Who Benefits, Who Loses and What can be done? - An Assessment of the Economic Impacts of Climate Change with and without Adaptation on Smallholder Farmers in Ghana

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Abstract:

This paper presents the empirical proof of the economic impacts of climate change on smallholder farmers in a semi-arid agro-ecological district in Ghana. We employ the Trade-off Analysis Minimum Data (TOA-MD) Model simulated yield projections from five climate model scenarios HADCM, CGCM, CSIRO, NCAR and MIROC with farm survey data to estimate the economic impacts of climate change on smallholder farmers in the Lawra district of Ghana with and without adaptation.. The findings reveal that smallholders in the district will suffer losses in net revenue, per capita income and increased poverty rates without adaptation. Adaptation will however, reverses the losses and results in potential gains with per farm net revenues and per capita incomes increasing between 10% to 17% and 1% to 7% respectively, while poverty rates decline by 13-20% for upland farms. Lowland farms are expected to experience a reduction in poverty of between 2-10%. Overall, adaptation has the potential of reducing poverty rates by as much as 8 -16% for all farms. The study recommends improving irrigation access to smallholder farmers in both upland and lowland areas to enable them adapt to water scarcity due to climate change. Key words: Climate change, small holder farmers, poverty reduction, TOA-model, Ghana

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1. Introduction

Crop yield projections in sub-Saharan Africa (SSA) are estimated to fall by 10 - 20% or even up to 50% due to climate change by 2050 (Jones and Thornton, 2009; Claessens et al., 2012; Adiku et al., 2015,). This is because; SSA agriculture is predominantly rain fed and fundamentally dependent on the vagaries of weather. Thus, as SSA's farmers strive to overcome poverty, the unabated phenomenon of climate change threatens to deepen their vulnerability, undermine their resilience, and jeopardise the continent's overall prospects for economic development (Zoellick, 2009). Hitherto, the agricultural sector is a major source of livelihood for approximately 80 percent of the rural population of SSA (World Bank, 2007a; MoFA 2014).

According to the Ghana Statistical Services (GSS, 2016), the agricultural sector contributed 20.3 percent to the country's gross domestic product (GDP) in 2015. In addition to the sector's contribution to national income, agriculture also provides food, income, empowerment, stability and resilience to farm households and leads to improvements in rural livelihoods and welfare (Bird and Shepherd, 2003).

In spite of the above contributions of agriculture, changes in rainfall patterns and increased temperatures are likely to bring considerable stress to the sector. In the Lawra district, agriculture is largely rain fed, and farmers commonly cultivate traditional crop varieties that have low adaptive capacities, low drought-resistance and heat-tolerance thresholds; and longer maturity periods. Meanwhile, declining levels and erratic distributions of rainfall are projected to reduce yields of maize, millet, groundnut and other food crops in the Guinea Savannah Agroecological (GSA) zone (Adiku *et al*., 2015). Whilst, precipitation-related climatic variability particularly affects the timing and duration of the cropping season, crop development and production; and compounds the risks already faced by farmers (Jaegermeyr, 2016).

Also, in the face of land fragmentation due to high population rate, and soil infertility due to continuous cultivation, farmers in Lawra district have little room for land expansion and use of conventional agricultural practices. To this end, farmers will need to adapt to climate change by adopting climate-smart agricultural practices to sustain current yield levels and sustainably boost total production (Amikuzuno and Hathie, 2013; Adiku et al., 2015). In other words, the IPCC Fourth Assessment emphasizes the need for adoption of climate smart agricultural practices (IPPC, 2007). Adaptation is however been observed to be a site- and context-specific (Deressa *et al*., 2008).

Consequently, only a few studies employ global climate models to evaluate the economic impact of climate change and adaptation strategies on agriculture (eg. Mendelsohn and Seo, 2007; Jaegermeyr *et al*., 2016, Sultan *et al*., 2013). Thus, addressing adaptation in the context of smallholder, semi-subsistence agriculture raises special challenges and high data demands including site-specific bio-physical and economic data availability (Antle and Valdivia, 2006; Claessens, 2012).

An empirical knowledge gap therefore exists, which requires the provision of downscaled farm level integrated assessment of climate change and climate change adaptation. Such an assessment would enable us estimate 1. The potential gains in net per farm returns, per capita incomes and poverty rates; and 2. The potential losses in net per farm returns, per capita incomes and poverty rates for smallholder farms in Lawra district with and without adaptation.

2. Study Area and Dataset

Lawra district in the Upper West Region of Ghana lies between 180 meters and 300m above sea level, and covers an area of 1,051.2 square kilometres with 78 percent of the working population being engaged in agriculture. The district is broadly representative of the GSA zone of West Africa, with a semi-arid climate of mean annual temperature between 27°C and 36°C; and two seasons, a dry season from October to April and a rainy season from May to September.

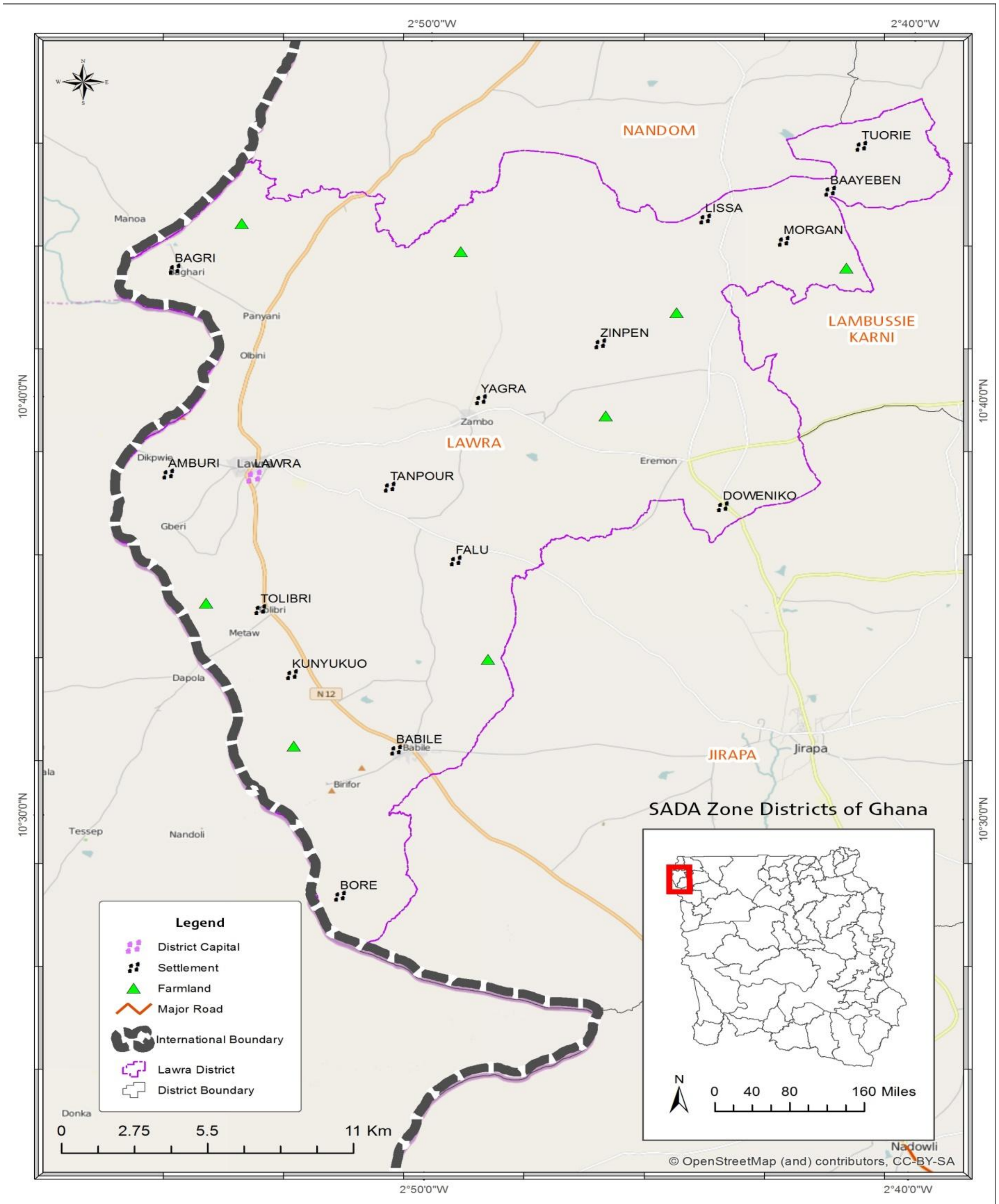

Figure 1: Map Showing the Study Area

(Source: Upper West Regional Directorate, 2013).

The socioeconomic farm level data was obtained from a sample of 300 farmers using semi-structured questionnaire. A summary of the key variables used to estimate the TOA-MD model parameters is presented in Table 1. From the variables presented, farm costs, revenues and net per farm returns were computed per each farm and averaged across the strata of farms using the following equations.Costs and revenues were estimated using the functions below:

$C = c(x, p)$ and $R = r(q, w)$ (1)

Where **x** and **q** are vectors referring to input and output quantities while ***p*** and ***w*** refer to their respective price vectors. The cost incurred is the sum of annual (seasonal) rent on land, money price of seed, money wage of labor, price of capital input and other direct expenses. The capital variable is computed as the sum of the cost of hiring animal and mechanical power for land preparation per farm, while other direct expenses is computed as sum of money price per farm of fertilizer, herbicide and pesticide. Revenue (R) is determined as a product of price of farm produce and quantity sold (the monetary equivalent of quantities consumed or given out were added to revenue). Net revenue was determined as $\pi = R - C = r(q, w) - c(x, p)$. These revenues and costs were determined for maize, soybean and groundnut.

Table 1: Key descriptive statistics of base system variables used in TOA-MD analysis

Parameter/ Strata		Upland Farms[1]			Lowland Farms	
Farm Characteristics	Mean	Stand. Dev.	CV (%)	Mean	Stand. Dev.	CV (%)
Household Size	9.48	4.64	48.93	10.14	7.02	69.24
Farm Size	1.82	1.46	80.30	2.06	1.23	59.87
Herd Size	22.95	19.25	83.90	20.70	15.84	76.52
Off- Farm Income	1664.07	1618.98	97.29	1815.35	1963.33	108.15
Maize						
Yield/ Farm (kg)	480.77	586.55	122.00	466.86	342.64	73.39
Var. Cost/ Farm (GHS)	440.38	504.12	114.47	533.39	281.89	52.85

[1] The Lowland farms represent the West, Center and South strata of the district. Whiles Upland farms represent the North and East strata of the district. Farms in different strata are assumed to experience different degrees of climate change impacts.

Net Rev./ Farm (GHS)	636.55	933.35	146.63	540.39	723.57	133.90
Cowpea						
Yield/ Farm (kg)	154.39	106.60	69.05	240.74	303.14	125.92
Var. Cost/ Farm (GHS)	59.08	91.75	155.29	207.09	320.16	154.60
Net Rev./ Farm (GHS)	621.76	458.94	73.81	924.39	1287.36	139.27
Groundnuts						
Yield/ Farm (kg)	324.06	300.28	92.66	380.84	332.93	87.42
Var. Cost/ Farm (GHS)	182.33	185.46	101.72	261.81	228.22	87.17
Net Rev./ Farm (GHS)	1664.81	1618.53	97.22	1832.80	1761.27	96.10
Livestock						
Var. Cost (GHS)	141.39	204.35	144.53	161.24	293.69	182.14
Net. Rev (GHS)	243.72	399.89	164.08	191.12	388.44	203.24

Source: Field Survey (2013)

3. Methodology: Conceptual and Theoretical Model

The TOA-MD) model, a unique simulation tool for multi- dimensional impact assessment that uses a statistical description of a heterogeneous farm population to simulate the adoption and impacts of a new technology, a change in environmental conditions, and ecosystem services supply on current farm systems, is used to analyse the data.

The model, as used in this study, is designed to simulate what would be observed if it were possible to conduct a controlled experiment in which a population of farms is offered the choice of continuing to use the current or "base" production system (System 1), or choosing to adopt a new production system (System 2) under changed climatic conditions. Using survey, experimental and crop models data in combination with climate change scenarios, the TOA-MD model simulates and compares economic outcomes from the two systems (1 and 2) assumed to be operating under altered conditions (Antle and Valdivia, 2010).

System profiles are summarised as follows:

Suppose that a farmer at site (s) is using a production system (h) with inputs prices (p) earns returns/ha equivalent to $V_t = V_t(s, h)$ each season. When the production system changes, because of a change in technology or climate or both, expected returns at each site also change. The effect on a farm's returns of changing from system j to system k is $\omega(p, s, h) \ = \ V(p, s,) - V(p, s, h)$. Thus, if $\omega(p, s, h)$ is positive it represents the loss associated with switching from one system to another.

The proportion of farms using system 2, referred to as the adoption rate of system 2[2], is given by the cumulative distribution function $r(p, 2, a) = \int_{-\infty}^{a} \emptyset(\omega|p)d\omega$, and the share of farms using system 1 is *r*(*p*, 1, *a*) ≡ 1 – *r*(*p*,2,*a*). In addition to economic outcomes $V(a, h)$, Antle *et a*l (2014) considered other environmental or social outcomes *z*(a, h). In this case, the distribution for the sub-population using each system is the joint outcome distribution between ω and $k = v, z$ truncated according to $\omega > a$ for system 1 and $\omega < a$ for system 2 (Antle et al 2014):

$$\emptyset(\omega, k|a, h) = \ \emptyset(\omega, k \mid h)/r(a, h) \ = \emptyset(k \mid \omega, h)\varphi(\omega)/r(a, h) \qquad \ldots\ldots.(2)$$

Thus, the outcomes (economic and social/environmental) are indexed by k = v, z while systems are indexed by h = 1,2.

Antle (2011) and Antle *et al* (2014) note that $\emptyset(\omega, k \mid h)/r(a, h)$ indicates a distribution that is truncated from below by ***a*** for system 1, and truncated from above by ***a*** for system 2, whereas $= \emptyset(k \mid \omega, h)$ shows a distribution defined over the entire population. The joint distribution of ω and $k = v, z$ in a population using both systems is a mixture of the distributions defined in equation (a) with mixing proportions$r(a, h)$.

The analyses examine five key climate model scenarios – the Hadley Center Model (HADCM), the Canadian Global Climate Model (CGCM), Commonwealth Scientific and Industrial Research Organization (CSIRO) model, National Center for Atmospheric Research (NCAR) model and the Model Interdisciplinary Research on Climate (MIROC). Climate change projections from the first two scenarios (HADCM and CGCM) suggests that by the year 2030, Malian average temperatures may increase by 1°C – 2.75°C, with precipitation declining slightly (Butt *et al*., 2003).

[2] Farmers with potential access to irrigation

These model scenarios were employed in this study because Mali as an example of Sub – Saharan Africa (SSA) country has a climate which is similar to the semi-arid nature of the Lawra district. On the other hand CSIRO and NCAR (Nelson *et al*., 2009) as well as MIROC (Jalloh *et al*., 2013) GCMs predicts crop yield changes for SSA by 2050 under climate change with no adaptation. Therefore the study uses the yields changes in these models to simulate the potentials effects of Climate change in Lawra district.

The study used three staple crops in the district for the projections basically Maize, Cowpea and Groundnut. These crops were used because the GCM's employed in this study had the various yield projections which were adapted for the analysis (Nelson, et al. 2009). The two model scenarios (HADCM and CGCM) show a decrease in livestock yield of 16 and 25 percent respectively, however, in all the three scenarios of CSIRO, NCAR and MIROC the study adapted a 10 percent decrease in yield of livestock (Amikuzuno and Hathie, 2013).

Figure 2: Mean Yield Change of Crops without irrigation adaptation

Sources: Adapted from Authors Projections (Butt et al., 2003, Nelson et al., 2009 and Jalloh et al., 2013)

4. Results and Discussions

The results are disaggregated across two strata of farms – Lowland farms and Upland farms, and aggregated for the entire farm population. The results of this study is based on five model scenarios showing the economic effects of Climate change without adaptation and a two model scenario also showing the economic effect of adaptation on poverty rates of smallholder farms, farms that would gain or lose from climate change and impacts on net per capita incomes.

Mean Net Returns without and with Climate Change

Firstly, results on the projected impacts of climate change on mean net returns of upland and lowland smallholder farmers without and with climate change are shown in Table 2.

Table 2: Projected Mean Net Returns (GHS) (without and with climate change), and no adaptation

Scenarios/ Stratum	Without climate change	With climate change	% change
HADCM			
Upland Farms	14540.84	2140.82	-85
Lowland Farms	14652.47	1959.94	-87
CGCM			
Upland Farms	14505.59	2023.4	-86
Lowland Farms	14613.25	1810.18	-88
CSIRO			
Upland Farms	14530.17	2143.3	-85
Lowland Farms	14625.15	1948.96	-87
NCAR			
Upland Farms	7649.15	722.79	-91
Lowland Farms	9358.77	955	-90
MIROC			
Upland Farms	14608.2	2446.65	-83
Lowland Farms	14714.6	2415.73	-84

(Source: Simulation Results, 2015)

The projected mean net returns by all the five GCM's indicate a decrease with climate change. This means that mean net farm returns are sensitive to climate change. Smallholder farmers in Lawra district will experience a decrease in their net revenue with climate change by 2030 (HADCM and CGCM) and 2050 (CSIRO, NCAR and MIROC) this will affects both upland and lowland farms. The effects of the decrease in mean net revenue could lead to food insecurity and malnutrition since farmers will not be motivated to produce as a result of climate change (Frayne et al., 2009).

This is particularly important because food and nutrition insecurity at the household level negatively impacts on general livelihoods. The danger of food and nutrition insecurity on sustainable livelihood development is the issue of diversion of resources. For instance, resources that might have been used to support the development of livelihoods such as education, health care, income generation and employment among others, get reallocated to ensure that basic food needs are met (Akudugu *et al*., 2012).

This also implies that urban areas in the country will also suffer the consequences because of their dependence on these smallholder farmers for their food stuffs. Thus, smallholders need to be assisted to adapt to climate change to reduce their vulnerability and increase their resilience.

Secondly, the study results on gains and losses of mean net revenue shows that smallholder farmer's in the district will continue to suffer the impacts of climate change in terms of net revenue loss if current production system is continued as indicated by all five climate scenarios in Table 3.

Table 3: Percent Gains, Losses and Net Losses, without adaptation

Scenarios/ Stratum	Gains (%)	Losses (%)	Net Losses%
HADCM			
Upland Farms (24.26)	11.31	66.39	55.08
Lowland Farms (20.71)	8.30	66.36	58.06
All farms	9.46	66.37	56.92
CGCM			
Upland Farms (23.95)	11.14	67.05	55.92
Lowland Farms (20.37)	8.14	67.20	59.06
All farms	9.29	67.14	57.85
CSIRO			
Upland Farms (24.22)	11.28	66.41	55.13
Lowland Farms (20.59)	8.23	66.48	58.26
All farms	9.40	66.45	57.06
NCAR			
Upland Farms (24.22)	12.15	71.55	59.40

Lowland Farms (22.40)	10.22	70.25	60.03
All farms	10.89	70.70	59.81
MIROC			
Upland Farms (24.96)	11.69	64.75	53.06
Lowland Farms (21.56)	8.65	64.04	55.38
All farms	9.82	64.31	54.49

NB: Adoption Rates (%) in parenthesis

(Source: Simulation Results, 2015)

All Farms will suffer great losses across all five GCM's between 66% and 67% (HADCM and CGCM); also between 64% and 70% (CSIRO, NCAR and MIROC) as compared to gains of 9% (HADCM and CGCM); 9% and 10% (CSIRO, NCAR and MIROC) by 2030 and 2050 respectively. While net losses are estimated to be ranging from 57% and 68% (HADCM and CGCM); 54% and 60% (CSIRO, NCAR and MIROC).

This implies that not all farms in Lawra district will be affected with the impacts of climate change in the same proportion. However adoption rates of base technology under a changed climate will range between 23% and 25% for upland farms whiles lowland farms will have an adoption rates also ranging between 20% and 22%. These adoption rates represent farms that are gainers from climate change.

Secondly, the study estimated per capita income of smallholder farmers in the district as shown in Table 4. Scenarios across four out of five GCM's show that without climate change lowland farms will have an estimated per capita income of GHS 2400 whiles NCAR shows an estimate of GHS 1630.47. On the other hand, upland farms will also have an estimated per capita income of GHS 2100, again NCAR shows an estimate of GHS 1218.27.

Table 4: Per Capita Income (GHS)

Scenarios/ Stratum	Without climate change	With climate change	% change
HADCM			
Upland Farms	2119.78	309.19	-85
Lowland Farms	2402.90	334.09	-86
All farms	2247.18	320.39	-86
CGCM			

Upland Farms	2115.17	297.37	-86
Lowland Farms	2397.18	317.28	-87
All farms	2242.07	306.33	-86
CSIRO			
Upland Farms	2118.38	309.44	-85
Lowland Farms	2398.91	332.86	-86
All farms	2244.62	319.98	-86
NCAR			
Upland Farms	1218.27	166.5	-86
Lowland Farms	1630.47	221.3	-86
All farms	1403.76	191.16	-86
MIROC			
Upland Farms	2128.59	339.96	-84
Lowland Farms	2411.96	385.25	-84
All farms	2256.11	360.34	-84

(Source: Simulation Results, 2015)

Also, per capita income of farms both lowland and upland farms would range from 190GHS to 360GHS as a result of climate change as shown in table 4.

The results in figure 3 show that climate change will affect poverty rates of most upland farms across all the 5 GCM's. Poverty rates of upland farms will range between 49% and 80% while's lowland farms poverty rate with climate change will also vary between 45% and 68% in the district.

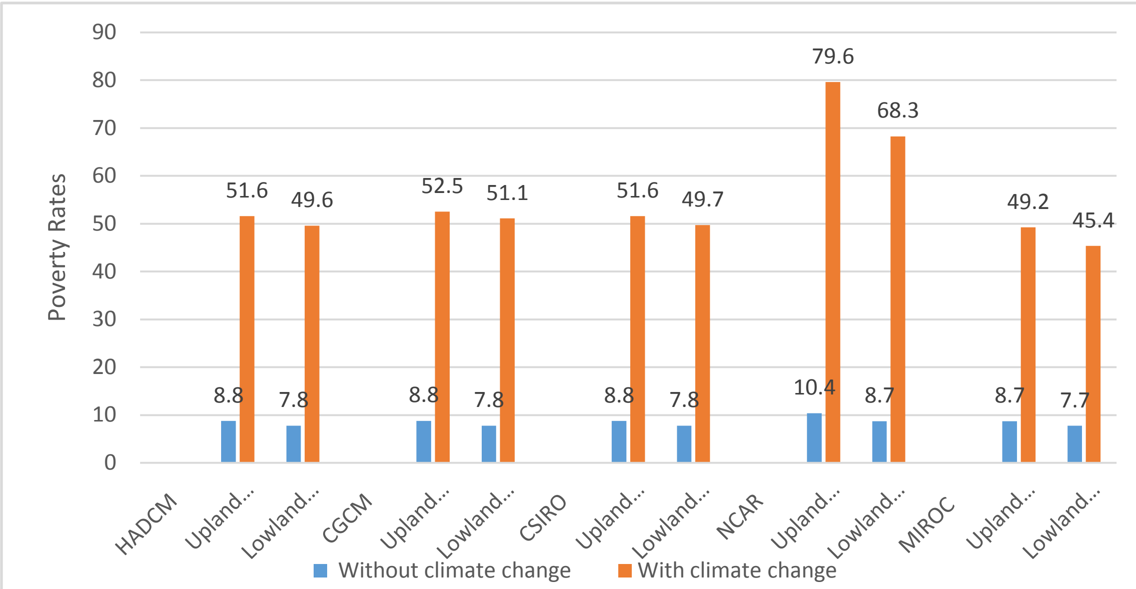

Figure 3: Poverty Rates (%) of Upland and Lowland Farms

Source: Simulation Results (2015)

However, figure 4 shows an estimated poverty rate of 8% (HADCM and CGCM) and 8% to 10% (CSIRO, NCAR and MIROC) without climate change. In other words without climate change poverty rates in the district among smallholder farmers will range from 8% to 10%. But with climate change in 2030 and 2050 poverty rates will rise to 51% to 52% (HADCM and CGCM) and 47% to 75% (CSIRO, NCAR and MIROC) scenarios respectively.

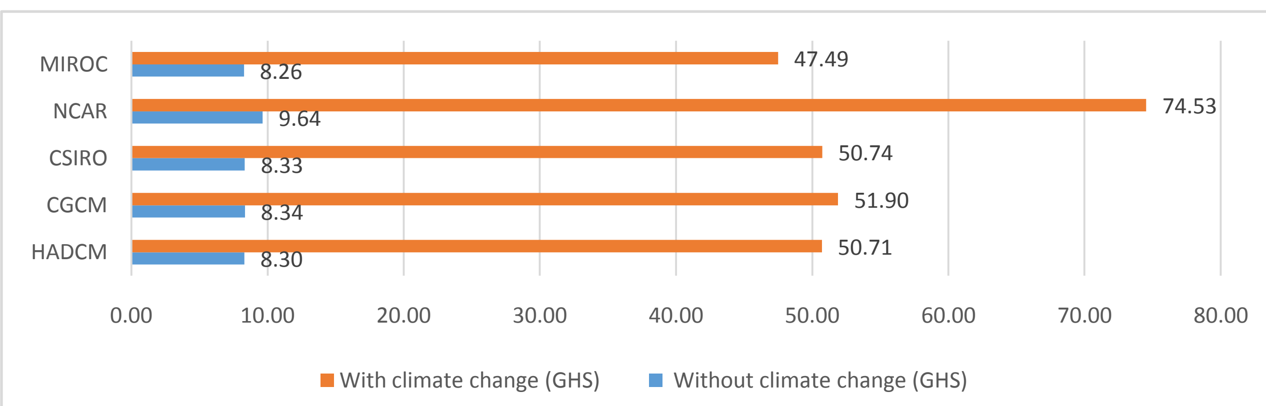

Figure 4: Poverty Rates (%) of All Farms
(Source: Simulation Results, 2015)

Wide spread poverty will remain a challenge under climate change in the Lawra district. This is because, the impacts of climate change in 2030 and 2050 will mean that majority of the population in the district who are smallholder farmers will fall between the estimated poverty rates ranging from 47% to 75% depending on less 1 US dollar per day.

Impacts of Climate in Future with Adaptation

Several studies have shown that the adverse effects of climate change on agriculture could be mitigated through adaptation. The following results are based on NCAR and CSIRO climate scenarios under irrigated Maize, Cowpea and Groundnut for 2050 climate projections adapted from Nelson *et al*., (2009).

Table 5 presents projected impact on mean net returns of adaptation to climate on upland and lowland farms.

Table 5: Projected Mean Net Returns in GHS (with and without adaptation)

Scenarios/ Stratum	Without Adaptation	With Adaptation	% change
CSIRO			
Upland Farms	2908.53	5053.85	74
Lowland Farms	3542.04	5318.91	50
All farms	3288.63	5212.88	59
NCAR			
Upland Farms	2676.37	5084.85	90
Lowland Farms	3240.07	5391.26	66
All farms	3014.59	5268.7	75

(Source: Simulation Results, 2015)

In the north, dependence on rain fed agriculture across the country makes smallholder farmers in Ghana particularly vulnerable to climate change. The results above reveals that without adaptation to climate change, smallholder farmers projected mean net income will range between 3288.63GHS (CSIRO) and 3014.59GHS (NCAR) under all farms scenarios because of the high level of dependence on agriculture for livelihoods and the district is also sensitive with low and decreasing rainfall and frequent, recurring droughts, as observed by farmers over a long period of time.

On the other hand, adaptation (irrigation) will potentially increase mean net revenue of smallholder farmers to between 5212.88GHS (CSIRO) and 5268.7GHS (NCAR) under all farms scenario by 2050. This observation seems to agree with the findings by Calzadilla *et al* (2009) that irrigation has the capacity to increase returns to poor households in terms of their physical, human, and social capital and enables smallholders to achieve higher yields and revenues from crop production.

Table 6 shows results on the adoption rates for system 2 (changed climate; adapted technology). It can be observed that upland farms are likely to have higher adoption rates than lowland farms with an adoption rate of 56% (CSIRO); 58% (NCAR) and 55% (CSIRO); 57% (NCAR). The adoption rates for the entire population of farms will also be 56% and 57% for CSIRO and NCAR scenarios respectively. The adoption rates refer to gain from adapting to climate change.

Table 6: Gains and Losses from adaptation of Mean Net Returns

Scenarios/Stratum	Adoption Rates%	Gains%	Losses%	Net gains%
CSIRO				
Upland Farms	56	38.27	25.80	12.47
Lowland Farms	55	37.77	27.44	10.33
All farms	56	37.96	26.82	22.80
NCAR				
Upland Farms	58	42.47	25.32	17.16
Lowland Farms	57	41.84	26.75	15.09
All farms	57	42.08	26.21	15.87

(Source: Simulation results, 2015)

In table 7, the per capita income of farms per annum (with and without adaptation) is presented based on projections from CSIRO and NCAR scenarios.

Table 7: Estimated Per Capita Income (GHS) (with and without adaptation)

Scenarios/ Stratum	Without Adaptation	With Adaptation	% change
CSIRO			
Upland Farms	598.15	602.31	1
Lowland Farms	781.72	711.11	-9
All farms	680.76	651.27	-4
NCAR			
Upland Farms	567.78	605.43	7
Lowland Farms	737.66	719.23	-2
All farms	644.22	656.64	2

(Source: Simulation Results, 2015)

From table 7, it could be observed that upland farms without adaptation will have a per capita income of GHS598.15 and GHS567.78 for CSIRO and NCAR scenario's respectively. Whilst upland farms with adaptation will have a per capita income of GHS602.31 and GHS605.43 under CSIRO and NCAR scenario's respectively.

Poverty rates are expected to be lower under climate change and adaptation among smallholder farmers. The results presented in table 8 indicate that farms without adaptation particularly upland farms will have poverty rates of 25.2% and 26.9% whiles lowland farms will also have poverty rates of 19.4% and 20.7% under CSIRO and NCAR scenarios respectively.

Table 8: Poverty Rates in Percent (with and without adaptation)

Scenarios/ Stratum	Without Adaptation	With Adaptation	% change
CSIRO			
Upland Farms	25.2	21.8	-13
Lowland Farms	19.4	19.1	-2
All farms	22.5	20.6	-8
NCAR			
Upland Farms	26.9	21.5	-20
Lowland Farms	20.7	18.6	-10
All farms	24.1	20.2	-16

(Source: Simulation Results, 2015)

Note: the poverty line is equal to GHS329.68 (1$ = GHS1.35)

However, farms with adaptation will experience poverty rates of 21.8% and 21.5% for uplands and 19.1% and 18.6% for lowlands farms for CSIRO and NCAR scenario's respectively. An earlier study by Irz *et al*., (2001) observed a link between agricultural yields and poverty, as increase in crop yields led to a decrease in the number of poor people by about 0.7 per cent.

This study anticipated that lowland farms will have greater future access to irrigation and by extension higher reduction in future poverty rates. The results seem to agree with the findings by Amikuzuno (2013) that intensive and expanded (I&E) scenario had a less profound effect on the simulated poverty rates among farmers in the WVB. Thus, the great variation in the base system variables especially off-farm income coefficient of variation (CV) might have influenced the projected net-income and poverty rates among farms in upland and lowland areas.

5. Conclusions, Recommendations and policy implications

The study presents empirical evidence of the economic impacts of climate change on smallholder farmers in the Lawra District of Ghana. The (TOA-MD) Model was used to simulate crop yield projections from five climate model scenarios viz. the HADCM, CGCM, CSIRO, NCAR and MIROC for lowland and upland farms.

The study concludes that there will be decrease in farmers' net revenue in the face of climate change without adaptation with estimated net losses in net revenue from 54% to 68% across the five GCM scenarios. With adaptation to climate change in the form of irrigation adoption, net revenues per farm and per capita incomes are expected to increase from 10% to 17% and 1% to 7% respectively from their baseline level; while poverty rates will decline from 8% -16% for all farms. In addition, the percent gainers due to the adoption of a water-saving irrigation practices by farmers will increase by 56% and 57% from their levels under the CSIRO and NCAR scenarios respectively.

Based on the above findings, the study recommends the adoption of water-efficient irrigation strategies as adaptation measures to bridge the already existing water insecurity gap in this semi-arid GSA of Ghana. Ultimately, policy measures which promote greater access to irrigation could go a long way to improve per capita farm incomes and net revenues; and reduce poverty levels among smallholder farmers in both lowland and upland farms under a prospectively drier midcentury climate in the Lawra District. The study also recommends further research on modeling potential impacts of future climate change in the district using drought resistant crop yield projections.

6. REFERENCES

Adiku, S.G.K Dilys S. MacCarthy, D. S., et al., (2015) Climate Change Impacts on West African Agriculture: An Integrated Regional Assessment (CIWARA). *World Scientific Books.* Imperial College Press. Pp. 25-73

Amikuzuno, J. and Hathie, I. (2013) Climate Change Implications for Smallholder Agriculture and Adaptation in the White Volta Basin of the Upper East Region of Ghana. Impacts World 2013, International Conference on Climate Change Effects, Potsdam May 27-30

Antle, J. (2011a). Parsimonious multi-dimensional impact assessment. *American Journal of Agricultural Economics*, 93(5), 1292-1311.

Antle, J.M. and Valdivia R.O. (2006) Modelling the supply of ecosystem services from agriculture: a minimum-data approach. The Australian Journal of Agricultural and Resource Economics, 50, pp. 1–15

Antle, J.M. and Valdivia R.O. (2010). TOA-MD Version 4: Minimum-Data Tradeoff Analysis Model. www.tradeoffs.oregonstate.edu.

Antle, J.M. and Valdivia R.O. (2011) TOA-MD Version 5: Minimum-Data Tradeoff Analysis Model. www.tradeoffs.oregonstate.edu.

Asafu-Adjaye, J. & Mahadevan, R. (2015) Exploring the potential for green revolution: a choice experiment on maize farmers in Northern Ghana. African Journal of Agricultural and Resource Economics Volume 10 Number 3 pages 207-221

Butt, T.A., McCarl, B.A., Angerer, J., Dyke, P.T., Stuth, J.W. (2003) Food Security Implication of Climate Change in Developing Countries: Findings from a Case Study in Mali. Published PhD Dissertation, Department of Agricultural Economics, Texas A&M University, and College Station, TX.

Calzadilla, A., Rehdanz, K. and Tol, R.S.J. (2008) Water scarcity and the impact of improved irrigation management: A CGE analysis. Research unit Sustainability and Global Change FNU-160. Hamburg, Germany: Hamburg University and Centre for Marine and Atmospheric Science.

Calzadilla, A., Zhu, T., Redhanz, K., Tol, R. S. J. and Ringler, C. 2009. How Can African Agriculture Adapt To Climate Change? Insights from Ethiopia and South Africa. Economy wide Impacts of Climate Change in Sub-Saharan Africa, IFPRI Discussion Paper No. 873 (Washington, DC: International Food Policy Research Institute, 2009).

Claessens, L., Antle, J.M., Stoorvogel, J.J., Valdivia, R., Thornton, P.K., Herrero, M. (2012) A method for evaluating climate change adaptation strategies for small-scale farmers using survey, experimental and modeled data. *Agricultural Systems*, 111. pp. 85-95.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., &Yesuf, M. (2008) Analysis of the Determinants of Farmers' choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. *International Food Policy Research Institute.* Washington, DC.

District Planning Co-Ordinating Unit (DPCU) (2009) Retrieved from Ghana Districts.com

Frayne, B., Battersby-Lennard, J., Fincham, R., and Haysom, G. (2009) Urban Food Security in South Africa: Case Study of Cape Town, Msunduzi and Johannesburg. Development Planning Division Working Paper Series No.15, DBSA: Midrand.

Ghana Statistical Services (2016) Retrieved from www.stats.ghana.gov.gh/gdp.

Ghana Statistical Service (2012) 2010 Population & Housing Census Summary Report of Final Results, Accra, Ghana.

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

Irz, X., Lin, L., Thirtle, C. and Wiggins, S. (2001) Agricultural growth and poverty alleviation. *Development Policy Review* 19: 449-466.

Jagermeyr, J. Gerten, D., Schaphoff, S., Heinke, J., Lucht, W. & Rockstrom, J. (2016) Integrated crop water management might sustainably halve the global food gap. *Environ. Res. Lett*. 11 (2016) 025002. Online at: http://iopscience.iop.org/1748-9326/11/2/025002

Jalloh, A., Nelson, G.C., Thomas, T.S., Zougmore, R., Roy-Macauley, H. (2013) *West Africa agriculture and Climate Change: a comprehensive analysis*. IFPRI Research Monograph, Washington DC: International Food Policy Research Institute. IFPRI press.

Jones, P.G. and Thornton, P.K. (2009) Croppers to livestock keepers: Livelihood transition to 2050 in Africa due to climate change. *Environment Science and Policy*, 12(4): 427 – 437.

Muller, Gattinger and Meier, (2016) Adaptation to Climate Change – There is Much More to It, Rural 21 Newsletter, **www.rural21.com**

Nelson GC, Rosegrant MW, Koo J, Robertson R, Sulser T, Zhu T, Ringler C, Msangi S, Palazzo A, Batka M, Magalhaes M, Valmonte-Santos R, Ewing M, Lee D. (2009) *Climate change: Impact on agriculture and costs of adaptation.* Washington, DC: International Food Policy Research Institute. (Available from http://www.ifpri.org/publication/climate-changeimpact- agriculture-and-costs-adaptation).

Shepherd, A., Gyimah-Boadi, E.,Gariba, S.,Plagerson, S.,and Musa, W.A. (2005) 'Bridging the North-South Divide in Ghana? Background Paper for the 2006 World Development Report,' World Development Report 2006: Equity and Development. Washington, DC: The World Bank.

Smit, B., Burton, I., Klein, R.J.T. and Wandel, J. (2000) "An Anatomy of Adaptation to Climate Change and Variability." *Climatic Change* 45 (1):223–251.

Vermeulen , S.J. Aggarwal , P.K.. Ainslie, A Angelone, C. Campbell, B.M. Challinor , A.J. Hansen, J.W., Ingram , J.S.I, Jarvis, A. Kristjanson , P. Lau , C. Nelson, G.C. Thornton , P.K. and Wollenberg E. (2012) Options for support to agriculture and food security under climate change. *Environmental Science and Policy* 15 (2012) 136-144

Zoellick, R. B. A. (2009) Climate Smart Future. The Nation Newspapers. Vintage Press Limited, Lagos, Nigeria. Page 18.