A COMPARISON OF METHODS OF CALCULATING POTENTIAL EVAPOTRANSPIRATION FROM CLIMATIC DATA

(A case study of FCT-Abuja-Nigeria)

BY

UMAR SADIQ ETSU

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

A COMPARISON OF METHODS OF CALCULATING POTENTIAL EVAPOTRANSPORTATION FROM CLIMATIC DATA

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A PROJECT REPORT IN AGRICULTURAL ENGINEERING (SOIL AND WATER OPTION)

BY

UMAR SADIQ ETSU

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CERTIFICATION

This project have been read and approved by the undersigned as having met the requirements for presentation of projects by the Department of Agriculture Engineering, Federal University of Technology, Minna.

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DEDICATION

This project is dedicated to my father Alhaji Sadiq Umar Ibrahim and my beloved mother; Hajiya Ashatu Idrisu.

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I also wish to extend my sincere gratitude to entire Ministry of Federal Capital Territory and Department of Agriculture in particular for the kind of support rendered for this course.

ABSTRACT

This study compared 3 methods of calculating potential evapotranspiration (ETp) from climatic data of Federal Capital Territory, Abuja.

The three models used were Blaney-Morrin Nigeria (BMN) model, Blaney-Craddle model and Hangreaves model.

Comparison these results with FAO values, BMN (ET) model was the best. However the BMN model over predicted the total (ETc) with value of 89. 536 mm/day compared with Blaney-Craddle model that under predicts (ETc) with a value of 33.020 mm/day. The Hangreaves model given an (ETc) value of 68.763mm/day.

The statistical analysis showed that the standard mean (ETp) was found to be 3.24mm/day, the deviation for each model were 0.857, 0221 and 0.471 for Blaney-Morrin Nigeria (BMN) model, Blaney-Craddle model and Hangreaves model respectively.

From the analysis of variance carriedout, there was a significant variation at 5% significant level between the various models. Further analysis with deviation suggested that the Blaney-Morrin Nigeria (BMN) model is most appropriate for the computation of (ETp) in Federal Capital territory-Abuja.

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CHAPTER ONE

1.0 INTRODUCTION

In designating water use by crops, evaporation and transpiration are combined into the term evapotranspiration (ET), as it is difficult to separate these two losses in cropped field.

1.1 EVAPORATION

Evaporation is the movement of gaseous water molecules from surfaces containing water. The process of evaporation of water in nature is one of the fundamental components of the hydrological cycle by which water change to vapour through the absorption of heat energy. This is the only form of moisture transfer from land and oceans in to the atmosphere (Michael, 1978).

1.2 TRANSPIRATION

Transpiration is the process by which water vapour leaves the living plants body and enters the atmosphere. It involves continuous movement of water from the soil into the roots, through the stem and out through the leaves to the atmosphere.

The process includes circular transpiration, or direct evaporation into the atmosphere from moist membranes through the cuticle, and stomata transpiration or out ward diffusion into atmosphere through the stomata and tentacles of water vapour previously evaporated from imbibed membranes into inter cellular spaces within the plant (Michael, 1978).

1.3 EVAPOTRANSPIRATION

Evapotranspiration or consumptive use is the water that is required by the crop or plant to satisfied all its demand for growth and development without hindrance and it is known as water requirement.

Evapotranspiration is very complex phenomenon, as evidenced the wide variety of formula, mostly empirical, used to estimate (ET). These formulas range from simple equations expressing (ET) as a function of temperature alone, to models requiring more extensive data. The formula developed by Blaney and Criddle (1950) is an examples of the former group of formulas, here after termed temperature based models.

The Penman (1948) formula is an example of the later. There is substantiated evidence, however, that temperature based (ET) models, though simple, are not sufficiently sensitive in areas where the temperature is relatively constant. While other meteorological factors that also promote evaporation vary (Michael, 1978). Hashemic and Habibians, 1979) Duru and Yusuf (1980) have shown this to be true under Nigeria 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 can be easily measured. In other words, the model that is easy to apply and requires a minimum of the commonly meteorological is to be preferred over a complex and sophisticated model with comparable accuracy prediction.

A modified form of the Blaney-morrin Nigeria evapotranspiration model, Blaney-criddle model, and Haigreaves model were proposed here to be used for comparison as satisfying these requirements.

The Blaney-morrin-Nigeria (BMN) (ET) model was compared with observed open-water evaporation and with Penman(ET) models considered by many to be the most rational one. Other commonly used evapotranspiration models were not included in the comparison because Duru and Yusuf (1980) had earlier compared these models under Zaria, Nigeria conditions and found the Penman model to give superior numerical prediction of the evapotranspiration. Further inclusion of the 'inferior' model in the comparison was therefore deemed without merit (Michael, 1978).

1.4 **SOIL TYPE**

The soil of Federal Capital Territory (FCT-Abuja) are classified into two groups (Mobagunje, 1977 and FACU, FDA, 1989):-

i. Soil Texture

ii. Soil Structure

(i) **SOIL TEXTURE**

Soil texture describes the relative proportion of sand, silt and clay properties of a given soil. The commonly textural classes of Fertility Capability Classification (FCC) Unit to which soils of Federal Capital Territory are generally loamy and clay dominant.

The investigation have revealed that about 60% of the Federal Capital areas have loamy textural classes on the surface. While only about 20% of clay texture are found in most of the depression areas within the surface, while the sub-soils have about 20% of clay loam to sandy clay loam. (FACU and FDA; 1989) and (Mobagunje, 1977).

(ii) **SOIL STRUCTURE**

The Federal Capital Territory is dominated by basement complex rocks in about three quarters of its land area. While the remaining portion in the South and Southwest of the Territory consists of rocks of sedimentary origin, mostly Nupe sand stone (Mobagunje, 1977).

1.5.1 CLIMATE

The Federal Capital Territory is blessed with a unique and beautiful climate that sustains the production of many crops and livestock that flourish in both savannah and rain forest environments. Being in between these geographical zones, it shares some of the characteristics of the two.

The climate of Federal Capital Territory is essentially the same as that of the Middle-belt of Nigeria. The West seasons generally lasts from April to October, approximately, 230 days (Mobagunje, 1977) and (FACU/FDA 1989). The dry season for a period is marked by harmattan condition, which may prevail for only several days.

1.5.2 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 1,200-1,600mm from North to South (Mobagunje, 1977). The rains are heaviest during the month of June to September each year. Table 2.1

1.5.3 MEAN DAILY TEMPERATURE

In Federal Capital Territory, the air temperature usually drops during the harmattan period. November to March, temperature are high with low relative humidity until it reach a peak in April just before the rain starts. (Mobagunje, 1977 and FACU/FDA, 1989). The mean daily temperature in Federal Capital Territory for the period 1992-2001 are 28oC and 32oC in the dry and wet season. Table 1.1.

1.5.4 RELATIVE HUMIDITY

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

The relative humidity for the study are is as shown in Table 3.1 The lowest mean relative humidity is 44% for the months of January and the highest 92% is recorded during peaks of the rainy season in the month of June-September. The relative humidity is in the range of 82-96% (Mobagunje, 1977).

1.5.5 WIND SPEED

The wind speed is the velocity of the air in motion. In Federal Capital Territory, the wind speed is generally moderate about 1116km/day in dry period and 50 km/day in wet seasons approximately. (FACU 1989) and

(Mobagunje, 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 rainfalls.

1.5.6 SUN SHINE RADIATION

Sunshine solar radiation in the Federal Capital Territory is virtually bisected for the 2500 sunshine hours annually see Fig. 2.1

The monthly pattern of variation is, however, the more critical issue. During he dry season months (November-April) the monthly variation in 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. As the rainy season approaches, the effect of the Jos, Plateau found to the North-East of the Territory is to increase cloudiness and create a remarkable loop in the Isohel pattern covering the whole of the area South of the Plateau (Mobagunje, 1977).

The decline in sunshine hours becomes more intense as the rainy season progresses and reaches its lowest values in the month of August. At this time, there is an interesting inversion within the Capital Territory such that its Northern parts have fewer sunshine hours then its Southern areas.

Detailed analysis of the pattern of sunshine in the Federal Capital Territory shows that during the period 1992-2001 from January to may the duration of sunshine ranges between 3.7 to 8 hours per day in the South to between 8 to 10 hours in the North. Table 4.1 shows the mean annual sunshine radiation duration recorded from 1992-2001 in Federal Capital Territory.

1.6 JUSTIFICATION FOR THE STUDY

If the comparison of methods of calculating potential evapotranspiration from climatic data in Federal Capital Territory are made, this will lead to the evapotranspiration models that is easy to apply, accepts commonly available meteorological parameters and predicts crop evapotranspiration with creditable accuracy.

1.7 OBJECTIVES

The general objective of this study is the comparison of methods of calculating potential evapotranspiration from climatic data in Federal Capital Territory

The specific objective is to compare different methods of calculating potential evapotranspiration from climatic data in Federal Capital Territory using Blaney-morrin Nigeria (BMN) model, Blaney-criddle model and Haigreaves model.

CHAPTER TWO

LITERATURE REVIEW

2.0 EVAPOTRANSPIRATION (ET)

Evapotranspiration: This is sometimes referred to as crop consumptive – water-usage. It is the 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, wind speed, vapour pressure, atmospheric humidity and solar radiation.

Evapotranspiration or consumptive use, denotes the quantity of water transpired by plants during their growth, or retained in the plants tissue, plus the moisture evaporated from the surface of the soil and vegetation.

Evapotranspiration is a very complex phenomenon, as evidenced the wide variety of formulas, mostly empirical, used to estimate (ET). These formulas range from simple equations, expressing (ET) as a function of temperature alone, to models requiring more extensive data. The formula developed by Blaney and Criddle (1950) is an example of the former group of the formulas, here after termed temperature-based models.

The Penman (1948) formular is an example of the later. There is substantiated evidence, however, that temperature based (ET), models, though simple, are not sufficiently sensitive in areas where the temperature is relatively constant, while other meteorological factors that also promote evaporation vary (Michael, 1978). Hashemic and Habibians 1979)Duru and Yusuf (1980) have shown this to be true under Nigeria 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 can be easily measured. In other words, the model that is easy to apply and requires a minimum of the commonly meteorological is to be preferred over a complex and sophisticated model with comparable accuracy prediction. A modified form of a Blaney-morrin (ET) model is also proposed here as satisfying these requirements.

The Blaney-morrin Nigeria (BMN) ET model was compared with observed open-water evaporation and with Penman (Et) models considered by may to be the most rational are other commonly used it models were not included in the comparison because Duru and Yusuf (1980) had earlier compared these model under Zaria, Nigeria conditions and found the Penman model to give superior numerical prediction of Et.

Further inclusion of the 'inferior' models in the comparison was therefore deemed without merit. (Michael, 1978).

2.1 **POTENTIAL EVAPOTRANSIPIRATION**

Potential – Evapotranspiration (PET). The concept of potential evapotranspiration PET was suggested by Thornth Waite (1948) who defined it as the Evapotranspiration from a large vegetation covered land surface with adequate moisture at all times. He felt that since the moisture supply was not restricted the PET depended solely on available energy.

Penman (1948) defined PET as the ET from an actively growing short green vegetation completely shading the ground and never short of moisture availability. Though Penman definition is complete it does not specify the name of the vegetation.

Jensen (1968) assumed PET as the upper limit of ET that would occur with a well watered agricultural crop having an aerodynamically rough surface such as luern with 30 to 50cm of top growth . Apparently, the concept of potential evapotranspiration can be visualized as the integral effect of all climatic factors governing the evapotranspiration process. It may be defined at the ET that occurs when the ground is completely covered by actively growing vegetation and where there is no limitation in the soil moisture. It may be considered to be the upper limit of evapotranspiration for a crop in a given climate (Michael, 1978).

2.2 REFERENCE EVAPOTRANSPIRATION

Blaney and Criddle observed that the amount of water consumptively used by crops during their growing seasons was closely correlated with mean monthly temperature and day light hours. The model requires only temperature as a major parameter, while relative, humidity, wind and sun shine hours are minor parameters. Evapotranspiration or consumptive use, denotes the quantity of water transpired by plants during growth, or retained in the plant tissues, plus the moisture evaporated from the surface of the soil and vegetation.

Penman defined evapotranspiration as the evapotranspiration from an actively growing short green vegetation and completely shading the ground and never short of moisture availability. Though Penman definition is complete it does not specify the name of the vegetation.

Thornth (1977) who defined it as the evapo-transpiration from a larger vegetation covered land surface, with adequate moisture at all times suggested the concept of reference evapotranspiration he felt that since the moisture supply was not restricted the ET depended solely on available moisture. Apparently, the concept of ET can be visualized as evapotranspiration limit of evapotranspiration that occurs when the ground is completely covered by actually growing vegetation and where there is no limitation in the soil moisture (Mohammed, 2000).

2.3.0 EVAPOTRANSPIRATION MODELS

An evapotranspiration model which parallels that proposed earlier by Blaney and Morrin has been developed for application in Nigeria. The model, designated as Blaney=Morrin Nigeria evapotranspiration model, predict potential evapotranspiration with accuracy and consistency that are better then the Penman model, under Nigeria conditions. It is suggested that the Blaney-morrin evapotranspiration concept may have similar potential else where when given specific form with appropriate constant derived to reflect climatic peculiarities (Duru 1984).

2.3.1 BLANEY MORRIN NIGERIA MODEL (BMN)

Duru, 1984 combined the Blaney and Morrin models and make them suitable for adaptation to Nigeria condition and able to estimate evapotranspiration more than the Penman models, in areas Nigeria such as (Jos, Zaria Samaru, Bakura) and Banjul Gambia (Mohammed, 2000).

The analysis yielded a simple evapotranspiration model which in a generalized form maybe expressed as:-

$$ETO = rf \frac{(0.45T+8)(520-R^{1.31})]}{100} \quad \ldots\ldots 2.1$$

where:

ETO = Potential Evapotranspiration, mm/day

rf = Ratio of monthly max radiation to annual max radiation

T = Atmosphere temperature $= \frac{Tmin + Tmas}{2}$

R = Relative humidity %

2.3.2 BLANEY AND CRIDDLE 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 consumption use factor (f) from mean temperature (T) and percentage (P) of total annual day light hours occurring during the percent being considered.

Blaney and Criddle observed that the amount of water consumptively used by crop during their growing seasons was closely related with mean monthly temperature and day light hours. The model requires only temperature as a major parameter, while relative humidity, wind speed and sunshine hours as minor parameters (Mohammed, 2000.

They have recommended the following, representing mean value over the given month, is expressed as:-

$$ETO = C[P(0.46T+8)]$$

$$= 25.4 \frac{PxT}{100} \quad .... (2.2)$$

where ETO = Potential evapotranspiration in mm/day for the month considered.

P = Mean daily percentage of total annual day time hours for a given month and latitude.

T = Mean daily temperature in ^{o}C or ^{o}F over the month considered.

C = Adjustment factor which depends on minimum relative humidity, sunshine hours and day time wind estimates.

2.3.3 PENMAN MODEL

For areas where measured data on temperature, humidity, wind and sunshine duration or radiation are available, an adaptation of the Penman method (1948) is suggested, compared to the other methods presented it is likely to provide the most satisfactory results.

Penman proposed an equation for evapotranspiration from open water surface based on a combination of energy balance and sink strength, based on intensive studies of the climatic and measured gross evapotranspiration data from various stations in the world and available literature on prediction of evapotranspiration. Dorreabos and Pruitt

(1977) proposed a modified method to facilitate the computation of evapotranspiration. (Mohammed, 2000).

The Penman equation consisted of two terms:-

The energy (radiation) term and the aerodynamic (wind and humidity) term. The relative importance of each term varies with climatic condition. Under calm weather conditions the aerodynamic term is usually less important than the energy term. The form of the equation used in this method is-

$$ETO = c[w.Rn + (1-w).f(u).(e_a-ed)]\ldots 2.3$$

where:

ETO -	Reference crop evapotranspiration in mm/day.
W -	Temperature related weighting factor
Rn -	Net radiation in equivalent evaporation in mm/day
F(u) -	Wind related function
(ea-ed)-	Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air both in Mbar.
C -	Adjustment factor to compensate for the effect of day and night weather conditions.

.3.4 HANGREAVES MODEL

Hangreaves equation is similar to Jensen-Haise and is subject to similar limitations.

$$ETp = 0.0135\,(T + 17.78)\,Rs \ldots\ldots. \quad 2.4$$

Where:

ETp - Crop potential consumptive use in long leys/day

T - Average daily temperature in ^{o}C.

Rs - Sunshine radiation in long ley/day

The sunshine radiation is measured with the help of:-

a. Stokes sunshine recorder

b. Solarimeter

c. Gum Bellain integrator (measured period of sunshine per day). This is similar to sundial.

The time of observation of sunshine recording and evapotranspiration is usually measured daily at 7a.m local time.

Estimates of crop consumptive use are calculated from ETP, determined from either the Penman or Jensen-Haise method by the use of a crop co-efficient which relates growth stage back to the reference crop.

:t = (Kco. ETp)----------------- (2.5)

Where:

ET = Estimated crop consumptive use.

Kco = Crop co-efficient

2.3.5 <u>THORNTH WAITE FORMULAR</u>

Thornth Waite (1948) assumed that exponential relationship existed between mean monthly temperature and mean monthly consumptive use. The relationship was basely largely on experience in the central and eastern United State. No allowances was made for different crops or varying land uses. The formular was originally developed for the purpose of a rational classification of the broad climatic patterns of the world. Suitable co-efficient should, therefore, be developed locally for reliable estimation of ET values. (Micheal, 1978).

Thornth Waite proposed the following formular:-

e = 1.6 (10T/1/)a 2.6

Where:

e = Unadjusted potential evapotranspiration, cm per month (month of 30 days each and 12 hours day time).

T - Mean air temperature °C

I - Annual or seasonal heat index, the summation of 12 value of monthly heat indices (i) when (i) = $(t/5)^{1.514}$

a = An empirical exponent computed by equation.

$a = 0.000000675I^3 - 0.000071I^2 + 0.0792I + 0.49239$

.3.6 RADIATION METHOD

The radiation method is essentially an adaptation of the Makkink formular (1957). This method is suggested for areas where available climatic data include measured air temperature and sunshine, cloudiness or radiation, but not measured wind and humidity. Knowledge of general levels of humidity and wind is required, and these are to be estimated using published weather descriptions, extrapolation from near by areas or from local sources.

The radiation method should be more reliable than the presented Blaney-Criddle approach. Infact, in equatorial zones, on small islands, or at high altitudes, the radiation method may be most reliable even if measured sunshine or cloudiness data are not available, in this case solar radiation maps prepared for most locations in the world should provide the necessary solar radiation data. The relationship recommended (representing mean value over the given period) is expressed as:-

ETO = c(w.Rs) mm/day------2.7

where:-

ETO - Reference crop evapotranspiration in mm/day for the periods considered.

Rs	-	Solar radiation in equivalent evaporation in mm/day.
W	-	Weighting factor which depends on temperature and altitude
C	-	Adjustment factor which depend on mean humidity and day time wind conditions.

2.3.7 PAN EVAPORATION METHOD

Evaporation pans provide a measurement of the integrated effect of radiation, wind, temperature, and humidity on evaporation from a specific open water surface. In a similar fashion the plant responds to the same climatic variables but several major factors may produce significant differences in loss of water. Reflection of solar radiation from a water surface is only 5-8 percent, from most vegetation surfaces 20-25%.

Storage of heat within the pan can be appreciable and may cause almost equal evaporation during night and day, most crops transpire only during day time. Also the differences in water losses from pans and from crops can be caused by difference in turbulence, temperature and humidity of the air immediately above the surfaces. Heat transfer through the sides of the pan can occur, which may be severer for sunken pans. Also the colour of the pan and the use of screens will affect water losses.

The sitting of the pan and the pan environmental influence the measured results, especially when the pan is placed in fallow rather than cropped.

Recommended relationships of pan evaporation method. Reference crop evapotranspiration (ETO) can be obtained from:-

ETO - Kp.Epan ----------(2.8).

where:

ETO - Potential evapotranspiration

Epan - Pan evaporation in mm/day and represents the mean daily value of the period considered.

Kp - Pan co-efficient.

2.3.8 JENSEN-HAISE METHOD

The Jensen-Haise equation is similar to Haigreaves method in which recommended relationship is expressed as:-

ETP - ct (T-Tx) Rs --(2.9).
where:

ct - A temperature co-efficient

T - Temperature in oC

Tx - The intercept on the temperature axis.

Rs - Incident solar radiation in long by per day.

The value of ct and Tx where determined as 0.0025 and 3 respectively.

ct - $(1/G + C_2 \text{ CH})$

CH - 50 Ubar/ $(e_2 - e_1)$

C1 - 38 (2^{o}C x EL/30S)

C2 - 70^{o}C

Where e_1 e_2 = Saturation vapour pressure of water at the mean max and minimum temp for the warmest month of the year in a given area.

Tx = -2.5 – 0.4 (e2-e1)°C/ubar – EL/550

2.3.9 CHRISTIANSEN METHOD

Christiansen (186) proposed a revised empirical formular, originally developed by him in 1966, to estimate pan evaporation from climatic data when reliable measured pan evaporation date are not available for estimation of evapotranspiration. The following is the Christiansen's revised equation developed at Logan (Utah), USA, for estimating pan evaporation.

EV = kev.R.et.cw.ch.cs.ce.cm ....(2.10)

where:

EV - is the computed pan evaporation – equivalent to class A pan evaporation.

KEV - is a dimensionless empirically developed constant the value of which is given Christiansen as 0.473.

R - is extra-terrestrial radiation in the same evaporation units as EV.

ct,cw,cn,cs and ce – Are the co-efficient for temperature, wind velocity, relative humidity, percent of possible sunshine and elevation.

cm - Is a monthly co-efficient and the values of cm mostly range between 0.90 to 1.10 and vary from latitude to latitude.

CHAPTER THREE

3.0 METHODOLOGY

In this studies three different models are considered in the comparison of methods of calculating potential evapotranspiration from climatic data obtained from Federal Capital Territory (FCT), Abuja.

3.1 LOCATION OF THE PROJECT AREA

The Federal Capital Territory (FCT) was created by Decree No. 6 of February, 1976. The same decree 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^{o}. 25' and 9^{o}.25 North of the equator and longitude 6o25' and 7p45' East of the green witch in the centre of Nigeria. The (FCT) has a total land area of about 8000km2. It was carved out of present day of Nasarawa, Kogi and Niger States before it 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 8000km2.

(Mobagunje, 1977) and (FACU/FDA, 1989) have observed that the Territory lies just North of the wide alluvial plan formed by the confluence of the Niger and Benue rivers.

The Federal Capital Territory is dominated by basement complex rocks in about three quarters of its land area, while the remaining portion in the South and South-West of the Territory consists of rocks of sedimentary origin, mostly Nupe sand stone (Mobagunje, 1977).

MAP SHOWING LOCATION OF PROJECT AREA FEDERAL CAPITAL TERRITORY, ABUJA

g. 7.3

MAP OF NIGERIA SHOWING THE STATES AND PROJECT AREA FEDERAL CAPITAL TERRITORY (F.C.T.) - ABUJA.

FCT BY AREA COUNCIL

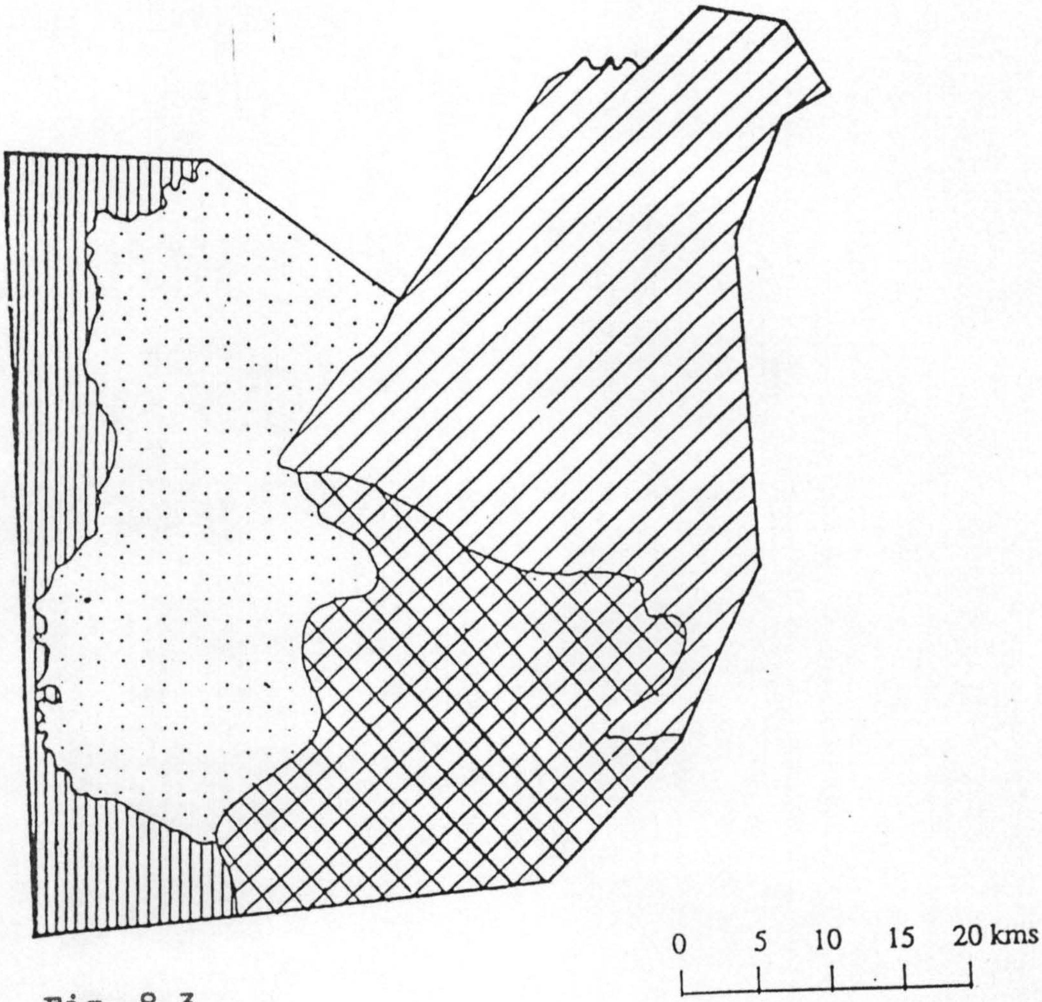

Fig. 8.3

KEY

MUNICIPAL AREA COUNCIL

GWAGWALADA AREA COUNCIL

KUJE AREA COUNCIL

ABAJI AREA COUNCIL

3.3 DATA COLLECTION

A record data of 10 years period (1992 – 2001) from the Abuja Airport and FCT-ADP Agro-meteorological station were collected and analysed for the purpose of the study.

Three models Blaney-Morin Nigeria evapotranspiration BMN, Blaney-craddle and Hangreaves model were used for computing the potential evapotranspiration (ET).

3.4 DETERMINATION OF EVAPOTRANSRATION USING BMN 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 equations.

$$ETc = Kc \times p + \frac{(H - R")}{100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Where:

ETc - Crop evapotranspiration (inches per period)

Kc - Crop co-efficient

P - Ration of max sunshine hours for period of interest to the annual max.

T - Air temperature ^{o}c

R - Relative humidity (%)

Duru then evaluated H and N under Nigerian 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 (See equation) 2.1)

3.4 DETERMINATION OF EVAPOTRANSPIRATION USING BLANEY-CRIDDLE 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. The relationship recommended, representing mean value over the given month, is expressed as (see equation 2.2.).

3.5 DETERMINATION OF EVAPOTRANSPIRATION

The Haigreaves equation is similar to Jense-Haise and is subject to similar limitations. (see equation 2.4).

3.6 DETERMINATION OF THE CROP GROWTH STAGES

For all the crops considered, the growing period was divided into:-

1. **Initial Stage**: From germination through establishments, slow increase in vegetative cover, with crop cover less than 10%.

2. **Crop Development Stage:** From end of the initial stage to full ground cover. Rapid increase in vegetative cover is attained.

3. **Mid-season stage:** From full cover to start to maturity when leave starts to yellow and fall.

4. **Late season stage**: From start of maturity to harvest (FAO, Irrigation and Drainage paper 24).

3.8 DETERMINATION OF KC VALUES

Suggested KC values at each stages of growth for each of the selected crops were obtained as presented by S. Abdulmumuni and Mr. Misari in their work on crop co-efficient of some major crops of the Nigerian semi arid tropics (1989).

3.9 DETERMINATION OF CROP EVAPOTRANSPIRATION (ETC)

The ETC was determined for each three models using Etc crop – KC.ETO. The ETC values were computed for the growing season of the crop considered.

3.10 STATISTICAL COMPARISON OF THE 3 MODELS USED

A statistical comparison of the 3 models was made with a view to choose the best model from these result. A two-way analysis of variance (ANOVA) was used to:-

1. Determine whether ETO varies among the various models used in computation.
2. Determination whether ETO varies with different month.

The mean square deviation for the models and months was computed, this was divided by the mean residual error. This statistic was used to test the hypothesis at a significant level of 5%. After the variations where determined, the best model was choosed based on the result of the deviation that each model shows from the standard calculated. These are presented in Appendix 2 Table 11.5.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 DETERMINATION OF EVAPOTRANSPIRATION (ET)

The three empirical models considered were Blanye-morin Nigeria (BMN) model, Blaney-criddle model and Haigreaves model differ widely in terms of the meteorological variables considered to be significant in predicting evapotranspiration for Federal Capital Territory.

The result shows that the Blaney-morin Nigeria BMN model predicted total mean annual ETP value of 55.96mm for Federal Capital Territory Abuja. The Blaney-criddle model predicted total mean annual ETP value of 20.638mm while Haigreaves model predicted total mean annual ETP value of 42.956mm (see Appendix Table 10.4).

The data given in Table 1.1-4.1 were used in the determination of potential evapotranspiration (ET) for the years 1992-2001 for the three models used.

4.2 DETERMINATION OF ETO USING BMN MODEL FROM (1992-2001)

The ETO was determined with the qualified form of the Blaney-morin Nigerian (BMN) by Duru (1984) as:-

$$ETO = \frac{rf\,[(0.45T+8)\,(520-R1.31)]}{100} \ldots\ldots 2.1 \quad mm/day$$

i.e. $rf = \dfrac{\text{monthly max radiation}}{\text{Annual max radiation}}$

Add all the rad: 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

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

Temp = 26.5, Relative humidity 67%

$$ETO\ Jan\ 1992 = \frac{0.057\,[0.45 \times 26.5+8)\,(520-67^{1.31})]}{100}$$

$$= \frac{0.057\,(19.925)\,(273.3063382)}{100}$$

ETO Jan 1992 = 3.104 mm/day

4.3 DETERMINATION OF ETO USING BLANEY-CRIDDLE MODEL FROM (1992-2001)

i.e. ETO Jan 1992 = P (0.46T+8)

= 0.057 (0.46x26.5+8)
= 1.150mm/day

4.4 DETERMINATION OF ETO USING HAIGREAVES MODEL FROM (1992-2001)

i.e. ETO Jan 1992 = 0.0135 (T+17.78) RS
= 0.0135 (26.5+17.78) 3.7
= 2.211mm/day

Other computed ETO for Feb 1992 – Dec, 2001 (See Appendix Table 5.3-9.3)

4.5 COMPUTED ANALYSIS OF MEAN ETP VALUES

Predicted for 1992-2001 from BMN model Blaney-criddle model and Haigreaves model (See Appendix 2 Table 10.4)

4.6 Plot graph for mean ETP values predicted by BMN model for the 10 years period (1992-2001) for FCT-Abuja.

MEAN ETP VALUES PREDICT BY THE BMN MODEL FOR THE 10 YEARS PERIOD (1992-2001)

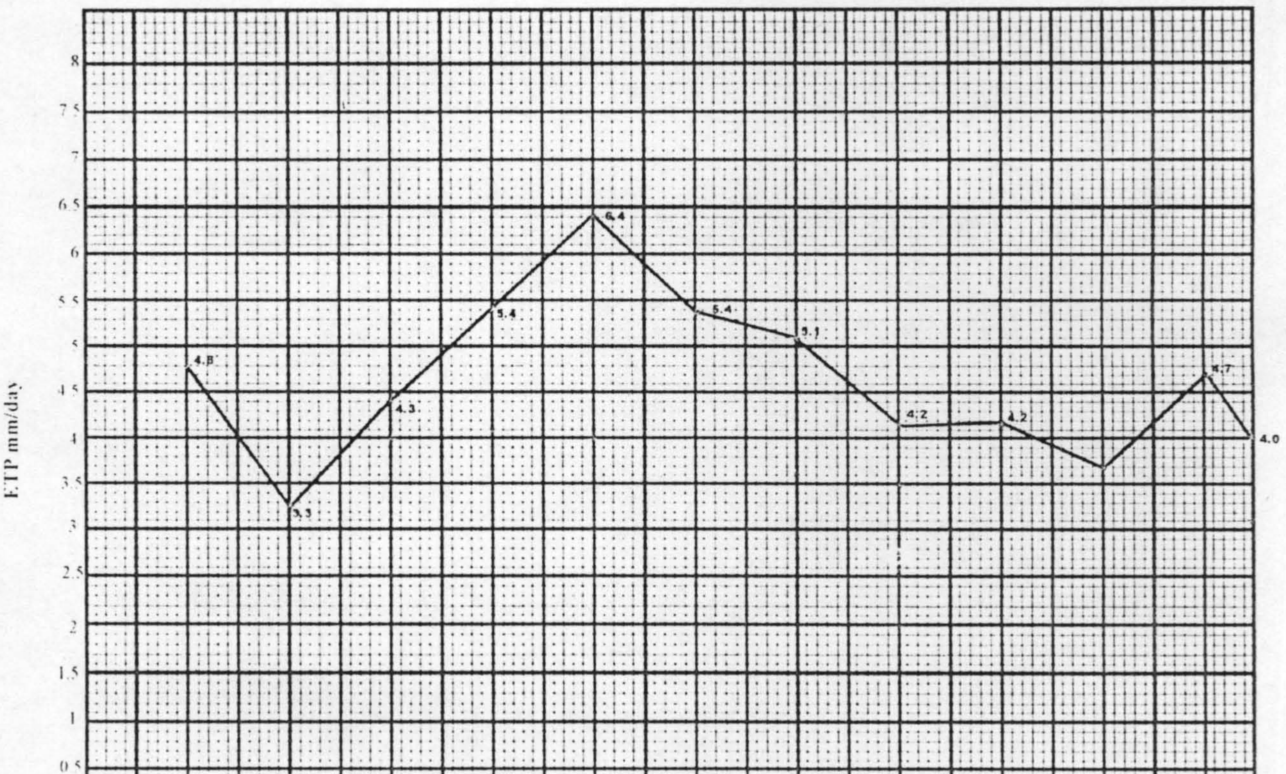

Fig 3.4

4.7 Plot graph for mean ETP values predicted by Blaney-criddle model for the 10 years period (1992-2001) for FCT-Abuja.

MEAN ETP VALUES PREDICTED BY BLANEY-CRIDDLE MODEL FOR THE 10 YEARS PERIOD (1992-2001) FOR FCT-ABUJA

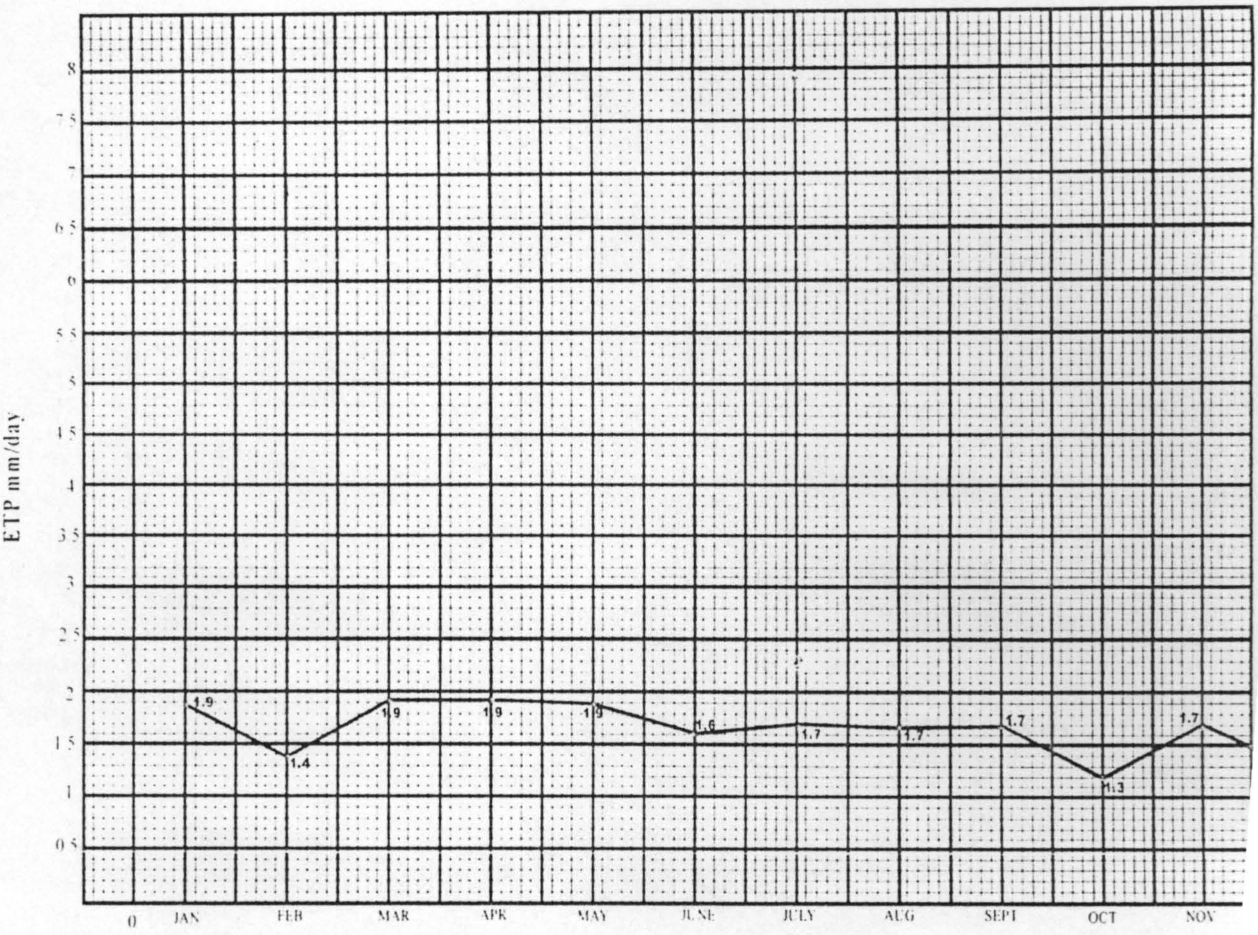

Fig 4.4

4.8 **Plotted graph for mean ETP-values predicted by Haigreaves model for the 10 years period (1992-2001) for FCT-Abuja.**

MEAN ETP-VALUES PREDICYED BY HAIGREAVES MODEL FOR THE 10 YEARS PERIOD (1992-2001) FOR FCT-ABUJA

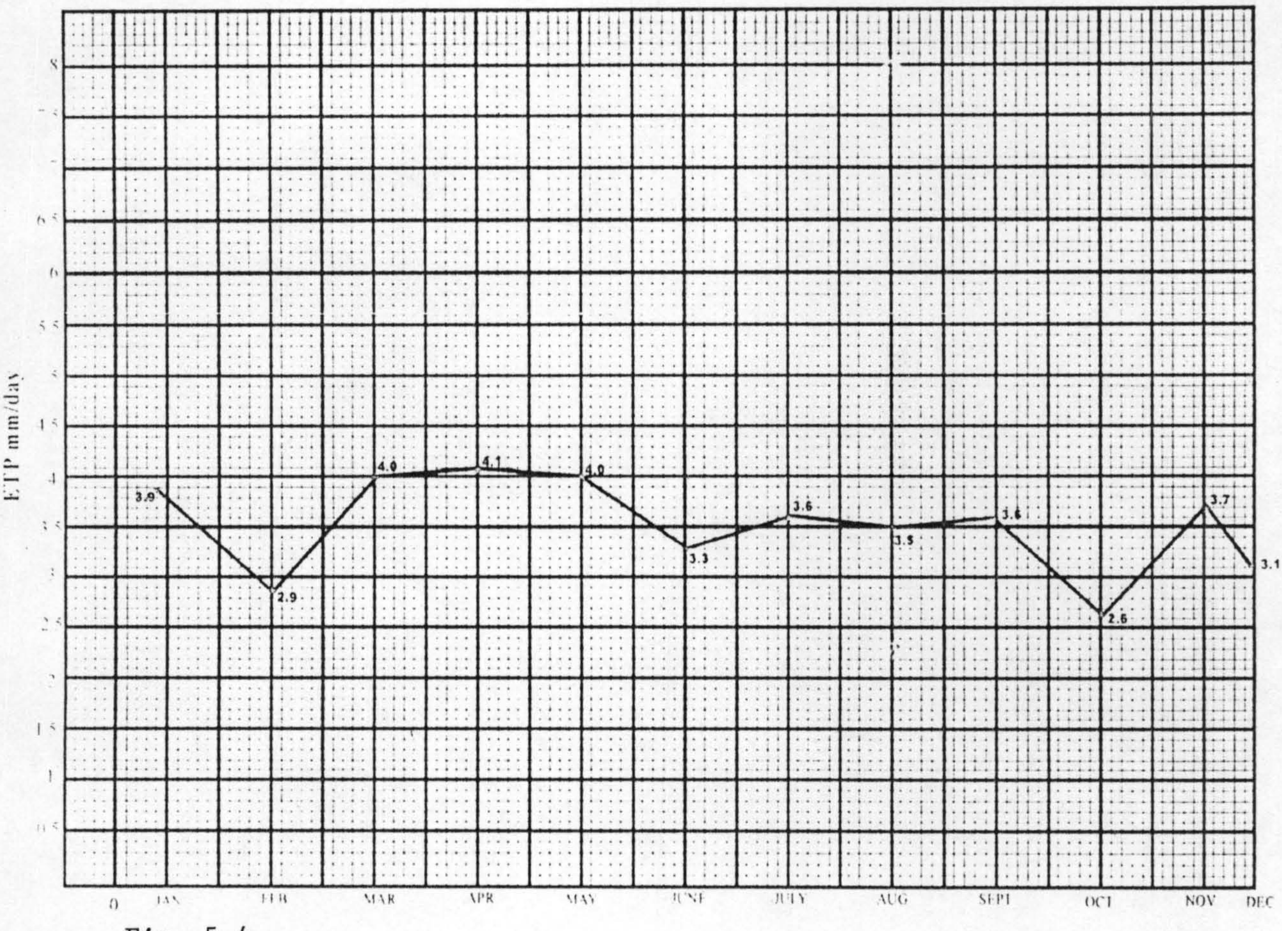

Fig 5.4

4.9 **Plotted graph for computed analysis of mean ETP-values predicted by the 3 models: BMN model, Blaney-criddle model and Haigreaves model for FCT-Abuja.**

COMPUTED ANALYSIS OF MEAN ETP-VALUES PREDICTED MODELS: MBN MODEL, BLANEY-CRIDDLE METHOD AND HAIGREAVES FOR FCT-ABUJA.

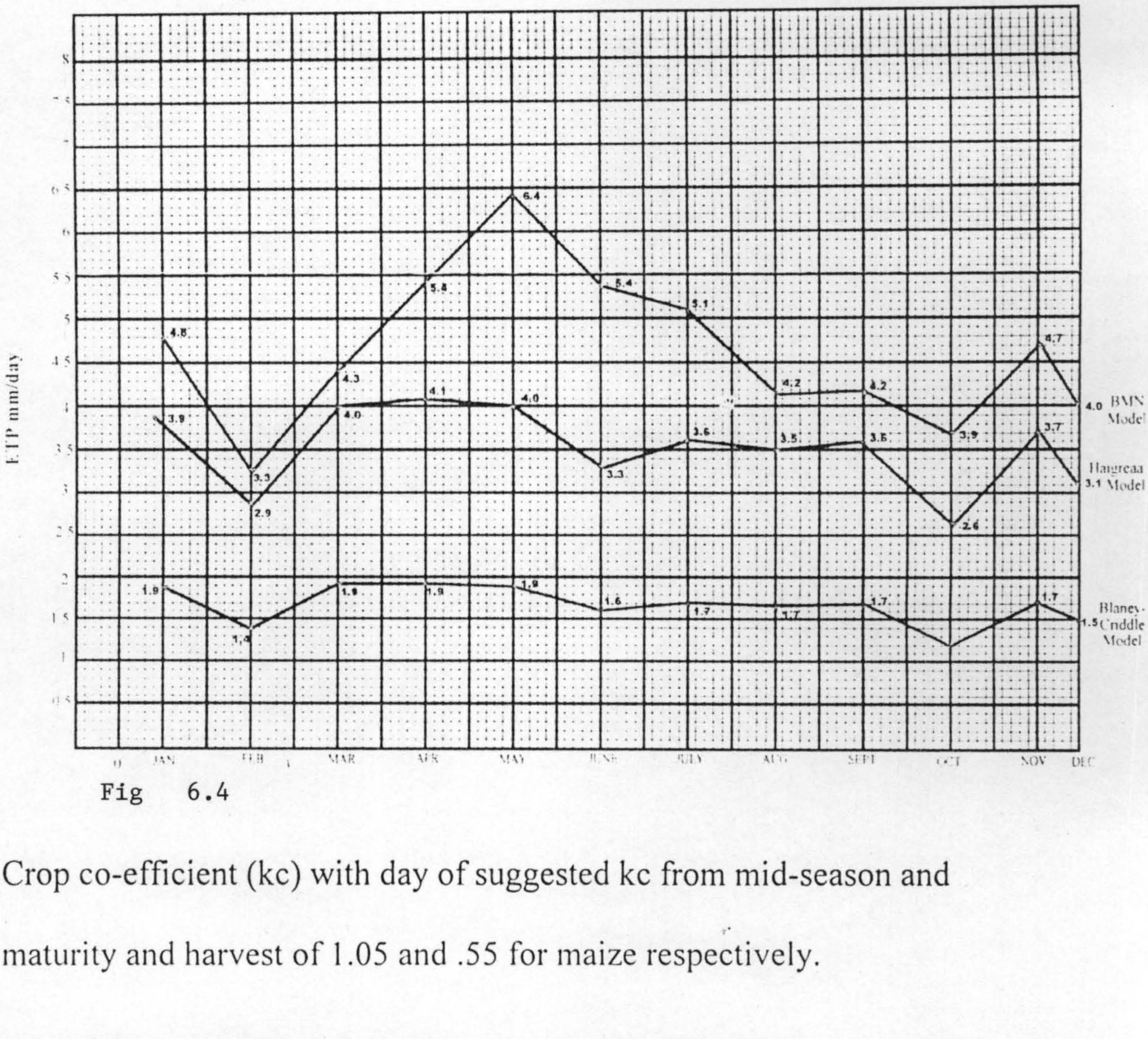

Fig 6.4

4.10 Crop co-efficient (kc) with day of suggested kc from mid-season and maturity and harvest of 1.05 and .55 for maize respectively.

4.11 DETERMINATION OF EVAPOTRANSPIRATION CROP (ETC)

The result for maize shows by the 3 models are:-

a. **BMN Model**

Etcrop = Kc. ETP
3 mid-season 1.05 x 55.96 = 58.758mm/day
4 maturity/harvest .55 x 55.96 = 30.778mm/day

b. **By Blaney-criddle model**

Etcrop = kc. ETO

3 mid-season 1.05 x 20.638 = 21.6699mm/day
4 maturity/harvest .55 x 20.638 = 11.3509mm/day

c. **By Haigreaves Model**

Etcrop = Kc.ETO
3 mid-season 1.05 x 42.956 = 45.1038mm/da
4 maturity/harvest .55 x 42.856 = 23.6258 mm/day

4.12 DISCUSSION

The results representative of three computations done in this study are presented and illustrated graphically.

Fig. 3.4 show the over prediction performance of the BMN model in comparison with Fig. 4.4 under prediction performance of Blaney-criddle model and Fig. 5.4 the prediction performance of Haigreaves model. If the models were perfect, the points in the graphs should fall along the line of perfect fit.

Reference crop evapotranspiration were also predicted using the three models. The result were consistent the Blaney-morin Nigeria (BMN) model over predict ETC of 89.536mm/day compared with Blaney-criddle model that under predicts ETC of 33.0208mm/day and Haigreaves model that predicts ETC of 68.7296mm/day.

From design and safety stand points, a model that over predicts should be preferred to one that under predict. Economic considerations, however set a practical limit to acceptable over prediction. Thus the better model is one that over predicts to a lesser degree. Duru (1984).

It is readily evident from Fig. 3.4 that the BMN model is the better predictor, under Nigerian conditions, than Blaney-criddle and Haigreaves model.

For agricultural operations, as an example irrigation is the only source of water during the dry period. It is essential, therefore to have an accurate prediction of evapotranspiration so as to determine irrigation requirements accurately. The BMN model gives a better seasonal fluctuation of ETP. The total ETP values predicted by the BMN model are in good agreement with measured values.

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 (ET) can be obtained from temperature, relative humidity and radiation. The effect of wind can be ignored without much less of accuracy with the BMN model. This can be seen from the fact that the BMN model proved to be better predictor than the Blaney-criddle and Haigreaves model which consider wind effects in a high wind region.

It was observed that in most areas of Nigeria radiation is the most important parameter in the model. However this depends on the magnitude of relative humidity. When relative humidity is low, about 40% less, radiation ratio is clearly the most important parameter with the temperature as the next most important parameter.

There are other observation on relative humidity in this model. One is that an over-estimation of this parameter causes under prediction of potential evapotranspiration. Another observation is that over-estimation of the parameter is more influential on prediction than the under estimation.

Since in irrigation and other water resources planning, under estimation (in terms of crops yield and safety of design) the need to measure relative humidity accurately as possible becomes more apparent. It would be advisable, then that no approximations should be made when reading or calculating relative humidity. If however, there is a reason to approximate figures should be rounded down instead of up for example, a reading of 64.5% should be approximated to 64% instead of 65%.

From the above discussions, it is observed that if the relative humidity is over-estimated the BMN model will over shoot than the Blaney-criddle and Hangreaves model respectively.

4.13 RESULTS OF STATISTICAL ANALYSIS OF THE 3 MODELS USED

The results are presented in Appendix 2 Table 11.5. The standard mean ETO was found to be 3.24mm/day, the deviation for each model were 0.857, 0.221 and 0.471 for Blaney-morrin Nigeria (BMN) model, Blaney-criddle model and Hangreaves model respectively. From the ANOVA Table Fet=4.41 and Fmr=2.77.

From the analysis of variance carried out, there was a significant variation at 5% significant level between the various models, further analysis with deviation suggested that the Blaney-morrin Nigerian (BMN) model is most appropriate for the computation of Etp in Federal Capital Territory, Abuja, Kassam et al (1977), Weiss, (1988).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Evapotranspiration were predicted using Blaney-morrin Nigeria model (BMN), Blaney-criddle model and Haigreaves model. These three models were compared in predicting evapotranspiration from climatic data collected from Abuja Airport meteorological station and FCT-ADP Agro-met Station in Federal Capital Territory.

The graphs has been drawn for comparison. Fig. 3.4 show the over-prediction performance of the BMN model in comparison with Fig. 4.4 that shows under-prediction performance of Blaney-criddle model and Fig. 5.4 shows the prediction performance of Haigreaves model.

The result shows that the Blaney-morrin Nigeria model (BMN) predicted the higher total mean annual ETP-value of 55.96mm for Federal Capital Territory While Blaney-criddle model predicted lower total mean annual ETP-value of 20.638mm and the Haigreaves model predicted total mean annual ETP-value of 42.956mm for Federal Capital Territory.

Comparison with (FAO, Irrigation and drainage paper 24) standard, reference crop evapotranspiration (ETC) were predicted using the three models. The results were consistent the Blaney-morin Nigeria (BMN) model over predicted ETC of 89.526mm/day compared with Blaney-criddle that under predicts ETC of 33.02098mm/day and Haigreaves model that predicts ETC of 68.7296mm/day.

From design and safety stand points, a model that over predicts should be preferred to one that under predicts. Economic considerations, however set a practical limit to acceptable over prediction. Thus the better model is one that over predicts to lesser degree. Duru (1984).

It is readily evident from Fig. 3.4 that the BMN model is the better predictor for Federal Capital Territory under Nigerian conditions, than Blaney-criddle and Haigreaves model.

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 so as to determine Irrigation requirements accurately. The BMN model gives a better seasonal fluctuation of ETP. The total ETP values predicted by the BMN model are in good agreement with measured values. The BMN model implies that under Nigerian conditions accurate prediction of (ETP) can be obtained from temperature, relative humidity and radiation.

It is observed that if relative humidity is over-estimated the BMN model will over shoot than the Blaney-criddle and Haigreaves model.

5.2 RECOMMENDATIONS

The Blaney-morin Nigeria (BMN) model prediction of potential evapotranspiration (ETP) for Federal Capital Territory are consistently higher than Blaney-criddle and Haigreaves models prediction. It is essential, therefore, to have an accurate prediction of evapotranspiration so as to determine the irrigation water requirement accurately in the Federal Capital Territory, Abuja.

The BMN model gives a better seasonal fluctuations of the predicted evapotranspiration (ETC). Also, the Federal Government should try as much as possible to set a comprehensive agro-meteorological stations in a different area of the Federal Capital Territory for better agricultural research for the progress of the Federal Capital Territory in terms of agricultural production and water management.

However, this agro-meteorological stations will enable the Federal Ministry of Water Resources to get the accurate data collection for their analysis of evapotranspiration prediction, in order not to depend on just ordinary meteorological station.

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APPENDIX 1

TABLE 5.3 **COMPUTED SUMMARY OF METEOROLOGICAL DATA IN USED IN COMPARATIVE ANALYSIS OF DIFFERENT METHODS OF CALCULATING POTENTIAL EVAPOTRANSPIRATION FCT-ABUJA FOR 10 YEARS 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001.**

Year Month	Temperature ^{o}c	Relative Humidity	Radiation Ratios	ETP: BMN Model Calculated	ETO: Blaney-Criddle Model Calculated	ETO: Haigreaves Method Calculated
1992						
JANUARY	26.5	67	3.7	3.104mm/day	1.150 mm/day	2.211 mm/a
FEBRUARY	27.5	76	4.5	3.219 "	1.424 "	2.750"
MARCH	28	86	4.5	2.528"	1.440"	2.781"
APRIL	30	73	3.6	2.937"	1.200"	2.322"
MAY	31	48	6.6	8.073"	2.270"	4.346"
JUNE	29	43	5.3	6.593"	1.749"	3.347"
JULY	26.5	51	5.5	5.884"	1.716"	3.287"
AUGUST	29	63	5.6	5.293"	1.835"	3.536"
SEPT.	27.5	58	5.7	5.661"	1.817"	3.484"
OCTOBER	25	78	4.7	3.076"	1.423"	2.714
NOV.	26	53	7.0	7.203"	2.156"	4.137"
DEC.	28	61	7.8	7.461"	2.505"	4.820"
TOTAL ETP				**61.023MM**	**20.75MM**	**39.735MM**
1993 JAN	29.5	80	10.6	5.597mm/day	2.717mm/day	0.638mm/day
FEB	30.5	70	10.6	7.082"	2.775"	6.908"
MARCH	32.5	87	10.6	4.921"	2.891"	7.195"
APRIL	30.5	65	9.2	6.699"	2.401"	5.996"
MAY	33.5	49	7.4	7.234"	2.060"	5.122"
JUNE	31.5	45	3.4	3.313"	0.899"	2.261"
JULY	27	59	2.2	1.630"	0.530"	1.329"
AUG.	29	61	9.9	7.433"	2.496"	6.252"
SEPT.	30.5	71	8.7	4.191"	2.269"	5.670"
OCT	26.5	62	2.3	6.674"	0.545"	1.374"
NOV.	30.5	58	3.4	4.967"	0.881"	2.216"
DEC.	29.5	64	5.6	3.620"	1.423"	3.574"
TOTAL ETP				**57.964mm**	**21.887mm**	**48.535mm**

APPENDIX 1

TABLE 6.3 **COMPUTED SUMMARY OF METEOROLOGICAL DATA IN USED IN COMPARATIVE ANALYSIS OF DIFFERENT METHODS OF CALCULATING POTENTIAL EVAPOTRANSPIRATION FCT-ABUJA FOR 10 YEARS 1994, 1995.**

Year Month	Temperature ^{O}c	Relative Humidity	Radiation Ratios	ETP: BMN Model Calculated	ETO: Blaney-Criddle Model Calculated	ETO: Haigreaves Method Calculated
1994						
JANUARY	31	79	8.5	4.976mm/day	2.359mm/day	5.597mm/day
FEBRUARY	30	88	5.1	2.303"	1.395"	3.289"
MARCH	33.5	92	3.4	1.417"	0.983"	2.353"
APRIL	33.5	73	6.7	4.728"	1.966"	4.638"
MAY	31.5	62	6.5	5.282"	1.821"	4.324"
JUNE	32.5	59	6.0	5.279"	1.721"	4.072"
JULY	29	70	7.4	5.065"	1.984"	4.673"
AUGUST	28.5	81	6.9	3.647"	1.815"	4.310"
SEPT.	28.5	75	6.9	4.191"	1.815"	4.310"
OCTOBER	28.5	59	8.2	6.674"	2.174"	5.123"
NOV.	28	71	7.6	4.967"	1.983"	4.697"
DEC.	27	79	6.7	3.620"	1.715"	4.050"
TOTAL ETP				**52.149mm**	**21.731mm**	**51.436mm**
1995 JAN	28.5	75	5.3	4.191mm/day	1.815mm/day	3.311mm/day
FEB	28	83	5.0	3.227"	1.691"	3.090"
MARCH	30	60	1.5	1.581"	0.523"	0.967
APRIL	33.5	74	5.3	4.742"	2.013"	3.669"
MAY	30	76	7.0	5.563"	2.463"	4.515"
JUNE	30	92	3.7	1.886"	1.308"	2.386"
JULY	29	91	7.2	3.733"	2.496"	4.547"
AUG.	27.5	88	7.4	4.093"	2.478"	4.523"
SEPT.	28	77	2.0	1.476"	0.668"	1.236"
OCT	28.5	36	5.1	7.012"	1.731"	3.186
NOV.	27	65	6.1	5.643"	2.021"	3.687"
DEC.	27.5	75	5.9	4.529"	1.961"	3.606
TOTAL ETP				**47.676mm**	**31.168mm**	**38.723mm**

APPENDIX 1

TABLE 7.3 **COMPUTED SUMMARY OF METEOROLOGICAL DATA IN USED IN COMPARATIVE ANALYSIS OF DIFFERENT METHODS OF CALCULATING POTENTIAL EVAPOTRANSPIRATION FCT-ABUJA FOR 10 YEARS 1996, 1997.**

Year Month	Temperature ^{O}c	Relative Humidity	Radiation Ratios	ETP: BMN Model Calculated	ETO: Blaney-Criddle Model Calculated	ETO: Haigreaves Method Calculated
1996						
JANUARY	26	79	7.7	3.075mm/day	1.457mm/day	4.550mm/day
FEBRUARY	26.5	88	9.9	3.135"	1.897"	5.918"
MARCH	27	92	10.2	2.858"	1.980"	6.166"
APRIL	27.5	73	9.8	4.622"	1.920"	5.990"
MAY	26.5	62	10.3	5.802"	1.978"	6.157"
JUNE	26.5	59	8.8	5.145"	1.675"	5.260"
JULY	29	700	9.4	4.847"	1.899"	5.936"
AUGUST	29	81	6.0	2.443"	1.216"	3.789"
SEPT.	26	64	7.6	4.080"	1.437"	4.491"
OCTOBER	27.5	59	6.4	3.867"	1.245"	3.912"
NOV.	26.5	71	9.7	4.653"	1.857"	5.798"
DEC.	27.5	79	9.0	3.704"	1.755"	5.501"
TOTAL ETP				**48.231mm**	**20.316mm**	**63.468mm**
1997 JAN	28.5	78	8.1	5.106mm/day	2.364mm/day	5.060mm/day
FEB	28.5	83	1.7	0.926"	0.485"	1.062"
MARCH	29.5	87	8.6	4.334"	2.545"	5.489"
APRIL	29.5	72	7.0	5.083"	2.070"	4.467"
MAY	28	57	2.0	1.781"	0.563"	1.236"
JUNE	29.5	53	8.0	7.922"	2.372"	5.106"
JULY	28.5	62	5.0	4.269"	1.456"	3.123
AUG.	27.5	73	8.5	5.815"	2.416"	5.195"
SEPT.	26	71	7.6	5.250"	2.095"	4.491"
OCT	26.5	62	4.2	3.433"	1.171"	2.510"
NOV.	25.5	76	6.7	4.103"	1.815"	3.914"
DEC.	25.5	71	4.9	3.312"	1.321"	2.862"
TOTAL ETP				**51.334mm**	**20.673mm**	**44.515mm**

APPENDIX 1

TABLE 8.3 **COMPUTED SUMMARY OF METEOROLOGICAL DATA IN USED IN COMPARATIVE ANALYSIS OF DIFFERENT METHODS OF CALCULATING POTENTIAL EVAPOTRANSPIRATION FCT-ABUJA FOR 10 YEARS 1998, 1999.**

Year Month	Temperature ^{o}c	Relative Humidity	Radiation Ratios	ETP: BMN Model Calculated	ETO: Blaney-Criddle Model Calculated	ETO: Haigreaves Method Calculated
1998						
JANUARY	26	93	5.1	2.387mm/day	1.716mm/day	3.014mm/day
FEBRUARY	26	88	2.5	1.385"	0.838"	1.477"
MARCH	29.5	85	7.5	4.946"	2.739"	4.787"
APRIL	30.5	71	5.8	5.404"	2.158"	3.780"
MAY	27.5	62	4.5	4.601"	1.569"	2.750"
JUNE	25.5	53	1.3	1.450"	0.434"	0.759"
JULY	25	76	7.8	5.819"	2.574"	4.504"
AUGUST	24	97	4.9	1.863	1.580"	2.763"
SEPT.	24.5	78	6.7	4.706"	2.177"	3.824"
OCTOBER	29	83	4.2	2.890"	1.515"	2.652"
NOV.	27.5	72	7.6	6.542"	2.663"	4.645"
DEC.	25	57	0.9	0.925"	0.292"	0.519"
TOTAL ETP				**42.918mm**	**20.255mm**	**35.474mm**
1999JAN	25	56	7.8	8.006mm/day	2.496mm/day	4.504mm/day
FEB	28	64	1.3	1.244"	0.438"	0.803
MARCH	30	63	4.5	4.652"	1.613"	2.902"
APRIL	28	41	2.4	3.136"	0.814"	1.483"
MAY	26.5	22	8.8	13.274"	2.907"	5.260"
JUNE	24	21	7.5	10.776"	2.341"	4.230"
JULY	24	29	9.0	12.176"	2.817"	5.076"
AUG.	24	46	4.0	4.512"	1.237"	2.256"
SEPT.	24	72	4.0	3.041"	1.237"	2.256"
OCT	25	59	3.9	3.833"	1.248"	2.252"
NOV.	26	73	4.1	3.220"	1.337"	2.423"
DEC.	24	54	3.5	3.579"	1.085"	1.974"
TOTAL ETP				**71.449mm**	**19.57mm**	**35.419mm**

APPENDIX 1

TABLE 93 **COMPUTED SUMMARY OF METEOROLOGICAL DATA IN USED IN COMPARATIVE ANALYSIS OF DIFFERENT METHODS OF CALCULATING POTENTIAL EVAPOTRANSPIRATION FCT-ABUJA FOR 10 YEARS 2000 and 2001**

Year Month	Temperature ^{O}c	Relative Humidity	Radiation Ratios	ETP: BMN Model Calculated	ETO: Blaney-Criddle Model Calculated	ETO: Haigreaves Method Calculated
2000						
JANUARY	25.5	44	7.5	8.681mm/day	2.328mm/day	4.382mm/day
FEBRUARY	26	44	5.6	6.549"	1.756"	3.309"
MARCH	30	52	6.5	7.522"	2.223"	4.192"
APRIL	29	78	6.8	4.931"	2.283"	4.294"
MAY	27	84	7.4	4.400	2.368"	4.473"
JUNE	25	87	8.0	4.187"	2.457"	4.620"
JULY	25	79	4.2	2.717"	1.287"	2.425"
AUGUST	24	80	4.5	2.747"	1.332"	2.538"
SEPT.	25	82	3.8	0.943"	1.150"	2.194"
OCTOBER	26	78	4.3	2.889"	1.337"	2.541"
NOV.	25.5	67	3.0	2.501"	0.927"	1.752"
DEC.	25	68	1.8	1.447"	0.546"	1.039"
TOTAL ETP				**49.514mm**	**19.994mm**	**37.759mm**
2001	25	56	1.3	1.751mm/day	0.546mm/day	0.750mm/day
FEB	25.6	64	2.0	2.522"	0.888"	1.195"
MARCH	29.5	63	5.1	7.029"	1.533"	3.255"
APRIL	28.5	41	6.9	12.356"	3.208"	4.310"
MAY	27	22	4.5	9.229"	2.021"	2.720"
JUNE	25.5	21	2.3	4.538"	0.986"	1.343"
JULY	25.5	29	2.5	4.687"	1.085"	1.400"
AUG.	25	46	2.0	3.127"	0.858"	1.55"
SEPT.	25.5	71	7.4	8.107"	3.235"	4.323"
OCT	28	62	1.2	1.591"	0.542"	0.741"
NOV.	27	53	3.5	5.252"	1.572"	2.115"
DEC.	28	76	6.4	8.451"	2.944"	3.955
TOTAL ETP				**68.64mm**	**19.417mm**	**27.322m**

APPENDIX 2

TABLE 10.4 **COMPUTED ANALYSIS OF MEAN ETP VALUES PREDICTED BY THE 3 MODELS FOR THE 10 YEARS PERIOD JANARY-DECEMER (1992-2001) FOR FCT-ABUJA**

Year Month	Temperature ^{0}c	Relative Humidity %	Radiation Ratios (HRS)	Mean ETP: BMN Method Predicted	Mean ETO: Blaney-criddle Model Predicted	Mean ETO: Haigreaves Method Predicted
JANUARY	27.15	70.7	6.56	4.8521mm/day	1.925mm/day	3.979mm/day
FEBRUARY	27.75	74.8	4.82	3.322”	1.432”	2.962”
MARCH	29.95	76.7	6.24	4.210”	1.938”	4.020”
APRIL	30.05	66.1	6.35	5.437”	1.985”	4.100”
MAY	28.85	54.4	6.5	6.482”	1.978”	4.091”
JUNE	27.9	53.3	5.43	5.406”	1.625”	3.348”
JULY	26.85	61.6	6.02	5.164”	1.750”	3.637”
AUGUST	26.75	71.6	5.97	4.273”	1.725”	3.588”
SEPT.	26.55	71.9	6.04	4.278”	1.738”	3.614”
OCTOBER	27.05	63.8	4.45	3.736”	1.30[illegible]”	2.693”
NOV.	26.95	65.9	5.87	4.710”	1.713”	3.782”
DEC.	26.7	68.4	5.25	4.00”	1.521”	3.152”
TOTAL MEAN ETP				**55.96mm**	**20.638mm**	**42.956mm**

TABLE 1.1 **MEAN MONTHLY MAXIMUM AND MINIMUM TEMPERATURE IN FCT FROM (1992-2001)**

YEARS	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV	DEC
1992	26.5	27.5	28	30	31	29	26.5	29	27.5	25	26	28
1993	29.5	30.5	32.5	30.5	33.5	31.5	27	29	30.5	26.5	30.5	29.5
1994	31	30	33.5	33.5	31.5	32.5	29	28.5	28.5	28.5	28	27
1995	28.5	28	30	33.5	30	30	29	27.5	28	28.5	27	27.5
1996	26	26.5	27	27.5	26.5	26.5	29	29	26	27.5	26.5	27.5
1997	28.5	28.5	29.5	29.5	28	20.5	28.5	27.5	26	26.5	25.5	25.5
1998	26	26	29.5	30.5	27.5	25.5	25	24	24.5	29	27.5	25
1999	25	28	30	28	26.5	24	24	24	24	25	26	24
2000	25.5	26	30	29	27	25	25	24	25	26	25.5	25
2001	25	26.5	29.5	28.5	27	25.5	25.5	25	25.5	28	27	28

NB: Temperature is measured in degree centigrade (^{o}C)
Source: Abuja Airport Dept. of Meteorological Services Federal Ministry of Aviation and FCT-ADP Agro-Met Station.

TABLE 2.1 **MONTHLY RAIN FALL IN F.C.T. FROM (1992-2001)**

YEARS	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	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	10003.3	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	206.0	0.0	0.0
1996	0.0	11.5	0.0	46.7	92.6	181.6	338.6	283.5	276.3	196.9	0.0	0.0
1997	0.0	0.0	26.1	44.6	138.9	146.8	256.1	261.6	233.7	211.5	26.0	0.0
1998	0.0	29.6	83.0	46.7	92.6	181.6	338.6	283.5	276.3	197.5	0.0	0.0
1999	0.0	35.0	32.5	80.9	138.9	146.8	256.1	261.7	234.0	213.8	TR	0.0
2000	0.0	0.0	75.0	494.5	869.6	1380.6	1780.7	2549.0	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	0.0	0.0

NB: Rainfall is measured in (mm)
Source: FCT-ADP Agro-meteorological Station.

TABLE 3.1 **MEAN MONTHLY RELATIVE HUMIDITY (%) IN FCT FROM (1992-2001)**

YEARS	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV	DEC
1992	67	76	86	73	48	43	51	63	58	76	53	6
1993	80	70	87	65	49	45	59	61	71	62	58	64
1994	79	88	92	73	62	59	70	81	75	59	71	79
1995	75	83	60	74	76	92	91	88	77	36	65	75
1996	79	88	92	73	62	59	70	81	64	59	71	79
1997	78	83	87	72	57	53	62	73	71	62	76	71
1998	93	88	85	71	62	53	76	97	78	83	72	7
1999	56	64	63	41	22	21	29	46	72	59	73	54
2000	44	44	52	78	84	87	79	80	82	78	67	68
2001	56	64	63	41	22	21	29	46	71	62	53	76

NB: The relative humidity is measured in percentage (%)

Source: FCT-ADP Agro-meteorological Station and Abuja Airport Dept. of Meteorological Services Federal Ministry of Aviation, Abuja.

TABLE 4.1 **MEAN MONTHLY RECORD OF SUNSHINE RADIATION (HRS.) IN FCT FROM (1992-2001)**

YEARS	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	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	10.6	9.2	7.4	3.4	2.2	9.9	8.7	2.3	3.4	5.6
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	4.1	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	7.6	4.2	6.7	4.9
1998	5.1	2.5	7.5	5.8	4.5	1.3	7.8	4.9	6.7	4.2	7.6	0.9
1999	7.8	1.3	4.5	2.4	8.8	7.5	9.0	4.0	4.0	3.9	4.1	3.5
2000	7.5	5.6	6.5	6.8	7.4	8.00	4.2	4.5	3.8	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

NB: -The duration of sunshine is measured in hour (hrs.)
Source: Abuja Airport Dept. of Meteorological Services Federal Ministry of Aviation and FCT-ADP Agro-Met Station.

Table 11.5 **RESULTS OF STATISTICAL ANALYSIS OF THE 3 MODELS USED**

MONTH	BMN MODEL	BLANEY-CRIDDLE MODEL	HANGREAVES MODEL	MEANS
January	4.8	1.9	3.9	3.5
February	3.3	1.4	2.9	2.5
March	4.3	1.9	4.0	3.4
April	5.4	1.9	4.1	3.8
May	6.4	1.9	4.0	4.1
June	5.4	1.6	3.3	3.4
July	5.1	1.7	3.6	3.4
August	4.2	1.7	3.5	3.1
September	4.2	1.7	3.6	3.1
October	3.7	1.3	2.6	2.5
November	4.7	1.7	3.7	3.3
December	4.0	1.6	3.1	2.8
Means	**4.6**	**1.6**	**3.5**	**3.24**
Deviations	**0.857**	**0.221**	**0.471**	

H_o - There is no significant variation in choosing an Eto model.
H_1 - There is no significant variation in Eto obtained from one month and another.

TWO-WAY ANOVA TABLE

VARIATION	SS	df	Ms	Fcai
Method of Eto	19.8	11	217.8	Fet=4.41
Monthly Values	34.1	3	102.3	
Error	1.3	33	49.2	Fmr=2.77

Fet Cal > F3, 11, 19.8 - (1)
Fmr. Cal > F3, 11, 34.4 - (2)

1.1 Mean monthly rainfall

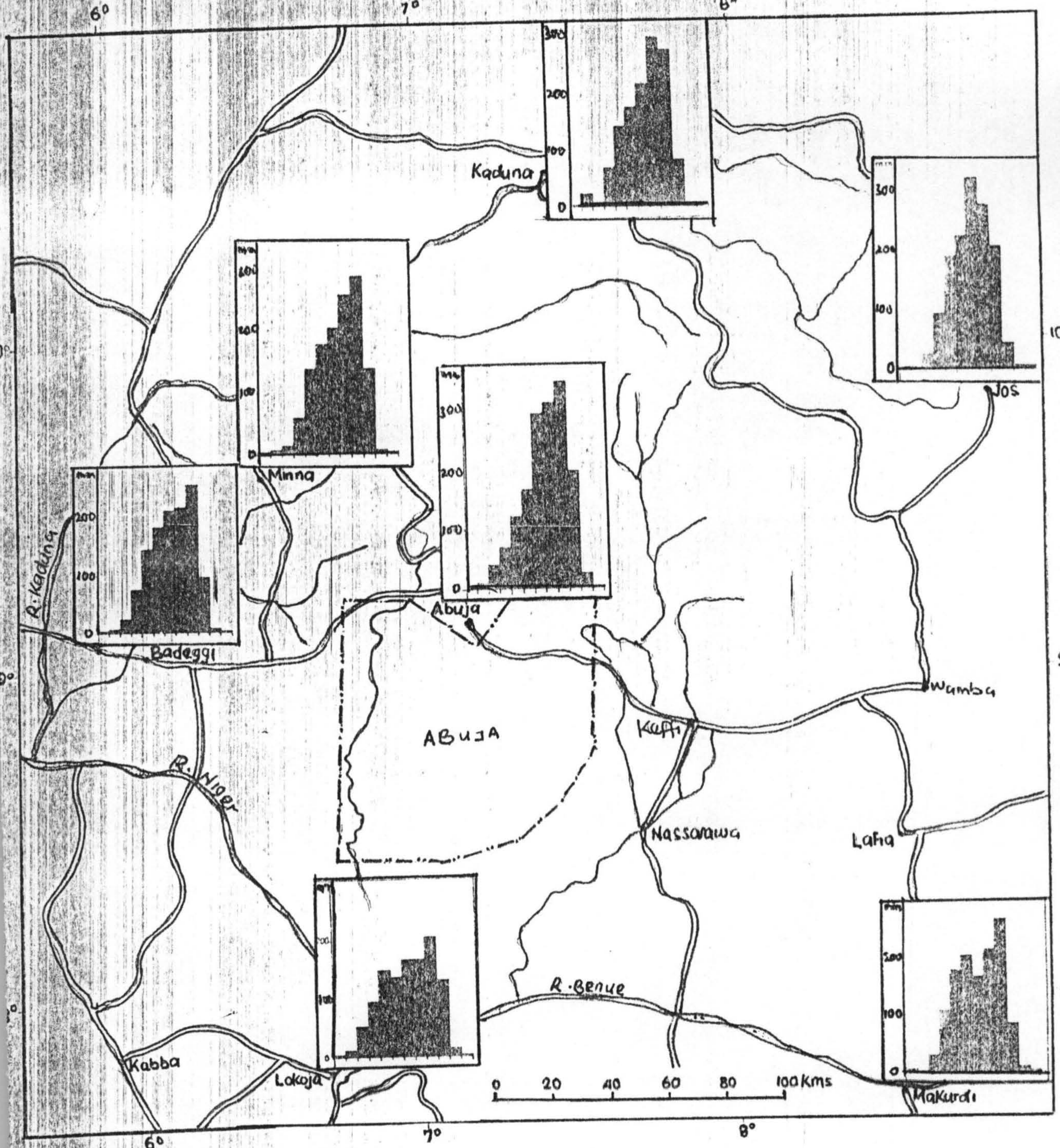

Fig 1.1 Mean monthly rainfall

2.1 Mean monthly Duration of sun shine

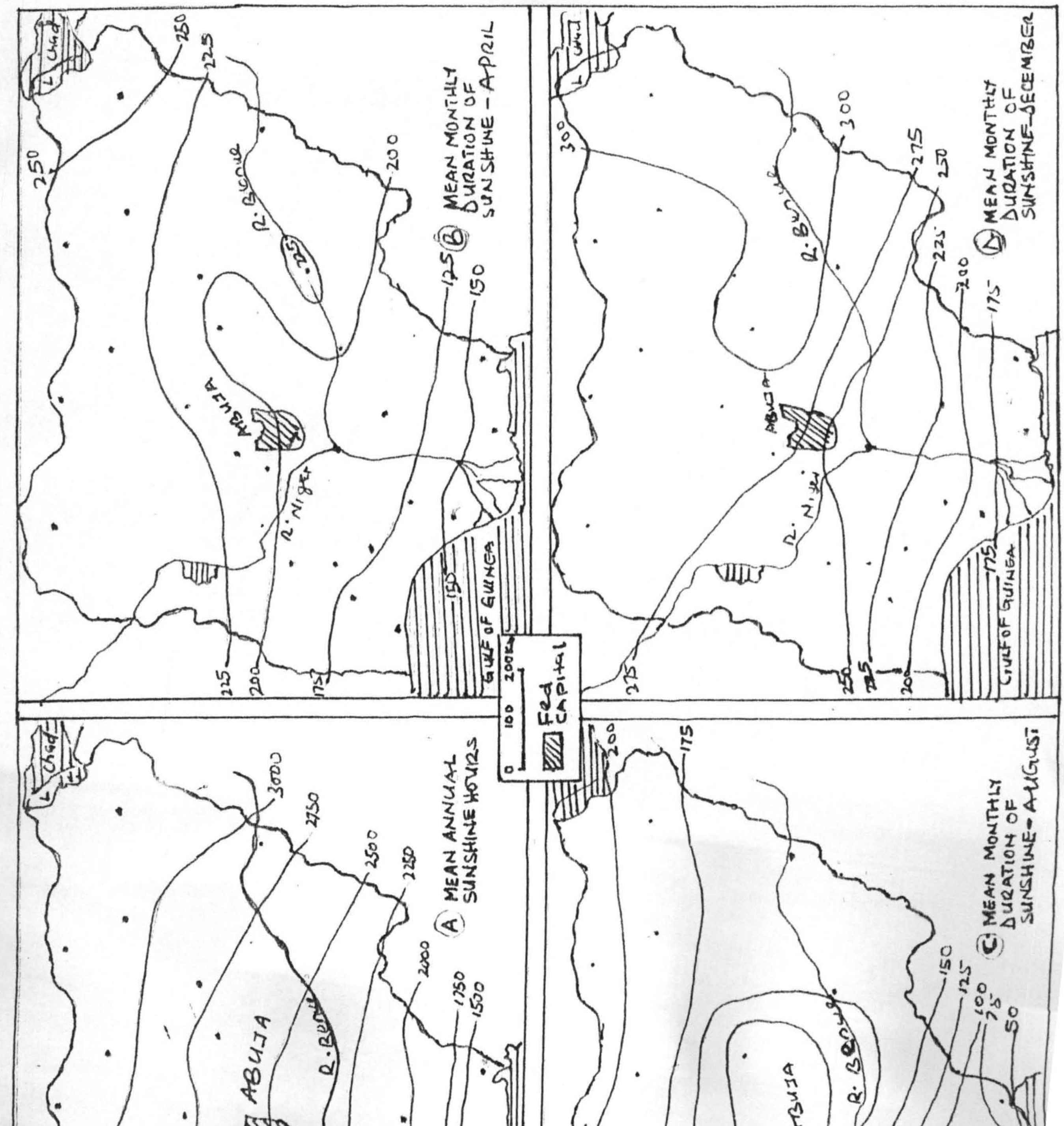

Fig 2.1 Mean monthly Duration of sun shine