjellstrom et al., 2014). The extent of risks of the poor and vulnerable people especially smallholder farmers in rural areas seems to be deepening and widening by existing global development processes and crises.

With regard to the smallholder farmer, the debilitating impacts of climate change and heat stress serves as a challenge to the achievement of the MDGs with particular reference to poverty eradication and environmental sustainability (Davies et al., 2008). In general terms, the rapidity and severity of different kinds of physical hazards determines the level of exposure to individuals, communities and group of people. Similarly, the level of response, coping and adaptation strategy to external stresses that confront an individual or a community is a key phenomenon of dealing with vulnerability (Kelly & Adger, 2000). Socio-cultural and traditional norms largely determine peoples exposure and/or resilience to vulnerability to natural hazards, climate variability and change (Klein, 2003; Ford, Smit, & Wandel, 2006;

Naess, Bang, Eriksen & Vevatne, 2005; Coulthard, 2008; Jones, 2010). The vulnerability model indicates that 'vulnerability of a system is a positive function of the system's exposure and sensitivity and a negative function of the system's adaptive capacity' (Ford & Smit, 2004, pp. 398-400).

The use of the vulnerability model to assess human and ecological susceptibility to climate change is not new. For instance, it has been applied to explain vulnerability in the context of forest management, risks of communities in the Canadian Arctic to climate change and sustainability science (Ford & Smit, 2004; Johnston & Williamson, 2007; Smit & Pilifosova, 2001; Turner et al., 2003).

While the authors acknowledge the usefulness and application of the vulnerability model in explaining risks to climate change, there is paucity of vivid studies applying the model in explaining vulnerabilities of heat stress and climate change in relation to smallholder farmers in the African region. In this regard, few studies have investigated the impacts of heat stress in developing countries outlining the repercussion of heat exposure in link with global climate change on smallholder farmers (Kjellstrom, 2009; Kjellstrom, Holmer & Lemke, 2009). In spite of current and predicted increase in temperature in African region, there is no significant research on heat stress on outdoor working population such as farmers (Costello et al., 2009), even though over 70 percent of the population in African region earn their livelihood through outdoor farming (Ziervogel et al., 2008).

Exposure to heat stress and climate change has the tendency of reducing hours of work and productivity (Kjellstrom, 2000; Langkulsen et al 2010), affecting farmers health and jeopardize their local economy (Kjellstrom, 2000; Costello et al., 2009; Kjellstrom, 2009; WHO, 2012). Accordingly, there is the need for a conceptual framework on climate change adaptation and social protection measures geared towards reducing vulnerabilities and building the resilience of smallholder farmers' exposure to heat stress and climate change. Based on the vulnerability model (Smit & Pilifosova, 2001; Ford & Smit, 2004; Johnston & Williamson, 2007), the framework on climate change adaptation and social protection operates on the assumption that, the degree of vulnerability of smallholder farmers is a function of exposure, sensitivity and adaptive capacity to heat stress and climate change. Hence, measures of heat stress and climate change adaptation and social protection are inextricably linked to the smallholder farmers' exposure and sensitivity to current and future heat stress and climate change conditions. Therefore, exposure and sensitivity of smallholder farmers to current heat stress and climate change influences exposure and sensitivity to future

heat stress and climate change as shown by the single-headed broken arrow. Similarly, exposure and sensitivity of smallholder farmers to current heat stress and climate change influences current adaptation strategies and vice versa as showed by the doubled-headed arrow (Figure 2.1).

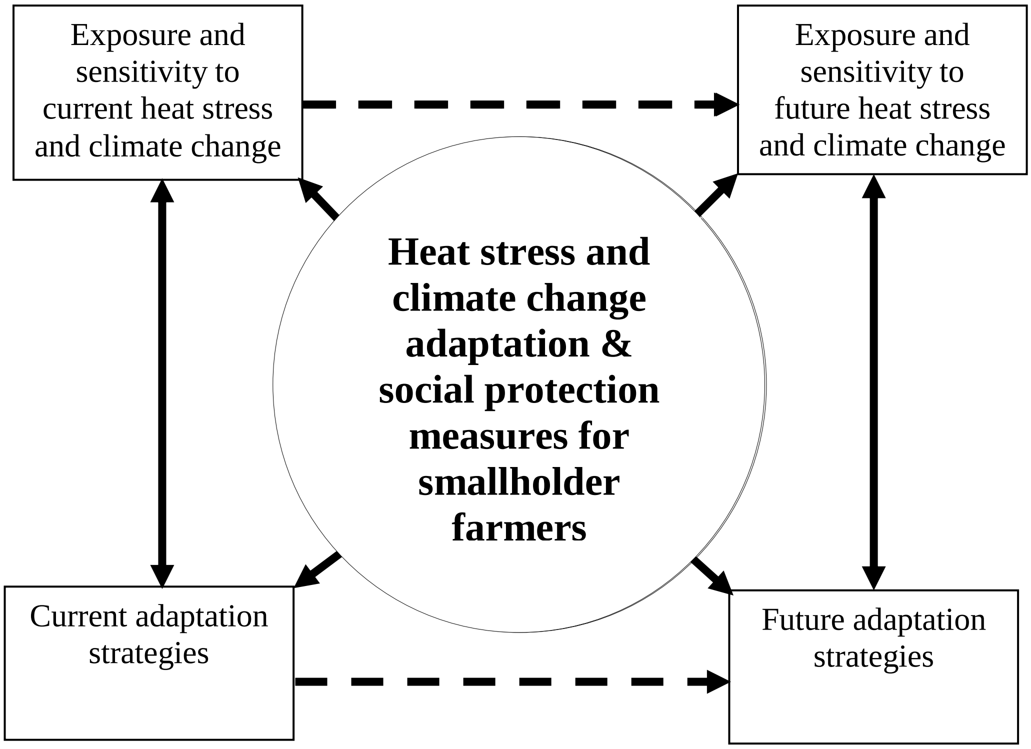

Figure 2.1: Heat stress and climate change adaptation and social protection for smallholder farmers: a conceptual framework.

On the other hand, exposure and sensitivity of smallholder farmers to future heat stress and climate change influences future adaptation strategies and vice versa as indicated by the double-headed arrow. In addition, current adaptation strategies influence future adaptation strategies as indicated by the single-headed arrow.

Significantly, heat stress and climate change adaptation and social protection are effective approaches to reducing vulnerabilities of people including smallholder farmers. The adaptation policies and social protection measures have much in common the potential capacity and objective of protecting the most vulnerable and promoting their resilience (Davies et al., 2008). The extent of reducing risks and managing impacts of heat stress and climate change is contingent on the adaptive capacity of the smallholder farmer based on the

influence of domestic and international policy, programmes and strategies on heat stress and climate change as well as social protection. Therefore, policies, programmes and strategies with adequate provision for heat stress and climate change adaptation and social protection improve on adaptation strategies and build resilience of smallholder farmers to vulnerabilities of heat stress and climate change. Climate change adaptation and social protection measures include cash transfer, asset transfer, insurance, input subsidies, services of agricultural extension officers, crop diversity, irrigation and drought resistant crops as well as reforestation and reduction in forest degradation (Devereux & Sabates-Wheeler, 2004; Davies et al., 2008). In the long run, these measures have the prospect of reducing smallholder farmers' vulnerability to exposure and sensitivity to heat stress and climate change as well as improving resilience of adaptation strategies to future environmental and economic shocks. It must be noted that the extent of reducing or aggravating heat stress and climate change impacts on smallholder farmers both at their working environment and at household level is contingent on their exposure, sensitivity, and adaptive capacity to heat stress and climate change. These are regulated by climate change adaptation policies and social protection mechanisms mediated by local and international interest.

2.5 CLIMATE CHANGE ADAPTATION AND SOCIAL PROTECTION POLICIES

The extent of vulnerability of individual, households and communities to hunger, poverty and heat stress as a result of climate change to a large extent depends on the provision of financial, physical, social, human and technological resources to satisfy their needs (Malik, 2014). Exposure to risks and vulnerability to poverty, heat stress and climate change can be managed through policies, programmes and strategies of social protection and comprehensive climate change adaptation policies in order to create opportunities for sustainable development. This section of the article stipulates the rationale, strengths and weaknesses of climate change adaptation and social protection policies of Ghana in the context of vulnerability of smallholder farmers to heat stress and climate change. The policies of climate change adaptation and social protection (Government of Ghana, 2007; UNDP/UNEP Programme, 2012) are used in this article as the basis for assessing and measuring the efficacy of reducing vulnerability and improving resilience of smallholder farmers to heat stress and climate change in Ghana as such measures are replicated in other parts of Africa and tropical developing world.

2.6 CLIMATE CHANGE ADAPTATION POLICY

The need for inculcating climate change policies into national agenda is driven by commitment of countries to the United Nations Framework Convention on Climate Change (UNFCC) and growing concerns about increasing impacts of climate change on individuals, communities and national and international development. Accordingly, the National Climate Change Adaptation Strategy of Ghana was formulated. The policy is quite comprehensive and oriented towards improving on the ecological, social and economic structures of Ghana in response to vulnerabilities and impacts of climate change.

It recognises the significance of the increasing incidence of climate change and its impact on the vulnerable state of the social, economic and ecosystem of Ghana. It also creates room for Ghana's adaptation development strategy. It is the goal of the policy to boost Ghana's present and potential development towards the impacts of climate change by bolstering her adaptation capacity in terms of reducing vulnerability and building resilience to climate change. The strategies of the policy relates to improving livelihoods, energy, agriculture, health, early warning, fisheries management, land use, and water (UNDP/UNEP Programme, 2012).

The policy spells out the devastating impacts of climate change on the economic and social sectors of Ghana. The economic sectors have been identified as agriculture, natural resources and energy while health and sanitation constituted the social sector. The policy document also mentioned infrastructure such as roads, power distribution lines, and houses among others. The vulnerability of Ghana has been attributed to the impact of climate change and socio-politically induced factors as well as inability of the population to cope and adapt positively without negative impact. Indeed, the extent of vulnerability of a system depends on the extent of exposure, sensitivity and adaptive capacity of the system to impacts of hazards such as climate change (Smit & Pilifosova, 2001; Ford & Smit, 2004; Johnston & Williamson, 2007).

As a development oriented policy, it recognizes agriculture as the backbone of socioeconomic development (National Development Planning Commission, 2010) and as the largest employer in the economy of Ghana. It also underscores the impacts of climate change on agriculture and the extent to which it is yet the most vulnerable to climate variability and change. Consequently, it stipulates that the increasing unpredictability in rainfall, intensifying

temperature and recurrent drought enhances the vulnerabilities related to agriculture and smallholder farmers and therefore make investment in farming more costly, insecure and unrewarding. With particular reference to agriculture, the strategy of the policy is to support the capacity of extension officers in innovative technologies of farming which would be used to enhance the ability of local farmers to increase agricultural productivity and awareness of climate issues. It is also geared towards promoting agricultural biodiversity, cultivation of crops and rearing of animals adaptable to harsh climatic condition in order to improve living standards of vulnerable groups through acquisition of alternative livelihood skills as well as minimize post-harvest losses of farm produce (UNDP/UNEP Programme, 2012).

Similarly, the priority adaptation programme to climate change as contained in the policy is to increase resilience and reduce vulnerability to climate change impacts through early warning systems, alternative livelihoods, improved land use management, enhanced research and awareness creation, development and implementation of environmental sanitation strategies, managing water resources, agricultural diversification, improved access to healthcare, and sustaining livelihoods through enhanced fisheries resource management. With regard to implementation strategy of the NCCAS, appropriate institution such as the Ministries, Departments and Agencies (MDAs) at the national level are responsible for policy planning, monitoring and evaluation of development programmes and projects, while the implementation of such programmes and projects are undertaken at the sub-national levels by the government agencies and district assemblies. This makes the policy imperative and timely as a guide to stakeholders in making informed policy planning, formulation, implementation and evaluation and to appreciate the alarming impacts of climate variability and change and to see the need for sustainable adaptive capacity for development.

However, not until the UNFCC meeting in Copenhagen in 2009, the national preparedness of Ghana to combat climate change was low, incoherent and focused on environment and forest degradation without recourse and emphasis to adaptation (Sarpong & Anyidoho, 2012). Besides, although agriculture plays a significant role in Ghana’s economy, it has only been given recognition in the policy discourse of climate change in recent times. The current national climate change and adaptation strategy document is expressive and devoid of pragmatic steps to address vulnerability of smallholder farmers to climate change and heat stress. It gives the overview of extreme weather events such as drought, erratic rainfall, and temperature upsurge with reference to heat waves. There is no single set of harmonized policy document and institution with adequate authority purporting to deal and

manage climate change issues in Ghana. The management of climate issues has been moving from one MDA to the other. For instance, as far back as 1991, Ghana Environmental Protection Agency (EPA) was responsible for climate issues. The main concern was to address climate impact on the environment, energy and forestry while little attention was given to the agricultural sector with regard to human adaptation (EPA, 2007). The "Ghana goes for Green Growth" has been the main climate policy document with a focus on agriculture which is regulated by Ministry of Environment, Science and Technology (MEST) (Ministry of Environment Science and Technology (MEST) 2010). Moreover, Ghana's Shared Growth and Development Agenda operating from 2012-13 on climate change shed lights on impact of climate change and agriculture (National Development Planning Commission, 2010). The document sought to outline adaptation and mitigation strategy for Ghana's development. As of 2007, the Ministry of Food and Agriculture (MOFA) had no policy component for climate change and agriculture (Sarpong & Anyidoho, 2012). In Ghana's effort to address climate change as submitted to UNFCC, only a marginal number of eight policies referenced agriculture, while a large number of 33 policies was assigned to energy. Land use management had eight policies (National Development Planning Commission 2011). From 2004-2011 funding for climate change intervention indicated that $493.6m was invested on adaptation activities as against $794.7m for mitigation projects (Cameron, 2011). Many of the activities are centred on reducing carbon emissions (Reducing Emission from Deforestation and Forest Degradation [REDD]) (Ministry of Environment Science and Technology (MEST), 2010).

Notwithstanding the uncoordinated modicum attempts by MDAs to address issues of climate change vulnerability (Sarpong & Anyidoho, 2012), the policies were depleted with programmes, policies and strategies to adequately reduce and mitigate heat stress and properly enhance resilience of smallholder farmers. The situation is more precarious in the wake of the fact that in humid countries in the tropical regions, the risk of additional temperatures can increase heat related morbidity and mortality (Willett & Sherwood, 2012). The population who work under the exposure of heat is likely to be affected by heat stress and its related illness. The issue of rising temperature is much pronounced in Northern Ghana. For instance, in the Upper East Region of Ghana, over 65 percent of the residents depend on agriculture for their livelihood (GSS, 2002). An estimated number of 88 percent of the population reside in rural areas and their living standard falls below the national poverty line (Whitehead, 2006). These problems have been as a result of the distribution of national

infrastructure in favour of southern Ghana right from colonial and post colonial era (Laube, Schraven & Awo, 2012).

In general terms the foremost discourse and account on climate change and agriculture is centred on the need to reduce emissions, vulnerability to the impacts of climate change through adaptation, and to promote economic growth and development. Yet, mitigation instead of adaptation has been preferred in climate change deliberations and funding. Notable mitigation projects include forestry and REDD which is usually motivated by external interest and to the benefits of local key actors (Sarpong & Anyidoho, 2012). Another area of critique in the climate resilient development debate relates to promoting technology transfer and climate proofing of agriculture instead of reducing vulnerability among the poorest through important small scale indigenous based strategies other than large scale agricultural transformation, technological fixes and mechanized farming (Ministry of Environment Science and Technology (MEST), 2010; Sarpong & Anyidoho, 2012).

2.7 SOCIAL PROTECTION POLICY

Social protection has become an integral component of any strategic effort to reduce the incidence and severity of vulnerability to hunger, poverty and climate change. The concept has various contextual connotations depending on national circumstances, institutions and legislations. Social protection has been conceptualised as all initiatives and actions that provide income or consumption transfers to the poor; protect the vulnerable against livelihood risks; enhance the social status and rights of the excluded and marginalized (Devereux, Teshome & Sabates-Wheeler, 2005; Sabates-Wheeler & Haddad, 2005). It is also regarded as a set of public and private policies and programmes aimed at preventing, reducing and eliminating poverty, deprivation and social exclusion and enhancing resilience and opportunities through promoting human capital and connecting people to decent and more productive employment (ILO, 2012; UNICEF, 2012; World Bank, 2012).

The deployment of social protection as a sustainable alternative approach to adaptation by reducing and managing risks, shocks and vulnerability to extreme poverty, deprivation and exclusion (Davies et al., 2008; Davies, Oswald, & IDS, 2009) is not a novelty in Ghana and the tropical developing countries. Formal and informal mechanisms of social protection for dealing with vulnerabilities in Ghana as adopted in other parts of Africa and tropical developing world are diverse and have been erratically implemented. Notable social protection laws, policies, programmes and strategies prior to the Ghana National Social

Protection Strategy in 2007 includes the Social Security Schemes (Social Security Act of 1965 and Social Security Law of 1991), Programme of Action to Mitigate the Social Costs of Adjustment (PAMSCAD) in the 1980s, Sasakawa Global 2000, Ghana Growth and Poverty Reduction Strategy[GPRS] I (2002-2005), National Health Insurance in 2003, Ghana School Feeding Programme in 2006, GPRS II (2006-2009)(Devereux, 2009; Dorward, Guenther, & Wheeler, 2008; Government of Ghana, 2007). Food transfers under the implementation of the food aid and food-for-work programme by United State Agency for International Development (USAID), Catholic Relief Service (CRS), Adventist Development Relief Agency (ADRA) and Technoserve (Dorward et al., 2008), as well as social transfers (capitation grants to basic schools, school feeding, supplementary feeding, and health exemptions), labour market interventions (national labour standards, minimum wage legislation, employment creation for youth, skills training and employment placement, regulations to protect the interests of workers), social insurance programmes (social security and pension schemes for formal sector workers, national health insurance), and humanitarian reliefs (disaster management and emergency food-aid) were also adopted.

These social protection initiatives were associated with inadequacies such as limited coverage and support for the informal sector, weak targeting methods, poor multi-sectoral linkage, inadequate coordination, poor institutional capacity, and inefficient and ineffective cost (Dorward et al., 2008; Government of Ghana, 2007) resulting in the formulation of the NSPS in 2007. The rationale to inculcate social protection strategy into the national agenda is to provide a policy direction and a coherent framework that seeks to extricate the socially excluded and vulnerable from conditions of extreme poverty and to build their resilience and potential to claim their rights and entitlements in order to manage their livelihoods, contribute and carry out their responsibilities towards national development (Government of Ghana, 2007). The need for the social protection framework had been informed by the obligation of Ghana to international and national protocols to reduce and manage risks, shocks and vulnerabilities to extreme poverty, hunger, exclusion, deprivation and climate change. Accordingly, the variables of risks, shocks and vulnerability as defined in the policy include economic risks, natural or manmade risks, health risks, life-cycle risks and denial of rights. In terms of natural or manmade vulnerabilities, the policy identified indicators such as unpredictable rainfall, drought, floods, bushfires, pest infestations, deforestation, declining soil fertility and depleting water sources as well as environmental degradation (Government of Ghana, 2007). The social protection strategy is based on local and previous experiences,

lessons and best practices of other countries in Africa, Asia and South America in developing a people centred approach to social protection in Ghana. In recognition of the prospects and challenges of prior social protection initiatives, policies and programmes, Livelihood Empowerment Against the Poor (LEAP) has been employed as the key mechanism of social grant programme in the form of cash transfers to assist the poor reduce, improve or cope with social risk and vulnerability. It focused on supporting the extremely poor and targeted groups with both conditional and unconditional grant on monthly basis for subsistence. The targeted vulnerable groups include subsistence farmers and fisher folks, extremely poor above 65 years, orphans and vulnerable children especially those affected by AIDS and with severe disabilities, incapacitated/extremely poor people living with HIV/AIDS and pregnant women/lactating mothers with HIV/AIDS (Government of Ghana, 2007). At the commencement of the programme in 2008, beneficiaries of the LEAP programme were allocated cash transfers that ranged from GH¢8 to GH¢15 but was increased in January, 2012 to a range of GH¢24 to GH¢45. For the months of September and October 2014, Ghc 4,918, 404 was allocated for 77,000 households in 103 out of the 175 districts in Ghana (Government of Ghana, 2007; Appiah, S. November, 2014). According to the Ghana Living Standards Survey report of the fifth round (GLSS 5), the average household size in Ghana is four (GSS, 2008), however, a single beneficiary in a household under the LEAP programme is to receive Ghc48, two beneficiaries in a household are to receive Gh60 and over four beneficiaries in a household are to receive Ghc90 to cover two months. In general terms the social protection strategy is appropriate in reducing vulnerabilities, essential and oriented toward poverty reduction, national development and achieving the MDGs.

Based on LEAP, there seem to be a significant but weak link between the NSPS and smallholder subsistence farming. Significantly, the amount is inadequate and cannot make ends meet taking cognisance of escalating trends of prices of goods and services. This is intercepted with frequent payment delays by the government, thereby making the LEAP programme to outlive its usefulness to reducing vulnerability and building resilience.

In linking social protection to adaptation, LEAP as the key focus of the NSPS is inadequate and unsustainable. This can be attributed to its inadequacy to enhance the provision, protection, prevention and transformation to social protection and its benefits for adaptation. For instance, it does not adequately lead to the protection of those most vulnerable to climate risks such as heat stress on outdoor farmers and those who have low level of adaptive capacity. Also, LEAP does not sustainably posses the benefits for adaptation as it

does not seek to satisfactorily prevent damaging coping strategies as a result of risks to weather-dependent livelihoods. Similarly, LEAP does not seem to facilitate resilience through diversification and security of livelihood and hence does not seek to help withstand climate-related shocks and promote opportunities arising from climate change. In terms of transformation, the programme is limited in facilitating sufficient changes in social relations in order to address underlying causes (Devereux & Sabates-Wheeler, 2004).

This system of social protection in the context of climate change and variability is deficient in driving Ghana to sustainable future. The emerging question is: how long can the government continue to distribute cash to create environmental resilience and improve livelihood of vulnerable communities. It is imperative for the government to refine the social protection system by empowering rural farmers and other vulnerable communities with mechanized system of farming such as irrigation to offset rain fed dependant agriculture and also improve farmers' accommodation system to make them climate friendly. This could include providing well ventilated houses as distinguished from round and non ventilated structures. Countries like Taiwan and Thailand have used irrigation agriculture to boost farm produce, increase revenue and breaking cycle of poverty. Cash transfers replicated in many social protection documents need to be improve and made more sustainable since it cannot meet future sustainability of building resilience of vulnerable folks in the emergence of climate change. Economic and environmental empowerment of the vulnerable communities in the perspective of the authors is the surest way of building resilience and reducing vulnerability of smallholder farmers in Ghana and the developing world at large.

2.8 CONCLUSIONS AND IMPLICATION FOR POLICY PLANNING, FORMULATION AND IMPLEMENTATION

Fundamentally, the literature review and the policy on NCCAS and NSPS recognises and underscores the impacts of climate change in general on agriculture and the extent to which it could affect vulnerable individuals like smallholder farmers. Based on the assessment of the two policy documents (NCCAS and NSPS) and the relevant literature, it is clear that in the current emergence of climate change, there is a yawning gap of information on the extent and magnitude of heat stress in outdoor occupations such as farming both on current and future activities. The two documents overlooked the precariousness of heat stress while key attentions were given to other sectors of climate change such as flood, drought, heat waves and coastal management and carbon mitigation. It is imperative for lessons of heat

stress in Europe that devastated human lives in 2003 to be mirrored in the social protection and climate change policy documents of Ghana and Africa as a whole to protect vulnerable individuals both at household level and on occupational setting from heat exposure.

The key obstacles confronting rural farmers as a result of heat stress include heavy physical workload and fatigue, inadequate knowledge of the government to identify that heat stress is a growing problem as climate is predicted to change. Moreover, socio-economic factors such as poverty expose a lot of smallholder farmers to heat stress vulnerability. Exposure and sensitivity of smallholder farmers to increasing unpredictability in rainfall, intensifying temperature and recurrent drought with inadequate social protection and climate change adaptation enhances vulnerabilities related to agriculture. This makes investment in farming more costly, apprehensive and less gratifying. Government of Ghana as in many African countries has no occupational guidelines for outdoor smallholder farmers and their life is left to the peril of atmospheric conditions as distinguished from the developed countries where there exist stringent social protection and occupational guidelines to safeguard lives. Moreover, there are no national records of heat stress fatalities or illness to enable proper policy measures to curb its effect on smallholder farmers and other outdoor workers.

Food security in Ghana and the African region is reliant on the ability of smallholder farmers to work on a healthy environment, since they form the bulk of farming population. As global climate is changing the increase in temperature will exacerbate farmers' exposure to heat stress. This is likely to affect food productivity since frequent breaks in work pace will be observed to avoid heat stress. Such process can slow down work pace thereby reducing work capacity and productivity. Since occupational safety is a right as stipulated by ILO (ILO, 2011), many workers have been denied the opportunity to enjoy such rights especially those in developing countries such as Ghana.

Based on the deficient climate change adaptation and social protection policies, important steps are required to enhance the resilience of smallholder farmers who form the workforce of the population in Ghana and the African region. Immediate improvement of the policy to capture the dangers of heat stress on outdoor farmers and other workers is timely and appropriate for sustainability of the growing farming population. Measures to combat heat stress at all level of outdoor occupation are imperative. Cash transfer as prime step within the social protection policy of Ghana is perceived as unsustainable due to the current strength, structure and management of the economy. Empowerment of smallholder farmers through adequate funding, mechanized agriculture and improvement of their living environment to

avoid heat stress and other climate change impacts are crucial and cardinal in ensuring sustainable livelihood. An effective, comprehensive and sustainable climate change adaptation and social protection policies by governments mediated by international donor agencies based on the conceptual framework can reduce the extent of current and future exposure and sensitivity to climate change and improve on the current and future adaptive capacity of farmers to impacts of heat stress and climate change. Indeed, improved adaptive capacity results in reducing vulnerabilities and building resilience to impacts of climate change. This has the ultimate effect of enhancing food security; promote sustainable development and achievement of the MDGs.

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CHAPTER 3

RECENT TRENDS IN TEMPERATURE AND RELATIVE HUMIDITY IN BAWKU EAST, NORTHERN GHANA

This chapter has been accepted and published by Journal of Geography and Geology, Volume 6, No 2; 2014, administered by Canadian Center of Science and Education. The chapter seeks to quantify recent trends in temperature and relative humidity. The idea behind this initial assessment and quantification of environmental temperature and relative humidity using meteorological station data hinges on the integration of temperature and relative humidity to determine heat exposure largely in a given area Seasonal maximum and minimum temperature as well as relative humidity were quantified and tested Durbin Watson statistical test and found that there were no autocorrelations in the residuals of the trend model. Significant rising trends in temperature were determined in Manga and Garu while inconsistent pattern in Binduri was observed. The details here are the same as what appeared in the journal. The layout has been changed to conform to the specifications of the thesis.

3.1 ABSTRACT

Extensive analyses of trends in mean annual and mean seasonal minimum and maximum temperatures and relative humidity were examined for Bawku East, northern Ghana, for the period 1961 to 2012. Mean monthly maximum and minimum temperatures were used to analyse and establish recent temperature trends on an annual and seasonal basis. The year was divided into rainy and dry seasons for the seasonal trends. Mean monthly relative humidity at 6 am and 3 pm from 1961 to 2012 were considered to show recent trends in humidity since temperature and humidity interact to determine the heat exposure for outdoor workers. Regression analysis was used to illustrate trends and calculate mean yearly and seasonal rate of change. A Durbin-Watson statistical test was employed to verify autocorrelation of the residuals of the trend models and none was detected. Results showed a gradual and statistically significant rise in both average minimum and average maximum temperatures at two stations (Manga and Garu). There was an inconsistent pattern of trend observed at the third station (Binduri). Declining trends in relative humidity were observed at

6 AM and 3 PM at seasonal and annual levels at Binduri and Garu, while there was a rising trend in relative humidity at Manga. The importance of this study hinges on the linkage between heat exposure (temperature and air humidity) and human health in the wake of climate change on outdoor farmers in developing countries who spend many hours doing manual work in the heat.

3.2 INTRODUCTION

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) revealed an increasing trend in global average temperature since 1850 and recognized that 11 of the last 12 years (1995–2006) before the publication of the report were ranked among the warmest years on record (Christensen et al., 2007; Jones et al., 2007; Pachauri, 2007; Trenberth et al., 2007). Global mean temperature was recognized to have increased by 0.76 °C within the period of 1850 to 2005. Depending on global action to reduce greenhouse gas emissions, a predicted further rise in temperature of 1-5 °C within and beyond this century is envisaged (Jones et al., 2007). The IPCC noted that the predicted increase in average global temperature was highly likely due to emissions of anthropogenic greenhouse gases (Hegerl et al., 2007). In most parts of the world, both minimum and maximum temperatures have increased with significant positive trends beyond that predicted to be caused by natural variability (Brown, Caesar, & Ferro, 2008). The regional projections of IPCC indicated that the West African region is likely to sustain a 3–4 °C increase in temperature over the period 1900–2100. Within this region a 3 °C rise is predicted to occur in the coastal and equatorial areas, while the western Saharan region is predicted to experience an increase 4 °C (Christensen et al., 2007). The warming trend of temperature in Africa is perceived to be likely responsible for the increased dryness of the Sahel (Hulme, 1996). Temperature affects evaporation and availability of water (Glantz, 1992), and regulates physiological processes in humans (Parsons, 2003), animals and crops (Collins, 2011), so rises in temperatures are likely to have wide-ranging impacts.

Many studies on recent temperature trends have been carried out (Cane et al., 1997; Kruger & Shongwe, 2004; Arora., 2005; Easterling., 2005;). The increasing trend of both minimum and maximum temperatures and decrease in the range of diurnal temperature in South Africa was demonstrated using meteorological data from 1951 to 1991 (Karl et al., 1993). However, studies of recent trends in temperature at more local scales are also

needed given the fact that broad-scale analyses may mask considerable spatial and temporal variation in climatic trends. For instance data from 26 meteorological stations throughout South Africa showed different trends in mean annual temperatures across the country within the time frame of 1960 to 2003 (Kruger & Shongwe, 2004). Inland stations showed significant and positive rises in mean maximum temperatures in line with global and national trends, while several coastal stations did not show such significantly positive trends (Kruger & Shongwe, 2004). They also showed that temperature trends differed across seasons of the year (e.g., much greater rises in autumn compared to spring). An analysis of the recent climatic changes in one locality in South Africa (West Bank in East London) for the period 1975–2011 found significant increasing trends in both maximum and minimum annual temperatures, although temperature trends for particular months and seasons were not significant (Kalumba et al., 2013).

The levels of ambient air temperature and humidity are fundamental in assessing environmental heat stress on the health of a given population, especially in the tropics of developing countries where there are larger numbers of outdoor occupations (Byass et al., 2010). In the Bawku East of northern Ghana it is estimated that 65% of the population are engaged in agriculture (Ministry of Agriculture, 2012). In the wake of climate change, the combined effect of heat and humidity is becoming more stressful to outdoor workers (Sherwood & Huber, 2010), and Bawku East is projected to experience an increase in temperature of 2.5–3 °C by the year 2050 (EPA, 2007). This makes it imperative to assess recent trends of temperature and humidity in this area in order to develop an appropriate community response to increases in temperature and heat exposure; the issue is further compounded by the fact that this region is among the poorest in Ghana with subsistent farming being the major occupation (Webber, 1996; Whitehead, 2006). Even though this study focuses on temperature trends and heat exposure on farmers' health, it is also worth mentioning that the effects of temperature on water content of the soil impacts on plant growth, especially at the early stage when the seeds are germinating (Helms et al., 1996). The rate of drought occurrence is linked with temperature variation (Arora et al., 2005). Thus sustainability of subsistence farming may be jeopardized with the emergence of changing climate and an upsurge in temperatures. For policy purposes, it is important to ensure enough farmers remain engaged in the production of food crops to alleviate food insecurity associated with this area. Assessment of recent climatic trends can contribute to risk assessments and evaluation of impacts associated with climate change.

In this study, data from three meteorological stations were used to analyse trends in mean annual and mean seasonal temperatures and relative humidity between 1961 and 2012 for the localities within Binduri, Manga and Garu in Bawku East. The specific objectives of this study were to establish trends in mean annual maximum and minimum temperatures and in mean annual relative humidity (for both morning and afternoon), as well as trends in seasonal mean temperatures and relative humidity. In excessively humid environments, the evaporation rate of sweat is compromised, which in turn leads to an increase in core body temperature (Parsons, 2003; Kjellström, 2009). In view of this, temperature and relative humidity are key parameters in determining heat exposures of outdoor workers. In Bawku East, a large proportion of the workers are engaged in outdoor farming where workers spend approximately 8 hours a day cultivating vegetables, cereals and legumes in direct sun. The area is renowned for being very hot (McSweeney, 2012), so that any increase in temperatures is likely to have a serious impact on people’s capacity to work outdoors. The high levels of poverty in this area (Webber, 1996; Whitehead, 2006) are also likely to increase if proper heat adaptation strategies are not implemented as it is likely to also become an issue of food insecurity if farm output is impacted.

Rainfall and temperature trends for the Ejura-Sekyedumase district of Ashanti, southern Ghana, showed a slightly decreasing pattern of rain and increasing in mean annual temperature. The central aim of their study was to relate perceptions of farmers about climate change to their degree of potential adaptation; however the authors did not consider the influence of relative humidity in their analysis and the study was conducted in a different climate zone compared to this study. Many studies exploring recent climate changes at local (Fosu-Mensah et al., 2012; Appiah, 2014) and continental scales (Cane et al., 1997; Easterling et al., 1997; Shrestha et al., 1999; Pascual et al., 2006;) also did not factor in relative humidity and its implications for increased heat stress as a component of climate change. This current study is therefore unique in that it was conducted in a previously neglected part of Ghana and considered the impact of humidity on the heat experience of farmers.

3.3 SETTING OF THE STUDY

Bawku East lies between latitudes 11°11' and 10° 50' north and longitudes 0° 18' west and 0° 61' east in the north-eastern part of the upper east of Northern Ghana (Ministry of Food and Agriculture, 2014); Figure 3.1). The area has only one annual period of rainfall with a

prolonged dry season. Rainfall starts in June and ends in October. The dry season is associated with hot, dry and dusty harmattan winds. Temperatures in the dry season range from 14 °C at night to temperatures that frequently exceed 37 °C and in the day. The average annual rainfall ranges from 800 mm to 850 mm (Government of Ghana Official Porter, 2014; Ministry of Food and Agriculture, 2014). The area is one of the poorest regions in Ghana characterised by a lack of social amenities, inadequate social infrastructure, and harsh climatic condition (Laube et al., 2011).

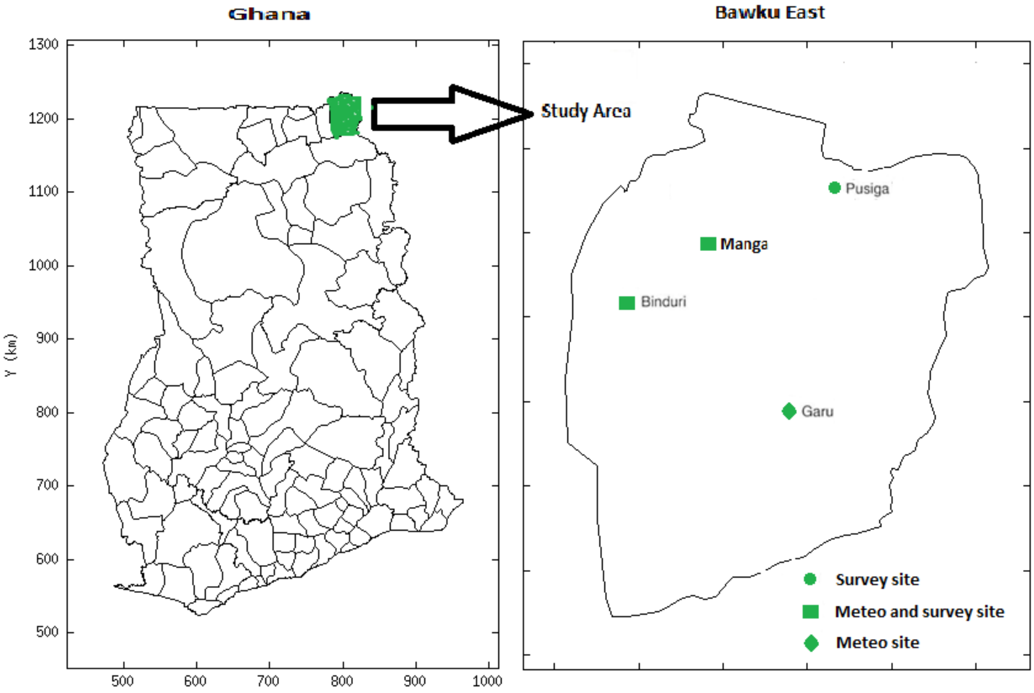

Figure 3.1 Map of Ghana showing Manga, Binduri and Garu (locations of meteorological stations).

3.4 DATA AND METHODOLOGY

In this study, data from three meteorological stations (Binduri, Manga and Garu) located in the Bawku East of northern Ghana (Figure 3.1) were used to analyse trends in mean annual and mean seasonal temperature and relative humidity between 1961 to 2012. These meteorological stations are located in the rural vicinity. Table 1 shows the location and coordinates of the meteorological stations.

Table 3.1: The locations of the three meteorological stations in Bawku East of Northern Ghana (Anayah & Kaluarachchi, 2009)

Station	Latitude °	Longitude °	Elevation in metres (m)
Manga	11.02	-0.27	231
Garu	10.85	-0.18	236
Binduri	10.97	-0.32	202

The Ghana Meteorological Agency provided the data for the study. Monthly averages of minimum and maximum temperature and relative humidity were obtained from the three meteorological stations. The data covers the period 1961 to 2012, though some years within this time frame were not available due to unexplained reasons from the meteorological service agency. The earliest available data started from 1961 (Manga), whereas the data from the other two stations started in 1976. Yearly mean temperatures were calculated from the monthly mean temperatures. Similarly, mean monthly relative humidity was used to calculate mean annual relative humidity at both 6 am and 3 pm. The data for the study was compiled and quality controlled by the meteorological agency in Accra, Ghana. The missing data were extrapolated to create continuity of the trend. The extrapolation was done using the previous data next to a gap and the data immediately after a gap to estimate the missing the data.

The temperature and relative humidity data were further divided into seasons to depict the seasonal patterns in Bawku East of Northern Ghana. These were June to October for the rainy season and November to May for the dry season. Both mean yearly and mean seasonal trends of minimum and maximum temperatures and relative humidity at 6 am in the dry and rainy seasons and at 3 pm in the dry and rainy seasons were determined.

The data were plotted for each available year to illustrate temporal trends and analysed using linear regression to determine average rate of change in yearly mean minimum and maximum temperatures and change in yearly mean relative humidity at 6 am and 3 pm. This method is used by many researchers in the analysis of temperature and other atmospheric data for identifying trends (Mote, 2003; Kruger & Shongwe, 2004). The Durbin-Watson test was used to verify autocorrelation of the residuals of the trend models; it was found that there was no auto-correlation.

3.5 RESULTS

3.5.1 Annual Trends in Temperature and Relative Humidity

There was a significant rising trend ($p < 0.001$) in a mean yearly minimum temperature in Manga, as shown in Fig 3.1, with a slope of 0.029 °C and a decadal change of 0.29 °C. Garu also showed a significant rising trend ($p<0.001$) in the mean annual minimum temperature with a slope of 0.042 °C and a decadal increase of 0.42 °C (Figure 3.6; Table 3.4). Binduri showed a different pattern with no significant rising trend in mean minimum yearly temperature and a slope of only 0.003 °C, which translate to a mean decadal increase of 0.03 °C (Figure 3.4). In terms of mean yearly maximum temperature, Manga had a significant rising trend (Figure 3.2, Table 3.2) with a slope of 0.022 °C and a decadal increase of 0.22 °C. A dissimilar trend in Binduri was found in mean yearly maximum temperature. However, between 2006 and 2010, there was a rising trend which sharply declined by the end of 2010 (Figure 3.4). The slope for Binduri was 0.021 °C with a decadal increase of 0.21 °C. Garu had a rising trend in average annual maximum temperature, as shown in Figure 3.6, with a slope of 0.060 °C and a decadal increase of 0.60 °C. Mean minimum temperature in Garu showed a rising trend with a slope of 0.042 °C and a decadal increase of 0.42 °C. In terms of mean annual relative humidity at 6 am, data from Manga showed an irregular pattern with no clear rising or falling trend (Figure 3.3). In Binduri, as illustrated in Figure 3.5, there was a declining trend in morning humidity with a sharp upsurge in 2008. Garu showed a decreasing falling trend in mean relative humidity at 6 am. At 3 pm in Manga there was a rising trend in mean relative humidity with an irregular pattern (Figure 3.2). Binduri showed an irregular trend at 3 pm (Figure 3.4), whilst Garu showed a falling trend at 3 pm with a sharp increase between 2006 to 2011 (Figure 3.6).

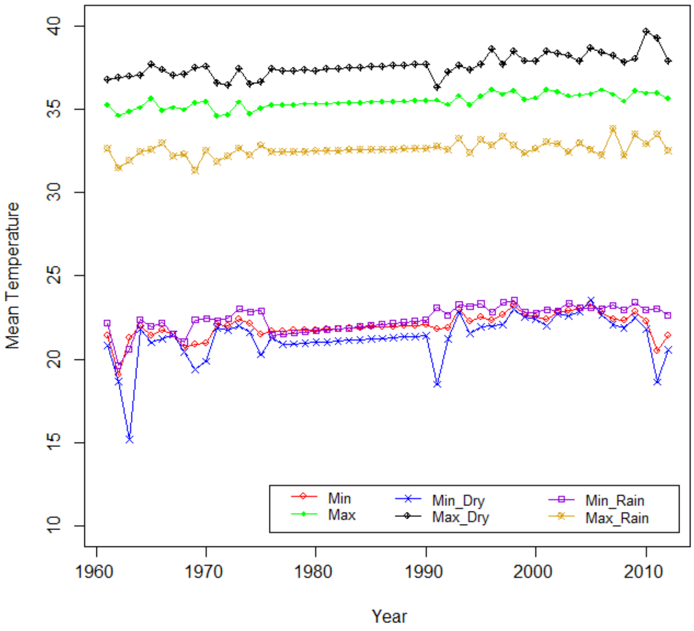

Figure 3.2. Seasonal and yearly trends of minimum and maximum temperatures in Manga (Bawku East). Min = Minimum mean yearly temperature; Max = Maximum mean yearly temperature; Min_Dry = Mean seasonal temperature for dry season; Max_Dry =- Mean maximum temperature in the dry season; Min_Rain = Mean seasonal temperature in the rainy season; Max_Rain = Mean Maximum temperature in the rainy season.

Table 3.2: Regression analysis of yearly temperature and relative humidity for Manga Bawku. Mn = minimum; Mx = Maximum; DW = Durbin Watson, DS = Dry season, SE = Standard Error

			Temperature								Relative Humidity		
variable	Slope	SE	t-value	P-value	R-square	DW	variable	Slope	SE	t-value	P-value	R-square	DW
Mean Mx Tem	0.022	0.002	9.368	< 0.001	0.637	1.950	Mean R.H 6 AM	0.083	0.038	2.188	< 0.034	0.105	1.641
Mean Mn Tem	0.029	0.006	5.114	< 0.001	0.343	1.421	Mean RH 3PM	0.0205	0.035	2.188	< 0.001	0.463	1.333
Mean Mx Tem DS	0.033	0.004	7.881	< 0.001	0.554	1.558	Mean RH 6 AM DS	0.136	0.051	2.674	< 0.001	0.148	1.889
Mean MXTem RS	0.016	0.003	4.676	< 0.001	0.304	2.567	Mean RH 6 AM RS	0.048	0.020	2.389	< 0.022	0.122	1.551
Mean Mn Tem DS	0.041	0.011	3.655	< 0.001	0.211	1.47	Mean RH 3PM DS	0.160	0.037	4.358	< 0.001	0.317	1.389
Mean Mn Tem RS	0.036	0.005	6.775	< 0.001	0.479	1.593	Mean RH 3PM RS	0.297	0.023	12.630	< 0.001	0.796	1.847

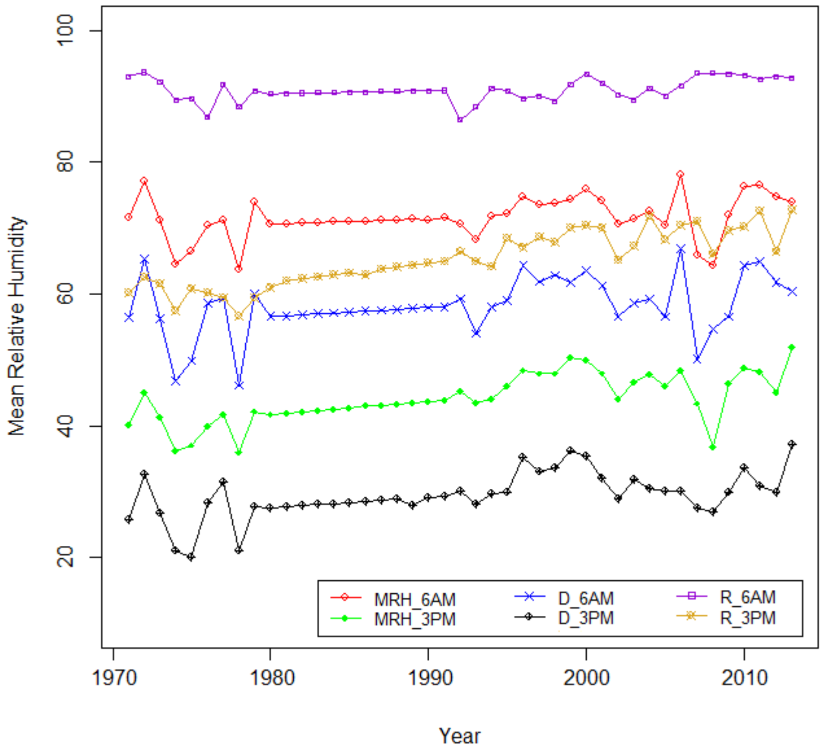

Figure 3.3 Seasonal and yearly trends of mean relative humidity at 6 AM and 3PM in Manga (Bawku East). MRH_6AM = Yearly mean relative humidity at 6AM; MRH_3PM = Yearly mean relative humidity at 3PM; D_6AM = Seasonal mean relative humidity at 6AM in the dry season; D_3PM = Seasonal mean relative humidity at 3PM in the dry season; R_3PM = Seasonal mean relative humidity at 3PM in the rainy season.

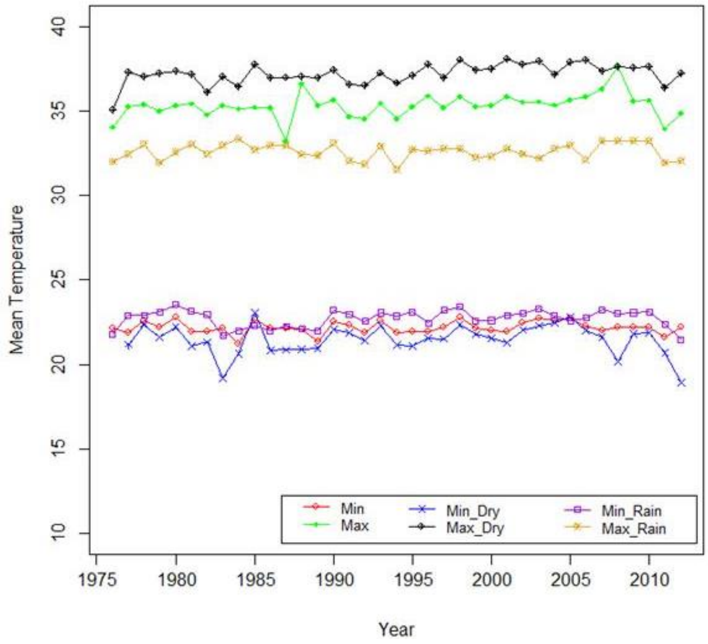

Figure 3.4 Seasonal and yearly trends of minimum and maximum temperatures in Binduri (Bawku East). Min = Minimum mean yearly temperature; Max = Maximum mean yearly temperature; Min_Dry = Mean seasonal temperature for dry season; Max_ Dry = Mean maximum temperature in the dry season; Min_Rain = Mean seasonal temperature in the rainy season; Max_Rain = Mean Maximum temperature in the rainy season.

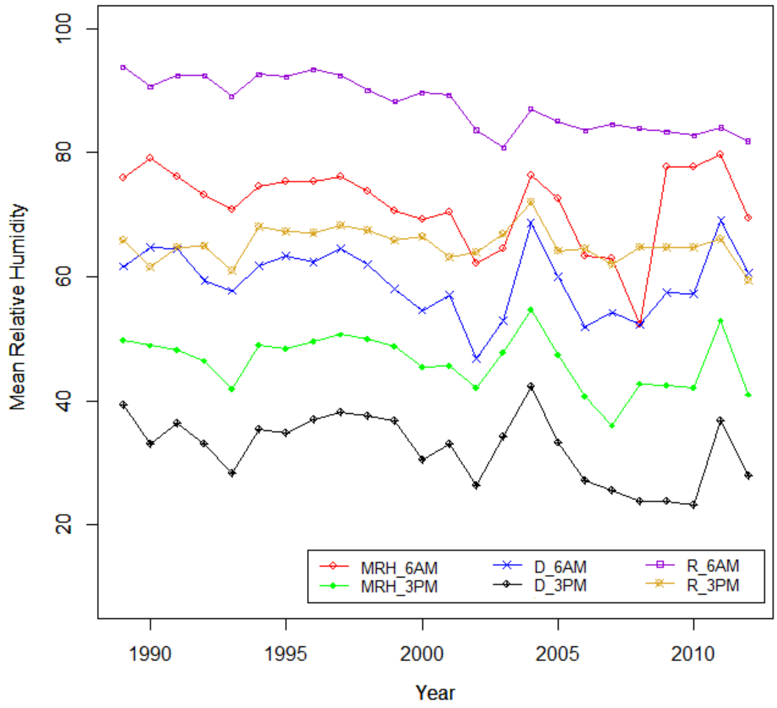

Figure 3.5. Seasonal and yearly trends of mean relative humidity at 6 AM and 3PM in Binduri Bawku East) MRH_6AM- Yearly mean relative humidity at 6AM, MRH_3PM – Yearly mean relative humidity at 3PM, D_6AM Seasonal mean relative humidity at 6AM in the dry season, D_3PM- Seasonal mean relative humidity at 3PM in the Dry season, R_3PM Seasonal mean relative humidity at 3PM in the rainy season.

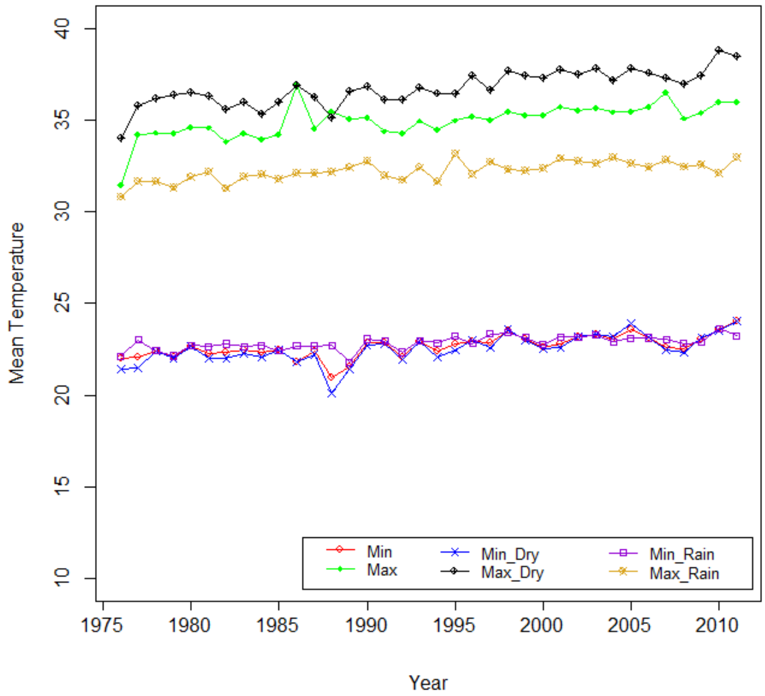

Figure 3.6. Seasonal and yearly trends of minimum and maximum temperatures in Garu (Bawku East). Min = Minimum mean yearly temperature; Max = Maximum mean yearly temperature; Min_Dry = Mean seasonal temperature for dry season; Max_Dry =- Mean maximum temperature in the dry season, Min_Rain = Mean seasonal temperature in the rainy season; Max_Rain = Mean Maximum temperature in the rainy season.

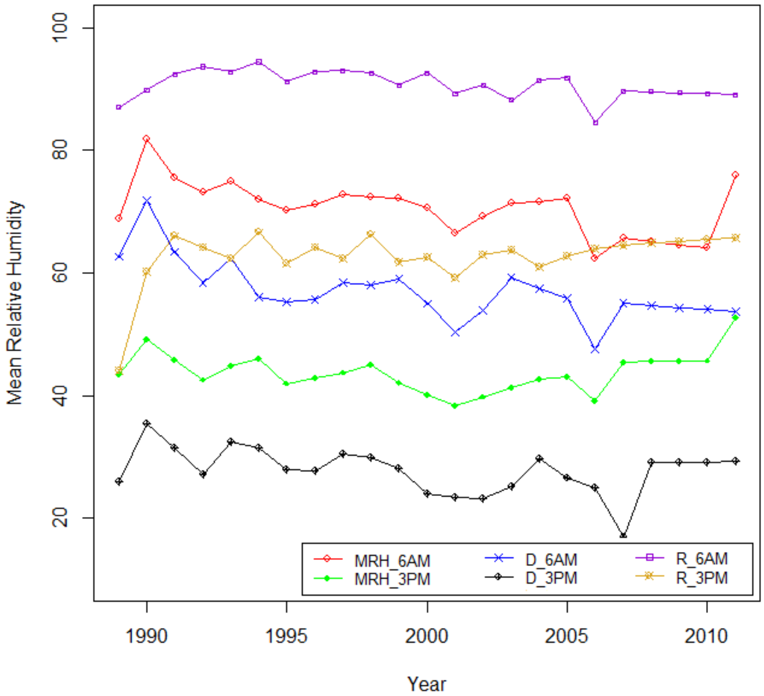

Figure 3.7. Seasonal and yearly trends of mean relative humidity at 6 AM and 15 PM in Garu (Bawku East) MRH_6AM- Yearly mean relative humidity at 6AM, MRH_3PM – Yearly mean relative humidity at 3PM,D_6AM Seasonal mean relative humidity at 6AM in the dry season, D_3PM- Seasonal mean relative humidity at 3PM in the Dry season, R_3PM Seasonal mean relative humidity at 3PM in the rainy season.

3.5.2 Seasonal Trends in Temperature and Relative Humidity

The seasonal trends that the study identified include mean annual minimum and mean annual maximum temperatures for the dry and rainy seasons, as well as the mean yearly relative humidity at 6 am and 3 pm in the rainy and dry seasons. Mean minimum and mean maximum temperatures in the dry seasons in Manga showed a rising trend, with increasing pace, as illustrated in Figure 3.2. The mean yearly trend of maximum temperature (in Manga) in the dry season had a slope rate of 0.033 °C with a decadal increase of 0.33 °C. The mean minimum yearly temperatures in the dry season had a slope of 0.041 °C with a decadal increase of 0.41 °C. The mean yearly trend of maximum temperature in the rainy season had a slope of 0.016 °C with a decadal increase of 0.16 °C. The mean yearly trend of minimum temperatures in the rainy season had a slope of 0.036 °C with a decadal increase of 0.36 °C

(Table 2). There were similar states of rise and fall of trends of mean relative humidity at 6 am and 3 pm in both dry and rainy seasons in Manga, as shown in Figure 3.3.

Table 3.3 showed that the mean yearly trend of maximum temperature in the dry season at Binduri had a slope rate of 0.026 °C with a decadal increase of 0.26 °C. The mean yearly trend of minimum temperature in the dry season had a slope of 0.045 °C with a decadal increase 0.45 °C. In the rainy season the mean yearly trend of maximum temperatures in Binduri had a slope of only 0.002 °C with a decadal increase of 0.02 °C. The mean yearly trend of minimum temperatures in the rainy season had a slope of 0.006 °C with a decadal increase of 0.06 °C. The mean yearly relative humidity in dry and rainy seasons at 6 am and 3 pm have shown significant falling trends, as presented in Figure 3.5.

Table 3: Regression analysis of mean yearly temperature and mean yearly relative humidity for Binduri (Bawku East). Abbreviations as per Table 2

Temperature							Relative Humidity						
Variables	Slope	SE	t-value	P-value	R-square	DW	variable	slope	SE	t-value	P-value	R-square	DW
Mean Mx Tem	0.021	0.011	1.876	< 0.069	0.091	1.923	Mean R.H 6 AM	-0.299	0.188	-1.594	< 0.125	0.104	1.396
Mean Mn Tem	0.003	0.006	0.576	< 0.568	0.009	2.142	Mean RH 3PM	-0.245	0.123	-1.994	< 0.059	0.153	1.600
Mean Mx Tem DS	0.026	0.008	3.159	< 0.003	0.222	1.793	Mean RH 6 AM DS	-0.208	0.157	-1.324	< 0.199	0.074	1.396
Mean MXTem RS	0.002	0.007	0.277	< 0.784	0.002	1.892	Mean RH 6 AM RS	-0.523	0.061	-8.606	< 0.001	0.771	1.470
Mean Mn Tem DS	0.045	0.029	1.523	< 0.137	0.062	1.418	Mean RH 3PM DS	-0.401	0.140	-2.857	< 0.001	0.271	1.488
Mean Mn Tem RS	0.006	0.008	0.801	< 0.429	0.018	1.505	Mean RH 3PM RS	-0.053	0.079	-0.671	< 0.510	0.020	1.655

The mean yearly trends of minimum and maximum temperatures in Garu in rainy and dry seasons have shown significant rising trends (Table 3.4). In the dry season, the mean yearly trend of maximum temperature had a slope of 0.075 °C with a decadal increase of 0.75 °C. The mean minimum trend of temperature in the dry season has a slope of 0.049 °C with a decadal increase of 0.49 °C (Table 3.4). The average yearly trend of maximum temperature in the rainy season had a slope of 0.036 °C with a decadal increase of 0.36 °C. The mean yearly trend of minimum temperature in the rainy season had a slope of 0.023 and a decadal increase of 0.23 °C. There were significant falling trends in all the mean yearly relative humidity at 6 am, 3 pm, in both rainy and dry seasons (Figure 3.7).

Table 3.4: Regression analysis of yearly mean temperature and yearly mean relative humidity for Garu Bawku East. Abbreviations as per Table 3.2

Temperature							Relative Humidity						
Variables	Slope	SE	t-value	P-value	R-square	DW	variable	slope	SE	t-value	P-value	R-square	DW
Mean Mx Tem	0.060	0.010	5.789	< 0.001	0.488	1.698	Mean R.H 6 AM	-0.383	0.118	-3.248	< 0.004	0.334	1.782
Mean Mn Tem	0.039	0.007	5.475	< 0.001	0.469	1.421	Mean RH 3PM	0.051	0.096	0.531	< 0.600	0.013	1.097
Mean Mx Tem DS	0.075	0.009	8.273	< 0.001	0.688	1.561	Mean RH 6 AM DS	-0.487	0.115	-4.228	< 0.001	0.460	1.578
Mean MXTem RS	0.036	0.006	6.192	< 0.001	0.530	2.274	Mean RH 6 AM RS	-1.45	0.068	-2.146	< 0.044	0.180	1.548
Mean Mn Tem DS	0.049	0.009	5.192	< 0.001	0.442	1.547	Mean RH 3PM DS	-0.169	0.107	-1.580	< 0.128	0.102	1.530
Mean Mn Tem RS	0.023	0.005	4.892	< 0.001	0.413	2.241	Mean RH 3PM RS	0.273	0.122	2.243	< 0.035	0.186	1.510

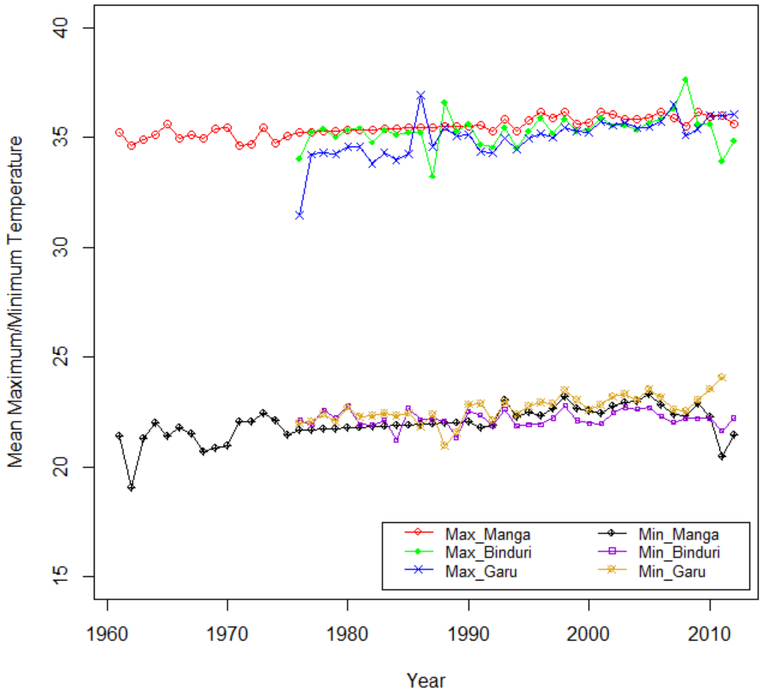

Figure 3.8 Yearly trends of mean maximum and mean minimum temperatures in Manga, Binduri and Garu.

3.6 DISCUSSION AND CONCLUSION

In the time frame from 1961–2012, in Bawku East of northern Ghana, Garu recorded a significant rise in mean temperatures above the national annual average of 0.027 °C per year. The greatest rate of increase was in the dry season with mean annual temperature rise of 0.075 °C and a decadal increase of 0.75 °C (Table 4). In all, there were a greater increase in temperature in Garu, than Manga and Binduri. Although having a lower rise in temperatures compared to Binduri, Manga also recorded a significant rise in temperature. Mean minimum temperatures in the dry season sustained a significant surge at Manga, followed by mean annual dry season temperature and mean annual temperature. Other temperature trends were not significant.

In Ghana there had been a reported annual temperature rise of 0.021 °C in the south (which translates to a decadal increase of 0.21 °C) and 0.027 °C in northern Ghana (McSweeney, 2012), which conforms with results of this study. Since 1960 and up to 2012, there has been a rise of 1oC of temperature throughout the country with northern Ghana experiencing a rapid increase than the south, although other parts of northern Ghana have higher rates of increase than the overall average (McSweeney, 2012). The Environmental

Protection Agency of Ghana has predicted that northern Ghana will experience a temperature surge of 2.5–3 °C by the year 2020 (EPA, 2007). Depending on climate change and its consequential effect on temperature, Bawku East is likely to have an additional surge of 1–1.5 °C of temperature if the pace of increase in temperature in Garu is sustained. This will be close to the prediction of the Ghana environmental protection agency (EPA, 2007).

In Garu, the humidity has fallen as temperatures have risen. In Manga, there were rising and falling trends with regard to relative humidity which failed to present a clear pattern. In Binduri, relative humidity showed a rise and fall pattern. In each case, the combination of high temperature and humidity is inimical to human health especially on people who work outside. A study in Abu Dhabi and Syria stipulated that the integration of temperature and humidity was responsible for reported cases of increased heat stroke (Shanks et al., 2004). There was a proliferation of heat cramps detected among people who work outside in Kuwait due to a combination of high temperature and humidity (Al-Ahwal et al., 2000). Both low and high air humidity when combined with high temperature have health effects for a given population. A combination of high temperature and low humidity has been assessed to be one of the causes of kidney failures (Al-Tawheed et al., 2003). Studies indicate that high temperature with low humidity in an outdoor working environment has the tendency to cause acute meningitis (Shaikhet al., 2003), kidney stones (Khan, 1991) and congenital hypothyroidism (Hashemipour et al., 2007).

Even though there has been an increase in average surface temperatures of the globe, the trend varies across continents and in local contexts (IPCC, 2007a). For instance, in an extensive analysis of temperature trends in Limpopo province of South Africa, trends in temperature over a 50 -year period were found not to be uniform throughout the province, though the study confirmed that there had been an upsurge in average yearly temperatures in each station (Tshiala et al., 2011).

This study has shown that hotness in a predominantly hot environment is being exacerbated by global climate change with more temperatures above critical levels. The number of days and months per year where temperatures exceeded such stressful conditions also increased over the last 50 years. For instance, between 1961–75 at Manga, an average of 2.3 months per year had mean temperatures greater than 37 °C, which had increased to 5.3 months per year between 1998–2012.

A large number of hot environments (temperatures regularly beyond 37 °C) will have a 1–2 °C increase in average temperature within this century, and beyond this temperature in

such environments is likely to increase by another 2–4 °C (IPCC, 2007b). Physical activities such as weeding, digging holes and other farming activities in hot environments induce heat internally that can be difficult to dissipate when air relative humidity is high (Kjellstrom, 2009). When there are inadequate cooling methods in hot outdoor working environments with workers wearing light clothing, taking breaks is the only way for a worker to reduce the effects of heat stress. However, such breaks could undermine the hourly work rate with consequential impact on economic productivity (Parsons, 2003). Even though the air relative humidity has decreased slightly, such levels still make outdoor work uncomfortable by reducing the mechanism of the body to dissipate heat.

The risk to human health imposed by high temperatures, especially for farmers, and other outdoor workers in Bawku East and other heat-prone environments in northern Ghana, warrant the need for policies and programmes to curb the heat stress impact on outdoor workers. There is the need by government to develop occupational health programmes specifically aimed at heat stress in northern Ghana. It is essential that farmers need to be supported to alleviate food insecurity and maintain sustainable agriculture in the region. Proper adaptation mechanisms need to be instituted since studies indicate that rural livelihood will be largely affected by health impacts of climate change and increases in temperature (Midgley et al., 2007)

In many parts of the world there are no data on temperature available for analysis of temporal trends (Frich et al., 2002). Meteorological data on climate and temperature are scarce in many parts of the developing world, including Africa (Caesar et al., 2006). Civil war, political instability, and scientific and technological inadequacy in many African countries have aggravated the problem of getting adequate climate information (McCarthy, 2001). On average, it is estimated that there is one weather station per 26 000 km^2 in the African region, which is 8 times below the minimum level recommended by the World Meteorological Organization. Moreover, the spread of these stations is uneven. There are no up to date climatic records in many stations in Africa (Washington et al., 2004).

Some studies indicate that the upward trend of temperature apparent from smaller scale analysis and simulation is difficult to attribute to anthropogenic causes rather than to natural variability (Hegerl et al., 2007). Even though this paper considers recent trends and levels of temperature and relative humidity, planned future study will measure human exposure to heat by taking into account local measurements of temperature and relative humidity every hour in a variety of settings (e.g., indoor and outdoor, shaded and full sun).

This will reveal the extent of heat exposure on outdoor workers, specifically farmers, across the day during their pursuit to achieve sustainable farming, as well as during the night and during other resting times.

Assessment of local heat exposure on a daily and monthly basis with heat measuring equipment in Bawku East and other parts of northern Ghana is timely and appropriate since it can help determine appropriate remedial action. Such actions include adaptation to reduce the impact of heat exposures like air conditioning or fans in the home, appropriate shade at the farm level to minimize heat impact and use of mechanised farming instead of human physical labor. This can help outdoor workers such as farmers to adapt to both current and future level of heat and climate change.

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CHAPTER 4

THE EXTENT OF HEAT ON HEALTH AND SUSTAINABLE FARMING IN GHANA –BAWKU EAST

This chapter is published in the Journal of Sustainable Agriculture Research administered by Canadian Centre of Science and Education. A preliminary investigation basically using lascar EL USB temperature and humidity sensor was used to record environmental heat exposure that farmers in Pusiga in Bawku East were exposed especially during hours of work. Hourly averages of wet bulb globe temperature were quantified to obtain a preliminary idea for a larger study involving the yearly trend of heat exposure. Farmers self-reported impact of heat their productivity were elicited. I conducted the entire study while editorial assistant was given by the co-authors.

4.1 ABSTRACT

Little is known about the health effects of heat in outdoor work and appropriate work and rest schedules for farmers working in developing countries. As temperatures continue to increase in tropical regions, such as Northern Ghana, it is necessary to evaluate how farmers experience and respond to high heat exposures. In this study, WBGT (Wet Bulb Globe Temperature) estimates and the ISO work / rest standards were applied to a cohort of farmers in the rural areas of Bawku East, Northern Ghana, to assess how farmers respond to high heat and how much they rest to protect their health, as well as the level of heat on their productivity. WBGT data was recorded over a period of 6 months among vegetable, cereals, and legume farmers. The ISO proposed and actual rest regimes observed by farmers in the same time period were evaluated. In the dry season the dry bulb temperature rose as high as 45 ºC, while during the humid months of March and April WBGT rose to levels as high as 34 ºC. Farmers worked for nine hours a day during these hot periods with insufficient rest, which has adverse consequences on their health and productivity.

4.2. INTRODUCTION

Working during periods of high temperatures, particularly in full sunshine, can have serious health consequences on farmers and can reduce their productivity by decreasing work comfort and performance (Parsons, 2003; Kjellstrom, 2009). Heat affects health and productivity but such impacts would be expected to worsen under climate change unless proper adaptation measures are instituted (Kjellstrom, 2000). Studies on heat stress and its physiological impact are scanty in the developing world. In contrast, in the developed world, copious research on heat and its physiological threat on human health are prominent in both indoor and outdoor occupational health research (Parsons, 2003; Ebi et al., 2006). As a result there are occupational safety guidelines to minimize heat stress in many indoor occupations such as manufacturing and other services industries (Kjellstrom et al., 2010). In developing countries there is much concern over the increased risk of heat stress on farmers as a result of rising outdoor temperatures, particularly as many farmers spend not less than eight hours every day in the full sunshine to cultivate or harvest (Kjellstrom et al., 2009). The IPCC predictions indicate that sub-Saharan Africa is expected to attain a sustained warming above the global average prediction and the poorest in the region would be the most at risk of the warming impact (Haines et al., 2006). The emergence of warming predominantly in the African region (IPCC, 2007b) requires improved adaptation that can maintain the wellbeing and work performance of workers (Kjellstrom, 2000).

Over the last fifty years, a one degree Celsius rise in average temperature predominantly in Northern Ghana has created a substantial increase in heat exposure (McSweeney, 2012; Frimpong et al., 2014). The increase in temperature has resulted in some 50 more hot days and 80 hot nights every year (McSweeney, 2012) which makes the situation disturbing and in need of remedial action. The plight of residents in Northern Ghana is made worse by the “harmattan” dry winds that come from the Sahara desert during November to February in contrast to the south- west monsoon winds that blow from the Atlantic Ocean to cool down people in the southern part of Ghana at this time of the year (Climate vulnerability monitor, 2012). Temperatures are projected to be extreme in the Northern Ghana by the year 2020 (EPA, 2007). This demands the need to undertake hourly assessment of heat for government led response. The rise in heat exposure in Northern Ghana has created a negative effect on the health of the resident population and its consequent impact on agriculture which is the key occupation of the people in the area (Climate vulnerability monitor, 2012). Heat stress is prevalent since almost all the farmers

work during the most heat extreme period of the day and this affects their productivity and impacts on the sustainability of farming (Climate vulnerability monitor, 2012). Studies that establish the relationships between human physiology, state of the climate and its impact on health and work capacity are well expatiated in literature of physiology, occupational health and ergonomics (Bridger, 2003; Parsons, 2003). As a result, extensive heat exposure has the tendency to reduce work performance since the human body naturally reacts to heat by reducing physical work activity in heat prone environments (Parsons, 2003; Kjellstrom, et al., 2009).

Many researchers have concentrated their efforts on estimating global averages of temperature which fail to depict the real extent of local heat exposure and local rise in temperature (Kjellstrom et al., 2013; Frimpong et al., 2014). The level of local climatic change will differ in each locality with regard to geographic and meteorological conditions unique to each area (Kjellstrom et al., 2009). The upsurge of local ambient temperature denotes that the people living in that environment will be exposed to high heat (Kjellstrom et al., 2009), and in hot tropics this could affect health and the productivity of outdoor workers (Kjellstrom, 2000; Kjellstrom et al., 2009).

In Pusiga of Northern Ghana, a large number of farmers live in round houses which have no adequate ventilation (Figure 2), though the grass used as roofing relatively cool down the temperature in the rooms as compared to roofing sheets. As in most developing countries more than 70 percent of farming work is labor intensive (FAO, 1987) as can be seen in Figure 1, and during periods of high temperatures, this could have a deleterious effect on agricultural productivity, sustainable farming and farmers' health (Kjellstrom et al., 2009). Studies have indicated that there is increased metabolic heat loads characterized with heavy work performance (Maté & Oosthuizen, 2011). Using shovel to scoop loose sand could be measured within the range of 266 $W.m^2$ and 407 $W.m^2$ (Leithead & Lind, 1964; Bethea et al., 1980;). In the same vein performing a task of drilling falls within 217 $W.m^2$ to 290 $W.m^2$ (Mate et al., 2007). Continuous work with shovel by a person of 75kg without rest or cooling can increase core body temperature (Maté & Oosthuizen, 2011). In categorization of task by ISO 7243, working with shovel, pick axe, drilling and cutlass are likely to fall within high and very high metabolic rate and work intensities (ISO, 1989). Heat related illness is prone to occur in high heat exposure where core body temperature exceeds 39ºC (Donoghue et al., 2000). Such level of heat can create dizziness to fatal heat stroke (Coris et al., 2004), during the performance of a task in the regime of high and very high work intensities in excessive heat environment without cooling or rest (Nybo, 2008).

Figure 4.1 A picture of labour intensive method of farming in Pusiga, (Bawku East) of Northern Ghana.

Figure 4.2. Typical houses with inadequate ventilation in Pusiga, (Bawku East) of Northern Ghana.

This paper used Wet Bulb Globe Temperature (WBGT) to illustrate occupational heat stress on the people of Pusiga in Bawku East of the Upper East part of Ghana where temperature reaches as high as 45 degrees Celsius (Frimpong et al., 2014; Laux et al., 2008). The purpose of the study is to undertake a preliminary investigation of the extent of heat stress on outdoor and indoor working and living areas of farmers respectively. The underpinning factor of the study is to serve as a methodological template for a larger study of heat stress on farmers covering the entire year. The WBGT is predominantly used by the Occupational Safety and the Health Administration of United States of America and the US Army to assess health related hazards from heat exposure on outdoor activities (Occupational Safety and Health Admnistration (OSHA), 1999; US Army center for Health Promotion and Preventive Medicine USACHPPM, 2003). The instrument and the index is known as WBGT. This index shows the level of heat exposure to which workers are exposed. It also regulates work and rest for the safety of workers health and avoidance of heat related injuries. Many outdoor occupations have adopted this heat index to regulate work and rest in many physically demanding activities in heat exposed environment.

In this present study WBGT index is applied to assess the level of heat exposure on farmers who work outdoor in Pusiga of North East Ghana. The average hourly trend of WBGT in January, February, March, April, May and June (2013) are illustrated. January to May months fall within the dry season while June commences the wet season (Laux et al.,

2008). Peak of highest temperature occur in the months of March, April and May (Frimpong et al., 2014). As a result of Climate change, rainfall now generally starts in June or late May instead of early May and sometimes in late May (Laux et al., 2008; Frimpong et al., 2014). Results of interviews of residents in (2013) regarding impact of high temperature and heat on health and outdoor farming work were shown to present the situation of heat and temperature and its future implication on sustainable farming. This study is unique in that there is no published study that has taken climate change impact assessment on local farmers in Ghana with the aim of estimating current heat impact and its progress as temperature continuous to increase. This is innovative in that it employed instruments that can measure heat for a year without human interference as distinguished from Questemp (heat measuring device) instrument which demands the care and operation of human personnel.

4.3METHOD

Heat monitoring equipment capable of recording readings every hour (Lascar EL USB temperature and humidity loggers) (Kjellstrom et al., 2009; Pradhan et al., 2013) were used to measure temperature, relative humidity and dew point at the workplace of farmers in selected rural crops growing communities at (Pusiga) in Bawku East, of Northern Ghana. The instruments were placed in the shade to prevent direct exposure to sunshine and they were secured to a tree for the duration of the monitoring period (9 January – 7 July). Computer software developed by Lemke (Lemke & Kjellstrom, 2012) which is predominantly used in the 'High Occupational Temperature Health and Productivity Suppression' (HOTHAPS is a global program of assessing heat stress) program was used to calculate WBGT from the recordings of the EL lascar USB instrument.

A questionnaire developed by the HOTHAPS program was adapted and administered to a cohort of crop (legume, cereals, vegetables) growing farmers in the study area (n=308) in order to elicit information related to their self-reported health status and the impact of heat on their day to day work activities. The questionnaire cohort was recruited from the farming communities of Pusiga, Binduri, and Manga. The survey was administered as part of a large study to gauge the levels of concern and knowledge that local communities have about the issues of heat and climate change. These data were correlated with environmental measurements from January to June, 2013. Farmers were selected through purposive sampling and random probability procedure based on the pre requisite that each participant lived in the rural area of Bawku East, which consists of a number of smaller farming communities, worked as a farmer and cultivated either cereal, vegetable or legume crops.

4.4 RESULT

4.4.1 Environmental Data

Figure 3 to 8 show mean hourly WBGT with the 95% confidence interval. In all the six graphs average WBGT begins to rise early in the morning, reaching its peak in the early to mid afternoon, thus the WBGT reaches its peak during the working day and drops off at night.. The vulnerability of the participating farmers to the impact of heat exposure were severe and were exacerbated by the fact that they generally spent at least 8 hours per day engaged in manual labour in the sun. There were no shade in the fields and no air conditioned homes to rest in which is typical of African farming system as reported by food and Agricultural Organization (FAO, 1987). Figure 9 represents average WBGT for every hour from 7 January to 7 July 2013. Figure 10 represent average WBGT in an hour in each month.

Table1 represents the levels of community concern for the impact of heat on health. Table 2 represents the effects of heat on income and productivity while Table 3 represents the WBGT in ISO 7243 recommended work load and average work rest ratio.

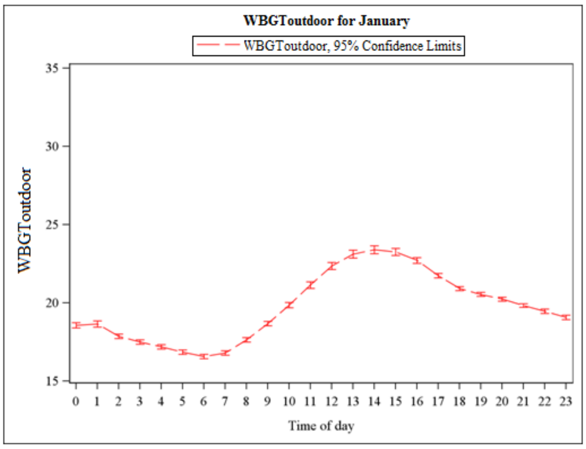


Figure 4.3. A pictorial representation of average WBGT in an hour in January within the 24 hr cycle is explained in the graph

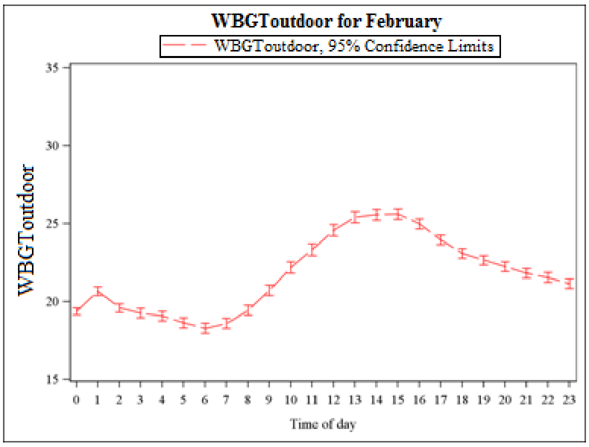


Figure 4.4. A pictorial representation of average WBGT in an hour in February within the 24 hr cycle is explained in the graph

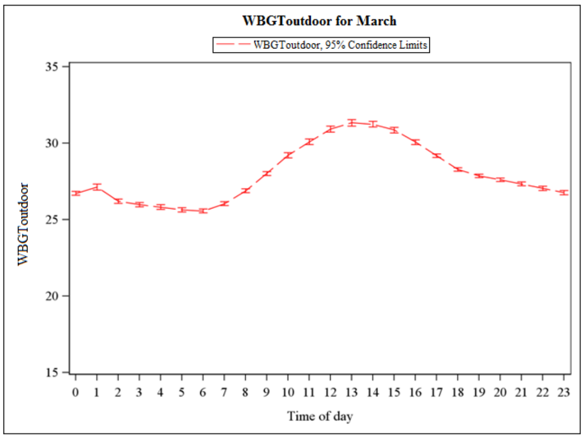


Figure 4.5. A pictorial representation of average WBGT in an hour in March within the 24 hr cycle is explained in the graph.

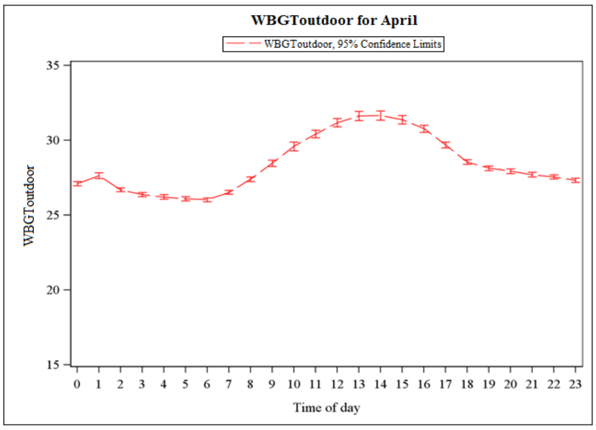


Figure 4.6. A pictorial representation of average WBGT in an hour in April within the 24 hr cycle is explained in the graph.

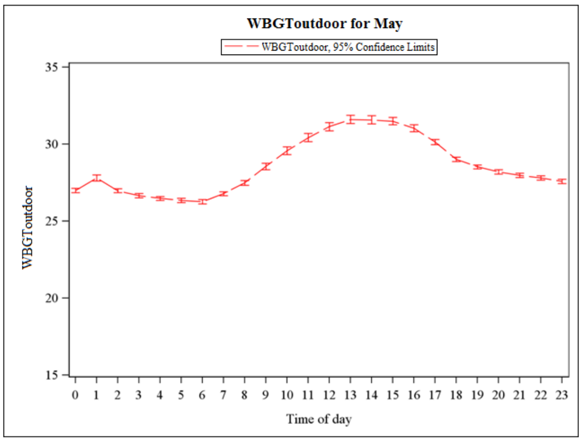


Figure 4.7 A pictorial representation of average WBGT in an hour in May within the 24 hr cycle is explained in the graph

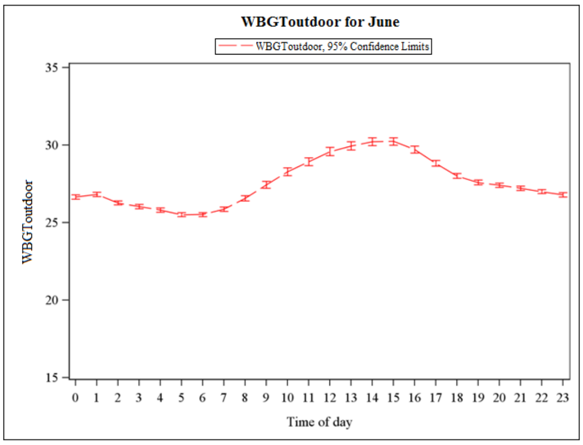
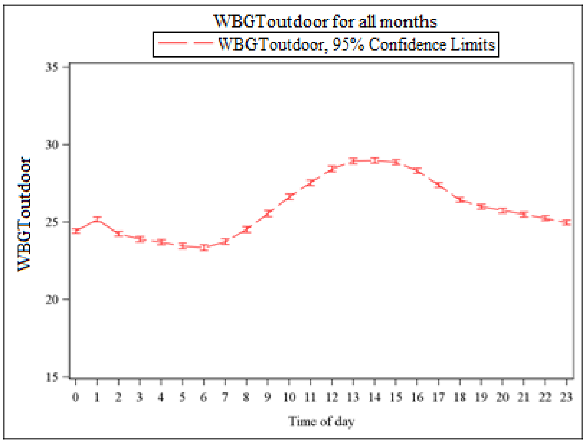


Figure4. 8. A pictorial representation of average WBGT in an hour in June within the 24 hr cycle is explained in the graph



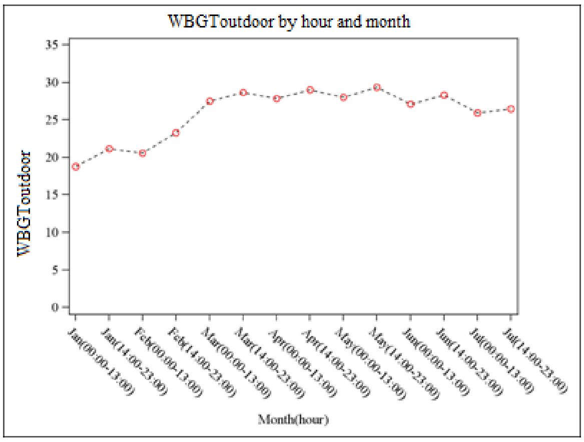


Figure 4.9. Average WBGT in an hour from 7 th January to 7th July is illustrated below.

Figure 4.10.Average WBGT by hour and month.

4.4.2 Responses from Survey

The survey data showed that farmers were concerned about heat and its impact on health.

Table 4.1: Concern of heat to health in Bawku East

	Age group												Total	
	less than 20		20-29		30-39		40-49		50-59		60+			
	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age
Concern of heat to health yes	13	92.9	45	91.8	56	94.9	49	89.1	88	98.9	36	97.3	287	94.7
NO	1	7.1	4	8.2	3	5.1	6	10.9	1	1.1	1	2.7	16	5.3
Total	14	100.0	49	100.0	59	100.0	55	100.0	89	100.0	37	100.0	303	100.0

Table 4.2: Effects of heat on income and productivity

	Age group												Total	
	less than 20		20-29		30-39		40-49		50-59		60+			
	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age
Effects of Heat on Income and Productivity of farmers														
Affect Productivity and Income by more than Half of what I used to get in the past	7	50.0	37	72.5	25	41.7	24	43.6	51	56.0	13	35.1	157	51.0
Affect productivity and income by half or less	3	21.4	4	7.8	17	28.3	15	27.3	12	13.2	12	32.4	63	20.5
Affect productivity insignificantly	4	28.6	10	19.6	18	30.0	16	29.1	28	30.8	12	32.4	88	28.6
Total	14	100.0	51	100.0	60	100.0	55	100.0	91	100.0	37	100.0	308	100.0

Table 4.3: ISO recommended work load and average work rest ratio

Work intensity	Light work in WBGT in degrees Celsius	Medium work WBGT degrees Celsius	Heavy work WBGT degrees Celsius	Very heavy work WBGT degrees Celsius
0% rest/hour continuous work	31	28	27	25.5
25% rest/hour	31.5	29	27.5	26.5
50% rest/hour	32	30.5	29.5	28
75% rest/hour	32.5	32	31.5	31
100% rest/hour no activity	39	37	36	34

4.5 DISCUSSION

The rainy season in the study area normally commences in April, however, there has been a shifting trend for rain to arrive later in the year at May-June (Laux et al., 2008).This has increased the length of the dry season, thus contributing to an increase in temperature in the region (Laux et al., 2008). Extreme temperatures and droughts are predicted to increase in the near future (EPA, 2007; Van de Giesen, Liebe, & Jung, 2010). The farm workers in this vicinity are from the poorest threshold in Ghana (Webber, 1996; Whitehead, 2006) and cannot afford mechanical agriculture. Like their other counterparts in Africa, muscular energy is the predominant form used to undertake farm activities (Food and Agriculture Organization, 1987).The farm work is strenuous and climate change will intensify farmers'

exposure to environmental heat. This study has shown that over 5 hours in a day are estimated to be above 26 ºC WBGT, while 6 hours in a day are estimated to be over 30 ºC WBGT in the month of March, April, and June. The ISO 7243 resting requirement was not applied as farmers rest opportunistically and generally aimed to get the work done. As such there was a potential influence on health effects regarding the state of insufficient rest on sustainable health. A large number of farmers engaged in heavy and very heavy work like cutting of trees with cutlasses and digging holes to get water for irrigating their crops because of inadequate rains. On their concern of heat to their health in all age group 93.5% expressed concern of heat to their health while 49% of the entire age group expressed that the increase in heat has affected their income much more than half of what they used to get in the previous years. This study is consistent with that on heat exposure impacts on rice harvesters in India (Sahu, Sett, & Kjellstrom, 2013). The fulcrum of this study is to present level of heat stress on outdoor farmers and its impacts on work output as climate change increased. Heavy and very heavy work (Table 4.3) is likely to become difficult and health threatening in the wake of increased temperature if adequate rests is not observed. However, hourly output with series of rest in such manual task like digging, cutting of trees, hand fetched water from boreholes to irrigate crops which fall in the zone of heavy and very heavy ISO 18 in heat prone environment will be undermined. The estimation of reduction in work output and productivity of manual farm work as heat increases in developing countries and poor environment such as Northern Ghana is a critical aspect of climate change impact assessment. This calls for the need of appropriate measure to improve work capacity, health and sustainable farming as climate change is intensified. Studies have shown that work productivity of farmers working in heat environments deceases as heat increases (Sahu et al., 2013).

From both historical trends and these study results, temperatures are usually at highest during the months of March and April in Bawku East and that clearly affects WBGT. The inland topography of Bawku East may be a key factor related to the high temperature in the area, since inland areas in the tropics have higher temperatures compared to coastal areas which tend to experience sea breezes (IPCC, 2007). In order to protect farmers in the rural communities of Bawku East, appropriate ISO 18 work/rest schedules need to be implemented, especially when heavy and very heavy manual labor is being performed. Continuous work for many hours without rest is likely to affect farmers' health which would in turn impact on the sustainability of farming in the region. Knowledge about work and rest regimes should be disseminated to farmers in the form of frequent education in rural communities. This will enhance their knowledge to protect their health especially when extreme climatic conditions

are predicted to worsen in the vicinity. The establishment of a heat monitoring service must be implemented and when the situation requires implementation of precautionary work/rest regimes this information needs to be conveyed to farmers through appropriate means. In the longer term, the provision of adequately ventilated housing and shelter out of the sun in the fields should be provided. A central air conditioned resting place with cool potable water should be provided where farmers can cool down when necessary. Improvements in the current irrigation system will enable farmers to obtain water for irrigation eliminating the need to dig bore holes and draw water manually.

4.6 CONCLUSION

Despite the physiological benefits by acclimatization of a person in a working environment coupled with implementation of heat stress intervention, heat stress related illnesses are still prevalent in many occupational settings. This attests to the need for further heat stress measurements and research to be intensified in occupations susceptible to heat stress (Maté & Oosthuizen, 2011). There is an association between climate change and sustainable development issues with regard to health, food security, employment, income, and livelihood. These are largely affected by the impact of high temperature especially when such activities are carried out in outdoor environment (Lundgren et al., 2013). The current policies in agricultural sector in Ghana do not make room for health protection for farmers who spend many hours in the sun. This is significant issue in the context of sustainable farming as temperature are predicted to increase globally (IPCC, 2007a), and in northern Ghana specifically (EPA, 2007).

Modification of the task in outdoor farming in Bawku East and other part of rural Ghana is imperative in the emergence of global warming and climate change. Manual labor which forms the predominant way of farming in African region needs to be replaced by mechanical farming where machines could be used for weeding, digging and harvesting. In this way the number of hours a person will spend in the outdoors under the direct exposure of hot sun will be reduced. Concern about heat impacts on health and productivity will be well managed as global warming is intensified.

The measurement of heat stress in the farming communities where the study took place serves as a prelude for deeper investigation with different heat measuring equipment for longer measurements. The exposure level measured with alternative heat measuring device can attest to the gravity of heat exposure to rural communities in the developing world such as

Bawku East. Moreover, quantification of farm work productivity and level of WBGT in each hour in several areas of manual task environment will assist in the progress of estimating climate change impact on poor and developing countries whose farmers work manually in exposure of heat and other weather hazards. The WBGT above 26 degrees affects work pace and productivity. Local economy will be massively affected when heat is increased because of climate change. Sustainable adaptation with the help of government and nongovernmental organization on better ways to confront environmental heat exposure is timely and appropriate at rural Ghana in this period of global warming and climate change.

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CHAPTER 5

GLOBAL WARMING AND THE YEARLY TRENDS OF HEAT EXPOSURE ON FARMERS IN NORTH EAST GHANA

This chapter has been submitted as a manuscript to International Journal of Biometeorology and is under review. This Journal is administered by springer publishing service. The content of the manuscript is the same in the thesis while the layout has been changed to conform to the specification and requirement of the thesis. The entire manuscript was prepared by the leading author while the co-authors provided editorial assistants. The chapter gives details of the quantification of heat stress using lascar EL USB Temperature and Humidity sensors to capture heat stress from various locations. This includes the field where farmers spend many hours during the day and their home or resting places where they cool down during and after work. Lascar El Temperature and Humidity sensors are able to record temperature and relative humidity for a year. This instrument has been identified to be suitable for local heat stress assessment since meteorological station data may mask the real extent that local people are exposed to heat stress. As climate change is happening it is timely and appropriate to quantify the real extent of heat exposure being faced at the local level. Samples of days for Questemp and lascar heat quantification are compared to the extent relationship and showed a statistically closed relationship which meant that this instrument is convenient to measure heat stress at the local level.

5.1 ABSTRACT

Environmental health hazards faced by farmers, such as exposure to extreme heat stress, are a growing concern due to global climate change, particularly in tropical developing countries. In such environments, farmers are considered to be apopulation at risk of environmental heat exposure. The situation is exacerbated due to their farming methods that involve the use of primitive equipment, and hard manual labourconducted in full sunshine under hot and humid conditions. However, there is inadequate information about the extent of heat exposure to such

farmers, both in their working environment and their resting places. This paper presents results from a study assessing environmental heat exposure on rural smallholder farmers in Bawku East, Northern Ghana. From January to December 2013, Lascar USB temperature and humidity sensors, as well as a calibrated Questemp heat stress monitor, were deployed in the field and homes of rural farmers at Pusiga in Bawku East to capture farmers exposure to heat stress in both their working and living environments as they executed regular farming routines. The Lascar sensors have the capability to frequently, accurately and securely measure temperature and humidity over long periods .The Questemp heat stress monitor was placed in the same vicinity andshowed strong correlations to Lascar sensors in terms of derived values of Wet-Bulb Globe Temperature (WBGT). The WBGT in the working environment of farmers peaked at 30^0C to35^0Cduring the middle of the day during the rainy season from March to October and dropped to $21\text{-}28^0$C in the early morning during this season. A maximum daily WBGTof $26\text{-}34^0$C was recorded in the resting and living environment of farmers, demonstrating little relief from heat exposure during the day.With these levels of heat stress, exposed farmers conducting physically demanding outdoor work risk suffering serious health consequences. The sustainability of manual farming practices is also under threat by such high levels of heat exposure.

5.2 INTRODUCTION

The vast majority of the world's farming population are smallholder farmers, comprising 85% of farms worldwide (Nagayet, 2005). Smallholder farmers make up around half of the world's population classified as hungry and three-quarters of persons who are hungry in Africa (Sanchez & Swaminathan, 2005). Invariably, the target of reducing poverty and hunger, as enshrined in Millennium Development Goals, hinges on global efforts to improve the livelihood of the increasing number of smallholder famers predominantly located in the African region. Among the numerous threats faced by smallholder farmers, environmental heat exposure is considered one of the most serious health risks that can potentially stifle smallholder farmers' pace of work and ultimately affect their work capacity and productivity (Kjellstrom, 2012). Global warming is projected to increase temperatures globally (Christensen et al., 2007; IPCC, 2014) and this combined with a concurrent increase in abslote humidity in many parts of the globe, especially in Africa, as predicted by the Clausius-Clapeyron theory (Meehl & Tebaldi, 2004; IPCC, 2007; Gleason et al., 2008; Willett & Sherwood, 2010), will likely increase risks of

heat stress (Al-Ahwal, Norman, & Brebner, 2000; Al-Tawheed et al., 2003). An increase in the incidence of extreme weather events due to climate changewill likely increase the threat of heat stress faced by smallholder farmers in developing countries, especially in the African region (Kjellstrom, 2009; Kjellstrom, 2015).

In West Africa, a large number of the rural economies depend on crop growing to provide a livelihood which is being negatively impacted by climate change (Boko et al., 2007; Collier, Conway, & Venables, 2008). Ghana is a tropical country located on the west coast of Africa with more than 55% of its population engaged in agriculture (Aryeetey & McKay, 2004). The northern-east part of Ghana is under-developed with a large number of the inhabitants depending on subsistence farming and the region has seen very little in the way of socioeconomic and infrastructure development over the last few decades, thereby exacerbating poverty, particularly in the rural areas (Webber, 1996; Whitehead, 2006; Laube et al., 2012). In the Upper East region of northern Ghana, an analysis of rainfall data collected over the last 60 years indicates a shift in the commencement of the rainy season from April to late May, and a systematically increasing length of the dry season (Laux et al, 2008). This region is associated with harsh climatic conditions with vulnerable food insecurity. Regional climate predictions include an increase in erratic weather events such as extreme temperatures, drought and unpredictable rainfall in the years ahead (Van de Giesen et al., 2010). There is little rainfall in this region from June to October, with July to September receiving most of the rains (Laube et al., 2012). A comparative analysis of temperature from 1931 to 1961 and 1962 to-1990 indicates an increasing trend in mean temperature in this region (Kranjac-Berisavljevic et al., 1999).

In the area of Bawku East in northern Ghana, mean annual temperatures for the period 1961 to 2012 increased at a rate of 0.075^0C which is above the national average of 0. 021°C per year(Frimpong et al., 2014) and the area is predicted to have an increase in mean annual temperatures of 2.5-3°C by the year 2050 (EPA, 2007). In humid countries, an increase in temperature is likely to have a more severe impact on working people (Willett & Sherwood, 2010); this is especially relevant to Bawku East where more than 65% of the people are engaged in agriculture (Ministry of Food and Agriculture, 2014). Farming practices are primitive and labour intensive and predominantly conducted in the sun. Tasks on the farms are often physically demanding and associated with a high metabolic heat load thus placing workers at risk on a regular basis during the hot months (Food and Agriculture Organization, 1987; MMWR, 2008).

In addition to the health hazards associated with extreme heat there are also impacts on the productivity of outdoor workers, especially in middle and low income countries (Kjellstrom, 2009; Kjellstrom 2015).

5.3 STUDY LOCATION AND SIGNIFICANCE OF THE STUDY

A retrospective analysis of temperature and relative humidity at Bawku East, as recorded at a nearby meteorological station, indicated that, for the period 1961-1975, 63 days of daytime temperature above 37°C was sustained in each year and this increased to 153 days per year from 1998-2012 (Frimpong et al., 2014). The Bawku East area of Ghana is known to be very poor with outdoor subsistence farming being the predominant occupation (Webber, 1996; Whitehead, 2006). Very few environmental heat- and climate-related studies have been conducted in that area, just like many other parts of Africa (Alexander et al., 2006; Gleason et al., 2008; Kenyon & Hegerl, 2008). As global temperatures are projected to increase (Pachauri, 2007; Trenberth, Stepaniak et al., 2001), climate change impact projections become meaningless unless efforts are made to access the impacts of such projections on local people who manually work outdoors and depend on the local economy (Kjellstrom et al., 2009). In low and middle income countries, there is limited assessment of climate change impacts on human health and little has been accomplished in Africa (Costello et al., 2009). In Ghana, no significant studies have been done to determine trends of heat exposure at a given locality and its projected impact on outdoor workers. This study comprehensively investigates heat exposures on farmers in Bawku East of Northern Ghana where temperaturesare projected to increase in the near future (National Development Planning Commission, 2011). This assessment provides a baseline parameter of climate change risk assessment for outdoor farmers and the required remedial action necessary to curb health impacts associated with extreme heat exposure. Lascar temperature and relative humidity data were utilised to predict Wet Bulb Globe Temperature (WBGT) according to the methods of Lemke & Kjellstrom (2012), in conjuction with measurement of WBGT from Questemp on selected days, and the data obtained from the two instruments were compared and correlated in order to validate the methods (Parsons, 2003).To comprehensively address the environmental heat situation in Bawku East, monthly exceedances of WBGT above accepted thresholds were calculated for the period January to December 2013. The international standard thresholds for work and rest (ISO7243) was used to evaluate the potential impact of heat stress

on farmers, in both the dry and rainy seasons. Descriptive statistics regarding WBGT predictions for outdoor in the shade and indoors (home and resting environments) are also presented.

5.4 METHODOLOGY

Establishing the relationship between the state of the atmospheric environment with physiological comfort is dependent on the interaction of various environmental and individual (human) parameters. Environmental factors include air temperature, humidity level, air movement and radiant heat load from the sun or alternative sources. Individual parameters include age, health status, gender, level of activity, type of clothing, level of acclimatisation, and individual tolerance (Falk, 1998). There is no specific universally acknowledged method of quantifying heat stress. There are a number of heat stress indices that vary widely in terms of their complexity, application in relation to inputs, physiological parameters, underlying assumptions and the purpose for which the index was developed (Willett & Sherwood, 2010).

In this study, the widely accepted WBGT index was used to evaluate heat stress of farm workers. The WBGT was originally developed for assessing risks during military training; however, it is now widely used for occupational heat stress assessment. The measurements required to calculate WBGT are relatively easy to obtain (dry bulb, wet bulb and globe temperature). The associated calculations are simple to perform and although wind speed is not measured directly, the cooling effect of wind is assessed through its effect on the wet bulb thermometer. The WBGT is a suitable index to use for outdoor work because it incorporates the globe temperature. Furthermore tables are readily available to estimate metabolic workload and the impact of clothing on the cooling capacity of workers from WBGT values. These tables are based on accepted equations (ISO 7243) and are routinely used with Questemp monitors to measure personal heat stress. The WBGT is recommended as an appropriate heat stress index by the International Standard Organization (ISO, 1989), and it is used globally to assess heat stress risks in occupational groups, during and after sporting events, and during military training (Parsons, 2006; Willett & Sherwood, 2010).

Due to the remoteness of the study location and lack of electricity, six Lascar EL USB-2-LCD sensors were used to record temperature and humidity and these data were used to estimate WBGT based on the methods of Lemke & Kjellstrom (2012). The instruments have a battery life of approximately 11 months and in this study the batteries worked for over a year and they were

programmed to record temperature and relative humidity every half hour. The equipment has the capacity to measure and store 16,379 relative humidity (RH) and temperature readings in the range of 0-100%RH and -35 to +80°C. The equipment is relatively easy to set up and does not require maintenance during the recording period. At the end of the sampling periods, data was downloaded by inserting the instrument into a computer USB port. The assessment of WBGT was based on the methods of Lemke & Kjellstrom (2012), who validated the formulas developed by Bernard & Pourmoghani (1999) for WBGT in the shade, and Liljegren et al. (2008) for WBGT outdoors in the sun. Since globe temperature was not measured using the Lascar sensors in this study and instruments were placed in shaded areas, the validation by Bernard & Pourmoghani (1999) was used. The formula used is as follows: WBGT id=0.67Tnwb+0.33Ta-0.048x log (ws) x (Ta-Tnwb), with indoor wind speed (ws) approximated to 3m/s and natural wet bulb temperature (Tnwb) derived from the globe temperature (Tg) by iteration. Other abbreviations in the equation are as follows: WBGT id is Indoor Wet Bulb Globe Temperature, Tnwb is natural wet bulb temperature, Ta is air temperature, and Pa is atmospheric pressure. The main deficiency in estimating WBGT from measurement taken from Lascar EL USB sensors is the fact that solar radiation and wind speed are not considered. Under full sun the results of WBGT would be underestimated. However, in this study the Lascar sensors were placed in shaded environments and this approach has been used to successfully estimate WBGT in agricultural fields in Nepal (Pradhan et al., 2013) and in India (Kjellstrom et al., 2009)**.**

The study was conducted in three sections as follows. The first part of the study consisted of the yearly measurement of heat with Lascar ELUSB temperature and humidity sensors. Measurement of WBGT over several days using Questemp was used to validate the results from the Lascar sensors. Additionally, meteorological station data regarding temperature and relative humidity at certain times of the day in February was compared to Lascar data on temperature and relative humidity.

5.4.1 Equipment placement

The Lascar EL 2B USB instruments were placed in strategic shaded locations both outdoors and indoors (in the homes and resting places used by farmers). The sensors were programmed to record temperature, humidity and dewpoint every 30 minutes for the months of

January –December, 2013. Three sensors were placed outdoors near the cultivated fields in shaded areas (usually in canopy of trees). Two instruments were placed in typical famers homes and one was placed close to a weather station in the shade. At the end of the sampling period the sensors were inserted into a computer USB port and data were downloaded and exported to Microsoft Excel for analysis.

Estimated WBGT values (using methods described above) were then used to evaluate the heat stress risk for famers based on the human work and rest regimes designed by the International Standard Organization for acclimatised workers wearing light clothing and performing heavy manual work (ISO 7243) as depicted in Table 3. Furthermore, a Questemp heat stress monitor was used to assess actual outdoor WBGT readings in the farmers working environment on randomly sampled days from January 2013 to July 2013. This equipment was place in the outdoor environment in non-shaded place to get access to radiant heat, which was ten metres away from Lacar USB sensors. This was done to validate the LASCAR estimates of WBGT.

5.6 RESULTS

WBGT levels as calculated from the Lascar sensor measurements are summarised in Table 5.1 (for resting environments) and Table 5.2 (for working environments). These show average WBGT being highest in the months of March, April, May, June and July and lowest in August, September, October, November and December, January and February with regard to resting environments (Table 5.1). The average WBGT in the working environment also increased dramatically from February to March, but also had a more gradual increase from July to October. June had the highest mean monthly maximum WBGT in the working environment of between 36 to 38^{0}C, depending on the sensor (Table 5.2). For most of the year the maximum outdoor WBGT measurements were in the range of 33-36^{0}C (Table 5.2), whereas they only reached these mean maxima indoors during the months June to September (Table 5.1).

In the working environment the mean WBGT in the daytime ranged from 23^{0}C in January and February to 30^{o}C and above between March to June. Mean WBGT subsidedslightly to 27^{0}C in July and August and achieved a consistent levelbetween September to November, being in the range 26-28^{0}C, with December recording the lowest mean daytime WBGT of 21^{0}C (Table 5.3). However, night-time average WBGT ranges from 21-27^0 Coutdoors (Table 5.3).

There was a much higher proportion or frequency of WBGT in the range of 27-30 ^{o}C in the working environment between the months of March-October (Table5.3). November-January had the lowestproportion of WBGT within the range of 27-30^{0}C. It is however important to note that a relatively high frequencyof daytime WBGT readings were above the threshold of 30 ^{0}C in March to October for farmers working in the field of cultivation (in the shade) (Table 5.3).

In April and May 2013, WBGT in the working environment was above 30 ^{o}C for over 25% of the time (table 5.3).

Table 5.1: Monthly estimated WBGT from January to December calculated from Lascar EL USB data collected at three different resting environments, two indoors and one in the shade outdoors. Mn is Minimum WBGT, Mx is Maximum WBGT, and CV coefficient of Variation

	Temp 3: WBGT inside home						Temp 1: WBGT inside home						Temp 2: WBGT outside in the shade					
	Mean	Median	Std	Min	Max	CV	Mean	Median	Std	Min	Max	CV	Mean	Median	Std	Min	Max	CV
Month																		
JAN	19.2	19.2	1.9	14.6	28.1	9.6	20.2	20.2	2.0	15.8	27.8	9.7	19.7	19.7	2.1	15.0	28.5	10.4
FEB	21.4	21.0	3.3	14.8	30.4	15.3	22.2	21.7	3.3	15.6	31.5	14.9	21.3	21.0	3.2	15.2	31.0	15.1
MAR	27.6	27.7	1.7	21.6	32.0	6.2	28.1	28.0	1.9	21.6	32.6	6.6	27.6	27.5	1.8	21.4	32.0	6.4
APR	27.5	27.2	2.5	18.2	37.5	9.3	28.4	28.2	1.9	18.2	33.4	6.7	28.3	28.1	1.7	18.2	32.4	6.0
MAY	29.1	29.0	1.8	23.0	31.8	6.2	28.4	28.2	1.8	23.3	33.5	6.3	28.5	28.3	1.7	23.6	32.6	5.8
JUN	26.8	26.7	2.3	21.2	33.0	8.7	27.4	27.5	1.9	22.4	32.2	7.0	27.8	27.8	2.0	22.5	32.2	7.1
JUL	26.0	26.0	2.0	15.6	33.6	7.7	26.1	26.0	2.0	14.0	33.9	7.7	26.2	26.1	2.1	14.5	34.2	7.9
AUG	26.0	25.9	1.1	23.1	28.9	4.2	25.9	25.9	1.1	23.1	29.1	4.3	25.9	25.8	1.1	23.1	28.8	4.1
SEP	26.4	26.4	1.3	23.2	34.8	4.9	26.3	26.3	1.3	23.1	33.5	5.1	26.4	26.4	1.3	23.6	33.8	4.9
OCT	26.7	26.6	1.2	22.6	29.5	4.6	26.6	26.6	1.2	22.6	29.8	4.5	26.6	26.6	1.2	22.6	30.0	4.6
NOV	24.6	24.9	1.9	19.1	28.1	7.6	24.6	24.9	1.9	19.4	28.4	7.6	24.6	24.8	1.9	19.1	28.1	7.6
DEC	19.6	19.4	1.6	15.3	24.0	8.3	19.6	19.4	1.7	14.8	24.1	8.6	19.5	19.4	1.7	15.3	24.0	8.5

(Lascar instrument is represented in locations as temp. Temp 1, 2, 6)

Table 5.2 Monthly estimated WBGT from January to December calculated from Lascar EL USB data collected at three different working environments, outdoor in a shade. Min is Minimum WBGT (mean of all daily minima for the month), Max is Maximum WBGT (mean of all daily maxima for the month), and CV is the Coefficient of Variation (of all measurements in the month).

Month year	Temp 4: WBGT in shade						Temp 5: WBGT in shade						Temp 6: WBGT in shade					
	Mean	Median	Std	Min	Max	CV	Mean	Median	Std	Min	Max	CV	Mean	Median	Std	Min	Max	CV
JAN	19.9	19.2	3.2	14.2	27.9	16.3	19.6	19.4	2.1	14.8	29.3	10.8	19.7	19.3	3.4	13.5	27.6	17.1
FEB	21.4	20.8	4.0	13.9	33.3	18.5	21.5	20.9	3.6	14.5	31.6	16.9	21.7	21.4	4.4	13.2	33.1	20.3
MAR	28.3	27.4	3.3	21.1	36.5	11.5	28.1	28.0	2.2	21.0	33.3	7.8	27.6	27.1	2.7	20.3	33.7	9.6
APR	29.0	28.0	3.2	22.8	36.9	11.1	28.0	27.7	2.5	18.2	38.1	8.9	27.8	27.3	2.6	22.2	34.2	9.4
MAY	29.3	28.4	3.1	23.7	36.8	10.5	28.4	28.0	2.2	22.2	37.1	7.7	27.8	27.6	2.6	19.6	33.9	9.4
JUN	28.2	27.5	3.1	22.8	36.4	11.0	27.6	27.5	2.1	22.8	37.6	7.7	27.5	27.5	1.8	23.7	35.9	6.6
JUL	25.9	25.9	2.2	14.0	33.9	8.4	26.2	26.0	2.0	15.1	33.8	7.7	26.2	26.3	2.8	15.9	33.4	10.7
AUG	26.4	25.9	2.1	22.5	34.6	8.0	26.8	26.4	1.7	23.5	33.0	6.3						
SEP	27.6	26.9	3.0	22.7	35.5	10.9	28.1	27.7	2.5	23.5	34.5	8.7						
OCT	28.2	27.3	3.1	22.3	35.3	10.9	28.3	27.9	2.2	23.7	34.4	7.8						
NOV	25.8	25.4	3.4	18.5	33.7	13.2	25.6	25.7	2.5	19.8	31.9	9.6						
DEC	20.6	20.1	3.2	14.3	29.0	15.7	20.3	20.3	2.3	15.2	26.7	11.1						

Table 5.3: Monthly percentage breakdown of WBGT into certain temperature ranges derived from hourly measurements of Lascar EL USB Sensors, and weighted averages of WBGT for day and night

Variable		Month											
		January	February	March	April	May	June	July	August	September	October	November	December
WBGT Indoor(in resting environment)													
% time < 27°C WBGT		99.4	87.1	16.0	12.4	8.3	22.8	82.3	100.0	100.0	100.0	100.0	100.0
% time 27-30°C WBGT		0.6	9.1	54.4	54.0	54.2	52.8	13.2	0.0	0.0	0.0	0.0	0.0
% time 30-33°C WBGT		0.0	3.6	27.2	25.4	29.6	22.5	4.4	0.0	0.0	0.0	0.0	0.0
% time >33°C WBGT		0.0	0.2	2.4	8.2	7.9	1.9	0.1	0.0	0.0	0.0	0.0	0.0
WBGT Outdoor (in a working environment)													
% time < 27°C WBGT		99.8	91.4	35.8	30.7	24.3	40.7	72.8	77.7	54.4	48.4	80.3	100.0
% time 27-30°C WBGT		0.2	6.9	44.5	43.3	49.1	44.6	23.4	21.4	40.7	45.3	19.7	0.0
% time 30-33°C WBGT		0.0	1.8	19.8	24.9	25.8	14.6	3.9	0.9	4.9	6.3	0.0	0.0
% time >33°C WBGT		0.0	0.0	0.0	1.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Averages													
WBGT Outdoor in shade	Average 24 hrs	20.8	22.7	28.9	29.3	29.5	28.6	27.1	.	.	.	.	.
WBGT Outdoor in shade	Average Day	22.4	24.6	30.8	31.1	31.3	30.0	28.5	.	.	.	.	.
WBGT Outdoor in shade	Average Night	19.5	21.4	27.6	28.1	28.3	27.6	26.2	.	.	.	.	.
WBGT Indoors	Average 24 hrs	19.7	21.6	27.9	28.3	28.5	27.6	26.1	26.2	26.9	27.3	25.0	19.9
WBGT Indoors	Average Day	21.3	23.4	29.7	30.1	30.2	28.9	26.6	26.9	28.1	28.8	26.6	21.0
WBGT Indoors	Average Night	18.5	20.4	26.6	27.0	27.3	26.6	25.7	25.7	26.0	26.1	23.9	19.2

Table 5.4: International Standard Organization work and rest ratio (ISO, 18)
For an average acclimatized worker in light cloth[1]

Work intensity	Light work in WBGT in degrees Celsius	Medium work WBGT degrees Celsius	Heavy work WBGT degrees Celsius	Very heavy work WBGT degrees Celsius
0% rest/hour continuous work[1]	31	28	27	25.5
25% rest/hour[1]	31.5	29	27.5	26.5
50% rest/hour[1]	32	30.5	29.5	28
75% rest/hour[1]	32.5	32	31.5	31
100% rest/hour no activity[2]	39	37	36	34

[1]The WBGT are approximate values extracted from International Standard Organization (ISO 18)

[2]No activity or 100% rest is recommended by National Institute of Occupational Safety and Health (NIOSH).

Figures 1 – 12 (next page) Graphs depicting monthly trend of WBGT data for Bawku East (Pusiga) for the dry and rainy seasons for January 2013 to December 2013. TEMP1= TEMP2=Etc Dry Season months: January, February, March, April, November, December,

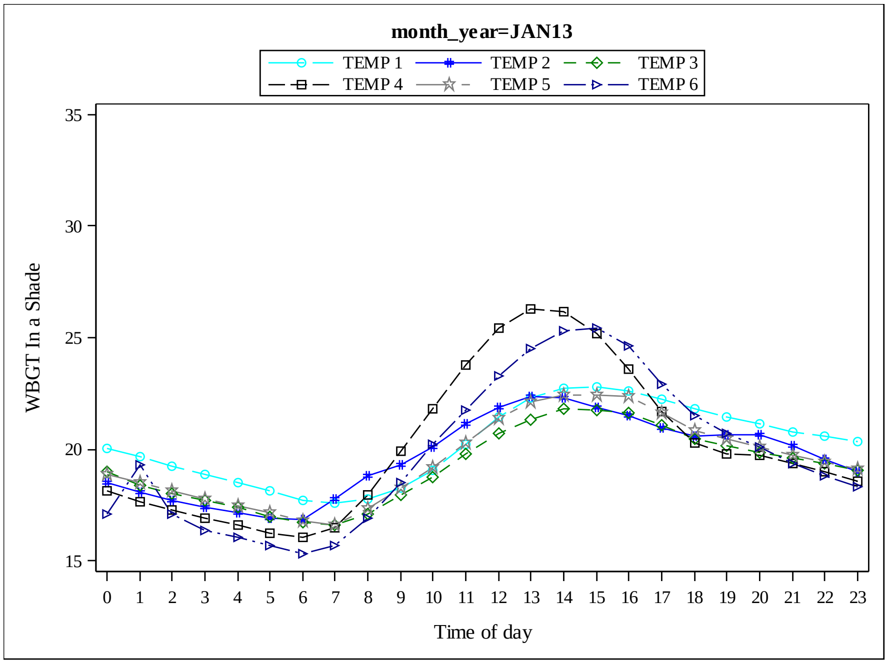

Fig 5. 1 Average hourly heat exposure for the month of January 00-23.00.

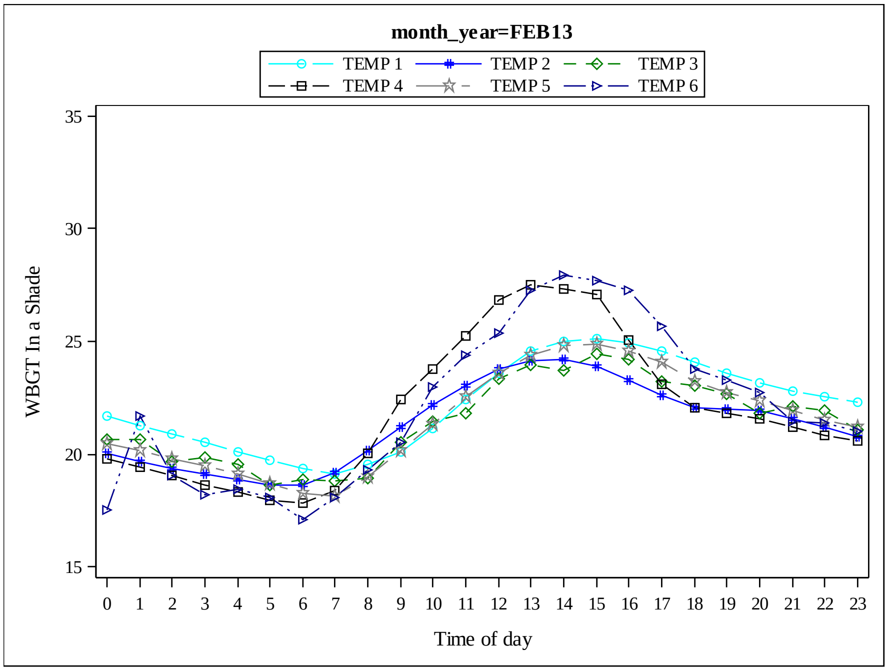

Fig 5. 2 Average hourly heat exposure for the month of February 00-23.00.

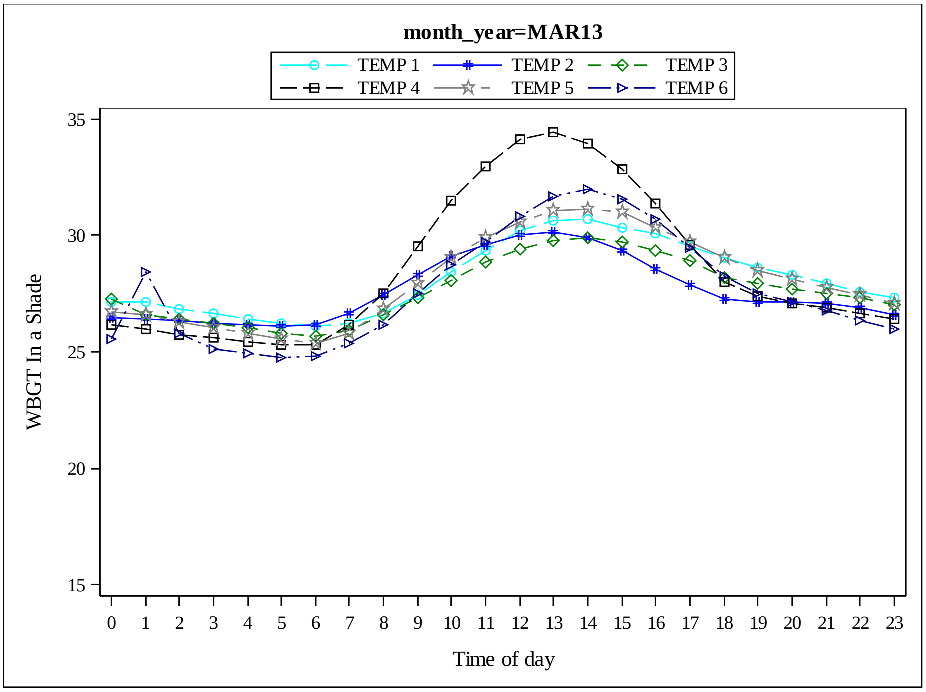

Fig 5.3: Average hourly heat exposure from 00.00 -23.000 in March

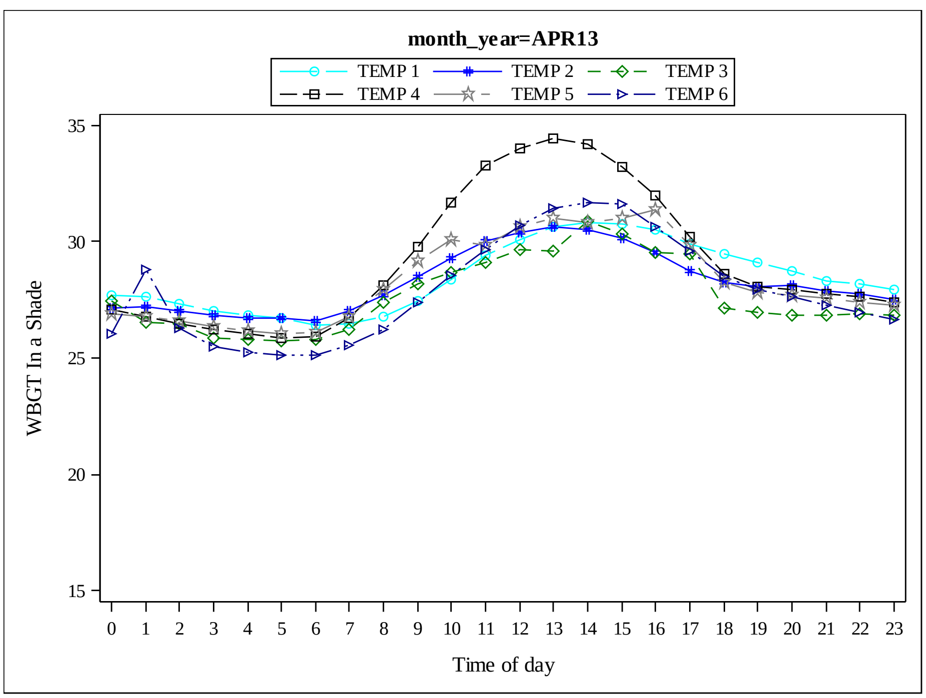

Fig 5. 4: Average hourly heat exposure for April ranging from 00:00-23:000

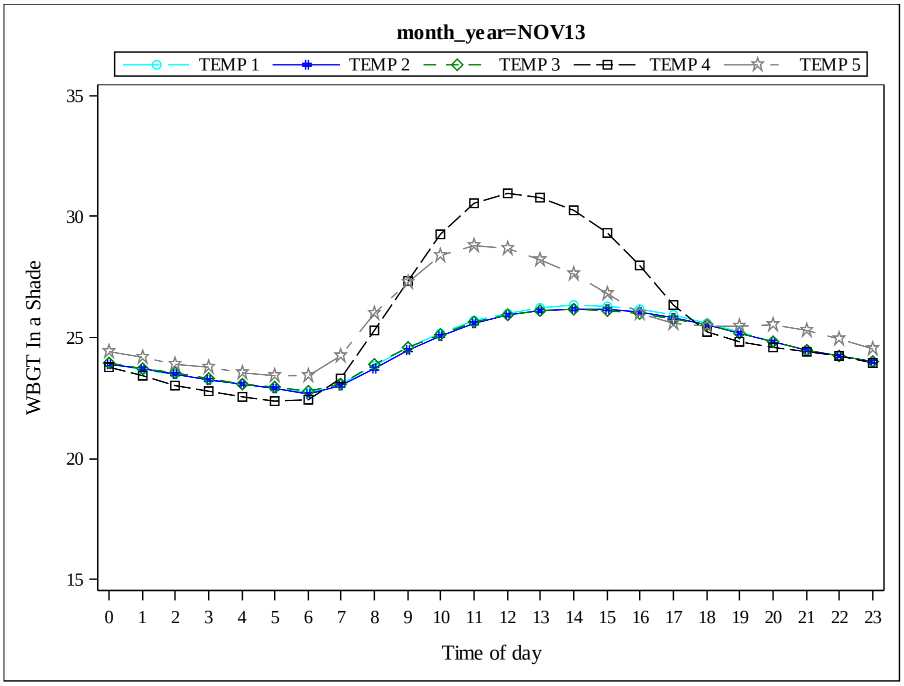

Fig 5. 5 Average hourly heat exposure for the month of November 00-23.00.

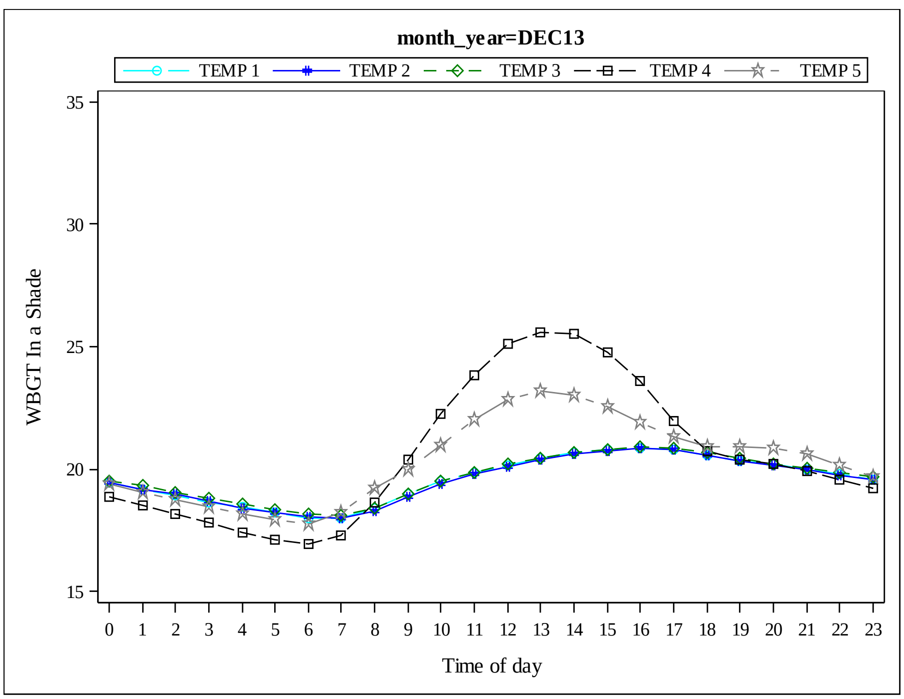

Fig 5. 6 Average hourly heat exposure for the month of December 00-23.00.

Average hourly heat exposure in the Rainy season spanning from May, June, July, August, September and October.

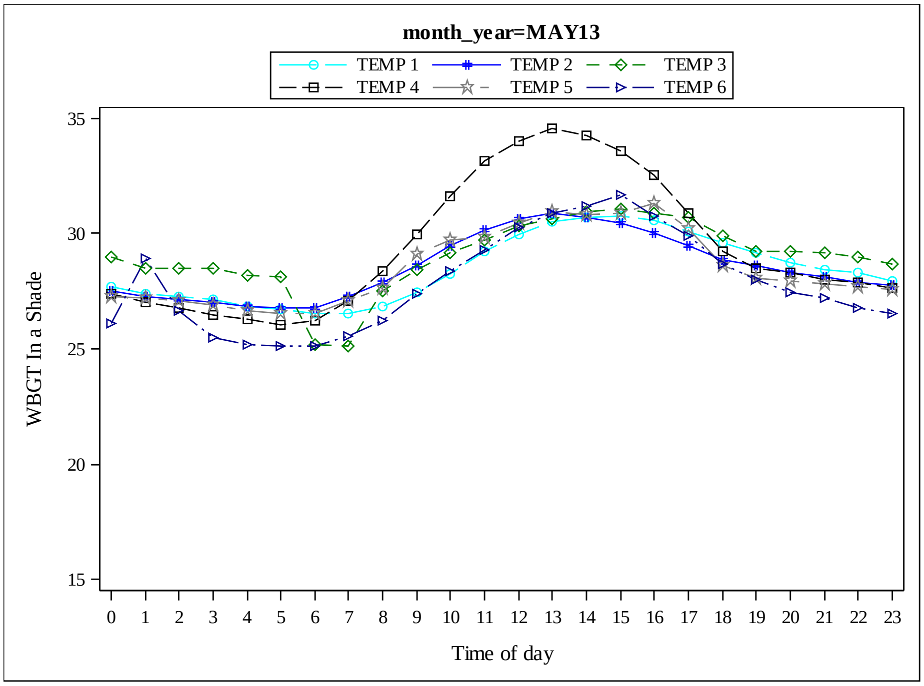

Fig 5. 7 Average hourly heat exposure for the month of May 00-23.00.

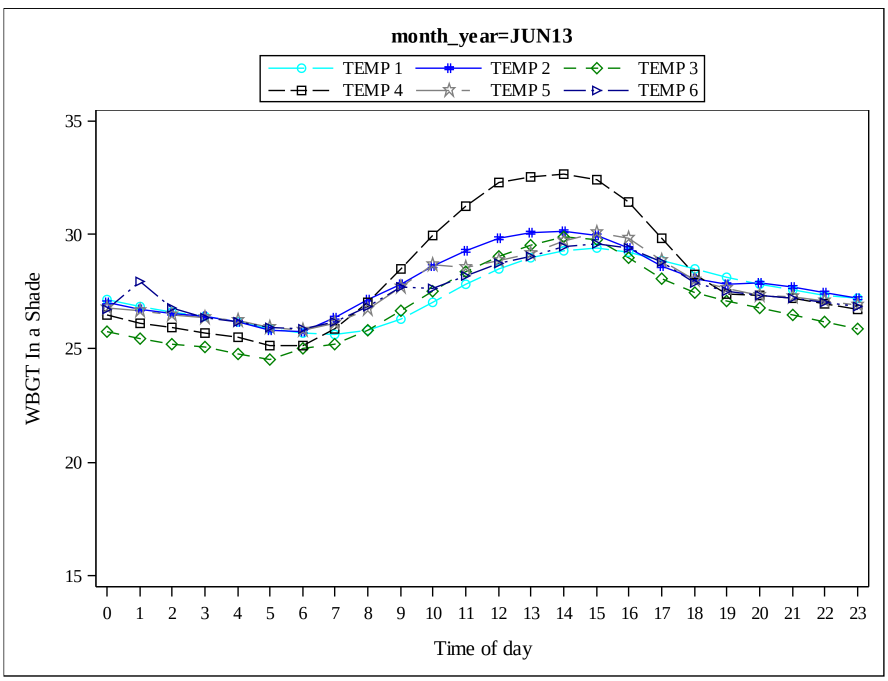

Fig 5.8 Average hourly heat in June 00:000-23:000

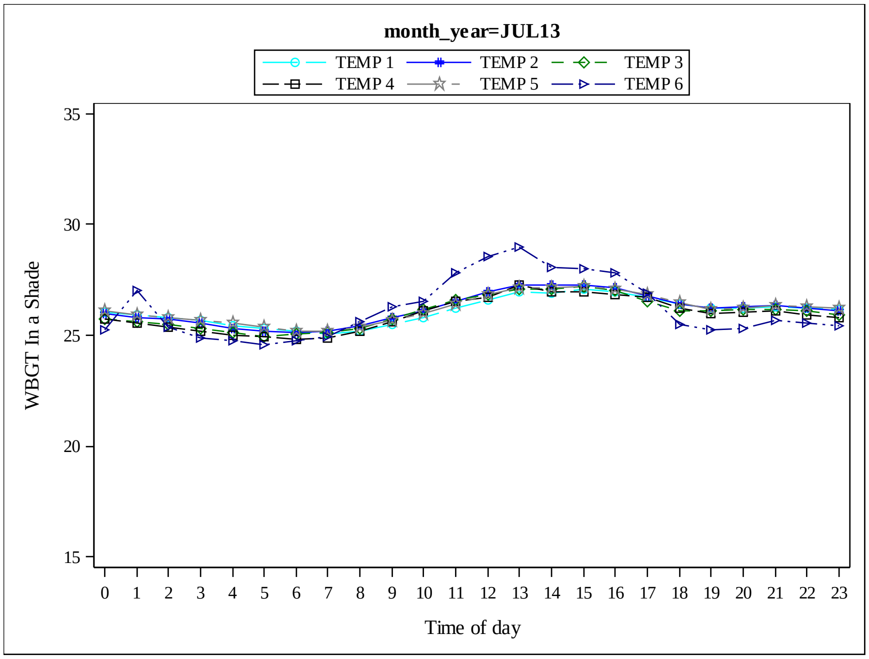

Fig 5.9 Average hourly heat in July 00:000-23:000

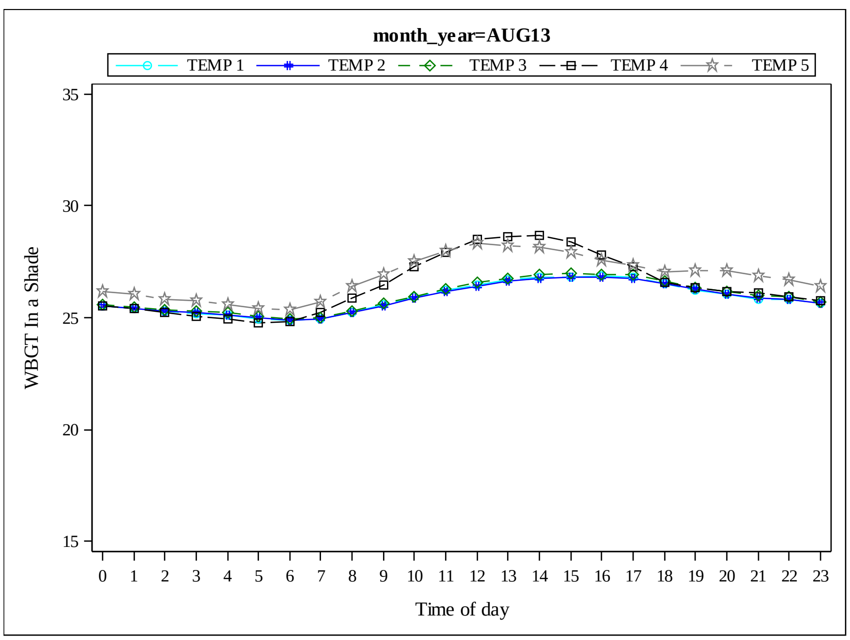

Fig 5.10 Average hourly heat in August 00:000-23:000

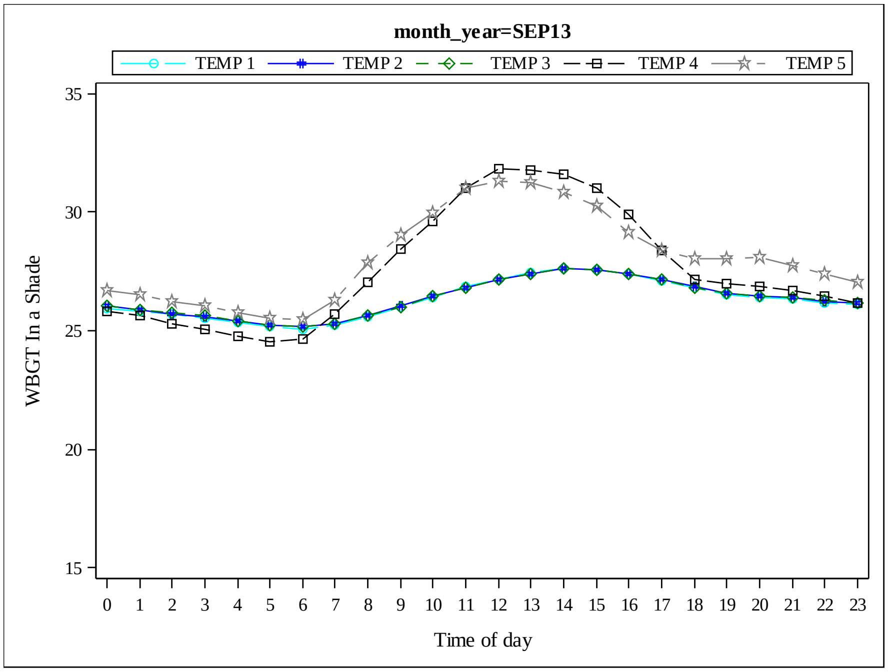

Fig 5.11 Average hourly heat in September 00:000-23:000

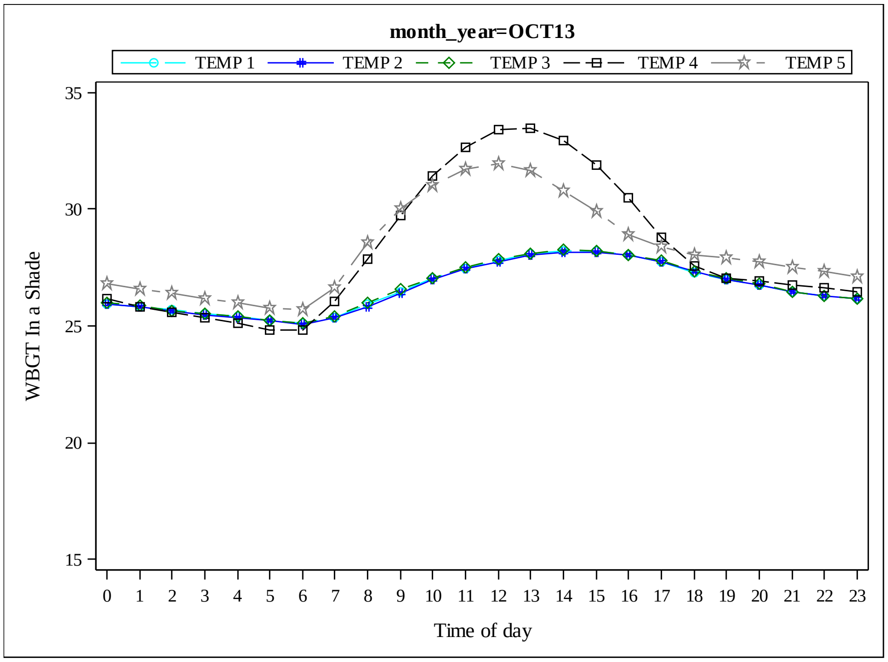

Figure 5. 12, Average hourly heat exposure for October

The test of the instruments for measuring heat exposure were carried out by randomly selecting days from January to July to simultaneously capture measurements from both Lascar and Questemp equipment. Theresults of this comparison are shown in Fig. 5.13 and demonstrate close correspondence in terms of WBGT which implies that, in the absence of Questemp equipment, the Lascar EL USB sensor can be used to accurately measure heat exposure across a range of temperatures and other conditions.

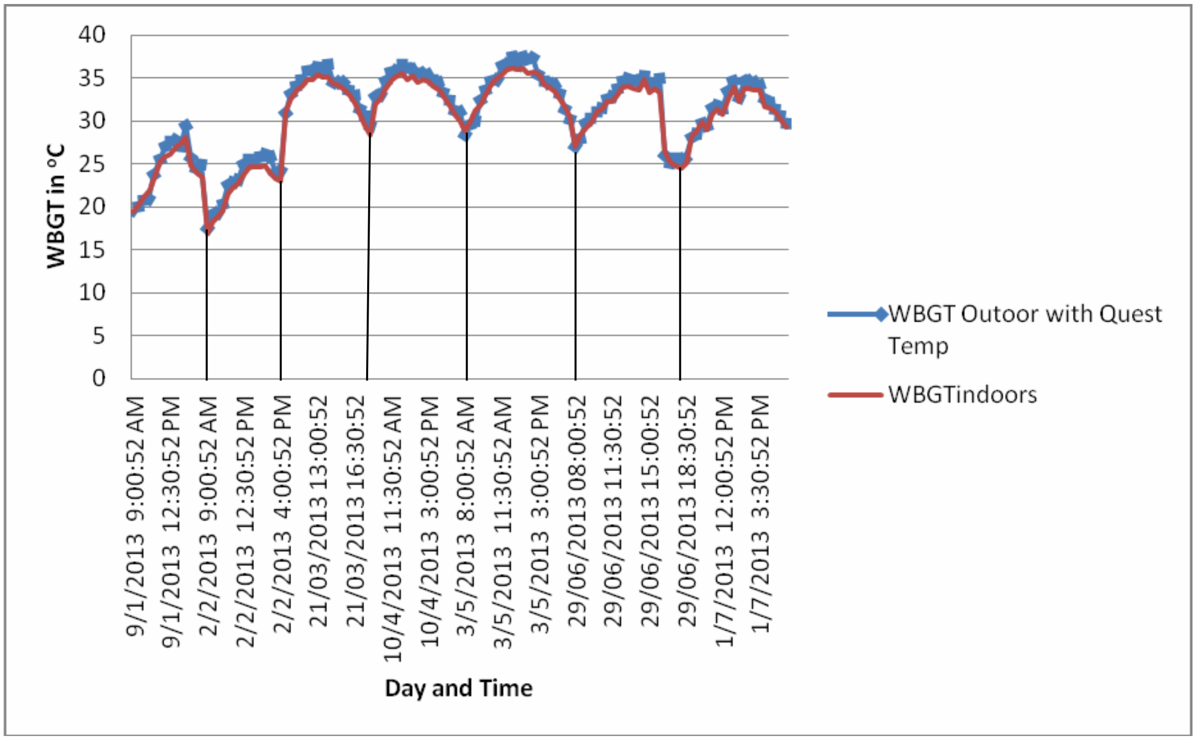

Fig 5.13 Sampled days of WBGT measurement from Lascar El USB Temperature and Humidity sensor and WBGT from Quest Temp.Blue Line indicates WBGT from Quest Temp, Red Line Indicates WBGT from Lascar EL USB Measurement. Vertical axis denotes WGBT ^{0}C, Horizontal denotes day and time.

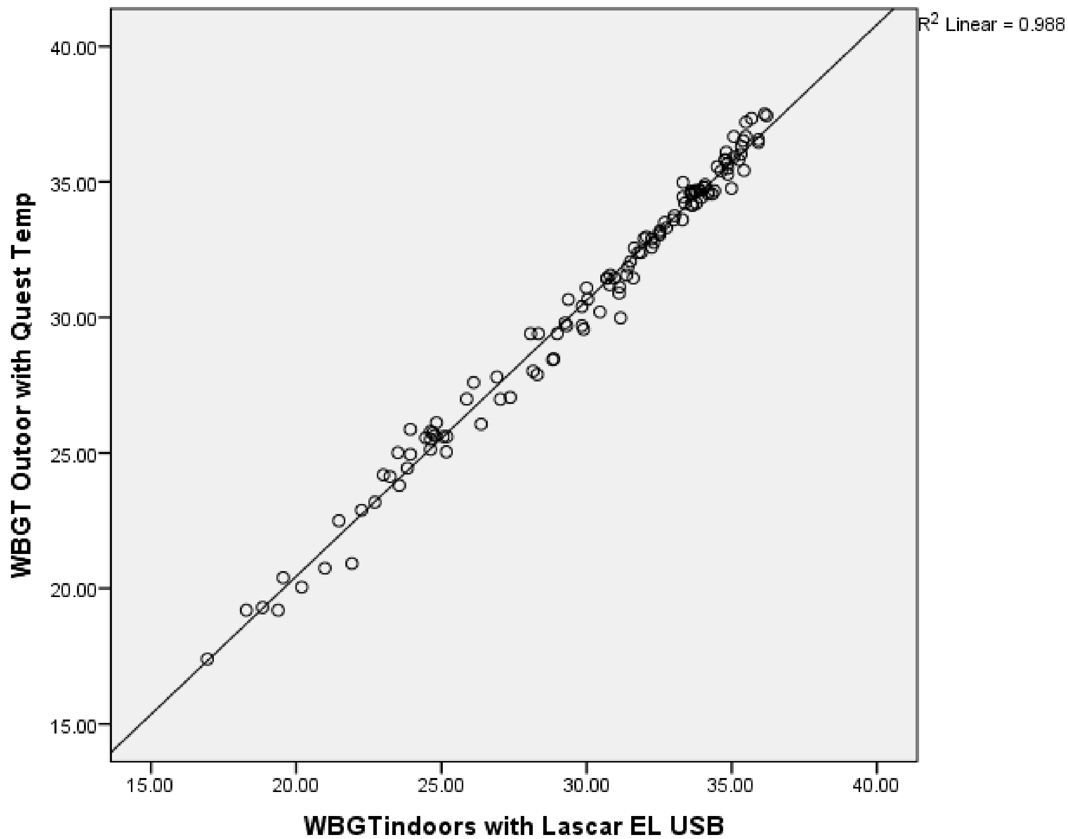

Fig 5.14 Test of the fit of the relationship between WBGT measuredusing Lascar EL USB and WBGT measured using Questemp(R^2 =0.988; n=21).

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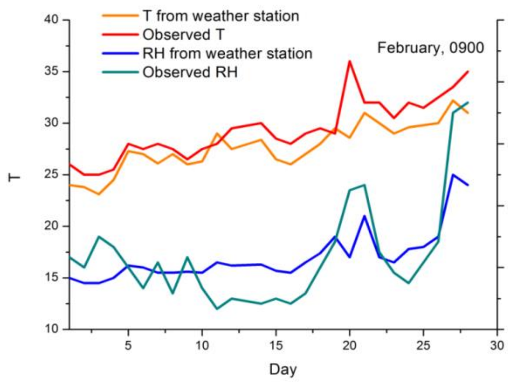
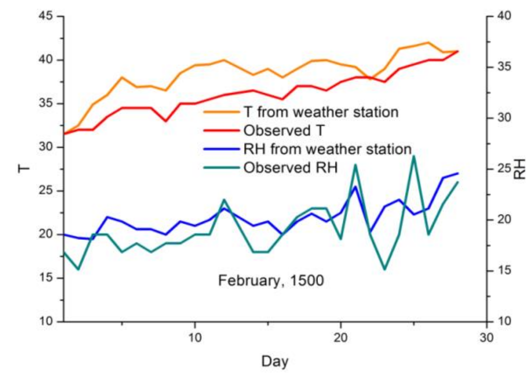


(a)



(b)

Fig. 5.15 Correspondence between temperature (T) and relative humidity (RH) measurements using Lascar EL USB sensors (observed) and nearby meteorological station taken at (a) 9 am and (b) 3 pm for each day in February 2013.

The relationships between temperature and relative humidity recordings from a Lascar EL USB sensor and that recorded at a nearby meteorological station in Bawku East are shown in Fig 15. The rationale for this comparison was to gauge the reliabilityof Lascar EL USB sensors in recording data at the local level instead of relying on weather station data some distance away. There was a good general agreement between measurements from Lascar sensors and the weather station. Although the Lascar temperature readings were a little higher in the morning, and a little lower. In the afternoon, they did follow much the same temporal pattern as that recorded at the meteorological station. The data from the lascar EL USB sensor help the researchers to estimate WBGT the level of heat stress to which farmers are exposed rather at some distance away.

5.5 DISCUSSION

The study has shown that Lascar EL USB temperature and humidity sensors can conveniently and accurately estimate WBGT without the need for heavy and expensive equipment. The accuracy of the Lascar El USB sensors is further strengthened by the strong association with temperature and relative humidity recorded at a nearby meteorological station at 9.00 AM and 3.00 PM (Fig's5.15 a, 5.15b)

As expected, the highest WBGT levels were recorded in the fields where farmers were working. The maximum WBGT value recorded was 37°C with other readings in the range of 33 to 35°C WBGT commonly recorded during working hours of 11 am to 4 pm, particularly in the wet season. When evaluating these readings against the ISO 7243 standard (Table 5.4) it is clear that these working conditions are potentially dangerous with no "heavy" physical work being recommended. The seriousness of these findings is exacerbated by the fact that the WBGT estimates were calculated in the shade and globe temperature was excluded from the WBGT calculation. Since the fields where people work are all or mostly in full sunshine, true WBGT exposures were most probably underestimated (Lemke &Kjellstrom, 2012). Due to the fact that farming methods are labour intensive, most of the work is considered to be heavy in terms of metabolic load. Another matter of concern is the fact that WBGT recorded inside homes where famers go to rest was also very high (30-33°C) with very little difference between indoor and outdoor readings in the shade. The most significant point to note is that the WBGT levels from midday are likely to be underestimated by 0.5-2^{0}C becausethe intensity of radiant heat from the sun is not taken into account.

In most industrialised countries where workers are exposed to heat stress and the ISO work–rest regimes are implemented, the workers are removed to an air-conditioned environment for their rest period and they are given adequate hydration so the body does cool down during the rest phase. In some cases workers have ice vests or ice baths where rapid cooling is facilitated and the workforce is generally well educated and trained to recognise the signs of heat stress and to remain hydrated (Oosthuizen, 2012). First aid and medical facilities are also relatively accessible to such workers. For the farmers in Bawku East (Pusiga) access to such facilities is not available, thus increasing their risks related to heat-induced illness. This is reflected in the high response rate for self-reported impacts of heat on farmer's health. About 94% of farmers expressed that heat has had an impact on their health. This indicates the urgent need for regular

assessment of heat exposure as a base to facilitate proper management of heat stress with temperatures, especially in this region (EPA, 2007), particularly so given the current warming trend due to global climate change. Seasonal variation in heat exposure was noted, with March, April, May and November (Fig's5.3, 5.4, 5.7, 5.5) having significantly higher WBGT than other months. With a uni-modal rainfall pattern in the study area, a lot of the manual labour, such as weeding, making mounds, drawing water from hand-dug bole holes to regularly irrigate crops, is undertaken in the dry season months of December to April. Although it is generally cooler in these months, the WBGT does still exceed 27^{o}C during the middle of the day, especially later in the dry season before the onset of rains. Further, there are reports of a temporal shift in the onset of the wet season (Laux et al., 2008) which would mean that some of the most strenuous labour is increasingly being done when WBGT are above the threshold for heavy labour.

Qualitative focus group data indicated that farmers have no safety plan with regard to the protection of their health from heat exposure (Frimpong et al, in press). The only recourse farmers have is to slow down on their work rate and to rest when they felt they were tired, this strategy of self-pacing is essential to prevent heat related illness but clearly has an impact on productivity and the long term sustainability of their farming practices. Many of the farmers were not aware of the possible health consequences of global warming even though they feel the current impact of heat exposure.

Studies in Thailand indicated that about 60% of Thai workers reported diminished work capacity in the heat and 20% expressed a high level of vulnerability to heat illness in the summer's period (Tawatsupa et al., 2010). In the USA, heat illness and heat-related mortality has been identified as an issue associated with meteorological phenomena, such as heatwaves (Borden & Cutter, 2008; Davis et al., 2003). Similarly, the relationship between high humidity and temperature and heat-related illness has been established in Abu Dhabi (Shanks & Papworth, 2001), Syria (Zawahri, 2004), and Kuwait (Al-Ahwal et al., 2000). Heat stress has a significant adverse effect on the productivity and safety of manual labourers (Taylor, 2006; Kjellstrom et al., 2009). Obviously, as over 90% of farmers surveyed in our study area expressed impacts of heat on their health, although the local hospitals keeps no record on heat stress illnesses, it is still vital to consider the state of heat exposure in the farming communities as threat to health. Our study suggests that the level of heat exposure typically experienced by farmers, both in their working and resting environments in northern Ghana, will likely lead to heat-related illnesses.

The main occupation of the people in Bawku East is agriculture and most of the crops that they produce are cereals, legumes and vegetables. Farming methods are labour intensive and are conducted under high heat exposure conditions. Rural economies can benefit from education and research aimed at increasing their levels of productivity, as well as improved technology for producing food crops, and this includes an understanding of heat stress and adaptation strategies that may improve productivity (Van der Ploeg, 2000). Rural agricultural growth in the developing world reduces poverty in the rural economies and increases food supply in the urban centres (Byerlee, 2000; Christiaensen et al., 2011). However, agricultureproductivity can be undermined due to heat exposure (McMichael et al., 2003; Sahu et al., 2013). Farming households obtain immense socioeconomic benefits with increased agricultural productivity, such as greater food security (De Janvry & Sadoulet, 2010). Safeguarding the productivity and resource needs (including human health) of smallholder farming in sub-Saharan Africa in the face of climate change is essential in order to achieve sustainable agriculture, food security and the Millennium Development Goals (Kleemann, 2013). It is projected that by 2050 the demand for grain globally will increase by 75% (MacIntyre, 2009). During physically laborious tasks, thermal conditions determine productivity (Lloyd, 1994), which makes it important for smallholder farmers to be protected from heat exposure. Little is known on the quantification of workplace heat exposure especially at the farm level in many developing countries (Sahu et al., 2013). The preliminary global estimate of the likely impact of heat exposure on workplace due to climate change by 2030 was 2.4 trillion $US PPP (DARA, 2012). WBGTs around 29 to 33 ^{o}C, commonplace in this study,signify that physical labour of moderate level becomes a health hazards when adequate rest and work regimes are not observed(ISO, 1989; Parsons, 2003). The higher strain exerted for farm output in heat prone environmentscontributes to rises in the selling prices of food stuff for local economies in rural areas, while it decreases farm output (Sahu et al., 2013). High temperatures, humidity and muscular demand of labour are obstacles to workers in tropical developing countries. Shadeless farming activities with high physical demands are predominant in tropical developing countries, such as harvesting of sugar cane in Costa Rica (Crowe et al., 2010), rice harvesting in India (Sahu et al., 2013) and vegetable, legume and cereal farming in northern Ghana (Frimpong et al., 2014). In poverty-prone farming environments, farmers have limited choice in the type of clothing they wear to regulate heat (Crowe et al., 2010). This is also a health issue and a problem of excess heat dissipation. In a

farming context where remuneration of farm workers is regulated by their hourly output, it is essential to embrace that for the sake of achieving hourly work targets, farm workers may eschew observance of breaks(rest time), as well as intake of water and food. (Mairiaux & Malchaire, 1985; Miller & Bates, 2007). In 1998 and 1999, an estimated 11% of deaths occurred to Indian farmers due to heat stress (Nag & Ashtekar, 2007). The prevalence of chronic kidney diseases in Central America is believed to be caused by heat exposure to people who execute heavy work loads (Torres et al., 2010). Chronic dehydration emanating from outdoor heat exposure in farming setting has the capacity to increase chronic kidney disease (Crowe et al., 2008). Many industries in developing countries such as India do not take cognisance of heat stress injuries (Ayyappan et al., 2009). In a large number of cohort studies among Thai workers, Tawatsupa et al (2010) assert that workers do not observe rest and work regime as indicated by International Standard Organization guidelines for the safety of workers health. This is the situation in the case of Bawku East where workers work without observing breaks and seemingly ignore the health impacts of heat stress. Also, in sugar cane harvesting fields in Costa Rica, Cowe et al (2010) indicated that the quest to achieve hourly output by farm workers whose wage are attached to their output, expose farm workers to intense heat stress. The need for cash relegates all safety measures to the background. This type of practice resonates with the results found in this study on the day to day practice of farming in Bawku East.

5.6 IMPLICATIONS, RECOMMENDATIONS AND CONCLUSIONS

Studies of the effects of rainfall, drought and desertification, as dimensions of climate change, have been accomplished by many researchers in Ghana. However, there has been little research on effects of rising temperature and humidity as consequences of climate change. The impact of heat exposure specifically on farmers' health and productivity has not been investigated. The upsurge of heat in the tropics and heat-related mortality already recorded in other countries like USA (MMWR, 2008) places a significant research importance on heat and its management in rural farming communities to foster sustainability of farming and improving rural economies across the developing world. A large cohort of farmers in Ghana are currently of older age and many of these continue to work long hours in the field. There is the dire need for these older farmers to be protected as they may be the most vulnerable to heat-related illnesses in the future. This warrants the need for research to be carried in Ghana on how older people are

coping with heat in the emergence of global warming. Measures to minimize heavy physical load on farmers are also imperative. Modernised agriculture is one way to minimise the impact of heat. However, government intervention with peasant farmers has been criticised. Even though many African peasant farmers are tied to the apron of traditional norms(Rostow, 1990), government intervention to modernize agriculture has been characterised bythe exploitation of peasant farmers (Bates, 1981; Sandbrook, 1985). Prices of farm produce need to be controlled by the government to eliminate consistent over exploitation of farmers by organized market owners from southern Ghana. Importation of vegetables, cereals and legumes need to be controlled to enable sustainable farming in the northern Ghana whose farmers predominantly engage in this type of crop growing. The quality of these imported crops can outstripthat of the home grown mainly because they are grown in more hospitable environments. In the context of sustainable farming, government need to enhance the capacity of these rural farmers to produce the crops that they have the expertise and environmental resources to cultivate. This can reduce rural urban migration, which is notable problem in this area of Ghana.

The study revealed that farmers are exposed to heat stress that can be injurious to their health especially with the predicted increase in global average temperatures.Moreover, the ambient temperaturesto which farmers are exposed have the potential to affect their health and stifle productivity, and those involved in manual farming practicesare most at risk. As a large number of farmers produce food through manual practice under high heat exposure, sustainable food supply is contingent on government-led interventions to improve the livelihood of these smallholder farmers such as improved irrigation system (rather than manual drawing of water to irrigate crops), mechanical farming, and better designed and built accommodation with improved ventilation.

Lascar ELUSB temperature and humidity sensors have been shown in this study to be vital and convenient to measure heat instead of using much more expensive equipment like Questemp monitors. With the exception of radiant heat that adds one or two degrees to WBGT heat index, Lascar has proven to be an accurate and easy way to measure heat exposure. This method of assessment can be used in many fields to assess occupational heat stress. With the emergence of global warming, it is timely and appropriate for that study to be continued every year in northeast Ghana to assess heat stress to establish a comprehensive trend over a longer period.

As temperatures increases in Bawku East, it is necessary for government to link with local peasant farmers to re-establish greenery across much of the cleared landscape to increase shade for outdoor farmers. Moreover, since heat stress has been considered as a research need in the time of climate change, it is imperative for government to conduct similar studies in other places where outdoor activities are common, like marketplaces where a lot of women sell their wares, and construction sites, such as in the emerging oil and gas industry in Ghana and existing minesites. Health surveillance in hospitals of heat stress illness is necessary to keep track of heat-related illnesses for policy purposes. Quantitative measurement on productivity loss is timely and appropriate in Ghana,as well as African regionmore broadly, to track climate change impacts on agriculture and other sectors of theeconomy.

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CHAPTER 6

EXPERIENCES OF HEAT STRESS VULNERABILITY AND CLIMATE CHANGE AMONG FARMERS IN GHANA

This chapter is published in Journal of Environment and Earth Science. Frimpong, the leading author wrote the entire article with the coauthors giving editorial help. This chapter addresses the fifth aim of the study. It uses household survey to elicit farmers' experiences of heat stress and climate change. This is fundamental to gauge the level of farmers' vulnerability to heat stress and climate in a precarious environment where temperature is high and above all projected to increase astronomically. Logistic regression is used to model whether farmers have experience climate change in recent time using duration of their stay, age, gender educational level and type of community where a farmer lives.

6.1 ABSTRACT

The trend over the last decade of increasing temperature associated with climate change with the impacts being felt in the poorest communities of the developing world is unequivocal. Bawku East of northern Ghana is assessed as one of the poorest communities. Being a farming community the study investigates the extent of farmers' experiences on heat and climate change. A selected number of 308 farmers from a farming population of over 15,000 were interviewed about heat stress and climate change to gauge their level of vulnerability to heat stress at the household and farm levels, as well as their general experiences of climate change. The age, gender, duration of residence, community where a farmer lives and educational level were used as predictors to elicit experiences of heat stress vulnerability and climate change using logistic regression models and empirical results. The significance of the study is to establish baseline parameters for effective adaptation of heat stress as temperature is projected to increase within and beyond this century in the study area. On balance, farmers have significant experience on heat stress vulnerability and climate change. The farmers who have lived longer in the study area showed significant experience of heat stress and climate change. Future study on level of adaptation to heat stress and climate change at household and farm level is timely and appropriate.

6.2 INTRODUCTION

The global economy is envisioned to lose 20% of Gross Domestic Product (GDP) by the year 2050 if a concerted effort is not devoted to tackle climate change and its consequential impact (Stern, 2007). The impact of climate change expressed as increased temperatures, changes in precipitation, more extensive flooding, and enhanced drought and heat waves, is projected to be different in each geographic location (IPCC, 2007a; May, 2008; Schellnhuber, 2008). Africa is predicted to suffer a large impact from climate change, even though its contribution to global emissions of greenhouse gas is insignificant (Christensen et al., 2007). A substantial part of climate change research involves measuring and establishing the recent changes in climate, projecting future climate changes, and identifying the causality of climate and anthropogenic greenhouse gas emissions (Bolin, 2007). Studies on the implications of climate change for humankind and options for responses have often been linked with conventional investigations of anthropogenic greenhouse gases and climate change (Smit & Wandel, 2006; Bolin, 2007;; Trainor et al., 2007; Dovers, 2009).

In all sectors of human endeavors and national economies, it is prudent to identify impacts and vulnerabilities of climate change since these phenomenon can adversely affect social wellbeing and economic development (Smith & Almaraz, 2004; Gössling & Hall, 2006; Maoh et al., 2008), whilst identifying vulnerability and locating mechanisms to confront them serves as a tool to reduce poverty in a given population (Halsnæs & Trærup, 2009).

Crop farming contributes over 75% of agricultural production in Ghana even though the system is inflicted with unsustainable methods (Diao, 2010). Agriculture is the mainstay of the Ghanaian economy (Aryeetey & McKay, 2004), and the sector is predominantly managed by small landholders for the purpose of subsistence farming. Agriculture has contributed about 40% to the GDP of Ghana, though over recent years there has been a systematic decline to about 32% (Diao, 2010). Each agro-ecological zone contributes a certain percentage of agricultural Gross Domestic Product (GDP) with the forest zone accounting for 43% (Diao, 2010). The northern savannah zones account for 20.5% of agricultural GDP with the farmers producing over 70% of the nation’s crops such as millet, maize, cowpea, sorghum, groundnut, and soya beans (Breisinger et al., 2008). Over 90% of income in the northern savannah zone is generated from farm proceeds of staple crops and livestock (Diao, 2010). Agriculture employs about 55% of the population and contributes 30-40% of foreign exchange earnings in Ghana (Ghana fact sheet, 2010).

Studies of climate in northern Ghana have indicated that from 1961-1975 there was an

average of 2.3 months of temperature per year above 37°C which rose to 5.3 months of temperature per year above 37°C between 1998-2012 (Frimpong et al., 2014). In the same study, it was shown that the decadal increase in mean minimum and maximum temperature were above the national average of 0.21°C. (Frimpong et al., 2014). With meteorological evidence of change in climate and a systematic increase in temperature, it is important to elicit the experiences of rural farmers in the vicinity since the major occupation of the residents are farming and the area is considered among the poorest in Ghana (Webber, 1996; Whitehead, 2006).

Knowledge of farmers' perceptions and experiences of heat and climate change is a prerequisite for effective adaptation strategies (Acquah, 2011). The propensity of farmers to experience and perceive that the climate has changed would inspire them to locate and implement effective adaptation options (Maddison, 2007). Conversely, inadequate knowledge on climate change and its impacts on agriculture and farming is a disincentive to sustainable agriculture, especially in developing countries (Kotei et al., 2007).

In spite of the sensitivity of farming to climate change, to the authors' knowledge, there have been no published studies of the experiences and perceptions of heat stress vulnerability and climate change and how heat exposure affects the rural farming communities in northern Ghana. This has become an important issue in the wake of prediction of 2.5-3°C upsurges in temperature by the year 2020 in northern Ghana (EPA, 2007). Eliciting the experiences, perceptions and understanding of the vulnerability of farmers to heat exposure and climate change constitutes important baseline information for government-led initiatives to ensure sustainable farming in the emergence of climate change. Arguably, understanding of farmers' experiences and perceptions of climate change and strategies for adaptation is also a necessary precursor for establishing cutting-edge policies and programs for instituting successful adaptation in the agricultural sector (Bryan et al., 2009). A further warrant for this research regards food insecurity in Bawku East of northern Ghana (Hesselberg et al., 1996; Whitehead, 2006), as distinguished from the forest zone in the south of Ghana where there is relatively adequate food for the residents (Songsore et al., 1995). Sustainable development in the emergence of climate change makes it imperative to examine environmental, social–cultural and economic concerns that undermine food security in a zone noted for its poverty and food insecurity. In view of inadequate knowledge regarding farmers' experience and perception of climate change (Fosu-Mensah et al., 2012), this study is aimed at investigating whether farmers in Bawku East are experiencing increasing heat stress and climate change and how this is impacting their lives.

6.3 RESEARCH OBJECTIVES

This paper reports the results of a survey administered to rural farmers in Bawku East, northern Ghana, documenting their vulnerability to climate change and heat exposure. The paper uses logistic regression to model the effects of age, gender, community of residence, educational level of farmers and duration of residence in Bawku East on farmer's experiences of increasing heat stress and climate change. The survey questionnaires were adapted and modified from a global program which explores workers' vulnerability to heat stress and climate change, called 'Hot Occupational Temperature Health and Productivity suppression' program or HOTHAPS (Kjellstrom et al., 2009). The survey presents results on duration of residence of farmers and their experiences of signs of climate change, heat impacts at the farm level, and heat impacts on sleep. The research questions elicit farmers' experiences on increasing heat stress and climate change in recent years. It further probes heat stress impact on farmers' sleep patterns. The impact of heat on their day to day activities at farm level is also examined. Recent signs and symptoms that denote a changing climate were investigated. Duration of residence was largely used to determine people's experiences on climate change and heat exposure since the number of years a farmer had lived in a community is likely to increase their knowledge and experience of these issues. Age of residents of farmers was used to determine the impact of heat at the farm level since the matured and the elderly are more likely to be affected by heat exposure (Fouillet et al., 2006). The conclusion of the paper includes discussion of the survey results in the context of scientific implications of climate change and sustainable development of rural farming in Bawku East of Northern Ghana.

6.4 METHODS

6.4.1 Study area

The study was conducted in Bawku East of Northern Ghana (Figure 1). The area is found between latitudes 11o 11^1 and 10^0 40^1 north and longitude 0^o 18^1w and 0^o 6^1 E in the north eastern part of the Upper East region (Ministry of Food and Agriculture, 2014). The three selected farming communities in Bawku East were Manga, Pusiga and Binduri which have an estimated active farming population of 15,000 (Ministry of Food and Agriculture, 2014).

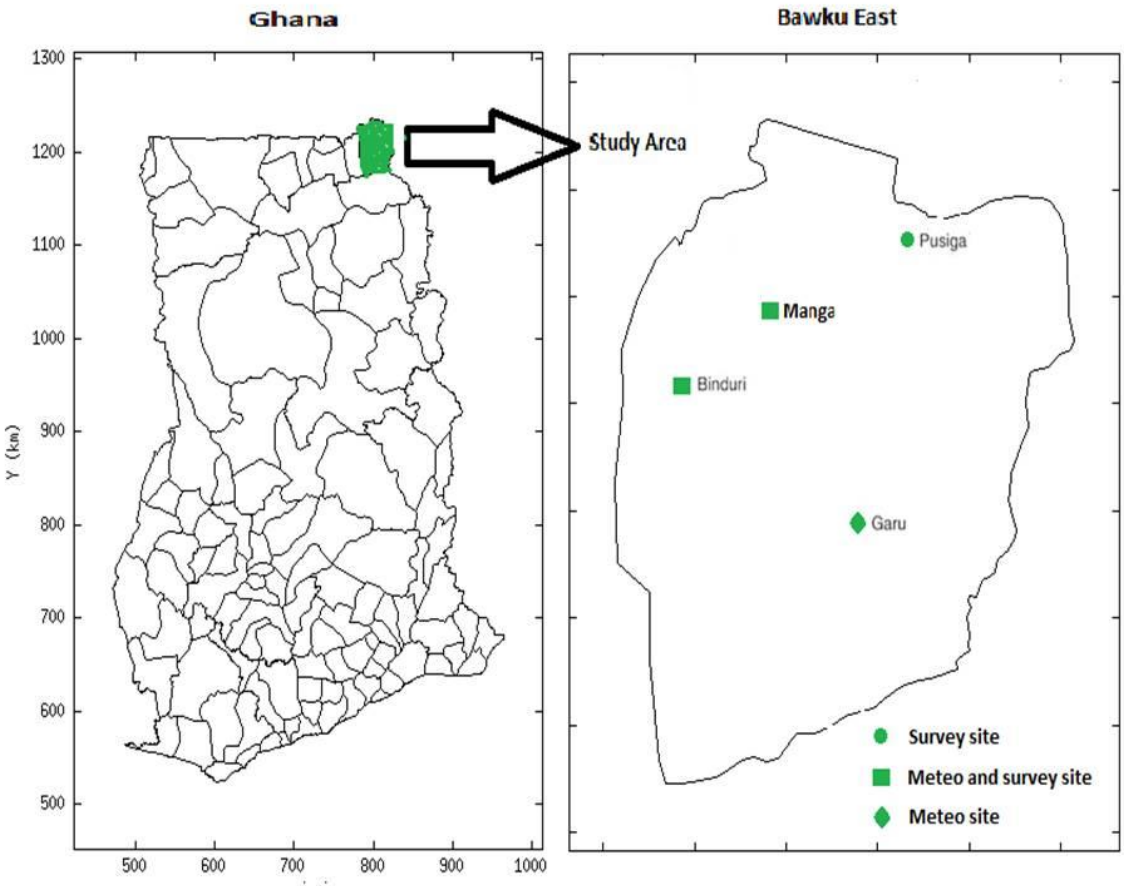

Figure 6.1: *A map of Ghana showing the study area*.

6.4.2 Sampling

The agricultural extension officers of the Ministry of Food and Agriculture in Bawku municipality assisted in conducting the survey in Pusiga, Manga and Binduri. Each of these communities has a lot of scattered villages, with houses surrounded by fields of cultivation of crops. Three hundred and eight farmers' households were randomly selected in these three farming communities for the survey. Interviews were conducted using structured questionnaires and focus groups discussion. Only one farmer was interviewed in each household to spread the range of responses in the event where a household has two or more farmers. The structured questionnaire focused on demographic information of the farmers, experiences on heat stress vulnerability and climate change (the focus of this paper), local adaptation strategies by various farmers (legume, cereals, and vegetables) and barriers associated with strategies to confront heat and climate change. Predominantly, face to face interviews were used to collect the data. The questionnaires were written in English, whereas the interviews were presented in their respective local languages by research assistants recruited from each locality. Both interviews and focus groups discussion questions were

adapted and modified from the ongoing global program of HOTHAPS. Interviews were conducted from January 2013 to May 2013. Data were analyzed using the Statistical Package for the Social Sciences (SPSS v.21). Focus groups discussion on heat stress vulnerability and climate change were done to obtain more detailed and richer responses from farmers.

6.4.3 Logistic regression model approach

To establish the effects of community type, duration of residence, educational level, age and gender on the farmers' experiences, perception and vulnerability to heat exposure and climate change, a binary logistic regression model was adopted (Acquah, 2011; Apata et al., 2009). The binary logistic regression model is a component of generalized linear model (Agresti, 2007). Binominal distribution is a prime assumption underpinning the binary dependent variable (McCulloch, 2006).The reason for utilizing this model was the dichotomous state of the dependant variable (having knowledge, experience on heat exposure and climate change, as against not having knowledge, experiences on heat exposure and climate change). This model determines the probability of estimating farmers' experiences, perception and vulnerability to climate change and heat exposure or not having experience on heat exposure and climate change based on the predictor variables (community, age, duration of residence, educational level, and gender) which are fixed into the regression model. In this case both categorical and quantitative independent variables can be used in the regression modeling. The binary logistic regression model is represented by equation (1) below:

$$\log\left[\frac{P(Y=1)}{1-P(Y=1)}\right]=\log\left(\frac{\pi}{1-\pi}\right)=\text{logit}(\pi)$$
$$=\alpha+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_n x_n \qquad (1)$$

Where $P(Y=1)=\pi$ denotes the probability of a farmer having experienced heat stress vulnerability and climate change in recent years, while $1-P(Y=1)$ represents the probability of a farmer not having experienced heat stress vulnerability and climate change in recent years. The $\log\text{it}(\pi)$, predicts the probability (π) of a farmer having experienced heat stress vulnerability and climate change. Such probability lies between 0 and 1 $(0\le\pi\le1)$ with regards to all the likely independent variables. As illustrated in equation (1), α represents the intercept and $\beta_1,\beta_2,...,\beta_n$ are the coefficients of the logistic regression model which are aligned to the set of n independent (or predictor) variables, denoted by $x_1,x_2,...,x_n$, whiles the

log transformation of the odd ratio ($\log it(\pi)$) is modeled as the dependent variable. The maximum likelihood approach was used to estimate the model parameters being the intercept and coefficients. The estimated coefficients quantify the effects of the predictor variables on the dependent variable which represent the contributions of the odd ratio by each predictor for its unit change (increase or decrease). Statistically, the significant effect of each predictor variable included in the model is determined by its P-value. Thus, the odd ratio, as stated earlier in this paper, denotes the likelihood of a farmer having experienced increasing heat and climate change with regard to a change in the independent variables that have been considered in the model.

6.5 RESULTS

6.5.1 Empirical Results

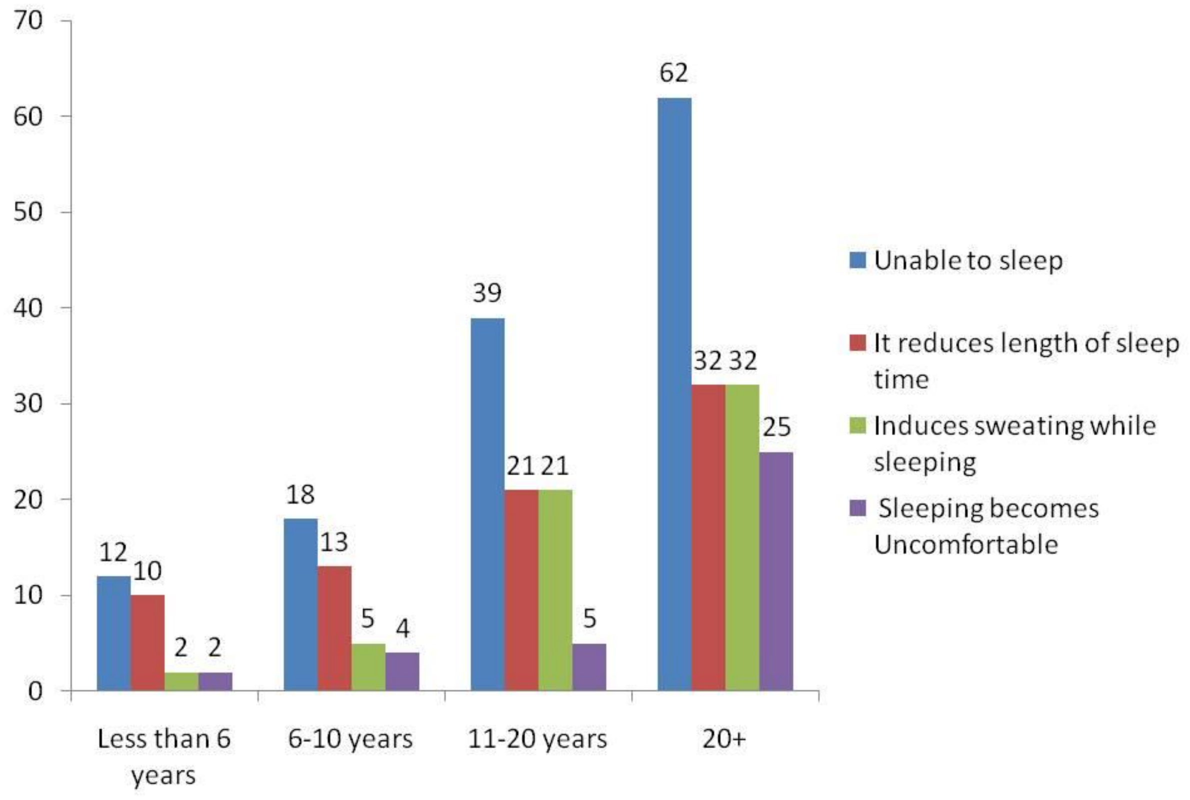

Figure 6.2: Farmer's responses (measured by number of responses) to heat impact on sleep and their duration of living in Bawku East (n=303 of 308, 5 non respondents).

Duration of residence of farmers in Bawku East was used to determine their responses on effects of heat on sleep (Figure 6.2). Out of 308 respondents, there were five non-responses to the question of how heat affects their sleep. Farmers who had lived in Bawku East for twenty years or more showed a higher response relating to 'unable to sleep'. Induced sweating and reduced length of time to sleep were the second highest response from persons who had lived longer in the communities. Those farmers who had lived 11-20 years reported a relatively higher effect of heat on sleep, with the least response emerging from those with less than 6 years of farming experience.

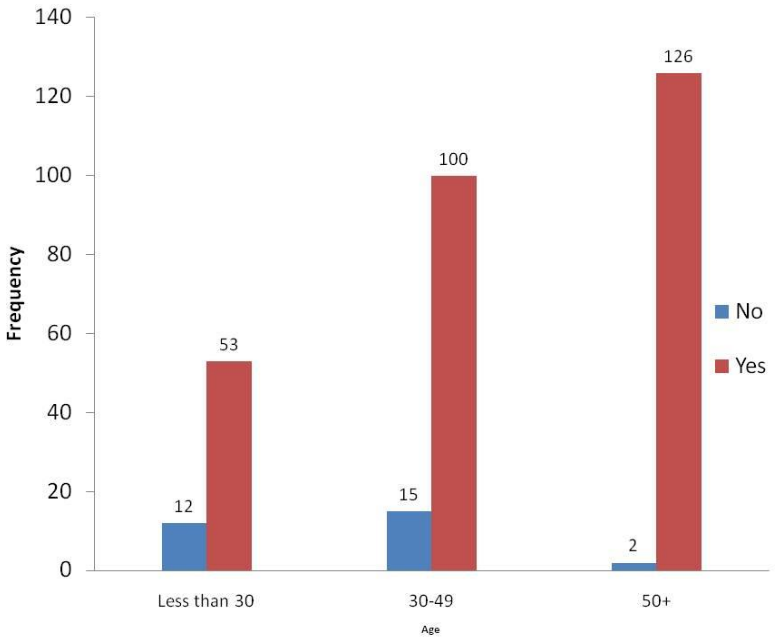

Figure 6.3: Experiences of farmers in Bawku East on increasing heat and climate change aggregated in age group (n=308). Farmers' perceptions and experiences of increasing heat and climate change were determined using the age groups of less than 30, 30-49 and 50 and above. Those who were 50 years and above showed a higher response (Yes) for having experienced heat and climate change impacts. The age group of 30-49 showed the next highest response to having personal experiences of heat exposure and climate change.

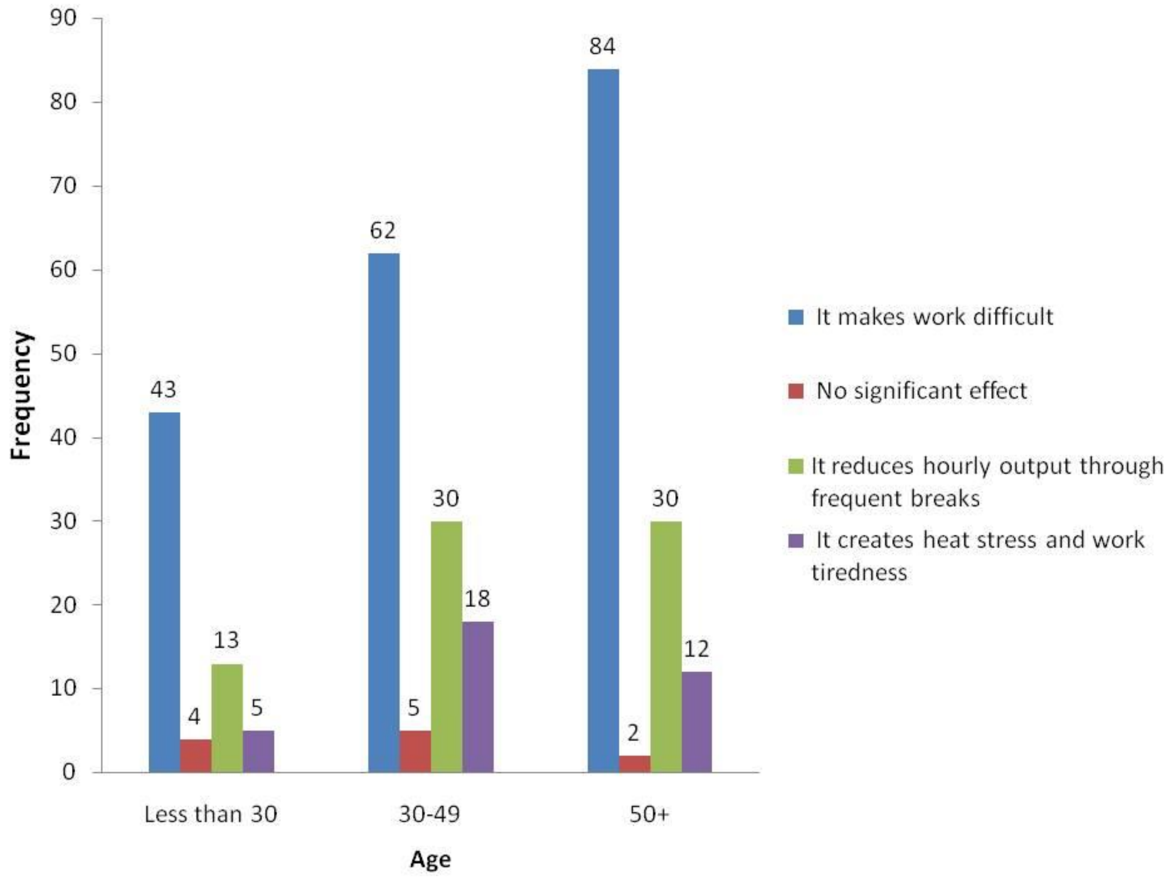

Figure 6.4 Experiences of farmers on impact of heat at farm level in Bawku East (n=308)

In the context of experiences of farmers with regard to heat at their farm level, those aged 50+ showed the highest impact of heat on their day-to-day activities at the farm level, which continues the trend of those with higher age having higher concern on the impact of heat.

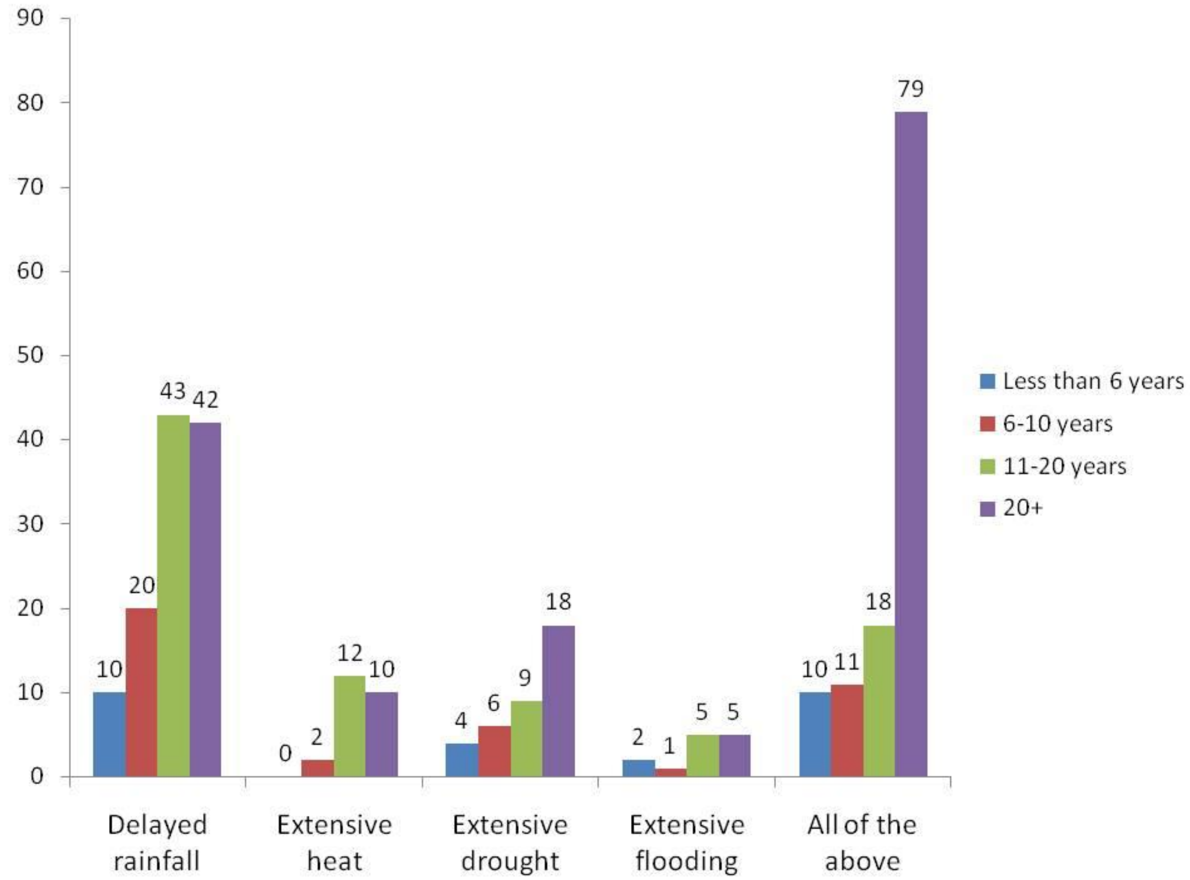

Figure 6.5: Farmers' experiences (signs) of climate change in recent years and duration of residence in Bawku east n=302 of 308, 6 non response). Farmers' duration of residence was used to compare their perceptions of the signs of climate change (Figure 6.5) . Farmers who had resided in the region for more than 20 years more often noticed signs such as delayed rainfall, extensive heat exposure, extensive drought and extensive flooding, followed by those who had resided in the area for 11-20 years. Thus farmers who had been in the locality longer, were more concious of climate change signs.

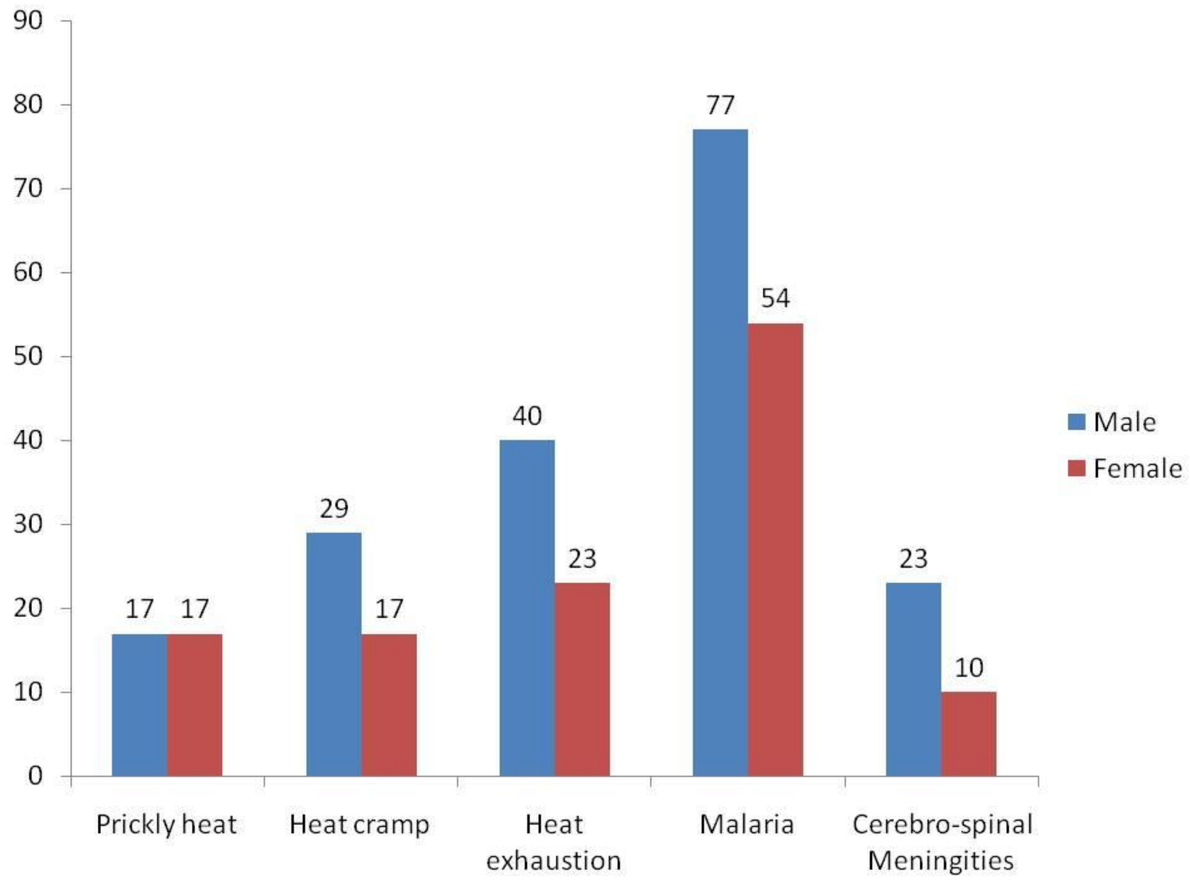

Figure 6.6: Experiences of farmers in Bawku East based on their gender and heat-related illness. Malaria is perceived as the most common heat related illness in Bawku East, with many males experiencing that condition. Cerebro-spinal meningitis is another illness which is enhanced by heat. It usually occurs when heat is at its high peak. Other less threatening heat-related illnesses reported by respondents were heat exhaustion, heat cramp and prickly heat

Age, gender, educational level, community of residence, and duration of residence were used as independent variables to measure farmers' responses on experiences of increasing heat exposure and climate change during recent years in Bawku East. The dependent variable was experiences of increasing heat and climate change in recent years in Bawku East.

6.5.2 Logistic regression results

Table 6.1: Results of logistic regression equation modeling examining the effects of community, age, gender, education and residency time on farmer's awareness of heat stress and climate change**.**

Variables	Coefficient	Standard Error	P-Value	Odd Ratio
Community				
Binduri	1.565	0.674	0.020	4.783
Pusiga	0.078	0.638	0.903	1.081
Manga	Ref			
Age				
< 30	-2.275	0.804	0.005	0.103
30-49	-1.373	0.707	0.052	0.253
Above 50	Ref.			
Gender				
Male	1.575	0.369	0.000	4.831
Female	Ref.			
Education				
Primary	2.213	0.480	0.000	9.143
Secondary	2.131	0.536	0.000	8.423
Tertiary	1.909	0.664	0.004	6.746
Non formal	Ref.			
Duration of residence				
<6years	1.330	0.863	0.123	3.781
6-10 years	0.172	0.605	0.123	1.188
11-20 years	0.744	0.471	0.114	2.104
Above 20	Ref.			

6.6 DISCUSSION

A large number of the respondents have shown that they were unable to sleep due to higher heat exposure. The farmers who had lived in Bawku East for over 20 years showed the highest level of responses to heat impact on sleep. Apart from the area being a poverty prone environment, farmers' livelihood is exacerbated by harsh climatic conditions, and poor socioeconomic infrastructure (Laube et al., 2012). Over 88% of the rural population lives

below the national poverty line (Ghana Statistical Service, 2000). The entire region did not receive any development under the past colonial administration and such trend was replicated by succeeding governments after independence (Laube et al., 2012). Previous studies indicated that rainfall commencement has shifted from April to May increasing a long dry season (Laux et al., 2008).Climate analyses have predicted increasing occurrence of extreme weather event such as heat, drought which is likely to worsen already food insecurity issues in the area (Van de Giesen et al., 2010). This corresponds to studies that stipulate that heat waves globally are projected to increase in intensity and frequency especially in the tropics (IPCC, 2007b). Therefore the entire evaluation of farmers' experiences of heat stress vulnerability and climate change is crucial and timely. Moreover, poor people are projected to have significant impacts related to changing climate as a result of low adaptive capacity (Parry, 2007). Bawku East being a poverty prone area (Webber, 1996; Whitehead, 2006), the incidence of high responses by farmers to high heat during sleep are likely due to poverty and low adaptive capacity to confront heat stress in their home and working places. Studies done by Frimpong et al., (2014) indicate a consistent increase in temperature in Bawku East, especially in Garu from 1961 to 2012. Those aged 50 and above showed the highest response rate of having experienced increasing heat and climate change during recent years. This was in agreement with the perceptions expressed by farmers in other part of northern Ghana on changes that have occurred in climate (Dietz et al., 2004). A study conducted in Asekyedumase of Ghana indicates that farmers have a clear perception that the climate has changed (Fosu-Mensah et al., 2012).

Farmers who were above the age of 50 showed high concerns on impact of heat on farm activities. This may be due to their feeble physiological capabilities to cope with heavy and very heavy tasks associated with farming, such as digging holes and drawing of water to irrigate crops in full exposure of heat. Exposure to high temperatures and humidity can cause heat-related illness like heat cramps, heat exhaustion; heat syncope especially in a given population that have respiratory diseases (McGeehin & Mirabelli, 2001) and such illnesses were commonly reported across all age groups in this study. Many diseases related to old age are likely to increase in heat prone environments.

With regard to changes in climate, the farmers who have lived for more than 20 years in Bawku East were more aware of the delay in wet-season rainfall, extensive heat, extensive drought, and extensive flooding. In 2007, there was extensive rainfall that caused damage to human and properties in the vicinity. Farmers who have lived longer in the area affirmed in focus group discussions that a lot of changes had occurred in the past 20 years. They

intimated that there is a delayed rainfall, which has shifted their planting season from April to May and sometimes June. These experiences of the farmers of shift of rainy season to May in many parts of northern Ghana were attributed to climate change (Dietz et al., 2004). The same concern about changes was expressed by farmers in Asekyedumase located in the Ashanti region of Ghana (Fosu-Mensah et al., 2012). Farmers stated that traditional symptoms they used to gauge the commencement of rainfall were not reliable any more (Dietz et al., 2004).

Farmers' experiences of heat-related illness indicated that more farmers were prone to acquiring malaria than any other heat-related illness, particularly so for males. This conforms to the study of malaria epidemics in Ghana, where Bawku East was noted as one of the high prevalence zones (Appiah, 2014). The spread and distribution of malaria are associated with the upsurge of mosquito populations which in turn is linked to climatic factors and geographical locations (Habib, El Zein, & Ghanawi, 2010). The impact of climate change resulting in changing trend of temperature, humidity, and rainfall is likely to affect the local distribution and severity of the spread of malaria disease (IPCC, 2007b; Sachs & Malaney, 2002). A copious amount of research in the Eastern Mediterranean have indicated an association between incidence of malaria due to increased temperature, humidity and rainfall changes (Habib et al., 2010). Since there is a systematic increase in temperature in Bawku East of northern Ghana (Frimpong et al., 2014), the high incidence of reported malaria cases by farmers (as shown in Fig. 6) is warranted.

The key independent variables (community, age, gender, education, and duration of residence) were used in a logistic regression to model their effects on the dependent variable, which is whether or not the farmers' were experiencing increasing heat stress and climate change in recent years. This was shown to be significantly higher in all the independent variables except duration of residence (Table 6.1). The selected farming communities within Bawku East showed significant differences in their experiences of increasing heat stress and climate change (Table 6.1).

The selected farming communities within Bawku East showed significant differences in their experiences of increasing heat stress and climate change with those from Binduri being most affected. This is likely attributable to ethnic differences and perhaps the architectectural style of housing. Age was significantly associated with experience of farmers to increasing heat stress and climate change. In empirical results derived from the survey, farmers over 50 years of age were more concern about increasing heat stress and climate change than younger farmers. Education was associated with farmers' experiences of increasing heat stress and climate change and this indicates that education enhances peoples'

understanding of the changing climate. The most important aspect of education is likely to stem from variation in behavioral responses to thermoregulation (Brager & de Dear, 1998) Duration of residence in the community was not significantly associated with concerns over climate change. However, in the empirical results (as presented in Fig. 6.2 and 6.4), duration of residence in the community showed that the longer a farmer had lived in the community the greater their concerns were regarding increasing heat stress and climate change.

6.7 CONCLUSION

In determining farmers' experiences to increasing heat and climate change, the age of farmers is cardinal since their age allows them to establish a frame of reference for assessing climate change and increasing heat exposure. Moreover, farmers' educational level is a factor to consider as it relates to their ability to understand and express the changes in climate they perceive in the sphere of scientific contexts. In a Bolivian farming community, the frequent occurrence of hailstorms was largely attributed to the curses the gods had meted out on the residents due to high incidence of teenage abortion and refusal to perform customs and rituals to honor gods and ancestral spirits (Chaplin, 2007). Such perceptions have no scientific relevance, hence the importance of education in shaping the thinking of rural farmers on the trends and changes in climate. Duration of residence, even though it did not prove significant in the logistic model, is an important aspect in eliciting peoples' experiences of climate change and heat vulnerability. The longer a farmer had lived in an area, the greater their awareness of climate change and their experiences can be well presented. Malaria is a heat-related illness that is triggered by an environment conducive for mosquitoes breeding and this related to higher temperatures.

It is imperative for government-led adaptation initiatives to be intensified in poor communities of developing countries to provide residents in heat-prone environments with well-ventilated accommodation and to reduce heat stress in the wake of global warming. Farmers who depend solely on the dictates of the weather need to be supported by government to enhance their resilience and increase food production to reduce poverty and food insecurity. Future studies on climate change and heat impact in a community, should consider using age, duration of residence in the community, and education level of residents when eliciting respondents' experiences on a particular experiences of climate change, since such variables have proven to be effective in eliciting farmers experiences to heat vulnerability and climate change in Bawku East of northern Ghana. To curb rural urban migration from Bawku East to the southern part of Ghana, it is imperative for the

Government to focus on sustainable measures, such as providing or encouraging well-ventilated accommodation in farming communities and developing programs of mechanized farming to reduce human physical outlay of labor in hot temperatures.

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CHAPTER 7

IMPACTS AND ADAPTATION TO HEAT EXPOSURE BY FARMERS IN NORTHEAST GHANA

This manuscript has been accepted for publication by Journal of Climate and Development administered by Taylors and Francis Publishing group. The entire study, preparation and writing of this manuscript were done by the lead author (Frimpong) with editorial help by the co authors. This chapter is an extension and builds on the fifth aim of the experiences of heat stress vulnerability and climate change. In this present chapter impacts and adaptation to heat stress and climate change are outlined based on household survey eliciting farmers level of impacts and level of adaptation both the household and on the field of cultivation.

7.1 ABSTRACT

Across tropical developing countries, smallholder farmers are confronted with various climate-related risks linked to agricultural activities. Climate change is predicted to impact smallholder farmers and their livelihood, especially within and beyond this century. Several studies have examined the impact of drought and rainfall on smallholder farmers as part ofclimate change impact assessment. However, there is limited information on the impacts and coping strategies of poor farmers to heat exposure, at the household and farm levels, in tropical developing countries. Global temperature is predicted to increase,impacting significantly on farmers in the African region due to their poverty and low adaptive capacity. This study evaluates how farmers in Bawku East of Northern Ghana experience the impacts of heat and how they cope with it both at the household level and on the field of cultivation. Using household surveys and focus group discussions, the authors elicited impacts and responses of heat exposure from 308 resident farmers in three selected farming communities in Bawku East to gauge their vulnerability to heat exposure. Even though farmers have various impacts and coping strategies to heat exposure, these are ineffective to prevent them from heat-related morbidity and mortality

at both the household and farm level. There is a need for government led intervention to assist farmers in their efforts to cope with heat stress as global temperatures will exacerbate heat stress impacts on smallholder farmers especially in Africa.

7.2 INTRODUCTION

Smallholder farmers make up some 6-8% of the global population, ranging from 500-700 million persons, and this group constitutes 85% of all farmers worldwide (Nagayet, 2005). About half of the global hungry persons are projected to be smallholder farmers with three quarters of these expected to be in the African region (Sanchez & Swaminathan, 2005). Achieving the target of United Nations (UN) Millennium Development Goals is contingent on renovating the livelihood of smallholder farmers. In the tropical developing world, a series of studies have examined drought, erratic rainfall and other weather impacts on smallholder farmers (Wright et al., 2014). However, few studies have focused on heat stress as a growing occupational health issue in the developing world (Kjellstrom, 2012). Apart from the negative impact of high temperatures on farmers' crops like cereals (Morton, 2007), increase in temperature as a result of global climate change has various socioeconomic and health impacts worldwide (Parry, 2007), especially on the health and productivity of smallholder farmers in the tropical developing world (Easterling et al., 1997; Parry, 2007; Costello et al., 2009; Kjellstrom et al., 2009). In the sphere of health impacts, it is identified that excessive heat stress can directly or indirectly cause or contribute to negative health effects, such as cardio-respiratory diseases and diarrhea, asthe incidence of extreme weather events increase with climate change (McMichael, 2003). Moreover, extreme temperatures will increase heat-related morbidity and mortality (IPCC, 2007). With the upsurge of mean temperatures associated with global warming, its concomitant rise in extreme temperatures and heatwave episodes is imminent (Hales et al., 2003; Fischer & Schär, 2010). Areas of the world where significant heat waves are already rife, it is predicted that such events will be experienced much more frequently (McMichael et al., 2008), particularly in tropical developing countries that are characterized by poverty and low adaptive capacity (Christensen et al., 2007). Among the weather-related hazards, heat exposure has resulted in more fatalities than other variables linked to climate change, such as drought, floods and storms (National Climate Data Center, 2006). It is rare to find studies that examine people's vulnerability to heat and how they respond to it in their daily lives (Sheridan, 2007) and, in the African region, there is no

published study evaluating outdoor peoples' exposure, self- reported impacts or response to heat (Costello et al., 2009). In view of that, it is imperative to regularly investigate how the most vulnerable groups in society can minimize their impacts from heat stress (Ebi et al., 2006). Certain sectors of human endeavors are more vulnerable to the harsh impact of climate change on rising temperatures and heat stress. These include farmers, fishers, foresters and construction workers, which are the predominant outdoor occupationsexposedto heat in Asian and African (IPCC, 2007; Kjellstrom et al 2010). Heat stress is predicted to become an occupational health issue in poor and smallholder farming communities in low and middle income countries as a result of climate change (Kjellstrom, 2012), it is imperative for the global community to assess the current impacts and coping strategies of poor farmers who work in hot outdoor environments under the exposure of full sunshine and heat.

In Ghana, a large proportion of the population are engaged in agriculture (Agyeman-Bonsu et al 2008), which is mainly undertaken indirect sunshine, farming methods are primitive and require hard physical labour, a feature characterized by much of developing world's agricultural sector (Food and Agriculture Organization, 1987; Kjellstrom, 2000; Kjellstrom, 2009). These people are also known to be poor (Morton, 2007; Laube et al., 2011), and they constitute the bulk of the agricultural labour force which is a key component needed for Ghana's socioeconomic development (Aryeetey & McKay, 2004). Over the past fifty years there has been a one degree rise in temperature in Ghana (Agyeman-Bonsu et al., 2008) with a corresponding increase in the number of hot days and nights (McSweeney, 2012). In the Bawku East area of the Upper East part of Northern Ghana, an aggregate of 2.3 months of day time temperature was assessed to be above 37 degrees Celsius from 1961-1975. This rose to 5.3 months per year for the period from 1998-2012 (Frimpong et al, 2014b). Investigating the impacts of heat exposure on farmers in northern Ghana is timely and appropriate to aid in the development of policies that can enhance their livelihood.

The impact of heat stress on individuals is linked to body physiology and its reaction to environmental factors. When there is excess heat generated by the body or a decrease in the dissipation of heat to the surrounding environment, it can result in heat-related morbidity. Over-production of heat can cause the body temperature to rise to dangerous levels due to the inability of the body to maintain thermal balance, this condition can be injurious to cells, leading to heat morbidity and even mortality. When core body temperature rises above 37°C, heat stroke, heat

exhaustion, heat syncope and heat cramp are likely to occur (Leithead & Lind, 1964; Kilbourne, 1997). The level and duration of air temperature, humidity and air movement are the key external determinants of human heat stress (Srivastava et al 2000). Further, by executing physically demanding tasks (commonplace in farming communities) in hot/humid areas, there is the risk that the core body temperature will rise above the normal limit, which can lead to reduced physical work capacity (Kerslake, 1972; Bridger, 2003), reduced ability to undertake mental tasks (Ramsey, 1995), greater risk of accidents (Ramsey et al 1983) and increased incidences of heat stroke (Hales & Richards, 1987). People living in a given environment are certainly acclimatized to their local climate with regard to physiological, cultural and behavioral stature (Kovats & Hajat, 2008). However, this potential for acclimation is limited by clear thresholds that the body can tolerate. As global climate change is presumed to exacerbate heat events (McMichael et al., 2008), there is the need to assess the impacts and level of response of a given population to current heat exposure. Using a poverty-prone farming community normally associated with low adaptive capacity (Morton, 2007; Kjellstrom et al 2009; Nti & Barkley, 2013) is a key step in evaluating current impacts and adaptation strategies more broadly, which can, in turn, assist in identifying tolerance ranges to temperature as a basis for postulating future impacts as global mean temperatures will increase in coming decades. Therefore, the aim of this study was to establish the impacts and responses to heat exposure, at both the household level and in the field of cultivation, of farmers in Bawku East of Northern Ghana where a significant number of the residents are poor (Webber, 1996), have low adaptive capacity to the predicted effects of climate change (Laube et al., 2011) and are regularly exposed to heat (Frimpong et al., 2014b). To achieve this objective, a survey was conducted to assess self-reported impacts and responses of heat exposure among the farming community of Bawku East, which encompasses the communities of Pusiga, Binduri and Manga. The paper is divided into four sections. Introduction preludes the paper with the state of smallholder farmers and overview of heat exposure. The second part of the paper outlines the methodology used in the study. Results and discussion are then followed expatiating impacts and responses of farmers to heat exposure. The final section addresses the policy and management implications of the findings.

7.3 METHODS

The study assessed farmers' vulnerability to heat exposure in Bawku East of Ghana. The study has been informed by the concept of vulnerability, which denotes that the methods of reducing the impacts of hazards on humans are the key basis for adaptation (Adger et al., 2004), and the ability to enhance livelihoodsand security is an important feature in successful adaptation (TERI, 2007). The study revolves around gauging the exposure, sensitivity and adaptive capacity in the sphere of individuals and communities (Smith et al., 2000; Smith & Pilifosova, 2003). Previous studies have applied this concept of vulnerability to forest management in assessing exposure, sensitivity and adaptive capacity of the forest sector (Smit & Pilifosova, 2001; Turner et al., 2003; Ford & Smit, 2004; Johnston & Williamson, 2007). The level of heat exposure in the sampled communities mainly determines their vulnerability. The methods of living and working then largely limit or intensify farmers' exposure to heat stress vulnerability. The effects of heat exposure in the study area on the sampled communities are represented as their sensitivity. This varies from individual to individual based on their physiological and socioeconomic capabilities. Exposure and sensitivity are contingent on both style and methods of farming in this study region. Adaptive capacity is an integral part of the tripartite concept of vulnerability, along with exposure and sensitivity (Smith et al 2000), and forms the fulcrum of this study. The ability of farmers to overcome the impact of climate change is reliant on their adaptive capacity (Ziervogel et al., 2008), and thereforetheir socioeconomic status is one of the key factors influencingtheir adaptation to heat exposure.

This mixed-method, exploratory study design encompassesboth quantitative and qualitative methods – this combination of approaches is used for achieving triangulation to further strengthen the research. Triangulation uses quantitative and qualitative data by collecting, analyzing, and seeking to confirm the worth of information rendered by the approaches (Creswell, 2003). Congruence between two or more sources of evidence in a study opens a space for clearer comprehension of the research problem, such as by integrating numeric patterns from quantitative data and direct details from qualitative sources (Marten, 2003). The study population was farmers from three farming communities (Binduri, Pusiga, Manga) in Bawku East who are constantly exposed to heat, especially in the their fields of cultivation, due to the labour intensive farming methods employed, and at residential level because of the nature of house architecture and a lack of electricity, the situation is further exacerbated by poverty. Three hundred and

eighty five (385) farmers were selected for the study usinga combination of purposive, simple-random and systematic sampling from an estimated farming population of fifteen thousand (which was an appropriate sampling size according to the criteria of (Krejcie & Morgan, 1970). Purposive sampling was used to selecting four participantsfor the focus group discussion. These were two chief farmers, a village head and an agricultural extension representative to join fifteen farmers who voluntarily expressed interest and signed a consent form to join the focus group to further discuss the impacts and response of heat stress. About 77 respondents were removed from the data set because they were engaged in others jobs in addition to farming. Data obtained from 308 farmers were used in the analysis. The household survey encompassed items on farmer's livelihood, coping strategies against heat exposure and their perceptions and experiences related to climate change. Before administering the survey the instrument was pilot testedon 10 randomly selected farmers. Many of the questions in the survey were extracted or modified from that used in a global program of heat stress research termed "HOTHAPS", which had been widely used and rigorously tested. The study area selected is one of the poorest areas in Ghana (Webber, 1996) with much exposure to high to extreme temperatures over recent years (Frimpong et al., 2014b) Both descriptive and inferential statistics were used in analyzing the data. The data was analysed usingSPSS version 21. The results covered the respective heat events categorized as impacts and responses which are presented in charts, and tables.

The study was conducted from January to May, 2013. Consistent withthe assessment of heat impacts on farmers, questions and analyses revolved ondetermining impacts on domestic chores, impacts on time and methods to cope with heat, age of participants and its association with general health status, types and methods of crops grown, the concernsof participants regarding heat, signs of heat-related sicknesses, effects of heat on income and productivity, and the association between work classification and health status.In the sphere of adaptation assessment, coping strategies to minimize heat during day and night and coping strategies at the farm level, with regard to both humans and crops, were assessed. Water availability and level of intake by farmers were examined. Selected variables such as impacts of heat on day to day activities, effects of heat on sleep, educational level of farmers, duration of farmers' knowledge regarding climate change, and farmers' experiences of heat-related illnesses were used to model their association with strategies and constraints (eg architectural style) to reduce heat at the household level. In the same vein, knowledge of the impact of clothing on heat, experiences of

heat-related illnesses, age, educational level, classification of tasks at the farm level, knowledge of climate change and general health status of farmers were used to model their association on methods to reduce heat stress at the farm (field) level.

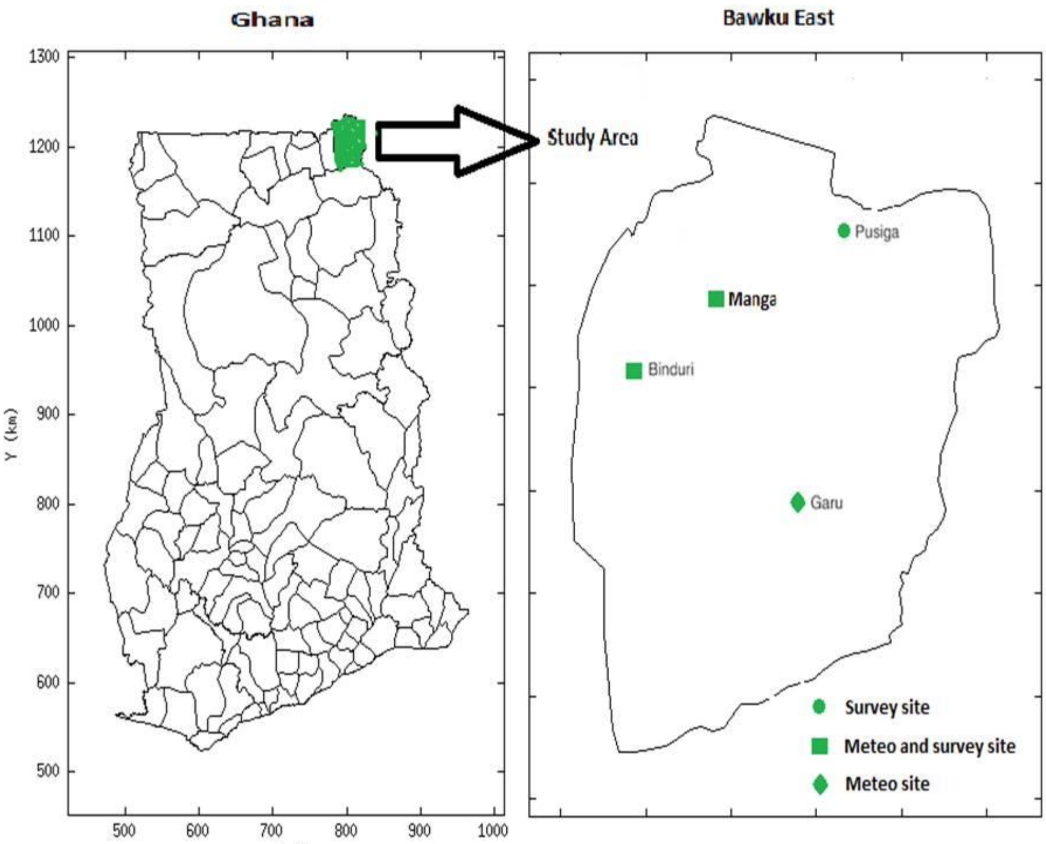

Fig 7.1   A map of Ghana showing Bawku East and the selected villages for the study.The nearest Meteorological stations are also shown.

7.4 RESULTS

7.4.1 Demographic Information

In terms of survey participants, 21.1% of the farmers were less than 30 years of age, whilst farmers aged 50 and above comprised 41.6% and 37.3% were in the age range of 30-49. Farmers who were married formed the largest proportion of the survey (75%).Farmers who were divorced made up 12.7% of the studied population. Males formed 60.4% of the sampled population. Over 36% had primary education followed by 26.9% with a secondary education and 14.4% with tertiary education.

Table 7.1: Impacts of heat at the household level as reported by 308 survey participants from Bawku East, Ghana, in 2013.

Impact of heat	Frequency	Percentage
Main impact on household activities		
No effect	11	3.6
Makes domestic chores difficult	189	61.4
Increases work hours	73	23.7
Creates stress and work tiredness	35	11.4
Main impact on sleep		
Unable to sleep	132	43
Reduces length of sleep	79	25.7
Induces sweating while sleeping	60	19.5
Makes sleeping boring	36	11.7
Impact on the time available to cope with heat at household level		
Moderate	47	15.3
High	151	49.2
Extreme	98	31.9
No impact	11	3.6

7.4.2 Impacts of Heat at Household Level

The impacts of heat on household activities such as domestic chores; comfort of sleep, and the amount of time available to cope with heat as reported by survey participants arepresented in Table 1. Large numbers of respondents (61.4%) stated that domestic chores became difficult

during high heat exposure. Increased work hours were noted with second highest number of respondents (23.7%; Table 1). Almost half of the respondents 43% indicated that heat disruptedtheir sleeping pattern, while 81% reported high to extreme impact in terms of time available to cope with heat. These findings indicate that there is a need to improve dwelling conditions to enable them to live and sleep comfortably. As many as 49.2% of respondents reported that heatimpacted 'highly' on their time to cope. This denotes that as temperature is projected to increase a lot of time might be needed to cope with heat if adaptive capacity is not improved.

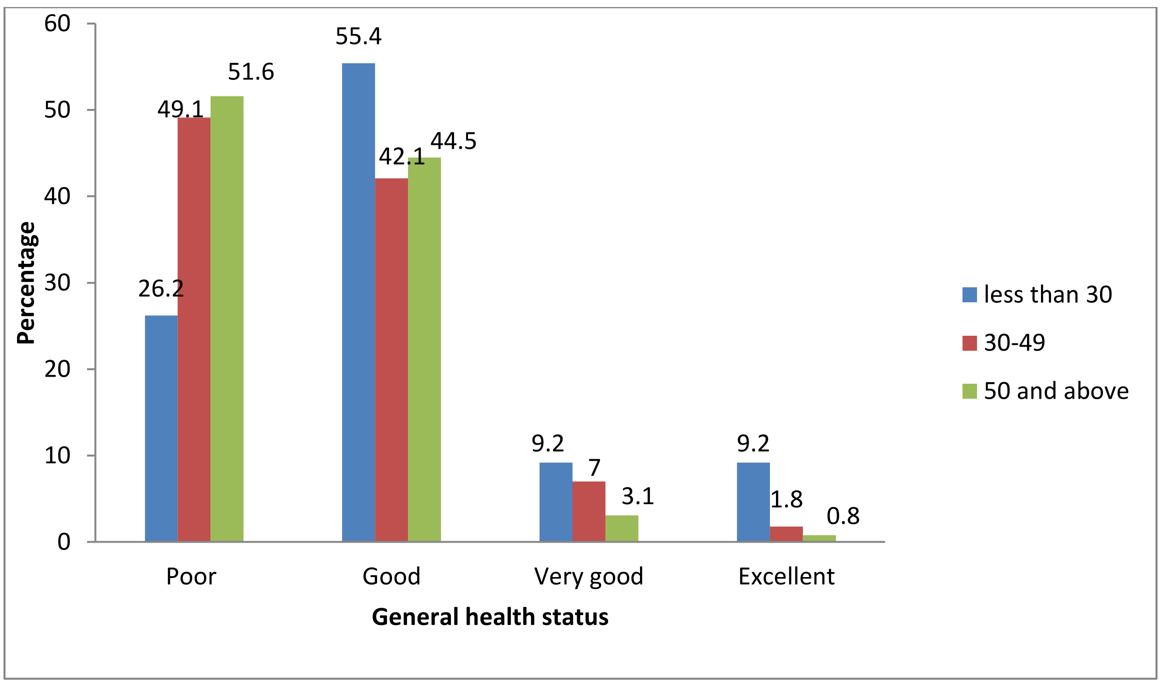

Figure 7.2. Self-reported health status of survey participants by age category

Self-assessed health status was significantly related to age category: Chi-Square = 22.93, P<0.001 (Fig. 7.2) across the three farming communities. Younger farmers were more likely to view their health as being good to excellent, with approximately half the farmers older than 30 reporting their health as being poor overall, compared to only 26% of farmers younger than 30 (Fig. 7.1).

Table 7.2: Impacts of heat at farming level

	% of Survey Participants		
Major concerns of heat	**Effected by more than half**	**Effected by half or less**	**No or Minor effect**
Sickness	51.9	22.2	25.9
Stress	47.8	39.1	13.0
Water loss in the body	62.5	9.4	28.1
Retard work pace	41.9	18.9	39.2
Creating heat Exhaustion	61.9	9.5	28.6

Percentage breakdown of survey participants in terms of their reported level of effects of heat on income and productivity for five types of major heat impacts of concern. Association between impact and concern: Chi-Square = 15.215; P-Value= 0.055**.**Farmer's major concern regarding heat exposure was used to model their relationship with its effects on income and productivity, and there was an almost significant association between these two factors (P=0.055, Fig. 1). Overall, around half of participating farmers reported their income and productivity was cut by more than 50%, however farmers who were most concerned about heat exhaustion and dehydration, both more severe effects of heat exposure, were more likely to report a loss of income/productivity of greater than 50% (Table 2). For farmers mostly concerned about a reduction in work pace, a more benign impact of heat, only around 42%reported a greater than 50% loss of income/productivity.

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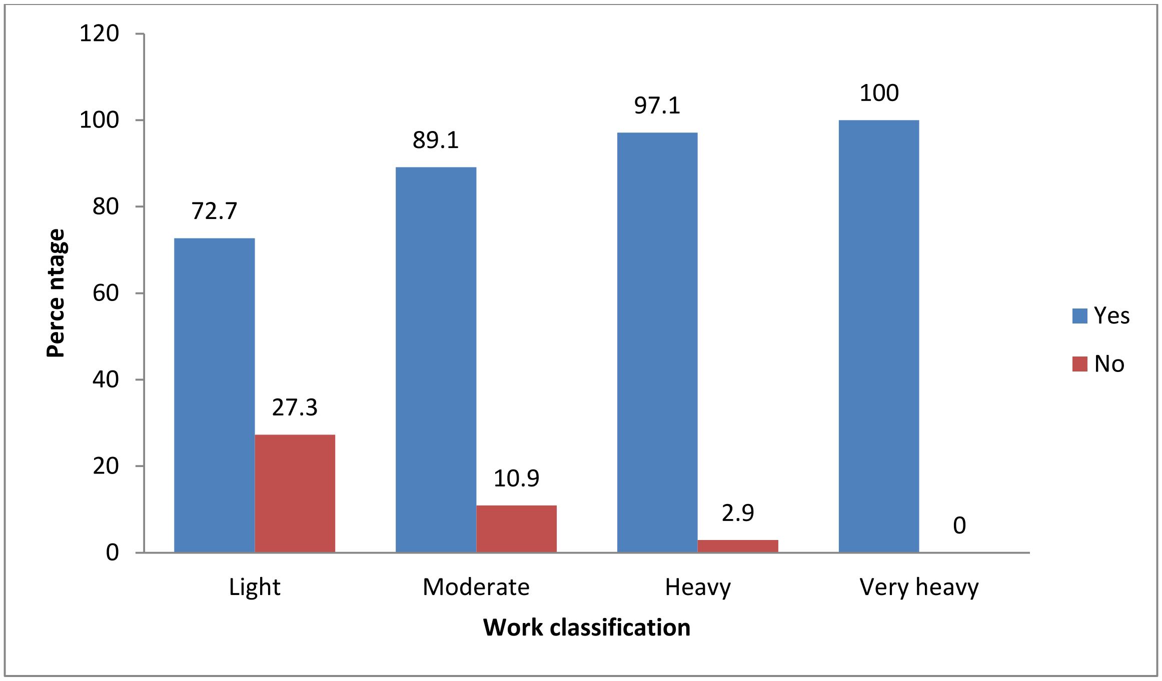

Figure 7.3. Percentage distribution of survey participants reporting impact of heat on their health for each work intensity class. Association chi-Square Value=27.13;P-Value=<0.001.

The association between the range of work intensity that farmers perform and its relationship on health was established (Fig.7. 3), withwork intensity perceived to have a significant impact on health. The perceived health impacts resulting from heat exposure significantly increased with intensity of work conducted by farmers (Fig 7.3). All farmers with a very heavy workload reported health impacts from heat exposure whilst only 73% of lightly working farmers reported such health impacts.

Table 7.3: Adaptation strategies employed at the household level as reported by survey participants. Responses (number and % of participants) to four questions are shown.

Adaptation strategies	Number	Percentage
Minimization of heat in room during the day		
Opening doors and windows	179	58.3
Usually not hot in room (do nothing to adapt)	12	3.9
Providing room standing fan	116	37.8
Minimization of heat in room at night		
Sleeping outside the room	74	24.2
Opening doors and windows	134	43.8
Taking very cool shower before sleeping	98	32.0
Hotness of room during hot season		
YES	298	97.1
NO	8	2.9
Information from government about heat and temperature		
Yes	268	87.3
No	38	12.4

Table 7.3shows self-reported methods that farmers use to adapt to heat exposure at the household level at day and night, their perception of hotness of their room, and their responses on guidance from the government to provide information on impending heat and temperature increases as adaptation information. A vast majority of participating farmers reported their homes as being hot during the hottest (dry) seasons and had received information from government sources about heat.

Table 7.4 Responses to series of questions on adoption of adaptation strategies to cope with heat exposure at farm and personal level.

Variable	Number	Percentage
Main methods of limiting heat exposure at farm level		
Get away to a shade for a while	82	26.6
Clothing removal for free air	13	4.2
Regular intake of water	61	19.8
Wearing a hat	52	16.9
Wearing of airy dress	100	32.5
Intake of water as coping measure		
Yes	295	95.8
No	13	4.2
Availability of sufficient water		
Yes	174	56.5
No	134	43.5
Intake of traditional diet to cope with heat		
Yes	175	56.8
No	133	43.2
Traditional or other main method to cope with heat		
Cover head with traditional scarf	10	3.2
Wearing traditional cloth which is airy	32	10.4
Eating traditional food which induces regular intake of water	142	46.1
No traditional food	124	40.3
Have financial investment to cope with heat		
Yes	69	22.4
No	239	77.6
Conflict of social life time and time to cope with heat		
Yes	286	93.5
No	20	6.5
Adaptation strategies for crops		
Mulching	175	57
Irrigation	46	15
Applying manure	70	22.8
Erecting shade to cover crops for sunshine and heat	16	5.2

Different kinds of self reported mechanism of adaptation have been instituted by the participating farmers in the study. About 58% (fig 4) used the methods of wearing airy dresses and staying in shade during high peak sun and heat to offset the impact of heat on

them. Significant number of farmers 46% (Fig 7. 4) used traditional meal that induces a lot of water intake to enable farmers to cool down, whilst mulching is much used as adaptation to crops in their farms. Farmers' social time 93.5% (fig 7.4) is significantly impacted by time spent coping with heat. This means that heat stress can affect farmers' quality social life.

Table 7.5. Architectural style of houses of participants divided into different demographic and knowledge classes, and results of statistical test of association.

Characteristics	Architectural style to reduce heat stress					
	Brick, roof with thatch, trees surrounding the house	Brick,s roof with thatch, no trees	Brick, roof with iron sheets, windows	Mud and roofed with thatch	Chi-Square Value	P-Value
Level of education						
Primary	30.3	25.7	37.6	6.4	26.541	0.002
Secondary	34.6	32.1	30.9	2.5		
Tertiary	46.3	19.5	24.4	9.8		
Non formal	25.8	28.8	22.7	22.7		
Duration of knowledge of climate change						
Less than 1 year	22.2	11.1	44.4	22.2	31.789	0.001
1-5 years	26.0	40.0	30.0	4.0		
6-10 years	44.4	19.8	30.9	4.9		
11-15 years	30.7	20	29.3	20.0		
16+	32.4	33.8	29.4	4.4		
Effects of heat on sleep						
Inability to sleep	36.2	33.9	26.0	3.9	39.924	0.000
Reduced length of sleep	26.3	22.4	43.4	7.9		

time						
Induce sweating while sleeping	49.2	16.9	20.3	13.6		
It makes sleeping boring	8.3	30.6	36.1	25.0		
Experience of heat illness						
Prickly heat	32.3	25.8	29.0	12.9	25.935	0.011
Heat cramp	39.1	43.5	10.9	6.5		
Heat exhaustion	44.3	29.5	19.7	6.6		
Malaria	26.9	22.3	39.2	11.5		
Cerebrospinal meningitis	26.7	23.3	43.3	6.7		

Table 7.5 shows the association between the architectural style of housing as a factor in mitigating heat at the household level and the impacts of heat on day to day activities, including effects of heat on sleep and its relationship with methods of limiting heat exposure, educational level and its relationship with architectural style of limiting heat exposure, duration of knowledge on climate change and its relationship with architectural style of limiting heat exposure and experiences of heat related illnesses and architectural style of limiting heat exposure. These variables were modeled with architectural style of limiting heat exposure at household level. The results showed statistical significance with the architectural style of limiting heat exposure at household level. Farmers are more likely to live in a house with limited capacity to reduce heat stress if they are less educated and know less about climate change impacts (Fig7.5). Also those in hotter houses are more likely to experience sleep deprivation and diseases associated with less ventilation as in (Fig 7.5).

Table 7.6: Methods of limiting Heat Exposure on the field of cultivation of participants divided into different demographic and knowledge classes, and results of statistical test of association.

	Methods of limiting heat exposure (%)						
Variables	**Get away to a shade for a while**	**Remove clothing for free air**	**Regular intake of water**	**Wea ring a hat**	**Wearing of airy dress**	**Chi-square value**	**P-Va lue**
Knowledge of impact of clothing on heat exposure							
Yes	25.9	2.9	20.5	17.6	33.1	14.7	0.0 05
No	33.3	16.7	13.3	10.0	26.7		
Experience of heat-related illness							
Prickly heat	47.1	5.9	23.5	5.9	17.6	48.1	0.0 00
Heat cramp	23.9	0.0	23.9	6.5	45.7		
Heat Exhaustion	33.3	11.1	15.9	17.5	22.2		
Malaria	16.0	1.5	19.8	21.4	41.2		
Cere bro spinal meningitis	39.4	6.1	15.2	24.2	15.2		
Age Group							
less than 30	40.0	6.2	12.3	13.8	27.7	15.4	0.0 52
30-49	22.6	6.1	18.3	15.7	37.4		
50+	23.4	1.6	25.0	19.5	30.5		
Level of education							
Primary	33.0	1.8	23.2	14.3	27.7	29.8	0.0 03
Secondary	26.5	7.2	9.6	18.1	38.6		
Tertiary	34.1	6.8	13.6	9.1	36.4		
Non formal	10.4	3.0	29.9	24.4	31.3		
Classification of task at farm level							
Light	45.5	9.1	18.2	18.2	9.1	13.3	0.3 48
Moderate	25.0	6.2	17.2	10.9	40.6		
Heavy	25.7	3.4	21.1	17.7	32.0		
Very heavy	23.4	2.1	19.1	21.3	34.0		
Day to day clothing for farming work							

Breathable cotton	22.1	5.7	13.9	25.4	32.8	15.5	0.051
Thick cotton overall	26.8	3.0	24.4	11.3	34.5		
Rayon/nylon	42.9	0.0	14.3	14.3	28.6		
Health status							
Poor	19.4	0.0	20.1	20.9	39.6	59.5	0.000
Good	30.5	5.7	20.6	14.2	29.1		
Very good	44.4	5.6	22.2	16.7	11.1		
Excellent	44.4	44.4	0.0	0.0	11.1		

The association between knowledge of the effect of clothing on heat exposure and methods of limiting heat exposure at the farm level was identified (Table 7.6) with those who reported knowing about the effect of clothing more likely to wear a hat and loose clothing than those who didn't' know about effects of clothing. Experiences of heat-related illnesses, age, education, level of task at the farm level, knowledge of climate change, day to day clothing at the farm level and health status are individually used to established its relationship with methods of limiting heat exposure at the farm level. A number of the variables showed statistical significance with the methods of limiting heat exposure at the farm level.

7.5 DISCUSSION

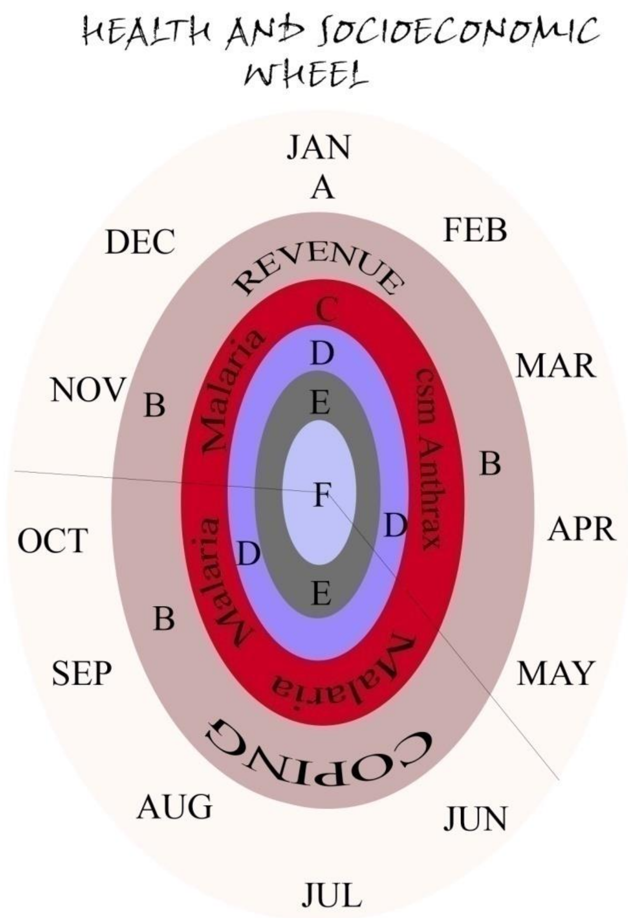

Figure 7.4Health and socio economic wheel extracted from Focus Group Discussion in Bawku East(Binduri, Pusiga and Manga)

The focus group discussions (FGDs) revealed the health and socioeconomic life patterns of the farmers in the examined communities and presented some key details that hinged on their day to day activities throughout the year (Fig. 7.4). The farmers through their experiences, impacts and responses to heat and climate change divideded the year in two periods. These were November to May inclusive (7 months) which broadly correspond to the dry season(summer) with no rains to aid their farming activities. The farmers stated that such months are characterised by intense heat, which make houeshold and farm activities very dificult. However, since these are difficult months, farmers who are able to work harder get the highest revenue from this season and generally over the whole year. Irrigation from hand-dug boleholeswithin dried-up river beds are mostly used to enable farming at this time of the year. Farmers who demonstrate higher resilience and undertake farm activities in this dry season are likely to earn more revenue for their crops than during the rainy season when all the farmers participapte in the farm activities which results in a lot more produce flooding the market..

The rainy season include the months June to October. During this time every farmer gets food from farm proceeds thereby leading to bumper harvest, low revenue and generally low income even though there are at least adequate amounts of food in each household.These months of the

rainy season are denoted as coping months in terms of financial revenue while months in the dry season are termed as the ‘revenue period’ for hard working farmers.The major diseases associated with the dry season include malaria, anthrax, and cerebrospinal meningitis (Fig. 7.4). Malaria incidence is associated with the high level of mosquitoes activity associated with these months. Farmers stated that anthrax is a disease that kills cattle. However, many of the farmers ignore the advice of the extension officers and consumed the dead animals. The farmers believe that when the meat is well cooked the diseases-causing organisms will die. This leads to a high rate of reported cases amongst farmers. Moreover, farmers stated that cerebrospinal menigitis kills a lot of farmers during months of high heat exposure. Farmers reported that when heat exposure is increased many of the farmers die because of this condition.

In the dry season, the most grown crops include onion,pepper,and tomatoes, whilst during the rainy season farmers mainly grow maize, cowpea, and sorgum (Fig. 7.4). Goat, sheep and cattle are reared year round as they provide an important souce of income to augment what farmers get from their crops. This study highlights importantlinks between health/socioeconomic status and productivity of farmers andthe impacts of and responses to climate change. Results clearly show (from both the survey and FGD) that farmers percieve a heat impact at the household level (Table7.1) manifesting in various ways such as stifling domestic chores.As there are many health issues aligned to heat exposure at both the household and outdoor level (Kovats & Hajat, 2008),there is a need for proper management of heat by linking government and the grass-root community activites to derive concrete actions to offset such impacts and to make rural livelihoods safer andmore congenial (Wright et al. 2014). Productivity is affected where there is intense heat exposure. Responses from farmers (Table 7.2) indicated that their productivity (and resultant incomes) at farm level is impacted through recent climate change and some farmers report a loss of crop yeild and income as high as 50%. Only a few farmers reported that heat has no significant effect on their productivity. Such assertions by the farmers are in line with a study of Indian farm worker (Sahu et al., 2013) which showed agriculture workers’ productivity declined as their heat exposure is increased. Previous assessment of heat exposure in our study area affirmed a range of wet bulb globe temperature (WBGT) between27-34^{o}C during working hours of the day (Frimpong et al., 2014a). This level of heat exposure means that farmers need to slow down the degree of work intensity to minimise bodily heat production to avoid cadiac strain and heat exhastion (Parsons, 2003). When farmers slow down their work

rates and increase their resting times, it tends to also reduce productivity (Kjellstrom et al., 2009). The study found that the adaptation mechanism of farmers at both household and farm levels are weak and could not be termed as adaptation Since the mechanisms adopted are mostly short-term measures they are rather better described as coping strategies (Pelling, 2010) This implies that to avert food insecurity, already known in this part of Ghana, key measures need to be put in place to augment farmers coping mechanisms to heat, an area that has not been investigated by the researchers and the government of Ghana. The relationship between work intensity at the farm level and heat impacts (Fig 7.3) showed that there is an impact of heat on famers' health at all level of work intensity with all farmers working at very high intensity reporting health impacts. This study also showed statitically significant relationshipsbetween methods of limiting heat exposure at the farm level and architectural style to reduce heat stress at the household level (Tables 7.5 &7.6). The results of the survey are mostly replicated by farmers responses from themes emanted from the FGD.

Farmers have confirmed that they are impacted by heat at both the household and farm level. Their home environments are mostly hot during the dry season and farm work is generally done early in the monings. A large number of the participants in the FGD agreed that heat sress makes household work very difficult. There is a lot of perspiration as a result of carrying out any task at household level. Many of the farmers expressed concerne that they are not able to sleep at all because the rooms are extremly warm. However, there are also a lot of mosquitoes that interrupt comfort of sleeping when windows and doors were opened. In effect there is a high impact of time used to manage heat which should have been used in other activities. Most of the farmers expressed that opening doors and windows are the key coping methods to offset the impact of heat.On the farm level, many of the farmers stated that they rest under the shade, and usually wear traditional airy dress, and indulged in high intake of water, eating traditional food that aids in the frequent consumption of water to cool their body down during the day.

7.6 CONCLUSION AND RECOMMENDATIONS FOR POLICY

This study has found that heat exposure results in significant impacts on smallholder farmers in northern Ghana at their household level. This implies that there is the need for some measures to be put in place to improve the existing measures of combating heat exposure whilst farmers are resting and sleeping inside their houses. Improvement in house design to enable cooler internal

conditions (such as shading by trees, insulated materials, opening windows with insect screening) are recommended but are dependent on adequate labour and financial resources. Heat-related illnesses are commonly reported in the communities where this study was conducted. Malaria and heat cramp was identified as one of the prominent recurring diseases that need attention. There is the need for hospital records to be commenced to track heat-related illness since we could not obtaininformation on heat-related illness in the communities apart from self-reported cases that the farmers stated in their responses to the survey and FGD.

The intensity of work that farmers undertake was identified as a key factor which exposes them to heat and itsadverse health effects. There is the need for the nature of farming to be modernized to incorporate mechanization in preference to current labour-intensive methods which exposes farmers to long hours of work in full sunshine. This could be very dangerous as temperatures are predicted to increase inthe study area. The coping mechanism that farmers undertake to reduce the impact of heat at the farm, level is viewed as mostly ineffective and unsustainable over the longer term. Opening doors and windows which is the predominant norm of cooling rooms is not effective as temperature will continue to rise. The architectural style of rural houses need to be improved to incorporate ventilation and modernized to suit climate change and heat exposure. Wearing airy dress and cooling in the shade are some of the simple mechanisms used by farmers to cool down during farming hours. These are crude methods which cannot stand the test of climate variability and change, especially in the context of maintaining productively to achieve food security. Education and farmers' knowledge of climate change need to be intensified since such variables have been identified to have a significant positive relationship with adopting appropriate house architecture to reduce heat loadings.

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CHAPTER 8

BARRIERS OF ADAPTAION TO HEAT STRESS IN NORTHEAST GHANA

This chapter presents largely from the perspective of focus group discussion the socioeconomic barriers to adaption. It also elicits the degree of effectiveness of farmers' adaptation to heat stress especially at the household level. This chapter has been accepted by the international journal social ecology and sustainable development and revision has been submitted. The leading author conducted the study and wrote the entire manuscript while the co-authors rendered editorial help.

8.1ABSTRACT

This paper focuses on the assessment of socioeconomic and cultural factors that exacerbate the exposure of rural farmers' exposure to heat stress and climate change in a tropical developing country. Using a household survey, the authors elicited responses from farmers on the effectiveness of their adaptation to heat stress, drawing data from 308 residents in the Bawku East part of north-east Ghana. The authors also used focus group discussion to establish socioeconomic and cultural issues that intensify farmers' exposure to heat stress. The study found that various levels of socioeconomic and cultural factors can predispose farmers to heat exposure. The study recommended the need for government-led policies to combat heat exposure in Ghana.

8.2 INTRODUCTION

Increases in the frequency of heat waves, droughts and floods are some of the key impacts of climate change worldwide (Fowler & Hennessy, 1995; Mearns et al., 1995; World Bank, 2012), and these climatic extremes are projected to increase within and beyond this century (McMichael, 2003; IPCC, 2007; IPCC, 2014). The predicted increase in global temperatures is likely to impact on food security and human health, including greater heat stress and heat-related illness (Battisti & Naylor, 2009). In 2003, the summer heat episode in Europe attributed to climate change took the lives of 14,800 peoples in France (Argaud et al., 2007). An

investigation of heat-related deaths among farming communities in United States of America between 1996-2006 showed a heat related death toll of 423 (MMWR, 2008). In view of this, investigating the effects of heat stress on populations is an indispensable aspect of climate change impact assessment (Byass et al., 2010). African vulnerability to heat exposure and climate change is largely associated with increasing poverty, low adaptive and weak institutional capacity to deal with general phenomenon of climate change (Boko et al., 2007). Heat stress research is gaining root in Asian developing countries (Kjellstrom, 2009) while little or least studies have been done in Africa on the repercussion of heat stress humankind and agriculture (Costello, 2009). Global food security could only be protected when society increase food production by 70% of what is produced today to afford the consumption needs of more than nine billion people by 2050 (FAO, 2009). This is alarming taking cognisance of the fact that three quarters of the global hungry persons are located in African region with over 70% of persons in the continent engaged in outdoor farming (Sanchez & Swaminathan, 2005; Ziervogel 2008). Heat related issue that affect farming is less investigated with no heat research on outdoor environment.

In Ghana, there has been a projection of a 1.5 to 3^0C increase in temperature by the year 2050 (EPA, 2007), while greater increases of 2.5-3^0C are predicted to occur in northern part of Ghana (EPA, 2007). Over the last 50 years, there has been an average increase of 1^0C in temperature in Ghana (UNDP/UNEP Programme, 2012) resulting in 50 more hot days and 80 hot nights annually (McSweeney, 2012). Studies have indicated that socioeconomic problems have exacerbated local vulnerability to climate change (O'Brien et al., 2004; Eakin, 2005; Belliveau et al., 2006). Bawku East is noted as one of the poorest areas in the upper east part of Northern Ghana with smallholder farming as residents' main source of livelihood (Webber, 1996; Whitehead, 2006). Over the last 50 years there has been a systematic increase in temperature in the region. Between 1961-1975 there was an average of 2.3 months with day time temperature above 37^0C which escalated to 5.3 months between 1998-2012 (Frimpong et al. 2014). In numerous studies, assessment of climate change vulnerability and adaptation planning is relegated to the background and not recognised as key socioeconomic factors (Füssel & Klein, 2006).

It has been identified that many groups in society that are vulnerable to climate change also face other multiple stressors that impact immensely on their lives (Eriksen et al., 2011). As

results, it is imperative to examine climatic, socioeconomic and cultural factors that may exacerbate the impact of climate change on humans. For instance, according to Eriksen et al. (2011), solving climatic issues requires the consideration of socioeconomic and cultural factors such as poverty. This phenomenon is having a negative impact on outdoor farming which is dependent on primitive methods requiring hard physical labour in the direct sun. This in effect undermines outdoor farming to a large extent. Recent studies in the region indicate that the commencement of wet season has gradually shifted from April to May; thereby prolonging the span of the dry season which has further exacerbated the issue of outdoor farming using hand dug bole holes to irrigate crops (Laux et al., 2008). This obviously means that many hours are now spent in hard outdoor work under intense heat exposure. Though there is vivid evidence of climate change in Bawku East over recent years (Frimpong et al. 2014), the problem has been magnified by population growth creating pressure on land resources since a large number of the population rely on subsistence agriculture (Wolfram et al., 2012). Most farmers in the region also live below the nationally approved poverty line (Webber, 1996; Whitehead, 2006). The vulnerability of the people is worsened by their frequent exposure to outdoor farming often without proper shade to protect them from the exposure to heat. Like other developing countries where farmers work not less than eight hours a day without due observance to the repercussion of health effects of heat exposure (Pradhan et al., 2013), farmers in Bawku East spend many hours in outdoor work under intense temperature without adequate breaks (Frimpong, et al 2014b).

Issues related to climate change adaptation and barriers to adaptation are prioritized in the research agendas of many developed countries (Burch, 2010, Jantarasami et al, 2010). However, little research has been accomplished into the impact of heat stress and associated barriers to adaptation for outdoor workers, such as farmers, in Africa (Costello, 2009), and none in Ghana. Therefore, this study was conducted to investigate the socioeconomic and cultural barriers that predispose smallholder farmers to heat exposure at the household level and on the field of cultivation. The study also evaluates the effectiveness of the adaptation strategies farmers adopt to cope with heat stress.

8.3 REVIEW OF LITERATURE

In the context of climate change, adaptation is classified as an adjustment of behaviour aimed at reducing the harsh impacts of climate change on a system, but it can also describe new opportunities in reaction to current or future changes in climate averages or variability (Adger et al., 2004). Barriers to adaptation are viewed as the obstacles that prevent a system or humankind from successfully adjusting to climate variability and change (Jones, 2010). These obstacles span from technological, economic, social (norms, values, rules etc) to cultural (Klein, 2003; Coulthard, 2008). Adaptation in the context of socioeconomic and cultural factors relates to mechanisms people adopt to reduce the impact of climate change on their livelihood, so that they can take advantage of new opportunities offered by the changing climate (TERI, 2007).

The fulcrum of the study hinges on the concept of exposure, sensitivity and adaptive capacity in the realms of humankind (Smith et al., 2000; Smith & Pilifosova, 2003). Even though the original concept of adaptation was applicable to ecology, increases in climate change impacts on humankind have made it useful to humans. The exposure in the context of this study is the level of heat stress that smallholder farmers face in the Bawku East region of Ghana by virtue of performing their day to day farming activities. The farming equipment used, such as cutlasses and hole diggers, demands extreme physical labour which intensifies farmers' exposure to heat stress. Unfortunately, these are the equipment predominantly used in farming in many parts of Ghana and Africa as a whole. Sensitivity of exposure to heat stress is the level of damage or injury that farmers sustain during their daily work activities. The nature of outdoor activities is very cardinal in determining and regulating farmers' exposure to heat stress. The magnitude of harm or injury that farmers can sustain in their exposure to heat is important to managing heat stress. The third most important aspect of exposure is adaptive capacity (Smith et al., 2000). Farmers' resilience to climate change impacts is reliant on their adaptive capacity (Ziervogel et al., 2008). The socioeconomic status and the technical equipment at the disposal of rural farmers directly determine their coping strategy to overcome the current and future impact of heat stress in the period of climate change. The examination of socioeconomic and cultural barriers impeding successful adaptation to heat stress is the basis of this study. Socioeconomic and cultural barriers are deemed neglected in the discourse of climate change adaptation (Jones, 2010). However, there is growing evidence that socioeconomic and cultural barriers of adaptation to climate change have received little attention in the research community

(Christensen et al., 2007). As a result and to the best of the authors' knowledge of the literature, there is no single study in Ghana that has documented barriers of adaptation to heat stress from farmers' point of view even though a large proportion of the population are engaged in outdoor farming (Aryeetey & McKay, 2004; Agyeman-Bonsu et al., 2008).

It is therefore imperative to assess the vulnerability of the people to heat exposure in the context of the barriers which can limit the uptake of adaptation strategies to cope with heat (Laux et al., 2008; Wolfram Laube et al., 2012). Such assessment ensures a holistic way of analysing the problem and causes of vulnerability (Hjerpe & Glaas, 2012). This in effect opens a broader space for a deeper solution to the problem involving a detailed exploration of societal and environmental interactions (Ziegler & Ott, 2011). In order to strengthen adaptation capacity towards sustainable development, Jones (2010) emphasised the importance of identifying key barriers of climate change adaptation and devising solutions that can enhance resilience of community adaptation. To achieve poverty reduction and to minimise climate change impacts (including heat stress) on humankind, Ulsrud et al (2008) argued that social inequity and environmental degradation need to be addressed by government and society in a proper manner, especially in developing countries. In the wake of global warming and the rise in atmospheric temperatures, it is appropriate and timely to investigate Bawku East since it is among the hottest areas in Ghana (EPA, 2007; McSweeney, 2012). Moreover, little research has been done on heat stress in the developing world (Kjellstrom, 2009). In the African region, there has been no research undertaken to investigate heat stress impacts on farmers as an aspect of climate change impact assessment (Costello et al., 2009), though Africa is perceived as the most vulnerable continent for climate change impacts due to its poverty and low adaptive capacity (Christensen et al., 2007). Since climate change and the occurrence of heat stress are both predicted to accelerate in coming decades, adequate knowledge about barriers to heat adaptation will inform policy makers and farmers on the need to put in place mechanisms and strategies that can address these issues and simultaneously improve food security in this part of Ghana and other part of the developing world.

8.4 METHODS

8.4.1 Study area and study location

Bawku East is located at the extreme north-eastern part of the Upper East region of Ghana (Fig. 1). The area covers about 2,067sq.km (Ministry of Food and Agriculture, 2014). Bawku East shares its boundary to the north with Burkina Faso, to the east with Togo, to the west with Bawku West and to the south with East Mamprusi district of Bawku. The study used focus group discussion and household level surveys to assess the extent of climatic, socioeconomic and cultural barriers of adaptation to heat stress and formed part of a major study into the impacts of heat in this region.

According to Patton (2002), the best way of identifying perceptions, feelings and intentions of people to encourage them to talk openly on what they feel about an issue. People's worldview and experiences are revealed during interactions when they willingly share their perceptions and thoughts (Liamputtong, 2009). From this perspective, the authors adopted focus groups discussion to elicit key socioeconomic and cultural adaptation barriers to heat as a component of climate change impact assessment and used survey questionnaires to inquire on how effectively respondents adapt to heat exposure. The study was conducted in March 2013 covering three rural farming communities of Binduri, Manga, and Pusiga in Bawku East. Firstly, some 308 farmers were surveyed on the effectiveness of their adaptation to heat (as well as other questions on climate change, heat vulnerability and heat impacts which will be addressed in subsequent papers). Three focus group discussions were then held to further explore barriers to adaptation (Tables 1 & 2). Fifteen farmers who had participated in the surveys willingly expressed interest to take part in the discussion and signed a consent form. These farmers cultivated cereals, legumes and vegetables and were divided into two groups based on their residential address (Table 2). The third group comprised members of various communities of residence such as chief farmers, village heads and agricultural officers (Table 2).

The main subject of investigation was barriers of adaptation to heat at the household level and during work in the field of cultivation. Since heat affects everybody a letter of request was attached to the earlier survey on heat vulnerability and those who voluntarily signed consent form for focus group discussion were invited. Sampling of the third group of chief farmers, village heads and agricultural office representatives was purposeful. This was done so that farmers who had lived longer in the communities and have had extensive experience on heat and climate change in the area could share their experiences on barriers of adaptation to heat. Ethical

approval was obtained from Edith Cowan University, Perth Western Australia and the Ministry of Food and Agriculture of Ghana.

A moderator was appointed and facilitated in each of the focus group discussion while research assistants helped in note taking. Tape recorders were used and transcribed. Predominantly, open-ended questions about barriers of adaptation to heat at household level and on the field of cultivation of crops were administered. Participants were motivated to explore issues about climate change and heat stress that was of paramount concern to them. The discussion spanned for two hours and was held in a convenient location to the participants.

8.5 DATA COLLECTION AND DATA ANALYSIS

Data collection and analysis commenced soon after the discussion. NVIVO 8 project (a qualitative data analysis package) was used to analyse responses from the focus group discussion. During the focus group discussion responses were typed exactly the way they were spoken, later translated into English by research assistants and imported to NVIVO 8 project. From the responses, themes and sub-themes were generated. Units of text were given unique nodes manually (Corbin & Strauss, 1990). Codes were obtained from NVIVO 8 analysis of participants' responses and codes were generated from similar studies on the basis of literature reviewed.

First, two different coding (descriptive coding and topic coding) were accomplished. The purpose was to identify key topics associated with the study emanating from the focus groups discussions. These included climate change and the climate profile of the area of study. Key problems that confront participants in their adaptation to heat, how participants adapt to heat and climate change, impact of heat on their day-to-day activities mostly at the farm level and home, and barriers associated with adaptation of heat at household and at farm level. What emanated from the discussion led to topic coding, where the text to be analysed were grouped into key topics associated with the study objectives (Richardson, 2005), which enabled the researcher to put all data (text) into similar category or topic in the same code or node (location). After topic coding was accomplished, the analytical coding was done. A thorough inspection of the coding was undertaken to locate differences and similarities and ensuring whether the coding assigned to each text was appropriate. Thematic analysis (Banister et al.,1994) was done by grouping similarly coded data or text into themes in line with the research objectives. Both audio recorded

information and the text from the focus group discussion formed the themes. These themes are found in the study results as text.

8.6 RESULTS

8.6.1 Results on farmers' effectiveness to adaptation of heat

The table below presents farmers perception and experiences of the effectiveness of their adaptation to heat stress with regard to their household level.

Table: 8.3: Age group and responses from level of effectiveness of methods to reduce heat exposure at home and farm level

Degree of effectiveness of adaptation to heat at household and farm level	Age group												Total	
	less than 20		20-29		30-39		40-49		50-59		60+			
	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age	Count	% within age
Effectiveness of methods to reduce heat exposure														
Slightly effective	10	71.4	40	78.4	26	43.3	36	65.5	64	70.3	22	59.5	198	64.3
very effective	3	21.4	5	9.8	17	28.3	7	12.7	1	1.1	5	13.5	38	12.3
Extremely effective	0	0	1	2.0	1	1.7	1	1.8	0	0	1	2.7	4	1.3
Not effective	1	7.1	5	9.8	16	26.7	11	20.0	26	28.6	9	24.3	68	22.1
Total	14	100.0	51	100.0	60	100.0	55	100.0	91	100.0	37	100.0	308	100.0

The following themes arose from focus group discussions on farmers' barriers to adaption to heat exposure and subsequent analyses:

8.6.2 Inadequate water supply at household level and on the field of cultivation.

Many of the participants indicated that owing to long dry spells there was inadequate supply of water at both household level and in the field of cultivation. This is rooted from the fact that many of the water bodies had dried up. Some pertinent quotes included: 'All the water bodies are dried up so there is scarcity of water to use to cool down in most parts of the year. There is insufficient supply of portable water to drink and to cool down.' Participant G (vegetable farmer) 'There are not many stand pipes to produce water by the government for drinking so that the body can be cooled down.' V (cereal farmer) 'Many trees shed their leaves thereby making it difficult to get shade when working in the farm due to prolonged dry season. No human made protective equipment to provide shade from the sun except resting under a tree or erected shade with woods and grass roofed.' K (Vegetable farmer)

8.6.3 High level of workload at the farm level

Many of the farmers indicated that they worked manually with rudimentary equipment like cutlasses and hole diggers. As results they did not accomplish much of their day to day tasks. Unlike developed countries, where there are machines for farm labour to increase productivity, productivity is undermined as result of usage of manual labour in full sunshine. 'There is all the time unfinished work at farm so I go to farm even though it is hot.' A (Corn farmer.) 'It is difficult to get grass to roof my house because they have been dried up.' M (Legume farmer). Most of the farmers have no proper shade to prevent them from the exposure of full sunshine. 'There are less number of trees in the farm level because of desertification.' (Z Legume Famer). 'I use manual labour in farming so I easily get hot even in the early hours of the day. I work 8 hours a day. I have large family size and I am compelled to work harder even though I am feeling hot.' (D Vegetable Famer).

8.6.4 Lack of infrastructure and suitable accommodation for farmers

Many of the houses were locally made with poor ventilation even though temperature is predicted to increase in this area of Ghana. As results of intensive drought many of the farmers

did not obtain grass to roof their houses. They relied on grass which was withered by the prolonged drought. ‘It is difficult to get grass to roof my house because they have been dried up.’ D (Cereal farmer) ‘Insects feed on the grass that I have used to roof my house and it is difficult to get replacement because of prolonged dry season’ B (Corn farmer) those who had iron sheets for roofing were unsatisfied with the heat accumulation in their room at night. ‘Iron sheet become hot thereby accumulating a lot of heat in the room during the night.’ A (vegetable farmer). ‘Mosquitoes bite me when I sleep in my compound. So I am forced to sleep in my room even though it is hot during the day and early part of the evening. No fan to cool me down’ E (Onion farmer). ‘I ride my bicycle from home to my farm and vice versa in the extreme sun shine. It makes me hot and get tired very often.’ H (Cabbage farmer). Many of the farmers complained that their locally made houses were not resilient to heat but they did not have access to government houses ‘No government provide housing for farmers. Only government workers.’ F (Pepper farmer).

8.7 EVIDENCE OF BARRIERS OF ADAPTAION

Large family size is seen as prestigious in many of the households in the study area. Even though they were poor many of the farmers had large family sizes, as well as early and sometimes multiple marriages which compelled them to work harder. In spite of the environmental challenges, they worked harder in full sunshine which made them to be exposed to high heat.

‘I like to have more children so that I can be respected in the family and the community’ S (Maize farmer). ‘The children can help me in my farm activities so I need three wives’ K(Vegetable farmer). Some of the women reported that cultural barriers prevent them from migrating to southern Ghana since their society frown on women who migrate to seek for greener pasture in southern Ghana. The level of heat exposure and other work opportunities outstripped that of northern Ghana. The implementation of adaptive strategy is contingent on cultural factors (Adger et al., 2012).

Table 8.1: Personal characteristics focus of group participants (Farmers) on barriers of adaptation to heat at farm and household level.

Number of Persons	**Gender**	**Age**	**Focus group number**	**Village**	**Type of crop grown**
1	Female	30	1	Pusiga	Onion
2	Male	64	1	Manga	Onion
3	Male	62	1	Manga	Legume
4	Male	40	2	Manga	groundnut
5	Female	38	2	Manga	Maize
6	Female	51	2	Binduri	Millet
7	Male	60	2	Pusiga	Millet
8	Male	42	1	Pusiga	Pepper
9	Male	48	1	Pusiga	Carrot
10	Female	32	1	Binduri	Cabbage
11	Male	40	1	Manga	Soya beans
12	Male	70	2	Pusiga	Sorgum
13	Male	61	2	Binduri	Millet
14	Female	43	2	Binduri	Onion
15	Male	61	2	Binduri	Tomatoes

Table 8.2: Demographic features of people in the third segment of focus group discussion

Participants	**Gender**	**Age**	**Status**	**Village**	**Type of crops grown**	**Focus group number**
16	Male	30	Agriculture officer		Extension officer	3
17	Male	64	Village head	Pusiga	Cereals and Legume	3
18	Male	61	Chief farmer	Manga	Cereal and vegetables	3
19	Male	58	Chief farmer	Binduri	Legume, cereal, vegetables	3

8.8 DISCUSSION

The study investigated the socioeconomic and cultural barriers that limit farmers in their adaptation to heat stress in the emergence of climate change. It found that inadequate supply of water for domestic and farming purposes, high level of unfinished work load as a result of using rudimentary equipment, inappropriate accommodation and infrastructure, and the cultural prestige of having large families (which demands more mouth to be fed) were some of the socioeconomic and cultural barriers to heat adaptation in the context of climate change in Bawku East of Ghana. Many studies have identified similar cogent barriers to adaptive capacity in many communities (the capacity of a system to successfully overcome the threat of climate variability and change). As also found in this study, social norms, culture and tradition strongly determine peoples' resilience to climate variability and change (Coulthard, 2008; Ford, Smit, & Wandel, 2006; Klein, 2003; Naess, Bang, Eriksen, & Vevatne, 2005) even though the need for economic and technological development in determining adaptive capacity is unequivocal (IPCC, 2001).

Socioeconomic and cultural barriers to adaptation have received little attention (Adger et al., 2009). Achieving a deeper understanding of the problems confronting a given community and devising appropriate solutions to reduce the impacts on them, demands involving the people to discuss their problems and voice their opinions. Lack of local people involvement by government policy makers is often responsible for inappropriate policies that adversely impact at the local level and as such do not meet the desired needs of the people (Van Aalst et al., 2008).

In this light, a similar study successfully used questionnaires to elicit farmers perceptions and willingness to pay for adaptation to climate change (Acquah, 2011), while questionnaires and focus groups discussions were used to elicit farmers' perception of climate change and adaptation in Ejura, in southern Ghana (Fosu-Mensah et al., 2012). Similarly, a focus group discussion of young, middle age and old age farmers was used to elicit rural farmer's barriers to adaptation on climate change in Northern Burkina Faso (Nielsen & Reenberg, 2010). The precarious nature of poverty in the study area, where almost all the inhabitants depend on natural resources for their livelihood (Webber, 1996; Laux et al., 2008; Laube et al., 2011), combined with the predicted increase in temperatures (EPA, 2007), makes it imperative for an assessment of the impeding factors confronting residents in their adaptation to heat exposure very timely and appropriate. The majority of farmers reported their adaptation strategies to heat was only 'slightly effective' (Table 3) and this warranted the focus group discussions to obtain a deeper

understanding of the problems impeding the farmers to achieve more effective and sustainable adaptation to heat exposure. Over 65% (Table 3) of the farmers in the age range of 40-49 reported ‘slightly effective’ mechanisms to combat heat at household and farm level. This age group formed the able men and women in their most productive age of farming. Many of the participants of the focus group stated that they have large family size. In this context their up keep demands a farmer to work harder irrespective of the atmospheric conditions. In the wake of climate change, acquiring food to feed large family through farm proceeds is likely to be even more challenging. Large families normally accounts for the existence of poverty in the area.

There is also minimal rainfall for much of the year (Ministry of Food and Agriculture, 2014) and so most of the farm activities are done with irrigation from hand-dug wells. Many hours are spent in outdoor farming in hot sunshine without shade. Poverty has accounted for long hours in working outside in hot temperature without shade. The key point is the nature of smallholder farm work with sole dependant on physical labour exposes farmers to much more heat exposure. To work to feed large family size demands a farmer to dispense even greater energy to their farm activities. This has exposed many residents with large family size to climatic hazards such as heat stress. Despite heat exposure being predicted to increase (Kjellstrom, 2009), there is no provision in the climate change adaptation policy documents of the Government of Ghana to include heat stress as an occupational issue in assessing climate change impacts in Ghana (UNDP/UNEP Programme, 2012). In the same vein, heat stress as an occupational issue in smallholder farming in African region has not been considered by policy makers and governments (Costello et al., 2009). In the sphere of sustainable adaptation, governments could play an important role in providing aid to farmers to improve their adaptive capacity. The agricultural sector contributes 30% of Ghana’s GDP and offers over 60% of employment and livelihood support to Ghanaians (National Development Planning Commission, 2010). As climate change continues, increased heat stress will be a major problem in the tropical developing countries and in areas such as northern Ghana. This area has only one period of rain per year and because of climate change this period appears to be shortening (now mostly from May to October), and it is a considerable challenge for residents to get water for most part of the year (Laux et al., 2008).

The study provides an insightful exploration of the level of effectiveness of adaptation and key barriers impeding farmers’ efforts to adapt to heat exposure. This study, as far as the

researchers are aware, is most thorough in terms of finding socioeconomic and cultural barriers of adaptation to heat in the context of climate change in northern Ghana. Household and farm level barriers of heat exposure are key issues that need to be addressed in sustainable adaptation planning since many of these obstacles are poverty driven. For example, insects feeding on grass used for roofing of houses could be solved by using other durable materials for roofing if government collaborate with communities in planning for housing and other social amenities. Mechanisms to reduce poverty and vulnerability from climate change impact are central to sustainable adaptation (O'Brien & Lichenko, 2007). Difficulty in achieving sustainable adaptation comes from the fact that governments do not collaborate with communities in adaptation planning (Sarpong & Anyidoho, 2012). The adaptation strategies become maladaptation where the methods of adaptation yield short-term results without adequately considering long term sustainability.

8.9 CONCLUSION

Weaknesses in climate adaptation planning occur as a result of inappropriate consideration of climatic stresses and the capacity of people to adapt. Integration of adaptation policy into other national sectors is important for climatic stresses to be viewed holistically than being solved in isolation (Biesbroek et al., 2010; Huq & Reid, 2004). The relationship between socioeconomic and climatic stresses has been given less research attention (Hjerpe & Glaas, 2012). Government urgently need to revitalize pathways of development. This can improve and reduce poverty in rural farming communities to enable farmers to cope with the impacts of climate change.

Rural housing that can use energy from the sun to provide electricity for cooling homes and generating power for farm work is necessary. The Ghana government climate policy needs to establish a long-term project that can lead to the realization of this objective. Moreover, national development needs to be concentrated in the rural population where over 65% produce food to support the nation. This will help solve the problem of rural urban migration due to unfavourable conditions at the rural level.

Heat stress management should be a high priority for the government of Ghana since almost all farmers in Ghana work outdoors under the exposure of heat and full sunshine. A national policy with explicit mention of heat exposure in the emergence of climate change is

needed for sustainability of outdoor occupations and farming specifically. The national climate change and adaptation policy document of Ghana has no provision to manage heat stress. Community consultation on barriers of adaptation to heat and climate change would help in planning since it can include the concerns of rural smallholder farmers in adaptation policies and thereby improve their practical implementation and acceptability by the very people that the policies are designed to help. The government should prioritise adaptation programs that reflect the needs of the poor in rural communities that are experiencing impacts of climate change.

Capacity building on poverty reduction is also imperative since poverty was identified as the primary cause of vulnerability to heat exposure in the communities where the study took place. Poor housing and roofing could be improved and free education and trade apprenticeship could be given to farmers' children to build their capacity to become productive.

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CHAPTER 9

SYNTHESIS, MAJOR FINDINGS, CONCLUSIONS AND RECOMMENDATION

This chapter integrates the various parts of the study to present a holistic account of heat stress and climate change as a key occupational and health issue in the context of sustainable development of farming and agriculture in Ghana and Africa as a whole. It draws inferences from the findings of each chapter to present heat stress as a problem that has been overlooked in the context of climate. It presents the findings, limitation and recommendations of the study. The entire contribution of this study to our understanding of future climate change impacts and heat exposure is then presented.

9.1 SYNTHESIS

The outcome of the study showed a general rise in temperature from the data of the three weather stations (Binduri, Manga and Garu) over the last fifty years and a sustained heat stress largely in the peak summer, with relatively high heat exposure throughout the year of 2013. Framers confirmed from household surveys that they were exposed to heat stress at household level and on the field of cultivation while their adaptive capacity is weak. Key barriers of adaptation to heat stress were identified as mainly socioeconomic and cultural factors.

These outcomes are cardinal for sustainable agriculture. The high range of heat stress in WBGT quantified from Lascar EL USB Temperature and Humidity sensors, which largely had marginal inclusion of radiant heat from the sun, especially during hours of work from 11 am to 4 pm, is a major health and occupational issue. It is not likely that Ghana and, for that matter, many other African countries, will make major shifts towards mechanized farming (which dramatically reduces the use of human labour and increases agricultural productivity) based on past trends of development and their current socioeconomic status. Even though there are mitigation efforts to reduce the emissions of greenhouse gases and, thereby, future impacts of global warming on vulnerable communities such as Ghana and Africa as a whole, the positive effects of the current mitigation measures will take longer than expected for its desired impact to be felt on the vulnerable population of the world. This means that farmers in

Africa who work outdoors in hot and humid environment in the context of climate change, and who possess low technological development and little capital-intensive farming equipment, will suffer from the reduction in labour capacity to raise output from day to day farming activities. This is clear based on previous estimates of studies on how heat stress can reduce labour output to the level of 90% in the apex summer months in the tropics (Dunne et al., 2013)

The study presented that coping strategies currently in place are inadequate to enhance farmers' resilience to combat climate change and heat stress both in the field of cultivation and at household level. These include poor ventilated of farmers' dwellings, poor roofing materials, and inadequate shade on the farm level working with airy cloth and eating traditional diet to induce intake of water at farm level. As the Environmental Protection Agency of Ghana has predicted, a 2.5-30°C rise in temperature within this century in northeast Ghana indicates that high WBGT at working hours especially in the summer periods can endanger farmers' health, reduce labour productivity and increase the problem of food insecurity known in this part of Ghana. An elevation of 2.5-3^0C temperature is likely to present additional figure at working hours. The implication for farmers work capacity and productivity is that all things being equal, with no mechanized farming and solely depending on physical labour, work capacity and productivity will decline (Kjellstrom, 2009). The precarious nature of poverty in the area will be increased. This will affect food insecurity problems known in this part of Ghana. The increase in humidity with high temperature can undermine sweat rate and can lead to heat related problems. This situation is likely to be replicated in many parts of Ghana and Africa as a whole where outdoor farming with primitive equipment and labour intensive is the norm for undertaking farming activities.

Labour regulations with regard to how many hours a worker can work in instances of extreme heat exposure are not in place in Ghana and many African countries. For farmers to achieve sustainable health and improve labour productivity at the farm level there is the urgent need for such protective laws to be crafted for farmers and other outdoor workers. The impact of heat stress is related to human body core temperature (37^oC) which when exceeded by 1-3^0C there is the likelihood that severe heat stroke or even death may occur. Hard physical jobs induce excess heat inside the body which makes working people in hot and humid environment particularly prone to heat exposure. Sweating is the only way of cooling the body temperature. This is undermined by high air humidity. Self-pacing by working slowly is the main way of keeping the body temperatures within safe limits. But this also affects productivity. The global cost of heat stress due to climate change is likely to be

substantial, especially in tropical countries. The current poverty situation in tropical developing countries is likely to worsen if global effort is not put in place to achieve effective adaptation to climate change and work place heat stress specifically.

9.2 MAJOR FINDINGS OF THE STUDY

The study has found that there is a trend of increasing temperature since 1961 up to 2013 when the study was conducted. Moreover, Lascar EL USB equipment is desirable and recommended to capture local temperature and relative humidity to present the state of heat exposure in any given community or environment. The level of heat exposure upon which farmers are confronted in the study vicinity was 29-37^{o}C WBGT during the day outdoors in the shade, and 28-35 ^{o}C indoors or in a home environment (Chapter 5).

A large number of Ghanaian smallholder farmers are experiencing heat stress and climate change across all ages with older smallholder farmers having significantly greater experience of heat stress and climate change. Farmers who have lived longer in a community have adequate knowledge about the climate and heat stress experiences (chapter 6).

Moreover, smallholder farmers have been impacted by heat exposure which affected their productivity and, in some instances, more than half of what they use to harvest (Frimpong et al., 2014; chapter seven). Farmers' adaptation strategies are devoid of sustainable returns in the long run. Thus, their adaptation offset them from the effects of heat stress and climate change is not sustainable. The study found that since their adaptation is weak, they could not be termed as adaptation tactics, but rather coping strategies (Pelling, 2010). The study invariably identifies inadequacies in climate and social protection policies of Ghana and many African countries to combat heat stress and climate change.

9.3 CONCLUSIONS & RECOMMENDATIONS FROM THE STUDY

With inferences from the present study, the following conclusions and recommendation for policy and management actions are made:

Firstly, it is imperative for routine assessment of heat exposure in many localities within Ghana to be conducted in order to reveal local conditions of heat patterns since national and global averages may mask the possibility of identifying the real extent of heat at the local scale within a particular country.

Moreover, quantification of heat exposure in many commonly-used outdoor environments such as construction sites, mine sites and market places, as well as farmers in other areas of the country, are important to manifest the extent of climate change impact on

working people and how measures can be put in place to improve social, economic and health impacts as temperatures are predicted to increase now and beyond this century.

Demographic characteristics such as education, age and duration of residence of a person in a given community can be routinely used to assess impacts of heat stress and climate change on farmers and other working people since such variables can indicate how a person has experienced and coped with climate change and heat stress in a given community.

As global climate change is projected to increase, there is the need for local health posts and hospitals to track heat-related illnesses in all regions in developing countries, especially in Northeast Ghana where temperatures are already high. Intensification of education on the threat posed by heat is necessary in farming communities where many hours are spent performing outdoor activities. Knowledge on the type of clothing to reduce heat stress is important. This will make farmers to understand the effects of clothing on heat stress and heat related illnesses.

Also, government need to provide and improve irrigation system to attenuate the issue of drawing water from hand dug bole hole which is known to be laborious in this part of Ghana. This is due to the fact that such activity is done in hot conditions which in effect affect health of farm workers.

Socio-cultural, infrastructural and institutional barriers need to be improved in many farming communities in Northeast Ghana. These include reducing the number of children per family so as to diminish food consumption per family associated with bigger family size. This can also assist farmers to give the necessary skill education that make farmers kids to be employable in skilled labour.

National policies on climate change and heat stress as well as social protection policies need to be revitalized to suit the needs of Ghanaian society. Advocacy on climate change and heat stress need to be instituted in relevant ministries such as Ministry of Food Agriculture (MOFA), Ministry of Health, Ghana, Ministry of Local Government and Rural Development, and these agencies need to collaborate to create the awareness of heat stress and its repercussion on long hours of work in hot conditions. Guidelines on heat management need to be developed for agriculture extension officers to be disseminated to local farmers so that it can enhance their adaptive capacity.

Building design capable of increasing ventilation need to be enforced by local authorities. This will reduce the proliferation of non-ventilated accommodation rife in the vicinity and in many other parts of Ghana.

There is the need for a Government office to be established to deal directly with climate change in Ghana. A full ministry of climate change will be appropriate to facilitate policy formulation and enforcement in all sectors. Ghana has a large population who work outdoors and such their care and wellbeing should be the priority of such an important ministry.

9.4 CONTRIBUTION TO KNOWLEDGE

Quantification and evaluation of farmers self-reported level of heat stress has exposed to government and the research community the precariousness of heat stress as health and occupational risks in the context of climate change and sustainable farming in Ghana and Africa as a whole. In the domain of climate change research in Ghana and many African countries, which usually pertain to drought, flood and rainfall assessments, heat stress evaluation as an occupational and health issue for outdoor farmers is a distinct and new research trajectory. The use of Lascar El USB Temperature and Humidity sensors to quantify heat stress, which have only been readily available in recent times, can now be routinely used to gauge the level of heat stress that construction workers, women selling at the market places and other outdoor workers are exposed. The study has drawn the attention that heat stress research predominantly confined in indoor research in Ghana and many African countries need to progress to outdoor occupational assessments with the emergence of climate change and need for sustainable development.

9.5 LIMITATIONS OF THE STUDY AND FUTURE RESEARCH DIRECTIONS

The following are areas recommended for future research which stem from my studies:

1. Local assessment of heat stress and trends of temperature is needed in many localities in Ghana as well as African countries. This is critical since national average of temperatures and heat stress can mask the possibility of identifying the level of heat stress that local communities are exposed.
2. Quantification of heat exposure in many outdoor environments such as construction workers and other agriculture activities in many parts of Ghana and Africa as a whole is imperative.
3. Databases for heat-related illness need to be maintained in all hospitals and health post throughout Ghana. This will help to track heat illness over time with the emergence of climate change.
4. Extensive research need to be conducted on socioeconomic and cultural barriers of adaptation. Adaptation is the only way that society can use to reduce heat stress and other climate change impacts.

9.6 LIMITATION OF THE STUDY

As heat stress has become a global issue, a broader research covering perhaps the northern, middle belt and the coastal savannah of Ghana would be helpful. Research on other outdoor occupations exposed to heat stress is timely and appropriate since heat weave death is increasing in other tropical developing countries.

9.7 REFERENCES

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APPENDICE 1: ETHICS APPROVAL

Dear Kwasi

Project Number: 8483 FRIMPONG

Project Name: Impact of climate change on African communities: An appraisal of experiences of climate change and adapative responses to heat by farmers in rural Ghana

Student Number: 10244925

The ECU Human Research Ethics Committee (HREC) has reviewed your application and has granted ethics approval for your research project. In granting approval, the HREC has determined that the research project meets the requirements of the National Statement on Ethical Conduct in Human Research.

The approval period is from 13 September 2012 to 18 October 2014.

The Research Assessments Team has been informed and they will issue formal notification of approval. Please note that the submission and approval of your research proposal is a separate process to obtaining ethics approval and that no recruitment of participants and/or data collection can commence until formal notification of both ethics approval and approval of your research proposal has been received.

All research projects are approved subject to general conditions of approval. Please see the attached document for details of these conditions, which include monitoring requirements, changes to the project and extension of ethics approval.

Please feel free to contact me if you require any further information.

Regards

Kim

Kim Gifkins, Research Ethics Officer, Office of Research & Innovation, Edith Cowan University, 270 Joondalup Drive, Joondalup, WA 6027 research.ethics@ecu.edu.au Tel: +61 08 6304 2170 | Mobile: 0428 035 397 | Fax: +61 08 6304 5044 | CRICOS IPC 00279B

In case of reply the
number and date of this
letter should be quoted

M.A. Form 7

Telephone: 233-21-666567 / 663036

My Ref. No: KC-5/287/02

Your Ref. No: ....

Republic of Ghana

MINISTRY OF FOOD & AGRICULTURE
P. O. Box M.37
Accra

11TH MAY, 2012

CENTRE FOR ECOSYSTEM MANAGEMENT
EDITHCOWAN UNIVERSITY
JOONDALUP – DRIVE 2067
WESTERN AUSTRALIA

Email: k.frimpong@ecu.edu.au

RE: REQUEST FOR A ETHICAL CLEARANCE TO CONDUCT A STUDY ON FARMERS ADAPTATION TO HEAT IN BAWKU MUNICIPALITY IN GHANA

We are glad to note that you are interested in conducting a study into how Farmers adapt to heat in Ghana especially within the Bawku Municipality.

This is dear to the heart of this Ministry and we are happy, without any reservation, to freely accept you for the Study. By this we are offering your request for Ethical Clearance for you to conduct the Study.

By copy of this letter we are informing the Director of Crops, Ghana, the Regional Director of Agriculture Upper East Region and the Municipal Director, Bawku to each expect you, Mr. Kwasi Frempong shortly.

FOR: HON. MINISTER
MAURICE TANCO ABISA-SEIDU
(CHIEF DIRECTOR)

CC: HON. MINISTER, MOFA

DIRECTOR, CROP SERVICES

REGIONAL DIRECTOR OF AGRIC
UPPER EAST

MUNICIPAL DISTRICT DIRECTOR
OF AGRIC, BAWKU

APPENDICE 2: QUESTIONNAIRE

SURVEY QUESTIONNAIRES TO ELICIT EXPERIENCES OF CLIMATE CHANGE, HEAT EXPOSURE AND ADAPTIVE RESPONSES IN BAWKU EAST AREA OF GHANA-2012-2013

Part A: Demographic Information

This questionnaire is solely for academic purposes. Your confidentially is strictly protected. In the event of feeling insecure in answering any of the questions you may withdraw

To answer the following questions, please mark an X in the box that best matches your response or write in the space provided below.

1 Age:... 2 Ethnicity...

3. Marital Status............................ 4. Number of Children......................................

5. Religion.......................................

6. Gender: Male.... Female..... Tick appropriate one

7. Educational level: 1 ☐Primary School 2 ☐ Secondary 3☐ Tertiary 4☐Non formal

8.How long have you live in this town 1. ☐ Less than 1 year

2. ☐ 1-5 years

3. ☐ 6-10 years

4.☐ 11-20 years

5. ☐ more than 20 years

9. What is your main occupation? a. Farming b. trading c. mining d. others..........

9b If farming is your occupation what particular crop do you produce?

a. Cereals b. Legume c vegetables d others................

9c If your answer is cereal, Legume or vegetable may I know how long you have engaged in that particular farming? A.1-3yrears b.3-5years c.5-7 years. D.7-10 years 10-20 f 20-30 g more than 30 years

Part B: Experiences on Heat Vulnerability and Climate change This component elicit peoples experiences of heat and its impact on their productivity and the trend of increase in heat and climate change

To answer the following questions, please mark and X in the box that best matches your response, or write a response in the space provided

10. Do you know about climate change?

(Open-ended) if question 10 was answered “Yes” progress to question 10a, otherwise move on to question 11

10a. when did you know about it?.............

10b. How did it come to your knowledge that the climate is changing?

10c Has the government given some recommendation to help you deal with climate change in your day to day activities?.............................

11 What is your heath status?

a) good b) very good c excellent d) poor

12. Do you feel any concern about heat to your health? a Yes b No

Have you been diagnosed about heat illness before? A yes b no

13. Have you ever taken sick leave due to heat? a yes b No

13 a. If Yes, approximately how many hours in a week? -------------- Month------------

13 b Have you ever been advised to take off due to heat related illness?

13 c Have ever been admitted in hospital due to heat related sickness? Yes/ No

14. On a scale of 1to 4, where ‘1’ means affect productivity and income by more than half of what I used to get, and 4 means has not affected productivity at all, how has heat affected your income and productivity?

1= affect productivity and income by more than half of what I used to get

2= affect productivity and income by half or less

3= affect productivity insignificantly

4= has not affected productivity at all

15. Which of the following statements best describes the impact of heat on your work

I am able to work all day without any interference from heat

I have some heat interference and difficult to work all day

I have many problems from heat and unable to work

16 Do you know that the type of clothing you wear affect your heat exposure?

☐ 1 Yes ☐2

16 b If yes what type of clothing do you normally wear during farming hours?

1 breathable cotton 2 Thick cotton overall 3 rayon/ Nylon

16 c Do you feel comfortable in your dress during work time?

a Comfortable b moderately comfortable c uncomfortable e others............

17 Does clothing reduce your work output?

a sure b may be c Not sure d No, not all

17 a If clothing impedes your work output, based on your on perception can you tell how much

a. about 10% b. 10-25% c.50% d not sure

18 Have you noticed any tendency towards higher heat exposure and climate change during recent years compared to 20-30 years ago (assuming you were around then)?..a) Yes b) No

19 Is heat exposure outside work (at home or commuting to work) affects your performance at work? ....

20 How does heat affect daily activities at homes? ....

21 How does heat affect sleep?

22 Are the homes built and equipped to reduce heat stress? ....

23.How is health affected by heat in the home ? Any specific vulnerable group? Children, women, and elderly?

24 How do you classify the task you do in your farm?

a light b moderate c heavy d very heavy

25Do you consider that your health is affected by heat in the past ten years?

a Yes b No

26. Have you noticed any changes in weather and climate since you became a farmer?

a. YES b NO

26a If your answer is yes, what type of change have you noticed in the climate and the weather

A delayed rainfall b extensive heat c extensive drought d extensive flooding. e all of the above f others ....

26 b What symptoms do you face during hamattan (Dry Season) ?

a Excessive sweating b Exhaustion C thirst e wanting to go to comfort zones

27 Have you ever been affected by any of the following 1 prickly heat 2 heat cramp 3 heat exhaustion 4 Malaria 5 Cerebrospinal meningitis

PART C: This part of the questionnaire evaluates local heat adaptation strategies by various farmers

28.How do you limit heat exposure when needed?

a. get away for a while b.remove clothing c drink water d any other method , do specify........

29 If you are feeling unwell from heat exhaustion how do you cope with this ?

1. Take rest. 2 cool shower bath 3 move to an air condition or cooler environment

30.Do you drink water at work? Yes /No

31. Is sufficient water available at all times when you need it? Yes? No

32.How much do you drink in a day in hot conditions.......................... litrs

33.Do you take any traditional special diet to cope with heat.....................................

34.What traditional or other methods do you adopt for coping with heat ? ....

35 Do you spend more money in hamattan to cope with heat

If yes then specify...........................

36 Do you spend more time to cope with heat / if yes how much time .... change to productivity time or personal time...

37 Does time spent on coping heat affect your social life? Yes? No

38 How does it affect your social life?

a. Moderately, b highly c Extremely, d No impact

39 How is your building made to cope with heat?

....

40.Do you own a fan? Yes /No

From the following list describe the type of fan you have in your home

Window fan

Room fan

Small personal fan

Other......

41 During high heat days what do you do at home or at work in farming place?

42 what type of adaptation strategy do you employ for your crops

Which type of crop is that? ....

How different is it from other crops?

Part D: This part evaluates barriers associated with current adaptation strategies to confront heat both at home and farm level

43.What barriers confront you in your adaptation to heat and climate change

a) Social Barriers

b) Economic Barriers

c) Cultural Barriers

d) Others....

44.Do you get information from government about heat and temperature increase?

45. Is your room very hot during hot season ? yes / No

45a If your room is hot do you prevent it during the day--------------------------------

45b How do you prevent it during the night? ....

46 How do you prevent heat on your crops ? ....

47. How do you prevent heat on your health at farm level.....................................

48.How do you prevent heat in your capacity to produce..

49 How effective is the method use to reduce heat exposure at work place ?

50 How effective is the method used to reduce heat exposure at home? ....

APPENDICE 3: CONSENT OF PARTICIPANTS

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Fax +61 8 6304 5509
Email k.frimpong@ecu.edu.au

INFORMED CONSENT OF PARICIPANTS

Edith Cowan University- School of Natural Sciences

Impact of Climate Change on African communities- An appraisal of experiences of climate change and adaptive responses to heat by farmers in northern Ghana

Investigators:

Mr Kwasi Frimpong- Lead Investigator

A/Prof. Jacques Oothuizen, Dr Eddie Van Etten

Consent form for the study- Questionnaires.

Thank you for your willingness to participate in this study

Before signing this form, please feel free to ask any question regarding this study that is not clear to you.

STATEMENT OF CONSENT

Having read the background information provided to me, and my rights and obligations well explained to my appreciation, I hereby give my consent by signing this form on the following notes:

I consent and appreciate the aims and methods of this study.

I have read the background information and comprehend with the content and questions regarding the study have been answered to my satisfaction. I have been given a copy of background information sheet and consent form.

I consent that my participation in this study is voluntary which allows me to withdraw at any time.

I consent with anonymity of research data from this study and publish results will not manifest my identity.

I acknowledge that personal information will be managed with strict confidentiality.

Participant full name ....

Signature ....

Date ....

Signature of Researcher ....

Date ....

APPENDICE 4: COPYRIGHT PERMISSION

Frimpong Kwasi

Accepted manuscript (ID 14-CDEV561-RA) and Part of thesis.

Accepted manuscript (ID 14-CDEV561-RA) and Part of thesis.

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3/23/15

To: Frimpong Kwasi Cc: cgordon@ug.edu.au

Dear Kwasi,

Our publisher has confirmed you can use the paper in your PHd, provided it is not for commercial use and you have acknowledgement of the Journal.

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Dear Kwasi,

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To: cdev@sei-international.org Cc: cgordon@ug.edu.au

Dear editorial board,

My manuscript is accepted for publication. However, this manuscript (ID 14-CDEV561-RA) will be a chapter in my thesis.

I am taking this opportunity to request authorization to use it as a chapter in my impending thesis.
Thank you for your time and I hope to hear from you soon.
Regards,
Kwasi Frimpong

To Whom It May Concern

I KWASI FRIMPONG contributed more than 80 % in the conceptual development, data collection, and writing of the entire papers that appear in the present thesis as chapters:

1. Frimpong, K., Oosthuizen, J., & Van Etten, E.J (2015). A review of climate change adaptation and social protection policies in Ghana: An evaluation of the extent of the policies in reducing impacts of climate change and heat stress on smallholder farmers in Ghana. Climate and Development, (Published by Taylor and Francis Publishing Group), under review

2. Frimpong, K., Oosthuizen, J., & Van Etten, E.J (2015). Impacts and Adaptation of Heat Exposure by Rural Farmers in Northeast Ghana. Climate and Development, (Published by Taylor and Francis Publishing Group). Accepted and in press.

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