WIDER Working Paper 2014/027

Climate variability and household welfare in northern Ghana

Paul Kwame Nkegbe and Naasegnibe Kuunibe*

January 2014

Abstract: Climate variability poses a major risk to agricultural incomes in Africa. In Ghana, most of the country's poor people live in the north and households find it difficult to hold back their productive assets during the lean season. This study investigates the impact of climate variability on household welfare in the area using a three-period panel data from the Ghana Living Standards Survey, in addition to data on annual rainfall and temperature for northern Ghana for the period 1991 to 2007. Using trend equations and the Ricardian approach to analyze the data, the results show rainfall exhibits a decreasing trend in all regions in the north of Ghana while temperature oscillates, with higher amounts of rainfall and moderate temperatures found to be significant drivers of improved welfare. The study thus concludes that climate variability negatively impacts household welfare, agricultural income, and farm revenue, and recommends inter alia households' diversification of economic activities into areas not directly affected by the vagaries of the climate.

Keywords: climate variability, panel data, welfare, individual heterogeneity, Ghana
JEL classification: I31, Q12, Q54

Acknowledgements: The authors are very grateful to the UNU-WIDER 'Development under Climate Change' project for the support to undertake this study.

---

*University for Development Studies, corresponding author: npk004@yahoo.com

This study has been prepared within the UNU-WIDER project 'Development under Climate Change', directed by Channing Arndt, James Thurlow, and Finn Tarp.

ISSN 1798-7237 ISBN 978-92-9230-748-6 https://doi.org/10.35188/UNU-WIDER/2014/748-6

Typescript prepared by Lisa Winkler at UNU-WIDER.

UNU-WIDER gratefully acknowledges the financial contributions to the research programme from the governments of Denmark, Finland, Sweden, and the United Kingdom.

1 Introduction

At the moment, global warming and climate change concepts are not new among policy makers as there has been increased awareness and understanding of the climate change phenomenon and its impact at least at the global and regional levels (Hassan 2010). The matter which seems to engage the attention of these policy makers has been which efforts to put in place to reduce greenhouse emissions even though it does not appear that there is a consensus with regard to the method to use. Whilst developed countries appear to be committed to reducing greenhouse emissions, developing countries are reluctant to show commitment on the basis that their contribution to the greenhouse problem in the first place has been little (Shalizi and Lecocq 2010). Meanwhile developing countries stand to suffer most from greenhouse gas accumulation and its effects on climate change because of their inability to respond adequately (Hassan 2010).

In Africa, for example, it is expected that climate change will severely affect both food production and access to food (Kurukulasuriya et al. 2006; Di Falco et al. 2011), because millions of small scale subsistence farmers are already struggling to produce food crops in extremely challenging conditions resulting in low yields and general food insecurity (Di Falco et al. 2011). These production uncertainties, particularly related to agricultural income risks, are believed to be a result of climate related events (Dillon et al. 2011).

The situation in Ghana is not very different as about 30 percent of the population as at 2008 lived below the poverty line (Quaye 2008) and most of them lived in the rural parts of Ghana and mostly in the three northern regions of upper west, upper east and northern. These regions are usually described as the poorest in the country (ODI and CEPA 2005) as households find it difficult to hold back their productive assets especially during the lean seasons.

This poverty situation in the north is mostly attributed to market exclusion and lack of infrastructure (Aryeetey and McKay 2004). However, these three regions in the north also share similar climatic features – variable rainfall patterns with extreme cases of drought and sporadic floods – with households depending almost exclusively on rain-fed farming for their food and livelihood security. Such conditions can affect economic outcomes, so that attempts at explaining and/or solving the poverty and food insecurity situations in the area must take into account these possible climatic factors (see, e.g., Aryeetey and McKay 2004).

Interestingly, there are very few studies (e.g., Quaye 2008) on the subject matter in the area, from which sound policy can emanate, so that policy conclusions and recommendations may not guarantee any long-lasting solutions, and this is probably why there is apparent difficulty in improving the development fortunes of the area. This study seeks to establish linkages between climate variability and welfare in the north of Ghana. To this end, the study analyses the trend of climate variability in northern Ghana for the period 1991 to 2007, and examines the relationship between climate variables and household welfare indicators.

2 Climate change impact on welfare

Climate change, though a physical process involving changes in climatic variables, impacts social, economic, and environmental systems and shapes prospects for food, water, and health security (Adger 1999; Christensen et al. 2007). The impact of climate change on these socio-economic outcomes ultimately affects household welfare albeit not directly. Indeed, studies on climate impact on welfare (see, e.g., Skoufias and Vinha 2013) have resorted to various welfare indicators such as consumption, health, and productivity. This is justifiably so, especially for agrarian economies, like northern Ghana, because uncertain and variable climatic conditions are a key feature of the world's major agricultural regions; serving as a major source of risk to long-term economic viability of such economies (IPCC 2007).

Generally, climate variability is seen as a major stumbling block to achieving food security in Sub-Saharan Africa because of high temperature, low precipitation, and low adoption of modern technologies (IPCC 2001; Kurukulasuriya and Rosenthal 2003). It is predicted the increasing intensity of drought/rainfall variability and floods in the region will continue to have a negative impact on agriculture and other sectors (Nyantakyi-Frimpong 2013). Indeed, the current comparative advantages of agriculture in different regions are likely to persist and even intensify going forward (Iglesias et al. 2011). IPCC (2007) notes that while climate change is beneficial to agricultural output of the temperate regions of Europe and North America, its effects on Africa's agriculture are negative. This situation is worrying because most African economies depend almost exclusively on agriculture, practiced under unfavorable conditions and relying on rainwater (Hassan 2010).

In Ghana, studies (see, e.g., Yaro 2010) show that the current climate challenges are severer and occur much more frequently than before and that the northern savannah bears the brunt of climate-induced livelihood impacts as agriculture is devastated and natural resource-based activities are threatened by the consequent degradation. Given that agricultural land use in Ghana is concerned mainly with food production, cocoa farming, oil palm farming, livestock, fisheries, and irrigated farming (Benneh 1994), the effects of climate change on the country's agriculture could be enormous.

A study commissioned by the Environmental Protection Agency in 1998 on the impact of climate change on cereal production, e.g., reveals the future climate change scenarios generated indicated that both the maximum and minimum temperatures increased over the years in all the agro-climatic zones of Ghana, but the increases were higher in the Sudan savannah zone where temperatures are normally the highest (EPA 2000). In addition, it was projected that percentage decrease in maize yield in the transition zone ranged from 0.5 percent in the year 2000 to 6.9 percent in the year 2020.

Even though the dangers of climate change affect all regions in Ghana, its effect on households in northern Ghana could be more devastating due to the physical and economic vulnerability of the regions in the area. The regions fall under the savannah ecological zone, which is characterized by a uni-modal rainfall distribution, an annual average rainfall of 1,000 mm, and a mean monthly temperature varying from 36°C in March to 27°C in August. The major livelihood activities in the communities of the savannah belt are crop farming, animal rearing, dry season gardening, processing of *Vitellaria paradoxa* (shea) nuts and *Parkia biglobosa* (dawadawa), petty trading, and charcoal production (Yaro 2010).

3 Methodology

3.1 Data sources

The study employed data from the Ghana Living Standard Survey (GLSS) rounds 3, 4, and 5. The GLSS is a series of nationwide surveys on the living conditions of the average Ghanaian. The first round was carried out in 1987/88. This study, however, uses data from the last three rounds because all three focused on the household as a key socio-economic unit and thus provide valuable insights into living conditions in Ghana. All three rounds were also based essentially on the same instruments and methodology (GSS 2008).[1] GLSS 3 was conducted from September 1991 to September 1992 on topics such as the demographic characteristics of the population, education, health, employment, housing, as well as household agriculture and household business activity. A representative sample of more than 4,500 households containing over 20,000 persons was covered. The particular focus of GLSS 3 was on collecting detailed income and expenditure data (GSS 1995).

The fourth round (GLSS 4) covered a period of 12 months from April 1998 to March 1999, with survey instruments and methodology based on those of the GLSS 3 with some minimal changes (i.e. addition of labor force module). A sample size of more than 5,988 households containing over 25,000 persons was covered (GSS 2000). The fifth round (GLSS 5) also spanned 12 months, from September 2005 to September 2006, with survey instruments and methodology based on those of GLSS 4 with minimal modifications (i.e. addition of non-farm household enterprise module). A sample size of 8,687 households containing 37,128 members was covered.

Because the GLSS data sets do not contain climate variables, data on climate variables (rainfall and temperature) were collected from regional meteorological stations in the upper west, upper east and northern regions. Monthly data were obtained for the period 1991 to 2007, however, yearly averages were calculated for the GLSS years (1991, 1998, and 2005). Hill et al. (2012) observed that using panel data of this nature can account for unobserved individual heterogeneity.

3.2 Theoretical framework

Measuring climate change impact has been a challenge to researchers just as the issue of climate change is to policy makers. The phenomenon takes place over a very long period and measuring its impact requires a long time series data covering decades, which is usually difficult to obtain. Where such data are available for climate attributes, records on production and consumption decisions for the same sample do not exist (Hassan 2010). As a remedy to these data problems, models such as the agronomic model, future agricultural resource model (FARM), agro-ecological zone (AEZ) model, integrated assessment models (IAMs) and the Ricardian (or cross-section) model (Hassan 2010) have often been used.

The agronomic and AEZ models, which have been widely used (see, e.g., Easterly et al. 1993; Iglesias et al. 1999; Chang 2002), usually do not adequately account for economic considerations, a situation which could lead to biases in economic analysis using such estimates.

The FARM on the other hand makes use of geographic information system to link climatically derived land classes with other inputs and agricultural output in a computable general equilibrium model of the world. Estimates from the model could be useful for economic decision-making because it captures interactions between farmers and downstream consumers of agricultural products that are likely to occur under climate change (Darwin 1999). However, the model might not be a good approach to modelling climate change impact at country or even regional levels.

The IAMs use projections of economic development over the next century and can make predictions of future greenhouse gas concentrations. However, it is not likely these models can value climate attributes in terms of their marginal effects on net revenues. This is where the Ricardian model comes in handy by making it possible to analyze the relationship between net

[1] In addition, the earlier rounds (i.e. 1 and 2) had a lot of missing variables, and not consistent with the latter rounds.

revenue from crops and climate, whilst controlling for key factors. The model values climate change attributes in terms of their marginal effects on net revenue as a proxy measure of changes in farmers' welfare. The difficulty with the Ricardian model is that it is suited for cross-sectional data, and unless panel modelling is used it completely ignores the fact that climate change variables are time variables. This study employs the Ricardian approach but uses panel data to take care of the time series nature of climate variability.

Whether a household will witness improved welfare or not depends crucially on its productivity (Di Falco et al. 2011), especially in a largely rural setting such as northern Ghana. Farm net revenue is often used as a proxy for productivity in the Ricardian analysis (see, e.g., Hassan 2010; Kurukulasuriya et al. 2006). The approach analyses household net farm revenue (crop and livestock) as a function of farmer household characteristics, climatic variables, input use, and market prices as specified in equation (1):

$$NR_{it} = \sum P_{it} Y_{it}(F, H, G) - \sum P_x X_{it} \tag{1}$$

where P_{it} is market price of crop i in period t, Y_{it} is output of crop i in period t, F is a vector of climatic variables, H is household labor and G is a vector of socio-economic variables and P_x is a vector of input prices. The standard Ricardian model relies on a quadratic formulation of climate variables (Kurukulasuriya et al. 2006; Hassan 2010) as in Equation (2):

$$NR_{it} = \delta_0 + \delta_1 F_{it} + \delta_2 F_{it}^2 + \delta_3 G_{it} + \delta_4 H_{it} + \mu_{it} \tag{2}$$

The Ricardian model is appropriate because it automatically captures farmers' adaptation response and controls for the effects of farm and household attributes (Hassan 2010).

3.3 Econometric model

Greene (2008) put forward the basic econometric framework for analyzing panel data as:

$$y_{it} = X_{it}'\beta + W_i'\gamma + e_{it} \tag{3}$$

where X_{it}' contains a number of K regressors, excluding a constant term, and e_{it} is the error term. The individual effects are captured by $W_i'\gamma$ where W_i' contains a constant term and a set of observable or unobservable individual or group-specific variables. The unobservable characteristics are all taken to be constant over time. Given the heterogeneity of individual effects is usually unobserved in most empirical studies, the focus of the analysis becomes finding a consistent and efficient estimation of the partial effects (Hassan 2010) as:

$$\beta = \frac{\partial E[y_{it}|X_{it}']}{\partial X_{it}'} \tag{4}$$

Equation (4) can be estimated using a population averaged (pooled), a fixed effects, or a random effects model (Gujarati and Porter 2009, depending on the assumption about the unobserved effects, whether the panel is balanced or unbalanced, whether the panel is short or long, or wide or narrow (Hill et al. 2012; Cameron and Trivedi 2010; Gujarati and Porter 2009).

Hill et al. (2012), for example, posit that the fixed effects model is not suitable for panels that are short (e.g. less than ten time series observation on each individual) whilst Cameron and Trivedi (2010) point out that fixed effects estimators are not efficient when the panel is unbalanced and propose the use of the random effects (RE) or pooled-average (PA) approach, which corrects for the panel complication, that the observations are correlated over time for a given individual. The

RE model, for example, treats the individual differences as random rather than fixed, so that the constant part is $\beta = \bar{\beta} + \mu_i$ and the error term now becomes $v_i = \mu_i + e_i$. If $\mu_i = 0$ for every individual then there are no differences to account for and there are no random effects, in which case the PA model is appropriate, which assumes that any latent heterogeneity has been averaged out.

Often times it is necessary to test for RE in panel data to choose which model to use. Greene (2008) proposes the use of Breusch-Pagan Lagrange multiplier test, which tests the hypothesis $H_0: \sigma_\mu^2 = 0$. If this hypothesis is rejected there are random effects and the RE model is appropriate, otherwise there are no random effects and the PA model is appropriate. This study employs this test to choose between the RE and PA models to estimate Equations (5), (6) and (7). Equation (5) specifies household agricultural income as:

$$AY_{it} = \sum \beta_i X_{it} + e_{it} \tag{5}$$

where AY_{it} is the dependent variable and represents household income from agriculture, β_i is a coefficient matrix, X_{it} is a vector of explanatory variables and includes temperature, rainfall, household size, household's food expenditure, household's total expenditure, age of economic head, and dummies for GLSS 4 and 5, and e_{it} is a vector of error terms.

Equation (6) specifies household farm revenue as:

$$FR_{it} = \sum \alpha_i Z_{it} + \varepsilon_{it} \tag{6}$$

where FR_{it} is the dependent variable (farm revenue), α_i is a coefficient matrix, Z_{it} is a vector of explanatory variables; temperature, rainfall, household size, household's food expenditure, household's total expenditure, age of economic head and dummies for GLSS 4 and 5, and ε_{it} is a vector of error terms.

Finally, equation (7) specifies household welfare as:

$$HW_{it} = \sum \delta_i M_{it} + \epsilon_{it} \tag{7}$$

where HW_{it} is the dependent variable; household welfare, a consumption-based index calculated by dividing total nominal expenditure by the product of price index and equivalence scale for Ghana.[2] The justification is that consumption is closely related to short-term fluctuations in income and less variable than income. It is appropriate for most developing countries (like Ghana), where household expenditure surveys are available (see Deaton and Zaidi 2002). δ_i is a coefficient matrix, M_{it} is a vector of explanatory variables and includes temperature, rainfall, household size, household's food expenditure, household's total expenditure, age of economic head, and dummies for GLSS 4 and 5, and ϵ_{it} is a vector of error terms.

3.4 Data and variable description, and summary statistics

Results in Table 1 show the panel is unbalanced, and this occurs when individuals are not always observed the same number of times. It thus implies that not the same individual households were observed during the GLSS surveys.

[2] See Ghana Statistical Service at www.gss.gov.gh for details.

Table 1: Panel description

Year	Frequency	Percent	Pattern
2005/2006	1904	58.01	1……..
1998/1999	740	22.55	.1…….
1991/1992	638	19.44	………1
Total	3282	100.00	x……xx

Note: Panel variable: id (uniquely identifies each observation). Time variable: year, 1991 to 2005.
Source: Ghana Statistical Service (1995, 2003, 2008).

The results also show the extent to which the panel is unbalanced and that GLSS 5 (2005/2006) contains 1,904 (58 percent) of the observations, followed by GLSS 4 (1998/1999) with 740 (23 percent) of the observations and GLSS 3 (1991/1992) with 638 (19 percent) of the observations.

The summary statistics in Table 2 show there has been some variations in climatic conditions over the GLSS years for all three regions in the north. Mean temperatures have been reducing for all years for northern and upper west regions but increasing for upper east region. However, there has been a reduction in rainfall for all three regions in the north.

Table 2: Summary statistics

Variable	Northern region			Upper east region			Upper west region		
	1991	1998	2005	1991	1998	2005	1991	1998	2005
Temperature ºC	34.1*	29.2	28.9	30.4	29.5	29.4	33.6	29.5	29.4
(annual av.)	(2.8)	(2.3)	(2.1)	(2.3)	(2.3)	(2.7)	(2.9)	(2.1)	(2.2)
Rainfall (annual	63.0	78.0	95.0	97.0	71.0	63.0	84.0	64.0	88.0
av.)	(60.1)	(82.7)	(95.5)	(101.9)	(86.9)	(85.9)	(81.6)	(77.7)	(87.5)
Household	1	7	27	1	6	23	1	5	26
expend.	(0.5)	(10)	(14)	(0.3)	(2)	(9)	(0.3)	(5)	(25)
Household size	6	5	6	6	6	5	6	5	7
	(4)	(3)	(3)	(3)	(3)	(3)	(3)	(2)	(4)
Total income	27	155	1344	23	118	597	26	123	619
	(31)	(258)	(2997)	(21)	(176)	(1058)	(48)	(305)	(1077)
Food	34	195	971	26	146	664	42	105	519
expenditure	(26)	(227)	(846)	(23)	(68)	(650)	(34)	(67)	(510)
Welfare index	4.4	4.4	4.6	4.0	4.1	4.2	4.3	3.9	3.9
(Ln)	(0.80)	(0.69)	(0.77)	(0.6)	(0.59)	(0.73)	(0.67)	(0.59)	(0.78)
Farm revenue	10.6	10.3	11.5	11.1	11.3	10.8	12.1	10.9	10.9
(Ln)	(1.44)	(1.49)	(1.54)	(1.76)	(1.68)	(1.59)	(1.81)	(1.33)	(1.47)
Agric. Income	2.24	3.97	6.22	2.26	3.85	5.05	2.16	3.39	5.17
(Ln)	(1.53)	(1.39)	(1.41)	(1.16)	(1.29)	(1.44)	(1.42)	(1.31)	(1.36)
Age of econ.	43.0	42.2	40.2	45.4	48.8	45.6	46.5	45.2	43.8
head	(14.6)	(12.0)	(13.4)	(17.6)	(16.8)	(14.7)	(14.4)	(13.1)	(16.5)
Remittances	16.1	11.1	9.77	20.2	18.3	4.81	19.81	19.8	35.8
	(52.1)	(33.8)	(30.2)	(42.3)	(32.4)	(21.5)	(52.5)	(50.2)	(136)

Note: * Figures are means and those in parentheses are standard deviations.
Source: Climate data from Ghana Meteorological Service and from Ghana Statistical Service (1995, 2003, 2008).

Welfare indicators such as household total income, agricultural income, total expenditure, and food expenditure (all in Ghana cedis) have been increasing over the GLSS years for all three regions. On the whole, households in the northern and upper east regions have witnessed a consistent improvement in welfare for 1998 and 2005 compared to previous years. However, households in the upper west region became worse off in 1998 compared to 1991 but had improvement in welfare in 2005 compared to 1998, even though this improvement still made them worse off in 2005 compared to 1991.

4 Welfare effects of climate variability

4.1 Trend of climate variables in northern Ghana

To determine the presence of a statistically significant trend in climate variables, two approaches could be used: the parametric approach, mostly through linear regression, and the non-parametric approach, usually through the use of Sen's estimator method (Jain and Kumar 2012). This study employs the parametric approach, using trend equations to determine the presence of trends in temperature and rainfall values in the three regions in northern Ghana. The justification for this approach is that the method is so sensitive that it picks up small trend effects, which could easily be missed by the non-parametric approach.

In practice, the general expectation is that plots of climate variables oscillate around the horizontal axis if there are no significant interventions, especially, coming from anthropogenic activities (Obasi and Ikubwaje 2012). In addition, the sign of the slope coefficient has implications for the identification of wet and dry seasons, whilst the R^2 points to the degree of variation in the particular climatic indicator.

Results in Table 3 show the degree of variability in rainfall is more than that of temperature across all three regions in northern Ghana. This result is corroborated by the trend graphs (see Appendix), in which there are more oscillations in rainfall than in temperature across the three regions. In the upper west region, for example, there were more rains between the periods 1994 and 1997; 1999 and 2000; and 2003 and 2004. In spite of this, the trend equation ($-0.0283X$) shows there were generally longer dry periods than wet periods, implying that the amount of rainfall has been decreasing over the period. The R^2 of 0.0001, however, suggests that the degree of variability in rainfall in the area is well below 1 percent. For the upper east region, oscillation in rainfall for the period is not as prominent even though the degree of variation is more than 1 percent, given the R^2 value is 0.0168. In fact, it can be said that the general variability in rainfall of over 1 percent for the whole of northern Ghana for the period was as a result of the relatively high degree of rainfall variation in the upper east region compared to that of upper west and northern regions.

Table 3: Trend equations for rainfall and temperature

Variable	Area	Equation on chart	$R^2 - \text{value}$	Variation (%)	Trend
Rainfall	UWR	-0.0283X	0.0001	0.01	Decreasing
	UER	-0.3550X	0.0168	1.68	Decreasing
	NR	-0.3064X	0.0080	0.80	Decreasing
	N Ghana	-0.2299X	0.0128	1.28	Decreasing
Temperature	UWR	-0.0998X	0.1414	1.40	Decreasing
	UER	0.3167X	0.0477	0.48	Increasing
	NR	-0.4778X	0.7044	7.04	Decreasing
	N Ghana	-0.0870X	0.0033	0.33	Decreasing

Source: Data from Ghana Meteorological Service.

The fact that there is a deceasing trend in rainfall across all three regions in northern Ghana is a source for concern since the main economic activity of the people is rainfed agriculture, mostly cereal farming and livestock rearing. The decreasing trend of rainfall means that farming is going to suffer more in the future since it is impossible to keep livestock or grow cereals without adequate water. This observation is consistent with the views expressed by Yaro (2010) that the northern savannah regions of Ghana bear the brunt of climate-induced livelihood impacts.

The trend equations for annual mean temperatures for northern Ghana surprisingly show a decreasing one. Except for the upper east region where there is an increasing trend, which is consistent with popular expectations because of the rate of degradation (see Yaro 2010) coupled with the decreasing trend in rainfall, temperature trends for upper west and northern regions are decreasing for the period under study. The only plausible reason for such a surprise is the fact that, for the two odd regions, periods when temperatures went below average were also period rainfall figures were above average. In the upper west region, for example, rainfall figures were above average for the period 1994 and 1997, and 1999 and 2000, and it was the same period that temperatures fell below average. Indeed, in the upper east region where temperature continues to increase, it is also observed that there are relatively longer periods of dryness compared to the other regions.

4.2 Relationship between climate variables and household welfare

Results from this study show there are significant differences in variation in rainfall and temperature across the three regions and this could have implications for household welfare in different parts of northern Ghana. The correlation results in Table 4 reveal rainfall positively correlates with both agricultural income and welfare, and this relationship is significant at the 0.01 level. However, while temperature negatively correlates with agricultural income at the 0.05 level, it positively correlates with welfare at the 0.01 level. In addition, there are significant differences in welfare across location (rural and urban) and administrative regions at the 0.01 level.

Table 4: Descriptive statistics on climate effects on household welfare

Climate variability across regions (median test)

	Northern	Upper east	Upper west	Total
Rainfall				
Less than median	698	720	260	1678
Greater than median	795	110	699	1604
Pearson $\chi^2(2) = 654.23$ Pr = 0.0001				
Temperature				
Less than median	1155	600	769	2524
Greater than median	338	230	190	758
Pearson $\chi^2(2) = 15.9494$ Pr = 0.0001				

Correlation among welfare, climate variability and agric. income

	Rainfall	Temperature	Agric. income
Welfare	0.1108 (0.0001)	0.0380 (0.0295)	0.1087 (0.0001)
Agric. income	0.1611 (0.0001)	-0.0977 (0.0001)	

Welfare variations across regions (median test)

Greater than median	Northern	Upper east	Upper west
No	542	442	657
Yes	951	388	302
Total	1493	830	959

Pearson $\chi^2(2) = 246.969$ Pr = 0.0001

Welfare variations across location (urban, rural): two sample t test

Group	Observations	Mean	Std. Dev.
Urban	589	1695316	1495773
Rural	2693	846126	807252.6
Combined	3282	998524.8	1020556
Difference		849189.5	

Diff = mean (urban) – mean (rural) t = 19.300 H0: diff = 0 df = 3280

H_a: diff <0 H_a: diff! = 0 H_a: diff >0

Pr(t<t) = 1.00 Pr(|T|>|t|) = 0.0001 Pr(T>t) = 0.0001

Source: Climate data from Ghana Meteorological Service and from Ghana Statistical Service (1995, 2003, 2008).

Climate variability can impact household welfare directly and indirectly (especially through agricultural incomes and farm revenue) in areas such as northern Ghana where the main economic activity is agriculture. To be able to find the effects of climate variability on household welfare, it is important to first look at its impact on agricultural incomes and farm revenue. In doing the analysis, the random effects and the population averaged approaches have been employed following Cameron and Trivedi (2010); the results are presented in Table 5.

In explaining income from agriculture, only results of the population averaged model are discussed. This is because the Breusch-Pagan Lagrangian multiplier test for random effects gave a chi-square value of 0.38 and *p*-value of 0.5394 for the model, indicating that for the income from agriculture model, there is no random individual heterogeneity, leaving the population averaged approach as the best method. For the farm revenue and household welfare models, the estimates of the random effects model are discussed since the Breusch-Pagan test gave a chi-square value of 6.39 and 2.92 with *p*-values of 0.0001 and 0.0873, respectively, confirming there is random individual heterogeneity at least at the 0.1 level.[3]

Table 5: Model results

Variable	Income from agric.		Farm revenue		Welfare	
	Random effects	Pop. average	Random effects	Pop. average	Random effects	Pop. average
Rain	-0.0067	-0.5451***	0.1761*	-0.3014***	0.0573*	0.0949***
	(0.0899)	(0.0553)	(0.0929)	(0.0506)	(0.0352)	(0.0187)
Rain^2	0.0001	0.0036***	-0.001*	0.0019***	-0.0004*	-0.0006***
	(0.0006)	(0.0003)	(0.0006)	(0.0003)	(0.0002)	(0.0001)
Temp.	29.984***	-7.8762***	68.63***	12.804***	8.4280***	5.1715***
	(8.8254)	(1.1813)	(8.967)	(1.2054)	(3.4025)	(0.4444)
Temp^2	-0.4579***	0.1156***	-1.0486***	-0.2030***	-0.1298***	-0.0805***
	(0.1338)	(0.0187)	(0.1359)	(0.0191)	(0.0516)	(0.0070)
Food exp.	0.0004***	0.0003***	-0.00002	-1.37e-06	0.0012***	0.0012***
	(0.0001)	(0.0001)	(0.0001)	(0.0009)	(0.0003)	(0.00003)
HH exp.	-0.0252***	0.0242***	-0.0010	-0.0001	0.0042***	-0.0026***
	(0.0054)	(0.0044)	(0.0021)	(0.0020)	(0.0008)	(0.0007)
HH size	0.1263***	0.1146***	0.0180***	0.0192***	-0.0930***	-0.0936***
	(0.0086)	(0.0088)	(0.0086)	(0.0086)	(0.0031)	(0.0032)
Age EcoH	-0.0142	-0.0227**	-0.0072	-0.0108	-0.0134***	-0.0121***
	(0.0092)	(0.0095)	(0.0096)	(0.0096)	(0.0035)	(0.0003)
Age EcoH^2	0.0001	0.0002**	0.0001	-0.0001	0.0001***	0.0001***
	(0.0001)	(0.0001)	(0.0001)	(0.00002)	(0.0003)	(0.00003)
Remittance	0.0001	0.0001	0.0001***	0.0001***	8.60e-06	0.00001
	(0.0004)	(0.0003)	(0.00002)	(0.00002)	(0.0001)	(0.00001)
UER	-0.8306***	-0.2160***	9.9881***	-0.1062	-0.4098***	-0.4344***
	(0.1183)	(0.0854)	(1.5962)	(0.0885)	(0.0449)	(0.0322)
UWR	1.2105**	-1.1827***	10.312***	0.6197	0.0641	-0.2053***
	(0.6123)	(0.6219)	(1.6388)	(0.0797)	(0.2353)	(0.0289)
GLSS4	6.4313***		-0.6056***		0.7026	
	(1.5683)		(0.1213)		(0.6049)	
GLSS5	8.2733***		4.482***		0.4759	
	(1.6203)		(0.6219)		(0.2353)	
Constant	-488.1***	-155.9***	-1116.9***	-178.79	-133.32***	-81.018***
	(147.9)	(18.51)	(150.41)	(18.548)	(57.072)	(6.8402)
Overall R^2	0.5460		0.0791		0.3778	
Wald χ^2	3145.58	2740.58	297.79	250.06	3028.25	2944.20
Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$H_0: \sigma_u^2 = 0$	$LM\ (\chi^2) = 0.38$		$LM\ (\chi^2) = 6.39^{***}$		$LM\ (\chi^2) = 2.92^{*}$	

Notes: *** significant at 0.01 level; ** significant at 0.05 level; * significant at 0.1 level; figures in parentheses are standard errors.

Source: Climate data from Ghana Meteorological Service and from Ghana Statistical Service (1995, 2003, 2008).

3 A seemingly unrelated regression (SUR) model was also estimated and the result of a Breusch-Pagan test of independence showed the three equations are dependent and should be estimated as a system. However, the results from the SUR estimation are not discussed because the model selection outcome did not favour a single approach for all three models, which is a basic requirement for the SUR.

Previous studies (see, e.g., IPCC 2001; Kurukulasuriya and Rosenthal 2003) have identified the negative long-term impact of climate change on economies in Sub-Saharan Africa, unless farmers adapt adequately to climate change (Nyantakyi-Frimpong 2003). Controlling for other factors, the present study finds that the decreasing trend of both rainfall and temperature has negative influence on household income from agriculture and farm revenue. Rainfall exhibits a negative effect but this effect does not diminish as the square term shows a positive influence. This could be attributable to the decreasing trend in rainfall amounts in the area. Temperature also exhibits a negative effect on income from agriculture. In their study, Hertel and Rosch (2010) explained that moderate warming reduces yields of crops such as maize and other coarse crops in semi-arid and tropical regions. Given farmers in northern Ghana produce cereals, mainly maize, this is understandable. Similarly, farmers also keep livestock such as cattle, sheep, and goats which find it difficult to survive during periods of very high temperatures. Given the availability of food in Sub-Saharan Africa critically depends on the productivity of farm households (Di Falco et al. 2011) the current situation where climate variability threatens farm productive outcomes presents a very challenging future to households in northern Ghana.

In examining the impact of climate variability on household welfare, it came to light that in their linear form both rainfall and temperature have significantly positive influence on household welfare. This implies households' experience increase in welfare during periods of high rainfall and temperatures. This is probably because while high rainfall leads to improvement in crop yield and availability of water for household use and rearing of livestock, dry seasons which are usually the periods of high temperatures, are not conducive for the breeding of insects such as mosquito which causes malaria, the most common disease in the tropics. Thus while high rainfall leads to improvement in the economic lives of the people, high temperatures lead to improved health.

It is, however, important to note that beyond certain points, increases in both rainfall and temperature lead to decreasing welfare of households. The quadratic terms of both rainfall and temperature are negative indicating diminishing effects of the two variables on welfare. This is probably because high rainfall could lead to flooding which, apart from the physical destruction to economic property, could lead to outbreak of communicable diseases such as cholera on the one hand while very high temperatures could bring about periods of drought which can also lead to loss of livestock and outbreak of diseases such as meningitis. This finding on rainfall and temperature is in consonance with the observation by Skoufias and Vinha (2013) that these variables have a concave relationship with agricultural productivity, and hence, potentially, welfare through their effects on consumption.

When climate variables are controlled for, household food expenditure positively affects income from agriculture and household welfare; household size influences income from agriculture and farm revenue positively, but affects household welfare negatively. This is not surprising because farmers in northern Ghana usually depend on family labor for their production: the more members are in a household the more likely it is that such a household can earn more from agriculture and also witness increases in farm revenue. On the flip side, however, is the high cost of taking care of the needs of household members; with more household members the costs of access to the basic needs of life such as food, shelter, and health are also likely to increase and ultimately affect household welfare adversely.

From the descriptive statistics, it emerged that significant differences exist in welfare across the three regions (see Table 4). In that regard, it is important to find out which region suffers most in terms of welfare losses and production outcomes. The results from Table 5 show that the upper east region consistently suffers losses in agricultural income, farm revenue and welfare, compared to the northern region (the base region). Consistent with the position taken by Ghana's Initial National Communication (2000), this probably reflects the fact the upper east region experiences more variability (increasing temperatures and low rainfall) than the other two regions such that the combined effects of these is what accounts for the negative impacts in that region. The upper west region on the other hand suffered more losses in agricultural income but gained more in farm revenue compared to the base region. There were, however, no significant differences in welfare between the upper west and the base region. These results reflect the findings by Skoufias and Vinha (2013) who reported differential effects of climate variability on welfare of households located in different regions.

5 Conclusion and policy implications

Consistent with the literature (see, e.g., Shalizi and Lecocq 2010), this study concludes that climate variability threatens to bring about significant shifts in precipitation and weather patterns in northern Ghana. Most part of the area is currently experiencing a decrease in the amount of rainfall (at least between 1991 and 2007), and it does not appear the future pattern will be any different as the trend coefficients for all regions are negative. Temperatures have also been increasing for some parts (at least in the upper east region) and the trend shows the situation might not change in the foreseeable future.

There are significant differences in welfare across the three administrative regions in northern Ghana. On the average, households in northern and upper east regions realized some marginal improvements in welfare in 2005 and 1998 compared to 1991, whilst those in the upper west region experienced deterioration in 2005 and 1998 compared to 1991. There are also significant differences in welfare between those living in the urban areas and those in rural savannah. Households in rural savannah tend to suffer more welfare losses than those in urban savannah.

The study further found climate variability impacts household productive outcomes significantly, especially agricultural income and farm revenue; and ultimately household welfare. While rainfall has a positive impact on welfare, the negative trend in rainfall poses a great challenge to ability of households to realize any increases in welfare. Household food expenditure is also significant in explaining welfare. Households are able to improve their welfare by increasing expenditure on food, an expenditure which could significantly reduce but for the threat that rainfall and temperature variability poses to agricultural production in the area.

For households in northern Ghana to experience sustained improvement in welfare, policy intervention must, in addition to the current policy initiatives such as the Savannah Accelerated Development Initiative, provide answers to the question of how to reverse current climate trend or at least help households cope with the current climate threat. In proposing answers to such policy questions, current debates are cast around two broad options: mitigation and adaptation.

Whilst mitigation is essential for future outcomes, households need to first deal with the problem of food insecurity arising from climate variability through adaptation. In this regard, the study recommends that government should initiate and support farmer households in northern Ghana to diversify their production options to include other activities that are not affected directly by the vagaries of the weather. This, in addition to expanding the earning portfolio of households, will also serve as a major source of engagement during off-farming seasons which are usually longer in northern Ghana because of reduced rainfall.

Households should also be encouraged and supported to practice intensive agriculture. They could be assisted to dig mechanized wells which could serve both as a source of irrigation water for backyard farming and for watering their animals during the long dry season.

References

Adger, N. W. (1999), 'Social Vulnerability to Climate Change and Extremes in Coastal Vietnam,' *World Development*, Vol. 27, 249–269.

Aryeetey, E., and McKay, A., (2004). *Operationalising Pro-Poor Growth: A Country Case Study on Ghana*, A joint initiative of AFD, BMZ (GTZ, KfW Development Bank), DFID, and World Bank.

Benneh, G., (1994), *A Report by Land Use Planning Committee*, Environmental Protection Council/Ghana Environmental Resource Management, Accra.

Cameron, A. C. and Trivedi, P. K. (2010), *Microeconmetrics Using Stata*. StataCorp LP, College Station, Texas.

Chang, C. C. (2002), 'The Potential Impact of Climate Change on Taiwan's Agriculture', *Agricultural Economics*, Vol. 27, 51–64.

Christensen J. H., Carter T. R., Rummukainen, M. and Amanatidis, G. (2007), 'Evaluating the Performance and Utility of Regional Climate Models: The PRUDENCE Project', *Climatic Change*, Vol. 81, 1-6.

Darwin, R. (1999), 'The Impact of Global Warming on Agriculture: A Ricardian Analysis: Comment', *American Economic Review*, Vol. 89, 1049-1052.

Deaton, A. and Zaidi, S. (2002), 'Guidelines for Constructing Consumption Aggregates for Welfare Analysis', LSMS Working Paper No. 135, World Bank.

Di Falco, S., Veronesi, M. and Yesuf, M. (2011), 'Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia', *American Journal of Agricultural Economics*, Vol. 93, 829-846.

Dillon, A., Mueller, V. and Salau, S. (2011), 'Migratory Response to Agricultural Risk in Northern Nigeria', *American Journal of Agricultural Economics,* Vol. 93, 1048-1061.

Easterly, W., Kremer, M., Pritchett, L. and Summers, L. H. (1993), 'Good Policy or Good Luck? Country Growth Performance and Temporary Shocks, *Journal of Monetary Economics*, Vol. 32, 459-483.

EPA (2000), Ghana's Initial National Communication under United Nations Framework Convention on Climate Change, Environmental Protection Agency, Accra.

GSS (2008), *Ghana Living Standards Survey Report of the Fifth Round (GLSS 5)*, Ghana Statistical Service, Accra.

GSS (2003), *Core Welfare Indicators Questionnaire (CWIQ) Survey, Ghana National Summary*, Ghana Statistical Service, Accra.

GSS (2000), *Ghana Living Standards Survey Report of the Fourth Round (GLSS 4)*, Ghana Statistical Service, Accra.

GSS (1995), *Ghana Living Standards Survey Report of the Third Round (GLSS 3)*, Ghana Statistical Service, Accra.

Greene, W. (2008), *Econometric Analysis (sixth edition)*, Pearson, New York.

Gujarati, D. and Porter, D. C. (2009), *Basic Econometrics* (fifth edition), McGraw-Hill, Boston.

Hassan, R. M. (2010), 'Implications of Climate Change for Agricultural Sector Performance in Africa: Policy Challenges and Research Agenda', *Journal of African Economies*, Vol. 19, ii77-ii105.

Hertel, T. W. and Rosch, S. (2010), 'Climate Change, Agriculture and Poverty', *Applied Economic Perspective and Policy*, Vol. 32, 355-385.

Hill, R. C., Griffiths, W. E. and Lim, G. C. (2012), *Principles of Econometrics* (Fourth edition). John Wiley and Sons, Inc., New Jersey.

IPCC (2007), *Climate Change 2007: Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

IPCC (2001), *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Iglesias, A., Garrote, L., Diz, A., Schlickenrieder, J. and Martin-Carrasco, F. (2011), 'Re-thinking Water Policy Priorities in the Mediterranean Region in View of Climate Change', *Environmental Science and Policy*, Vol. 14, 744-757.

Iglesias, A., C., Rosenzweig, C. and Pereira, D. (1999), 'Agricultural Impacts of Climate Change in Spain: Developing Tools for a Spatial Analysis', *Global Environmental Change*, Vol. 10, 69-80.

Jain, S. K. and Kumar, V. (2012), 'Trend Analysis of Rainfall and Temperature Data for India', *Current Science*, Vol. 102, 37-49.

Kurukulasuriya, P., R., et al. (2006), 'Will African Agriculture Survive Climate Change? *The World Bank Economic Review*, Vol. 20, 367-388.

Kurukulasuriya, P., and Rosenthal, S. (2003), 'Climate Change and Agriculture: A Review of Impacts and Adaptations', Climate Change Series 91, Environment Department Papers, World Bank, Washington, DC.

Nyantakyi-Frimpong, H. (2013), 'Indigenous Knowledge and Climate Adaptation Policy in Northern Ghana', Africa Portal Backgrounder No 48, Available at: www.africaportal.org (accessed 30 March 2013).

Obasi, R. A. and Ikubuwaje, C. O. (2012), 'Analytical Study of Rainfall and Temperature Trend in Catchment States and Stations of the Benin-Owena River Basin, Nigeria', *Journal of Environment and Earth Science*, Vol. 2, 9-20.

ODI and CEPA (2005), 'Economic Growth in Northern Ghana', Report Prepared for DFID Ghana, Overseas Development Institute and Centre for Policy Analysis, London/Accra, available at: http://www.odi.org.uk/resources/details.asp?id=2676&title=economicgrowth-northernghana (accessed 29 March 2013).

Quaye, W. (2008), 'Food Security Situation in Northern Ghana, Coping Strategies and Related Constraints', *African Journal of Agricultural Research*, Vol. 3, 334-342.

Shalizi, Z. and Lecocq, F. (2010), 'To Mitigate or to Adapt: Is that the Question? Observations on an Appropriate Response to the Climate Change Challenge to Development Strategies', *The World Bank Research Observer*, Vol. 25, 295-321.

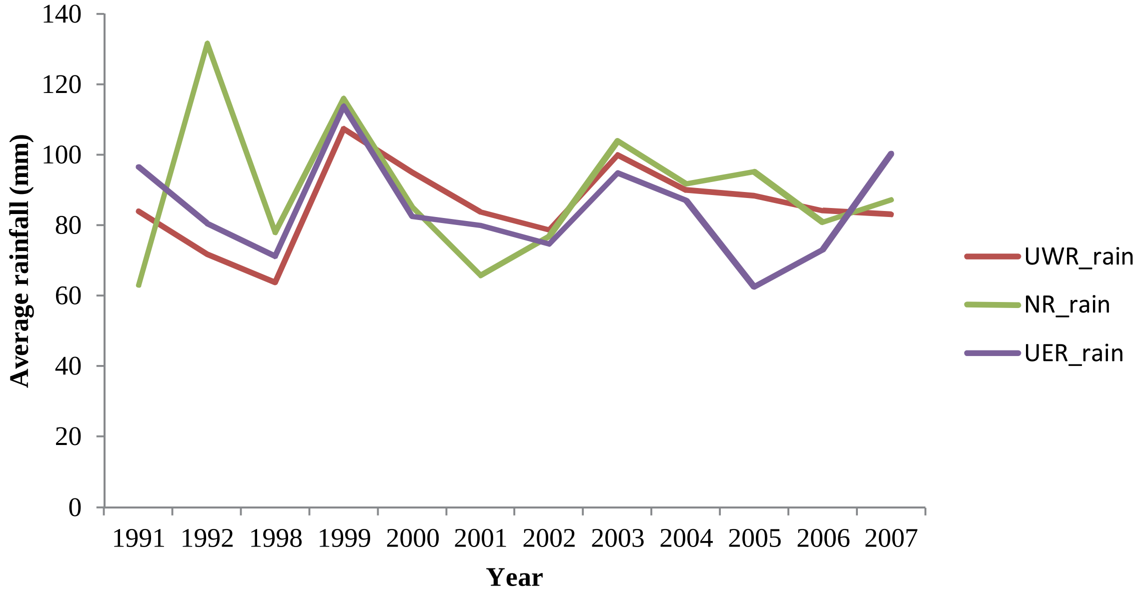
Skoufias, E. and Vinha, K. (2013), 'The Impacts of Climate Variability on Household Welfare in Rural Mexico', *Population and Environment*, Vol. 34, 370-399.

UNEP (1986), 'The State of the Environment', United Nations Environment Programme, available at: www.unep.org (accessed 5 April).

Yaro, J. A. (2010), 'The Social Dimensions of Adaptation to Climate Change in Ghana', World Bank Discussion Paper No 15, The International Bank for Reconstruction and Development/World Bank.

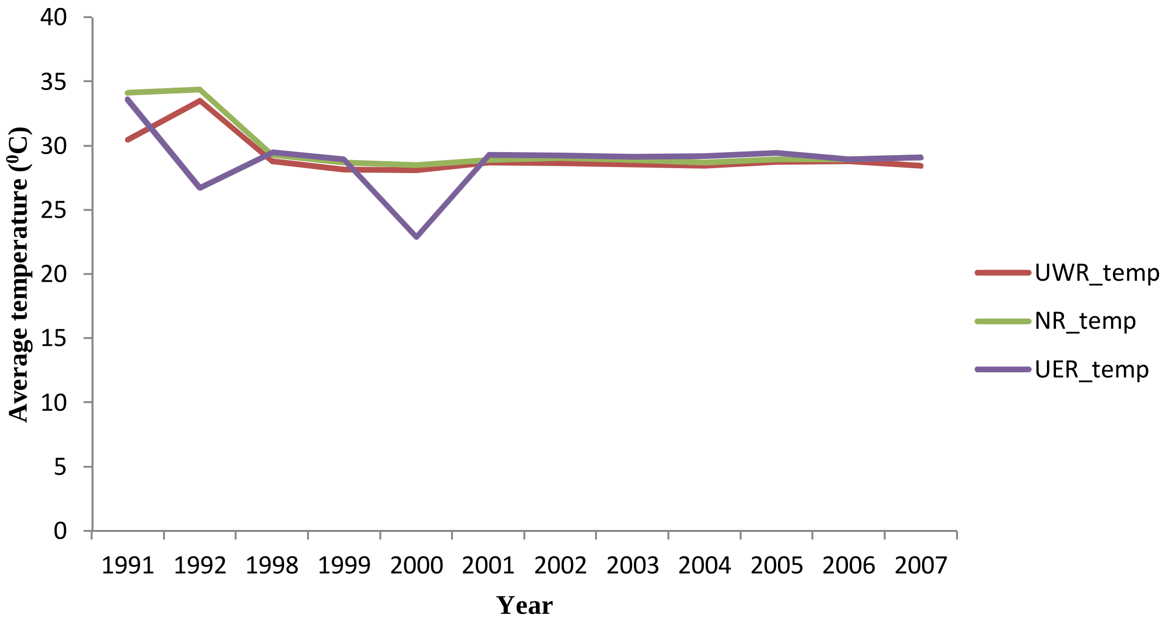
Appendix: Trend graphs

Appendix Figure A1: Rainfall trend across the regions in northern Ghana



Source: Data from Ghana Meteorological Service.

Appendix Figure A2: Temperature trend across the regions in northern Ghana



Source: Data from Ghana Meteorological Service.