S.A.Mohammed.M.Y.Otache, I.E. Ahaneku,A.Halilu ISSN..........0189-9546
NJTD (2011) 8(1):31-39 Faculty of Engineering & Technology, University of Ilorin, Ilorin, Nigeria.

MAIZE YIELD RESPONSE TO RESIDUAL SOIL MOISTURE IN INLAND VALLEY OF MINNA, NIGERIA

S. A. MOHAMMED[1], M.Y. OTACHE[2], I.E. AHANEKU[3], A. HALILU[4]
Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria; E-mail: [1]ask4dwiseone@yahoo.com, [3]drahaneku@yahoo.com

ABSTRACT

Two sets of experiments were conducted in three replicates each on both upper and lower fringes of Minna inland valley, Niger State, Nigeria. While the upper fringe was subjected to surface irrigation the residual moisture in the lower fringe provided the maize crop with all water requirements from planting to maturity. Randomized Complete Block Design was utilized for the study. The results showed that the actual maize yield obtained in plots 1, 2 and 3 on the upper fringe were 100.15 kg/ha, 180.45 kg/ha and 200.45kg/ha, respectively, whereas 168.78 kg/ha, 240.16 kg/ha and 271.20 kg/ha were recorded in the lower fringe for similar plot conditions. The difference in means of the maize yield grown under irrigation and residual moisture were statistically insignificant at 5% and 1% levels of significance.

Keywords: Irrigation, inland valley, residual moisture, yield response, evapotranspiration.

1.0 INTRODUCTION

Irrigation is an age-old practice, which has its history from the beginning of civilization. It is aimed at augmenting natural rainfall, by ensuring that adequate soil moisture is readily available throughout the length of the cropping season for the purpose of crop production (Michael, 1995). This practice is specifically carried out during periods when there is minimal or no rainfall. Water is the most important factor that determines the productivity of any crop. Its best use would not only increase crop production but also enhance yields. The proper understanding of the effect of water-rainfall and/or irrigation on crop growth and development is required if high yield is to be achieved.

Most Fadama users in the inland valley of Minna, Niger State, Nigeria seldom venture into residual moisture utilization during the dry periods, due to the fact that they are ignorant about the practice and uncertain as to whether or not the available soil moisture can sustain their crops throughout the growing period.

Several studies have shown that flooding along the river channels of most inland valleys (IVs) during the rainy season ensures that adequate water is stored beneath the soil surface in flood plains as residual moisture (Lillesand and Kiefer, 1987). Efficient utilization of this available moisture for crop production is another possible way of relieving some of the current pressure being exerted on the natural resource base (upland) for crop production. The surveys conducted regarding inland valleys revealed that there are about 10-20 million hectares of IVs in West Africa Equatorial Guinea savanna (Hekstra and Andriesse, 1983), 130 million hectares in inter-tropical Africa (Raunat, 1985) and 40,200 hectares in Niger State, Nigeria

The agricultural potentials of these IVs during the dry seasons have not been fully explored.

This study was targeted towards addressing the following objectives: investigating the maize yield response in relation to residual moisture in Chanchaga Inland Valley; establishing maize yield response factor for the ecological zone and to determine the financial benefits of the inland valley cropping.

2.0 MATERIALS AND METHODS

2.1 Experimental Site

The study was conducted at Chanchaga Inland Valley, Minna, Nigeria (Lat. 09°N, Long. 06°E). The site is located 8 km south of Minna. The topography of the land is undulating and rich in organic matter contents. The rainfall distribution pattern of Minna and its environs is unimodal, which has an average annual precipitation ranging from 1000-1200 mm and average maximum and minimum temperatures of 37°C and 21°C, respectively (NIMET, 2006). It has numerous and extensive farm settlements, whose peasants take advantage of the important valley resource (river) for irrigating upland crops such as maize, sorghum, vegetables, sugar cane, paw-paw, rice, and tree crops.

The experiment was carried out in 2006 (January-April) irrigation season. Usually, during the dry period, irrigation is necessary in augmenting the depleted soil moisture for raising maize crops grown on the upper fringe, while residual moisture in the flood plain provided the maize crop with its water requirements from planting to maturity.

Piezometers were installed at different locations of the experimental plots to monitor the water table fluctuations. The two piezometers installed on the upper fringe attained a depth of 1.5 m, with no significant water-table reached, whereas at a depth of 0.6 m a useful water depth was attained in the lower fringe.

2.2 Experimental Design

Two sets of experiments were simultaneously conducted in order to determine the crop yield response to water supply/availability. The two experiments utilized the Randomized Complete Block Design (RCBD) with three replicates for each. The first set was performed on the upper fringe where irrigation water was applied, while the second experiment was carried out in the lower fringe in which the residual moisture was the source of water required for crop growth and development, covering the same duration.

Maize breed (Jo-195) seeds were treated with apron-star (fungicide) before planting. The depth of each seed drill was 6.0 cm, planted at maximum seed rate of four (4) per hole and spaced at 16.0 cm interval. The size of the first plot was 383.2m^2(0.040 ha), while the second plot was 246.5m^2(0.025 ha). The first plot consisted of sixteen check basins, whereas the second plot had fifteen checks with each of the basins having a plant population of 220 stands per basin.

Weeding was done manually once in every fortnight for a period of two months. The compound fertilizer NPK 15: 15:15 was used at a dosage of 5g per base which was applied twice (7 and 28 days) after planting (DAP) in line with the recommended cultural practice of the area.

ISSN...........0189-9546
Faculty of Engineering & Technology, University of Ilorin, Ilorin, Nigeria.

2.3 Modelling Equations

2.3.1 Yield Response factor (ky)

The response of yield to water supply was quantified through the yield response factor (K_y) which relates relative yield decrease (1-Ya/Ymax) to relative evapotranspiration deficit ($1-ET_a/ET_{max}$) FAO (2001) thus:

(1) $$(1-Y_a/Y_{max}) = K_y\,(1-ET_a/ET_{max}) \quad (1)$$

where:

K_y = maize yield response factor
Y_a = actual harvested yield (kg/ha)
Y_m = maximum or theoretical harvested yield (kg/ha)
ET_a = actual evapotranspiration (mm/day)
ET_m = maximum evapotranspiration (mm/day)
ET_m = maximum evapotranspiration (mm/day)

2.3.2 Potential Evapotranspiration

The Blaney-Morin-Nigerian (BMN) Evapotranspiration model, equation (2), developed by Duru (1984), was adopted for use in computing the potential evapotranspiration of the maize crop for each month during the cropping period.

$$ET_p = \frac{\left[rf(0.45T+8)(520-R^{1.31})\right]}{100} \quad (2)$$

Where:

ET_p = potential evapotranspiration of crop (mm/day)
rf = radiation factor
T = air temperature (°C)
R = relative humidity (%)

2.3.3 Crop Coefficient

Equation (3) was used in determining the maize crop coefficient based on the potential evapotranspiration for each month (James, 1992):

$$K_c = mET_p^n \quad (3)$$

Where: m and n are the coefficient and exponent, respectively, which depend on the frequency of irrigation.

2.3.4 Crop Evapotranspiration

The maize crop evapotranspiration for each month was evaluated using the following relationship (FAO, 2001):

$$ET_c = K_c\,.\,ET_p \quad (4)$$

2.3.5 Frequency of Irrigation

The design irrigation frequency for the irrigated plot (upper fringe) was determined from (Michael, 1995):

$$i = \frac{[pS_a D]}{ET_m} \tag{5}$$

where:

i = irrigation frequency (days)
p = soil water depletion fraction
S_a = total available soil water (mm/m)
D = root zone depth (m)
ET_m = maximum evapotranspiration (mm/day)

2.3.6 Available Soil Water Index (ASI)

ASI was estimated using equation (6), (FAO, 2001):

$$ASI = \frac{[In + W_b - (1-P)(Sa.D)]}{ET_{monthly}} \tag{6}$$

Where:

In = net irrigation application (mm/month)
W_b = actual depth of available soil water at the beginning of the month (mm/root depth)
S_a = total available soil water (mm/m)
D = root depth (m)
$ET_{monthly}$ = monthly evapotranspiration (mm/month)

3.0 RESULTS AND DISCUSSION

3.1 Particle Size Distribution Analysis

Table 1 presents the results of the particle size distribution and physical properties of the soil at the study site. The soil textural class ranges from sandy-loam to clay-loam on the upper fringe, and from loam-sand to sandy-clay in the lower fringe. The soil physical properties determined include infiltration rate, porosity, particle density, bulk density and field capacity.

Table 1. Particle size analysis and other physical properties of the soil at different depth

Sample depth(cm)	Soil textural class	D_b (g/cm^3)	Dp (g/cm^3)	Soil porosity (%)	F.C (mm/m)	Infiltration Rate (cm/hr)
Upper fringe						
0 20	Sandy-loam	1.2	5.45	78.0	38.7	10.14*
20 40	Sandy-loam	1.3	4.23	69.3	40.8	
40 60	Clay loam	1.6	3.85	58.4	42.0	
Mean		1.4	4.51	68.6	40.5	
Lower fringe						
0 20	Loam sand	1.4	4.10	65.8	40.5	9.18*
20 40	Sandy-clay-loam	1.5	3.12	52.0	45.1	
40 60	Sandy-clay	1.6	2.45	34.7	48.4	
Mean		1.5	3.20	50.8	44.7	

* = mean infiltration rate of each experimental plot , D_b=Bulk Density, D_p=Particle Density, and F.C= Field Capacity

3.2 Potential Evapotranspiration

Table 2. shows the meteorological parameters used in the computation of potential evapotranspiration (ET_p) of the maize crop for each month during the growing period (January April, 2006).

Table 2. Climatic data of Minna, during the cropping period (January April, 2006

Month	Temperature (°C)	Relative humidity (%)	Radiation factor (rf)
January	27	48	0.0861
February	29	56	0.0843
March	32	54	0.0944
April	30	65	0.0756

Source: Nigerian Meteorological Station (NIMET), Minna Airport.

Table 3. presents the Maximum Potential Evapotranspiration (ET_{max}) and the Crop Reference Evapotranspiration (ET_c). The parameters recorded their peak values in March. Crop coefficient (K_c) of the maize yield for each month was also determined using equation (3), assuming m= 0.904, n= -0.216 (James, 1992).

Table 3. Potential Evapotranspiration, Crop Reference Evapotranspiration and crop coefficient for various developmental stages of maize during the growing period

Month	ET_p mm/day	Kc	ET_c (mm/day)	ET_c mm/10-day period)
January	6.3	0.61	3.8	38.0
February	5.8	0.62	3.6	36.0
March	7.1	0.60	4.3	43.0
April	4.6	0.65	3.0	30.0
Mean	6.0	0.62	3.7	37.0

3.3 Available Soil Water Index

Generally, for a medium-textured soil, Sa is 140mm/m and maize root depth D of 1.2 m may be adequate. Net Irrigation (In) application of 140mm/month for maize and fraction p used for this computation is 0.4 (FAO, 2001). At the beginning of irrigation, W_b is zero on the upper fringe where irrigation frequency interval of 7 days was obtained using equation (5) and the depth of remaining available soil water ((1p) Sa.D) was calculated as 100.8-mm/root-depth.

At maximum evapotranspiration of 10.0mm/day, and mean available soil-water index 0.13, the actual evapotranspiration ET_a was obtained from yield response to water as 4.7 mm/day (FAO 2001).

3.4 Maize Yield Performance

The results of maize yield trials are presented on Table 4. The result shows that the maize yield from the upper fringe (480.90 kg/ha) was lesser than that obtained from the lower fringe (680.59 kg/ha). The reason for this may be attributed to water stress resulting from the irrigation interval of 7days in which the crop was subjected to, rise in atmospheric temperature as shown in Table 2, and depreciating soil fertility due to continuous cropping practices on the upper fringe.

Table 4. Maize yield trials on both upper and lower fringes of the valley (kg/ha)

Treatment	Trial				
				Y_i	Y_i
	1	2	3		
Upper fringe	100.15	180.45	200.30	480.90	160.30
Lower fringe	168.78	240.61	271.20	680.59	226.86

The Analysis of Variance (ANOVA) of maize yield grown under both irrigation and residual soil moisture utilization practices are shown in Table 5. The analysis shows that the F-calculated value is by far less than the F-required at 5% and 1% levels of significance. Hence, the mean yield of maize is statistically insignificant.

Table 5. Analysis of Variance (ANOVA) of Maize Crop grown under Irrigation and Residual Moisture.

Source of variation	df	SS	MS	F Observed	F Required 5%	1%
Treatment	1	6646.02	6646.02	1.19ns	18.51	98.50
Error	2	11152.43	5576.21			
Total	3	17798.46				

Table 6 shows the various yield response factors K_y obtained from the field experiments. The Maximum Theoretical Field values of maize yield Y_{m1} (2.1t/ha) and Y_{m2} (3.7t/ha) were adopted for use, in these computations as reported by Adeniji (1985) and Egharevba *et al.*, (2001) respectively. The mean K_y value for these experiments as presented in A shows the closeness of the computed figures to the standard FAO Field value. The FAO field value for maize is 1.25, which covers the crop total growing period.

Table 6 Experimental field K_y values for maize yield

Experimental plot	A	B
		(k_y)
Upper fringe	1.45	1.64
Lower fringe	1.38	1.54
Mean	1.37	1.59

A= Ky values for maize yield obtained using Ym1, and B= Ky obtained using Ym2
Ym1 and Ym2 = maximum theoretical Field values of maize yield obtained using equation 1

3.5 Production Cost

Table 7 shows that while about N 3380.00 was spent on irrigating the upper fringe, there was no cost implication in irrigating the lower fringe. A total sum of N 9150.00 was spent on treatment A, while N 6770.00 was expended on treatment B.

Table 7. Cost per treatment for Maize Cultivation

Cost items	Cost per treatment (₦)	
	A (Upper fringe)	B (Lower fringe)
Labour Expenses		
Land clearing/preparation	2,000.00	2,500.00
Seed planting	150.00	150.00
Weeding (manual)	250.00	250.00
Fertilizer application	500.00	500.00
Irrigation service	3,380.00	NIL
Harvest	1000.00	1,500.00
Miscellaneous Expenses	1,400.00	1,500.00
Material cost		
Maize seeds	150.00	150.00
Fertilizer	100.00	100.00
Apron-star (fungicide)	120.00	120.00
Total Expenditure	9,050.00	6,770.00

3.6 Overall crop performance and financial benefit

Table 8 presents a summary of the overall economic analysis for the two treatments. The table indicates that more profit was realized in the lower fringe treatment than that of upper fringe. The benefit/cost ratio for the upper and lower fringes were obtained as 1.10 and 1.24, respectively.

Table 8 Cost and returns on investments for the treatments per hectare

Treatment	Maize yield (kg/ha)	Total production cost (₦)	Gross income (₦)	Profit realized (₦)	Benefit/ cost ratio
Upper fringe	480.90	9150.00	10,100	950	1.10
Lower fringe	680.59	6770.00	8,400.00	1,630	1.24

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

From the study, the following conclusions were made:

(I) Inland valley cultivation is a possible way of increasing food production annually. It is possible to sustain a second cropping after the rain-fed cultivation.

(ii) This study has shown that while an actual yield of 480 kg/ha was obtained from irrigated plots (upper fringe), 680.59 kg/ha was realized from the lower fringe.

(iii) Lower fringe does not require additional expenses on irrigation, yet it makes the best use of the available residual moisture to meet the crop water requirements throughout the crop-growing period.

(iv) The mean yield response factor (K_y) for maize as determined from the experimental fields was 1.37, which is close to the FAO Standard field value of 1.25.

(v) The probable cause for low yield on the upper fringe could be attributed to water stress. The 7 day irrigation interval for the maize crop was much. To this end therefore, if the irrigation interval of 3 to 5 days were used, irrigated maize yield might be improved. However, this may entails additional cost on the project.

(vi) The total cost of irrigated plots summed up to N 9,150.00 while the profits realized from maize sales were N 950.00/ha from the irrigated plots and N 1650.00/ha from residual moisture utilization.

4.2 Recommendations

(i) Farmers should be sensitized on the potentials of inland valley cultivation.

(ii) Agricultural Research Institutes are advised to intensify efforts in conducting experiments on the reliability and sustainability of inland valley agro-systems cultivation, in order to support second cropping season and to boost annual food production.

REFERENCES

Adeniji, F.A. (1985). Inventory of irrigation scope in Nigeria. Final Report, Federal Ministry of Agriculture, Water Resources and Rural Development, Federal Department of Water Resources, 43 Bourdillon Road, Ikoyi, Lagos.

Duru J.O. (1984). Blaney-Morin-Nigeria Evapotranspiration Model. Journal of Hydrology.70:71-83

Egharevba N.A., J.O. Mudiare and J.K. Adewumi (2001). Estimation of Ground Water Contribution to Crop Water Use in Musa Inland valley, Badeggi, Nigeria. Proceedings of the 3rd Annual Engineering Conference, Federal University of Technology, Minna, Nigeria. pp. 98-103.

FAO (2001). Yield Response to Water. Irrigation and Drainage Paper, No.33 of the Food and Agriculture Organization of the United Nations. pp. 1-43.

Hekstra, P. and W. Andriesesse (1983). Wetland Utilization Research Project, West Africa Phase1. The Physical Aspects Inventory Vol. II. International Institute for Land Reclamation and Improvement (ILRI) Wageningen, Netherlands.

James, L.G. (1992). Principles of Farm Irrigation System Design: John Wiley and Sons, Ltd. New York, Revised Edition. pp. 9-38, 110, 131-132Lillesand, T. M. and P. Kiefer, (1987). Remote Sensing and Image Interpretation. John Wiley and Sons Ltd. Canada.

Michael, A. M. (1995). Irrigation Theory and Practice. VIKAS Publishing House Ltd., New Delhi, India. pp: 448-552, 644

NIMET (2006). Nigerian Meteorological Station Weather Report. Minna International Airport.

Raunat, M. (1985). Bas-fonds et riziculture en Afrique. Approche Stru[illegible]rale Comperative. Lagronomie Tropicale. 40(3): 181-201.

Shiawoya, E.L. (1996). Personal Communication. School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Nigeria.