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Economic Impact of Climate Change on Maize Production in Northern Nigeria

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ABSTRACT

In recent years, climate change has become a more serious issue than any other environmental problem. One of the main concerns is the risk it poses to food production in developing countries, due to heavy reliance on agriculture. This study examined the influence of climate change on net revenue from maize production in northern Nigeria and the role of socioeconomic factors on farm adaptation. The results are intended to inform farmers, researchers and policy makers, on the impact of climate change on net revenue from maize production in the study area. A farm survey of the respondents found that, there was a significant correlation between climate change (temperature and rainfall) and net revenue from maize production. Results of the study revealed that precipitation plays a more important role as a determinant of farm net revenue, as against temperature, particularly during the rainy season. Furthermore, socioeconomic factors were found to have a mix effect on net revenue. In conclusion the study found that climate change affects net revenue from maize production in the area and there is the need to focus attention on the greatest environmental threat of our time, an issue that previous studies have not addressed comprehensively. The policy implications of the results, if carefully evaluated are expected to serve as a framework for developing climate change adaptation and mitigation options in the study area.

Key words: Impact, climate change, net revenue, maize, northern Nigeria

INTRODUCTION

Today's fast tracking world is becoming progressively mindful of the phenomenon climate change. This refers to a significant and persistent change in the distribution of weather pattern. While scientific evidence showed that the earth climate has continuously changed throughout history, recent climate change acceleration in the past two centuries was unusual and is generally attributed to emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide by humans, mainly from transport, agriculture, manufacturing, energy and other critical sectors of the economy. This human induced climate change is commonly referred to as global warming. The unhampered growth of the greenhouse gas emissions is raising the temperature of the earth. The attendant consequences include melting polar ice caps, extreme weather events and changing seasons. These consequences together with rising world population, threaten the vital sectors of the world economy, such as the water supply, ecosystems, coastal habitats, industries, health and agriculture.

Agriculture is the main stay of Nigeria's economy, over 70% of the populace relies on rain fed agriculture (BNRCC., 2011) it is also a significant part of the GDP contributing 22% to GDP in 2013 (NBS., 2014). Nigeria is highly vulnerable to climate change impact and according to FMEN (2012) the country will lose between 2-11% of GDP by 2020 and as much as 6-50% of GDP in 2050 due to climate change. Furthermore climate change is forecasted to have a devastating negative impact on agriculture in Nigeria lowering crop productivity, especially maize over the entire country with a predicted loss of 30-50% by 2020 and as much as 90% by the year 2100 with greater impact affecting maize crop in northern Nigeria (BNRCC., 2011). In addition changing rainfall pattern will increase the incidence of pest, diseases, drought and flooding; this will eventually increase the possibility of food shortages and price increase, thus wiping out most of the gains made in reducing poverty that will be realized without climate change (Bello *et al.*, 2012). At this point, it is clear to see why though research on the impact of climate change is important for all sectors in Nigeria, concern for agriculture is paramount. However, despite these drastic forecasts, there has been evident lack of empirical assessment of the economic impact of climate change on agriculture in Nigeria.

It is important at this point to note that among the few studies that considered the assessment of the economic impact of climate change on agriculture in Nigeria (Ajetomobi *et al.*, 2011; Odozi *et al.*, 2013; Bosello *et al.*, 2013; Fonta *et al.*, 2011) majority of them concentrated only on the southern part, their assessment is therefore based on areas with uniform climates; this provides a sketchy picture of the impact. In addition the studies did not focus on cereal crops which mainly serve as sources of food. Furthermore literature from previous studies is nearly silent on the vulnerability of farm net revenue to climate change in Nigeria. To provide a comprehensive picture of the impact of climate change on farm net revenue in northern Nigeria, an in depth assessment is vital. This study which is the first regional scale study that cuts across 3 agro ecological zones in northern Nigeria, attempted to bridge these gaps by undertaking to assess the impact of climate change on net revenue from maize production. Findings of the research are likely to be beneficial in improving the knowledge of climate change impact on net revenue in northern Nigeria.

To advance the understanding of the economic impact of climate change on agriculture, the study explores the impact on net revenue from maize. The following research questions drive this study:

- How does climate change affects net revenue from maize production?
- What is the impact of marginal change in temperature and precipitation on net revenue?
- What is the impact of future climate change scenarios on net revenue?

More specifically the study has the following objectives:

- To measure the impact of climate change (temperature and precipitation) on net revenue from maize production in northern Nigeria
- To measure the impact of marginal change in temperature and precipitation on net revenue
- To forecast the impacts of future climate change scenarios on net revenue

MATERIALS AND METHODS

Study area: The study uses cross sectional data, obtained from farm survey in some selected states of northern Nigeria. The area consists of about two third of the entire area of Nigeria. It is located between latitudes 7° and 14° North and longitudes 3° and 15° East. The area comprises of 19 out of the 36 states of Nigeria. It takes up about 692,826 km² of the entire area of Nigeria. The climate

is characterized by high temperature all the year round with an average annual rainfall of 500 mm. Subsistence agriculture is mainly the predominant occupation of people in the area. Millet, sorghum, maize, rice and cowpea are the major staple foods. The area encompasses 3 agro ecological zones, the Southern guinea savanna, the northern guinea savanna and the Sudan savanna. The choice of the area for the study was compelled by its agricultural potential and the observed trend of the negative impacts of climate change. The region provides a suitable climate for maize and as such serves as the corn belt of Nigeria. Even without climate change atmospheric water supply is low in the area; additional decline in water supply due to changing climate will further harm the agricultural productivity of this area.

Sampling: The population for this study consisted of households who engage in maize production, across all the sampled States in northern Nigeria. The units of analysis were farmers who produce maize in the area. The sampling frame was a list of farmers in the area managed over the years by the government extension service. Due to lack of proper record of the target population, an alternative sampling frame was not available. To enable the study include respondents with the desired characteristics, multi stage sampling was used. This justified the reason why in the first stage States and local governments with high concentration of maize farmers were purposively selected. This technique, in addition to being straight forward in selecting the desired respondents, is also cost effective and accurate. However, the method is sometimes prone to bias. In the second stage, respondents from two local government areas in each of the selected States were randomly selected via lottery method. One of the good features of the random sampling method is that it can be used with large sample population. It also avoids bias and ensures that a significant percentage of the population is represented. It is however not totally devoid of error.

At this juncture, it should be observed that in order to ensure the availability of a large sample for the study, to improve the usage of the survey and also lower the impact of measurement errors, 700 respondents were selected from the sampling frame (Molua and Lambi, 2007; Kabubo-Mariara and Karanja, 2007). A total of 530 surveys were finally realized in the sample out of which 483 were useable, representing 75 response rate. All the useable surveys were included in the analysis. Expedience sampling method (selecting respondents based on availability) was used to determine the sample size. This was the only feasible option giving the unique situation of the study.

Data collection: The survey was conducted in January 2013 using a structured questionnaire by trained enumerators. To ensure clarity and interpretability, the questionnaire was pre-tested on 40 respondents from the target population, before the main survey. Permission was sought from the respondents before each interview and no incentives were provided to the respondents for completing the questionnaires. The questionnaire survey was the most appropriate choice giving the circumstance of the study (Kurukulasuriya and Mendelsohn, 2008; Seo and Mendelsohn, 2008; Nhemachena *et al.*, 2010; Ajetomobi *et al.*, 2011). Data for the study was collected in 8 States of northern Nigeria and the Federal Capital Territory. The States are Kaduna, Katsina, Kwara, Kebbi, Nassarawa, Niger, Sokoto, Zamfara and Abuja. Two local governments' areas were selected to represent each State. The local governments were selected based on their scale of maize production. Farms were randomly selected from two districts in each local government area. The sampling at district level was clustered in villages to save time and reduce cost.

Model specification: In applying the Ricardian technique the net revenue function is specified as follows:

$$R = \sum P_i Q_i(X, F, G, Z) - \sum P_x X \quad (1)$$

Where:

R = Net revenue per hectare

P = Market price of crop_i

Q = Output of crop_i

X = Vector of purchase output

F = Vector of climate variables

G = Set of economic variables such as livestock ownership

Z = Set of soil variables

P_x = Vector of input prices

Following Mendelsohn *et al.* (1994) the study specifies the model net revenue model as follows:

$$V = \beta_0 + \beta_1 F + \beta_2 F^2 + \beta_3 G + \beta_4 Z + U \quad (2)$$

Where:

V = Net farm revenue

F = Vector for climatic variables

G = Set of economic variables

Z = Soil variables

U = Error term

The analysis of the Ricardian model involves linear as well as quadratic terms for the climatic variables (temperature and precipitation). The quadratic term was included in order to estimate known nonlinear relationship between net revenue and climate variables, when the sign of the quadratic term is positive the net revenue function is U shaped and it is hill shape when the quadratic term is negative.

Data analysis: District level data obtained in January 2013 via structured questionnaire were used for the study. The questionnaire was designed to collect farm level data about small scale traditional agriculture and large scale mechanized agriculture with certain level of improved technology from 3 agro ecological zones in northern Nigeria. It aimed at collecting information on relevant variables that explained variations in farm net revenue such as crop production practices, production costs, marketing, soil type, socio economic factors, climate change perceptions and farm adaptations options from the 3 agro ecological zones. The questionnaire was divided into 5 parts. Part I relates to questions on agricultural/environmental problems affecting the area. Part 2 focused on maize production practices and production cost, part 3 deals with the economic characteristics of the respondents, part 4 was on climate change perception and finally part 5 centered on the respondent's demographic variables.

Data for the study: The climate of the area was defined by two seasons the rainy season and the dry season in line with the climatic characteristics of northern Nigeria. Two main climatic elements (temperature and rainfall) were considered for the study, the climatic data was obtained from the Nigeria meteorological agency. The agency is responsible for collecting and managing meteorological data for Nigeria. Soil data was sourced from the Nigeria reconnaissance soil survey

2009, it was obtained from Federal Department of Land Resources; Abuja. The report provides information on the characteristics and fertility status of soils found in all States of Nigeria.

Variables for the study

Dependent variable: Net revenue per hectare was used as the dependent variable for the analysis. It was obtained from the household survey conducted by the study. It was given as the product of gross net revenue (price multiplied by quantity in kg) minus the relevant production costs such as (seeds, fertilizer, chemicals, tillage, weeding, harvesting, transport, storage and processing) divided by the farm area in hectares. The study used the net revenue per hectare to define the dependent variable due to lack of established measure of land value in the study area.

Explanatory variables: Climate variables, hydrology variables, soil variables and relevant socio economic variables were the explanatory variables used for the study.

Climatic variables: Temperature (°C) and rainfall (mm) are the climatic variables used for the study. Both temperature and rainfall were reported for rainy season (May to October) and dry season (November to April) in line with the climatic set up of northern Nigeria. The dry season temperature variable equals the average temperature of the dry season (November to April) for all the sampled States. The rainy season temperature corresponds with the average temperature of rainy season (May to October). Similarly the rainy season precipitation is identical with the average precipitation of the rainy season and the dry season precipitation is equivalent to the average precipitation of the dry season. It is important to note that the climate in northern Nigeria is marked by two distinct seasons, rainy and the dry seasons, agricultural production is mainly carried out during the rainy season, although irrigation is sometimes practiced to supplement rainfall during drought situation, it is largely exercised during the dry season on a small scale mainly to grow vegetables and irrigated rice.

Soil: Additionally the study identified six groups of soils in the area based on the Nigeria reconnaissance soil survey 2009 classification. These are Orchic luvisol, Orchic Acrisol, Dystric regosol, Ferric luvisol, Eutric fluvisol and Ferric Acrisol. The soils differ in physical and chemical properties, as well as in their fertility status. These properties when combined with the influence of climate can affect farm productivity and consequently net revenue. The soil classes were ranked according to their fertility status based on the classification of the reconnaissance survey.

Socio economic variables: So far there is examined only climatic and soil variables, socio economic characteristics are also important determinants of the level of farm technology and net revenue. The study examined the effect of farm power, farm size, house size, market and livestock keeping on farm net revenue. For the level of farm power a dummy for (Hand, animal and tractor) was used to test the effect of farm power. Farm size in hectare was used to assess the effect of farm size on net revenue. House size was used as a proxy for labor that was not included in the calculations for net revenue. This was because the majority of the farmers rely on the house hold to supply farm labor and there is difficulty in establishing wage for the house hold labor. House hold size was therefore included as a proxy to account for the impact of labor. Similarly distance to input market in kilometers was used to test the impact of distance of market on net revenue. Distance is expected to have a negative effect on net revenue. Livestock is an important component

of agriculture in northern Nigeria. Livestock animals are used as source of farm power, manure and as a risk management strategy. Keeping livestock is anticipated to contribute to farm net revenue positively.

Statistical analysis: The SPSS statistical package was used to estimate the models for northern Nigeria. Two main sets of Ricardian models were estimated at different stages. In the first stage climatic variables were combined with soil variable which defines the model without adaptation. At the next stage, farm characteristics such as farm power, house size, farm size, livestock ownership and distance to market were integrated into the first model to define the model with adaptation. This will enable the study, assess the role of adaptation in reducing climate change impact on net revenue from maize production. Although, there is a significant variation of temperature across geographic location in northern Nigeria temperature do not vary widely across time. A strong multi collinearity between the linear and quadratic variables for rainy season temperature was observed and all attempts to correct for the multi collinearity including demeaning the climatic variables fails, as the last option to correct for the problem the quadratic variable for the rainy season temperature was excluded from the model on the ground of multi collinearity and non-significance. The problem of heteroscedasticity and outliers typical to most cross sectional data was also dealt with in the study. Similarly other socio economic variables such as access to credit, extension, education, experience and irrigation which do not contribute to the model and are not significant were all dropped from the model. Presence of heteroscedasticity was tested and outliers were identified and removed from the dataset.

RESULTS

Descriptive statistics: A summary of the basic statistic of the dataset for the variable used in the study was presented in Table 1. The result showed that the average net revenue per hectare is ₦44,891. The net revenue ranges from a minimum of ₦1760 to a maximum of ₦91,900 ha⁻¹. Six major types of soils were identified and ranked according to their fertility by the study. The mean fertility was 2.38 with a minimum fertility of 1.50 and a maximum of 3.50. The average distance

Table 1: Descriptive statistics for the variables used in the study

Variables	Observed	Minimum	Maximum	Mean	Standard dev.
Net revenue (₦/ha)	483	1760	91900	44891	2017
Dry season temperature (°C)	483	25.80	36	33.66	2.20
Dry season temperature squared (°C)	483	812	1296	1138.21	143.22
Rainy season temperature (°C)	483	26.80	35	31.90	2.37
Rainy season temperature sq. (°C)	483	718	1225	1023.56	147.73
Dry season precipitation (mm)	483	0.20	16.60	3.93	4.517
Dry season precipitation squared (mm)	483	0.04	275.50	35.84	71.45
Rainy season precipitation (mm)	483	77	200	144.43	40.03
Rainy season precipitation sq. (mm)	483	5929	40000	22460	4.67
Soil	483	1.50	3.50	2.38	0.67
Distance to market (km)	483	1.0	50	10.87	9.26
Livestock (No.)	483	0.0	85	3.08	7.27
Farm size (ha)	483	0.20	200	4.07	13.60
House hold size (No.)	483	1	40	8.05	5.418
Hand (1/0)	483	0	1	0.366	0.48
Animal (1/0)	483	0	1	0.32	0.47
Tractor (1/0)	483	0	1	0.30	0.45

₦: Nigerian currency

Table 2: Regression result for net revenue function model

Variables	Coefficient	t-value
Constant	334342.5	0.95
Dry season temperature	-18835.8	-0.76
Dry season temperature squared	253.94	0.69
Rainy season temperature	-286.47	-0.12
Dry season precipitation	6448.81**	2.15
Dry season precipitation squared	-280.69*	-1.86
Rainy season precipitation	698.95*	1.66
Rainy season precipitation squared	-3.36**	-2.03
Soil	9873.54***	3.41
Market	-213.66**	-2.35
Livestock	307.12**	2.53
Farm size	100.50	1.55
House size	-228.65	-1.48
Animal	3416.13	1.56
Tractor	7253.74***	3.37

***p-value significant at 1%, **Significant at 5%, *Significant at 10%

to input market was 10.87 kilometers, the distance varies widely between a minimum of 1.0 km to a maximum distance of 50 km. The average number of cattle owned by the respondents was 3.0 with a minimum of 0 and a maximum of 85. The average land area allocated to maize production was 4.07 ha, a minimum of 0.20 ha and a maximum of 200 ha. Household size is defined as the number of persons related or unrelated living under one roof. The average size of the household was 8 people with a minimum of 0 and a maximum of 40 people. Farm power dummy was included in the model as hand, animal or tractor; this is used as a proxy for farm technology.

Regression analysis: The study estimated two models, a model with only climatic and soil variables and another model that incorporates the socioeconomic variables into the first model (Table 2). Inclusion of socio economic variables has improved the second model as indicated by the higher adjusted R^2 which demonstrated the importance of socioeconomic variables in explaining variation in net revenue in northern Nigeria. Regression of estimates for net revenue function model which included the socio economic variables was presented in Table 2. In this result the sign of the coefficients for the quadratic terms of the dry season and rainy precipitation were negative and opposite to the linear terms indicating a hill shape relationship between net revenue and climate but the sign of the quadratic term of dry season temperature was positive and thus maintains a U-shape relationship with net revenue. As presented in column 3 of the table all the coefficients for the linear and quadratic terms of precipitation variables were significant. The signs of the linear terms for both dry season and rainy season temperature coefficients showed a negative relationship with net revenue although the relationship was not statistically significant. Similarly, soils had a positive effect on net revenue and the relationship was statistically significant ($p > 0.01$) as presented in columns 3 of Table 2.

Distance to input market, where the farmer purchased inputs and sold produce measured in kilometers was also examined, column 2 of Table 2 showed that the variable for market is negative and significant ($p > 0.05$). The variable for livestock animals was also modeled in the analysis to show the contribution of livestock keeping to net revenue. The coefficient for livestock revealed a positive impact on net revenue as in column 2 of Table 2. The impact of livestock variable was also statistically significant ($p > 0.05$). The variable for farm size was included to show the effect of farm

Table 3: Marginal impact of climate on crop net revenue

Climates	Marginal impact	Annual impact	Annual elasticity
Temperature (°C/ha/°C)			
Dry season temperature	-1740		
Rainy season temperature	-4,255	-5995	-4.4
Precipitation (mm/ha/mm)			
Dry season precipitation	4,247		
Rainy season precipitation	-970	3273	6.7

Source: Calculated using values from coefficients in Table 2, Annual temperature elasticity is % change in net revenue over % change in temperature, annual precipitation elasticity is % change in net revenue over % change in precipitation

Table 4: Climate change impact on future scenarios

Parameters	2030	2060	2090
Temperature (°C)	+1	+2.1	3.7
Impact (₦/ha)	-4281	-8620	-14969
Precipitation (mm)	+0%	+1%	+4%
Impact (₦/ha)	-271	-280	-310

Source: Calculated by author using data from GCM climate projections for Nigeria based on A2 climate scenario

size to net revenue the result in column 2 of Table 2 indicated that the coefficient for farm size was positive. House size was included in the analysis as a proxy for labor that was not included in the model. The coefficient for house size as expected was negative as shown in column 2 of Table 2. On the level of farm power usage, coefficients for both animal and tractor as sources of farm power were positive indicating that they both contributed to net revenue, while the coefficient for animal is not significant the coefficient for tractor was statistically significant ($p > 0.01$) as presented in column 2 of Table 2.

Marginal impact analysis: Marginal impact analysis was done to examine the annual impact of 1°C change in temperature and 1mm change in precipitation on net revenue per hectare. The results presented in Table 3 shows a decline of ₦5,995 on net revenue due to 1°C rise in temperature and an increase in net revenue of ₦3,272 for 1mm increase in rainfall. Results in addition showed that the marginal impacts of both the temperature and precipitation coefficients are elastic. Furthermore the study used the A2 emission scenario of the Global Circulation Model (GCM) to project the impact of climate change on net revenue. This gave a picture of how future climate scenarios will affect net revenue, the analysis forecasted the impact for the years 2030, 2060 and 2090 using the coefficients for the net revenue function. Projection on the impact of temperature was made based on forecast of increasing temperature for Nigeria by as much as 1°C in 2030, 2.3°C in 2060 and 3.7°C in 2090 as well as a slight increase in precipitation by 0% in 2030, 1% in 2060 and 4% in 2090 (BNRCC., 2011; McSweeney *et al.*, 2010).

Future climate change impacts: Results for the future climate impact were presented in Table 4. With a projected 1°C rise in temperature by the year 2030 net revenue will decline by about ₦4,281 ha⁻¹ for the maize industry in northern Nigeria. While in the year 2060 temperature is projected to rise with about 2.1°C this will lead to a decline in net revenue of about ₦8,620 ha⁻¹ and in the year 2090 net revenue will decline by about ₦14,969 ha⁻¹ due to 3.7°C rise in temperature. The result shows an increasing trend in the decline in net revenue with rise in temperature. Similar trend was observed with respect to precipitation. In the year 2030 ₦271 will

be lost, while a decline in net revenue of about ₦280 was projected for the year 2060 due to 1% increase in precipitation and in the year 2090 a decline of ₦310 was forecasted due to 4% increase in precipitation.

DISCUSSION

Regression result for the net revenue function model was presented in Table 2, coefficients for the quadratic terms of the precipitation variables were negative indicating that the relationship between net revenue and precipitation is nonlinear. However, the signs for the linear terms of both the dry season and rainy season temperature coefficient were also negative; this shows that higher temperature will be harmful to net revenue. The coefficients for the linear terms of the precipitation variables were positive but the coefficients for the quadratic terms were negative as indicated in column 2 of Table 2. This implies that rainfall contributes positively to net revenue in northern Nigeria to a certain limit, beyond which it is detrimental to farm net revenue, the coefficients for the dry season and rainy season precipitation are statistically significant at $p > 0.05$ and $p > 0.10$, respectively. The result may justify the fact that rainfall may play a more important role in determining net revenue than temperature. Temperature may not be a limiting factor for maize production because the area is characterized by all year round high temperature which meets the minimum requirements for the crop. The variable for market shows that distance negatively affect farm net revenue. The results suggest that farms that are closer to market stand to benefit more than farms that are farther away from the market. The coefficient for market is statistically significant ($p > 0.05$) this shows the importance of market distance in determining net revenue. Livestock keeping, as a priori expectation contributes positively net revenue. The coefficient for livestock as shown in column 3 of Table 4 is statistically significant ($p > 0.05$) this underscores the importance of livestock in contributing to farm net revenue. Livestock is an important part of agriculture in the area; it provides a source of farm power, manure and net revenue as well as risk aversion strategy.

Due to the abundance of large expense of arable land in northern Nigeria compared to other parts of the country, farmers tend to cultivate a large portion of land mainly under extensive agriculture. This practice could be productive in the short run but turns out to be inefficient in the long run due to the inability of farmers to manage land effectively. Findings of the study show that farm net revenue increases as the farmer cultivates more land. This could be explained by the fact that bigger farms may have lower cost of production due to economies of scale effect and hence higher net revenue. The coefficient for house size as expected was negative as presented in column 2 of Table 2. The negative impact of house size on net revenue could signify low productivity of rural households in northern Nigeria. The negative impact of house size may not be unconnected to age or physical fitness of many farmers, rendering a significant percentage of the agricultural labor force less vibrant. This is consistent with the findings of (Kurukulasuriya and Mendelsohn, 2008).

Additionally, as a proxy for farm technology, a dummy for hand, animal and tractor as a variable for level of farm power usage was introduced into the model to assess the contribution of each source of power to net farm revenue and examine its role in adaptation. The coefficients for animal and tractor as sources of farm power were positive and significant ($p > 0.01$) in the case of tractor as shown in columns 2 of Table 2. The result as a priori expectation reveals that adopting the use of improved source of farm power could raise net revenue. Although the impact of both animal and tractor was positively related to net revenue tractor might contributes more to net

revenue. An important implication of the findings on farm power usage is that using tractor as source of farm power may be more cost effective, timely and efficient than using alternative sources of power.

Results of the marginal impact of climate change on net revenue were presented in Table 3. The results showed the impact of 1°C rise in temperature and 1mm increase in precipitation. Findings showed that net revenue declines with ₦5,995 ha⁻¹ due to marginal rise in temperature per annum while an increase of ₦3,273 ha⁻¹ due to 1mm increase in precipitation per annum was observed. To give a picture of how net revenue will be affected by future climate change the analysis projected future impact for the years 2030, 2060 and 2090. In 2030 net revenue was predicted to decline by about ₦4281 ha⁻¹ due to 1°C rise in temperature. A loss of ₦8620 ha⁻¹ will be incurred due to a projected 2.1°C increase in temperature in the year 2060 while in the year 2090 temperature is forecasted to rise with 3.7°C this will result to a decline in net revenue of ₦14969 ha⁻¹. The analysis showed that the trend in decline of net revenue is increasing with rise in temperature. Similarly forecasts from different models projected a slight increase in precipitation across Nigeria. The study found that in the year 2030 with 0% increase in precipitation net revenue will fall by ₦271 ha⁻¹, in 2060 due to 1% increase in precipitation net revenue will decline with ₦280 ha⁻¹ while in the year 2090 ₦310 ha⁻¹ will be lost as a result of 4% increase in precipitation. Findings revealed a similar increase in the trend of decline in net revenue due to an increase in precipitation. Results of the future climate change impact implied that in future increase in both temperature and precipitation will be harmful to net revenue although rise in temperature will be more harmful to net revenue.

The concern for declining farm net revenue as a result of the impact climate change has compelled researchers to pay more attention to agriculture, especially food crops sector. This study examined the potential impact of climate change on net revenue from maize production in northern Nigeria. To date; it is the first study that investigated the impact of climate change on net revenue from maize production across different agro ecological zones in the area using the Ricardian technique. Based on sample evidence, the result indicates that climate change can influence net revenue from maize farms in northern Nigeria. One of the most significant findings of the study was the negative impact of temperature on net revenue and the positive relationship between rainfall and net revenue during the growing season. The study additionally predicted that future climate change especially rise in temperature will affect farm net revenue. The significant relationship between precipitation and net revenue clearly showed that precipitation is an important limiting factor to maize production in northern Nigeria This is consistent with the findings of previous studies that postulated that climate change affects crop yield and consequently farm revenue (Kurukulasuriya and Mendelsohn, 2008; Seo *et al.*, 2009; Kabubo-Mariara and Karanja, 2007; Ater and Aye, 2012).

CONCLUSION

The study provides a sound empirical evidence of the impact of climate change on net revenue from maize production in northern Nigeria. Relying on survey of farms in the area, the study reveals that climate change might be one of the most important determinants of net revenue for maize farms in the area. The model tested predicted that increase in temperature will be harmful to net revenue, while additional rainfall to a certain limit will raise revenue for maize farms. Furthermore projections of climatic scenarios showed an increasing trend in the decline of net revenue as a result of increase in both temperature and precipitation in the future. This study is

distinguished from previous studies that assessed the economic impact of climate change on agriculture in Nigeria in 3 significant ways. First, the analysis covered most of the entire northern Nigeria, largely regarded as the corn belt of Nigeria. Second, Maize, the third most important cereal crop in Nigeria is considered; lastly, the analysis predicts marginal impact and impact on future climate scenarios for the area. To reduce the vulnerability of maize to climate change in northern Nigeria researchers and government should devote more resources as well as attention in developing adaptation options to cushion the effect in the short run. The current analysis is limited to two important elements of climate temperature and rainfall prospective researchers should include other climatic elements that would affect net revenue and strive to cover wider area.

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