THE USE OF BLANEY MORIN NIGERIA EVAPOTRANSPIRATION MODEL TO ESTIMATE THE IRRIGATION WATER REQUIREMENT OF MAIZE CROP IN ABUJA NIGERIA.

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(MATRIC NO. PGD/AGRIC.ENG/2000/2001/118)

(SOIL AND WATER OPTION)

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF POST-GRADUATE DIPLOMA IN AGRIC. ENGINEERING.

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JUNE, 2002

CERTIFICATION

This is to certify that this thesis has been read and approved as meeting the requirement of the Department of Agricultural Engineering , for the Award of Post Graduate Diploma (PGD).

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DEDICATION

This Research work is Sincerely Dedicated to my Lord Jesus Christ and the families of KAYODE VICTOR OLAWALE.

ACKNOWLEDGEMENT

I thank the Almighty God for his kindness, guidance, protection, provision, wisdom and understanding bestowed upon me during the period of this course of study.

I am extremely indebted to many people directly or indirectly for their immeasurable contributions to the success of this research work. My sincere appreciation goes to my able and dedicated supervisor DR. ENGR. N. A. EGHAREVBA, the able and dynamic head of Agricultural Engineering Department DR. ENGR. D. ADGIDZI, Dr (Engr) S.A. Ajisegiri , Eng Bashir, and all the able and dedicated developmental lecturers for their helpful and friendly guidance throughout the course of this research work.

Without prejudice, I expressed my profound gratitude to you all especially my supervisor for your constant objective criticism, encouragement and particularly the interest you have in this research work.

I am equally very grateful to Engr. Bashir of Agricultural Engineering for his immense contributions towards the success of the project and all the Post Graduate students of 2000/2001 session.

I am very grateful to the pastors and Leaders of MFM church Kuje for their prayers, which has helped me to scale through this course.

I am equally very grateful to the management of FCT-ABUJA ADP for the opportunity given to me pursue this course.

Finally, I will like to express my profound gratitude to my Darling wife (Mrs Esther Kayode), my mother (Mrs Ruth Kayode) and all my children , all my brothers and sisters for their moral, financial, physical, spiritual supports.

Victor O. Kayode

ABSTRACT

The research work is focused on the use of Blaney-morin - Nigeria Evapotranspiration model to estimate the irrigation water requirement for maize in FCT. This is aimed at maximizing the available irrigation water for optimum usage in FCT. The parameters used to determine the water requirement from climatic data obtained from Abuja Airport Meteorological Station and FCT ADP Agro-Meteorological Station were Temperature, relative humidity, sunshine and Radiation. The mean potential Evapotranspiration ETP were calculated using both the BMN and Blaney criddle models. The coefficient factor (kc) for maize crop for the 4 months of dry season were calculated to determine the irrigation water requirement for maize crop in FCT-Abuja. The results of the research carried out gave BMN model over predicting annual ETp value of 55.96mm/day while Blaney-criddle model predicted lesser total mean annual ETp of 20.638mm/day. Actual crop Evapotranspiration (ETc) were also computed, with BMN Model giving a value of 827.71mm while the Blaney-criddle gave an ETc value of 317.07 mm. Comparison of the results with FAO values ranging between (550 - 800) it is evident that BMN model implies that under Nigerian conditions resulted in more accurate prediction of Evapotranspiration in Federal Capital Territory. It can therefore be used to determine Irrigation water requirement for maize accurately.

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ABBREVIATIONS

°C	=	Degree centigrade
cm	=	Centimeter
BMN	=	Blaney –Morin –Nigeria
ETo	=	Reference crop Evapotranspiration
Etc	=	Actual crop consumptive use.
Kc	=	Crop – coefficient
mm	=	Millimeter
P	=	Daily Light percentage
Sec.	=	Second
m^2	=	Square meter
L	=	Length
Kg	=	Kilogram
Max.	=	Maximum
Min.	=	Minimum
Hr	=	Hour
T	=	Temperature
R	=	Relative humidity
ET	=	Evapotranspiration
Hr	=	Hours

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CHAPTER ONE

1.0 INTRODUCTION

The need to produce sufficient food to feed the daily increasing population is a great challenge. The rainfed cropping must be supplemented with irrigation so that food will be available all the year.

In countries where sources of water are not easy to go by the little water must be adequate managed.

For successful irrigation design it is essential to know how much water would be applied to crops and how frequently , specifically the crop water requirements are to be made at the period of peak moisture demand.

In planning an irrigation system for an area, data on irrigation water requirement and intervals are sometimes already available for local field experiments. In such cases, planning becomes largely an engineering problem/

For this project the use of Blaney –Morin –Nigeria (BMN) Evapotranspiration model is considered to estimate the irrigation water requirement of maize crop.

Irrigation is generally defined as the application of water to the soil to supply moisture essential for the plant growth and there-by eliminate the moisture limitation to the crop production. The practice includes the development of water sources, the method of application, efficient water management .

Evapotranspiration, ET, is often predicted on the basis of climatological data. The magnitude and variation of Evapotranspiration to one or more climatic factors (temperature day length , humidity, wind , sunshine, radiation etc) . In estimating the irrigation water requirement of maize crop in Abuja – Nigeria.

There is substantiated evidence, however that temperature –based ET models through simple are not sufficiently in areas where the temperature is relatively constant while other meteorological factors that also promote evaporation vary (Michael 1978, Hashemi and Habibian , 1979) Duru and Yusuf (1980) have shown this to be true under Nigerian conditions.

But the need to be able to compute ET rapidly and accurately remains undisputed. In Nigeria and perhaps in other developing countries, there is the added need to compute ET from those meteorological parameters which requires a minimum of the commonly available parameters over a more complex and sophisticated model with comparable accuracy of prediction.

A modified form of the Blaney – Morin ET model is proposed here as satisfying these requirements. Other commonly used ET models were not included in the comparison because Duru and Yusuf (1980) had earlier compared these models under Zaria in Nigeria conditions and found the penman model to give superior numerical prediction of ET.

1.1 OBJECTIVES OF THE PROJECT

The main objectives of the project are: -

- To use Blaney-Morin-Nigeria Evapotranspiration model to estimate the irrigation water requirement of maize crop.
- To maximise the available irrigation water for optimum usage in the Federal Capital Territory (FCT) Abuja.
- Comparison of results obtained from BMN ET model and Blaney – Criddle model.

1.2 SCOPE OF THE PROJECT.

The scope of this project involves :-

- The use of climatological data in determining ET from BMN ET model.
- Comparing the results obtained from BMN model with Blaney – Criddle model using Abuja as a case study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 IMPORTANCE OF IRRIGATION

In 1968, Gulhati of India stated well the importance of irrigation in the world. Irrigation in many countries is an old art as old civilization – but for the whole world, it is a modern science, the science of survival.

The pressure of survival and the need for additional food supplies to feed our teaming population which increases everyday are necessitating, a rapid expansion of irrigation.

Even though irrigation is of first important in the more and regions of the world. It is becoming increasingly important in humid regions.

Irrigation aims at replenishing lost moisture in the soil for the benefit of plants. It is recommended that moisture in the soil should be near or at field capacity.

To supply water to field capacity level, it is important to know the water requirement of the crops and how much water can be retained in the soil. Such knowledge will provide a safeguard against the risk of either over-irrigation or under-irrigation , both of which have negative effects on both soils and crops.

Various attempts have been made especially in the U.S.A to estimate crop-water-requirement. Of all the relationships available, the one based on penman's equation (penman, 1948) seems closer to reality and has a more universal application until Blaney-Morin-Nigeria (BMN) ET model was established under the conditions of Nigeria.

The main draw backs to it being sizeable data input and computations.

Instruments such as evaporation pan and lysimeters are also used nowadays to estimate crop water requirement based on evaporation from these devices.

2.1.1 CROPS

Most crops can be grown under irrigation but the choice of a particular crop generally depends on one or a combination of the following reasons:

2.1.2 ECONOMY

Is the crop likely to bring higher profits than any other crop?

2.1.3 LENGTH OF GROWING SEASON :-

With the available resources, it is possible to grow and harvest the crop within the cropping season or should harvesting commence earlier to avoid early rainfall?

2.1.4 SUFFICIENT WATER

Is sufficient water available or should cropping commence with late rains and terminate with irrigation ?

2.1.5 SOIL TYPE AND DEPTH

The presence of restricting layer along with other considerations should guide the farmer in his choice of crops to grow, in this case maize crop is chosen.

The amount of water stored in the soil for crop use depends largely on the structure and texture of the soil. Texture is most important as far as available water holding capacity is concerned. Among soils, clay which is fine textured, has a higher ability to hold more water within its particles than the coarse textured soil such as fine or coarse. The loamy soils fall in between the two extremes.

Generally, the depth from which moisture is extracted from soils by plant depend on the depth at which most of the moisture extracting roots are concerned.

2.2 CLIMATE

The Federal Capital Territory is blessed with a unique and beautiful climate that sustains the production of many crops like maize and livestock that flourish in both savannah and rain forest environments.

The climate of Federal Capital Territory is essentially the same as that of the middle belt of Nigeria.

The wet season generally lasts from April to October. The dry season for a period is marked by harmattan condition which may prevail for only several days. FACU/FDA, (1989)

2.3 EVAPOTRANSPIRATION

This is sometimes referred to as crop consumptive-water-usage. It is combined loss of moisture from plants by transpiration and soil by evaporation. To the atmosphere its value is influenced not only by the nature of the soil and crop type but also by variation in latitude and prevailing weather condition.

More specifically air temperature, mean Annual Rainfall, Relative Humidity, wind speed, sunshine radiations.

2.3.1 MEAN DAILY TEMPERATURE

In Federal Capital Territory, the air temperature usually drops during the harmattan period from November to March, temperatures are high with low relative humidity until it reaches a peak in April just before the rain starts. (Mabogunje, 1977) and FACU/FDA (1989).

The mean daily temperature in Federal Capital Territory for the period of 1992-2001 are 32^0c and 28^0c in the dry and wet seasons.

2.3.2 MEAN ANNUAL RAINFALL

The annual rainfall normally starts in April and ends around early November. Therefore the mean annual rainfall varies between 180 days to 230 days of effective rainfall within an estimated annual rainfall ranging from 1200 mm – 1600 mm from North to south. The rains are heavier during the month of June to September each year.

2.3.3 RELATIVE HUMIDITY

There is a considerate decrease in vapour pressure in Federal Capital Territory during the dry season (harmattan period) giving a marked drop in humidity.

The lowest mean relative humidity is 44%. For the months of January and the highest 92% is recorded, during the peaks of the raining season in the month of June – September. The Relative humidity is the range of 82 – 96% (Mabogunje , 1971)

2.3.4 WIND SPEED

The wind speed is the velocity of the air in motion. In Federal Capital Territory the wind speed is generally moderate about 116km/day in dry period and 50km/day in wet seasons. (FACU, 1989) and (Mabogunje 1977). The location of the Federal Capital Territory on the Wind ward side of the Jos Plateau also means the existence of the conditions highly favourable to frequent rainfall.

2.3.5 SUNSHINE RADIATION

Sunshine solar radiation in the Federal Capital Territory is virtually bisected by the line for the 2500 sunshine hours annually.

The monthly pattern of variation is however the more critical issue. During the dry season months (November – May) the monthly variation is the amount of sunshine follows the general trend of an increase from under 250 hours in the south of the Capital Territory to over 275 hours in the North – East.

The decline in sunshine hours becomes more intense as the raining season progresses and reaches its lowest values in the month of August. Detailed analysis of the pattern of the sunshine in the FCT shows that during the period 1992 – 2001 from January to May the duration of sunshine ranges between 3.7 to 8 hours per day.

CHAPTER THREE

3.0 METHODOLOGY

3.1 LOCATION OF THE PROJECT AREA

The Federal Capital Territory (FCT) was created by degree No 6 of February, 1976. The same degree also established the Federal Capital Development Authority (FCDA) as the sole agency responsible for the design, plan and development of the (FCT) Abuja Investment opportunities 2000.

The Federal Capital Territory is located between latitudes $8^0 25^1$ and $9^0 25^1$ North of the Equator and longitude $6^0 25^1$ and $7^0 25^1$ East of green witch in the centre of Nigeria.

The FCT has a total land of area of about $8000km^2$. It was carved out of present day of Nasarawa, Kogi and Niger states before its creation. The appraisal report jointly prepared by FACU/FDA, (1989) for the FCT –Agricultural Development project (ADP) indicated that the Federal Capital Territory occupies an area of about $8000km^2$.

3.2 Map showing location of the project area in Federal Capital Territory – FCT Abuja.

3.3 DATA COLLECTION

A record data of 10 years period (1992 – 2001) from Abuja Airport and FCT – ADP Agro Meteorological station were collected and analysed for the purpose of this study. These ten-years data are shown in Tables 3.1 to 3.4.

PROJECT AREA FEDERAL CAPITAL TERRITORY, ABUJA

FCT BY AREA COUNCIL

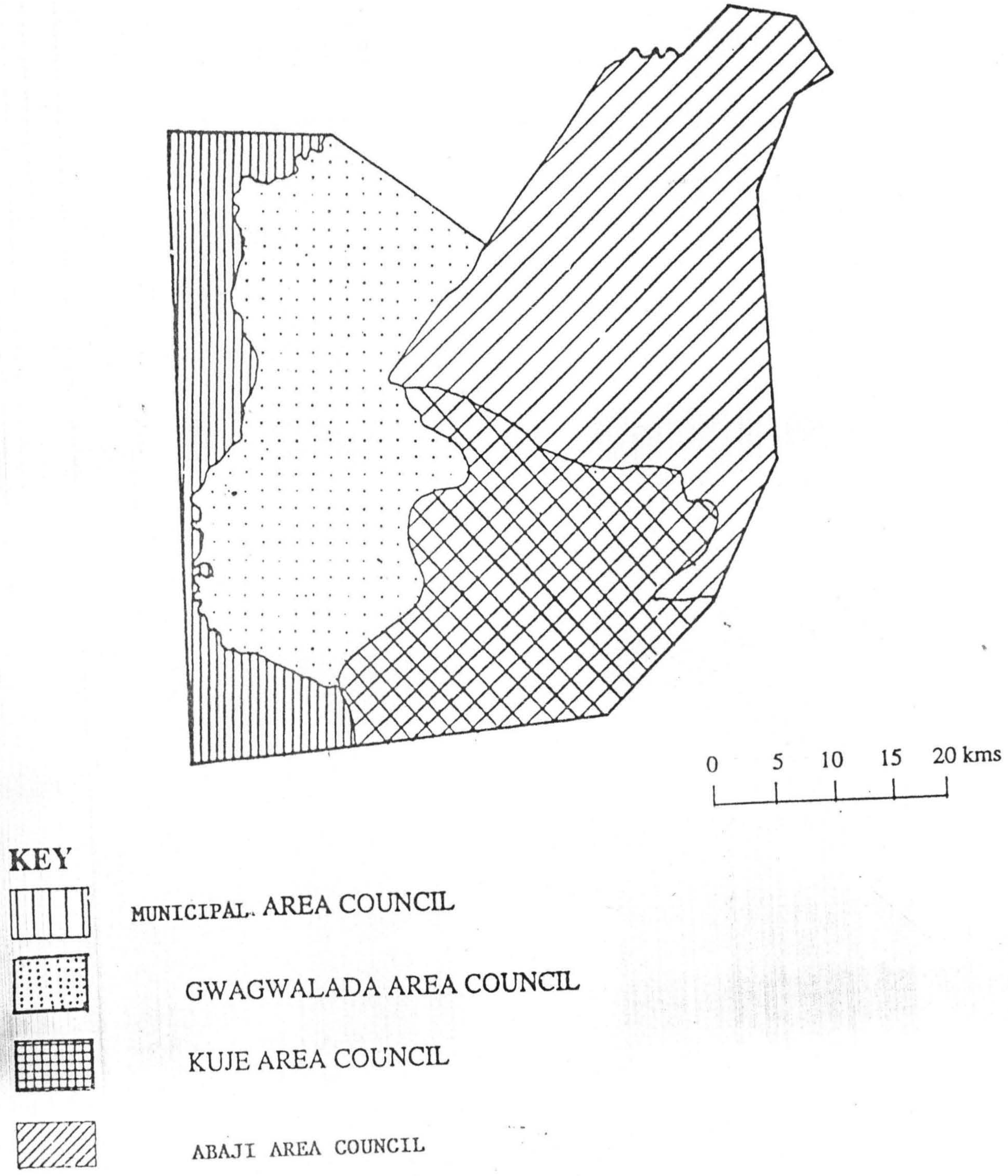


Fig 3.1

Table 3.1

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE (0C) IN FCT FROM 1992 – 2001

YEARS	JAN		FEB		MAR		APRIL		MAY		JUNE		JULY		AUG		SEP		OCT		NOV		DEC	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1992	33	20	34	21	35	21	38	22	36	26	31	27	32	21	35	23	33	22	31	19	32	20	33	23
1993	36	23	40	21	41	24	40	21	41	26	27	26	33	21	34	24	36	25	33	20	40	21	37	22
1994	38	24	40	20	43	34	41	26	39	24	28	27	36	22	35	22	35	22	35	22	35	21	35	19
1995	35	22	36	20	38	22	41	26	37	23	25	25	34	24	34	21	34	22	34	23	35	19	34	21
1996	33	19	32	21	34	20	36	19	34	19	35	18	36	22	35	23	34	18	34	19	35	18	35	20
1997	34	23	36	21	39	20	38	21	36	20	36	23	36	21	36	19	32	20	32	21	32	19	30	21
1998	30	22	30	22	36	23	36	25	33	22	31	20	30	20	29	19	30	19	32	26	33	22	31	19
1999	31	19	34	22	36	24	33	23	32	21	31	17	29	19	29	19	29	19	30	20	32	20	31	17
2000	32	19	32	20	36	24	35	23	32	22	30	20	30	19	29	19	31	19	31	21	31	20	31	19
2001	32	18	33	20	36	23	35	22	32	22	30	21	29	19	28	22	28	23	32	24	32	22	33	23

Table 3.2

MONTHLY RAINFALL (MM) IN FCT FROM 1992 – 2001

YEARS	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
1992	47.0	0.0	43.7	87.0	190.0	192.5	191.3	469.4	219.8	222.6	0.0	0.0
1993	0.0	0.0	20.6	91.5	1003.3	204.2	212.2	372.8	244.8	183.2	2.2	0.0
1994	11.5	47.0	35.3	50.3	261.3	189.6	184.7	310.2	257.7	214.5	41.9	0.0
1995	0.0	0.0	0.0	108.8	175.1	243.0	163.4	175.9	260.9	106.0	0.0	0.0
1996	0.0	11.5	0.0	46.7	92.6	181.6	338.7	283.5	276.3	196.9	0.0	0.0
1997	0.0	0.0	26.1	44.8	138.9	146.8	338.6	261.6	234.3	211.5	26.0	0.0
1998	0.0	29.6	83.0	46.7	92.6	181.6	256.1	282.5	233.7	197.5	0.0	0.0
1999	0.0	35.0	32.5	80.9	138.9	146.8	228.6	261.7	234.0	213.8	T.R	0.0
2000	0.0	0.0	75.0	494.7	869.6	1380.6	1780.7	1549.0	1563.8	321.2	0.0	0.0
2001	0.0	0.0	66.3	436.7	813.2	786.2	2546.8	1713.6	1825.6	513.5		

Table 3.3

MONTHLY RELATIVE HUMIDITY (RH) % IN FCT FROM 1992 – 2001

YEARS	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
1992	67	76	86	73	48	43	51	63	58	76	53	61
1993	80	70	87	65	65	45	59	61	71	62	58	64
1994	79	88	92	73	73	59	70	81	75	59	71	79
1995	75	83	60	74	74	92	91	88	77	36	65	75
1996	79	88	92	73	73	59	70	81	64	59	71	79
1997	78	83	87	72	72	53	62	73	71	62	76	71
1998	93	88	85	71	71	53	76	97	78	83	72	57
1999	56	64	63	41	41	21	29	46	72	59	73	54
2000	44	44	52	78	78	87	79	80	82	78	67	68
2001	56	64	63	41	41	21	29	46	62	62	53	76

Table 3.4

MONTHLY RECORD OF SUNSHINE DURATION (HRS) IN FCT FROM 1992 - 2001

YEARS	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
1992	3.7	4.5	4.5	3.6	6.6	5.3	5.5	5.6	5.7	4.7	7.0	7.8
1993	10.6	10.6	10.5	9.2	7.4	3.4	2.2	9.9	8.7	10.3	3.4	5.3
1994	8.5	5.1	3.4	6.7	6.5	6.0	7.4	6.9	6.9	8.2	7.6	6.7
1995	5.3	5.0	1.5	5.3	7.0	3.7	7.2	7.4	2.0	5.1	6.1	5.9
1996	7.7	9.9	10.2	9.8	10.3	8.8	9.4	6.0	7.6	6.4	9.7	9.0
1997	8.1	1.7	8.6	7.0	2.0	8.0	5.0	8.5	6.7	4.2	6.7	4.9
1998	5.1	2.5	7.5	5.8	4.5	1.3	7.8	4.9	4.0	4.2	7.6	0.9
1999	7.8	1.3	4.5	2.4	8.8	7.5	9.0	4.0	3.8	3.9	4.1	3.5
2000	7.5	5.6	6.5	6.8	7.4	8.0	4.2	4.5	7.4	4.3	3.0	1.8
2001	1.3	2.0	5.1	6.9	4.5	2.3	2.5	2.0	7.4	1.2	3.5	6.4

3.4. The two models used in this paper are

i. The Blaney – Morin – Nigeria (BMN) ET model and

ii. The Blaney –Criddle ET model

3.4.1 BLANEY – MORIN – NIGERIA (BMN) ET MODEL

This method was developed in Nigeria by Duru (1984) and is an extension of the Blaney – Morin Evapotranspiration equation. Duru (1984) gave a generalised form of the Blaney – Morin – Nigeria equation as : -

$$\mathbf{ETc} = \frac{Kc\,P\,t\,(H - R^{n})}{100} \qquad \mathbf{3.1}$$

ETc = Crop Evapotranspiration (inches per period)

Kc = Crop coefficient

P = Ratio of maximum sunshine hours for period of interest to the annual maximum

t = Air temperature

R = Relative humidity (%)

H and N = Constant

Duru then evaluated H and N under Nigeria conditions.

After replacing the sunshine term P, with radiation term of which he suggested as a better reflector of seasonal weather changes than sunshine, the result is the Blaney – Morin – Nigeria model which has the form : -

$$\mathbf{Etp} = \frac{rf\,(0.45\,t + 8)\,(520 - R^{1.31})}{100} \qquad \mathbf{3.2}$$

Where : -

Etp = Potential Evapotranspiration (mm / day)

rf = radiation ratio, that is ratio of maximum possible radiation for a given month to maximum possible radiation for the year.

T = Air temperature (°C)

R = Relative humidity (%)

3.4.2 Blaney – Criddle – ET model

This method is suggested for areas where available climatic data cover air temperature data only.

The original Blaney – Criddle equation (1950) involves the calculation of the consumptive use factor (f) from mean temperature (T) and percentage (P) of total annual daylight hours occurring during the period being considered. An emperically determined consumptive use crop coefficient Kc is then applied to establish the consumptive water requirements (Cu) or $Cu = K.f = \frac{(P.T)}{100}$ …... 3.3

T. = Temperature

Cu = Amount of water required to meet the Evapotranspiration needs of vegetable areas so that plant production is not limited by lack of water.

For a better definition of the effect of climate on crop water requirements , but still employing the Blaney – Criddle temperature nd day length related (f) factor a method is presented to calculate the references crop Evapotranspiration (ETo).

The original form of Blaney – Criddle equation is given as

Cu = 25.4 KEtp / 100 = 25.4 KF………… **3.4**

Where :-

Cu = Consumptive use of crop (mm/day)

E = Sum of the consumptive use factors for the period (sum of the products of mean temperature and percent of annual day – time $\frac{(t \times p)}{100}$

F = Factor for an annual day-time period.

K = Empirical coefficient (annual) , Irrigation season or growing season.

T = Mean temperature (of)

P = Percentage of day –time hours of the year occurring during the period.

Blaney – Criddle model requires only temperature as a major parameter, while relative humidity wind speed and sunshine hours as minor parameters (Mohammed B, 2000)

They have recommended the following representing mean value over a given month in its simplest form ; as

$$ETo = C[P(0.46\ T + 8) = 25.4\ \frac{(t \times p)}{100} \quad \ldots\ldots\ldots\ldots 3.5$$

Where :-

ETo = Potential Evapotranspiration in mm/day for the month considered.

P = Mean daily percentage of day-time hours of the year occurring during the period

3.5 REFERENCE CROP EVAPOTRANSPIRATION

Collect and evaluate climatic and crop data based on meteorological data available and accuracy required , select production method to calculate ETo.

The meteorological data was collected from FCT / ADP Abuja.

The data collected covered the years 1992 – 2001.

3.6 MAIZE CROP

Maize is conventionally sown at Abuja in early June and matures after 120days. The length of normal growing season or period is 4 months.

3.7 CROP COEFFICIENT (Kc)

Select cropping pattern and determine time of planting or sowing, rate of crop development, length of crop development stages and growing period.

Select Kc for maize crop and stage of crop development.

In Abuja, Nigeria maize crops are generally grown under irrigation during the months of October/November to March/April and during these months, rainfall is generally less than 25mm/month. For all latitudes therefore rainfall is assumed to be zero for ease of budgetting.

So the irrigation season November to may will be regarded as no rainfall period. Soil moisture **MUST NOT BE** allowed to fall below 50% of field capacity *(FC). In other words water should be increased by irrigation when the quantity of water left in the soil is half that of the available water.

The Kc for maize crops for initial stage, crop development and maturity stage determined. Crop coefficient Kc for other months were plotted.

The crop water requirement ETc for both the dry season and the raining season were determined, by multiplying the reference Evapotranspiration ETo by the crop factor coefficient (Kc).

The Blaney-Morin – Nigeria (BMN) ET model implies that accurate prediction of ET can be obtained from temperature, relative humidity and radiation.

The effect of wind can be ignored without much loss of accuracy with BMN model while the Blaney – Criddle model considered wind effects in a high wind region.

The BMN model shows that annual ETo – value over predicted while the Blaney – Criddle under predicted.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 DETERMINATION OF EVAPOTRANSPIRATION (ETO)

The two empirical models considered were Blarney – Morin – Nigeria (BMN) and Blaney – Criddle models. They differ widely in terms of the meteorological variables considered to be significant in predicting Evapotranspiration for federal capital territory.

4.2 BMN POTENTIAL EVAPOTANSPIRATION (ETO)

The BMN model formula was developed in 1984--- Eqt 3.2 and the data given in tables 3.1 – 3.4 were used in the determination of crop potential Evapotranspiration (ETO) Sample 4.1.

$$Eto = rf \left\{ \frac{(0.46\,T + 8)\,520 - 12^{1.31}}{100} \right\}$$

$$rf = \frac{\text{monthly max. radiation}}{\text{annual max. radiation}}$$

Add all the radiation's for 1992 – 2001

3.7 + 4.5 + 4.5 + 3.6 + 6.6 + 5.3 + 5.5 + 5.6 + 5.7 + 4.7 + 7.0 + 7.8 = 64.5

$$rf = \frac{3.7}{64.5} = 0.057$$

$= 0.06$

T = 26.5oc

R = 67%

$$Eto = 0.06 \frac{(0.45 \times 26.5) + 8 (520 - 671.31)}{100}$$

$$= 0.06 \frac{(19.93) 273.3)}{100}$$

Eto Jan. 1992 = 3.28 mm/day

4.3 BLANEY – CRIDDLE ETO FOR 1992 – 2001

$$Eto = p(0.46 T + 8)$$

$$= 0.6 (0.46 \times 26.5 + 8)$$

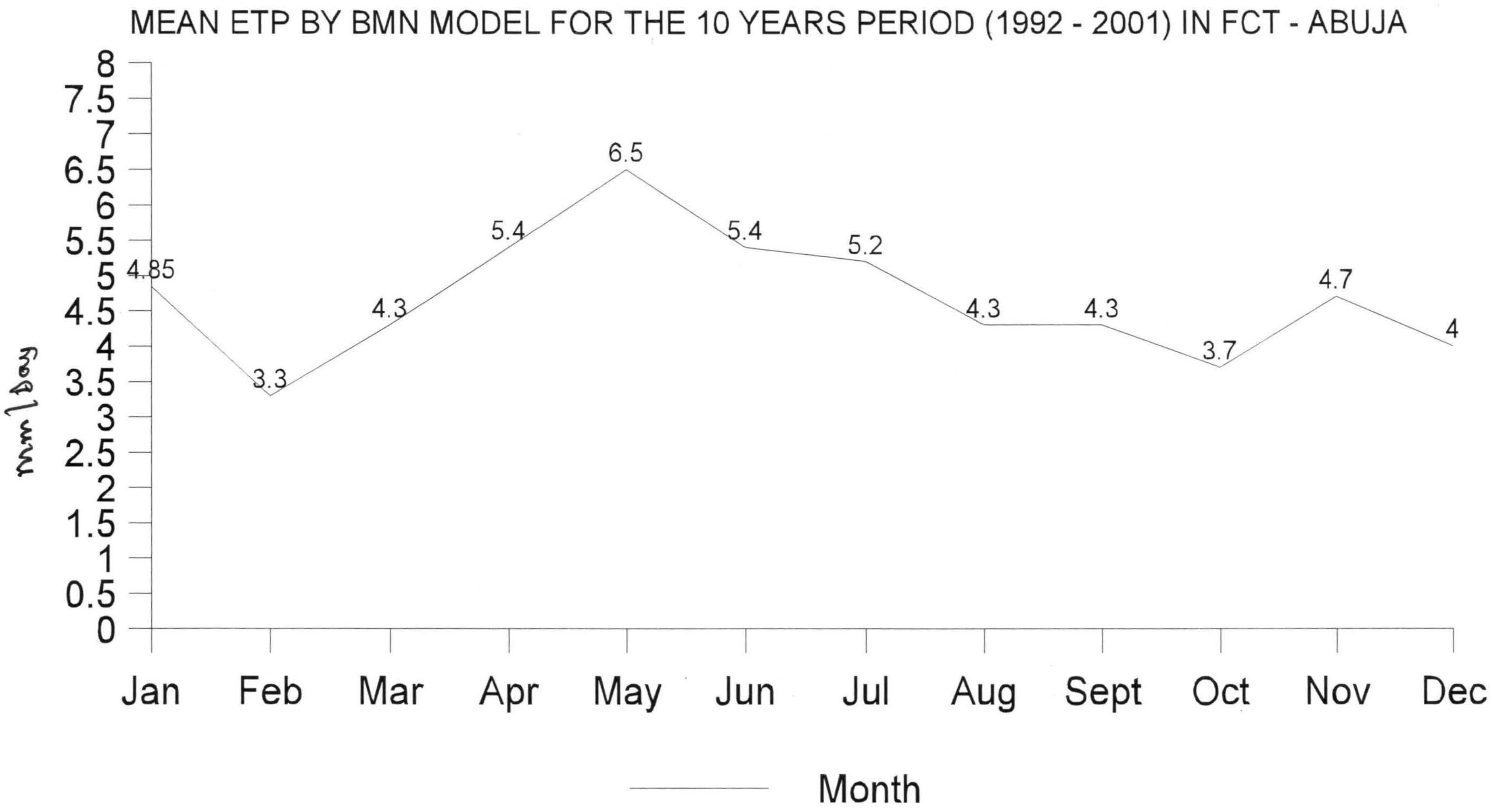
$$= 1.21 \text{ mm/day}$$

The computed results are shown in Table 4.1a – 4.1j

4.4 Computed Analysis of mean Eto values for 1992 – 2001 from BMN & Blaney – Criddle model.

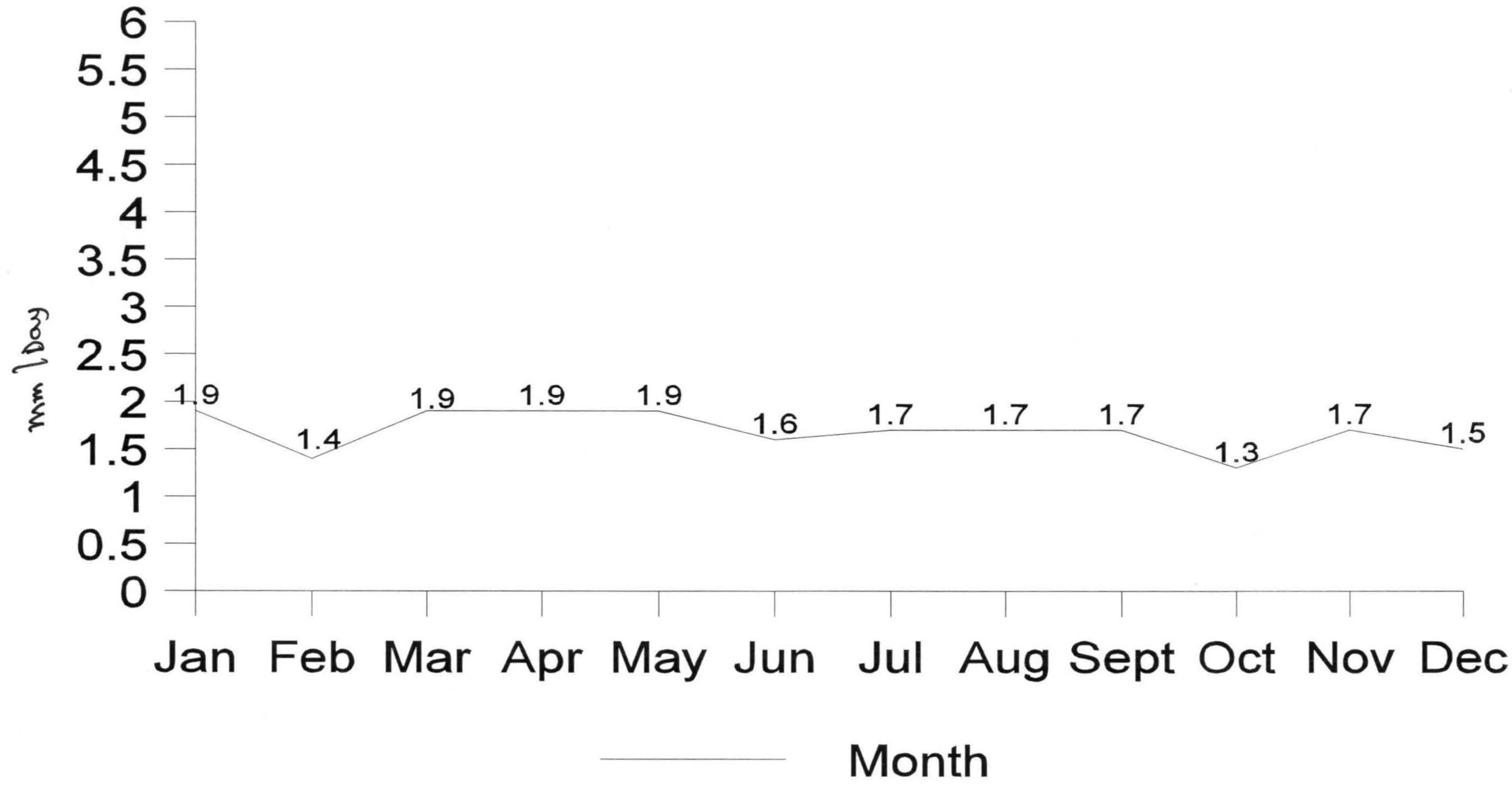
The plotted graphs for mean Eto values for 1992 – 2001 from BMN & BLANEY – CRIDDLE MODELS are shown in Figs. 4.1 to 4.2. The detailed corresponding Tables are indicated in Appendix A (Tables A1 - A3).

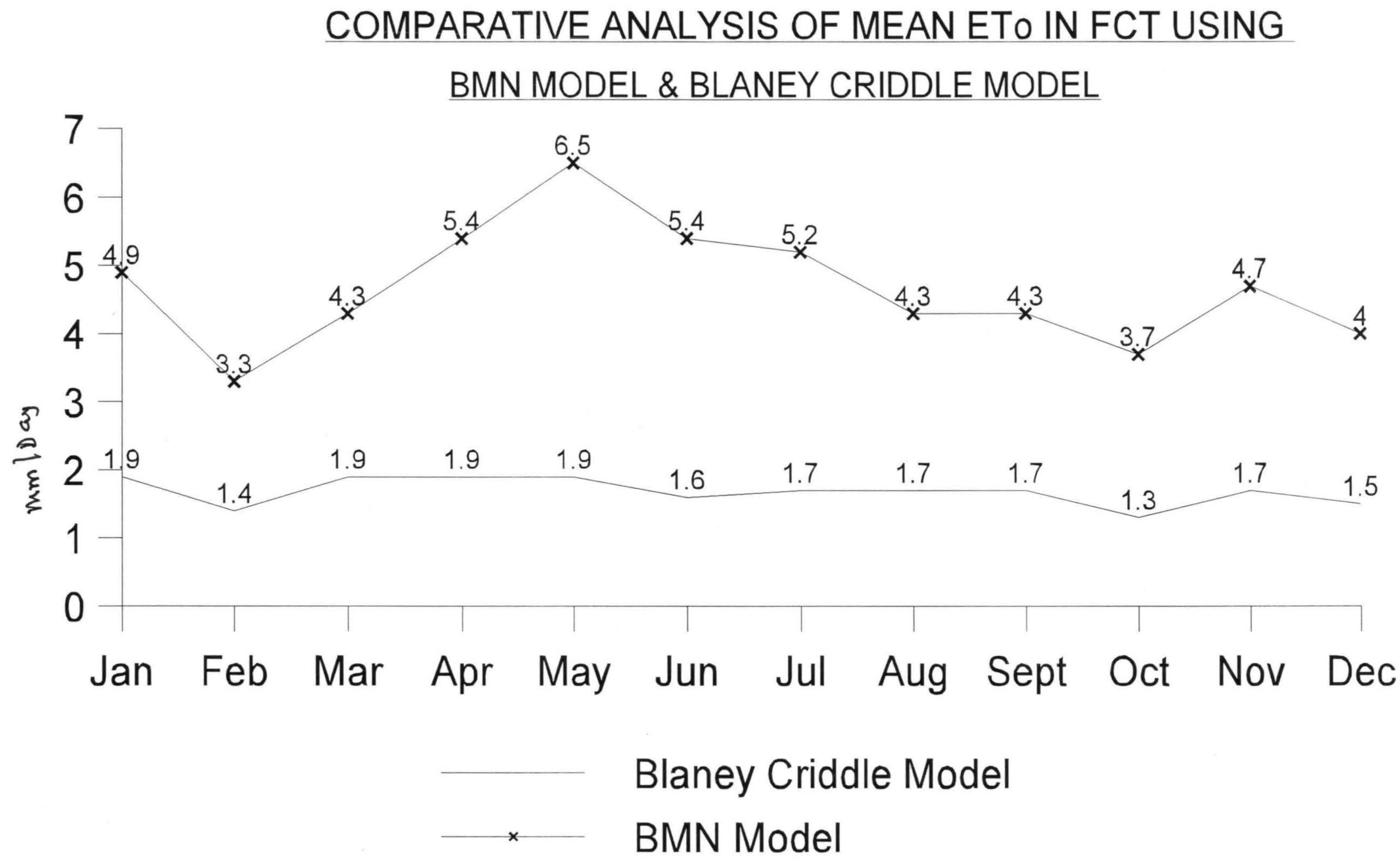
4.5 COMPARATIVE ANALYSIS OF MEAN ETo VALUES COMPUTED FROM BMN & BLANEY – CRIDDLE MODELS FIG 4.3.



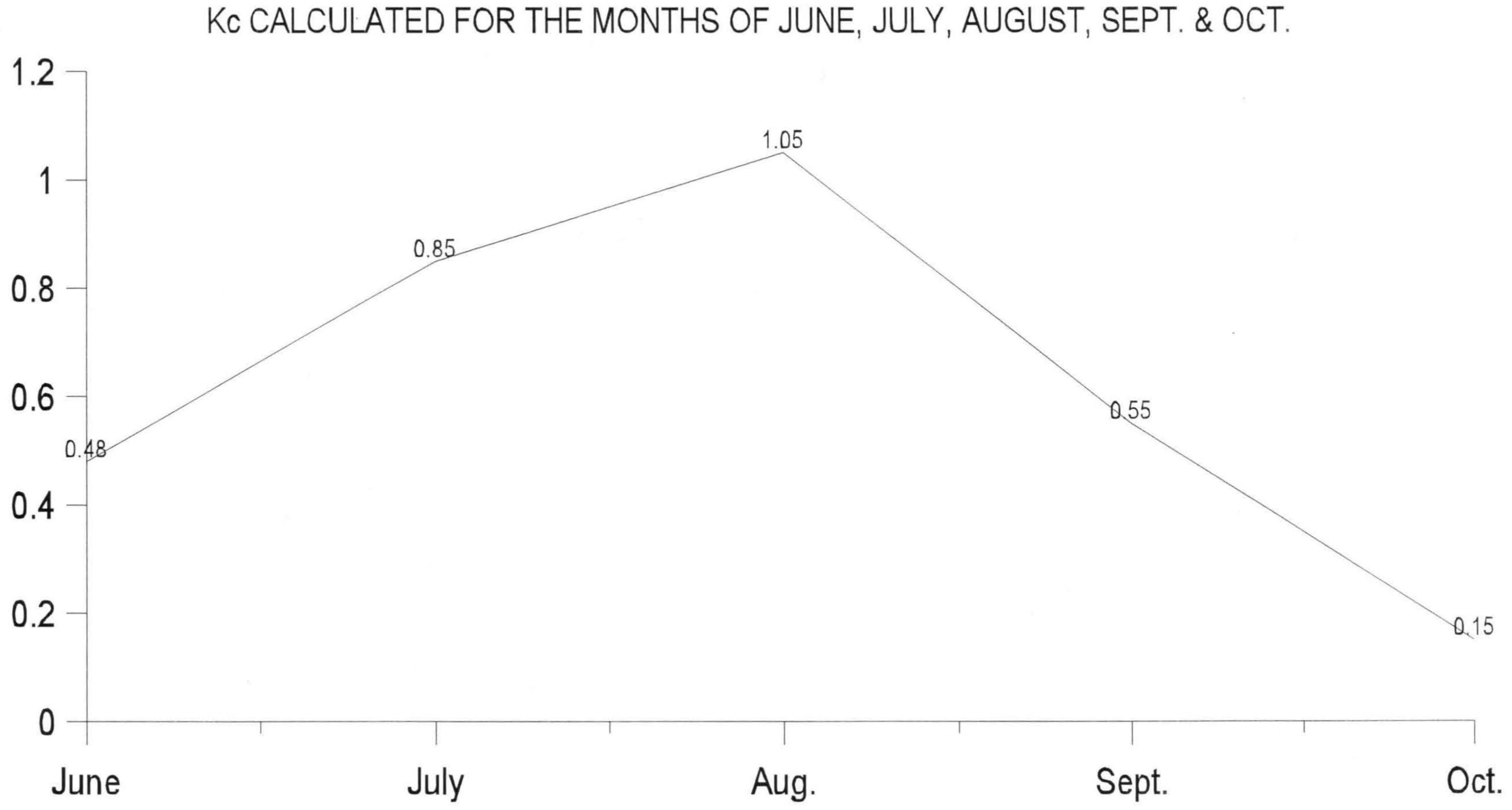
MEAN ETP BY BMN MODEL FOR THE 10 YEARS PERIOD (1992 - 2001) IN FCT - ABUJA
mm/Day
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
4.85
3.3
4.3
5.4
6.5
5.4
5.2
4.3
4.3
3.7
4.7
4
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month

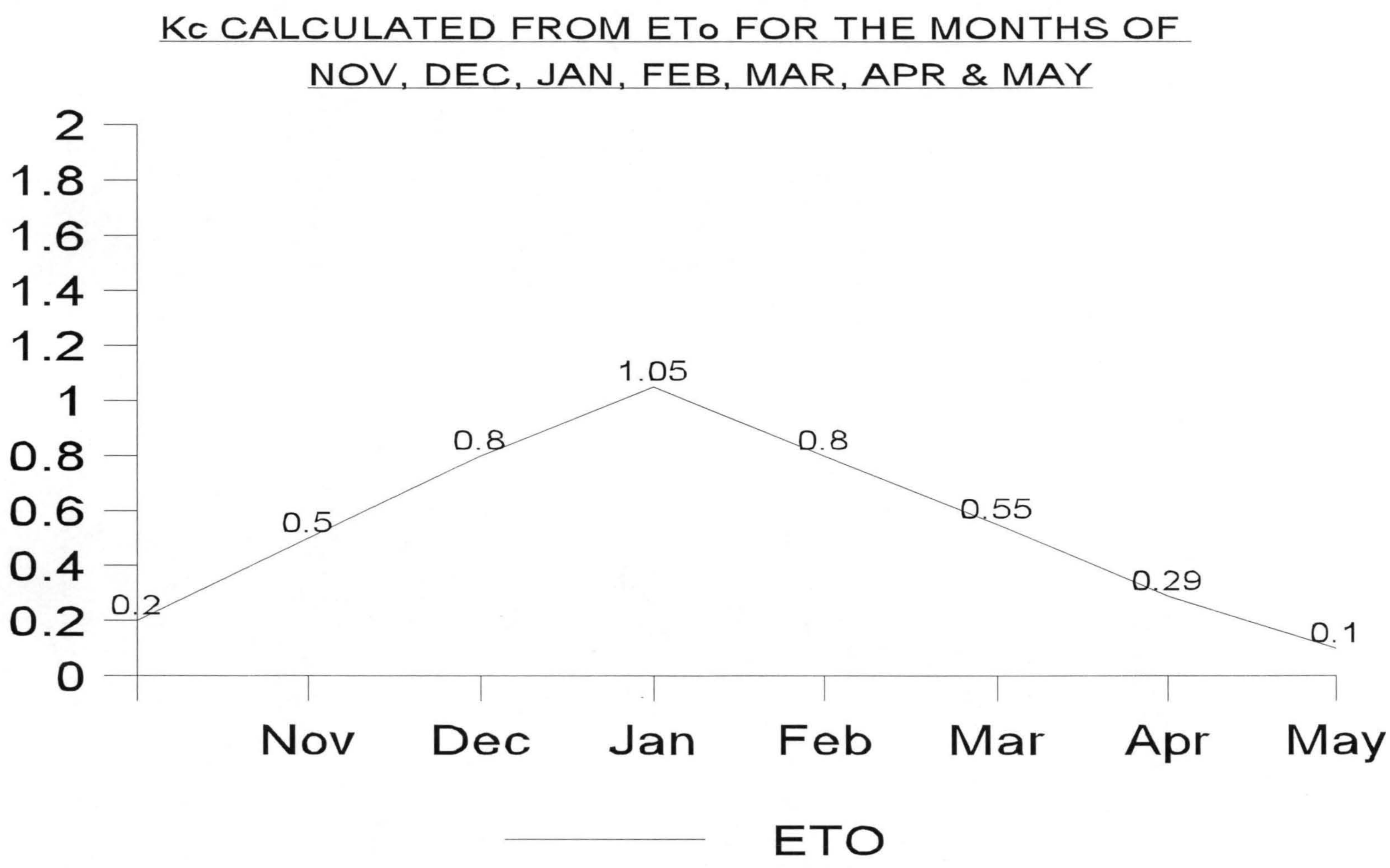
MEAN ETO BY BLANEY CRIDDLE MODEL FOR THE 10 YEARS PERIOD (1992 - 2001) IN FCT - ABUJA





COMPARATIVE ANALYSIS OF MEAN ETo IN FCT USING
BMN MODEL & BLANEY CRIDDLE MODEL
mm/Day
7
6
5
4
3
2
1
0
4.9
3.3
4.3
5.4
6.5
5.4
5.2
4.3
4.3
3.7
4.7
4
1.9
1.4
1.9
1.9
1.9
1.6
1.7
1.7
1.7
1.3
1.7
1.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Blaney Criddle Model
BMN Model


Kc CALCULATED FOR THE MONTHS OF JUNE, JULY, AUGUST, SEPT. & OCT.
1.2
1
0.8
0.6
0.4
0.2
0
0.48
0.85
1.05
0.55
0.15
June
July
Aug.
Sept.
Oct.


Kc CALCULATED FROM ETo FOR THE MONTHS OF
NOV, DEC, JAN, FEB, MAR, APR & MAY
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.2
0.5
0.8
1.05
0.8
0.55
0.29
0.1
Nov
Dec
Jan
Feb
Mar
Apr
May
ETO

4.6 COMPUTATION FOR KC (MAIZE)

MAIZE

Variety – T2SR – white (tropical zone streak resistant)

Open pollinated and certified seed.

Planting date – June

Germination – 4 days

2 weeks after planting – fertilizer application (split)

6. weeks after planting – formation of leave flag

6. weeks after planting – teaseling fand cobins

10 weeks after planting – maturing

12 weeks after planting – Brown colouration on cob

Total of 125 days from planting to harvesting

SUMMARY for Maize Kc

June – planting sub-humid Nigeria and early October harvesting

planting date – June

Initial stage – 20 days

Crop development – 30 days

Mid – season – 40 days

Late season – 30 days

120 days

Above is situated between 70 N – 140 E

Latitude and mid-summer RH min is greater than 70%

Crop coefficient (Kc) for field and vegetable crops for different stages of crop grower and prevailing climate conditions were obtained from (Table A.4) in Appendix A.

Kc for June = 0.48

Kc for Development stage = 1.05

Kc for maturity stage = 0.55

The graph plotted for the crop coefficient (Kc) for initial stage crop development stage and maturity stage is showed in Fig 4.4.

Kc June = 0.48

Kc July = 0.84

Kc Aug = 1.05

Kc Sep = 0.55

Kc Oct = 0.16

4.7 Crop coefficient (Kc) for (Dry season) November – May.

Curve graph plotted for initial stage, crop development stage and maturity state is shown in Fig 4.5

Form the curve graph Fig 4.5 the crop coefficient (Kc). For the months November – May were obtained.

Kc – Nov. = 0.50

Kc – Dec. = 0.82

Kc – June = 1.05

Kc – Feb = 0.82

Kc – Mar = 0.55

Kc – Apri = 0.30

Kc – May = 0.60

4.8 DETERMINATION OF CROP EVAPOTRANSPIRATION (ETc)

Using BMN model

Assuming 1 ha of land.

$$A = 1ha$$
$$= 100 \times 100m^2$$
$$= 10000m^2$$

The Irrigation water requirement for the months of November -February (120 days)

Kc for November	=	0.5
Kc for December	=	0.82
Kc for January	=	1.05
Kc for February	=	0.82

ETc November = ETp x Kc November

= 4.71 x 0.5

= 2.36mm/day

The water required by the maize crop in November

= No. of days in November x ETc.

= 30 x 2.36

= 70.8mm = 70.8×10^{-3}m

Water required by the farmer for the month of November for the 1ha

Volume = A x d

= $10000 \times 70.8 \times 10^{-3}$

= 708m^3

Taking an Irrigation Efficiency of 60%

$$= \frac{708}{0.6} = 1180m^3$$

water required = 1180m^3.

For the month of December

ETc December = 4.00 x 0.82

= 3.28 mm/day.

The water required by the maize crop in December

= No. of days in December x ETc

= 31 x 3.28 = 101.68×10^{-3}m

Water required for 1ha

$$= 10000 \times 101.68 \times 10^{-3}$$

$$= 1016.8m^3$$

$$\frac{1016.8}{0.6} = 1694.666$$

$$= 1694.67m^3$$

For the month of January

ETc January $= 4.85 \times 1.05$

$= 5.09$mm /day.

The water required by the maize crop in January

ETc January $= 31 \times 5.09$

$= 157.79mm = 157.79 \times 10^{-3}m$

Water required for 1ha

$$= 10000 \times 157.79 \times 10^{-3}m$$

$$= \frac{1597.9}{0.6} = 2663.1666$$

Water required $= 2663.17m^3$

For the month of February

ETc February $= 3.32 \times 0.82$

$= 2.72$ mm/day

The water required by the maize crop in February

$$= 28 \times 2.72 = 76.16 \times 10^{-3}m$$

water required for 1ha

$$= 10000 \times 76.16 \times 10^{-3}m$$

$$= 761.60m^3$$

Total water required for the four months

$$= 1180 + 1694.67 + 2663.17 + 1269.33$$

$$= 6807.17m^3$$

using Blaney criddle model

ETc Nov. = ETo Nov x Kc Nov

= 1.71 x 0.5

= 0.86mm/day

The water required by the maize crop in November

= 30 x 0.86 = 25.8mm/month

= 25.6×10^{-3}m.

Water required for the month of November of 1ha.

Volume = A x d

= $10000 \times 25.8 \times 10^{-3}$

= $258m^3$

Efficiency of 60%

= $\frac{258}{0.6} = 430m^3$

Volume = $430m^3$

For the month of December

ETc = ETo Dec x Kc Dec.

1.52 x 0.82 = $1.25m^3$/day

For the month = 31 x 1.25 = 38.75mm/month.

Water required for 1ha = $10000 \times 38.75 \times 100^{-3}$m.

= $387.5m^3$

Efficiency 60% = $\frac{387.5}{0.6} = 645.83m^3$

For the month January

ETc = ETo Jan x Kc Jan.

= 1.93 x 1.05 = 2,03mm/day

For the month = 31 x 203

= 62.93mm/month

For 1ha = $10000 \times 62.93 \times 10^{-3}m^3$

= $629.3m^3$

Efficiency of 60% = $\frac{629.3}{0.6}$ = $1048.83m^3$

For the month of February

ETc Feb. = ETo Feb x Kc Feb

= 1.43 x 0.82

= 1.17mm/day

For 1 month = 28 x 1.17 = $32.76 \times 10^{-3}m$

For 1 ha = $10000 \times 32.76 \times 10^{-3}$

= $327.6m^3$

Total water required using Blaney Criddle

= 430 + 645.83 x 1048.83 + 327.6

= $\underline{\underline{2452.26m^3}}$

DISCUSSION

The wide variety of empirical models in use differ widely in terms of the meteorological variables considered to be significant in predicting ET. The Blaney-Morin model implies that , under Nigerian conditions , accurate prediction of Etp can be obtained from temperature, relative humidity and radiation.

The effect of wind can be ignored without much loss of accuracy with the BMN model while the Blaney – Criddle model considered wind effects in a high wind region.

The results showed that the Blaney – Morin – Nigeria (BMN) ET model over predicted annual ETp – values of 55.96 for Federal Capital Territory while Blaney – Criddle model predicted lesser total mean annual ETp – value of 20.638mm for Federal Capital Territory (see Fig. 4.1 - 4.2 Tables 4.2 - 4.3).

Compared with (FAO, 1983 irrigation and drainage paper – 24) standard, the results were consistent of the BMN model over predicted total ETc of 827.71mm/day compared to Blaney – Criddle that under predicts ETc of 23.021 mm/day.

From design and safety stand points a model that over predicts is preferred to one that under predicts.

Economic considerations however set a limit to acceptable over prediction thus the better model is one that over predicts to lesser degree. Duru, (1984).

For agricultural operations , irrigation is the only source of water during the dry period. It is essential therefore to have an accurate prediction of Evapotranspiration in Federal Capital Territory.

The BMN model also gives a better seasonal fluctuation of the predicted Evapotranspiration and can be used in Federal Capital Territory for agricultural research, food production and water management.

The amount of water required for the 4 months of operations using BMN model is 6801.17m^3 for 1 ha while Blaney Criddle model is 2452.26m^3. The BMN model is the best model for the water management to avoid excess application of water to the maize crop which is detriment to the growth of plants. The model is best to maximize the available irrigation water for optimum usage in FCT.

RECOMMENDATIONS

The use of BMN Evapotranspiration model to estimate the irrigation water requirement of crops is a challenge to our Agricultural Engineers in Nigeria to do more research work by using our climatic data in enhancing crop production in Nigeria rather than relying on the research work carried out by the foreign Engineers.

APPENDIX A. (TABLES)

Table A1 (Table 4.1a - 4.1j)	**Computed potential Evapotranspiration values for Abuja Area from BMN and Blaney Criddle Models for the year 1992 - 2001.**
Table A2	**Mean ETo for the year 1992 - 2001.**
Table A3	**Computed crop Evapotranspiration values for Abuja Area from BMN & Blaney Criddle Models for 1992 - 2001.**
Table A4	**Crop coefficient Kc for field and vegetable crops for different stages of crop growth and prevailing climatic conditions.**

TABLE A1:

COMPUTED POTENTIAL EVAPOTRANSPIRATION VALUES FOR ABUJA AREA FROM BMN AND BLANEY CRIDDLE MODELS FOR THE YEAR 1992 – 2001

Table 4.1a

				BMN	LANEY CRIDDLE
Year/Month	TEMPER-ATURE °C	RELATIVE HUMIDITY %	RADIATION RATIOS	ETo mm/day	ETo mm/day
1992					
Jan	26.5	67	3.7	3.27	1.15
Feb	27.5	76	4.5	3.25	1.42
March	28	86	4.5	2.56	1.44
April	30	73	3.6	3.15	1.22
May	31	48	6.6	7.92	2.27
June	29	43	5.3	6.43	1.75
July	26.5	51	5.5	6.23	1.72
Aug	29	63	5.6	5.54	1.84
Sept	27.5	58	5.7	5.79	1.82
Oct	25	76	4.7	3.09	1.42
Nov	26	53	7.0	7.34	2.16
Dec	28	61	7.8	7.46	2.51
Total e Eto				62.03mm	20.72,mm

Table 4.1b

1993					
Jan	29.5	80	10.6	5.33	2.72
Feb	30.5	70	10.6	6.75	2.78
Mar	32.5	87	10.6	4.69	2.89
April	30.5	65	9.2	6.15	2.40
May	33.5	49	7.4	6.58	2.06
June	31.5	45	3.4	3.31	0.90
July	27	59	2.2	1.25	0.53
Aug	29	61	9.9	6.99	2.50
Sept	30.5	71	8.7	4.96	2.27
Oct	26.5	62	10.3	6.51	0.55
Nov	30.5	58	3.4	2.74	0.88
Dec	29.5	64	5.6	3.67	1.42
Total ETo				58.93mm	21.90

Table 4.1c BMN BLANEY CRIDDLE

YEAR/ MONTH	TEMPERATURE ^0C	RELATIVE HUMIDITY	RADIATION RATIOS	ETOMM/mm/ day	ETo
1994					
Jan	31	79	8.5	5.16	2.36
Feb	30	88	5.1	2.16	1.40
March	33.5	92	3.4	1.35	0.98
April	33.5	73	6.7	4.50	1.97
May	31.5	62	6.5	5.27	1.82
June	32.5	59	6.0	5.63	1.72
July	29	70	7.4	4.90	1.98
Aug	28.5	81	6.9	3.82	1.82
Sept	28.5	75	6.9	4.39	1.82
Oct	28.5	59	8.2	6.48	2.17
Nov	28	71	7.6	5.23	1.98
Dec	27	79	6.7	3.45	1.72
Total ETo				52.34mm	21.74

Table 4.1d

1995					
Jan	28.5	75	5.3	4.39	1.82
Feb	28	83	5.0	3.19	1.69
Mar	30	60	1.5	1.32	0.52
April	33.5	74	5.3	1.4.96	2.01
May	30	76	7.0	5.42	2.46
June	30	92	3.7	1.89	1.31
July	29	91	7.2	3.83	2.50
Aug	27.5	88	7.4	4.09	2.48
Sept	28	77	2.0	1.47	0.67
Oct	28.5	36	5.1	6.84	1.73
Nov	27	65	6.1	5.70	2.02
Dec	27.5	75	5.9	4.77	1.96
Total ETo				47.97mm	21.17mm
				47.97mm	

Table 4.1e BMN BLANEY CRIDDLE

YEAR/ MOUNT	TEMPERATURE ^{0}C	RELATIVE HUMIDITY %	RADIATION RATIOS	Eto mm/day	ETo
1996					
Jan	26	79	7.7	2.95	1.46
Feb	26.5	88	9.9	3.00	1.90
Mar	27	92	10.2	2.95	1.98
April	27.5	73	9.8	4.47	1.02
May	26.5	62	10.3	5.92	1.98
June	26.5	59	8.8	4.49	1.68
July	29	70	9.4	4.90	1.90
Aug	29	81	6.0	2.57	1.22
Sep	26	64	7.6	3.97	1.44
Oct	27.5	59	6.4	3.80	1.25
Nov	26.5	71	9.7	4.55	1.86
Dec	27.5	79	9.0	3.92	1.26
Total ETo				47.96mm	20.35mm

Table 4.1f

1997					
Jan	28.5	78	8.1	.02	2.36
Feb	28.5	83	1.7	0.81	0.49
Mar	29.5	87	8.6	4.41	2.55
April	29.5	72	7.0	5.30	2.07
May	28.	57	2.0	1.98	0.56
June	29.5	53	8.0	7.92	2.377
July	28.5	62	5.0	4.33	1.46
Aug	27.5	73	8.5	5.97	2.42
Sep	26	71	7.6	5.97	2.10
Oct	26.5	62	4.2	5.50	1.17
Nov	25.5	76	6.7	3.55	1.82
Dec	25.5	71	4.9	4.02	1.32
Total Eto =				3.46	20.69
				52.27mm	

Table 4.1g

BMN BLANEY CEIDDLE

YEAR/ MONTY	TEMPERATURE ^0C	RELATIVE HUMIDITY %	RADIATION RATIOS	ETo mm/day	ETo mm/day
1998					
Jan	26	93	5.1	3.34	1.72
Feb	26	88	2.5	1.32	0.84
Mar	29.5	85	7.5	5.06	2.74
April	30.5	71	5.8	5.52	2.16
May	27.5	62	4.5	4.84	1.57
June	25.5	53	1.3	1.34	0.43
July	25	76	7.8	5.73	2.57
Aug	24	97	4.9	1.80	1.58
Sep	24.5	78	6.7	4.58	2.18
Oct	29	83	4.2	2.85	1.52
Nov	27.5	72	7.6	6.59	2.66
Dec	25	57	0.9	1.23	0.29
Total Eto =				44.25mm	20.26

Table 4.1h

1999				ETo mm/day	ETo mm/day
Jan	25	56	7.8	8.13	2.50
Feb	28	64	1.13	1.19	0.44
Mar	30	63	4.5	4.40	1.61
April	28	41	2.4	3.22	0.81
May	26.5	22	8.8	12.91	2.91
June	24	21	7.5	10.51	2.34
July	24	29	9.0	12.34	2.82
Aug	24	46	4.0	4.86	1.24
Sep	24	72	4.0	3.28	1.24
Oct	25	59	3.9	3.59	1.25
Nov	26	73	4.1	3.36	1.34
Dec	24	54	3.5	3.77	1.09
Total Eto =				71.56mm	19.59mm

Table 4.1i BMN BLANEY CEIDDLE

YEAR/ MONTH	TEMPERATURE ^0C	RELATIVE HUMIDITY %	RADIATION RATIOS	Eto (mm/day)	ETo mm/day
2000					
Jan	25.5	44	7.5	8.83	2.33
Feb	26	44	5.6	6.70	1.76
Mar	30	52	6.5	7.37	2.22
April	29	78	6.8	5.07	2.28
May	27	84	7.4	4.55	2.37
June	25	87	8.0	4.37	2.46
July	25	79	4.2	2.88	1.29
Aug	24	80	4.5	2.75	1.33
Sep	25	82	3.8	2.29	1.15
Oct	26	78	4.3	3.02	1.34
Nov	25.5	67	3.0	2.66	0.93
Dec	25	68	1.8	1.55	0.55
Total Eto =				52.04mm	20.01mm

Table 4.1j

2001				ETo mm/day	ETo mm/day
Jan	25	56	1.3	1.88	0.55
Feb	26.5	64	2.0	2.29	0.89
Mar	29.5	63	5.1	3.32	1.53
April	28.5	41	6.9	12.20	3.21
May	27	22	4.5	9.32	2.02
June	25.5	21	2.3	4.54	0.99
July	25.5	29	2.5	5.12	1.09
Aug	25	46	2.0	2.84	0.86
Sept	25.5	71	7.4	7.91	3.24
Oct	28	62	1.2	1.84	0.54
Nov	27	53	3.5	5.46	1.57
Dec	28	76	6.4	6.60	2.94
Total Eto =				63.32mm	19.43mm

Table A2

MEAN ETo FOR THE 1992 – 2001

YEAR/ MONTH	TEMPERATURE ^0C	RELATIVE HUMIDITY %	RADIATION RATIOS	BMN Eto (mm/day)	BLANEY CRIDDLE Eto mm/day
Jan	27.15	70.70	6.56	4.56	1.93
Feb	27.75	74.80	4.82	3.32	1.43
Mar	29.95	76.70	6.24	4.31	1.94
April	30.05	66.10	6.35	5.44	1.99
May	28.85	54.40	6.50	6.48	1.98
June	27.90	53.30	5.43	5.41	1.63
July	26.85	61.60	6.02	5.16	1.75
Aug	26.75	71.60	5.97	4.27	1.73
Sep	26.55	71.90	6.04	4.28	1.73
Oct	27.05	63.80	5.25	3.13	1.30
Nov	26.95	65.90	5.87	4.71	1.71
Dec	26.70	68.40	5.25	4.00	1.52
Total Eto =				55.96mm	18.377mm

Table A3

COMPUTED CROP EVAPOTRASPIRATION VALUES FOR ABUJA AREA FROM BMN & BLANEY CRIDLE MODELS FOR 1992 – 2001

YEAR/ MONTH	TEMPRATURE ^0C	RELATIVE HUMIDITY %	RADIATION RATIOS	Kc	BMN Eto	BLANEY CRIDDLE ETo
Jan	27.15	70.70	6.56	1.05	5.09	2.03
Feb	27.75	74.80	4.82	0.82	2.72	1.17
Mar	29.75	76.770	6.24	0.55	2.37	1.07
April	29.95	66.10	6.35	0.30	1.63	0.60
May	30.05	54.40	6.50	0.60	3.89	1.19
June	28.85	53.30	5.43	0.35	2.60	0.78
July	27.90	61.60	6.02	0.84	4.33	1.47
Aug	26.85	71.60	5.97	1.05	4.48	1.82
Sept	26.55	71.90	6.04	0.53	2.3.5	0.95
Oct	27.05	63.80	5.25	0.16	0.60	0.21
Nov	26.95	65.90	5.87	0.560	2.36	0.86
Dec	26.70	68.40	5.25	0.82	3.28	1.25
Total Eto					35.70	13.40

Table A4

CROP COEFFICIENT (KC) FOR FIELD AND VEGETABLE CROPS FOR DIFFERENT STAGES OFCROP GROWTH AND PREVAILING CLIMATIC CONDITIONS

Crop	Humidity		RHmin	>70%	RHmin	<20%
	Wind m/sec		0-5	5-3	0-5	5-8
	Crop stage		Use Fig. 7 by interpolation			
	initial	1				
	crop dev.	2				
	mid-season	3				
	at harvest or maturity	4				
Castorbeans		3	1.05	1.1	1.15	1.2
		4	.5	.5	.5	.5
Celery		3	1.0	1.05	1.1	1.15
		4	.9	.95	1.0	1.05
Corn (sweet)		3	1.05	1.1	1.15	1.2
(maize)		4	.95	1.0	.05	1.1
Corn (grain)		3	1.05	1.1	1.15	1.2
(maize)		4	.55	.55	.6	.6
Cotton		3	1.05	1.15	1.2	1.25
		4	.65	.65	.65	.7
Flax		3	1.0	1.05	1.1	1.15
		4	.25	.25	.2	.2

Source: (FAO 1983 Irrigation and drainage paper 24)

REFERENCES

1. Blaney, H.F and Criddle W.D 1950, Determining water requirements in Irrigated areas from climatological and Irrigated data. U.S. Dept. Agric . Div. Irrig. Water conservation Washington, D.C., SCS. Tp- 96, 27 pp.

2. Blaney , H.F. and Morin , K.V (1942). Evaporation and consumptive use of water. Empirical formulas. Trans. Am. Geophys. Union, 23(part 1) : 76 – 83.

3. Michael, A.M. 1978. Irrigation Theory and practice. Vikas publishing house PVT, New Delhi, 801 (see pp. 520 – 545) .

4. Linsley, R.K, M.A. and Paulhus, J.L.H, 1975 Hydrology for Engineers. Mc Graw. Hill , New York, N.Y.; 428 pp.

5. Standhill, G.A. 1961. A comparison of methods of calculating potential Evapotranspiration from climatic data. Israel J. Res. 11: 159 – 171.

6. Tanner C.B. 1967. Measurement of Evapotranspiration , Irrigation of Agricultural lands. Amer. Soc. Agron. Monograph. No . 11 , pp, 534 – 574.

7. Stephens J.C and Stewart E.H. 1963. A comparison of procedures for computing evaporation and Evapotranspiration Pub . 62 Intern. Assoc. of Sci. Hydrol; Berkeley, California pp 123 – 138.

8. Duru , J.O. 1981. A simple Evapotranspiration model for northern Nigeria. Paper Presented at 5th Annual conference Niger Society Agricultural Engineers University of Ife, Ile Ife . August 26 – 28.

9. Duru, J.O and Yusuf, S.A. 1980. Potential of temperature – based Evapotranspiration models for Northern Nigeria Agriculture. Pap. Presented at 4th Annual conf. Niger. Soc . Agric. Eng. University of Ibadan. Ibadan . August 27 – 29, 1080.

10. FACU and FDA, (1989). The appraisal report Jointly prepared for the FCT – ADP.

11. EGHAREVBA, N.A. And MOHAMMED, B. (1999) Evapotranspiration of selected cereals in Niger state. A paper presented at the 21st Annual Conf. Of the Nigerian Society of Agricultural Engineers at the Federal Polytechnic, Bauchi.

12. MOHAMMED, B (2000) Comparative Analysis of Reference Evapotranspiration models in Minna. Paper presented at the International Millenium Conf. Of the Nigeria. Institute of Agricultural Engineers in Ibadan.

13. Pruitt W.O 1960. Relation of consumptive use of water to climate. Trans. Am. Soc. Agric. Engr. 3(1): 9 – 13, 17.