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Impact of Climate Change on Soybean Production in Lapai Local Government Area of Niger State

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Authors' contributions

This work was carried out in collaboration between all authors. Author FDI designed this study, performed the statistical analysis and wrote the first draft of the work. Authors PAI and AUG provided the data on climatic variables. Authors AJJ, RKU and AO did the field work and obtained cross sectional data from respondents. Author AIO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study employed a Ricardian Model to measure the impact of climate change on soybean production in Lapai local government area of Niger state. The study utilized time series data on climatic variables for the period 1980-2012 and primary data on socioeconomic background, production cost, yield and prices of output from 80 randomly selected farmers. Results showed that rainfall and humidity statistically affected the net revenue of soybeans at 10% and 5% levels of significance. Rainfall had a negative coefficient of -68399.5 implying that as rainfall increases, output of soybeans decreases and subsequently the net revenue reduces. The interaction variable between rainfall and temperature and humidity and temperature were significant at 1% and 5% respectively. This suggests that the interaction effects of rainfall and temperature and humidity and temperature had significant effect on the net revenue of the soybean farmers in the study area.

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Findings also revealed that the critical value for marginal impacts is the annual temperature implying that 1mm increase in rainfall would reduce net revenue of soybean by N68,369.82/ha. From these findings, it is recommended that farmers should concentrate on mitigation effects against increased rainfall by planting towards the ends of the rains or before the rains fully establishes.

Keywords: Ricardian model; climate change; soybean; production; rainfall.

1. INTRODUCTION

Soybeans (*Glycine max*) belongs to the family Papilionoideae, it is cultivated largely throughout the world. They are one of the most valuable crops in the world not only as an oil seed crop and feed for livestock and aquaculture, but also as food of great nutritional value for human consumption [1,2]. The world annually, produced 28.6 million metric tons of soybeans in 1961-65, and reached 217.6 million metric tons in 2005-07 the quantity increased 7.6 times during the half century. The United States of America (USA), produced more than 50 percent of the world soybean production until the 1980s but that share declined to 37.0% in the years 2005-07. Brazil and Argentina though significantly increased their shares steadily over the same period. Brazil is the second largest producer with 53.9 million tons, or 24.8% of world production. Argentina ranks third producing 41.4 million tons and 19.0% of world output. The top five highest producers of soybeans in the world are United States of America, Brazil, Argentina, China, and India, producing more 92% of the world's soybeans. Food and Agriculture Organization of the United Nations [3,2].

Soybean was introduced into Nigeria as early as 1980 but it's cultivation as a crop can be attributed to the introduction of the Malayan variety in 1937. The Malayan variety is low yielding susceptible to bacterial diseases and is late maturing. Breeding to improve the existing Malayan variety was undertaken by the Institute of Agricultural Research (IAR) at its Mokwa station in Niger State and later at its Yandev station in Benue State. The institute carried out the crossing between the Malayan and the Clemson non-shattering variety from the United States, this produced a number of promising progenies which led to the release of a number of varieties, such as *Samsoy 2* and *M3ST*. According to [4] it contains about 40% protein, 30% carbohydrate 20% oils and 10% minerals. Industrial and domestic processing of soybean has given rise to numerous products utilized for both human and animal consumption. The products also serve as raw materials in plant, pharmaceutical and confectionary industries. Soybean has been variously reported to have 140-365 applications due to its versatility in the composition of both human and animal consumption [5,6].

Many efforts have been made to measure the economic impact of climate change on agriculture, focusing mainly on the United States and other developed countries [7,8,9,10]. Agricultural production systems in developing countries and especially in Africa are more vulnerable to climate change because they have lower capital intensity and technological flexibility to adapt and most are in already hot climates that are likely to get hotter [11]. Several research studies have been carried out on soybeans, which includes studies variously on production, utilization and processing, by [4, 5,12,13]. Others include adoption, marketing and world trend forecasts studies by [14,2,15,16]. [17,18], reported that climate change conditions could decrease national production of soybeans by 28% by the year 2050, compared with their production under current conditions. In the event of the dynamic and changing effect of climate change on crop production, it is the burgeoning interest of farmers/producers of soybeans to understand the impact of climate change on soybean production, hence the need for this study. The objective of this study is to analyze and measure the economic impact of climate change on soybean production in Niger State, using the Ricardian Approach.

2. METHODOLOGY

2.1 Study Area

The study was conducted in Lapai Local Government area of Niger State. The area is estimated to have a population of 110,127 persons [19]. It lies between latitude 9° 3` N and longitude 6° 4` E and has an area of 3,051 km^2. Three stage sampling technique was employed, firstly four villages were purposely selected. These are Akoyi, Gupa, Ebbo and Yelwa due to their widespread soybean production. Secondly twenty (20) soybean farmers/producers were randomly selected with the aid of a random number table, giving a total sample size of 80 respondents. Primary data was collected through questionnaire dissemination on information such as socioeconomic background, production costs, yield and prices of output. Secondary data on climatic variables and soil data were obtained from the National Cereals Research Institute (NCRI) Badeggi weather station, Bida. Climatic variables were monthly average rainfall, humidity and temperature over the period 1980- 2012. As the net revenue per hectare is expected to be influenced by factors other than climatic variables, other variables like soil type and socioeconomic variables were also included. The study employed the Ricardian Approach using the net Revenue per hectare as the dependent variable. Net revenues were regressed on the climatic, soil and socio economic variables. The Ricardian model following [20] is specified thus:

$$NR/Ha = \beta_0 + \beta_1 F + \beta_2 F^2 + \beta_3 Z + \beta_4 G + u \quad (1)$$

Where

NR/Ha = Net Revenue per hectare
F = Climate variables (rainfall, humidity and temperature)
Z = Soil variable (dummy variable 1 for well drained loamy soil, 0 otherwise)
G = Socio economic variable (household size and farm size)

The model specified for this study is given in equation 2, following [18];

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_1^2 + \beta_5 X_2^2 + \beta_6 X_3^2 + \beta_7 X_4 + \beta_8 X_5 + \beta_9 X_6 + \beta_{10} X_1 X_2 + \beta_{11} X_1 X_3 + \beta_{12} X_2 X_3 + u \quad (2)$$

Where

Y = Net revenue/ha (Naira/ha)
X_1 = Rainfall (mm)
X_2 = Humidity
X_3 = Temperature (centigrade's)
X_4 = Soil type
X_5 = Household size
X_6 = Farm size (has)
β_0 = Intercept
β_1 - β_2 = Linear regression terms
β_4 - β_6 = Quadratic regression terms
β_{10} - β_{11} = Interaction regression terms

Net revenue per hectare from soybean was computed as gross revenue less the total cost of production. The independent variables included the linear climatic, soil, and socioeconomic variables, the quadratic soil and socioeconomic variables, the quadratic climatic variables and the interaction climate variables. The quadratic climatic terms were included to capture second order effects of climate on net revenues. The interaction between climate variables was also included to analyse the cross impacts of climate variables on net revenue of soybeans. Ordinary least squares estimation procedure using "STATA" statistical and econometric software were used to fit the model. To overcome the problem of heteroscedasticity, a robust estimation of the standard errors was undertaken. In the case of overcoming the problem of multicollinearity, identified correlated variables were dropped from the model. Marginal impacts of significant variables were estimated for the model.

3. RESULTS

The regression results indicated that the climatic variables and the variable farm size had a significant impact on the net revenue from soybean production. The estimated coefficient of some of the linear and interaction terms of the climatic variables (i.e rainfall and temperature, humidity and temperature) were statistically significant (Table 1).

4. DISCUSSION

4.1 Summary Statistics

The basic summary statistics for the relevant variables used in the studies revealed a mean net revenue per hectare of N71, 124.13 naira. The mean values of the climate data were 33.87℃ for relative temperature, 96.27 mm for relative rainfall and 72.51% for the relative humidity. The average farm size devoted to soybean production was 2.53 ha's. This indicates that soybean production in the study area is still predominantly on a small scale level. Other socioeconomic variables such as age of the respondents gave a mean of 40 years, household size gave an average of 7 persons and level of education revealed a mean of 2 years. This suggests that respondents had not acquired any form of western education.

Table 1. Parameter estimates of soybean net revenue/ha model

Net revenue/ha	Coefficient	t-value	p-value
Intercept/constant	4071.362	1.3192	0.1915
Rainfall	-68369.5	-2.7780	0.00707
Humidity	106214	1.7470	0.0850
Temperature	-33969.8	-0.2750	0.7838
Loamy soil	3030.306	1.1029	0.2739
Household size	167.79	0.6565	0.5137
Farm size	2275.44	2.0930	0.0400
Rainfall squared	-6.0581	-0.4849	0.6293
Humidity squared	-116.408	-0.4860	0.6285
Temperature squared	1132.72	0.3968	0.6927
Rainfall* humidity	117.416	1.2717	0.2078
Rainfall* temperature	1796.39	2.8540	0.0057
Humidity* temperature	-2960.49	-2.3200	0.0220
Adjusted R^2	0.40		
N	80		
F-value	5.41	2.53E-06	

***, ** & * *Implies significant at 1%, 5% and 10% respectively, source result output, 2013*

4.2 Regression Results

Findings from the Table 1 revealed that the climatic variables rainfall and humidity statistically affected the net revenue of soybeans at 10% and 5% levels of significance. Rainfall had a negative coefficient of -68369.5 indicating an inverse relationship with the net farm revenue. This implies that as rainfall increases, output of soybean decreases and subsequently the net revenue reduces. Temperature had a negative coefficient of -33969.8 implying an inverse relationship with the net revenue of soybean. Climatic data for this study covered the period between 1980 -2012. The rainfall and temperature ranges were between 70 -127 mm for rainfall and 33 – 35℃ for the temperature. However, it was not significant at any conventional level. The variables of soil type, household size, quadratic variables and the interaction between rainfall and humidity were not significant.

The interaction variable between rainfall and temperature were significant at 1% and 5% respectively. This implies that the interaction effects of rainfall and temperature and humidity and temperature had significant effect on the net revenue of soybean in the study area.

4.3 Marginal Effects

The marginal impact of significant variables on net revenue of soybeans was analysed and results on Table 2, showed that the critical value for marginal impacts is the annual rainfall because of the size and magnitude of the variable. The implication is that one millimetre increase in rainfall would decrease net revenue of soybean by ₦68, 369.82 also a 1% and 1℃ increase in the effects of humidity and temperature would also reduce net revenue of soybean by ₦2, 959.79.

On the other hand, 1% increase in humidity would increase net revenue of soybean by ₦106, 215.08. Findings revealed a mean revenue from soybean of ₦ 71,124.13, this translates to about 33.03% change. Similarly, an increase in farm size by 1ha would also increase the net revenue of soybean by ₦2271.06 while 1ha and 1°C increase in the gross impacts of farm size and temperature would increase net farm revenue by ₦1795.52. The indication of this result is that farmers should concentrate on mitigation effects against increased rainfall by planting towards the ends of the rains or before the rains are fully established following the agronomic practices of soybean production.

Table 2. Marginal impact of significant variables on net revenues of soybean

Net revenue (₦/ha)	Coefficient	p-value
Rainfall	-68369.82	0.006
Humidity	106215.80	0.083
Farm size	2271.06	0.041
Rainfall* temperature	1795.52	0.005
Humidity* temperature	-2959.79	0.021

***, ** & * *Implies significant at 1%, 5% and 10% respectively, source result output, 2013*

5. CONCLUSION AND RECOMMENDATIONS

The Ricardian approach was applied in the study to help understand the effect of climate change on farm revenue and it can be concluded that rainfall influenced farm revenue negatively while humidity and farm size had positive influence on farm revenue. The study therefore recommends that farmers should increase their farm size and adhere to mitigation practice of planting before the rains are fully established or towards the ends of the rains in order to improve their farm revenue.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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