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Estimation of Water Requirements of Selected Field Crops in South- West and South- East Nigeria

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ABSTRACT

Estimation of crop water requirement of some selected field crops was carried out based on twenty-one years and ten years meteorological data at Abeokuta and Umudike respectively. These crops include as maize, pepper and tomato. Reference evapotranspiration was calculated using BlaneyCriddle model for Abeokuta and Penman Model for Umudike. The result obtained showed that the seasonal crop evapotranspiration (ETcrop) for maize, pepper and tomato were 378.33, 558.51 and 505.92mm/month in Abeokuta and 353.13, 130.97, and 464.82mm/month in Umudike. Effective rainfall (ER) was lower than the water requirement in the months of May and June for maize cultivation in Abeokuta, similarly, effective rainfall was lower that the water requirement in the months of March, April, May and August for pepper in Abeokuta. This indicates that supplemental irrigation was needed during these months. Irrigation water requirement (IR) was 11.73mm for soils of Umudike. The study also established that pepper and maize could be grown conveniently during their growing season without supplemental irrigation in Umudike. However, the sufficient water availability for crops in Umudike during their growing season will produce good yields and good quality crops compared to Abeokuta.

Key Words: Estimation, Crop Water Requirement, Maize, Pepper, Tomato, Evapotranspiration.

1.0 INTRODUCTION

Water is important for plant growth and food production. There is competition between municipal, industry users and agriculture for the finite amount of available water, estimating irrigation water requirements accurately is important for water project planning and management (Michael, 1999). Adequate moisture is necessary for good crop establishment, good growth, good yields and good quality. The amount of water needed during a growing season depends on the crop, yield goal, soil, temperature, solar radiation and other cultural factors.

The amount of irrigation required for crop production depends on the particular season's useful rainfall, the soils' water holding capacity and the crop water need. Hess (2005) defined crop water requirements as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Broner and Schneekloth (2003) reported that water requirements of crops depend mainly on environmental conditions. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions.

Sufficient data on water requirements of most crops is not available in developing nations of the world. The most general and widely used equation for calculating reference ET is the Penman equation. The Penman-Monteith (1948) variation is recommended by the Food and Agriculture Organization. The simpler Blaney-Criddle (1950; Blaney et al, 1942; Blaney and Criddle, 1962) equation was popular in the Western United States for many years. Other solutions used include Makkink (1957) which is simple but must be calibrated to a specific location, and Hargreaves and Samani, (1985).

The objective of this study was to determine crop water requirements of some selected field crops such as maize, pepper and tomato for agricultural activities in Abeokuta and Umudike.

2.0 Materials and Method

2.1 *Study areas*

The study areas are Abeokuta, Ogun state and Umudike, Abia state.

Abeokuta, the capital of Ogun state is located in the South Western part of Nigeria in the derived savanna region of the country and falls within latitude 7^{o} 10^{1} N and 7^{o} 15^{1} N and longitudes 3^{o} 17^{1} E and 3^{o} 26^{1} E. It has an average elevation of 74 m above sea level. Abeokuta lies in the plane which is developed on rocks of the basement complex found in the savanna zone. It covers an approximate area of 40.63 km^{2}. Abeokuta is drained by River Ogun. The main tributaries of River Ogun are Rivers Oyan, Ofiki and Opeki Rivers. The region is characterized by relatively high temperature with mean annual air temperature being about 30^{o}C.

Umudike is one of the popular cities in Abia State, Nigeria. Umudike is located in the humid forest zone of Nigeria and lies within latitude 05^{0} 29′ N and longitude 07^{0} 33′ E (Chukwu, 1999) with an altitude of 122 m above sea level. Annual rainfall in Umudike ranges from 1900mm to 2200 mm, bimodal distributed with peaks in July and September. The soil is Sandy clay loam (coarse textured) and classified as an Ultisol (Njoku et al, 2001). The two cities are host to two of the three Federal Universities of Agriculture in the country.

2.2 METHOD

The study was based on 10 years meteorological data collected from the Nigeria Meteorological Agency Oshodi (NIMET). The meteorological data collected for Abeokuta

study area was between (1990 -2010) and Umudike was between (1997 - 2006). Meteorological data on Monthly rainfall, Relative humidity (maximum and minimum), temperature (maximum and minimum), sunshine and wind speed of 10 years duration were collected and analyzed. These helped in obtaining the reference crop evapotranspiration (ETo), crop coefficient (Kc), crop evapotranspiration (ETcrop), and irrigation water requirement (IR). The processed data for Abeokuta were used in the estimation of monthly evapo-transpiration by using BlaneyCriddle method, while Penman Model was used in estimation of Umudike data.

Crop Water Requirement

The crop water requirement for Umudike and Abeokuta was estimated with the meteorological data collected at Nigerian Meteorological Agency, Oshodi. The water requirement of maize were determined using total growth period of 110 days. The growth periods were separated into initial, crop development, mid-season, late season stages of 20, 30, 50 and 10 days respectively. The water requirements of pepper were determined using total growth period of 130days.

The growth periods were separated into initial, crop development, mid-season, late season stages of 8, 48, 10 and 64 days respectively. The water requirements of tomatoes were determined using total growth duration of 150 days. The initial stage is 35 days, the crop development stage is 40 days, and the mid-season stage is 50 days and late season stage is 25 days. The estimation of crop evapotranspiration involved 3 stages; Reference or potential evapotranspiration (ET_O), crop coefficient (K_C) and crop evapotranspiration (ET_{crop}).

Estimation of Reference Evapotranspiration

Reference crop evapotranspiration (ET_O) is defined as the rate of evaporation of an extended surface of 8 to 15cm tall green grass cover actively growing completely shading the ground and not short of water (Iren and Osodeke, 2006). The reference evapotranspiration for a reference crop of grass for Umudike was calculated based on the penman equation as follows:

$$ET_O = C[W + Rn + (1 - W) \times f(u) \times (e_a - e_d)] \quad .. \quad .. \quad .. \quad .. \quad 1$$

RH = Relative humidity and (e_a) at T (temperature)

The reference evapotranspiration for a reference crop for Abeokuta was calculated based on BlaneyCriddle method as follows;

$$ETo = p(0.46Tmean + 8) .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad 2$$

Estimation of Crop Coefficient (Kc)

The Kc value varies with crop development stage of the crop, and to some extent with wind speed and humidity. For most crops, the Kc value increases from a low value at time crop emergence to a maximum value during the period when the crop reaches full development, and declines as crop matures (FAO, 1986). Crop coefficients (Kc) for maize with 0.40, 0.80, 1.15 and 1.00 for initial, crop development, mid-season, late season stages days respectively.

Crop coefficients (Kc) for pepper with 0.35, 0.70, 1.05 and 0.90 for initial, crop development, mid-season, late season stages of 8, 48, 10 and 64 days respectively. The Crop factors (Kc) for tomato has the initial stage as 0.45, the crop development stage as 0.75 and the mid-season stage as 1.15 while the late season stage is 0.84. The Kc values at each of the growth stage were converted to monthly Kc as:

$$\text{Kc month} = \frac{\text{Kc growth stage} \times N}{30} \quad .. \quad .. \quad .. \quad .. \quad 3$$

Crop Evapotranspiration (ETcrop)

Crop evapotranspiration (ETcrop) refers to conditions when water is adequate for unrestricted growth and development (Allen et al., 1998) *i.e*, when soil water is not limited, also called water requirements in mm/day or mm/period. Crop evapotranspiration (ETm or ETcrop) was determined as:

$$ET\ crop = ETo \times Kc \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad 4$$

Crop evapotranspiration (ETcrop/ month) was obtained as the product of the monthly mean ETo in mm/day and the kc for the crop over each 30-day period. Seasonal ET crop values were calculated by summing the monthly values.

Irrigation Water Requirement (IR)

This was calculated as the difference between ETcrop and Effective Rainfall (ER) using the formular of Brouwer and Heibloem (1986). Effective Rainfall (ER) was calculated as follows:

$ER = 0.8r - 25$, if $R > 75mm$ / month (4) 5

Or

$ER = 0.6R - 10$, if $R < 75mm$ / month (5) 6

Table 1. Mean of 10 Years Climatic Data of Umudike (from 1997 to 2006)

Month	Rainfall (mm)	Days (mm)	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Max RH (%)	Min RH (%)	Mean RH (%)	Sunshine (hr/day)	Wind speed (km/h)	U Day (m/sec)	U night (m/sec)	U Day/U Night (m/sec)	ETo (mm/day)	ETo (mm/month)
Jan	16.65	2	32.60	21.70	27.15	58.38	40.29	49.34	4.82	9.50	3.0	2.0	1.5	3.71	115.01
Feb	47.41	2	34.30	22.90	28.60	69.86	45.86	57.86	5.19	10.20	3.0	2.0	1.5	3.76	105.28
Mar	86.86	6	33.90	23.60	28.75	76.86	56.00	66.43	4.29	10.20	3.0	2.0	1.5	4.03	124.93
Apr	172.37	11	32.90	23.90	28.40	80.14	64.71	72.43	5.23	8.80	3.0	2.0	1.5	4.04	121.20
May	261.05	15	31.90	23.30	27.60	81.71	70.14	75.93	5.63	8.80	3.0	2.0	1.5	4.00	124.00
Jun	314.02	18	30.60	22.90	26.75	85.00	74.71	79.86	4.53	8.80	3.0	2.0	1.5	3.48	104.40
Jul	304.30	21	29.60	22.80	26.20	86.57	67.57	77.07	3.18	9.50	3.0	2.0	1.5	3.26	101.06
Aug	264.99	19	29.20	22.70	25.95	74.71	68.14	71.43	2.37	8.80	3.0	2.0	1.5	2.26	70.06
Sep	324.07	21	29.70	22.60	26.15	85.29	76.71	81.00	2.70	8.80	3.0	2.0	1.5	3.14	94.20
Oct	262.77	18	30.70	22.70	26.70	83.14	73.00	78.07	3.75	8.80	3.0	2.0	1.5	3.44	106.64
Nov	56.25	4	32.00	23.00	27.50	80.57	55.43	68.00	5.08	8.80	3.0	2.0	1.5	3.72	111.60
Dec	4.21	1	32.00	21.50	26.75	73.00	50.57	61.79	5.57	9.50	3.0	2.0	1.5	3.63	112.53
Total	**2114.95**	**138**	**379.40**	**273.60**	**326.50**	**935.23**	**743.13**	**839.18**	**52.34**	**110.50**	**3.0**	**2.0**	**1.5**	**42.47**	**1290.91**
Mean	**176.25**	**12**	**31.62**	**22.80**	**27.21**	**77.94**	**61.93**	**69.93**	**4.36**	**9.21**	**3.0**	**2.0**	**1.5**	**3.54**	**107.58**

Key: ETo = reference crop evapotranspiration; Max = maximum; Min = minimum; Temp = Temperature; Uday = day wind speed; Nday = night wind speed; RH = relative humidity

Table 2. Mean of 21 Years Climatic Data of Abeokuta (from 1990 to 2010)

Month	Rainfall (mm)	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Wind speed (m/s)	Max. RH (%)	Min. RH (%)	Mean RH (%)	Sunshine hr/day	P (%)	ETO mm/day	ETO mm/month
Jan	4.77	34.48	22.96	28.03	2.55	70.29	42.29	56.29	5.13	0.21	4.45	137.95
Feb	25.70	36.27	24.70	30.49	3.00	73.29	41.57	57.43	5.15	0.22	4.85	135.80
Mar	52.66	35.65	24.41	30.54	2.86	78.24	51.76	65.00	5.24	0.22	4.85	150.35
Apr	129.27	34.16	24.60	29.38	2.89	81.29	61.24	71.27	5.15	0.22	4.73	141.90
May	146.92	32.46	24.07	28.28	2.52	82.33	68.33	75.33	5.55	0.23	4.83	149.73
Jun	188.66	31.00	23.52	27.26	2.41	85.14	73.70	79.42	4.25	0.18	3.70	111.00
Jul	205.40	29.69	23.00	26.35	2.41	87.43	76.67	82.05	3.15	0.13	2.62	81.22
Aug	105.71	28.80	22.78	25.79	2.41	87.67	76.43	82.05	2.45	0.10	1.99	61.69
Sep	202.91	30.10	23.13	26.62	2.36	86.86	73.71	80.29	3.00	0.13	2.63	81.53
Oct	125.70	31.90	23.62	28.64	2.37	85.38	67.62	76.50	5.80	0.24	4.98	154.38
Nov	16.33	33.62	23.65	28.64	2.37	82.76	54.10	68.43	6.10	0.25	5.29	158.70
Dec	10.13	34.16	23.82	28.99	2.40	75.81	48.91	62.36	5.60	0.23	4.91	152.21
Total	**1214.16**	**392.29**	**284.26**	**339.01**	**30.55**	**976.49**	**736.33**	**856.41**	**56.57**	**2.36**	**49.83**	**1516.46**
Mean	**101.18**	**32.69**	**23.69**	**28.25**	**2.55**	**81.37**	**61.36**	**71.37**	**4.71**	**0.20**	**4.15**	**126.37**

Key: ETo = Reference crop evapotranspiration; P = percentage duration of sunlight; Max = maximum; Min = minimum; Temp = Temperature; RH = relative humidly.

Table 3. Estimated monthly crop coefficient (Kc) and Crop evapotranspiration (ETcrop) for Maize

Months	ETO mm/month		Kc/month		ETcrop mm/month	
	Abeokuta	Umudike	Abeokuta	Umudike	Abeokuta	Umudike
April	141.90	121.20	0.4	0.4	56.76	48.48
May	149.73	124.00	0.91	0.91	136.25	112.84
June	111.00	104.40	1.15	1.15	127.65	120.06
July	81.22	101.06	0.71	0.71	57.67	71.75

Table 4. Estimated monthly crop coefficient (Kc) and Crop evapotranspiration (ETcrop) for Pepper

Months	**ETO mm/month**		**Kc/month**		**ETcrop mm/month**	
	Abeokuta	**Umudike**	**Abeokuta**	**Umudike**	**Abeokuta**	**Umudike**
March	150.35	124.93	0.35	0.35	52.62	43.73
April	141.90	121.20	0.70	0.70	99.33	84.84
May	149.73	124.00	0.90	0.90	134.76	111.60
June	111.00	104.40	1.05	1.05	116.55	109.62
July	81.22	101.06	1.00	1.00	81.22	101.06
August	61.69	70.06	1.20	1.20	74.03	84.07

Table 5. Estimated monthly crop coefficient (Kc) and crop evapotranspiration (ETcrop) for Tomato

Months	**ETO mm/month**		**Kc/month**		**ETcrop mm/month**	
	Abeokuta	**Umudike**	**Abeokuta**	**Umudike**	**Abeokuta**	**Umudike**
March	150.35	124.93	0.45	0.45	67.66	56.22
April	141.90	121.20	0.70	0.70	99.33	84.84
May	149.73	124.00	0.95	0.95	142.24	117.80
June	111.00	104.40	1.15	1.15	127.65	120.06
July	81.22	101.06	0.85	0.85	69.04	85.90

Table 6. Estimation of Crop evapotranspiration (ETcrop), Effective rainfall (ER) and Irrigation maize

Months	ETcrop (mm/month)		ER (mm)		ER - ETcrop		Total Rainfall (mm)		Irrigation water requirement (IR) (mm)	
	A	U	A	U	A	U	A	U	A	U
March	52.62	43.73	21.60	44.49	-31.03	0.76	52.66	86.86	31.03	0.00
April	99.33	0.4	78.42	112.90	-20.91	112.50	129..27	172.37	20.91	0.00
May	134.76	0.91	92.54	183.84	-42.22	182.93	146.92	261.05	42.22	0.00
June	116.55	1.15	125.90	226.22	9.38	225.07	188.66	314.02	0.00	0.00
July	81.22	0.71	139.32	218.44	58.10	217.73	205.40	304.02	0.00	0.00
August	74.03	84.07	59.57	186.99	-14.46	102.92	105.71	264.99	14.46	0.00
Seasonal Values	558.51	130.97	517.36	972.87	-41.14	841.90	828.62	1403.59	108.62	0.00

NOTE: A: Abeokuta and U: Umudike

Table 7. Estimation of Crop evapotranspiration (ETcrop), Effective rainfall (ER) and Irrigation requirements of Pepper

Months	ETcrop (mm/month)		ER (mm)		Months		Total Rainfall (mm)		Irrigation water requirement (IR) (mm)	
	A	U	A	U	A	U	A	U	A	U
April	56.76	48.48	78.42	112.90	21.66	64.42	129.27	172.37	0.00	0.00
May	136.25	112.84	92.54	183.84	-43.72	71.00	146.92	261.05	43.72	0.00
June	127.65	120.06	125.93	226.22	-1.72	106.16	188.66	314.02	1.72	0.00
July	57.67	71.75	139.32	218.44	81.65	146.69	205.40	304.30	0.00	0.00
Seasonal Values	378.33	353.13	436.20	741.39	57.87	388.26	670.25	1051.74	45.44	0.00

NOTE: A: Abeokuta and U: Umudike

Table 8. Estimation of Crop evapotranspiration (ETcrop), Effective rainfall (ER) and Irrigation requirements of Tomato.

Months	ETcrop (mm/month)		ER (mm)		Months		Total Rainfall (mm)		Irrigation water requirement (IR) (mm)	
	A	U	A	U	A	U	A	U	A	U
March	67.66	56.22	21.60	44.49	-46.06	-11.73	52.66	86.86	46.06	11.7
April	99.33	84.84	78.42	112.90	-20.91	28.06	129.27	172.37	20.91	0.00
May	142.24	117.80	92.54	183.84	-49.71	66.04	146.92	261.05	49.71	0.00
June	127.65	120.06	125.93	226.22	-1.72	106.1	188.92	314.02	1.72	0.00
July	69.04	85.901	139.32	218.44	70.28	132.5	205.40	304.30	0.00	0.00
Seasonal Values	505.92	464.82	457.80	785.88	-48.12	321.0	722.91	1138.6	118.4	11.7

NOTE: A: Abeokuta and U: Umudike

4.0 CONCLUSION

This study established that pepper and maize could be grown conveniently during their growing season without supplemental irrigation in Umudike. However, crop water requirements of tomato in Umudike can be met by effective rainfall if sowing date falls between April and August. In Abeokuta, effective rainfall was lower than the crop water requirement for maize, pepper and tomato cultivation. This indicates that supplemental irrigation would be needed during the growing season for the crops to perform optimally. In view of sufficient water availability for crops in Umudike, crop yield and production during growing season will produce good yields and good quality of crops in Umudike compared to Abeokuta.

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