The economic impact of climate change on small farms in Nigeria: A Ricardian approach

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Abstract
The study employed econometric techniques to generate information on the aggregate net economic damages and benefits of climate change on farm value. Such information is crucial to shed light on how much to compensate the sector. The study was limited to cross sectional analysis of farms at a point in time and therefore a static analysis. Climate change impact was found to be huge for the whole country with impact variation across agricultural zones. It concludes that the ability of smallholder farms to sustain continual output of crops for local and regional markets depend critically on effective adaptation measures that seek to maintain optimal conditions of climate for agricultural production and government effective response.

Key words: Climate change; Ricardian valuation; sustainable adaptation practices; agricultural resources; farm productivity and governance

Introduction

Recent studies have implicated agriculture as one of the sectors that will be most impacted by climate change in Nigeria (Odjugo, 2010; Anuforom, 2010; Olaniran, 2002; Adejuwon, 2006 and Obioha, 2009). This is plausible because agriculture and climate are intrinsically tied particularly in rain fed agriculture of Nigeria. Land is a critical factor in the sector and has multiple functionality such as source of income, food production, employment and environmental services (including wide products and bio-diversity). The biophysical environment of land is affected through heavier rains and persistent droughts, increased soil erosion and water runoff. Higher temperatures also mediate faster loss of soil moisture and prolonged droughts and increasing temperatures create favourable conditions for pest and diseases to multiply (Hisali et al., 2011). Such conditions influence land use and the cost of production. Theoretically land owners are rational and would cultivate the most fertile parcel that would yield the highest profit rather than on [1]marginal lands. The use of adaptation measures to enhance the productivity of land, though a positive response, might also conflict with environmental concerns increases the long term cost of climate change on farm lands. The study employed econometric techniques to generate information on the aggregate net economic damages and benefits of climate change on farm value.Estimating the impact of climate change is an important tool for policy makers to measure the phenomenon from an economic perspective. Also to derive information about the opportunity to act in order to reduce the negative impacts and to take advantage of positive ones(Gambarelli and Goria, 2004).

[1]Marginal lands are lands of low quality and earn no rent because if any rent were charged for it, there would be no takers. The rent on a parcel of land is the difference between the cost of producing the output on that land and the cost of producing it on marginal land.

Determining the economic value of climate conditions, like other environmental goods, often poses serious methodological challenge. The use of monetary measures to value climate change impact has been controversial since the 1990s. The first argument against it is the uncertainty regarding the process of global warming and the consequential effect on human and natural systems. Second is the large temporal lag between causes and impacts. The third is the difficulty in isolating climate from other influences of land use. Land productivity is also affected by other factors such as population pressure that is well established from the time of Malthus. Studies in support of Malthus views population pressure as leading to land degradation. There are also studies that support the view that population growth leads to intensification of agricultural systems. Population pressure stimulates changes in land use cropping patterns, traditional modes of farming such as shifting cultivation, and the extent of land use for agriculture.

The hedonic pricing of environmental attributes approach has been widely applied in empirical works. Several studies have used this approach to value the environmental conditions of land (Maddison (2000) Miranowski and Hammes (1984), Brown and Barrows (1985) and Ervin and Mill (1985) Palmquist and Danielson (1989). A subset of the hedonic application is the Ricardian land use spatial econometrics used by Mendelsohn et al.(1994), Dinar et al. (1998) and Evenson and Alves(1998) to measure the impact of climate on agriculture. The Ricardian approach specifically captures the full range of human response possibility. However it is fraught with another problem of the valuation of land. Vuuren (1975) argued that the prevailing market prices of land connote short-run value rather than the long-run value of land. That prevailing market prices of land deviate considerable from theoretical long-run land values because of possible dis-equilibrium in existing land markets arising from rapid changes in technology and urbanisation. Some authors have argued against the feasibility of using market price of land in developing countries. It is argued that agricultural land is hardly sold at all, and where it exists considerations of investment security and prestige may push the price well above the market price. Studies have also used the rental value of the land. Other measures used are farm revenue or net revenue. The limitation in each of these land value concepts, suggest some arbitrariness in the choice of land value concept (Mendelsohn and Dinar, 2009).

This study is distinguished from other studies in using the estimated value of land by farm owners themselves over a large geographical area. In this way help to reduce the miss match problem when linking plot level economic observation with climate observations collected over larger geographical space. This is practicable in Nigeria given the problem of sparse weather stations. The paper is divided into six sections. The first section presents background information on crop land use and factors influencing crop land use. Section two and three discuss the theoretical framework, model specification and estimation while section four presents the results. Section five presents the implication for land management practices while section six concludes.

Nature of agriculture and land use in Nigeria

Nigeria's agricultural system covers 77% of total land area estimated at about 91.07 million hectares, while 13% is forests and woodland (Eboh et al., 2004). Of this amount estimated at 74 million hectares in 2005 (FAOSTAT, 2009), 32 million hectares is arable crops, 39.2 million hectares permanent pasture and 3 million permanent crops (Okoro and Ujah, 2009). The climate is humid tropical and diverse arising from spatial differences in a number of features such as topography, relief, geology, meteorology, vegetation, soils, population density, ground water potentials and human activities. The farming system is diverse but consists of crop farming, livestock farming, poultry farming and fishery. Crop farming appears the dominant system. (National agricultural sample survey (NASS) (2012).

Except for livestock which is mostly on free range, land is often allocated to one or more crops as a strategy for food self-sufficiency and security at the household level. There are more than seventeen million (17,010,754) small crop farm holders in Nigeria. Large corporate crop farmers exist, but are few and made up of private limited company, cooperative and government farms (NBS/CBN, CCC, 2012). Smallholder crop farm as the name implies is a production system operated at a small scale of less than 2 hectares and of rain fed technology. Ownership consists of an individual member of the household, two or more members of the same household and members of different households. The cropping pattern in most cases is mixed consisting of cereal/legume systems in the northern part and mixed root/cereal cropping systems in southern Nigeria(NFRA/ NAERLS, 2009).The cropping system includes small scale rain fed system, low-lying fadama and large scale irrigation farming systems (National agricultural sample survey (NASS) (2012).

Table 1.2 presents the distribution of land area cultivated in hectares for selected food crops in Nigeria across years. The table reveals 15% expansion of land area over 1995 – 1998 to 2007 – 2010 (From 25,954,000 to 29,846, 000 hectares). Land area under cotton, maize and cassava almost doubled between 2007 – 2010 relative to the period 1995- 1998. While 20.67% of cropped land was devoted to millet production during the period 1995 -1998, it declined to 13.13% over the period 2007 – 2010. Sorghum declined slightly from 19.99% in the second half of the 1990s to 17.35% over the period 2007 – 2010. Maize crop shows an increasing trend from 11.80% during the 1995 -1999 period to 16.77% over the period 2007 – 2010.

Table 1. **Land area cultivated in hectares for selected crops from 1995-2010 in Nigeria**

	1995 – 1998	**1999- 2002**	**2003 – 2006**	**2007 – 2010**
CROPS	**Ha ‘000**	**Ha ‘000**	**Ha ‘000**	**Ha ‘000**
MILLET	5365.35	3673.91	3847.535	3917.433
SORGHUM	5188.255	4301.143	4018.905	5178.883
GROUND NUT	2281.655	2023.988	2185.273	2308.703
COW PEA	3023.238	2456.02	2206.508	3122.72
YAM	2165.168	2102.828	2086.13	2981.53
COTTON	309.05	303.29	265.17	591.0767
MAIZE	3063.573	3126.66	3291.478	5005.81
CASSAVA	2299.605	2415.203	2587.965	3706.383
RICE	1482.918	1552.535	1443.038	1986.523
MELON	489.4375	410.0975	510.615	612.85
COCOYAM	286.195	266.9275	304.73	434.7067

Area planted	**25954.44**	**22632.6**	**22747.35**	**29846.62**

Source: NFRA/ NAERLS, 2009

Materials and methods.

Theoretical framework

The Ricardian framework posits that the value of land represents the capitalized values of expected future earnings from the best use of land. That land values are correlated with local climate conditions such as rainfall, temperature, soil quality and that knowing the variation across farms provides information on how farmers have adjusted to climatic change and the implication on land values (Darwin, 1999, Reinsborough, 2003). This model was pioneered in Mendelsohn et al., (1994) and the essence is expressed as follows:

$$V_{LF} = \int_0^\infty P_{LF^{-rt}} dt = \int_0^\infty \frac{[P_i Q_i - C_i(Q,P,F)]e^{-rt}}{L_i(F)} dt (1)$$

WhereV_{LF}, denotes the value of land (L) tied to the environmental attributes F and correlates with the annual cost or rent P_{LF}that accumulates over time.The production function links markets with climate input (F) in the production of good Q. It accounts for both the direct effects of climate on agricultural production and the indirect effect resulting from the substitution or adaptation of farming activities. A number of assumptions underlie the framework. It assumes profit maximization and a competitive economy where output and input markets function perfectly and land used for a purpose is the best use for that purpose. It assumes full adaptation by land owners to the prevailing climate conditions without adjustment costs other than the cost of the land. The framework does not consider other changes such as extreme weather events and climate variability other than change in average temperature and precipitation. Also assumes that input and output prices are unchanged and that farms adjust their market inputs and outputs to adapt as the environment changes. The study relied on the general household survey data on smallholder farms collected by the National Bureau of Statistics (NBS) in 2010 and baseline climate observations from 1950-2000 and projections (2000-2050) of the World Climate Data Base (WCDB). Complementary data on population, soil and altitude for 774 Local Government Areas (LGA) sourced from National Population Commission (NPC) and Food and Agriculture Organisation (FAO). Variables from NBS were farm value, farm revenue, crops cultivated, land size, area planted, household size and age. Variables from WCDB were Mean Temperature (MT) and Mean Precipitation (MP) for various seasons

To specify the model empirically, climate-land productivity regression is specified whereby land value per unit hectare is regressed on climate and non-climate factors as expressed below.

$$landvalue_i = \beta_0 + \beta_{1i}F + \beta_{2i}F^2 + \beta_{3i}Z + \beta_{4i}S + \varepsilon_i (2)$$

Where F and F^2 denotes the linear and quadratic specification of various climate measures respectively, Z the soil quality variables and S the socio economic variables. $\beta$and ε represent the coefficients and error terms. The error term follows the classical assumption of an independently and identically distributed (iid) normal error distribution. Farm value as perceived by farmers themselves is used as the dependent variable. F denote the key explanatory variables defined as average temperature and precipitation. They are categorised into various season. Z represents variables such as percentage clay soil, percentage sandy soil and percentage silt soil. Population density, latitude and altitude. S denote socio economic characteristics of farmers. In the date set used the socio economic characteristics are many and in order not to make the model noisy, index were created. The functional form of the model is often linear or semi log specification with a quadratic specification for the climatic variables and linear function for all other determinants. Both functional forms were explored for the best fit. The unit of analysis is the area council level. This reduces the challenge of linking farm level economic observation with observations collected over larger geographical space such as climate and soil variables. To control for aggregation bias and to capture the role of social interactions in the process of land use, Mendelsohn suggested the use of crop revenue weighting approach. Thus weighted least square was used to estimate the equation in STATA 11 package. Marginal impact is calculated as:

$$\frac{\partial LandValue}{\partial f_i} = (LandValue)^* b_{1i} (3)$$

Where b_{1i} is the estimated coefficient for variablef_i. With squared terms included the marginal effect following the documentation in Mendelsohn et al.,(2009) is calculated as:

$$\frac{\partial LandValue}{\partial f_i} = (LandValue)^* (b_{1i} + 2b_{2i} f_i)(4)$$

The annual marginal values are calculated by summing both the linear and squared coefficients and average climate values (*f*) and then multiply by the expected value of the farm. The model estimates the marginal impact of a unit change in climate and used to simulate the potential impact of future climate change on land value. To estimate the potential changes in a future time, the simulated economic impact due to long term changes in climate is defined as the difference between land value under the present climate, and the expected value of the same indicator assuming future climate change.

Results

Pattern of Rainfall.

The figure below presents 30 years average monthly values for rainfall across five [2]agro ecological zones. The Sahel agro ecological zone is located in the extreme north eastern part of the country, the Sudanese Sahel (Northwest), Guinea Sudanese (North central),savannah zone (South West) is a kind of transition zone between the forest and guinea Sudanese zone and the forest zone (South east).In the figure, rainfall pattern follows a decreasing gradient from forest to Sahel.

[2]The five agro ecological zones are distinguished following the natural variation in climatic conditions and vegetation. On the basis of topography, mountainous climate, the upland and low lying flood plains have also been distinguished.

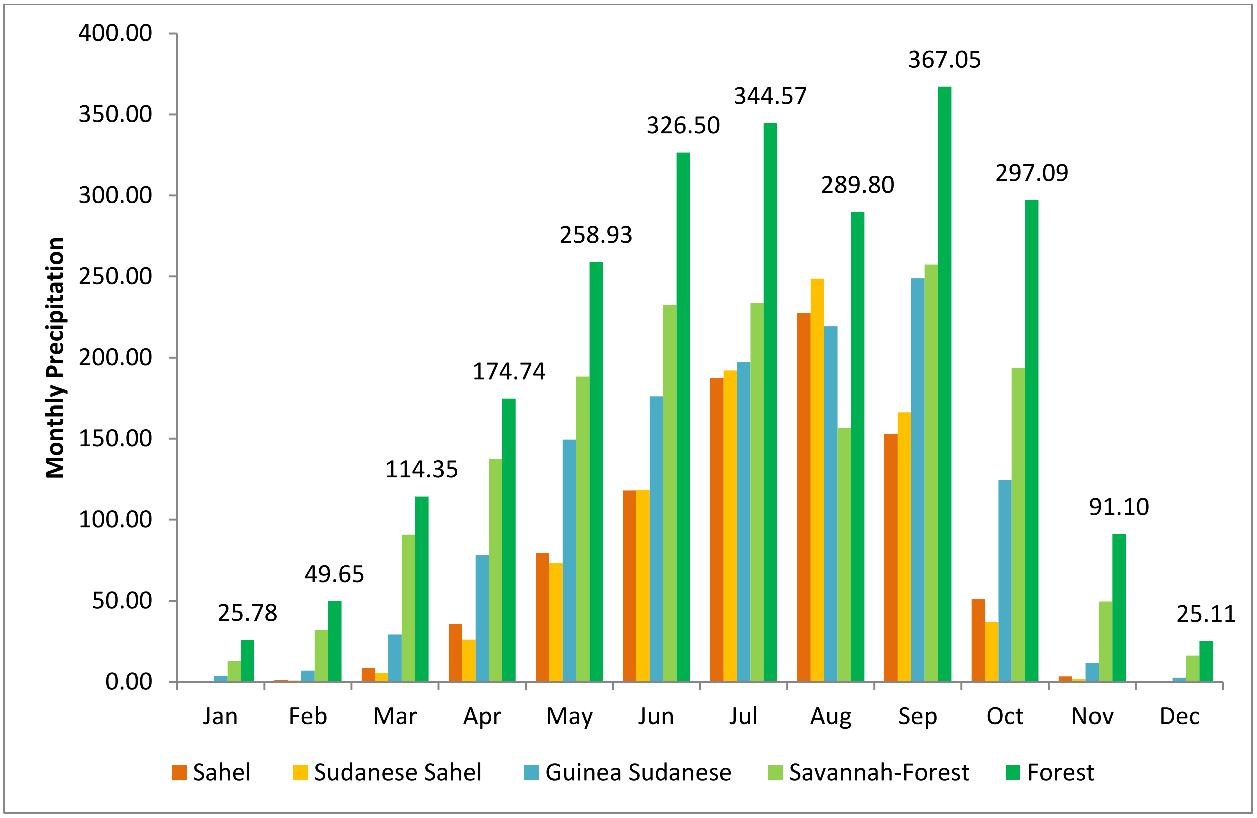

Figure1: Rainfall pattern

The highest average rainfall is observed in the Forest agro ecological zone during the months of June, July and September with respective values 326.50mm/mo, 344.57mm/mo, 367.05mm/mo. Accordingly, The months of June – September is often the peak of rainfall with a slight drop in the month of August. April to October period is regarded as the wet growing season. The Forest agro ecological zone experiences the highest amount of rainfall during this season, followed by savannah/forest while the least rainfall is experienced in the Sahel agro ecological zone. As shown in the figure, there is little or no rainfall for up to 9 months in Sahel agro ecological zone compared to the forest zone where even the little rainfall is much higher than in Sahel and Sudan Sahel zones. November to March period is also regarded as dry season. September to November period can be viewed as a kind of transition between the wet season and the dry season where most harvesting and dry season planting takes place. March to May period in the southern part in particularly, represents the period of land preparation and planting. It also marks the onset of rainfall in the southern agro ecologies. Late onset of rainfall often ranges from mid-march to late June or early May to late July in northern ecologies (Takeshima, 2012).

Absolute change in the pattern of monthly precipitation (Hadley low emission prediction)

The table below presents absolute change in average monthly rainfall by agro ecological zones. The absolute change in rainfall is calculated as the difference between the baseline climate and Hadcm3 projections for 2050 under the low emission scenario. Deficit in rainfall is expected in the Sahel agro ecological zone across all seasons with high severity in March, April, May, June and October while the months of July, August and September are expected to be moist. Deficit in rainfall is also expected in Sudan Sahel but not as severe as in Sahel. Much rainfall is expected in Guinea savannah across all the months with substantial changes in rainfall in the months of August, September and October by 35%, 52% and 32% respectively. Deficit in rainfall is also expected in the Forest and savannah/forest agro ecological zones in some of the months with severe increases in rainfall in November and December.

Table 3: Absolute change in monthly precipitation

	Sahel	Sudan Sahel	Guinea Savannah	Savannah	Forest
January	-0.33	-0.02	1.39	0.47	-3.44
February	-0.98	-0.02	3.38	-0.40	-5.37
March	-6.73	-0.84	6.27	-7.88	-5.14
April	-15.73	-6.93	0.02	-24.99	-36.98
May	-13.31	0.35	9.05	-15.35	-32.43
June	-10.67	8.46	3.10	-26.72	-47.19
July	57.84	40.30	5.79	-25.30	-42.78
August	83.12	52.55	35.75	-2.52	-24.44
September	41.42	71.10	52.64	19.78	-6.15
October	-15.27	-2.34	34.94	-2.92	-22.14
November	-1.85	-0.05	9.62	3.51	8.67
December	-0.38	0.01	2.37	0.96	0.78

Source: underlying data from World Clim Data Base

Temperature pattern and absolute change

The table below shows the distribution of mean temperature across zones. There appears little variation in temperature but the months of March – May have highest temperature. The absolute change in mean monthly temperature is presented in table 2 below. As shown in the table, mean temperature on the average is expected to change across all the zones. Savannah agro ecological zone is expected to have a cooler climate in all the months of the year compared to Sahel. The Sahel is expected to have the hottest climate with an average annual change in temperature by 1.72 centigrade. This is followed by Guinea Savannah and Forest agro ecological zones with temperature changes of 1.29 and 1.25 centigrade respectively.

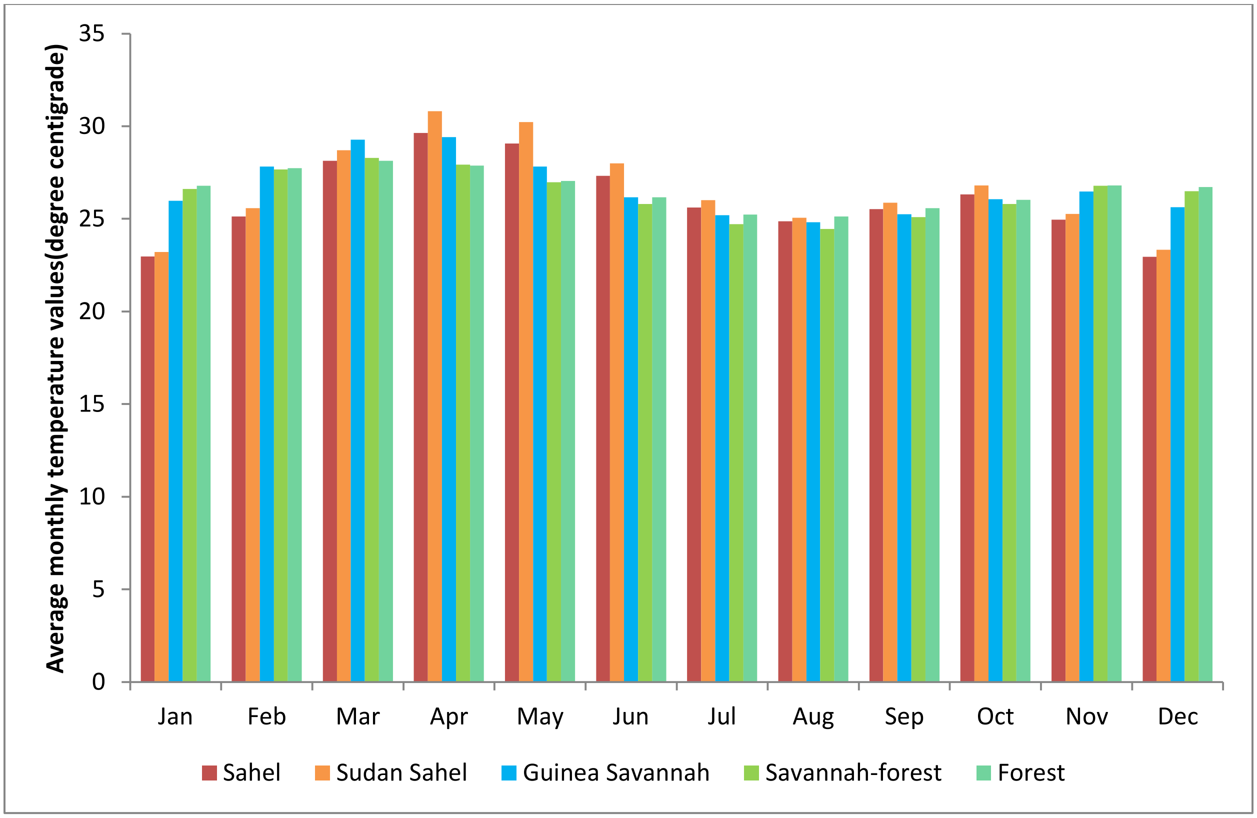

Figure2: Temperature pattern

Table 4: 30 years absolute change in average temperature values by agro ecological zones (2050 prediction had26)

	Sahel	Sudan Sahel	Guinea Savannah	Savannah-forest	Forest
January	1.18	0.88	1.70	-0.11	1.43
February	2.07	1.26	1.76	-0.17	1.34
March	1.88	1.03	1.24	-0.34	1.10
April	1.81	0.84	0.97	-0.22	1.26
May	2.24	1.59	1.08	-0.19	1.25
June	2.20	1.61	1.31	-0.02	1.33
July	1.46	0.89	1.14	-0.23	1.19
August	0.75	0.58	1.04	-0.33	1.08
September	1.44	1.25	1.19	-0.24	1.14
October	1.60	1.12	0.97	-0.32	1.14
November	2.30	1.54	1.36	-0.30	1.30
December	1.71	1.19	1.73	0.05	1.44
Average	1.72	1.15	1.29	-0.20	1.25

Source: underlying data from World Clim Data Base

Mean distribution of key economic variables across agro ecological zones

The table below provides the mean distribution of key economic variables across agro ecological zones. The variables are farm size and land value. From the table, the average farm size for the whole country ranges from 2.7 hectares on the average to 7.41 hectares maximum. The upper range is the same across all agro ecological zones except for forest zone where the upper range of farm size is 4.71 hectares maximum. In Sahel and Sudan Sahel zones, the farm sizes are respectively 3.84 hectares and 3.19 hectares above the average for the whole country. In Guinea savannah zone, the farm size is 2.92 hectares higher than the average for the whole country and that for savannah/forest (2.57 hectares). From the table the mean land value for the pooled data is 194693.3 naira and varies from a minimum of 10,714.29 naira to a maximum of 1,619,433 naira per hectare. The average for Guinea Savannah zone is 239,528.9 naira and ranges from 195,186.5 to 1,043,536 naira per hectare. For Sahel and Sudan Sahel, the mean land values are respectively 91,362.92 naira and 100,030.9 naira per hectare. For forest and savannah/forest, the mean values are respectively 299,329 naira and 349,025.6 naira per hectare respectively.

Analysis of coefficients

This section examines the Ricardian regression estimations for the pooled and across zones. Several regression trials were carried out to arrive at the appropriate functional form. In the first regression experiment, climate variables (climate only model) with a linear quadratic specification were experimented. In the second experiment, climate and non-climate variables (full model) with a linear quadratic specification as well as climate interaction terms were experimented. To control for aggregation bias, share of crop land cultivated was used as weights initially but crop revenue weighting approach showed more consistent results and therefore used for all the estimations. In the climate only model, only 11 variables were significant at $p<0.05$. The model explained between 7% and 1% of the variance in farm value and with an F-statistic at 0.88 suggesting that the fitness of the model was not statistically significant ($p>0.05$). When both climate and non-climate variables were included with the same linear quadratic form, the F statistics increased from 0.88 to 2.78 while the variance explained increased from 7% to 35%. The number of significant variables however reduced from 11 to 4. In the third experiment, the log linear specification with climate interaction terms was applied. Of a total of 31 variables included, the number of significant coefficients increased to 20. The R-squared for increased to 90% and the F (31,264) statistics at 48.36 was significant. Using the log linear quadratic specification, the table below presents the coefficients and the t-statistic of the Ricardian model. The sign of the coefficients are consistent with apriori expectation. As shown in the table, the coefficients of the quadratic and linear temperature and precipitation measures showed opposite signs in most cases particularly for temperature. The sign of the quadratic coefficients reveals the shape of the relationship between climate and land value. The negative sign reflects a hill shaped relationship while the positive sign reflects a U- shaped relationship.

Effect of temperature

For the pooled data (WC, the whole country), the sign for the linear and quadratic temperature coefficients for September-November, June-August and December-February growing seasons were respectively negative and positive and significant at $p< 0.05$. The findings suggest a hill shape relationship between temperature and land value. Meaning that there is a maximum level of temperature in which either more or less will affect optimal land use (see Mendelsohn, 1994).

Effect of precipitation

For the pooled data (WC), all the quadratic coefficients for all the growing seasons were negative and significant at $p<0.05$ except for March – May and December - February seasons with positive signs. This reflects a mixed pattern of hill and U-shaped relationship between farm value and precipitation. Therefore for precipitation, there is a maximum and minimum level of precipitation that either more or less will affect farm value. For example, March-May season represents the period of land preparation and planting and there is a minimum level of precipitation beyond or below which germination of seeds or land preparation could become problematic. Climate interaction measures appear significant. The interaction climate terms reveals the importance of the effect of interaction between temperature and precipitation on farm value. Percentage sand and silt in top soil came out stronger in explaining differences in farm value across farms. The socio-economic variables included were both positive and significant at $p<0.05$. Population density is significant and positive at $p<0.05$. Of the environmental variables, latitude is insignificant; altitude has a slightly negative effect, while soil variable proxy by the percentage of clay in top soil had a more negative effect and significant at $p<0.05$.

Marginal estimates of Baseline temperature and precipitation measures

The coefficients of the table above were used to predict the marginal impact of baseline climate measures on land value. These estimates are presented in the table below in naira per hectare and in percentages across agro ecological zones and for the pooled (WC, whole of the country). For the pooled data, all season's monthly temperature reduced per hectare land value by -6.01%, while precipitation increased per hectare land value by 6.50%. This suggests a detrimental temperature effect and a beneficial precipitation effect on land value. As shown in the table, the overall detrimental effect of temperature (-6.01%) can be attributed to the land value reducing effect of the following seasons: June-August (-15.96%), September-November (-14.72%) and December-February (-14.60%). On the other hand, March-May (27.71%) and November-March (11.55%) growing seasons had an increasing countervailing effect on the overall impact of baseline temperature. Across zones, the findings are mixed. For example while overall temperature is beneficial in Sahel and Savannah/forest by 0.24% and 4.22% respectively, precipitation appeared detrimental in Sahel and Sudan Sahel zones by -0.27% and -0.44% respectively.

Table 5: Ricardian marginal estimates.

Climate variables	Pooled	G. Sudan	Sahel	Sudan Sahel	Forest	Savannah/forest
TEMPERATURE						
Sept-Nov	-80989.95 (14.72)	52528.92 (20.74)	225011.5 (7.83)	-21568.02 (13.63)	-250265.2 (47.65)	-46166.18 (9.71)
June-August	-87795.82 (15.96)	29334.44 (11.58)	-104709.7 (3.64)	-21399.02 (13.52)	68180.53 (12.98)	222772.2 (46.88)
March-May	152451.7 (27.71)	-95239.39 (37.60)	292960.5 (10.19)	28287.57 (17.88)	173779.2 (33.09)	-135034 (28.41)
Dec-Feb	-80309.36	-24111.24	899094.1	-29579.73	-21130.58	7601.687

	(14.60)	(9.52)	(31.27)	(18.69)	(4.02)	(1.60)
Nov-March	63566.9 (11.55)	20007.53 (7.90)	-1305516 (45.40)	43209.14 (27.31)	4392.464 (0.84)	-29133.52 (6.13)
All seasons	-33076.5 (6.01)	-17479.7 (6.90)	6840.4 (0.24)	-1050.06 (0.66)	-25043.6 (4.77)	20040.19 (4.22)
PRECIPITATION						
Sept-Nov	384.53 (0.07)	732.55 (0.29)	-9444.32 (0.33)	-699.93 (0.44)	-354.66 (0.07)	1331.53 (0.28)
June-August	487.98 (0.09)	69.92 (0.03)	2264.60 (0.08)	-564.96 (0.36)	-198.27 (0.04)	-1983.50 (0.42)
March-May	1415.62 (0.26)	-522.34 (0.21)	12964.07 (0.45)	956.67 (0.60)	4306.59 (0.82)	2000.29 (0.42)
Dec-Feb	58122.2 (10.56)	18670.64 (7.37)	4976.21 (0.17)	-6174.65 (3.90)	1201.43 (0.23)	17352.43 (3.65)
Nov-March	-24637.28 (4.48)	-12055.62 (4.76)	-18397.51 (0.64)	5791.10 (3.66)	-1395.78 (0.27)	-11856.68 (2.49)
All seasons	35773.06 (6.50)	6895.15 (2.72)	-7636.94 (0.27)	-691.76 (0.44)	3559.31 (0.68)	6844.06 (1.44)

Source: author's calculation

Temperature impact was most detrimental in Guinea Savannah followed by forest while it was more beneficial in savannah/forest compared to Sahel. For Guinea savannah zone, March-May season temperature (-37.60%) and December-February temperature (-9.52%) turned out important factors increasing the detrimental effect of the overall seasonal temperature (-6.90%). Also in forest zone, September-November temperature (-47.65%) accentuated the detrimental effect of the overall temperature effect. In savannah/forest, March-May temperature reduced farm value by -28.41%. However, the increasing land value effect of June-August temperature by 46.88% more than offset the detrimental land value effect of March-May temperature such that overall temperature effect of the zone turned out beneficial by 4.22%.

Climate Change Impact simulations

This section explores the simulated impact of climate change on land value across farms in Nigeria. The simulation assumes all other conditions such as changes in prices, investment, population and technology are constant. It is not a forecast of how farm value will change but simply what could happen in the future by isolating the effect of climate change on land value. Climate predictions are mild case scenario of co2 emissions of Hadley models. The Ricardian simulated impact of climate change using these predictions are presented in the table below. Given Hadley model prediction of 1.89mm increase in precipitation and a 1.03 degree centigrade rise in temperature, the Ricardian model predicts losses in land value by -62.79% in the near term(2050)for the whole country. Variation is also observed across agro ecological zones. For Guinea savannah zone, losses of -8.24% in farm value is expected in 2050.

Losses of -41.95% and -44.96% are respectively predicted for Sahel and savannah/forest. While climate will be beneficial for forest

Table 6: Simulated climate change impact

Agricultural zones	WC	NC	NE	NW	SE
Baseline(N)	536508	275924	188892	127620	475413
HADCM3 2050(N)	199610	253179	109653	118438	491407
Change(N)	-336898	-22746	-79238	-9181.7	15994
%	-62.79	-8.24	-41.95	-7.19	3.36
MG	357460	289866	150736	117746	533741
Change(N)	-179048	13941.2	-38156	-9873.7	58327.6
%	-33.37	5.05	-20.2	-7.74	12.27

Source: author's calculation

by increasing land value by 3.36% in 2050, there is -41.95% losses in land value for Sahel zone, the value is lower than the average for the pooled data but the most detrimental impact on land value after savannah/forest zone estimated at -44.96% in the near term (2050). However estimates depend on the climate model prediction used. For example using CGMG3 model (absolute mean change in temperature and precipitation:0.78mm and 0.81 degree centigrade respectively), Ricardian model predicted losses in land value by 33.37% in the near term (2050) for the pooled data. Losses in land value for Sahel turned out the most across all the zones. Land value losses for Sahel is estimated at -20.20%. In contrast, changes in absolute mean climate increased land value in Guinea savannah and forest zones by 5.05% and 12.27% respectively in the near term.

Conclusion.

With the challenge of climate change globally, the issue of what happens to the profitability of smallholder farming in sub-Saharan Africa has aroused increased public concern. Current and future climate conditions have influence on the decisions farmers make and on the cost of farm operation. The study employed econometric techniques to generate information on the aggregate net economic damages and benefits of climate change on farm value. Theoretically the value of land represents the capitalized values of expected future earnings from the best use of land. That knowing the variation across farms provides information on how farmers have adjusted to climatic change and the implication on land values. The study was limited to cross sectional analysis of farms at a point in time and therefore a static analysis. The climate change impact simulation assumed constancy of prices, CO_2, technology and infrastructural development over time while climate variables specifically temperature and precipitation were assumed to vary. Soil quality variables used were assumed to be homogenous within states and heterogeneous between states. This however is a strong assumption because within each locality there could be extensive variation in soil quality. Hydrology is an important factor affecting differences in land value and this was not included because of the difficulty of assessing such data. Findings suggest that beyond the optimal range of temperature and precipitation land use for crop cultivation becomes detrimental particularly for temperature. Average temperature reduced per hectare farm value by -6.01%, while precipitation increased per hectare farm value by 6.50%. The simulated impact of climate change using Hadley model prediction of 1.89mm increase in precipitation and a 1.03 degree centigrade rise in temperature, revealed losses in farm land value by -62.79% in the near term(2050)for the whole

country. Variation was also observed across agricultural zones. For north central zone, losses of -8.24% in farm value is expected in 2050. Losses of -41.95% and -44.96% are respectively predicted for north east and south west. While climate will be beneficial for south east by increasing farm value by 3.36% in 2050.Simulated impact can be lower or higher depending on the climate model prediction used. From the findings, it can be concluded that the ability of smallholder farms to sustain continual output of crops for local and regional markets depend critically on their ability to produce under optimal conditions of climate. Climate change impact was found to be huge for the whole country with impact variation across agricultural zones. Based on the findings and conclusions, the following recommendations are hereby made
:

- Use of alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies.
- Changing land topography to address the moisture deficiencies associated with climate change and reduces the risk of farm land degradation.
- Implementing irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought.
- Changing timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.
- Integration of land use, soil conservation and principles for management of agricultural inputs for environmental management into agricultural policy.

Finally, further research is however necessary in this emerging area of research. It is also important to explore other modelling techniques such as dynamic systems modelling that consider both adaptation and mitigation. Use of GMM for spatial consideration and panel data for the Ricardian modelling. Use of a unified framework to estimate the impact of climate change on profit, land area used and crop choices. To simulate climate change impact beyond two climate models and to explore General equilibrium analysis.

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APPENDIX

Table 7: Summary statistics of key variables

Summary	Pooled	G. Sudan	Sahel	Sudan Sahel	Forest	Savannah/forest
Farm size (ha)	2.71	2.92	3.84	3.19	1.58	2.57
SD	1.90	1.89	1.57	1.95	1.31	2.08
Min	0.006	0.15	0.0009	0.007	0.04	0.03
Max	7.41	7.41	7.41	7.41	4.71	7.41
Farm value(N/ha)	194693.8	239528.9	91362.92	100030.9	299329	349025.6
SD	584147	687347.3	471318.3	220593.3	468485.8	992811
Min	10714.29	195186.5	18000	17666.67	41880.28	320367
Max	1619433	1043536	692982.5	355110.9	712796.5	1619433

Source:author's calculation

Table 8. RICARDIAN REGRESSION ESTIMATES

Variables	Pooled	G. Sudan	Sahel	Sudan Sahel	Forest	Savannah/forest
TEMPERATURE MEASURES						
Sept-Nov	-21.691	173.025	232.3363	-59.837	-295.798	-190.668
	(1.35)	(1.38)	(2.22)	(2.15)	(0.78)	(0.58)
Jun-Aug	-23.423	96.557	-109.33	-59.786	80.0377	911.8163
	(2.39)	(2.32)	(1.06)	(2.48)	(0.68)	(2.77)
Mar–May	40.7234	-313.32	306.7976	79.5435	202.4042	-552.14
	(3.06)	(2.40)	(1.65)	(3.26)	(0.84)	(3.45)
Dec–Feb	-21.407	-80.632	902.1514	-83.27	-25.205	32.1056
	(1.01)	(0.80)	(3.03)	(1.71)	(0.16)	(0.17)
Nov–Mar	16.968	66.6589	-1322.56	118.1608	5.1088	-122.288
	(0.54)	(0.45)	(2.99)	(1.65)	(0.02)	(0.37)
Sept-Nov^2	0.493	-3.102	-6.218	1.2036	5.6182	4.5371
	(1.61)	(1.39)	(2.78)	(2.35)	(0.79)	(0.69)
Jun-Aug^2	0.386	-1.843	3.3935	0.8509	-1.624	-20.137
	(2.19)	(2.55)	(1.89)	(2.05)	(0.75)	(2.93)
Mar–May^2	-0.668	5.5006	-5.645	-1.231	-3.198	10.7522
	(2.97)	(2.45)	(1.74)	(2.98)	(0.80)	(4.09)
Dec-Feb^2	0.369	2.2337	-21.088	1.5069	0.2583	-0.584
	(0.85)	(1.11)	(3.15)	(1.53)	(0.09)	(0.17)
Nov-Mar^2	-0.294	-2.282	29.4565	-2.185	0.0657	2.0364

	(0.47)	(0.80)	(3.08)	(1.57)	(0.01)	(0.35)
PRECIPITATION MEASURES						
Sept-Nov	0.103 (0.45)	2.3919 (1.47)	-9.749 (1.88)	-1.97 (3.02)	-0.419 (0.17)	5.5338 (2.21)
Jun-Aug	0.130 (1.09)	0.2265 (0.23)	2.3254 (0.78)	-1.546 (3.84)	-0.239 (0.22)	-8.315 (4.42)
Mar–May	0.378 (0.86)	-1.749 (0.64)	13.7275 (2.41)	2.6799 (1.9)	5.201 (1.21)	8.6082 (1.98)
Dec–Feb	15.519 (4.68)	61.5304 (1.18)	19.5095 (0.39)	-18.96 (1.15)	1.3797 (0.12)	73.0104 (4.32)
Nov–Mar	-6.58 (2.91)	-40.117 (1.30)	-29.325 (0.88)	16.8662 (1.4)	-1.656 (0.25)	-49.821 (3.79)
Sept-Nov^2	-0.00021 (2.24)	-0.00059 (0.84)	0.000645 (0.26)	-0.00049 (1.24)	2.74E-05 (0.08)	0.00164 (1.27)
Jun-Aug^2	-0.00027 (5.12)	-0.00015 (0.27)	-0.00093 (0.39)	0.000744 (3.27)	0.000105 (0.77)	-7.5E-06 (0.03)
Mar–May^2	0.000341 (1.39)	-0.0037 (1.91)	0.00607 (1.25)	0.000496 (0.44)	-0.0023 (1.32)	-0.0069 (1.83)
Dec-Feb^2	0.013 (2.93)	0.0928 (1.20)	1.6273 (1.19)	-0.21 (3.57)	0.00281 (0.38)	-0.043 (2.41)
Nov-Mar^2	-0.0026 (1.51)	0.00087 (0.05)	-0.591 (1.09)	0.0473 (3.25)	0.000604 (0.14)	0.0092 (1.40)

TEMPERATURE * PRECIPITATION INTERACTION MEASURES						
Sept-Nov	-0.001 (0.11)	-0.088 (1.40)	0.4013 (2.0)	0.0824 (3.33)	0.0151 (0.16)	-0.238 (2.29)
Jun-Aug	0.000232 (0.05)	-0.0078 (0.26)	-0.073 (0.89)	0.0492 (3.88)	0.00665 (0.15)	0.3414 (4.20)
Mar-May	-0.016 (1.09)	0.1002 (1.05)	-0.506 (2.55)	-0.085 (1.89)	-0.157 (1.09)	-0.248 (1.86)
Dec-Feb	-0.604 (4.79)	-2.336 (1.16)	-0.586 (0.27)	0.9533 (1.44)	-0.055 (0.13)	-2.713 (4.19)
Nov-Mar	0.2577 (3.06)	1.4491 (1.26)	1.0824 (0.85)	-0.78 (1.69)	0.0564 (0.24)	1.8498 (3.93)
CONTROL VARIABLES						
Latitude	-0.023 (0.30)	0.118 (0.28)	0.2185 (0.43)	-0.144 (1.62)	-0.256 (0.40)	-0.066 (0.10)
Altitude	-0.00071 (0.96)	-0.014 (2.69)	-0.0011 (0.44)	-0.00065 (0.42)	-0.00047 (0.05)	-0.0097 (1.23)
Sand	0.0548 (1.57)	-0.18 (1.30)	0.0434 (0.26)	0.0183 (0.44)	0.0613 (0.39)	-0.11 (1.10)
Silt	0.0678 (1.18)	-0.085 (0.37)	-0.01 (0.04)	#VALUE!	#VALUE!	#VALUE!
Clay	#VALUE!	#VALUE!	#VALUE!	0.0562 (0.61)	0.00581 (0.02)	0.439 (1.57)

Socio economic 1	-0.054 (0.69)	-1.135 (2.42)	-2.817 (2.68)	-0.314 (1.68)	0.2134 (0.76)	0.7521 (5.89)
Socio economic 2	-0.042 (0.58)	-0.504 (2.04)	-0.164 (0.65)	0.2714 (2.86)	0.4118 (1.78)	1.0397 (2.03)
Pop den	-5.5E-07 (0.50)	3.44E-06(1.21)	2.1E-06 (0.46)	7.11E-06 (2.42)	3.07E-06 (0.75)	-1.1E-06 (0.24)
Cons	9.314091 (1.35)	11.95418 (1.38)	-372527 (0.32)	6.583982 (1.76)	10.49828 (0.79)	5.847646 (0.56)
No. of sign variable						
F(37,208)	52.60	2.56	15.71	11.30	4.31	66.33
R-squared	0.8877	0.8815	0.9902	0.9329	0.8261	0.9981
Adj R-squared	0.8708	0.5367	0.9271	0.8503	0.6342	0.9831
No. of obs	246	44	38	59	62	37

Author’s calculation