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Economic effects of climate change on sorghum in North-Central Nigeria

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Abstract

The study was conducted in north central Nigeria to determine current and future economic effects of climate change on sorghum. Data were collected from 147 respondents purposively selected based on farm experience of 10 years and above. Mean Annual rainfall, and precipitations data (1951-2011) were collected from the Nigeria Meteorological Agency, Lagos. Ricardian Model was used to analyze data. Annual rainfall effect on sorghum land value was negative and significantly different from zero at 10% level of probability; average temperature had positive effect on sorghum land value. We found positive future Climate change effects on sorghum under all climate scenarios for years 2020, 2060, and 2100.However, highest, and lowest economic gains from sorghum were 3143% under HADCM3 Climate Scenario for year 2060, and 111.88% under PCM, scenarios for year 2020 respectively. There is need for increased investment on farm technology, particularly, improved varieties, with proven adaptation to high hydrological conditions.

Keywords: Sorghum, Climate change; North-Central Nigeria; Temperature; Precipitation

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1. Introduction

Sorghum is a cereal crop grown for food, feed, and industrial uses. The crop does well on deep, fertile well-drained loamy soil and is therefore, grown in the southern and northern Guienea Savannahs and in the suddan savannah of Nigeria. The industrial demand for the crop is increasing particularly in the food, beverage and livestock industries. Consequently, significant efforts have gone into research and development of improved sorghum varieties and production practices by both public and private sectors. Despite of these, production of sorghum has been on the decline over the past 3 decades in northcentral Nigeria(Kwara State Agricultural Development Project, 2011; Benue State Agricultural and Rural Development Agency, 2011). Consequently, small-farmers' income derived from sorghum production have not shown significant increase (USAID, 2009). Given that climate is the major significant factor affecting yield of crops (Abdulhamid et al., 2011; DFID, 2009), it has become imperative to quantify how much of current variability in economic yield of sorghum which is due to climate change, and also to ascertain the role which climate may play in the future in terms of its economic impacts on regional sorghum production.

Furthermore, if farmers understand the nature and pattern climate may likely take, they will most likely undertake some proactive adaptation measures to remain climate- resilient. However, such empirical information vis-à-vis Sorghum production is generally scanty in area of study. Against the backdrop of the implication of climate change for food security and human welfare, this climate change research, therefore, examined the economic effects of climate change on sorghum production in North-Central Nigeria using baseline climate data and further investigated likely future impacts under climate change scenarios.

2. Methods of the study

2.1. The study area

The study was conducted in north central Nigeria. The area is located between latitude 8^{o}N and 10^{o} N and Longitude 3^{o}E and 10^{o}E (Balogun, 2009). North central Nigeria is characterized by a Tropical Continental Climate marked by a wide variation of annual temperature regime and a restricted rainfall, with temperatures and rainfall varying with location and period of the year. The Mean annual temperature ranges from 24^{o}C to 37^{o}C, while the Mean annual rainfall is between 100 and 200 Cm^{3} (Iloeje, 2007). The climate of north central Nigeria is characterized by a rainy season which extends from April to October, and a dry season which starts in December and lasts till March. The recession of harmattan for the rains is heralded by the moist Tropical Maritime Air Mass of the Southwest Trade winds. This point is usually marked by hot sunny days with temperatures being highest about March to April.

Soil resources of the area are either friable, porous, coarse-grained sandy or lateritic usually grey or reddish in colour, generally low in fertility (Iloeje, 2007). The soil supports a wide variety of crop species including cereals such as Maize, Rice, Millets, and Sorghum. These crops supply much of the average farm family's subsistence food requirements as well as a marketed surplus for income.

2.2. Sampling and data collection

The analyses were based on primary and secondary data. Primary data were collected from a sample of 147 sorghum producers, composed of 50, 47 and 50 respondents purposively selected, respectively, from Benue, Kwara, and Niger states based on farmers with sorghum cultivation experience of 10 years and above. The states were selected due to wide spread cultivation of sorghum. Sorghum was selected for analyses because it is the most important cereal crop in Nigeria (Agboola, 1979; Maikasua and Ala, 2013). Meteorological data mainly annual rainfall, and temperatures were obtained from Nigerian Meteorological Agency, Lagos.

2.3. Data analysis

Descriptive statistics mainly means was employed to describe the variables used in the study. The standard Ricardian Regression was used to determine climate economic impacts on sorghum. The hedonic model which expresses farm net revenue as a quadratic function of climate variables as used by Fonta, Williams, and Urama(2011) was specified as follows:

$$NR_i = \beta_0 + \sum(\beta_1 T_1 + \beta_2 T_2^2 + \beta_3 P_3 + \beta_4 P_4^2) + \sum_{i=1}^{2} \lambda_i S_i + \sum_{i=1}^{2} \phi_i E_i + \sum_{i=1}^{22} f_i Z_i + \mu \quad (1)$$

NR_i= Net revenue per hectare of sorghum.

Where $T_i$and P_i represent normal temperature and precipitation in each season.

S_i = a set of soil texture class dummies (i = 1, 2,) such that S_1 = clay soil, a dummy variable which takes on a value of 1 if soils of a farm are predominantly clay in texture, 0, if otherwise.

S_2 = Sandy soil. A dummy variable which takes on value of 1 if soil of a farm environment are sandy, 0, if otherwise

E_i= Set of economic variables (i = 1, 2…, n) such that

E_1=Price of sorghum (₦/kg)

E_2 = Farm credit. Measured as a dummy variable which takes on the value of 1 for farmer who has procured and used farm credit, and 0 if not.

Z_i=Set of relevant socio-economic, and other controlled variables.(i = 1,2, … 24) such that

Z_1=Number of years of education of the household head

Z_2=Size of household in person per farm family.

Z_3=Gender of household head. A dummy variable which takes on value of 1 if household head is male, 0, if otherwise.

Z_4=Age of the household head (years).

Z_5=Non-farm income of household head (Naira).

Z_6=Livestock ownership. A dummy variable which assumes a value of 1 if household owns livestock, 0, if otherwise.

Z_7=Extension contact on crop and livestock. Dummy variable that takes on value of 1 if household is visited by extension agents, 0 if otherwise.

Z_8=Farmer-farmer extension. Dummy variable which takes on value of 1 if household experiences farmer-farmer extension, 0, if otherwise.

Z_9=Use of High Yielding Varieties. Dummy variable which takes on value of 1 if household used High Yielding Variety of a cereal, 0 if otherwise.

Z_{10}=Farm size in hectares

Z_{11}=Ownership of radio. A dummy variable which takes on value 1if household has owns a radio 0, if otherwise.

Z_{12}=Access to electricity. Dummy variable which takes on value of 1 if household has access to electricity 0, if otherwise

Z_{13}=Membership of production association. A Dummy variable which takes on value of 1 if household head participate in association, 0 if otherwise.

Z_{14}=Farm experience in years

Z_{15}=Irrigation use. Dummy variable whose value is one if irrigation is used, 0 if otherwise, included to capture the impact of water availability on farm value, and to compare the climate sensitivity of irrigated land to rain fed land.

Z_{16}=Latitude of the district (proxy for solar radiation)

Z_{17}=Local Agro-ecology(Lowland). A dummy variable representing lowland agro-ecology which takes on value of 1, if district is located in lowland, area, 0 if otherwise.

Z_{18}=Local agro-ecology (Highland). A dummy variable which takes on value of 1, if farm environment is on a highland, 0, if other otherwise.

Z_{19}=Mixed cropping dummy variable which assumes value of 1 if, practiced, 0 otherwise.

Z_{20}=Altitude. Measured as distance above sea level in meters, for a given location (includes as proxy for day length). β_0, $\beta_{1...}\beta_4$, λ_i,ϕ_i and f_i represent regression coefficients to be estimated.

Z_{21} = use of large equipment (eg tractors). A measure of the extent of farm mechanization.

Z_{22} = population density of locality. Included to control for urban influences on agricultural land value.

μ = error term.

Equation (1) represents the empirical model to be estimated for north central Nigerian cereal farmlands

2.3.1. Method of simulation

In order to evaluate the impact of future change in climate, impacts of climate in the current years (1951-2011) were estimated using the Ricardian model. After fitting the model, new variables were adjusted to

meet new climate conditions in the future to achieve this climate change scenarios were employed to create new adjusted variables for temperature, and precipitation.

The current variables in the primary data set were added by some ^{0}C to calculate the new temperature variable in case of future temperature, and the precipitation variables was were multiplied by the percentage change in future precipitation forecasted by climate models. The simulation mechanism is as follows:

Consider the standard Ricardian model of equation (2)

$$y_t = \alpha N_t + \beta N_t^2 + \mu \quad (2)$$

Where y_t = agricultural land value at time period t

α , β = regression coefficients to be estimated

N represents climate variables such as precipitation or temperature.

After estimating equation (2), all the coefficients were determined and fitted regression equation based on base model dataset (1951- 2011) was obtained as follows (Amiraslany, 2010):

$$\hat{y_t} = \hat{\alpha} N_t + \hat{\beta} N_t^2 \quad (3)$$

Now to simulate future climate in time, t +1, the equation (3) needs to be subtracted from equation (4):

$$\widehat{y_{t+1}} = \hat{\alpha} N_{t+1} + \hat{\beta} N_{t+1}^2 \quad (4)$$

so that,

$$\Delta Y = \widehat{y_{t+1}} - \hat{y_t} = \hat{\alpha} (N_{t+1} - N_t) + \hat{\beta} (N_{t+1} - N_t)^2 \quad (5)$$

Now by plugging in the change between the old and the new (modified) variables in the regression results, change in sorghum land values (ΔY) were simulated. In this analysis, the expected future climate were derived from the Special Report on Emission Scenarios(SRES) models of IPCC for years 2020, 2060, and 2100 which was prepared for driving climate change models(IPCC, 2001)(Table1).

Table 1. Predictions of SRES models for 2020, 2060, and 2100

TEMPERATURE (Δ^{0}C)					PRECIPITATION (Δmm)			
Model	**Current**	**2020**	**2060**	**2100**	**Current**	**2020**	**2060**	**2100**
CGM2	26.4	27.9	28.9	32.4	1626	1466	1350	1200
$HADCM_3$	26.4	28.9	39.66	32.7	1626	1758	1790	1800
PCM	26.4	26.9	27.69	29.13	1626	1695	1740	1805

Source: Fonta, Ichoku and Urama (2011)

We applied forecast from 3 climate models: Parallel climate model (PCM), Hadley Centre Coupled model (HadCM3), and Coupled Global Climate model (CGCM2) to see climate change effects on net revenue per hectare of sorghum for years 2020, 2060, and 2100.

3. Results and discussion

3.1. Base model results

The presence of heteroscedasticity in the distribution of the error term often violet the assumption of OLS regression and provide bias coefficients. This econometric problem was, therefore, checked in SPSS version 16 using normal probability plots that compared the distribution of standardized residuals (e) to normal distribution. The regression Standardized Residuals followed normal distribution with zero mean and constant variance implying the absence of heteroscedasticity in the Ricardian regression.

The Ricardian regression results for sorghum production are reported in Table2. Annual rainfall means had, significantly, ($P < 0.10$) negative impacts on sorghum net revenue. Mean annual temperature, however, had direct positive effect on net revenue hectare. A 1^0C of further warming increases the performance of the crop much greatly. Sorghum can be successfully grown between latitude 40^oN and 40^oS of the equator, in hot and warm countries characteristic of the semi-arid environment (www.vasat.icrisat.org). The crop tolerates high temperatures throughout its life cycle. Extreme hydrological conditions marked by flooding, erratic rainfall distribution and drought as witnessed in recent times appear to be unfavourable to sorghum production.

The estimated model accounted for about 48.1 per cent variation in sorghum net revenue hectares and was highly significant ($F=5.67$, $P <0.01$). Population density and access to electricity, access to credit facilities, use of improved varieties of sorghum, and household head membership of farm association had positive significant influence on sorghum farmland values at various probability levels.

The results were in general agreement with those of Abdulhamid et al. (2011) who found that the most important climatic condition for maturity of sorghum and its yield was air temperature. The authors showed that maximum and soil temperature though not statistically significant, were positively correlated with yield of sorghum in the savannah area of Nigeria. In the future, therefore, warming trend might not be a significant risk factor in sorghum production in the area.

3.1.1. Marginal Economic impacts of climate on sorghum.

Results show that means annual temperature had positive marginal effects on sorghum, but a negative marginal impact was observed in the case of precipitation. A 1mm increase in current annual rainfall means on average would result in more than ₦500/ha decrease in sorghum. A 1^0C rise in mean annual temperature would increase sorghum land value by ₦86, 534.73. Elasticity estimates showed that a 1% increase in

precipitation would cause sorghum net revenue to fall by 0.38%. However, sorghum revenues were more sensitive to average temperature, having temperature elasticity of 64.72%.

Table 2. Results of Ricardian regression of net revenue from sorghum production in northcentral Nigeria. Model parameter Estimates. Dependent variable: Sorghum net revenue per hectare

Variable	Coefficient	SE	T	Pr>|t|	Mean
Intercept	-2858682.87	4270425.88	-0.669	0.505	
Mean rainfall	-508.36	264.69	-1.92*	0.06	123.13
Mean temperature	86534.73	123173.20	0.703	0.48	27.15
Unit price	5750.50	6872	0.84	0.40	68.45
Latitude	40623.03	59580.05	0.68	0.50	8.30
Population density	0.40	0.234	-1.71*	0.09	14862
Altitude	107.33	71.65	1.50	0.14	350
Farm size	4297.56	2652.62	-1.62	0.11	2.41
Household size	-104.24	1214.98	-0.09	0.93	11.00
Age	-177.09	856.24	-0.21	0.84	46.00
Sex	1049.04	17131.53	0.06	0.95	0.82
Marital status	7281.68	22219.81	0.33	0.74	0.93
Years of education	238.06	762.40	-0.31	0.76	9.00
Farm experience	461.99	912.65	-0.51	0.61	28.00
Access to electricity	27869.97	12866.99	-2.17**	0.03	0.61
Sandy soil	8397.27	15540.98	0.54	0.59	0.76
Access to credit	65373.49	21637.41	-3.02***	0.003	0.05
Use of large equipment	3638.88	5453.95	-0.67	0.51	0.08
Off farm income	0.02	0.08	0.20	0.84	78702.70
Own livestock	-60.17	11368.90	-0.01	1.00	0.62
Extension contact	3240.46	6082.29	-0.53	0.60	0.95
Farmer-farmer extension	4629.70	5281.08	-0.88	0.38	1.02
Improved variety use	30397.93	15505.27	-1.96**	0.05	0.49
Ownership of radio	10152.25	15205.26	0.67	0.51	0.80
Membership of associations	21157.50	12224.12	1.73*	0.09	0.59
Mean dependent variable		36301.70	R- Squared		0.584
Standard Deviation of dependent variable		7004.25	Adjusted R- squared		0.481
Included observations		147	F(29, 117)		5.67
Number of parameters		25	Prob(F-Statistic)		0.0001***

**** Statistic significant at 1% alpha level ** Significant at 5% level. S.E =Standard error*
Source: field data 2012

3.2. Simulated climate economic yield effects on sorghum

Climate change impacts on land value were simulated under scenarios to examine the role which climate might play in future human welfare. Economic yield impacts were simulated in terms of change in net revenue per hectare of sorghum.

Table 3. Simulated economic impacts of climate on Sorghum farmland value under climate model forecast.

Climate model	Impact	Year		
		2020	2060	2100
CGM2	ΔR (₦)	123642.62	205714.24	502808.16
	%	340.60	566.68	1385.08
HADCM3	ΔR(₦)	159333.17	1141134.57	538471
	%	438.91	3143	1483
PCM	ΔR(₦)	40613.28	107241.80	229347.96
	%	111.88	295.42	361.78

ΔR = Change in sorghum net revenue per hectare. Source: field data 2012

We found positive future Climate change impacts on sorghum under all climate scenarios (models) for years 2020, 2060, and 2100.However**,** highest, and lowest economic gains from sorghum were 3143% under HADCM3 Climate Scenario for year 2060, and 111.88% under PCM, scenarios for year 2020 respectively (Table3).

4. Conclusion

Increase in mean annual temperature would lead to improvement in sorghum land values while further increase in current average precipitations would lead to a decline in sorghum value. However, the three climate scenarios used in economic simulation support the fact that climate change would create an opportunity for sorghum producers in northcentral Nigeria to gain from future environmental change and improve upon welfare.

5. Recommendations

Expansion of area planted to sorghum in future years would improve human welfare in the face of climate change in northcentral Nigeria. More importantly, increased investment on farm technology particularly improved varieties of sorghum with proven adaptation to high hydrological conditions would ensure sustained economic benefits to producers in future years.

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