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INFLUENCE OF METEOROLOGICAL AND TIME FACTORS ON MAIZE YIELD IN IDOFIAN, NIGERIA

Makanjuola, M. B. James, D. and S. A. Adekeye
National Centre for Agricultural Mechanization (NCAM),
P.M.B. 1525, Ilorin, Nigeria.
Email: firmight@gmail.com

Abstract

Meteorological variables which include rainfall, solar radiation, wind, temperature, relative humidity, and evapo-transpiration affect and solely determine the global distribution of crops and livestock as well as their productivity. The effect of these variables on the yield of an improved variety of maize planted on different dates was carried out.

The study revealed the effect that climatic factors, such as rainfall, evaporation, relative humidity, maximum and minimum temperature have on the yield of maize in the study area. Statistical analysis showed significant correlation of the variables with maize yield. Maize yield was highly correlated with rainfall (0.996), but weakly correlated with maximum temperature (0.095). It also revealed that maize has a coefficient of determination of 0.672. This indicates that 67% of the variance in maize can be adduced to the climatic parameters examined. This suggests that the remaining 33% of the variance is associated with other factors which could include the fertility of the soil, crop variety and other farm management practices.

The implication of these findings for a country like Nigeria that practices the rain-fed system of agriculture is that crop production should be restricted to regions where availability of soil moisture is ensured during critical crop growth while irrigation practice is encouraged for regions with limited water availability. Successful crop production also depends on the right choice of varieties so that the length of growing period of the crop matches the length of the growing season.

Keywords: rainfall, evapo-transpiration, maize yield

Introduction

Factors influencing crop production vary but they can be categorized generally as soil, relief, climate and diseases. Agriculture largely depends on climate to function and many of the problems facing agricultural products are climate related (Ayoade, 1983). Meteorological variables which include rainfall, solar radiation, wind, temperature, relative humidity, and evapo-transpiration affect and solely determine the global distribution of crops and livestock as well as their productivity. Rosenzweig *et al.*, (2008) opined that increasing air temperatures and decreasing rainfall are the major aspects of climate change that influence agricultural productivity. Change in climate results to changes in total seasonal rainfall amounts while an increase in the daily amount of evapo-transpiration has tremendous effect on water regime of crops.

Rainfall is a dominant controlling variable in tropical agriculture because it is the major source of water supply to crops. Water is an essential requirement for most facets of life and it has been observed to be the principal yield-limiting factor for crop growth. Worldwide, the agricultural sector has been, and continues to be, the largest consumer of water (World Bank, 1992). However, the great challenge facing the agricultural sector has been how to increase the production of more food from a dwindling supply of water. Kijne *et al.* (2003) stated that this could be achieved by increasing crop water productivity. Nigeria is an agrarian country with about 70% of the population involved in agricultural production. The country also practices the rain-fed system of agriculture which implies that it depends entirely on rainfall stored in the soil profile. This system accounts for 60% of production in developing countries (FAO, 2003).

Rainfall is characterized by its amount, intensity and distribution in time and space. Rainfall amount is a very important factor determining the productivity of crops. Mudiare (1985) defined light rainfall activity as a calendar day in which the rainfall depth is less than or equal to 6.4 mm. Arnon (1975) on the other hand found that the minimum depth of rain that would contribute to soil moisture storage in dry regions under natural vegetal cover ranges between 15.0 and 20.0 mm for a single event. Although the small depth of water produced by light rainfall activity may not contribute directly to soil moisture, meteorological conditions associated with these events will reduce the actual evapo-transpiration during the event and also reduce the withdrawal of water from soil moisture on days following the rain. Therefore they can be considered as a major factor affecting the amount of water required to produce a mature crop.

Rainfall constitutes a major limitation in agricultural production when it is too much, too little or unevenly distributed. Mutsaers *et al.*, (1997) stated that crop yields are most likely to suffer if dry periods occur during critical developmental stages such as reproductive stage. In most grain crops, flowering, pollination and grain – filling phases are especially sensitive to water stress. Excessive wet years, on the other hand, may cause decline in crop yields. Prolonged water logged soil condition results to rot of plant roots and provides an enabling environment for pests to thrive. In addition, intense rainstorms cause havoc to young plants and exacerbate soil erosion. The resulting damage will depend on rainfall duration, how long the fields are inundated, the growth stage of the crop as well as the air and soil temperatures.

Among the major annual upland crops grown by small-scale farmers, maize has received increased attention in recent years due to increased local demand with the expansion of animal feed industry. Maize is an efficient user of water in terms of total dry matter production and among cereals; it is potentially the highest yielding grain crop. Adeogun and Idike (1999) determined the crop coefficient of maize in order to estimate the crop water use. They obtained values ranging between 0.4 – 1.3, an indication of variation based on the stage of crop maturity, time of the year and most importantly, the prevailing weather conditions.

Much research has gone into studying various problems associated with the role of water in aiding growth and enhancing the yields of plants. Ayotamuno *et al*. (2000) studied the functional relationship between crop yield and amount of water use, for corn, with a possibility of increasing its production through proper management of water. They observed that the volume of water intake by a plant is influenced by factors such as temperature, humidity, wind movement, intensity and duration of sunlight, stage of development of the crop, type of foliage and nature of leaves. In another study on the effects of climatic variables on crop production by Tunde *et al*. (2011), they found maize production to highly correlate with rainfall amount (0.73) while other variables were very weak. Evaluating the response of maize to a changing climate can provide viable options for enhancing adaptive capacity of small holder farmers.

The effect of climate change on the characteristics of precipitation is enormous. It has become very difficult to predict the onset, cessation and length of growing season in recent decades. It thus becomes expedient to analyze agro-meteorological data especially rainfall in order to understand seasonal working patterns and be able to choose cropping practices suited to a particular climate. Hence this study focuses on examining selected climate variables and their impact on maize yield. The objective of this investigation is to study the effects of some meteorological variables such as rainfall, temperature, relative humidity and evaporation on the yield of maize planted on different dates thus enabling farmers deduce proper management plan to make for optimum production in a changing climate.

Methodology

The study was conducted at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State. Ilorin is situated on Longitude $4^{o}\,35^{\prime}$ East and Latitude $8^{o}\,29^{\prime}$ North with an altitude of 370 m above sea level. The mean annual rainfall is about 1,200 mm while the rainfall distribution is bimodal. The rainfall season spans from April through October with a dry spell in the month of August.

Meteorological data for a period of twenty – one years (1994 – 2014) obtained from NCAM Meteorological station was used for the analysis. From this, rainfall amount, duration and intensities were extracted. The reliability of rainfall within the study area was determined. This was achieved by categorizing rainfall data for each month into 3 periods of 10-day interval. The rainfall in each period for each available year was added up resulting in a table of 10-day totals for 36 periods in each of the recorded years. This data were re-arranged in order of magnitude. Consequently the lower, median and upper quartile was obtained. These correspond to 80, 50 and 20% rainfall probabilities. A graph of these values depicts the trend of rainfall throughout the year.

An estimate of potential evapo-transpiration, E_T was super imposed on this graph to determine periods of adequate rainfall and risk periods. Evapo-transpiration data was obtained from evaporation data as recorded from the Class ‘A’ pan, E_o. It was multiplied by a correction factor, which is dependent on the humidity and wind of the location. For the study area, this factor was given as 0.75 (Michael, 1979; FAO, 1986 and Dorrenbos and Pruitt, 1997).

Maize, TZSR variety (open pollinated), was planted on staggered dates within the months of July and August for two consecutive years in a Complete Randomized Block Design (CRBD) with four replications. The soil type is sandy loam with good drainage. Ploughing operation and subsequent harrowing operations was carried out to ensure good pulverization of the seedbeds. The planting depth was between 3 cm – 4 cm, spaced 75cm x 25 cm apart with one plant per stand.

The data was subjected to statistical analysis to establish the relationship between meteorological parameters and also to show the percentage contribution of the variables to maize yield.

Results and Discussion

Effect of rainfall on yield:

Rainfall showed more annual fluctuations than any other climatic factor considered. The mean annual rainfall obtained for the study period is about 1200 mm as shown in Table 1. The general pattern observed was rainfall occurring between the months of April to October while the months of November through March are usually dry months with little or no rainfall events. This is in consonance with rainfall trend obtained within this climatic zone. Figure 1 shows the decade wise trend of rainfall in the study area. The trend also shows the rainfall regime with two peaks in the months of June and September respectively. From this available wet periods for each regime can be estimated, say 140 days for the first period and 110 days for the second. It is observed that the amount of rainfall in the first regime is less than that obtained in the second. Hence planting is scheduled such that planting is planned for these periods in such a manner that enough plant cover is developed before intense rains fall.

Table 1: Climatic Data of Idofian for the period 1994 – 2014

Year	Annual Rainfall (mm)	Annual Evaporation (mm)	Mean Maximum Temp. (^{o}C)	Mean Minimum Temp. (^{o}C)	Mean Relative Humidity (%)
1994	1253.22	71.47	32.14	25.30	83.06
1995	1349.60	70.87	32.80	25.80	83.48
1996	1124.70	77.50	32.80	26.40	83.00
1997	1392.50	72.78	33.20	25.20	84.62
1998	1165.00	74.45	33.05	25.50	83.64
1999	1601.10	64.53	32.40	25.70	82.89
2000	1098.20	79.94	33.80	26.16	81.90
2001	960.20	77.70	33.50	26.30	82.30
2002	1119.80	74.04	32.70	25.30	66.76
2003	1339.20	72.57	33.10	24.50	63.42
2004	1157.60	71.91	32.20	21.90	81.00
2005	1227.80	71.92	32.70	22.20	83.00
2006	1264.10	66.50	32.20	22.10	80.00
2007	1301.20	70.20	33.16	21.70	82.60
2008	1410.10	65.89	32.10	21.70	84.00
2009	1077.50	64.00	31.70	20.50	78.57
2010	953.60	59.45	32.70	21.55	82.30
2011	805.70	65.50	32.50	21.50	73.76
2012	973.50	65.86	33.00	21.70	75.20
2013	930.20	63.45	34.70	23.00	69.20
2014	1564.50	83.84	34.00	23.90	69.86
Mean	**1193.77**	**70.68**	**32.88**	**23.71**	**78.79**

Table 2 further reveals that about 20% of the total rainfall is contributed in the month of September while there is about 50% variation in the month of August. It has been stated often that it is the distribution of water rather than lack of total seasonal amounts that affects crop growth and ultimate yield (Monteith, 1991). The uneven seasonal distribution of rainfall exposes the crop to a range of mild to severe intra-seasonal dry spells, which may subsequently affect the yield adversely. The implication of this is that the critical stage of the crop development must be timed to coincide with the period of sufficient moisture in order to obtain the expected yield.

Table 2: Rainfall data for the growing season at Idofian (1994 – 2014)

Growing season	Average total (mm)	Maximum monthly (mm)	Minimum monthly (mm)	Coefficient of variation (%)	Percent of growing month rain to annual total (%)
July	147.7	312.20	62.30	45.3	12.4
August	147.5	297.30	24.10	49.7	12.3
Sept.	237.4	324.70	110.20	22.6	19.9
Oct.	143.6	297.90	35.80	47.8	12.0

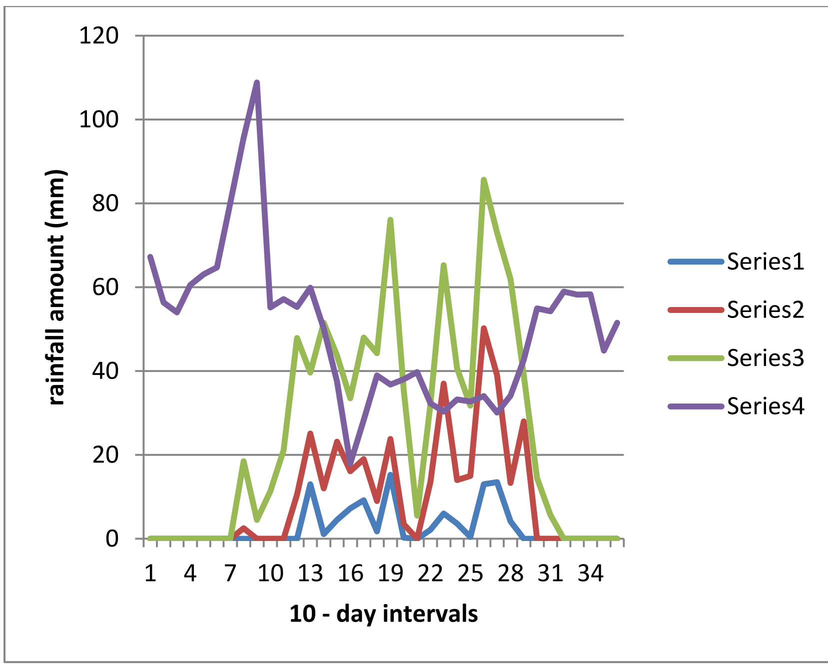

Fig. 1: Graph showing the Confidence intervals for 10 – day total rainfall, Idofian (1994 – 2014) where 1, 2 and 3 represent the lower, median and upper quartiles respectively, while 4 is the superimposed evapo-transpiration.

The plot of lower, median, upper quartiles with a superimposed evapo-transpiration provides the information needed to evaluate the crops performance. Fig.1 shows that the median rainfall only starts to exceed evapo-transpiration by the 22^{nd} decade, which is the month of July. Generally, crops will not suffer water stress when the median rainfall exceeds ET. However, if the lower quartile falls below ET and the crop is at full leaf canopy or at a sensitive stage of growth, the crop will probably suffer. On the other hand, when the upper quartile values is greatly in excess of twice the ET, there is high possibility of flooding in lowland sites and water logging, leaching and accelerated erosion in upland sites. Fungal diseases and spoilage of ripening crops may also occur.

Effect of Temperature on yield:

The temperature range, more than any other factor, is very consistent over the study period. Both the daily maximum and minimum temperatures rise to their annual peak just before the onset of the rains. According to Miedema *et al.* (1987), the optimum temperature for growth processes in maize is around 30 °C. For the growing period, the minimum temperature was 18 °C while the highest was 37 °C, which according to Best (1959) falls within the optimum temperature for grain yield. Maize has been classified as a C4 crop because it tolerates hot and dry atmospheric conditions so long as sufficient water is available to the plant and temperatures are below 45 °C (FAO 2015). However, it has been noted that even C4 crops become adversely affected when the critical temperature thresholds are exceeded (Rosenzweig *et al.*, 2008).

Effect of Relative Humidity on yield:

The dry months of November through March recorded very low relative humidity while higher values were recorded in the rainy season with the month of August rising up to 94%. The ability of the atmosphere to evaporate water is the driving force for soil evaporation and plant transpiration. Factors such as solar radiation, temperature, wind and relative humidity all increase the amount of water the plant most transpire to keep cool and produce biomass. Thus, the higher the amount of water available in the air, the less the amount of water the plant looses to transpiration.

Effect of Evaporation on yield:

The evaporation from the Class "A" pan showed a relatively close pattern with air temperature. Although there were annual fluctuations from month to month, the trend was constant over the years. The highest mean monthly value was recorded in the month of March 2000 (12.3 mm) while the lowest was obtained in July 2010 (2.6 mm).

The crop coefficient (k_c) relating the crop evapotranspiration (ET_{crop}) to the reference evapotranspiration (ET_o) for the different developmental growth stages of grain was determined for the study location, Idofian to be 0.4 – 0.5 for the initial stage, 0.6 for the development stage, 0.6 – 1.3 for the mid-season stage and 0.6 – 0.8 during the late season stage (Adeogun and Idike, 1999). They obtained cumulative water required for ET_o and ET_{crop} of 470 and 690 mm respectively. This is an indication that for good plant development, the amount of moisture requirement for the plant must be available to obtain the expected yield. The variability in rainfall amount is found to be more limiting than the total annual rainfall generated. From the study data it can be observed that some years had very low rainfall total within the growing seasons which were grossly below the crop water requirement.

Among cereal crops, the maize plant has been adjudged to be an efficient user of water in terms of total dry matter production (FAO, 2015). Depending on the climate of the area where maize is planted, it requires between 500 – 800 mm of water for maximum production of the grain crop. Omoyo *et al.,* (2015) also revealed that maize plants tend to experience extreme sensitivity to water deficit during its critical growth period when there is high water requirement in terms of evapo-transpiration and high physiological sensitivity when determining its main yield components such as the number of ears per plant and number of kernels per ear.

Effect of Planting date on Yield

It was observed that for the two growing season under review, planting in the month of July yielded more than in the month of August. This could be attributed to the fact that planting in July when there was adequate rainfall till the point when the seed started sprouting was more beneficial to the plant than when the germination stage coincided with the August break. The availability of required water at the critical sensitive stage of flowering and grain filling was also seen to fall within the peak month of September. The knowledge of water requirement at the critical stages of growth is essential in the supply of water at the appropriate time and amount to crops in order to avoid massive reduction in crop yield especially under conditions of limited water supply. FAO (2015) stated the month of June to be the ideal planting date in Nigeria. However, the changing climate has over the years affected time of onset and cessation of rainfall. In a situation where the timing is drastically altered, there is attendant decrease in yield because water availability might not tally with the plants growth stage. It thus implies that the variety planted is important and it must be such that it is in conformity with the climatic pattern of the area.

Table 3: Planting Date, crop duration and yield data for 2013/2014.

Date of planting	Crop duration (days)	Grain yield (kg ha^{-1})
08-07-13	145	1977
22-07-13	130	2317
05-08-13	120	1652
19-08-13	109	713
17-07-14	143	4612
28-07-14	139	3613
20-08-14	117	2055
27-08-14	112	1337

Statistical Analysis

Correlation Analysis

Table 4 revealed the correlation between climatic variables and crop yield at 0.05 level (2 – tailed). All the factors are less than 0.5 except rainfall indicating significant correlation. From the table, rainfall is highly correlated with maize yield (0.996), but weakly correlated with maximum temperature (0.095). The implication of this is that the higher the rainfall the higher the yield of maize, while higher temperature values will imply that the threshold will be exceeded thus resulting in less yields.

Table 4: Correlation analysis between climatic variables and crop yield

Crop	Rainfall	Max Temp	Min Temp	Rel. Humidity	Evaporation
Maize	0.996	0.095	0.175	0.189	0.294

Regression analysis for the crop yield and climatic variables

The regression analysis computed revealed that maize has a coefficient of determination of 0.672. This indicates that 67% of the variance in maize can be adduced to the climatic parameters examined (Table 5). This suggests that the remaining 33% of the variance is associated with other factors which could include the fertility of the soil, crop variety and other farm management practices.

Table 5: Regression analysis for the crop and climatic variables.

Crop	R	R^2	Standard Error	Adjusted R^2	F	P-value
Maize	0.672	0.452	0.176	0.061	1.155	0.415

Soils with high levels of organic matter and improved soil structure have greater resistance to erosion and high potentials for crop yield. It is an established fact that the level of usage of our fragmented farmlands has intensified over the years necessitated by the need to continuously farm the same parcels of land year in year out in a bid to curb poverty and to provide food for the teeming populace. The practice of land fallow which could have resuscitated the soils fertility has long being jettisoned due to pressure on land, a very limiting resource. The soil not only loses its nutrients, but also the texture from over-cultivation. It becomes very loose, highly detachable and transportable, hence promoting erosion and land degradation with attendant loss in yield.

CONCLUSION AND RECOMMENDATIONS

The study has revealed the effect that climatic factors, such as rainfall, evaporation, relative humidity, maximum and minimum temperature have on the yield of maize in the study area. Rainfall is a dominant controlling variable in tropical agriculture because it is the major source of water supply to crops. Rain fed agriculture, as majorly practiced in Nigeria, ought to be restricted to regions where rainfall distribution ensures continuing availability of soil moisture during the critical growing period for crops. Irrigation practice is thus encouraged in regions with limited water availability. Successful crop production also depends on the right choice of varieties so that the length of growing period of the crop matches the length of the growing season.

The gradual decline in soil fertility occasioned by overuse should also be addressed. Thus, practices aimed at increasing the organic matter content of the soil such as mulching, are recommended to arrest the decline in soil fertility and ensure long-term sustainability of the cropping system.

Factors such as soil fertility, availability of adequate water for crops, suitable temperature, area of land under cultivation, correct timing of planting and good cultural practices (such as spacing of strands), protection of crops from weeds, pests and diseases and planting of high yielding varieties affect crop production in the study area.

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