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EFFECTS OF AGRO-CLIMATIC VARIABLES ON YIELD OF SELECTED VARIETIES OF RICE IN TARABA STATE, NIGERIA

Ezra, A[1]., Adebayo, A. A[2].,Umar, A. S.[3] and Martins, I. K.[4]
[1,2&3]Department of Geography, ModibboAdama University of Technology, Yola
Correspondent: andrewezra12@gmail.com 07067679410, 08089030370

ABSTRACT
Rice is one of the major crops cultivated in Nigeria and serves as source of employment opportunity to many people. However, it production is being affected by many factors among which are agro-climatic parameters. In regards to this, this study examined the effect of Agro-climatic variables on Rice Yield in Taraba State. Secondary data such as climatic variables and Rice Yield (Local, Ofada, FARO 44 and FARO 58 Varieties) based on stations (Local Government Area) and years were the data used for this study and were collected from Taraba state Agricultural Development Program (TADP). Stepwise regression in SPSS 20.0 was used to analyze the data collected using Station-Year method. Result on the effect of agro-climatic variables on local rice variety revealed that, mean annual temperature was identified to be the important climatic factor affecting the yield of the variety and it is statistically significant at p<0.01. Minimum Temperature, Solar Radiation and June Rainfall on the other hand were identified to be the critical climatic factors affecting the yield of Ofada rice variety and the variables were statistically significant at p<0.01 to the variation in yield of the rice variety in the state. In the case of FARO 44 rice variety, the Prediction model reveals that, Mean temperature, August and September rainfall were identified to be the most influencing climatic factors affecting the yield of the variety in the State and the variables were highly significant at p<0.01 to the variance in the yield of the variety. Result on the effect of climate on FARO 58 on the other hand showed that, mean temperature, August and October rainfall were identified to be the critical climatic variables affecting the yield of the variety in the state and were highly significant at p<0.01 to the variation in yield of FARO 58. Following the result obtained, it was concluded that mean annual temperature, Minimum temperature, Solar Radiation, June rainfall, August rainfall, September rainfall and October rainfall were the important variables controlling the growth and yield of rice in the State. It was also concluded that, the volume of rainfall received in a year and LRS doesn't determines the growth and yield of rice instead, the efficiency of the rainfall amount distributed at the various developmental stages of the crop especially the important stages of the crop development that determine the growth and yield of rice in the State. Cultivation of local, Ofada, FARO 44 and 58 rice varieties should be encourage in places with high temperature and August rainfall amount and low September and October rainfall in the state. In addition, there is a need for government assistance in terms of improved varieties of rice and other agricultural input.
Key words; Agro-climatic variables, Local, Ofada, Faro 44 and Faro 58 Rice Varieties

INTRODUCTION

Rice is one of the major crops cultivated in Nigeria, and it plays a very significant role in food security and provision of employment. However, its production is faced with some challenges among which are climate.Climate is very sensitive to all stages of crop production;from land clearing and preparation, through crop growth and management to harvesting, storage, transportation and marketing of the product (Ayoade, 2005). The amount and distribution of precipitation, solar radiation, wind, temperature, relative humidity affect and solely influence the global distribution of crice as well as their productivity and also determine the types of rice variety a farmer cultivate, the yield of the crop and hence farmers' profit (Ayoade, 2005;Stigter, 2004). In addition, the amount of Sunlight, temperature, moisture and carbon dioxide (CO_2) determinesseed germination, the time emergence of plant, the rate of growth of roots, stems, and leaves and flower development. They also determine when plant produces flowers, and consequently the filling of grain or the expansion of fruits (David and Mark 2007).

In Taraba State, the Government has designed programs on food security in the past to meet up with the demands of the growing population. These programs include the integrated rural development program which is anchored on the Agricultural Development Program (ADP), Agricultural Mechanization Program in 2005, Taraba State palm oil production program in 2001, Taraba State fertilizer voucher system policy in 2010, Taraba State Policy on tractorization in 2007 and Taraba State Agricultural Produce and Marketing Agency (TAPMA) 2007 which focused on maize and rice production (Auta and Dafwang, 2010). Although these programs were set to boost agricultural practices in the state, but farmers are still battling with some challenges among which are climate related issues.For example, study by Jifin (2017) reported that climate affects agricultural production in the state in many aspects of farming activities which include; change in agricultural pattern, pests and disease attack on crops, crop failure, and poor harvest. In the same vein, Angela and Fidelis (2013) revealed that rice farmers in the state are facing serious climatic challenges such as; stunted rice growth, widespread of pest and diseases, difficulties in predicting rice planting period, drying and withering of rice seedlings, delayed rainfall and too much heat which evaporates water from rice plant. Consequent to all these challenges mentioned, there is a clear indication that rice being one of the major crops cultivated in the state is affected by climate, and unless appropriate measures are taken, there is going to be more crop yield failure and reduction.It is in view of this,this study examined the critical climatic variables affecting different varieties of rice in the State.

MATERIAL AND METHODS

Taraba State was carved out of the former Gongola State on 27th August, 1991 by the then regime of General Ibrahim Babangida. The State is one of the Nigerian thirty-six (36) state located between latitude 6^{o}31$^{'}$ and 9^{o}37$^{'}$ North of equator and longitude 9^{o}9$^{'}$ to 12^{o}1$^{'}$ East of the Greenwich meridian (Figure 1).

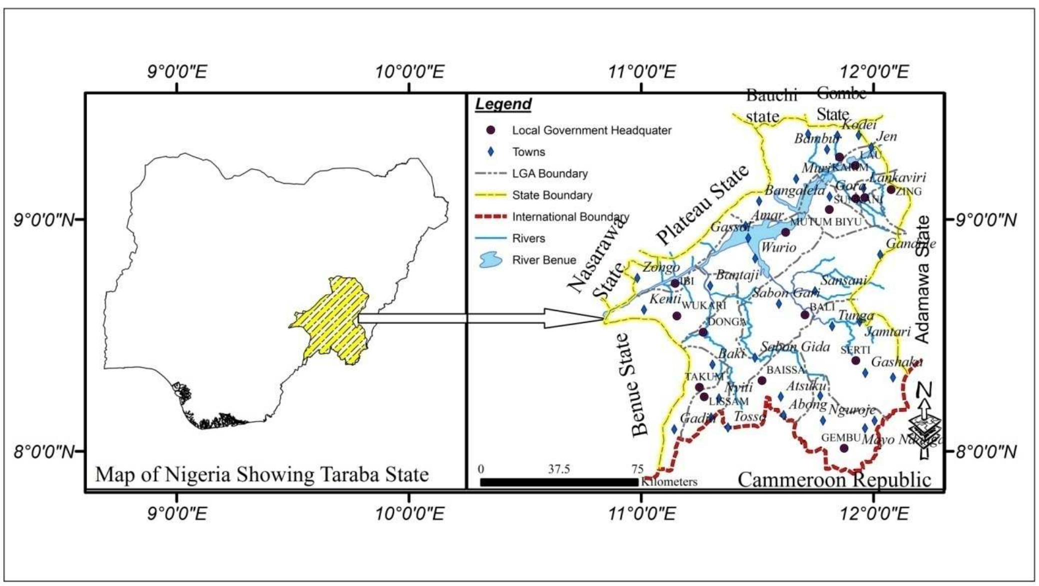

Figure 1: Taraba State

Relief of the area is made up of high plains which covered parts of the Benue low lands lying above flood level but below 1000 foot contour line and include places around KarimLamido, Jalingo, Sunkani and, some part of Wukari while the high highlands are erosional in nature and are cut in sedimentary formations Udo (1978). River Benue is the major river in the state (Adebayo and Umar, 1999). River Donga and Taraba are the dominant river systems which flow across the Muri plains to drain the entire State together with the minor ones, such as the Lamorde and Mayo RanewoTaraba Youth Progressive Association of Nigeria (TYPA)(TYPA, 2009).

Climate of the State is mainly influenced the rain-bearing south-west air mass and the dry dusty north-east trades or harmattan. The rainy season in Mambilla Plateau lasts from February to November with a mean annual rainfall of about 1850 mm, while at the other part of the state lasted from April to October with mean annual rainfall varying between 1058mm around Jalingoand Zing, to about 1300mm around Serti and Takum (Emeka and Abbas, 2011).

Temperature during rainy season in Mambilla drops to as low as 15°C while the mean annual temperature around Jalingo is about 28°C with maximum temperature varying between 30°C and 39.4°C and minimum temperatures range between 15°C to 23°C (Emeka and Abbas, 2011).

Alluvial soil type are type are found on the flooded plains of rivers they run along Benue River and other rivers (Iloeje, 2001). Sudan Vegetation, Northern Guinea Savanna, Southern Guinea Savanna, Forest derive savanna and mountain forest and grassland are the major vegetation types in the area (Ekaete, 2017). Sudan vegetation covered places around KarimLamido, Lau, Jalingo, Ardo Kola, Yorro and Zing LGA, while Northern and southern savanna covers the major part of the State and include LGAs such as Gassol, Ibi, Wukari, Donga, Bali, Takum, Ussa, Kurmi and Gashaka LGA.

Data Collection

Annual rainfall, monthly rainfall, dry spell, onset date of rain, cessation date of rain, Length of Rainy Season (LRS), seasonality index and hydrological ratio were extracted from the daily, monthly and annual rainfall for a period of 38 years (1979 to 2017) while, monthly and annual minimum temperature, maximum temperature, mean temperature, relative humidity, solar radiation and wind speed for the period 1979 to 2015 which is the longest period for which records of the variables are available in the State were obtained from Upper Benue River Basin Development Authority (UBRBDA), Taraba State Agricultural Development Program (TADP) (Area, Zonal and Head office) in the State, Taraba State University Jalingo, Federal Polytechnic Bali and Nigerian Meteorology (NIMET) Ibi. Rice yield data based on varieties (Local, Ofada, FARO 44 and FARO 58 varieties) and LGAs on the other hand were collected from Taraba State Agricultural Development Program (TADP) Area, Zonal and Head office in the State for the available years (2011-2017). The varieties were selected based on the fact that they are the major varieties of rice cultivated in all the Local Government Areas of the State. The yield records were collected by the staff of TADP annually through a survey method called Crop Area Yield Survey (CAYS). In this survey method, rice yield record based on varieties and cultivated area of rice farmers in each LGA of the State were collected, analyzed, summarized and recorded in tons per hectare.

According to Ayoade (2005), there are two methods of crop-climate study; Simulation or physiological method and statistical or empirical method. Simulation or physiological method examines the impact of climatic factors on physiological characteristics of plant (Number of leaves, leave length, stem diameter, plant height among others) while. In regards to the aim of this research and the data required to achieve this objective, statistical or empirical method which studies the relationship between climatic factors and crop yield over time and spacewas used to examine the impact of climatic variables on rice yield as also used by many authors in their analysis(Mahmood., Ahmad., Hassan and Bakhsh 2012;Govinda 2013; Saliu., Jude., Taibat., Alhassan and Samuel 2015;Deotrephy., Feroze., Ram and Lala 2017).

Data Analysis

In other to examine the effect of climatic variables on rice yield over time and space, station-Year method suggested by Adebayo (2000) as the best and accurate method of studying spatio-temporal impact of agro-climatic variables on rice yield was used. Applying the method, Agro-climatic variables (minimum, maximum and mean temperature, relative humidity, solar radiation, wind speed, dry spell, onset, cessation, LRS, seasonality index, hydrological ratio among others) as well as rice yield were arranged based on the available stations (LGAs) and years of record in the state for efficient regression analysis. This method was conducted on all the selected rice varieties using SPSS and MiniTab statistical packages. Regression analysis was used to examine the relationship between the climatic variables and yield of different varieties of rice as well as the effect of the climatic variables on rice yield. The Statistical model used in this research is presented below;

$Y = a + b_1x_1 + b_2x_2 + b_3x_3$ (Regression model) - - - Equation 1

Where:

Y = Rice yield

X = Agro-climatic variables

a and b are constant.

RESULTS AND DISCUSSION

Effect of Agro-climatic Variables on Local Rice Variety

Table 1 showed the effect of critical Agro-climatic elements on Local Rice yield in the study area. The result revealed that the mean temperature is the only agro-climatic variable that is highly significant to the cultivation of Local rice yield in the State. The prediction model showeda significant F-value of 28.726 at $p<0.01$ and the coefficient of determination (r^2 values) is 0.431, this implies that the variation in Local rice yield is accounted or explained by agro-climatic variable to 43.1% leaving the remaining percentage for other factors to explain. Mean Temperature as the only critical climatic element that is highly significant to Local rice yield showed a positive significant T-value of 5.36 at $p<0.01$. The coefficient value of the critical element is 0.526 which implies that increase in Mean Temperature will lead to an increase in Local Rice yield in the State, while holding other variables constant. Prediction of mean temperature as the critical climatic element influencing Local rice yield in the State also suggested that Local rice cultivation is highly determined by the sufficiency of temperature for it effective production, and implies that places of high mean temperature in the state are good for cultivation of local rice variety while places with low mean temperature amount are detriment to local rice cultivation in the state. This is not surprising because Mean Temperature is one of the critical climatic elements that influence rice yield at the different developmental stage of its production and the optimum temperature for normal development of rice ranges from 27^0C to 32^0C (Wahid *et al.*, 2007; Farrell *et al.,* 2006 and Yin et al.,1996). This result also agrees with the findings of Deotrephy*et al.,* (2017).

Table 1: Stepwise regression result between local variety and climatic variables

Predictor	Coef	SE Coef	T	R^2 (%)	R^2(adj)	R^2(pred)	VIF
Constant	-11.971	2.671	-4.48**				
Mean Temp	0.52644	0.09816	5.36**	0.431	0.416	0.3690	1.000

** T-value is significant at 1%

Effect of Agro-climatic Variables on Ofada Rice Variety

The critical Agro-climatic elements that influence the yield of OFADA rice varietyis presented in Table 2. All the selected Agro-climatic variables were subjected to stepwise multiple regressions and the model selected three Agro-climatic variables (June Rainfall, Minimum Temperature and, Solar Radiation) that are highly significant to Ofada rice yield. Selection of June Rainfall, Minimum Temperature, and Solar Radiation showed that the variables are the critical contributors to variation in yield of Ofada rice variety in the state and their variation over time and space influences the growth and yield of Ofada rice in the State. The model is statistically significant with F-value = 14.21 at $p<0.01$ and the coefficient of determination (r^2 values) is 0.6398, this implies that the variation in Ofada rice yield is accounted or explained by agro-climatic variable to 64% leaving the remaining percentage for other factors to explain. Solar Radiation has the strongest negative contribution of 0.7836 to variation in yield of Ofada rice followed by Minimum Temperature with a positive contribution of 0.3384 and then June Rainfall with a negative contribution of 0.0033. The positive contribution of Minimum Temperature to the yield of Ofada rice variety suggested that a unit increase in Minimum temperature will lead to an increase in yield of Ofada rice with 0.3384, while a decrease in its amount will decrease the yield of the variety. Unlike the Minimum Temperature, June rainfall and Solar Radiation show a negative contribution of -0.0033 and -0.7836 respectively, this negative contribution suggested that a unit increase in June rainfall and Solar Radiation will decrease the yield of Ofada rice yield with 0.0033 and 0.7836 respectively. In addition, the 64% contribution of the Agro-climatic variables to yield of Ofada rice signifies that growth and yield of Ofada rice is strongly determined by the amount of these three parameters and place of high minimum temperature will increase Ofada rice yield, while places of high Solar Radiation and June Rainfall will reduce the yield of Ofada rice variety in the State. This supported that heat parameters like Minimum temperature and solar radiation play a significant role in the growth and yield of rice (Sridevi and Chellamuthu, 2015). Moreover, the June rainfall coincides with the planting to seedling (Nursery) stage of rice development in the State, as such, places with excess rainfall will make the rice plot to be submerged with water thereby making the place to be impaired to Ofada rice development since water requirement for rice production from planting to seedling is low (Expert System for Paddy, 2018; Agropedia, 2018). In addition, excess rainfall at planting to the emergence stage of rice will make the rice field to be submerged for a long period of time which leads to the deficiency of essential nutrients like nitrogen, magnesium, potassium, and calcium required for plant growth (Jackson, 2013).

Table 2: Stepwise regression result between ofada variety and climatic variables

Predictor	Coef	SE Coef	T	R^2 (%)	R^2(adj)	R^2(pred)	VIF
Constant	13.119	6.171	2.13*				
Min. Temp	0.33836	0.09385	3.61**	0.4070	0.3842	0.3331	1.009
Solar Rad.	-0.7836	0.2362	-3.32**	0.5517	0.5158	0.4748	1.173
June Rain.	-0.0033	0.00137	-2.42*	0.6398	0.5945	0.5306	1.164

** T-value is significant at 1%

* T-value is significant at 5%

Effect of Agro-climatic Variables on FARO 44 Variety

The stepwise regression result between the agro-climatic variables and FARO 44 rice yield is displayed in Table 3. The prediction model contains three predictors and showed a significant F-value of 19.117 at p<0.01 and the coefficient of determination (r^2 values) is 0.614, this implies that the variation in Faro 44rice yield is accounted or explained by agro-climatic variable to 61.4% leaving the remaining percentage for other factors to explain. The model also showed a significant positive T-value of 5.981 and 3.440 at p<0.01 for Mean Temperature and August rainfall respectively, while September rainfall showed a significant negative T-value of 2.592 at p<0.05. This result implies that Mean Temperature contributed high to variation in yield of FARO 44 in the State with a coefficient value of 0.5013 and R^2 to 46.44%, followed by August rainfall with a coefficient of 0.0044 and the R^2 increases from 46.44% to 54.26%. September rainfall is the only parameter that showed a negative coefficient of 0.0026 and increased the R^2 to 61.44%. This climatic contribution explained that a unit increase in Mean Temperature and August rainfall will lead to an increase in yield of FARO 44 rice of 0.5013 and 0.0044 respectively, while a unit increase in September rainfall will reduce the yield of the variety with 0.0033. In addition, the result clearly suggested that places with high mean temperature and August rainfall support the growth and yield of FARO 44 but places with a low amount of the parameters are detriment to the growth and yield of the rice variety. This is not surprising because places with low mean temperature amounts of <20^o C are not suitable for the growth and yield of rice (Joseph *et al.,,* 2013 and Getachew and Solomon 2015). The negative contribution of September rainfall, on the other hand, suggested that places of high September rainfall are detriment for growth and yield of FARO 44 while places with low September Rainfall are favorable for FARO 44 cultivation. This relationship is not coincident because FARO 44 (SIPI) has a maturity period of 90 to 100 days and given that rice planting in the State started from the month of June, this clearly suggest that September is the maturity period of FARO 44 and maturity period of rice required less or no rainfall especially in the last 15 to 20 days where water from the farm plot is drained completely. In addition, rice variety mature within stipulated time frame and any climatic amount recorded after it maturity will be insignificant to it yield since rice growth is very sensitive to climate at different growth stages (Ogbuene, 2010; Craufurd and Wheeler, 2009 and Wahid *et al.*, 2007). The positive contribution of August rainfall is also not surprising because the month of August corresponds with the critical development stage of rice in the study area (Reproductive Stage) where rainfall amount is very critical to rice growth. The stage is recognized to be critical because a high rainfall amount in the stage determines the effectiveness of the stage and any unfavorable rainfall supply will damage the crop yield (Expert System for Paddy, 2018; Agropedia, 2018).

Table 3: Stepwise regression result between faro 44variety and climatic variables

Predictor	Coef	SE Coef	T	R^2 (%)	R^2(adj)	R^2(pred)	VIF
Constant	-11.508	2.312	-4.98**				
Mean temp	0.50128	0.08379	5.98**	0.4644	0.4503	40.39	1.027
August Rain	0.0044	0.001285	3.44**	0.5426	0.5179	42.85	1.143
Sept. Rain	-0.0026	0.0009975	-2.59*	0.6144	0.5823	46.98	1.163

** T-value is significant at 1%

* T-value is significant at 5%

Effect of Agro-climatic Variables on FARO 58 Variety

The stepwise regression result between FARO 58 and the climatic variables in the state is shown Table 4. The result explained that the prediction model contains three different climatic variables that are critical in determining the variation in yield of FARO 58 rice variety. The model presents the percentage contribution of the selected agro-climatic variables to variation in yield of FARO 58 variety. It also predicts the yield of FARO 58 as a result of a unit increase in the selected climatic variables in the study area. The model revealed that the Mean temperature, August Rainfall, and October Rainfall are the highly significant climatic variables that determine the variation in yield of FARO 58 rice variety in the study area. It predicted that the three variables are highly significant with an F-value of 21.42 at $p<0.01$ and the coefficient of determination (r^2 values) is 0.712, this implies that the variation in Faro 58 rice yield is accounted or explained by agro-climatic variable to 71.2 % leaving the remaining percentage for other factors to explain. It also revealed that the Mean temperature and August rainfall contributed positively to the yield of FARO 58 while October rainfall contributed negatively to the yield of the crop. The positive contribution of Mean Temperature and August Rainfall suggested that a unit increase in mean temperature and August rainfall will lead to an increase in yield of FARO 58 rice variety with 0.351 and 0.008 respectively while the negative coefficient of October rainfall implies that a unit increase in rainfall amount in the month of October will decrease the yield of FARO 58 with 0.0039 in the State. In addition, the positive effect of Mean Temperature and August Rainfall suggested that places of high temperature and August rainfall are favorable to the cultivation of FARO 58, while places of high rainfall amount in the month of October is not favorable to FARO 58 rice cultivation. Rainfall amount in the month of August coincides with the vegetative stage of rice growth in the State where water requirement at this stage is high compare to other stages and any deficiency in rainfall amount within the stage will damage rice yield (Expert System for Paddy, 2018 and Agropedia, 2018). Unlike the month of August, the month of October is marked as the end of the growing season and harvesting period in the State. This stage is recognized to be the maturity stage of rice growth where a high rainfall amount is a detriment to rice. In fact, during this stage especially in the last 15 to 20 days before harvesting, water is not required; instead, all water in the farm is drained out.

In summary, Mean Temperature is one of the critical climatic elements that positively influence the yield of Local, FARO 44 and 58 rice varieties in the State. The nature of the relationship clearly suggested that places with high mean Temperature amount in the State support the growth and yield of rice compared to places with low Mean Temperature which is a detriment to rice yield in the state. This is not surprising because temperature is identified to be one of the critical climatic elements that influence growth and yield of rice crop at different growth stage of rice and the optimum temperature requirement is between 27^o C to 32^o C (Mahmood *et al.*, 2012;Govinda 2013 and Arif *et al.*, 2017). Similarly, rainfall amounts in the months of June, August, September, and October during the growing period of the crop are critical and determine the yield of the selected varieties of rice in the State.

Following the result of the analysis obtained, it is clear that annual rainfall is not a major determinant of the growth and yield of the varieties in the State. This is not surprising because it is not the volume of rainfall received in a year that determined the yield of rice, but how efficient is the rainfall amount distributed at the various developmental stages of the crop especially the critical stages of the crop development. In the same vein, rice yield is not determined by the volume of rainfall received in a year but the efficiency of the rainfall at different developmental stages of the crop growth (Mostafa*et al.*, 2015; Sawa and Adebayo 2011 and Tesfamariam *et al.*, 2010).

Table 4: Stepwise regression result between faro 58variety and climatic variables

Predictor	Coef	SE Coef	T	R^2 (%)	R^2(adj)	R^2(pred)	VIF
Constant	-8.029	2.972	-2.70*				
Mean Temp	0.3513	0.1044	3.36**	0.3856	36.37	0.3053	1.306
August Rain	0.007772	0.001702	4.57**	0.6389	61.22	0.5623	1.304
October Rain	-0.0039	0.001524	-2.57*	0.7119	67.87	0.6463	1.027

** T-value is significant at 1%

* T-value is significant at 5%

CONCLUSION

Following the result on the climatic variables influencing rice yield in the State, it was concluded that Mean annual temperature is an important variable controlling the growth and yield of local rice variety in the State, while, Minimum temperature, June rainfall and,Solar Radiation are the key variables for the growth and yield of Ofada rice variety. Mean annual temperature, total August rainfall and September rainfall on the other hand are the major climatic parameters influencing the growth and yield of FARO 44, while FARO 58 growth and yield are determined by Mean annual temperature, total August and October rainfall. It was also concluded that, it is not all about the volume of rainfall received in a year that determinant the growth and yield of rice but the efficiency of the rainfall amount distributed at the various developmental stages of the crop especially the important stages of the crop development.

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