# IMPACT OF METEOROLOGICAL PARAMETERS ON RICE YIELD: AN APPROACH FOR ENVIRONMENTAL RESOURCE SUSTAINABILITY IN EBONYI RICE FARMLAND, NIGERIA

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## ABSTRACT

*This survey considered the impact of meteorological parameter on rice yields, poverty reduction, environmental resource sustainability and management. Data were generated through the use of multiple linear regression and cross-correlations analysis. Other tools include correlograms, histogram, and bar graphs. The correlation variable results indicated that the tonnage of rice yield over the years was a function of meteorological condition in the area. The consequences of continuous variation in meteorological condition were severe reduction and deterioration in annual tonnage of rice yield and environmental resource sustainability. In the light of the above, it then became expedient to promote agro-meteorological advisory services as well as promotion of best practices that are climate change resilient in rice production.*

*Keywords: Meteorological parameters, rice yield, environmental resource, sustainability*

## INTRODUCTION

Meteorological conditions influence the tonnage and quality of rice yield in Ebonyi rice farmland environment. The area experiences variation in meteorological conditions. Rice which is the major crop grown in the area depends on weather and climatic condition to thrive. Adequate meteorological information is needed for the formulation of weather model which will help improve tonnage of rice yield and environmental resource sustainability. Agricultural production is not insulated from the vagaries of weather despite the many years of advancement and improvement of crop production and animal husbandry in the country. In 1973, the rains failed in greater part of Nigeria, causing widespread crop failure. Oguntoyinbo (1981) captured this situation when he observed that early planting encouraged by the false start of the rains was subsequently followed by rainfall cessation. In consequence, crops already planted and beginning to germinate after the early planting rains were rapidly destroyed by lack of moisture. This 1973 situation was repeated in 1987. This had grave impact on crop yield and environmental resource sustainability. Presently, rainfall cessation constitutes a major setback in crop production, animal husbandry and other socio-economic activities.

Climate is perhaps the most important of natural environmental resources, which affects geographical processes such as soil formation, growth, development and adaptation of plants. The major essentials of life such as air, water, food and shelter are climate dependent (Tilman, 1999 and Blair, 2002). Climate and weather condition which influence human activities and environmental resources sustainability includes; rainfall, temperature (minimum, average, maximum), pressure, humidity, solar-radiation, visibility, evaporation, soil temperature at various depth, wind speed and direction among others (Bhalme, 1997 and Ogbuene, 2007).

Industrialization, deforestation, infrastructural development, urbanization among others, has resulted to the imbalance in rainfall and temperature. This exposed the environment to the following hazards; soil and coastal erosion, flood, climate change, biodiversity loss/degradation, drought, desertification, pollution among others, which is the present state of the environment (Adinna, 2001; Anyadike 2009 and Ogbuene, 2007). Based on the foregoing, this study assesses the impact of meteorological parameters on rice yield: an approach for environmental resource sustainability in Ebonyi Rice Farmland, Nigeria.**THE**

## IMPACT OF METEOROLOGICAL PARAMETERS ON RICE YIELD

Wilson (1990), maintained that climatic factor of importance are precipitation and its mode of occurrence, humidity, temperature and wind (speed and direction), all of which directly affect evaporation and transpiration. Solar radiation has a linkage with evapo-transpiration and rainfall, which upshots soil temperature and control environmental resources, the tonnage of crops yield and other categories of human activities in the area.

Rainfall disparity triggers environmental problems such as flood, gully erosion, drought and desertification, which have serious impact on the tonnage of crops yield and biodiversity loss in the study area (Anyadike 2009, Bhalme, 1998, Ogbuene 2009). This regular increase in rainfall disparity makes agriculture a risky, unlucrative and low paid profession, thus leaving the population with the option of over exploitation of forests, wild life and other natural resources (Bhalme, 1998). The consequences of over exploitation of forest are climate change, land degradation, serious gully erosion, pollution, flood, drought among others. Lobell et al (2008) agued that climate variability/change adversely affect water resources and agricultural activities in Philippines. Long term temperature and rainfall trends at various stations as well as hydrologic parameters in multipurpose dams in the Philippines were examined. The results indicated generally increasing trends of yearly temperature at representative stations. Fraser (2008) opined that weather prediction has helped to improve significantly varying levels of rice self-sufficiency by the agriculture-based economies of Indonesia, Malaysia, Philippines, and Thailand.

Battisti and David (2009) maintained that Climate variability is a threat to food production and environmental resources sustainability. Typhoons, floods, and droughts caused 82.4% of the total Philippine rice losses from 1970 to 1990. In 1990 alone, domestic losses due to climatic constraints amounted to US$ 39.2 million. Climatic fluctuations such as El Niño and the growing concern for their effects on agriculture have stimulated academic, public and policy-level interests on the analysis of the impacts of climate variability on agricultural production systems and environmental resource sustainability. The impact of climate variability on crops yield is a global setback on agriculture, food security and environmental resource sustainability. In Ebonyi environment, large hectares of rice farmland and other crops has been destroyed by excess rainfall and destructive winds. However in Cambodia, there is no specific report of serious weather anomalies affecting agriculture. There have been reports of heavy rainfall and floods, which have affected development of the early rice crop in parts of the country, specifically in Kratie province in the east, and of drought in other

parts (World Meteorological Organization, 1999 and Knapp, Fay and Blair, 2008).

In China, during July and August, the worst drought in 20 years is reported to have seriously affected crops, particularly in the provinces of Henan, Hebei, Shanxi, Hubei, Liaoning and Jilin in central and north eastern parts of the country. Officially it is estimated that up to two thirds of the country have been affected by prolonged dry spells, whilst six million hectares of crops have been particularly damaged. The recent rain also improved conditions for planting winter wheat, normally sown from the second half of September, in central parts of the country, though more rain is still needed (World Meteorological Organization, 2007).

In India, no extreme weather anomalies have so far been experienced over the years due to a possible El Niño effect. The southwest monsoon, which provides 80 percent of annual precipitation, has begun withdrawing, most of the country having received average long term rainfall. Although the overall rainfall situation has been normal, poor temporal and spatial distribution of rains adversely affected crops in southern states (Hopkin, 1999).

The recent report of climate, weather and crops condition in China, India and Cambodia disclosed that crop yields and environmental resource sustainability depend highly on climatic condition of the area. Rice is a sensitive crop that depends highly on weather condition. In the Ebonyi environment, rice is the major farm crop. It provides employment opportunity, food and source of income to the government and individuals. Improved climate and weather condition enhances rice yield and environmental resource sustainability in the area.

## METHODOLOGY

The design of this study is a survey. Ebonyi environment falls within the guinea wood-land derived vegetation zone, which lies between the semi-arid north and wet southern part of Nigeria. It lies approximately between longitudes 70' 261 and 70' 361 E of prime meridian and latitude 60' 211 and 60' 261 N of the equator (Fig 1). Rainfall and temperature in the zone is largely seasonal and varies highly from year to year. The area records annual rainfall which ranges between 1613.8mm to 2136.27mm, while mean temperature range is usually between 24.0$^{o}$C to 32.49$^{o}$C over the year. Two distinct seasons are observed, dry and wet. The dry season extends over a period of about 6 to 7 months, from October to March or April while the wet season extends over a period of about 5 to 6 months, from May to September. However, these meteorological conditions vary widely and this is a factor of present global climate change, which awakens the interest of this study.

Data on rainfall, rainy days, relative humidity(R.H), minimum and maximum temperature for the period of 2000 -2008 were collected from the archives of the Nigerian Meteorological Services, Oshodi Lagos, Ebonyi State Agricultural Development Programme and Enugu airport. The data obtained include: total volume of rainfall (mm) per annum, total monthly rainfall (mm), Total number of rainy days, Relative humidity (%), Minimum and Maximum temperature ($^{o}$C ). The Nigeria Meteorological Services (NIMET, 2008) used the Dines, Tilting and the British Standard rainguages, thermometer, hygrometer, and direct observations to collect the data used in this study. The positions of these weather instruments have not been tainted since the commencement of the record keeping. Therefore, data may not have suffered from non-homogeneity.

Data on annual tonnage of rice yield (for the period of 2000 - 2008) were obtained from the Federal Office of Statistics (FOS), which is the central organization for data collection in Nigeria. Annual collection of data on agricultural production were through household sample surveys by the FOS, National Household Survey Capability Program (NHSCP), Ebonyi State Agricultural Development Programme (ESADP 2009), Nigeria National Integrated Survey of Households(NNISH), Rural Agricultural Sample Survey (RASS) and Central Bank of Nigeria (CBN) annual survey.

In addition, direct observations into various farmlands within the environment of the study area were also utilized to examine how flood, erosion and drought adversely influence rice yield in the area.

It should be noted that rice species, characteristics and conditions that favors each species were not considered specie by specie. It is generally known that some rice may adapt to minor drought, but extreme drought, flood, erosion constitutes a serious threat on annual tonnage of rice yield in the study area.

Multiple Linear Regression estimates the coefficients of the linear equation, involving one or more independent variables, which best predict the value of the dependent variable. In the multiple linear regression analysis, independent variables such as rainfall, rainy days, maximum temperature, minimum temperature and relative humidity (R.H), were utilized to determine tonnage of rice yield, which is the dependent variable over the years (2000 - 2008). Multiple linear regression were applied to determine the level of relationship between climatic data and tonnage of rice yield over the years of study. It can be expressed mathematically as:

$$b = \frac{n\sum xy - (\sum x)(\sum y)}{n\sum x2 - (\sum x)2} \quad \text{---------- (1)}$$

Where:

| | | |
|---|---|---|
| n | = | number of years of analysis (8 years) |
| y | = | independent variables (rainfall, rainy days, maximum temp, minimum temp, Relative humidity) |
| x | = | dependent variable (Rice yield) |
| $\sum$ | = | summation of data |

Source: Holden et al (1993)

Cross-correlations analysis, a vital statistical analysis for Environmental Managers (EM) is applied to draw several cross-correlograms between two or more variables. It plots the cross-correlation function of two or more series for positive, negative, and zero lags. The Cross-Correlations procedure is appropriate only for time series data. It established the movement of such variable of study within a possible range of autocorrelation coefficient (-1 to +1) in cross format. Cross-Correlations analysis is useful in establishing proper predictor variables, which is actually responsible for increase in rice yield in this study. This cannot be determined with regression analysis (Holden, Peel and Thompson, 1993). The Statistical Package for Social Sciences (SPSS) was the computer package utilized to diagnose the various statistical techniques applied in this study.

## RESULTS AND DISCUSSION

The result of various correlation variables that have high and moderate correlation values from the multiple regression analysis in appendix 1 were selected and presented on table 1.

**Table 1:** Correlation Variables Results of Rice and Available Meteorological Parameters (2000 -2008)

| S/N | Correlation variables | High score | Moderate score |
|---|---|---|---|
| 1 | Rice yield & Rainfall | 0.779* | |
| 2 | Rice yield & Rainy days | -0.605* | |
| 3 | Rice yield & Temp min | | 0.446 |
| 4 | Rainfall & Rainy days | | -0.435 |
| 5 | Rainy days & Temp max | | -0.469 |
| 6 | Rainy days and Temp min | -0.880** | |
| 7 | Temp max & Temp min | 0.788* | |
| 8 | Temp max & Relative humidity | -0.539* | |

(Source: Field Work, SPSS Analysis Result 2010)

Correlation variables with score of 0.5 and above indicate high positive correlation among the parameter of study. The implication is that rainfall, rainy days, relative humidity, minimum and maximum temperature at this point, have serious positive significant impact on tonnage of rice yield in Ebonyi environment. While correlation variables with score of 0.4 and less than 0.5, indicate moderate positive significant impact on rice yield in the area. This implies that rainfall, rainy days, relative humidity, minimum and maximum temperature at this points, have moderate positive significant impact on tonnage of rice yield in the study area. The histogram which is a product of regression analysis illustrates the changes in Rice yield in Ebonyi farmlands over the years.

**Cross-Correlations Analysis:** This vital statistical analysis for Environmental Managers (EM) is applied to draw several cross-correlograms between two or more variables. It Plots the cross-correlation function of two or more series for positive, negative, and zero lags. The Cross-Correlations procedure is appropriate only for time series data. It established the movement of such variable of study within a possible range of autocorrelation coefficient (-1 to +1) in cross format. Cross-Correlations analysis is useful in establishing proper predictor variables, which is actually responsible for increase in rice yield over the years.

Simple bar charts were plotted to establish the impact of rainfall on rice yield in the area, using Cross-Correlations value for the number of years of analysis. This disclosed coefficient and confidence limits of rainfall in the graph. Cross-Correlations and simple bar chart established the extent of rainfall disparity on rice yield over the years of analysis. The extent of fluctuation determines the rate of excess rainfall or insufficient rainfall. This may trigger the incidence of flood or drought which is a major threat in the tonnage of rice yield in the area.

**Impact of meteorological condition on rice yield:** Rainfall, rainy days, relative humidity (RH), maximum and minimum temperature have positive and negative impact in the tonnage of rice yield and environmental resource sustainability in the study area. It was established that the condition of rainfall, rainy days, relative humidity, minimum and maximum temperature impinge on farming activities and tonnage of rice yield, right from farm planning, clearing of the land, planting, growing, harvesting and preservation of rice. The tonnage of rice yield is highly determined by weather condition as illustrated in Figure 4.

In the chart, rainfall and rainy days have a serious impact on tonnage of rice yield in the area. Also in table 1, the regression result of rainfall and rice yield is 0.779 which indicates high positive relationship. The Correlogram of

cross-correlation analysis in fig 1 proves that the tonnage of rice yield is a function of rainfall variation in the area. This has a serious impact on environmental resource sustainability in the area. Farmers at the on-set of the season wait for rain to come. The inception of rainfall marks the beginning of farming activities in the area. Any year there is delay in rainfall, the farming activities are also delayed. This could result into reduction in the quantity of rice planted and invariably affects annual tonnage of rice yield and environmental resource sustainability. Hence, serious delay in farming schedule shortens the farming period and reduces crop yield. The fundamental problem that could upshot from this serious delay in rainfall is drought (Ogbuene 2007, Anyadike 2009).

Excess rainfall lower surface and soil temperature and constitutes a serious problem to the tonnage of rice yield and environmental resource sustainability in the area. It result into flood and cause physical damage to farmland by eroding and sweeping away the topsoil, which is necessary for rice yield. It may sweep-off the rice seed, plants or the root from the soil. It could inundate the farmland for days, which may result into decay of the planted rice seed, growing rice plant, or the root (Ofomata 1985).

Survey outside the study area revealed that in mid - September, forty-two communities in Anambra West and East Local Government Area, were hit by the floods which displaced an estimated 22,000 persons. Farmlands were destroyed and only few tubers of yam, cassava, rice and potatoes were salvaged. The consequences are severe foot shortage and environmental resource deterioration in the area (United Nation Children's Fund, Nigeria, October - December 2007).

## CONCLUSION AND RECOMMENDATIONS

Weather and climate variability/change adversely affect water resources and agricultural activities in the study area and the world at large. It has been recognized as the major threat to rice production. Floods and droughts have resulted into total drop in the quantity and quality of rice grown in Ebonyi rice farmland. This is a global setback on agriculture, tonnage of crops yield and food security. Heavy rainfall and floods constitutes a serious impact on development of the early rice in the area. In the attempt to improve tonnage of rice yield and environmental resource sustainability, there is urgent need to apply the results of this study in the area.

The impacts of meteorological parameters on rice yield in the study area have been assessed with multiple linear regression and cross-correlation analyses. This confirms that the area experiences rainfall and temperature disparity which

makes the area prone to different environmental hazards such as flood, erosion, drought and desertification among others. This makes it difficult for more farmers to invest in rice production in the area. In that light, considering disastrous state of the area, it is imperative to apply the following recommendations:

- There is need to promote Agro-meteorological advisory services which will be useful in farm planning and environmental resource sustainability. Closer collaboration among the meteorologist and agricultural scientist is needed to increase the awareness about the existing data base, crop-weather models among others, with a view to reaping the full benefits of research on specific problems and sustainable environmental resource management.
- Environmental impact assessment (EIA) should be compulsory to any type of development in the area and Nigeria at large.
- It is also necessary to promote the development of a special network on climate and agriculture, within the frame work of climate agenda and investigation formed for most suitable arrangements, for instance through Food and Agriculture Organization (FAO) collaboration centre.
- Promoting best practices that are climate change resilient in rice production, use of cleaner energy that emits less toxic materials and soil conservation.
- Adaptation of strategies to safeguard rice production and environmental resource sustainability. Adaptation of strategies will be very significant due to variation in rainfall, rainy days, temperature, relative humidity and water discharge regimes, as observed in the study.

Broadly, these adaptations will include refinement of early warning system to enable timely remedial measure, effective water-use-strategies, adequate basin management and intensive research into evaporation, rain formation mechanism, rainfall erosivity and erodibility of the study area. A central element of adaptation approach therefore should be ecosystem management restoration activities such as afforestation, watershed rehabilitation and management, effective water harvesting and conservation.

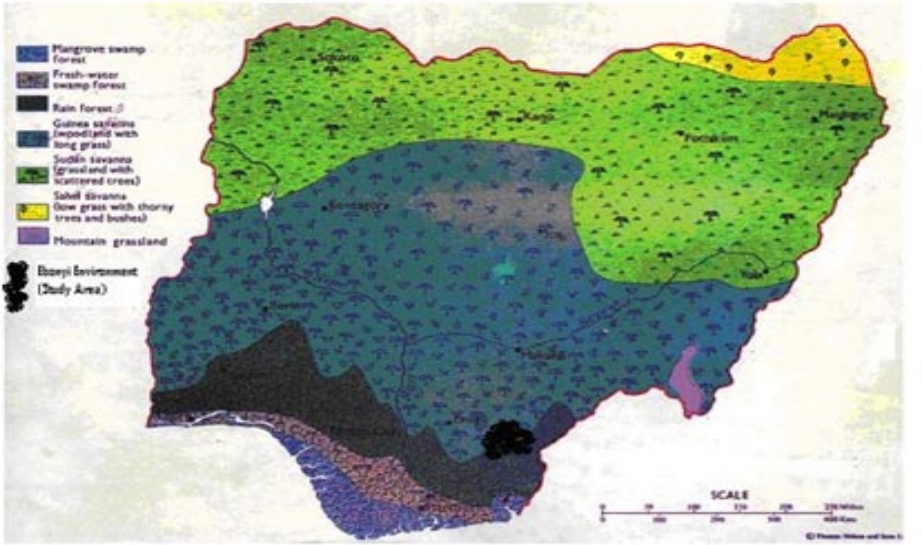


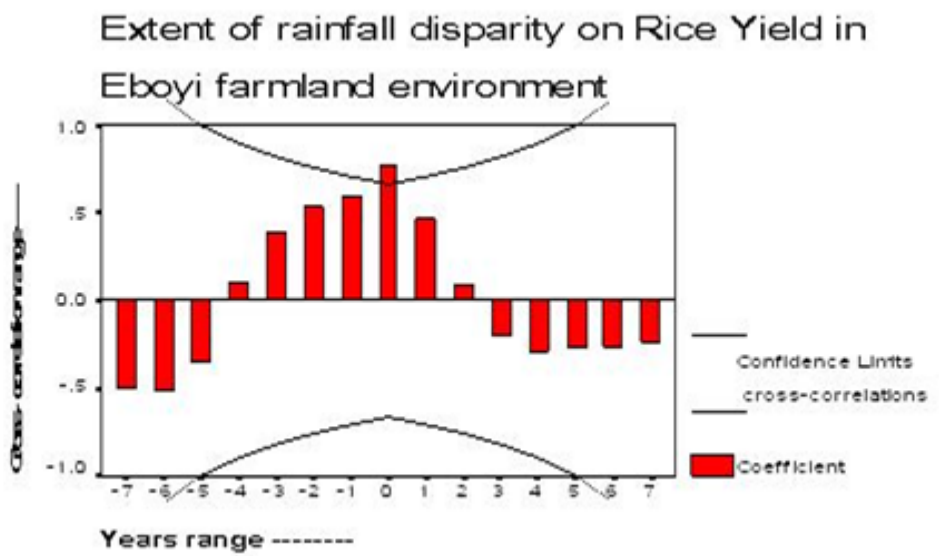

**Fig 1: Map of Nigeria Showing natural vegetation and Ebonyi Rice farmland (Study area) (Source: Anika 2010)**

| Cross | Stand. Corr. | Err. | -1 | -.75 | -.5 | -.25 | 0 | .25 | .5 | .75 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -7 | -.492 | .707 | | | | | | | | | |
| -6 | -.514 | .577 | | | | | | | | | |
| -5 | -.350 | .500 | | | | | | | | | |
| -4 | .104 | .447 | | | | | | | | | |
| -3 | .387 | .408 | | | | | | | | | |
| -2 | .540 | .378 | | | | | | | | | |
| -1 | .595 | .354 | | | | | | | | | |
| 0 | .779 | .333 | | | | | | | | | |
| 1 | .472 | .354 | | | | | | | | | |
| 2 | .094 | .378 | | | | | | | | | |
| 3 | -.204 | .408 | | | | | | | | | |
| 4 | -.288 | .447 | | | | | | | | | |
| 5 | -.274 | .500 | | | | | | | | | |
| 6 | -.259 | .577 | | | | | | | | | |
| 7 | -.235 | .707 | | | | | | | | | |

Plot Symbols: Autocorrelations * Two Standard Error Limits .

Total cases: 9 Computable 0-order correlations: 9

**Fig 2b:** Correlogram of Cross Correlations Analysis of relationship between Total Rainfall and Tonnage of Rice yield over the years
(Source of data: NIMET, 2008 and ESADP 2009)



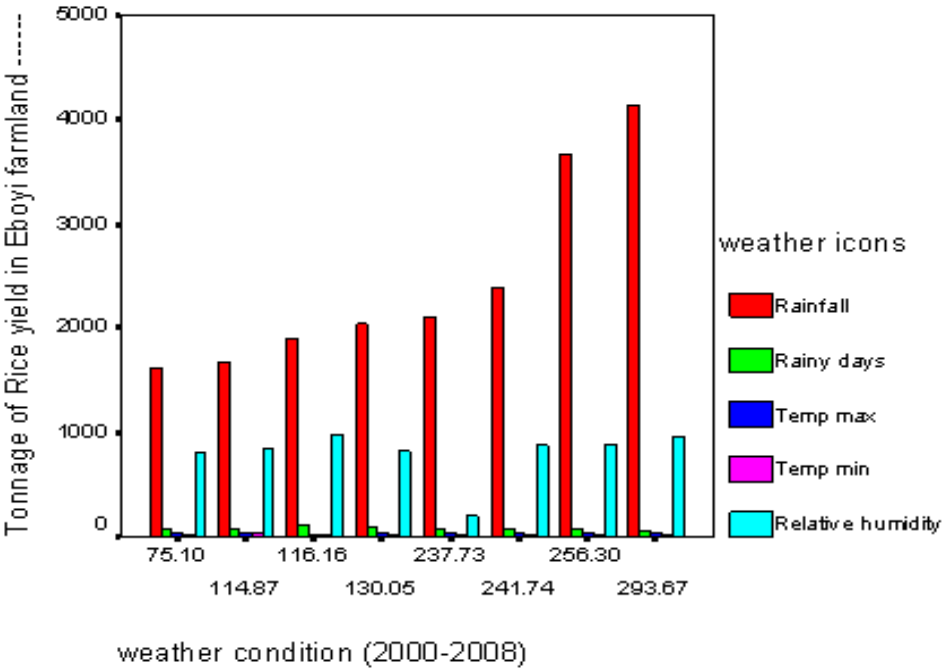



**Fig 3b:** Seasonal variation in weather condition over rice yield in Ebonyi environment. (Source of Raw data: NIMET, 2008 and ESADP 2009)

**Fig 2: Rice farmland adversely affected by seasonal drought (consequences of insufficient rainfall)**
(Source: Authors field work, 2010)

Fig 3: Soil Erosion (consequences of excess rainfall)
(Source: Authors field work, 2010)

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