

Climate Change Impact on Nigeria's Agriculture: A comparison of Revenue Versus Self-Reported Land Value

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ABSTRACT

This study investigates the sensitivity of Ricardian climate impact estimates to different land value conceptualizations in Nigerian agriculture. Using farm-level data from the National Bureau of Statistics and climate projections from the WorldClim database, the paper compares two Ricardian model specifications: one based on farm revenue (Net Revenue, NR) and the other on Self-Assessed Value of Land (SAVL). The NR model captures current earnings from crop and livestock production, while SAVL reflects farmers' perceived market value of land, incorporating future uncertainty. To ensure comparability, NR was adjusted using a 5% interest rate to approximate the discounted stream of future returns. A semi-log functional form was employed, with climate variables specified as seasonal averages and quadratic terms, while soil, altitude, and socio-economic indices were included as controls. Weighted least squares regression was used to address spatial aggregation bias. Results show that climate variables significantly influence both models, though the direction and magnitude of effects differ. Temperature generally had a detrimental effect on land value (-6.01%) but a modest positive effect on revenue (+1.45%), while precipitation increased land value (+6.50%) but reduced revenue (-1.85%). The NR model produced more extreme marginal estimates across seasons and overestimated climate-induced damage by 3.6% compared to the SAVL model, a difference found statistically significant at the 10% level. These findings support the hypothesis that unadjusted revenue models exaggerate climate impacts due to their failure to account for future uncertainty. The study underscores the importance of land value conceptualization in climate impact modeling and recommends caution in using revenue-based proxies for policy analysis in developing agricultural economies.

Keywords: Climate Change, Agriculture, Land Value, Nigeria, Ricardian model, and Valuation

INTRODUCTION

The Ricardian model, pioneered in Mendelsohn et al. (1994) has been widely used in assessing the impact of

climate change on agriculture. In Nigeria, only a few researchers have applied the model to Nigerian agriculture despite the spread over the last two decades (e.g., Ajetomobi et al., 2010; Fonta et al., 2011; and Odozi,



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Table 1: Various Concepts of Land Value Across Countries and Studies

Country	Land concepts	Authors
India	Net revenue	Kumar and Parikh (1998) Sanghi <i>et al.</i> (1998)
Kenya	Crop revenue	Kabubo-Mariara and Karanja (2007)
Zimbabwe	Net revenue	Mano and Nhemachena (2006)
Nepal	Net revenue	Thapa and Joshi (2010)
Sudan	Net revenue	Amassaib, <i>et al.</i> (2015)
USA	Gross revenue, land values	Mendelsohn <i>et al.</i> (1994)

Source: Author's compilation from several studies

2015). Fundamentally, the model regresses land values across farms on climate and non-climate factors from which the impact of climate change is evaluated. The Ricardian model views impact as the degree to which a system is affected by climate change in terms of damage, losses, and adaptation activities of landowners (Odozi, 2015). With the implied consideration of adaptation processes, the model contrasts the agronomic method that views impact in terms of physical measures- total production, productivity (e.g., crop yields or total factor productivity). Despite the merits, estimates can be sensitive to several methodological concerns for which this study aims to address.

Among the methodological concerns, there is the spatial spillover and autocorrelation estimate sensitivity that have been raised and addressed by some authors (e.g. Polsky (2004) and Seo (2008). Deschênes and Greenstone (2007) Le (2009) and Schlenker and Roberts (2009) Schlenker *et al.*, (2005, 2006); Lippert *et al.*, 2009, Dall'erba and Dominguez (2015). There is the incomplete model specification sensitivity (Mendelsohn 2000; Kurukulasuriya and Rosenthal 2003) and land value concept sensitivity (Mendelsohn, *et al.*, 1994). Surprisingly, not much has been advanced on estimating sensitivity to approaches for Nigeria's agriculture. This article takes up the methodological issue of whether Ricardian estimates of climate impact are sensitive to the various measures of land value. The objective is to compare the estimates of two measures of land value, namely, a Ricardian model of Net Revenue (NR) and the Ricardian model of Self Assessed Land Value (SALV), using Nigeria's data.

Empirical Literature presents several proxy values used to capture land value. (Table 1) shows the various concepts of land value across countries and studies. Gross revenue, net revenue, and land values are commonly used. Other concepts include land prices, self-assessed land values, and rental prices of land. Revenue is gross when only the value of the output from land is considered and it is net when the deductions of cost of production are made on the value of the output from land.

Theoretically, land value is viewed as the market value of a piece of land measured by its competitive price. Although the price of land best captures the potential profitability or productivity of a parcel of land, it is jettisoned by researchers in developing countries on account of the

underdeveloped agricultural land markets. It is also believed that in areas where land markets exist, considerations of investment security and prestige push the price well above the competitive price. Again, getting the cost of land use for agricultural production is often complicated and as such some researchers rely on the value of output from land. In previous studies, the choice of land value has been arbitrary (Mendelsohn and Dinar, 2009), the sensitivity of estimates to land measures is often ignored and thus the motivation for this paper.

MATERIALS AND METHODS

Analytical framework

In traditional agricultural societies, the practice of share cropping is common, where landowners rent out a part of their land to another farmer to cultivate, and at harvest, a portion of what is produced on the land is given to the landowner as rent for the use of the land. Ricardo (1817) argued that land rents would reflect the net revenue of farmland under a competitive market and viewed the value of land today as the present value of future net revenue from the use of the land. In other words, the value of land is analogous to the productivity of the land. The Ricardian model is expressed as:

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

Where V_{LF} denotes the value of land and P_{LF} , the annual rent from land. Agricultural output Q_i is produced on a parcel of land denoted as L_i with characteristics F tied to the land. The cost of producing the agricultural good is denoted as C_i and consists of the purchase of inputs at price P while agricultural good Q_i is sold at price P_i . The equation above states that the annual rent (P_{LF}) is equal to the annual profits from producing Q while the value of land (V_{LF}) is equal to the present value of future rents (P_{LF}). The equation views the value of land (V_{LF}) as different across farms because of differences in the attributes across land. Climate is an important factor determining annual profit from land ($P_i Q_i - C_i(Q, P, F)$) because it is tied to land and beyond a certain threshold, it affects land value (V_{LF}) through its effects on output, cost of production and ultimately on profit.

There is also the increased risk associated with climate conditions that raise the discount rate (rt) and consequently a drop in the value of land. There are also non-climatic factors affecting the value of land namely a farmers socioeconomic characteristics, government policies, urbanization and the demand for land.

In this paper, we conceptualize the value of a farmer's operational land using various measures and test the hypothesis that the magnitude of damage predicted by a Ricardian model differ by land value concepts (Mendelsohn et al., 1994). In this paper, we compare the Self-Assessed Value of Land (SAVL) and Net Revenue (NR) and posit a large estimate using NR compared to SAVL. NR is the earnings that accrue to farmers at present and are measured as the gross income from crop production and livestock. It does not capture future uncertainty and therefore a flow concept. On the other hand, SAVL represents farmers' reports of the current market value of their farms per hectare. It captures future uncertainty because it is the discounted value of future streams of annual revenue from the farm. To make SAVL and NR concepts comparable, NR is adjusted to capture future uncertainty. Mendelsohn et al. (1994) suggested two adjustment approaches: the Interest rate of capital and the rate of profit on farms. In Nigeria, there are challenges regarding the choice of interest rate on capital investment. First, in the agricultural sector, subsistence farming and partial commercialization dominate. Second, agricultural risk linked to climate conditions is heterogeneous and thus interest rate on capital investment is expected to differ across regions and local government areas. However, to achieve comparability, we assume a 5% interest rate of capital investment following Mendelsohn. A scale factor is generated that reflects the rate at which NR accumulates over time using the formula:

$$\frac{SAVL}{NR} = (1 + r^n)$$

Thus,

$$SAVL = NR(r^n)$$

Where r is the interest rate of capital and n , the time frame.

The model is applied empirically as SAVL and NR equations. The equations relate respectively net revenue and self-assessed value of land to a vector of exogenous variables expressed as:

$$\begin{aligned} SAVL_i &= \beta_0 + \beta_{1i}F + \beta_{2i}F^2 + \beta_{3i}Z + \beta_{4i}S + \varepsilon_i \\ NR_i &= \beta_0 + \beta_{1i}F + \beta_{2i}F^2 + \beta_{3i}Z + \beta_{4i}S + \varepsilon_i \end{aligned}$$

The key explanatory variable is long term climate average specifically temperature and rainfall denoted by F . β represent the coefficients to be estimated and ε the error term. F^2 denotes the quadratic specification of the long-term climate. The climate variables are specified as 3 months seasonal averages defined as: (1) September –

November (2) June – August (3) March – May (4) December – February (5) November – March. Non climate variables are denoted by Z representing percentage clay soil, percentage sandy soil and percentage loamy soil. Population density, latitude and altitude. S denote socio economic characteristics of farmers. In the data set used the socio-economic characteristics are many and in order not to make the model noisy, index was created using principal component analysis. These variables are hypothesized to influence NR and SAVL models.

The functional form of the model is semi log specification with a quadratic specification for the climatic variables and linear function for all other determinants. A log transformation of the dependent variable outperforms a linear specification since land values are typically highly skewed (Fezzi and Bateman, 2011). The unit of analysis is the area council level. This reduces the challenge of linking farm level economic observation with observations collected over a larger geographical space, such as climate and soil variables.

This, however, comes with spatial error and aggregation bias. Hence, while the use of Ordinary Least Squares to estimate farmland value equations provides useful results, it cannot capture spatial differences within regions and control for aggregation bias (see Polsky and Easterling, 2001). This study used a Weighted Least Squares regression. Mendelsohn used two weighting mechanisms, the share of crop land cultivated and crop revenue, to control for spatial effects on land use. The intensity of farming varies across households and regions in Nigeria, and therefore, it is important to emphasize regions where agriculture is important based on the relative value of output produced or the share of crop land cultivated (Polisky et al. 2001). A priori, the sign of the estimated climate parameter is both positive and negative. The sign reveals the nature of the impact as well as the shape of the climate–farm value relationship. In terms of impact, the negative sign reflects a reducing impact while the positive sign reflects a beneficial impact. In terms of shape, the negative sign of the quadratic coefficient reflects a hill-shaped relationship, while the positive sign reflects a U-shaped relationship. From the parameter estimates, the marginal impact or implicit value of climate is derived as:

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

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

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

The marginal values are calculated by summing both the linear and squared coefficients and average climate values

Table 2: Mean distribution of key variables

Variables	Mean/SD
Net revenue in ₦	54014.41 (50180.08)
Self Assessed Value of Land in ₦	194693.8 (184147)
Land size in hectares	3.889 (18.231)
% sand top soil	58.1314 (8.4826)
% silt top soil	23.6344 (5.1721)
% clay top soil	18.2342(4.0770)
Altitude in meters	250.0006(215.5426)
Latitude in meters	8.6436(2.7925)
Socio economic index 1	2.12e-10(1.1533)
Socio economic index 2	8.65e-10(1.476)

Table 3: Baseline average and projected absolute change in climate for Nigeria

Months	Baseline average monthly climate		Projected absolute climate change	
	Precipitation mm	Temperature	Precipitation %	Temperature %
Jan	9.3557	25.38	-0.57	0.96
Feb	20.0398	26.94	-1.05	1.14
Mar	53.5341	28.46	-3.47	0.88
April	92.8394	28.93	-19.27	0.86
May	150.345	28.02	-12.60	1.08
June	196.114	26.58	-18.33	1.18
July	231.926	25.29	0.30	0.82
Aug	225.503	24.85	21.83	0.58
Sept	232.259	25.44	30.93	0.87
Oct	142.089	26.15	-3.38	0.82
Nov	34.7632	26.18	4.33	1.12
Dec	9.7534	25.29	0.77	1.14

(f) and then multiply by the expected value of the land. The values generated are summed across climate measures for each of the observation and averaged to arrive at impact. To the extent that climate conditions increase or decrease the discounted stream of net returns to land value, favourable or bad climate conditions imply higher or lower land values.

Data

Baseline climate observations from 1950-2000 and projections (2000 -2050) were obtained from the World Climate Database (WCDB) (Hijmans et al., 2005, available at <http://www.worldclim.org>).

From the data set, seasonal climate measures were constructed into seasonal averages using an Excel spreadsheet. The average climate was calculated for each of the Local Government Area Councils (LGA) and captures the finest spatial resolution for which climate variables can be obtained from the database. Complementary data on population, soil, and altitude were also calculated for the Local Government Area Councils. These complementary data were sourced from the databases of the National Population Commission (NPC) and the Food and Agriculture Organisation (FAO). Variables from WCDB were Mean Temperature (MT) and Mean Precipitation (MP) for wet and dry seasons. The socioeconomic data were sourced from the National Bureau of Statistics (NBS) General Household Survey

(GHS) data with a panel component (Odozi and Awoyemi, 2015). The survey data set for 2010/2011 of the panel was used. Variables used for the analysis from NBS were self assessed value of land, farm revenue, land size, crops cultivated, area planted and socio-economic characteristics of farmers such as age and household size.

RESULTS AND DISCUSSION

Table 2 provides the mean and standard deviation in brackets of key variables used in the analysis. From the (Table 2), the mean reported farm value is ₦194693.3 while farm revenue is ₦54014.14. Table 2 shows the baseline average and projected absolute change in temperature and precipitation for Nigeria's climate. From (Table 3), the highest average precipitation is observed during June, July, and September with respective values 196.11mm/mo, 231.93mm/mo, and 231.26mm/mo. The months of July – September is often the peak of rainfall with a slight drop in August. April to October is regarded as the wet growing season. November to March is also regarded as the dry season. September to November 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. The March to May period in the southern part, in particular, represents the period of land preparation and planting. It also marks the onset of rainfall in the southern agricultural zones. Late onset of rainfall often ranges from mid-March to late June or early May to late July in northern agricultural zones (Takehima,

2012). Table 3 also presents the absolute change in precipitation and temperature calculated as the difference between the baseline climate and projections for 2050 under the low emission scenario. Deficit in precipitation is expected in January, February, March, April, May, June and October with high severity in April, May and June while the months of July, August and September are expected to be moist. Table 3, there appears little variation in temperature across months, but the highest temperature is observed for March – May. The absolute change in mean monthly temperature is also presented. As shown in the (Table), the mean temperature on the average is expected to change across months by 2050.

Model Estimates

Comparing SAVL and NR climate estimates

Table 4 presents the coefficients and the t-statistic for both models. For both models, the F statistics were significant at $p < 0.0001$. For the SAVL model, 89% of the variance was explained by the included variables, while for the NR model, 89% was explained. As shown in the (Table), the signs of the climate variable estimates are the same for both models except for Mar-May temperature, Sept–Nov precipitation, and Nov-Mar Precipitation estimates. The number of coefficients that were significant at $p < 0.05$ was 17 and 22 for the SAVL and NR models, respectively. (Table 5) presents the marginal estimates of the two models. The marginal estimates were generated using the coefficients in (Table 4). The demeaned climate measures were used to multiply the coefficients presented in the (Table) above and then summed across the climate measures for each of the observations. The values are averaged to arrive at the impact. The marginal estimates of all-season temperature and precipitation are presented. The marginal estimate defines the effect of a change in temperature and precipitation on NR and SAVL. For the SAVL model, a unit change in all seasons' monthly temperature reduced per-hectare SAVL by 6.01%, while precipitation increased per-hectare SAVL by 6.50%. This suggests a detrimental temperature effect and a beneficial precipitation effect on SAVL. For the NR model, a unit change in all seasons' temperature increased NR by 1.45%, while all-season precipitation reduced NR by 1.85%.

However, the marginal estimates of the NR model appear more detrimental for most of the seasons compared to the SAVL model. These findings conflict with the argument that the impact of environmental effects would be exaggerated by an NR model because NR was not adjusted for future uncertainty. Using the adjustment approach presented in the methodology section, NR overestimates damage by 3.6%. This was found to be statistically significant at 10% using simple ANOVA as shown in (Table 4). Table 4 shows the difference between SAVL and NR unadjusted. There is a statistical

difference between the two estimates at $p < 0.05$, but the estimated change appears outrageous at 126%. This reflects the importance of adjustment (Table 6). This study supports the hypothesis of an NR overestimation of the climate effect.

Table 4: SAVL and NR Ricardian Models coefficients for Nigeria

Variables	Self-Assessed Land Value	Net Revenue
Temperature measures		
Sept-Nov	-21.691(1.35)	-3.2744(0.19)
Jun-Aug	-23.423(2.39)	-12.0472(1.15)
Mar–May	40.7234(3.06)	-48.5608(3.40)
Dec–Feb	-21.407(1.01)	-108.7765(4.81)
Nov–Mar	16.968(0.54)	178.0038(5.31)
Sept-Nov ²	0.493(1.61)	.0135(0.04)
Jun-Aug ²	0.386(2.19)	.2539(1.35)
Mar–May ²	-0.668(2.97)	.7936(3.30)
Dec-Feb ²	0.369(0.85)	2.0568(4.40)
Nov-Mar ²	-0.294(0.47)	-3.3170(4.94)
Precipitation measures		
Sept-Nov	0.103(0.45)	-.4987(2.04)
Jun-Aug	0.130(1.09)	.1160(0.90)
Mar–May	0.378(0.86)	-1.5262(3.26)
Dec–Feb	15.519(4.68)	-15.8579(4.47)
Nov–Mar	-6.58(2.91)	10.7117(4.43)
Sept-Nov ²	-0.0002(2.24)	.0001(1.20)
Jun-Aug ²	-0.0003(5.12)	-.00005(0.96)
Mar–May ²	0.0003(1.39)	-.0003(1.23)
Dec-Feb ²	0.013(2.93)	-.0138(2.90)
Nov-Mar ²	-0.0026(1.51)	.0060(3.18)
Latitude	-0.023(0.30)	-.0879(1.07)
Altitude	-0.00071(0.96)	-.0030(3.79)
Sand	0.0548(1.57)	-.0947(2.54)
Silt	0.0678(1.18)	-.1315(2.14)
Socio economic 1	-0.054(0.69)	.2172(2.59)
Socio economic 2	-0.042(0.58)	.0417(0.54)
Pop den	-5.5E-07(0.50)	-1.36E-08(0.01)
Cons	9.314091(1.35)	20.4566(5.79)
F(37,208)	52.60	65.64
R-squared	0.8877	0.9079
Adj R-squared	0.8708	0.8941
No. of obs	246	246

Source: Author's computation. () T-statistics

Table 5: Marginal estimates of Ricardian SAVL and NR

Climate measures	SAVL	NR
TEMPERATURE		
All seasons	-33076.5 (6.01)	2214.25(1.45)
PRECIPITATION		
All seasons	35773.06 (6.50)	-2824.49 (1.85)

Source: Author's computation. (Elasticity in percentage)

Table 6: Estimates Test

Self Assessed Land value	992902.2	
Net revenue adjusted	1028500	
Difference	-35598	3.60%
T-statistics	-1.0125(0.1561)	

Source: Author's computation.

Conclusion

While global warming-associated climate changes are evident in many local sites in Nigeria, there is a lack of empirical knowledge regarding their economic impacts. More importantly, there is the slow advancement in the knowledge frontier on climate change economic impact analysis, which is still in its infancy for Nigeria. Only a few studies have examined the extent to which climate

conditions are capitalized in land values using the Ricardian model. Given the various ways land value is conceptualized in the literature, this study compares the impact estimates of Net Revenue, measured using gross farm revenue and the self-assessed value of land, across a cross-section of small farmers in Nigeria, utilizing relevant data sources. Findings showed that when farm revenue is adjusted by a risk factor to control for future uncertainty, farm revenue overestimates capitalized damage by 3.6% supporting the hypothesis that the net revenue of farm revenue overestimates damage arising from climate change. This finding implies that the impact estimate of climate change might be exaggerated if the Ricardian model is limited to the use of net revenue. There is a need to combine the various conceptualizations of land value in a Ricardian analysis for a broad understanding of the damage estimate in agriculture arising from climate change.

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