

THE APPLICATION AND ANALYSIS
OF THREE EVAPOTRANSPIRATION MODELS
IN EASTERN NORTH CAROLINA

by

Stephen Powell Moore

APPROVED BY:

SUPERVISOR OF THESIS

Donald H. Steile

CHAIRMAN OF THE DEPARTMENT OF GEOGRAPHY

F. L. C. G.

DEAN OF THE GRADUATE SCHOOL

Joseph H. Boyette

QC
915.5
M6

THE APPLICATION AND ANALYSIS
OF THREE EVAPOTRANSPIRATION MODELS
IN EASTERN NORTH CAROLINA

A Thesis
Presented to the
Faculty of the Department of Geography
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts in Geography

by
Stephen Powell Moore
July, 1977

Moore, Stephen Powell. THE APPLICATION AND ANALYSIS OF
THREE EVAPOTRANSPIRATION MODELS IN EASTERN NORTH CAROLINA.
(Advisor: Dr. Donald Steila) Geography.

OCT 17 1977

The Thornthwaite, Blaney-Criddle, and Holdridge methods of calculating evapotranspiration have been applied in a broad range of climatic regimes. Each model has proved in certain areas to yield more accurate results than the other two depending on the soils and climate. This research examines the applicability of the three methodologies for prediction of actual evapotranspiration in eastern North Carolina.

Soil moisture retention was calculated with the use of Bouyocos gypsum blocks on ten soil series under a uniform stand of field corn (*Zea mays* L.). Field observations were conducted twice weekly, while rainfall, temperature, humidity, and crop growth stages were continuously monitored. From the soil moisture retention values, AE was calculated which was then compared to each of the computed values of the three methodologies being examined. Correlation coefficients indicated substantial agreement between the predictive ability of the three methodologies but revealed a weak relationship between the actual data and the three methodologies.

The predicted values had a tendency to lag behind the actual moisture release values as evidenced by the moisture stress on the crop. On the average the methodo-

logies deviated from the actual values by 20% but this does not emphasize these periods when actual soil moisture would be as little as 5 mm in the rooting zone and the predicted values would indicate moisture in the rooting zone to be as high as 55 mm (a range of error of 110%). This large departure could severely endanger crops if irrigation periods were based upon these theoretical predictions.

The theoretical data was subsequently divided into four 25% categories from the highest to the lowest moisture holding values and a correction factor was derived for each category. This corrected data was then compared with the actual data and yielded significantly stronger correlations than the previous comparison. This corrective alteration of the theoretical methodologies could prove invaluable in the determination of irrigation practices and serve as a guideline for further experimentation on predictive moisture-exchange models in other climatic regimes.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS.....	iv
LIST OF TABLES.....	v
ACKNOWLEDGEMENTS.....	vii
INTRODUCTION.....	1
Chapter	
I. MOISTURE EXCHANGE.....	3
Evapotranspiration.....	3
Potential Evapotranspiration.....	4
Methodologies Examined.....	4
Thornthwaite.....	5
Blaney-Criddle.....	7
Holdridge.....	9
II. MONITORING SOIL MOISTURE.....	12
Methods For Measurement.....	12
Field Capacity And Wilting Point.....	15
III. THE TEST SITE.....	17
Location.....	17
Soil Series.....	17
Instruments Used.....	20
Recording Procedure.....	20
Crop Conditions.....	21
IV. STATISTICAL ANALYSIS.....	24
Theoretical And Observed Data.....	24
Computed Statistics.....	25

Theoretical Comparisons.....	30
Correction Factors.....	35
Areal Implications.....	41
Summary And Conclusion.....	46
APPENDIX.....	48
REFERENCES.....	

ILLUSTRATIONS

Figure

- 1-1. A comparison of lysimeter derived ET to the
Thornthwaite and Balney-Criddle computed
curves.....10
- 2-1. Resistance block connected to wires which lead
to the surface for monitoring (photo).....13
- 2-2. Bouyucos resistance meter wired to subsurface
gypsum blocks (photo).....13
- 3-1. Test site location (map).....18
- 3-2. Test site (map).....18
- 3-3. U.S. standard weather screen (photo).....22
- 3-4. Standard rain guage (photo).....22
- 4-1. Method for obtaining correction factors.....38

LIST OF TABLES

3-1.	Test Soils And Moisture Capacity.....	19
4-1.	Correlation Coefficients For The Comparison Of The Theoretical And Observed Data.....	27
4-2.	Slope Of The Theoretical To Observed Data Scattergram.....	28
4-3.	Correlation Levels Of Significance For The Theoretical To Observed Comparisons.....	29
4-4.	Skewness Of The Theoretical And Observed Data Sets.....	31
4-5.	Standard Error For Each Set Of Theoretical And Observed Data.....	32
4-6.	Standard Deviation For Each Set Of Theoretical And Observed Data.....	33
4-7.	Coefficients Of Determination For The Theoretical To Observed Data Comparison.....	34
4-8.	Correlation Coefficients Comparing Theoretical Data Sets.....	36
4-9.	Average Correction Factors Calculated From The Summation Of The Means Of Each Retention Category And Divided By The Number Of Soils In That Category.....	39
4-10.	Correlation Coefficients Employing The Correction Factors For Theoretical Vs. Observed Comparisons On Three Sample Soils....	40

4-11.	A Comparison Between Correlations Run Including And Excluding The Monitoring Days Exhibiting Capacity On Two Sample Soils.....	42
4-12.	Correlation Coefficients Employing The Correction Factors For Theoretical Vs. Theoretical Comparisons On Three Sample Soils.....	43

Acknowledgements

I would like to thank all the people who have contributed their time and expertise aiding in the completion of this thesis. To Dr. Ronald Swager and Jim McCluskey I would like to extend my appreciation for their help in the statistical analysis of this research.

My very personal and heartfelt thanks go to my advisor and close friend, Dr. Donald Steila, without whose guidance and friendship this project would never have been completed.

I am especially indebted to my parents for their continued interest and encouragement for the completion of this research.

INTRODUCTION

The recognition of the need for an adequate water supply is constantly observed by man. One aspect of moisture about which man is very aware is that of water availability for plant growth. All too frequently the supply of moisture is the factor most recognized with little attention being focused on the loss of moisture to the atmosphere from the earth's surface. In regions with high seasonal or annual temperature regimes the atmospheric demand for moisture is intense. Research performed at the North Appalachian Experimental Watershed near Coshocton, Ohio, revealed a water loss from an open lake surface to be as much as .177 inches per day at a mean daily temperature of 71.8 degrees Fahrenheit (McGuinness, 1972). Although moisture release from a soil body is not of the magnitude of the above example, the atmospheric moisture demand remains large.

Recently geographers have turned their attention to the earth's hydrologic system and its related problems. At one time this field of study was largely limited to meteorologists, agriculturalists, and hydrologists. Geographers are now seeing the hydrologic system as having extreme geographic ramifications in terms of the biologic activities occurring in specific areas.

As increased numbers of areas are sampled for soil moisture flux, the understanding on the exchange of

moisture between the surface-air interface increases. Differing climatic areas and soil bodies account for large variations in behavioral character of moisture exchange.

If potential evapotranspiration can be accepted as a function of climate only, which most researchers believe is the case, the question then arises whether by analyzing climatic parameters, the PE may be estimated. In the professional literature at least a dozen methods have been proposed that this can be done. This thesis examines the methodologies of Thornthwaite (1948), Blaney-Criddle (1950), and Holdridge (1959), comparing the predicted moisture exchange obtained using each method with actual observed values.

These three techniques for estimating evapotranspiration have been tested in many parts of the world. In some experiments very positive results have been recorded. In other tests the results have proven grossly inaccurate. This study is designed to enhance the geographical knowledge of surface moisture exchange and to examine the possibility of deriving a correction factor for soil texture differences which can be incorporated in the above methodologies.

The selection of eastern North Carolina as the study area broadens the scope of the field as this area has not previously been monitored comparing theoretical moisture release methodologies with observed field data.

CHAPTER I

MOISTURE EXCHANGE

Evapotranspiration

Evapotranspiration is the set of processes occurring when moisture is returned from the earth's surface to the atmosphere. It consists of both evaporation from open surfaces (vegetation free) and from intercellular stomata of plants (transpiration).

The transpiration rate through stomatal openings is determined by both available energy and available water. During water deficit conditions the stomata partially close reducing the transpiration rate (Chang, 1968). Brouwer (1965) found that for a given stomatal aperture, the transpiration rate is proportional to the incident radiation. Given a mature vegetative cover, transpiration accounts for a greater percentage of evapotranspiration than evaporation.

Evapotranspiration flux is dependent upon the atmosphere's energy availability which is primarily affected by turbulence, humidity, radiation, and temperature.* Air temperature, according to many researchers, is a

*Mukammal and Bruce (1960) assessed the relative significance of the radiation, humidity, and wind factors as 80:6:14 in determining pan evaporation.

function of radiation. Optimum conditions for maximum evapotranspiration occur with high turbulence, low humidity, and high radiation and temperature. Since temperature determines the amount of moisture the air can hold, it is probably the single most important factor in evapotranspiration.

Potential Evapotranspiration

Actual evapotranspiration (AE) may differ from the total amount of moisture the atmosphere is capable of absorbing from the surface. Given specific meteorological conditions and time--the atmosphere has a capability of evapotranspiring a certain quantity of moisture. This capability is referred to as potential evapotranspiration (PE). If the surface moisture is below field capacity, the subsurface moisture supply will be released at a rate insufficient to fulfill PE demand, thus causing AE and PE to differ. As soil moisture decreases from field capacity towards the wilting point, the intensity of the moisture deficiency (PE minus AE) increases, with the soil retaining its remaining water with greater capillary attachment.

Methodologies Examined

The methodologies for estimating PE fall into four categories, each group utilizing different variables:

1) air temperature, 2) air temperature and solar

radiation, 3) all available climatic parameters, 4) energy balance and aerodynamics. This thesis deals with PE formulae that depend upon air temperature alone. The methodologies examined are those of Thornthwaite, Blaney-Criddle, and Holdridge. The Thornthwaite and Blaney-Criddle formulae have been examined under a wide range of climatic regimes whereas the Holdridge technique has had limited application in the tropical regimes.

The Holdridge PE formula is also the most recently developed of the three as it was introduced in its refined form in 1959.

Thornthwaite

C. W. Thornthwaite's (1948) methodology for evaluating PE was based on lysimeter and watershed observations in the central and eastern United States.* The 1948 formula was initially derived for use in estimating monthly PE, and is:

$$PE = 1.6(10 TC/I)^a;$$

where;

PE-monthly Potential Evapotranspiration in mm

TC-monthly mean temperature in degrees C.

I-heat index (sum of 12 monthly index values)

a-empirically derived exponent (function of I)

This method was subsequently modified to compute daily PE values with the use of a photoperiod correction factor.*

*Earlier research in the 1930's revealed a different form of the equation.

*Black (1967) devised a program to compute daily values on a long term basis.

It is the daily PE evaluations which are the focus of this thesis.

The Thornthwaite formula functions best in the temperate, continental climate of North America where it was derived. In this area temperature and radiation exhibit a strong correlation, a framework upon which the methodology is founded. Positive results from the application of this method have been obtained by Burman and Partridge (1962) in Wyoming, Decker (1962) in Missouri, Mather (1954) in New Jersey, Baker (1958) in Minnesota, and Sanderson (1950) in Canada. Fitzgerald and Rickard (1960) also reported accurate PE estimates in New Zealand.

Thornthwaite's method has exhibited short-comings in other parts of the world. The main reason is that temperature is not a good indicator of the total amount of energy available for evapotranspiration. At De Bilt in the Netherlands for example, air temperature is about the same during November (5.4 degrees C.) and March (5.0 degrees C.); whereas solar radiation varies greatly, 67 and 195 langleys/day respectively. Van Wijk and de Vries (1954) found PE in March to be nearly four times greater than in November. Yet, the Thornthwaite method did not differentiate between the two months. Air temperature is slow in its response to radiation and the method exhibits a noticeable lag in the predicted PE values. Another weakness of the Thornthwaite technique is that when air temperature falls below 0 degrees C.

evapotranspiration is considered to cease. Although evapotranspiration may be small at temperatures below 0 degrees C. it is not nonexistent (Crow, 1954).

The advantage of the Thornthwaite method is that it only requires temperature data to determine PE and it can be used to present the broad climatic patterns of the world. Its simplicity has fostered its worldwide popularity.

Blaney-Criddle

H. F. Blaney and K. V. Morin (1942) derived a PE methodology in the semi-arid and arid areas of Texas and New Mexico. The original formula was stated as:

$$U = KTP(114 - h)$$

where;

U-monthly consumptive water use in inches
 K-crop coefficient
 T-mean monthly temperature in degrees F.
 P-monthly percentage of daytime hours of the year
 h-mean monthly relative humidity

Blaney and Criddle (1950) subsequently eliminated the humidity term; thus leaving the equation:

$$U = KTP$$

The methodology was eventually revised to permit the calculation of PE on a daily basis in the form of:

$$PE = (0.0173 TA - 0.314) * KC * TA (DL / 4465.6)$$

where;

TA-mean daily air temperature in degrees F.
 KC-crop growth stage coefficient
 DL-day length in hours
 4465.6-sum of day lengths for 37 degrees north latitude for the year

(When TA is less than 35 degrees F., the first term in parenthesis is given a constant value of 0.3.)

The Blaney-Criddle formula has been the most widely applied method for estimating PE in the western United States. Its simplicity, much the same as the Thornthwaite technique, permits an easy assessment of moisture demand. Tomlinson (1953) reported that the correlation of the predicted values checked very closely with the water needs of hay in Wyoming. In other parts of the world the equation has been less successful. Jackson (1960) found the methodology responded poorly for crops in central Australia and Dagg (1965) reported similar results from experiments in eastern Africa.

The strong point of the Blaney-Criddle formula is the inclusion of a crop factor. The authors realized that consumptive water use* by crops in arid climates may vary greatly with the physiognomy of the physical stand. As the height of the vegetation increases, their coefficients increase proportionally.

The Blaney-Criddle and Thornthwaite methods have been compared in various parts of the world. In lysimeter experiments in Coshocton, Ohio (W.M.O., 1968) the Blaney-Criddle formula proved more reliable than the Thornthwaite technique even though neither proved

*Consumptive water use-the amount of water consumed by plants determined by precipitation, temperature, solar radiation, humidity, wind, growing season, crop type, growth stage, and plant species.

very precise (Figure 1-1). Stanhill (1961) compared several methodologies, including the aforementioned, in the arid climate of Israel. In this test both the Thornthwaite and Blaney-Criddle techniques gave close approximations to recorded values. In an experiment in arid and sub-humid regions Cruff and Thompson (1967) examined five techniques in which the Blaney-Criddle formula displayed the best fit although none of the predicted values exhibited close correlation with the observed values. Correlation coefficients were derived by Stephens and Stewart (1963) comparing actual pan evaporation with theoretical values in Florida for a 16 year period. In this test the Blaney-Criddle method had a high correlation with the Thornthwaite formula although neither provided good results.

Holdridge

The Holdridge (1959) methodology is perhaps the simplest of all equations in its estimation of PE. This technique was devised in the tropics and very few tests have been applied to the middle-latitudes. The equation for estimating daily PE takes the form:

$$PE = ((T/N) * C) / N$$

where;

T-mean daily temperature of month between 0 degrees and 30 degrees C.

$\bar{T}$ -sum of all mean temperatures

N-number of days in the month

C-constant (5.00 for months with 31 days, 4.84 for 30, and 4.56 for February)

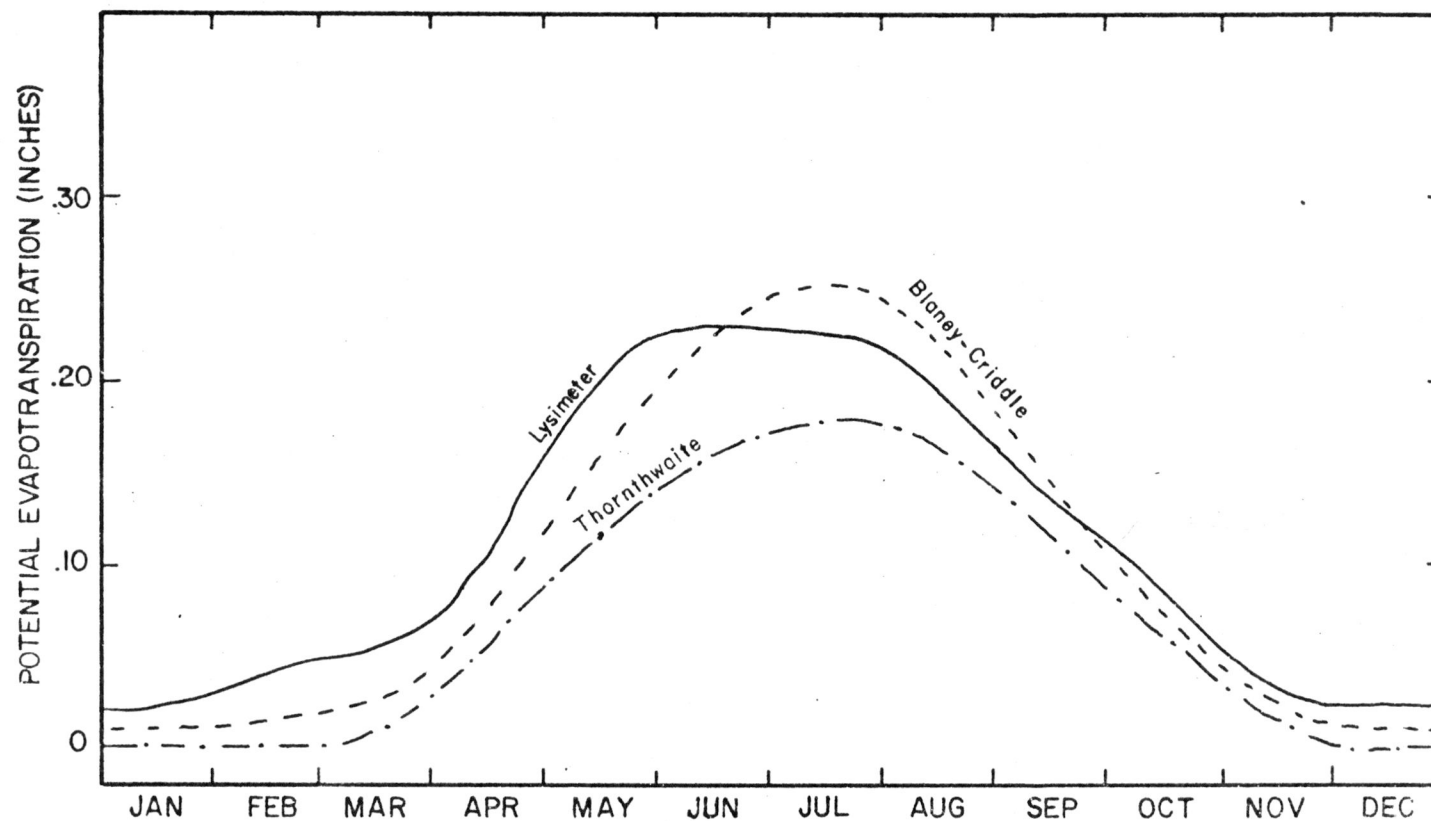


Figure 1-1. A comparison of lysimeter derived ET to the Thornthwaite and Blaney-Criddle computed curves.

Source: W.M.O., Agricultural Meteorology.

The Holdridge formula gives equal PE values for every day of the month, making it inadequate for irrigation planning. In addition, it does not take into account days of high incidence of cloudiness reducing radiation when PE would be greatly reduced. For these reasons the methodology has been limited in its application. However, the time periods being examined in this thesis are during the summer with generally high radiation and relative humidity rates which can be compared with tropical conditions where the methodology proved most feasible.

CHAPTER 2

MONITORING SOIL MOISTURE

Methods For Measurement

Many methods have been devised for monitoring soil moisture. These techniques range from the difficult and costly to the simple and inexpensive. Some of the devices used for field measurement are applicable only in situ whereas others are mobile and used in testing soil in different locations. Equipment commonly used includes; lysimeters, electrical resistance blocks, tensiometers, gravimetric assessors, and the neutron scattering probe. Each device possesses certain advantages or disadvantages depending upon its application.

The technique for monitoring field moisture utilized in this study is electrical resistance analysis, and it is applied to soil bodies in situ (Figure 2-1). The electrical resistance unit (Bouyucos Gypsum Block) is implanted in the soil where it attains a moisture content that is in equilibrium with the surrounding soil. Response of the unit to moisture change is closely correlated to that of the adjacent solum. With changes in moisture content, the electrical resistance of the block also changes--a response that is registered as a percentage by an above-the-surface meter



Figure 2-1. Resistance block connected to wires which lead to the surface for monitoring.



Figure 2-2. Bouyococos resistance meter wired to subsurface gypsum blocks.

that is wired to the unit (Figure 2-2). The resistance of the units must be measured with an a.c. bridge, usually 1000 cycles/second (W.M.O., 1948), to avoid electrolysis and polarization which occur with direct measurement. Various materials are used in the construction of resistance blocks. The general design consists of two carefully spaced electrodes impacted into a substance sensitive to changes in water content. Gypsum, nylon, and fiberglass are among the most widely used of the water absorbent materials covering the electrodes.

Gypsum units have been found especially functional over the drier ranges of soil moisture. On waterlogged or heavily irrigated soils, however, they tend to disintegrate rapidly. Their useful life depends on how rapidly the gypsum decomposes, a factor that varies according to soil pH. The electrical resistance of the units is slightly affected by the soluble salt content of the soil when its percentage is less than the gypsum itself (Weaver and Jamieson, 1951). Gypsum blocks exhibit an approximate time lag of one day. The size of the block is 6x4x1 cm, with electrodes 5 cm long and 2 cm apart (Carrell, 1958).

For each type of resistance unit separate calibration is necessary. Each soil type also requires individual calibration which may be done in the field or laboratory, usually relying upon a drying curve (Cope and Trickett, 1965).

The use of thermocouples built into the resistance unit corrects errors associated with temperature and eliminates hysteresis. The electrical resistance method is advantageous in that it is inexpensive and readings can be taken rapidly. The technique is suited to the semi-skilled worker as long as calibration of individual soils remains intact.

The resistance units used in this experiment were gypsum covered and some deterioration of the material occurred during the saturated periods of the growing season. The blocks did not deteriorate to the point that accurate measurement would have been affected.

When monitoring soil moisture in a cultivated field it is advantageous to utilize a technique which permits readings to be taken rapidly. The placement of resistance blocks in the soil does not interfere with normal agricultural practices making this technique applicable for monitoring the average farm. The units can also be placed at different depths in the rhizosphere, allowing comparisons to be made regarding moisture demand of the crop at various depths.

Field Capacity And Wilting Point

When monitoring soil moisture, the field capacity of the soil must be known to give meaning to moisture withdrawal rates. The water in the soil that is available to plants exists between the field capacity and wilting point. The availability of this moisture varies greatly

with different soil types, slope, and vegetative cover. Veihmeyer and Hendrickson (1931) defined field capacity as "the amount of water held in the soil after the rate of downward movement of water has materially decreased." Field capacity is a statement of the upper limit of available moisture (Peters, 1965). This amount is often difficult to ascertain due to soil conditions, such as impeded drainage, which may alter the upper limit.

The wilting point is the lower limit of moisture availability for plants. This concept was introduced by Briggs and Shantz (1911) although the idea dates back long before this. The permanent wilting point is defined as "the water percentage of a soil when plants growing in that soil are first reduced in an approximately saturated atmosphere (Peters, 1965)." The period between the beginning stage of wilt (Incipient stage) and the permanent wilting point constitutes the wilting range. Incipient wilt occurs when the water content of the soil diminishes to a level at which the lowest leaves of a plant wilt and fail to recover in a saturated surrounding. The wilting stage was monitored during the entire period covered by the project, as it plays a key role in the crop development.

CHAPTER 3

THE TEST SITE

Location

The site of this research project is a farm located on the north side of highway N. C. 43 on the north-west side of Greenville, N. C. (Figure 3-1 and 3-2). A gentle slope exists from the highway to a relict river bed which in the past contained the Tar River which flowed through the lower portion of the fields.

Soil Series

Ten soil series were monitored on the test farm. The textures of the series ranged from a loam to a fine sandy loam. The texture characteristics of each soil were determined to arrive at the field capacity for the rooting zone on the corn crop (Table 3-1). Six of the ten soils were situated on gentle slopes of 6 to 10 percent. The remaining four soils were on surfaces with slopes not exceeding 4 percent.

The corn crop characteristics were unique for each site. On soils prone to give up moisture rapidly, the crop had a tendency to increase in stature rapidly and attain a greater height at maturity. Soils with coarse surface layers tended to impede the germination stage by

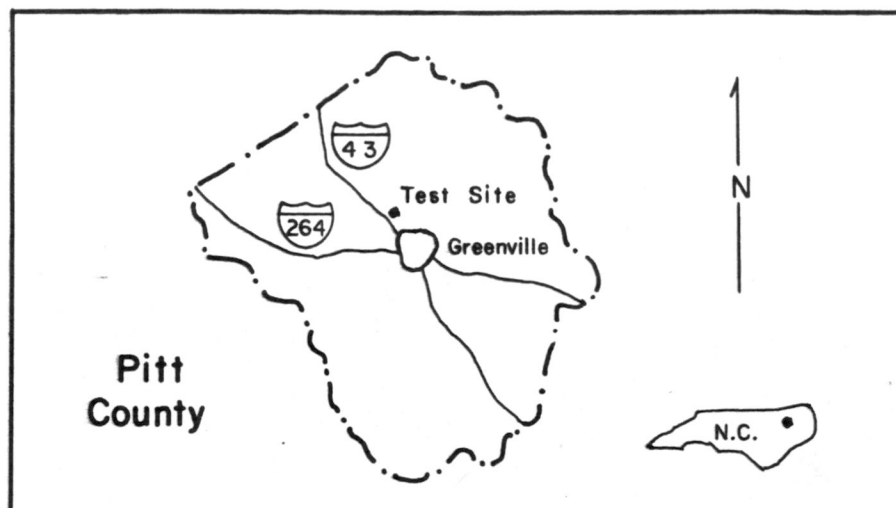


Figure 3-1. Location Of Test Site.

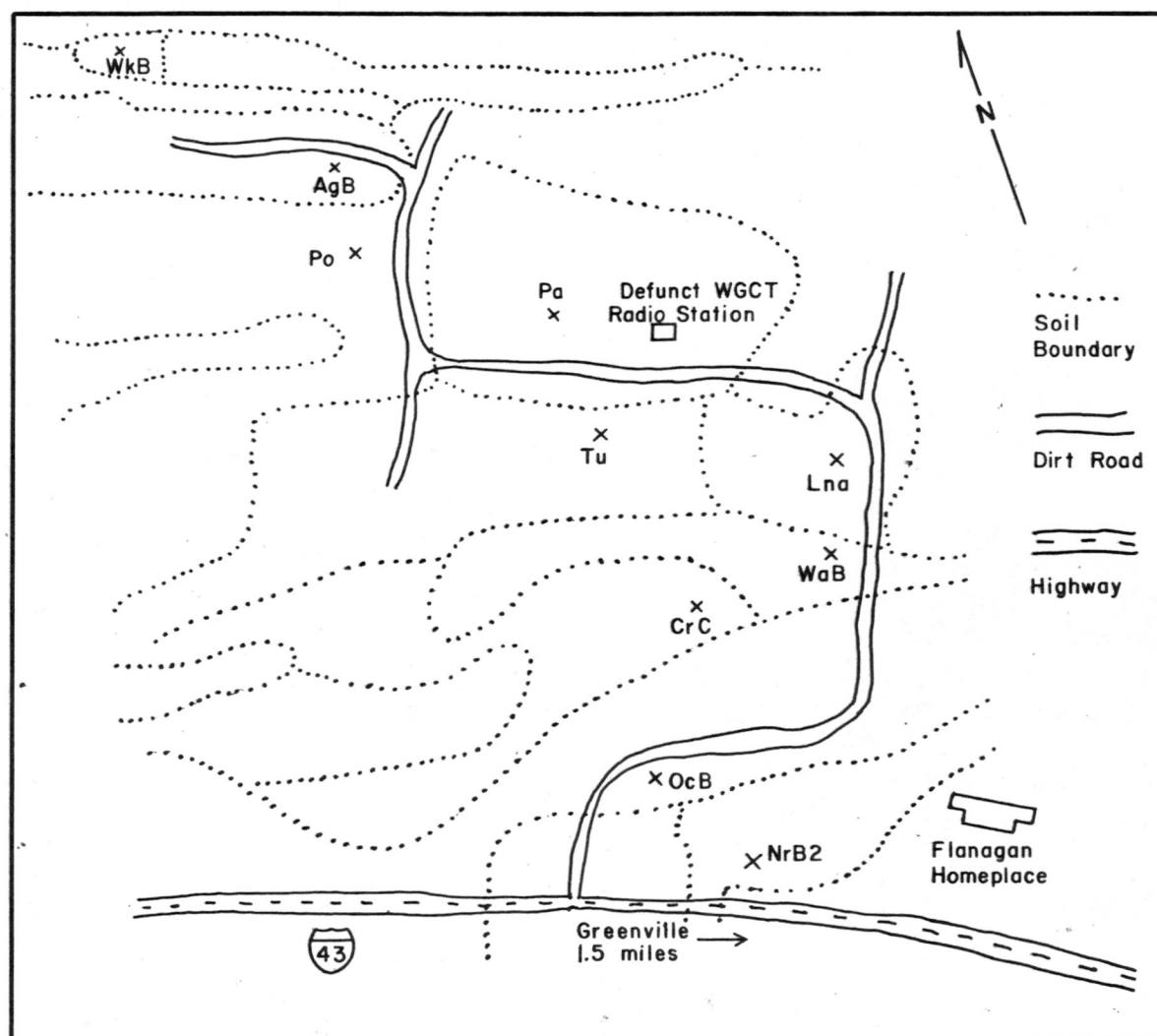


Figure 3-2. Map Of Test Site.

TABLE 3-1
TEST SOILS AND MOISTURE CAPACITY

Soil Series	Abbreviation	60 cm depth Capacity in mm
Ocilla loamy fine sand	OcB	45
Norfolk sandy loam	NrB2	80
Craven fine sandy loam	CrC	79
Wagram loamy sand	WaB	49
Lenoir fine sandy loam	LnA	86
Tuckerman fine sandy loam	Tu	76
Pactolus loamy sand	Pa	43
Portsmouth loam	Po	93
Alaga loamy sand	AgB	43
Wickham sandy loam	WkB	81

Source: Pitt County Soil Survey

as much as one week behind the first plant emergence of other series.

Instruments Used

Several kinds of measurements were taken at each test station throughout the experiment. Soil moisture was monitored with the use of Bouyucos Gypsum Blocks; air temperature and humidity with a Bacharach Recording Hygro-thermograph; precipitation with a standard rain guage; crop density with a one meter frame separated into ten cm blocks; and crop height with a tape measure.

Recording Procedure

Gypsum blocks were implanted in each of ten soil series on the test farm at depths of 15, 30, and 45 cm. The wires leading to the blocks were attached to stakes for ease in both monitoring and locating sites. The solum was replanted keeping the soil texture as uniform as possible with the different depths. Each test site was located as close to the center of each soil body as possible. The test sites were also located in landscape positions which were not subject to intense water run-off or collection, avoiding to a great extent moisture recharge discrepancies. Recordings were taken twice a week at the three depths in each soil body.

The hygro-thermograph was placed in a U. S. standard weather screen and subject to unrestricted air flow

(Figure 3-3). The recording graphs were changed weekly and average daily temperature was computed from these readings.

A standard rain guage was located in a clearing free of obstacles (Figure 3-4). The rain guage was checked after each rainfall period thus keeping an accurate tabulation of moisture available for soil recharge.

Throughout the two growing seasons monitored (Summer, 1975 and 1976) conditions such as wilting and crop development were noted as they related to moisture conditions.

Crop Conditions

The 1975 summer corn crop of the test site was planted late in the season. The crop was seeded in the middle of May during excellent moisture conditions. By mid-June soil moisture supply had dwindled causing wilting conditions to occur in the lower leaves of the crop. Moisture deficiency continued thereafter until two heavy rains broke the droughty conditions on July 10, 1975. It was estimated that 30% of the crop never fully recovered its vigor but much of the stand returned to an excellent condition. The available soil water at 8 out of the 10 sites examined reached the 0 percent point during this period. Subsequent moisture conditions remained favorable from July 10, 1975 through the middle of August, 1975. In mid-August a dry period occurred which lasted 19 days,



Figure 3-3. U.S. standard weather screen.



Figure 3-4. Standard rain gauge. The rain gauge should be in a location in which surrounding trees cannot influence its reception of atmospheric moisture.

although this dry spell was of little consequence to the crop which had already reached maturity.*

The 1976 summer season differed significantly from that of 1975. Moisture was plentiful during planting in mid-April. The plants germinated* early in the season and grew without a moisture deficient period until their maturation in early July. Moisture supply was excellent right through the tasseling and silking period, yielding a very healthy stand of corn. Minor moisture deficiencies occurred toward the end of July, but by this time the crop had already peaked.

In each growing season no labor was performed on the crop after spraying for weed control which took place two days after planting. The moisture retention blocks were implanted the day after spraying in 1975 and four days after spraying in 1976. All tillage and planting had to be complete before sites could be chosen for the gypsum blocks.

*Maturity-the development of a plant to the point in which growth has reached its upper limit.

*Germination-the initial opening of the plant seed below the surface.

CHAPTER 4

STATISTICAL ANALYSIS

Theoretical And Observed Data

A method was devised upon the termination of the monitoring of soil moisture during the two growing seasons in which to compare the observed data with the theoretical data derived from the three models. It is intended that this comparison will lead to a predictive equation which will be significant in its use in field application for determining moisture availability. The first step in this analysis was to place each set of data into a comparative format. Theoretical PE had to be transformed into soil moisture retention units comparable to the observed data.

Data monitored from the gypsum blocks determined the available moisture present in the soil. This data was in the form of percentage of field capacity currently in the soil. Using the known field capacity for each soil sampling site percentage figures were transformed into actual mm of moisture in the observed depths* throughout the two seasons.

Holdridge, Blaney-Criddle, and Thornthwaite designed

*Percentage of values of soil moisture were converted to millimeters of water in the solum with an area-depth relationship comparable to precipitation.

their theoretical equations to predict PE (from which AE is derived) on a daily basis. In this research, PE was computed for each equation for each day during the two seasons. A soil moisture drawdown curve was consulted (Thorntwaite and Mather, 1957) for each soil body to determine daily AE based upon theoretical PE. AE minus rainfall was totaled for all days in each interval between field observations to determine composite soil moisture drawdown. The composite soil moisture drawdown units were then subtracted from the soil moisture retention for each of the theoretical models. Water budgets were devised for each theoretical set of data on each soil series (Appendix III).

Computed Statistics

Data were transformed into a standard form to determine the relation between the observed data and the predicted values. Soil moisture retention values for the theoretical methods and observed data were recorded as mm of water which would exist assuming that all the water could be drained from the soil unit. The next step was to determine the degree of correlation between the actual and each theoretical set of data. To perform a correlation that is reliable the data must first be normal. In a normality check, the data proved normal at

the .05 level of significance for all the theoretical data sets with no transformations. The Holdridge data exhibited a maximum difference of .063 with a significance difference of .088; Blaney-Criddle .073 and .088 significance; and Thornthwaite .067 and .088 significance. The observed data did not prove normal under any condition. However, since the observed data in this test is the independent variable it is not necessary to be normalized to determine a correlation (Hsu, Maxfield, and Stephenson, 1969), as long as the dependent variables are normal.

Coefficients were run for each soil series comparing actual moisture retention with predicted values. Correlation between the theoretical and actual values was weakest for the Ocilla series with values of .31455, .33759, and .30736 for the Holdridge, Blaney-Criddle, and Thornthwaite systems. The Tuckerman series had the strongest correlations: .71166, .77622, and .82253 respectively (Table 4-1). The average slope on the scattergrams for the theoretical-actual comparisons was .22 while the average slope comparison between theoretical sets of data was .95 (Table 4-2).

The level of significance varied widely according to each soil series (Table 4-3). An alpha level of .01 was the significant criterion. Only the Ocilla series failed to fall within the significance range chosen for examining the correlations.

TABLE 4-1
CORRELATION COEFFICIENTS FOR THE COMPARISON
OF THE THEORETICAL AND OBSERVED DATA

Soil Series	Holdridge Vs. Actual	Blaney-Criddle Vs. Actual	Thorntwaite Vs. Actual
OcB	.31455	.33759	.30736
NrB2	.65543	.71711	.71716
CrC	.67194	.68619	.72829
WaB	.50226	.63557	.59472
LnA	.70084	.73708	.69400
Tu	.71166	.77622	.82253
Pa	.53057	.53570	.58255
Po	.69684	.73457	.73370
AgB	.51326	.56006	.58162
WkB	.63050	.67440	.67459

Source: Computer program comparing field data collection

TABLE 4-2

SLOPE OF THE THEORETICAL TO OBSERVED DATA SCATTERGRAM

Soil Series	Holdridge Vs. Actual	Blaney-Criddle Vs. Actual	Thorntwaite Vs. Actual
OcB	.20228	.22175	.20973
NrB2	.22450	.28363	.26309
CrC	.25755	.29599	.29968
WaB	.27562	.34887	.33212
LnA	.29252	.33851	.30730
Tu	.34677	.28648	.42580
Pa	.27887	.31961	.33246
Po	.27309	.33230	.32805
AgB	.29677	.36305	.36562
WkB	.30149	.37782	.35688

Source: Computer program comparing field data collection

TABLE 4-3
CORRELATION LEVELS OF SIGNIFICANCE FOR
THE THEORETICAL TO OBSERVED COMPARISON

Soil Series	Holdridge Vs. Actual	Blaney-Criddle Vs. Actual	Thornthwaite Vs. Actual
OcB	.08481	.06327	.09258
NrB2	.00002	.00001	.00001
CrC	.00001	.00001	.00001
WaB	.00211	.00004	.00016
LnA	.00001	.00001	.00001
Tu	.00001	.00001	.00001
Pa	.00125	.00109	.00030
Po	.00001	.00001	.00001
AgB	.00162	.00047	.00025
WkB	.00006	.00001	.00001

Source: Computer program comparing field data collection

For each set of theoretical and actual data the skewness, standard error, and standard deviation were computed (Tables 4-4 through 4-6). The standard deviations for the observed data sets averaged 75 to 100 percent higher than those of the theoretical data sets indicating the considerable distance away from the mean that most of the observed figures fell. The observed data exhibited a skewness which exceeded the theoretical data sets by 100 percent or more in most cases, also indicating the large variance of the observed data.

Data were further analyzed by the coefficient of determination (r^2) using a .5 or greater value as a close comparison between the observed and theoretical sets of data (Table 4-7). The weakest r^2 value was .09447 for the Thornthwaite values as compared to the observed data coefficient for the Ocilla series. The strongest coefficient (.67656) was associated with the Tuckerman series, Thornthwaite-observed comparison. Only five of the ten soil bodies had coefficients of .5 or better in any of the three comparisons, and only the Tuckerman exceeded .5 for all three of the theoretical-actual comparisons.

Theoretical Comparisons

Although the correlations and coefficients of determination between the theoretical and observed data

TABLE 4-4
SKEWNESS OF THE THEORETICAL AND OBSERVED DATA SETS

Soil Series	Holdridge	Blaney-Criddle	Thornthwaite	Actual
OcB	.04114	.01840	-.89870	-1.08543
NrB2	-.24202	-.45080	-.46085	-.73735
CrC	-.22508	-.43012	-.46018	-.96016
WaB	.05561	-.05995	.03102	-.76810
LnA	-.16027	-.31762	-.35978	-.69375
Tu	-.31405	-.14322	-.18206	-.48700
Pa	.03389	-.09176	-.11468	-.54441
Po	-.23364	-.31169	-.42982	-.95038
AgB	.08255	-.03463	-.03255	-.88481
WkB	-.26943	-.34765	-.55710	-1.32100

Source: Computer program comparing field data collection

TABLE 4-5
STANDARD ERROR FOR EACH SET
OF THEORETICAL AND OBSERVED DATA

Soil Series	Holdridge	Blaney-Criddle	Thornthwaite	Actual
OcB	1.78	1.82	1.89	2.77
NrB2	1.85	2.14	1.98	5.40
CrC	1.95	2.19	2.09	5.09
WaB	1.88	1.88	1.91	3.42
LnA	2.33	2.57	2.48	5.59
Tu	2.45	1.85	2.60	5.02
Pa	1.59	1.81	1.73	3.04
Po	2.52	2.91	2.87	6.42
AgB	1.59	1.78	1.72	2.74
WkB	2.05	2.40	2.27	4.29

Source: Computer program comparing field data collection

TABLE 4-6
STANDARD DEVIATION FOR EACH SET
OF THEORETICAL AND OBSERVED DATA

Soil Series	Holdridge	Blaney-Criddle	Thorntwaite	Actual
OcB	9.92	10.14	10.53	15.44
NrB2	10.95	12.64	11.72	31.97
CrC	11.56	13.01	12.41	30.15
WaB	11.10	11.11	11.29	20.23
LnA	13.61	14.97	14.44	32.61
Tu	14.48	10.97	15.39	29.72
Pa	9.31	10.57	10.11	17.71
Po	14.68	16.05	16.75	37.46
AgB	9.38	10.52	10.20	16.23
WkB	11.96	14.02	13.24	25.02

Source: Computer program comparing field data collection

TABLE 4-7
COEFFICIENTS OF DETERMINATION FOR THE
THEORETICAL TO OBSERVED DATA COMPARISON

Soil Series	Holdridge Vs. Actual	Blaney-Criddle Vs. Actual	Thornthwaite Vs. Actual
OcB	.09894	.11396	.09447
NrB2	.42958	.51424	.54196
CrC	.45150	.47086	.53041
WaB	.25227	.40395	.35369
LnA	.49118	.54329	.48164
Tu	.50646	.60252	.67656
Pa	.28150	.28697	.33936
Po	.48559	.53959	.53832
AgB	.26344	.31367	.33838
WkB	.39753	.45482	.45507

Source: Computer program comparing field data collection

were weak for the majority of cases, this was not the case for the correlations between the theoretical techniques (Table 4-8).

Comparisons for the theoretical techniques against each other proved them very close. The correlation coefficients for each of these tests, with few exceptions, were in excess of .9. This strong correlation indicates the relative uniformity of the computed figures for each equation. The major argument in the professional literature on moisture release deals with the degree of accuracy of predicted moisture release. The findings in this research reveal that even though these equations reviewed differ mathematically, their results are essentially the same. Comparison of theoretical formulae with actual data, however, proved the former insufficient for agricultural planning purposes.

Correction Factors

Correlation coefficients between theoretical and observed data sets were weakest on the soil bodies with field capacities less than 50 mm. Soil bodies were subsequently classified into two categories (Category 1: 0-50 mm; Category 2: >50 mm), since the soils differed in response to moisture release, to derive separate equation correction factors. Soil moisture retention was analyzed according to four arbitrarily chosen categories of available moisture:

TABLE 4-8
CORRELATION COEFFICIENTS COMPARING
THEORETICAL DATA SETS

Soil Series	Holdridge Vs. Thorndwaite	Blaney-Criddle Vs. Holdridge	Thorndwaite Vs. Blaney-Criddle
OcB	.97221	.96291	.91836
NrB2	.97051	.97009	.96731
CrC	.97701	.97655	.98611
WaB	.85602	.84227	.97733
LnA	.96623	.98018	.98630
Tu	.97243	.93417	.96490
Pa	.97665	.97362	.99498
Po	.99009	.99253	.99393
AgB	.97530	.97211	.99220
WkB	.97106	.97449	.97110

Source: Computer program comparing field data collection

0-25%, 26-50%, 51-75%, 76-100%. Departure of theoretical from actual soil moisture retention was calculated for each sample site. This provided a data base from which the mean "departure error" could be calculated for each quartile division of soil moisture retention (Figure 4-1). The mean "error of departure" was transposed into a mean "correction factor" (Table 4-9).*

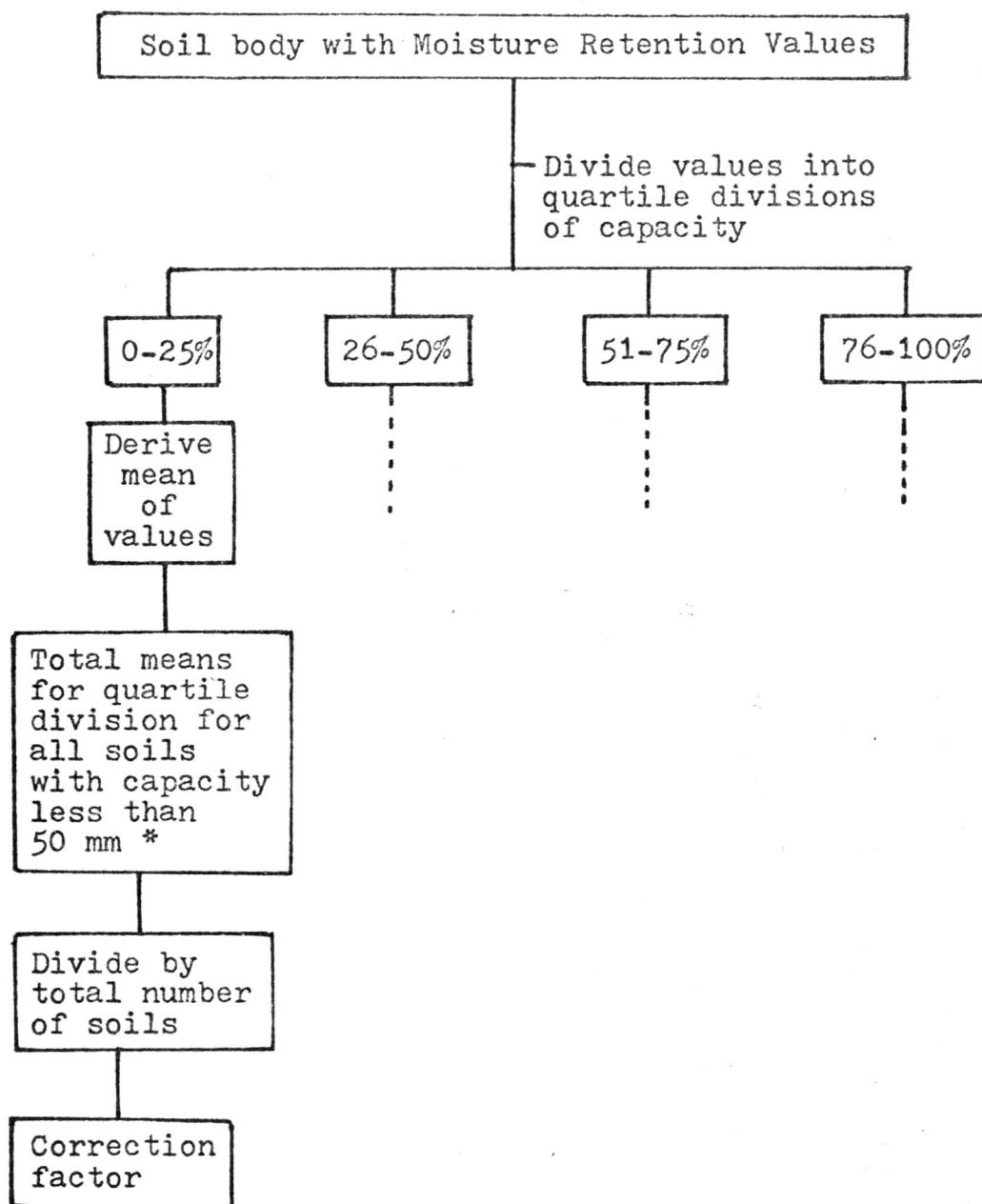
Theoretical PE was recalculated for the sample sites utilizing the correction factors. A modified set of AE and soil moisture retention values were then obtained by interpreting the significance of the new PE data from the soil drying curve (explained in Chapter 3). Correlation coefficients were then determined for the modified sets. In all three cases modified data-sets improved prediction of soil moisture retention and AE in excess of 20 percent (Table 4-10).

In all of the soil bodies observed, field capacity values appeared for a lengthy period (of up to two weeks) following a saturation rainfall. This resulted from drying in the upper three to four inches and gravitational drainage prior to moisture withdrawal actually occurring in the moisture block planted at the 6 inch depth.

*Since theoretical soil moisture retention is derived by using a uniform soil drying curve based upon theoretical PE formulae, the only variable subject to variation in obtaining a soil moisture value is the equation by which PE is obtained. Thus, it appears logical that PE, rather than soil moisture, corrections were needed.

FIGURE 4-1

METHOD FOR OBTAINING CORRECTION FACTORS



*Repeat process for all soils with capacities exceeding 50 mm.

Source: Method devised by author.

TABLE 4-9

AVERAGE CORRECTION FACTORS CALCULATED FROM THE
 SUMMATION OF THE MEANS OF EACH RETENTION CATEGORY AND
 DIVIDED BY THE NUMBER OF SOILS IN THAT CATEGORY*

Moisture Retention Category	Capacity >50 mm	Capacity <50 mm
0-25%	1.79	1.55
26-50%	1.24	1.25
51-75%	1.20	.77
76-100%	.81	.50

*Correction Factors are multiplied into the theoretical equations to predict PE which determines AE on a moisture drawdown curve.

Source: Derived from Figure 4-1.

TABLE 4-10
CORRELATION COEFFICIENTS EMPLOYING THE
CORRECTION FACTORS FOR THEORETICAL VS. OBSERVED
COMPARISONS ON THREE SAMPLE SOILS

Soil Series	Holdridge Vs. Observed	Blaney-Criddle Vs. Observed	Thorntwaite Vs. Observed
OcB	.55173	.71154	.72372
Tu	.92243	.91843	.91552
Pa	.67918	.84179	.77890

Source: Computer program comparing field data collection

Assuming that these processes might bias the correction factor, soils were tested for observed to theoretical correlations omitting those days in which observed moisture status remained at the 100 percent level. The resulting coefficients exhibited very minor variation from the complete data set, indicating the test data results were not enhanced by further correction for the lengthy saturation of moisture blocks (Table 4-11).

The theoretical equations were also compared with each other after implementing the correction factors. Correlations exceeded the initial results and demonstrated the increased uniformity of data provided by the corrected theoretical formulae. Hence, the correction factors are applicable for each of the theoretical techniques (Table 4-12).

Areal Implications

The seasonal characteristics of the unaltered Holdridge, Blaney-Criddle, and Thornthwaite predicted values were on the average 20 percent off the adjusted equations. However, this does not emphasize the periods in which the original techniques grossly underestimated moisture conditions when the observed crop reached the critical moisture level. An example occurred during late June and early July, 1975, when the Lenoir series contained less than 7 mm of water in the rooting zone.

TABLE 4-11

A COMPARISON BETWEEN CORRELATIONS RUN
INCLUDING AND EXCLUDING THE MONITORING DAYS
EXHIBITING CAPACITY ON TWO SAMPLE SOILS

Capacity Figures Included			
Soil Series	Holdridge Vs. Actual	Blaney-Criddle Vs. Actual	Thorntwaite Vs. Actual
OcB	.55173	.71154	.72372
Pa	.67918	.84179	.84180
Capacity Figures Excluded			
Soil Series	Holdridge Vs. Actual	Blaney-Criddle Vs. Actual	Thorntwaite Vs. Actual
OcB	.52027	.71377	.71694
Pa	.66351	.84180	.75564

Source: Computer program comparing field data collection

TABLE 4-12
CORRELATION COEFFICIENTS EMPLOYING THE
CORRECTION FACTORS FOR THEORETICAL VS. THEORETICAL
COMPARISONS ON THREE SAMPLE SOILS

Soil Series	Holdridge Vs. Blaney-Criddle	Blaney-Criddle Vs. Thorndthwaite	Thorndthwaite Vs. Holdridge
OcB	.93877	.95386	.91660
Tu	.98849	.99212	.98920
Pa	.93804	.95649	.92202

Source: Computer program comparing field data collection

During this same period (June 28 through July 10) all of the theoretical equations predicted moisture values in excess of 55 mm with the exception of one monitoring day in which the soil displayed a reading of 52 mm. Miscalculations of this nature would be extremely detrimental to the irrigation planning for certain crops. With the correction factors applied to the equations, the theoretical depletion of moisture compared closer to the observed data with many of the theoretical figures falling below 25 mm of retention on the Lenoir series. These figures are low enough to predict that stress will appear in the crop and irrigation is necessary.

The regional economic impact of a miscalculation such as the original techniques predicted could be very severe. For example, the stress occurring on the test farm crop in June and July, 1975, was estimated to have injured the corn crop to the degree that 30 percent never fully recovered. On a regional basis this event had a crippling effect. The "N. C. Weekly Weather And Crop Bulletin" (July 7, 1975) provided estimates that the state's 1975 corn crop would be less than the 1974 crop by 13 percent, yielding 101 million bushels to the 114 million bushels in 1974. The coastal plain corn crop which was the most severely injured of the state was estimated to yield 24 percent less than the 1974 crop accounting for a large part of the overall 13 percent decrease. With the corrected equations and proper

irrigation equipment this loss and others of its kind could be avoided. The implementation of a long term study, utilizing various correction factors on several differing soil textures, could conceivably enhance the decision as to when irrigation would be profitable or economically feasible.

The intraregional ramifications of this study are considerable. This test has proven the weaknesses of the original equations for the study area along with the feasible usefulness of the corrected equations. Unfortunately, these corrections are suitable only for the south-eastern coastal plain soil textures which are predominantly sand to a fine sandy loam. In areas which exhibit clays and clay loams the correction factors devised in this thesis would probably not provide very accurate results. It is this reason which should prompt continued experimentation in other climatic and soil regions to derive corrected equations for those areas.

The equations examined were designed to determine PE (AE is a function of PE) on a large areal scale. The results of this research reveal that these techniques need to be confined to specific soil regions unless they utilize appropriate corrective factors to suit local soil conditions as was done in this study.

A question which these results raise is the validity of the Thornthwaite climatic maps of the world. Since

his maps are based upon the water balance equation tested in this thesis it would follow that if the results are unwarranted in this study area then perhaps the same holds true for many other regions of the world also.

It is the opinion of this author that the research findings of this study suggest the need for a re-examination of the geographical outlook on moisture release studies and increased emphasis on the field.

Summary And Conclusion

The current literature dealing with soil moisture release contains many discrepancies as to which theoretical equation best predicts moisture release. The purpose of this thesis has been to analyze three (Holdridge, Blaney-Criddle, and Thornthwaite) of these techniques in eastern North Carolina to determine their accuracy. None of these techniques approximated the soil moisture release with a degree of accuracy which would be beneficial to agricultural planning and water resource management. Correction factors were devised to yield more positive results for the three equations in the study area. The efficiency of the equations was increased with the correction factors by approximately 20 percent which would provide more meaningful predictions of the moisture status in field applications.

The three formulae computed relatively close estimates of PE, with and without the correction factors. This finding reveals that although the format of the equations is varied the results are basically the same. Further research of this topic would be made simpler by using the Holdridge technique alone since its predictions are the easiest of the three to derive.

The use of the corrected equations could prove to be extremely helpful in making irrigation and water management decisions in situations such as the excessively dry conditions recorded in eastern North Carolina in June and July, 1975, and more recently southern Georgia during May and June, 1977. The expansion and future testing of this methodology could possibly alter the present irrigation practices in eastern North Carolina as well as other technologically advanced areas of the world.

APPENDICES

- (1) DESCRIPTION OF SOILS MONITORED
- (2) OBSERVED SOIL MOISTURE RETENTION IN MM
- (3) WATER BUDGETS FOR THE THEORETICAL DATA SETS
 - (A) Holdridge PE Data
 - (B) Blaney-Criddle PE Data
 - (C) Thornthwaite PE Data

APPENDIX 1
DESCRIPTION OF SOILS MONITORED

Ocilla

The Ocilla loamy fine sand occurs on broad flats and smooth side slopes in the uplands and stream terraces. These soils are somewhat poorly drained with rapid infiltration and slow runoff. This soil has a 2.5 foot depth to its seasonal high water table. In a typical profile the 0-22 inch layer is a loamy sand with the 22-75 inch layer being a sandy clay loam. Its permeability rate in the surface layer is 2.0 to 6.3 inches per hour.

Norfolk

The Norfolk sandy loam is a well drained soil on smooth side slopes in the uplands. It expresses a 1 to 6 percent slope and occurs in irregular shapes. The surface layer of this soil is eroded thus making it difficult to keep it in good tilth. This soil has a seasonal high water table in excess of 5 feet. In the soil's typical profile the 0-10 inch layer is a sandy loam, the 10-72 inch depth is a sandy clay loam, and the 72-84 inch depth is a sandy loam. Its permeability rate in the surface layer is 2.0 to 6.3 inches per hour.

Craven

The Craven fine sandy loam is a moderately well

drained soil on narrow side slopes in the uplands. It occurs on slopes of 6 to 10 percent with rapid runoff which must be controlled in cultivated areas. The depth to the seasonal high water table on the Craven is 2.5 feet. In the 0-12 inch surface layer the texture is a fine sandy loam and a clay occurs in the 12-78 inch layer. Its permeability rate is .63 to 2.0 inches per hour.

Wagram

The Wagram loamy sand is a well drained soil on slightly convex broad divides on uplands and stream terraces. It occurs in irregular shapes with a slow runoff rate. The depth to the seasonal high water table is in excess of 5 feet. In the 0-25 inch surface layer the texture is a loamy sand, sandy clay loam in the 25-66 inch layer, and loamy sand in the 66-84 inch depth. The permeability rate of this soil is from 6.3 to 20 inches per hour.

Lenoir

The Lenoir fine sandy loam is a somewhat poorly drained soil which occupies broad divides on stream terraces. Wetness is a severe limitation and artificial drainage is required for successful cultivation. The depth to the seasonal high water table in this soil is only 1.5 feet. A fine sandy loam occurs in the 0-7 inch surface layer, clay in the 7-36 inch depth, and loamy sand to coarse sand in the 36-58 inch depth.

The permeability rate of this soil is 2.0 to 6.3 inches per hour.

Tuckerman

The Tuckerman fine sandy loam is a poorly drained soil on broad flats and in slight depressions on stream terraces. Slopes are from 0 to 1 percent and shapes are irregular. Ponding sometimes occurs on this soil. The seasonal high water table is at the surface on this soil and artificial drainage is required for good cultivation. In the 0-20 inch surface layer the texture is a fine sandy loam, sandy clay loam in the 20-36 inch layer, and loamy sand in the 36-72 inch layer. The permeability rate of this soil is .63 to 2.0 inches per hour.

Pactolus

The Pactolus loamy sand is a moderately well drained soil on broad, smooth divides in the uplands and on stream terraces. Slopes are very minor from 0-2 percent with slow runoff and wetness limitations in cultivation. The depth to the seasonal high water table is 2.5 feet. A loamy sand occurs in the 0-64 inch surface layer and coarse sand is present in the 64-90 inch depth. The permeability rate is 6.3 to 20 inches per hour.

Portsmouth

The Portsmouth loam is a very poorly drained soil

on broad, smooth flats in slight depressions. Ponding is frequent and artificial drainage is necessary for successful cultivation. The seasonal high water table is at the surface on this soil. In the 0-15 inch layer the texture is a loam, sandy loam occurs in the 15-39 inch layer, and sand in the 39-68 inch layer. The permeability rate is 2.0 to 6.3 inches per hour.

Alaga

The Alaga loamy sand is a somewhat excessively drained, sandy soil on broad, high divides on stream terraces. At depths of greater than 6 feet a banded substratum of sandy loam occurs. The seasonal high water table is at a depth greater than 5 feet. In the 0-72 inch surface layer loamy sand occurs with pure sand lying in the 72-85 inch depth. The permeability rate of this soil is from 6.3 to 2.0 inches per hour.

Wickham

The Wickham sandy loam is a well drained soil with a 0 to 6 percent slope. It occurs on long, narrow areas of irregular shape. Runoff is slow to medium. The depth to the seasonal high water table is in excess of 5 feet. In the 0-17 inch surface layer the texture is a sandy loam, sandy clay loam exists in the 17-42 inch depth, and loamy sand in the 42-80 inch depth. The permeability rate

of this soil is from 2.0 to 6.3 inches per hour.

APPENDIX 2
OBSERVED SOIL MOISTURE RETENTION VALUES IN MM

Soil Series	<u>1975</u>	<u>May</u>	20	22	28	<u>June</u>	3	5
Ocilla			45	45	45		45	45
Norfolk			70	74	80		80	80
Craven			79	79	79		79	79
Wagram			49	49	49		49	49
Lenoir			85	86	86		86	86
Tuckerman			75	76	76		76	76
Pactolus			43	43	43		43	43
Portsmouth			93	93	93		93	93
Alaga			43	43	43		43	43
Wickham			81	81	81		81	81

Soil Series	9	16	19	23	26	30	<u>July</u>	3	7
Ocilla	45	45	45	45	40	25		4	3
Norfolk	80	79	66	24	8	6		6	3
Craven	79	79	63	28	1	1		0	26
Wagram	49	49	37	6	0	0		0	7
Lenoir	86	77	64	43	27	15		7	6
Tuckerman	68	50	35	19	5	7		6	8
Pactolus	43	43	43	28	10	6		0	7
Portsmouth	93	93	93	75	44	31		7	0
Alaga	43	43	35	28	13	11		9	4
Wickham	81	81	81	76	61	55		35	23

Soil Series	11	15	18	22	28	<u>August</u>	4	11
Ocilla	5	34	45	45	45		27	18
Norfolk	8	80	80	80	80		44	24
Craven	27	79	79	79	76		69	71
Wagram	0	49	49	49	46		14	47
Lenoir	5	86	86	86	74		49	44
Tuckerman	11	76	76	76	63		26	24
Pactolus	6	33	43	43	23		0	0
Portsmouth	0	82	93	93	84		51	6
Alaga	17	38	44	43	25		4	10
Wickham	29	79	81	81	78		72	69

Soil Series	18	23	29	<u>September</u>	8
Ocilla	12	11	7		34
Norfolk	0	0	0		56
Craven	16	0	0		76
Wagram	2	0	0		49
Lenoir	3	0	0		43
Tuckerman	5	0	0		29
Pactolus	0	0	0		34
Portsmouth	0	0	0		35
Alaga	0	0	0		40
Wickham	16	2	0		49

Soil Series	<u>1976</u>	<u>June</u>	3	7	10	14	17	21
Ocilla			45	45	45	45	45	45
Norfolk			80	80	80	79	80	80
Craven			79	79	78	64	79	79
Wagram			49	49	47	39	49	49
Lenoir			86	86	86	83	86	86
Tuckerman			76	76	72	60	76	76
Pactolus			43	43	43	43	43	43
Portsmouth			93	93	93	93	93	93
Alaga			43	43	43	43	43	43
Wickham			81	81	77	61	81	81

Soil Series	24	<u>July</u>	5	11	14
Ocilla	45		NO DATA		
Norfolk	76		69	71	67
Craven	73		78	76	43
Wagram	42		48	45	29
Lenoir	84		66	59	26
Tuckerman	71		76	74	59
Pactolus	40		30	24	8
Portsmouth	93		93	93	93
Alaga	43		43	43	42
Wickham	76		69	76	66

APPENDIX 3 TABLE A
WATER BUDGET UTILIZING THE HOLDRIDGE PE DATA*

May 1975	20	21	22	23	24	25	26	27	28	29	30	31
Temp. °C	21	21	21	21	21	21	21	21	21	21	21	21
PE mm	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
PPT mm							12	9			9	
OcB ST	45	42	40	37	34	32	40	45	42	40	45	42
AE		3	2	3	3	2	3	2	3	2	3	3
NrB2 ST	70	68	66	64	62	59	67	72	70	67	75	73
AE		2	2	2	2	3	2	2	2	3	3	2
CrC ST	79	77	75	73	70	68	76	79	77	75	79	77
AE		2	2	3	2	3	3	2	2	2	3	2
WaB ST	49	46	43	41	37	35	43	48	45	42	49	45
AE		3	3	2	4	2	3	3	3	3	3	4
LnA ST	85	82	80	77	74	72	80	85	82	80	85	83
AE		3	2	3	3	3	3	3	3	2	3	2
Tu ST	75	72	69	66	62	59	67	73	70	67	75	72
AE		3	3	3	4	3	3	3	3	3	3	3
Pa ST	43	41	38	36	33	31	39	43	41	38	43	41
AE		2	3	2	3	2	3	3	2	3	3	2
Po ST	93	90	88	85	81	79	87	92	89	87	93	90
AE		3	2	3	4	2	3	3	3	2	3	3
AgB ST	43	41	38	36	33	31	39	43	41	38	43	41
AE		2	3	2	3	2	3	3	2	3	3	2
WkB ST	81	79	77	74	71	69	77	81	79	77	81	79
AE		2	2	3	3	2	3	3	2	2	3	2

*Storage and Actual Evapotranspiration given in mm and missing Precipitation data represents non-rain days

June		1	2	3	4	5	6	7	8	9	10	11	12
Temp. °C		23	23	23	23	23	23	23	23	23	23	23	23
PE mm		3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
PPT mm		10											16
OcB	ST	39	45	41	38	35	32	30	28	25	23	21	34
AE		3	3	3	4	3	3	3	2	3	2	2	3
NrB2	ST	70	80	77	74	70	68	66	63	60	58	56	69
AE		3	3	3	3	3	4	2	2	3	3	2	3
CrC	ST	74	79	77	74	70	68	66	63	60	58	56	69
AE		3	3	3	2	3	4	2	2	3	3	2	2
WaB	ST	41	49	45	41	38	35	33	30	28	25	23	36
AE		4	3	4	4	3	3	2	3	2	3	2	3
LnA	ST	80	86	82	79	76	73	70	68	65	62	60	73
AE		3	3	4	3	3	3	3	2	3	3	2	3
Tu	ST	69	76	73	70	67	63	60	58	56	53	51	64
AE		3	3	3	3	3	4	3	2	2	3	2	3
Pa	ST	38	43	40	36	33	31	29	27	24	22	21	34
AE		3	3	3	4	3	2	2	2	3	2	1	3
Po	ST	87	93	89	86	82	79	77	74	70	68	66	79
AE		3	3	4	3	4	3	2	3	4	2	2	3
AgB	ST	38	43	40	36	33	31	29	27	24	22	21	34
AE		3	3	3	4	3	2	2	2	3	2	1	3
WkB	ST	76	81	78	75	73	70	68	65	62	60	58	72
AE		3	3	3	3	3	3	2	3	3	2	2	3

June		13	14	15	16	17	18	19	20	21	22	23	24
Temp. °C		23	23	23	23	23	23	23	23	23	23	23	23
PE mm		3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
PPT mm					6								
OcB	ST	32	29	27	30	28	25	23	21	20	18	17	16
AE		2	3	2	3	2	3	2	2	1	2	1	1
NrB2	ST	66	64	61	64	62	59	57	54	53	51	49	47
AE		3	2	3	3	2	3	2	3	1	2	2	2
CrC	ST	66	64	61	64	62	59	57	54	53	51	49	47
AE		3	2	3	3	2	3	2	3	1	2	2	2
WaB	ST	33	31	28	31	28	26	24	22	20	19	17	16
AE		3	2	3	3	3	2	2	2	2	1	2	1
LnA	ST	70	67	64	62	59	57	54	53	51	49	47	45
AE		3	3	3	2	3	2	3	1	2	2	2	2
Tu	ST	61	58	57	60	58	56	53	51	49	46	45	43
AE		3	3	1	3	2	2	3	2	2	3	1	2
Pa	ST	32	29	27	30	28	25	23	21	20	18	17	16
AE		2	3	2	3	2	3	2	2	1	2	1	1
Po	ST	76	73	70	73	70	67	64	62	60	58	55	53
AE		3	3	3	3	3	3	3	2	2	2	3	2
AgB	ST	32	29	27	30	28	25	23	21	20	18	17	16
AE		2	3	2	3	2	3	2	2	1	2	1	1
WkB	ST	69	66	64	67	64	62	59	57	55	53	51	49
AE		3	3	2	3	3	2	3	2	2	2	2	3

June		25	26	27	28	29	30	July	1	2	3	4
Temp. °C		23	23	23	23	23	23		25	25	25	25
PE mm		3.8	3.8	3.8	3.8	3.8	3.8		4	4	4	4
PPT mm				21								9
OcB	ST	14	13	31	28	26	24		22	20	19	24
AE		2	1	3	3	2	2		2	2	1	3
NrB2	ST	45	44	62	60	58	55		53	51	49	54
AE		2	1	3	2	2	3		2	2	2	4
CrC	ST	45	44	62	60	58	55		53	51	49	54
AE		2	1	3	2	2	3		2	2	2	4
WaB	ST	15	14	32	30	27	25		23	21	19	24
AE		1	1	3	2	3	3		2	2	2	4
LnA	ST	44	42	60	58	56	53		51	49	47	52
AE		1	2	3	2	2	3		2	2	2	4
TU	ST	40	39	57	55	53	51		49	46	44	49
AE		3	1	3	2	2	2		2	3	2	4
Pa	ST	14	13	31	28	26	24		22	20	19	24
AE		2	1	3	3	2	2		2	2	3	4
Po	ST	51	49	67	64	62	59		57	54	52	57
AE		2	2	3	3	2	3		2	3	2	4
AgB	ST	14	13	31	28	26	24		22	20	19	24
AE		2	1	3	3	2	2		2	2	1	4
WkB	ST	47	45	63	60	58	56		54	52	50	55
AE		2	2	3	3	2	2		2	2	2	4

July		5	6	7	8	9	10	11	12	13	14	15	16
Temp. °C		25	25	25	25	25	25	25	25	25	25	25	25
PE mm		4	4	4	4	4	4	4	4	4	4	4	4
PPT mm			12	17				7		41	67		10
OcB ST		22	30	43	40	36	33	36	33	45	45	41	45
AE		2	4	4	3	4	3	4	3	4	4	4	4
NrB2 ST		52	60	73	70	67	64	67	64	80	80	77	80
AE		2	4	4	3	3	3	4	3	4	4	3	4
CrC ST		52	60	73	70	67	64	67	64	79	79	76	79
AE		2	4	4	3	3	3	4	3	4	4	3	4
WaB ST		22	30	43	40	36	33	36	33	49	49	45	49
AE		2	4	4	3	4	3	4	3	4	4	4	4
LnA ST		50	58	71	68	66	63	66	64	86	86	82	86
AE		2	4	4	3	2	3	4	2	4	4	4	4
Tu ST		46	54	67	63	59	57	60	57	76	76	72	76
AE		3	4	4	4	4	2	4	3	4	4	4	4
Pa ST		22	30	43	40	36	33	36	33	43	43	40	43
AE		2	4	4	3	4	3	4	3	4	4	3	4
Po ST		54	62	75	72	69	66	69	66	93	93	89	93
AE		3	4	4	3	3	3	4	3	4	4	4	4
AgB ST		22	30	43	36	33	36	33	43	43	40	43	43
AE		2	4	4	3	4	3	4	3	4	4	3	4
WkB ST		53	61	74	71	68	66	69	66	81	81	78	81
AE		2	4	4	3	3	2	4	3	4	4	3	4

July		17	18	19	20	21	22	23	24	25	26	27	28
Temp. °C		25	25	25	25	25	25	25	25	25	25	25	25
PE mm		4	4	4	4	4	4	4	4	4	4	4	4
PPT mm		13								9			
OcB	ST	45	41	38	35	32	30	27	25	30	28	25	23
AE		4	4	3	3	3	2	3	2	4	2	3	3
NrB2	ST	80	77	74	70	68	65	62	60	65	62	60	58
AE		4	3	3	4	2	3	3	2	4	3	2	2
CrC	ST	79	77	74	70	68	65	62	60	65	62	60	58
AE		4	2	3	4	2	3	3	2	4	3	2	2
WaB	ST	49	45	41	38	35	32	30	27	32	30	27	25
AE		4	4	4	3	3	3	2	3	4	2	3	2
LnA	ST	86	82	79	76	73	70	67	64	69	66	64	61
AE		4	4	3	3	3	3	3	3	4	3	2	3
Tu	ST	76	72	68	64	60	57	54	51	56	53	50	47
AE		4	3	4	4	3	3	3	4	3	3	3	3
Pa	ST	43	40	36	33	31	28	26	24	29	27	24	22
AE		4	3	4	3	2	3	2	2	4	2	3	2
Po	ST	93	89	86	82	79	76	73	70	75	72	69	66
AE		4	4	3	4	3	3	3	3	4	3	3	3
AgB	ST	43	40	36	33	31	28	26	24	29	27	24	22
AE		4	3	4	3	2	3	2	2	4	2	3	2
WkB	ST	81	78	75	72	69	66	64	61	66	64	61	59
AE		4	3	3	3	3	3	2	3	4	2	3	2

July	29	30	31	August	1	2	3	4	5	6	7
Temp. °C	25	25	25		26	26	26	26	26	26	26
PE mm	4	4	4		4.1	4.1	4.1	4.1	4.1	4.1	4.1
PPT mm		14								22	
OcB ST	21	31	28		26	24	22	20	18	36	33
AE	2	4	3		2	2	2	2	2	4	3
NrB2 ST	55	65	62		60	58	55	53	51	69	66
AE	3	4	3		2	2	3	2	2	4	3
CrC ST	55	65	62		60	58	55	53	51	69	66
AE	3	4	3		2	2	3	2	2	4	3
WaB ST	23	33	31		28	26	24	22	20	38	35
AE	2	4	2		3	2	2	2	2	4	3
LnA ST	59	69	66		64	61	59	56	54	72	69
AE	3	4	3		2	3	2	3	2	4	3
Tu ST	44	49	46		44	42	39	38	35	53	51
AE	3	4	3		2	2	3	1	3	4	2
Pa ST	20	30	27		24	22	20	19	17	35	32
AE	2	4	3		3	3	2	1	2	4	3
Po ST	64	74	71		68	66	63	60	58	76	73
AE	2	4	3		3	2	3	3	2	4	3
AgB ST	20	30	27		24	22	20	19	17	35	32
AE	2	4	3		3	2	2	1	2	4	3
WkB ST	56	66	64		62	59	57	54	52	70	68
AE	3	4	2		2	3	2	3	2	4	2

August		8	9	10	11	12	13	14	15	16	17	18	19
Temp. °C		26	26	26	26	26	26	26	26	26	26	26	26
PE mm		4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
PPT mm												9	
OcB	ST	31	28	26	24	22	20	18	17	16	14	19	18
AE		2	3	2	2	2	2	2	1	1	2	4	1
NrB2	ST	64	61	59	56	54	52	50	48	46	44	49	47
AE		2	3	2	3	2	2	2	2	2	2	4	2
CrC	ST	64	61	59	56	54	52	50	48	46	44	49	47
AE		2	3	3	3	2	2	2	2	2	2	4	2
WaB	ST	32	30	27	25	23	21	19	18	16	15	20	19
AE		3	2	3	2	2	2	2	1	2	1	4	1
LnA	ST	66	64	61	59	56	54	52	50	48	46	51	49
AE		3	2	3	2	3	2	2	2	2	2	4	2
Tu	ST	48	45	43	40	38	36	34	33	31	29	34	33
AE		3	3	2	3	2	2	2	1	2	2	4	1
Pa	ST	30	27	25	23	21	19	18	16	15	13	18	17
AE		2	3	2	2	2	2	1	2	1	2	4	1
Po	ST	70	67	64	62	57	54	50	48	53	51	49	48
AE		3	3	3	2	3	2	3	2	2	2	4	1
AgB	ST	30	27	25	23	21	19	18	16	15	13	18	17
AE		2	3	2	2	2	2	1	2	1	2	4	1
WkB	ST	65	62	58	55	53	51	49	47	44	49	47	45
AE		3	3	2	2	3	2	2	2	2	4	2	2

August		20	21	22	23	24	25	26	27	28	29	30	31
Temp. °C		26	26	26	26	26	26	26	26	26	26	26	26
PE mm		4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
PPT mm								17					
OcB	ST	17	15	14	13	11	11	24	22	20	19	17	16
AE		1	2	1	1	2	0	4	2	2	1	2	1
NrB2	ST	45	44	42	40	38	37	50	48	46	44	43	41
AE		2	1	2	2	2	1	4	2	2	2	1	2
CrC	ST	45	44	42	40	38	37	50	48	46	44	43	41
AE		2	1	2	2	2	1	4	2	2	2	1	2
WaB	ST	17	16	15	13	12	11	24	22	20	19	17	16
AE		2	1	1	2	1	1	4	2	2	1	2	1
LnA	ST	47	45	44	42	40	38	51	49	47	45	44	42
AE		2	2	1	2	2	2	4	2	2	2	1	2
Tu	ST	31	29	27	26	24	23	36	35	33	31	29	28
AE		2	2	2	1	2	1	4	1	2	2	2	1
Pa	ST	16	14	13	12	11	10	23	21	19	18	17	15
AE		1	2	1	1	1	1	4	2	2	2	1	1
Po	ST	49	47	45	44	42	40	53	51	49	47	45	44
AE		2	2	2	1	2	2	4	2	2	2	2	1
AgB	ST	16	14	13	12	11	10	23	21	19	18	17	15
AE		1	2	1	1	1	1	4	2	2	1	1	1
WkB	ST	45	44	42	40	38	37	50	48	46	44	43	41
AE		2	1	2	2	2	1	4	2	2	2	1	2

Sept.	1	2	3	4	5	6	7	8	June 1976	1
Temp. °C	24	24	24	24	24	24	24	24		19
PE mm	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9		3
PPT mm	24									
OcB ST	36	33	31	28	26	24	22	20		45
AE	4	3	2	3	2	2	2	2		
NrB2 ST	61	59	56	54	52	50	48	46		80
AE	4	2	3	2	2	2	2	2		
CrC ST	61	59	56	54	52	50	48	46		79
AE	4	2	3	2	2	2	2	2		
WaB ST	36	33	31	28	26	24	22	20		49
AE	4	3	2	3	2	2	2	2		
LnA ST	62	60	58	55	53	51	49	47		86
AE	4	2	2	3	2	2	2	2		
Tu ST	48	44	41	37	34	32	29	27		76
AE	4	4	3	4	3	2	3	2		
Pa ST	35	32	30	27	25	23	21	19		43
AE	4	3	2	3	2	2	2	2		
Po ST	64	62	59	57	54	52	50	48		93
AE	4	2	3	2	3	2	2	2		
AgB ST	35	32	30	27	25	24	21	19		43
AE	4	3	2	3	2	2	2	2		
WkB ST	61	59	56	54	52	50	48	46		81
AE	4	2	3	2	2	2	2	2		

June		2	3	4	5	6	7	8	9	10	11	12	13
Temp. °C		19	19	19	19	19	19	19	19	19	19	19	19
PE mm		3	3	3	3	3	3	3	3	3	3	3	3
PPT mm			52	6							4		
OcB ST		42	45	45	42	40	37	35	33	31	32	30	28
AE		3	3	3	3	2	3	2	2	2	3	2	2
NrB2 ST		77	80	80	77	75	73	70	68	66	65	63	61
AE		3	3	3	3	2	2	3	2	2	3	2	2
CrC ST		77	79	79	77	75	73	70	68	66	65	63	61
AE		2	3	3	2	2	2	3	2	2	3	2	2
WaB ST		46	49	49	46	43	41	38	36	33	34	32	30
AE		3	3	3	3	3	2	3	2	3	3	2	2
LnA ST		83	86	86	83	81	78	76	74	71	72	70	68
AE		3	3	3	3	2	3	2	2	3	3	2	2
Tu ST		73	76	76	73	70	67	64	61	58	59	57	55
AE		3	3	3	3	3	3	3	3	3	3	2	2
Pa ST		41	43	43	41	38	36	33	32	30	31	29	27
AE		2	3	3	2	3	2	3	1	2	3	2	2
Po ST		90	93	93	90	88	85	82	80	77	78	76	74
AE		3	3	3	3	2	3	3	2	3	3	2	2
AgB ST		41	43	43	41	38	36	33	32	30	31	29	27
AE		2	3	3	2	3	2	3	1	2	3	2	2
WkB ST		79	81	81	79	77	74	72	70	68	69	67	65
AE		2	3	3	2	2	3	2	2	2	3	2	2

June		14	15	16	17	18	19	20	21	22	23	24	25
Temp. °C		19	19	19	19	19	19	19	19	19	19	19	19
PE mm		3	3	3	3	3	3	3	3	3	3	3	3
PPT mm					9			6		27			9
OcB ST		27	25	23	29	27	25	28	27	45	42	40	45
AE		1	2	2	3	2	2	3	1	3	3	2	3
NrB2 ST		59	58	56	62	60	59	62	60	80	77	75	80
AE		2	1	2	3	2	1	3	2	3	3	2	3
CrC ST		59	58	56	62	60	59	62	60	79	77	75	79
AE		2	1	2	3	2	1	3	2	3	2	2	3
WaB ST		28	27	25	31	29	27	30	28	49	46	42	49
AE		2	1	2	3	2	2	3	2	3	3	3	3
LnA ST		66	64	62	68	66	64	67	65	86	83	81	86
AE		2	2	2	3	2	2	3	2	3	3	2	3
Tu ST		53	51	49	55	53	51	53	51	76	73	70	76
AE		2	2	2	3	2	2	3	2	3	3	3	3
Pa ST		25	24	22	28	26	24	27	25	43	41	38	43
AE		2	1	2	3	2	2	3	2	3	2	3	3
Po ST		71	69	67	73	70	68	71	69	93	90	88	93
AE		3	2	2	3	3	2	3	2	3	3	2	3
AgB ST		25	24	22	28	26	24	27	25	43	41	38	43
AE		2	1	2	3	2	2	3	2	3	2	3	3
WkB ST		63	61	59	65	63	61	64	62	81	79	77	81
AE		2	2	2	3	2	2	3	2	3	2	3	2

June	26	27	28	29	30	July	1	2	3	4	5
Temp. °C	19	19	19	19	19		23	23	23	23	23
PE mm	3	3	3	3	3		3.6	3.6	3.6	3.6	3.6
PPT mm							25	37			
OcB ST	42	40	37	35	33		45	45	41	38	36
AE	3	2	3	2	2		3	3	4	3	2
NrB2 ST	77	75	73	70	68		80	80	77	75	72
AE	3	2	2	3	2		3	3	3	2	3
CrC ST	77	75	73	70	68		79	79	77	75	72
AE	2	2	2	3	2		3	3	2	2	3
WaB ST	46	43	41	38	36		49	49	46	42	39
AE	3	3	2	3	2		3	3	3	4	3
LnA ST	83	81	78	76	74		86	86	82	79	77
AE	3	2	3	2	2		3	3	4	3	2
Tu ST	73	70	67	64	61		76	76	72	68	65
AE	3	3	3	3	3		3	3	4	4	3
Pa ST	41	38	36	33	32		43	43	40	36	34
AE	2	3	2	3	1		3	3	3	4	2
Po ST	90	88	85	82	80		93	93	89	86	83
AE	3	2	3	3	2		3	3	4	3	3
AgB ST	41	38	36	33	32		43	43	40	36	34
AE	2	3	2	3	1		3	3	3	4	2
WkB ST	79	77	74	72	70		81	81	78	75	73
AE	2	2	3	2	2		3	3	3	3	2

July		6	7	8	9	10	11	12	13	14
Temp. °C		23	23	23	23	23	23	23	23	23
PE mm		3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
PPT mm			13							
OcB	ST	33	43	40	36	34	32	29	27	25
AE		3	3	3	4	2	2	3	2	2
NrB2	ST	70	80	77	75	72	70	68	65	63
AE		2	3	3	2	3	2	2	3	2
CrC	ST	70	80	77	75	72	70	68	65	63
AE		2	3	3	2	3	2	2	3	2
WaB	ST	36	46	42	39	36	33	31	29	27
AE		3	3	4	3	3	3	2	2	2
LnA	ST	74	84	81	77	75	72	69	67	64
AE		3	3	3	4	2	3	3	2	3
Tu	ST	61	71	67	63	60	57	54	52	50
AE		4	3	4	4	3	3	3	2	2
Pa	ST	32	42	39	36	33	31	28	27	24
AE		2	3	3	3	3	2	3	1	3
Po	ST	80	90	87	83	81	77	74	72	69
AE		3	3	3	4	2	4	3	2	3
AgB	ST	32	42	39	36	33	31	28	27	24
AE		2	3	3	3	3	2	3	1	3
WkB	ST	70	73	70	67	65	62	60	58	56
AE		3	3	3	3	2	3	2	2	2

APPENDIX 3 TABLE B

WATER BUDGET UTILIZING THE BLANEY-CRIDDLE PE DATA*

May 1975		20	21	22	23	24	25	26	27	28	29	30	31
Temp. °F		72	75	77	79	71	72	74	77	74	73	74	77
PE mm		3	3	3	3	2	3	3	3	3	3	3	3
PPT mm								12	9			9	
OcB ST		45	42	40	37	36	33	41	45	42	40	45	42
AE			3	2	3	1	3	3	3	2	3	3	3
NrB2 ST		70	68	66	64	63	62	69	74	72	70	74	71
AE			2	2	2	1	1	3	3	2	2	3	3
CrC ST		79	77	75	73	71	69	77	79	77	75	79	77
AE			2	2	2	2	2	3	3	2	2	3	2
WaB ST		49	46	43	41	39	37	45	49	46	43	49	46
AE			3	3	2	2	2	3	3	3	3	3	3
LnA ST		85	82	80	77	76	74	82	86	83	81	86	83
AE			3	2	3	1	2	3	3	3	2	3	3
Tu ST		76	73	70	67	65	62	70	75	72	70	76	73
AE			3	3	2	3	3	3	3	2	2	3	3
Pa ST		43	41	38	36	34	33	41	41	39	37	43	41
AE			2	3	2	2	1	3	3	2	2	3	2
Po ST		93	90	88	85	83	81	89	93	90	88	93	90
AE			3	2	3	2	2	3	3	3	2	3	3
AgB ST		43	41	38	36	34	33	41	41	39	37	43	41
AE			2	2	3	1	3	3	3	2	2	3	2
WkB ST		81	79	77	74	73	70	78	81	79	77	81	79
AE			2	2	3	1	3	3	3	2	2	3	2

*Storage and Actual Evapotranspiration given in mm and missing Precipitation data represents non-rain days

June		1	2	3	4	5	6	7	8	9	10	11	12
Temp. °F		74	74	74	72	76	78	79	64	68	70	70	71
PE mm		4	4	4	3	4	4	4	3	3	3	3	3
PPT mm			10										16
OcB ST		39	45	41	39	36	33	30	28	27	25	23	40
AE		3	4	4	2	3	3	3	2	1	2	2	3
NrB2 ST		68	74	71	69	66	64	60	59	57	55	53	66
AE		3	4	3	2	3	2	4	1	2	2	2	3
CrC ST		74	79	77	74	71	68	65	63	61	59	58	71
AE		3	4	2	3	3	3	3	2	2	2	1	3
WaB ST		42	49	45	42	39	36	32	30	28	27	25	38
AE		4	4	4	3	3	3	4	2	2	1	2	3
LnA ST		80	86	82	80	77	74	70	68	66	64	62	75
AE		3	4	4	2	1	3	4	2	2	2	2	1
Tu ST		69	76	72	69	65	61	57	55	53	51	49	62
AE		4	4	4	3	4	4	4	2	2	2	2	3
Pa ST		38	43	40	37	34	32	29	27	25	24	22	25
AE		3	4	3	3	3	2	3	2	2	1	2	3
Po ST		87	93	89	87	83	80	76	74	71	69	67	79
AE		3	4	4	2	4	3	4	2	3	2	2	3
AgB ST		38	43	40	37	34	32	29	27	25	24	22	25
AE		3	4	3	3	3	2	3	2	2	1	2	3
WkB ST		76	81	78	75	72	69	66	64	62	60	59	74
AE		3	4	3	3	3	3	3	2	2	2	1	3

June		13	14	15	16	17	18	19	20	21	22	23	24
Temp. °F		78	71	74	80	78	81	81	82	72	68	72	74
PE mm		4	3	4	5	4	5	5	5	4	3	4	4
PPT mm					6								
OcB	ST	36	34	32	35	32	29	26	23	22	20	19	17
AE		4	2	2	3	3	3	3	3	1	2	1	2
NrB2	ST	64	62	59	62	60	57	54	52	50	48	47	45
AE		2	2	3	3	2	3	3	2	2	2	1	2
CrC	ST	68	66	64	67	64	61	58	55	53	51	49	47
AE		3	2	2	3	3	3	3	3	2	2	2	2
WaB	ST	35	33	30	33	31	28	25	23	21	20	18	17
AE		3	2	3	3	2	3	3	2	2	1	2	1
LnA	ST	72	69	66	69	66	63	60	58	55	53	52	50
AE		3	3	3	3	3	3	3	2	3	2	1	2
Tu	ST	58	57	53	56	53	50	46	43	41	39	38	35
AE		4	1	4	3	3	3	4	3	2	2	1	3
Pa	ST	23	22	20	23	21	19	17	16	15	14	13	11
AE		1	1	2	3	2	2	2	1	1	1	1	2
Po	ST	76	73	70	73	70	66	64	60	59	57	54	52
AE		3	3	3	3	3	4	2	4	1	2	3	2
AgB	ST	23	22	20	23	21	19	17	16	15	14	13	11
AE		2	1	2	3	2	2	2	1	1	1	1	2
WkB	ST	72	70	67	70	68	64	61	58	56	54	52	50
AE		2	2	3	3	2	4	3	3	2	2	2	2

June	25	26	27	28	29	30	July	1	2	3	4
Temp. °F	78	79	75	72	72	75		73	70	77	76
PE mm	4	4	4	4	4	4		4	4	5	5
PPT mm			22								9
OcB ST	16	15	33	32	29	27		24	22	20	25
AE	1	1	4	1	3	2		3	2	2	4
NrB2 ST	43	41	59	57	55	53		51	49	46	51
AE	2	2	4	2	2	2		2	3	3	4
CrC ST	45	43	60	58	56	53		51	49	46	51
AE	2	2	4	2	2	3		2	2	3	4
WaB ST	16	14	32	30	27	25		23	21	19	24
AE	1	2	4	2	3	2		2	2	2	4
LnA ST	48	46	64	62	60	58		56	53	51	56
AE	2	2	4	2	2	2		2	3	2	4
Tu ST	34	32	50	47	45	43		40	38	36	41
AE	1	2	4	3	2	2		3	2	2	4
Pa ST	10	9	27	25	23	21		18	18	16	21
AE	1	1	4	2	2	2		2	1	2	4
Po ST	50	48	66	64	62	59		57	54	52	56
AE	2	2	4	2	2	3		2	3	2	4
AgB ST	10	9	27	25	23	21		19	18	16	21
AE	1	1	4	2	2	2		2	1	2	4
WkB ST	48	46	64	62	60	58		55	53	50	55
AE	2	2	4	2	2	2		3	2	3	4

July		5	6	7	8	9	10	11	12	13	14	15	16
Temp. °F		71	72	76	76	79	79	79	72	74	76	77	77
PE mm		4	4	5	5	5	5	5	4	4	5	5	5
PPT mm			12	17						41	67		10
OcB ST		23	31	44	40	36	32	35	33	45	45	41	45
AE		2	4	4	4	4	4	4	2	4	5	4	5
NrB2 ST		49	56	69	66	62	59	62	60	80	80	76	80
AE		2	4	4	3	4	3	4	2	4	5	4	5
CrC ST		49	56	69	66	62	59	62	60	79	79	76	79
AE		2	4	4	3	4	3	4	2	4	5	3	5
WaB ST		22	30	43	39	35	32	35	32	49	49	45	49
AE		2	4	4	4	4	3	4	3	4	5	4	5
LnA ST		54	62	75	71	68	64	67	64	86	86	81	86
AE		2	4	4	4	3	4	4	3	4	5	5	5
Tu ST		39	46	59	56	52	49	52	50	76	76	71	76
AE		2	4	4	3	4	3	4	2	4	5	5	5
Pa ST		19	27	40	36	32	29	32	30	43	43	39	43
AE		2	4	4	4	4	3	4	2	4	5	4	5
Po ST		54	62	75	71	68	64	67	64	93	93	88	93
AE		2	4	4	4	3	4	4	3	4	5	5	5
AgB ST		19	27	40	36	32	29	32	30	43	43	39	43
AE		2	4	4	4	4	3	4	2	4	5	4	5
WkB ST		53	61	74	71	68	64	67	64	81	81	77	81
AE		2	4	4	3	3	4	4	3	4	5	4	5

July		17	18	19	20	21	22	23	24	25	26	27	28
Temp. °F		76	77	72	75	80	82	83	83	80	71	67	77
PE mm		5	5	4	5	5	6	6	6	5	4	3	5
PPT mm		13								9			
OcB ST		45	41	38	35	32	28	25	22	27	25	23	21
AE		5	4	3	3	3	3	3	3	4	2	2	2
NrB2 ST		80	76	73	70	66	64	62	60	68	66	64	60
AE		5	4	3	3	4	2	2	2	2	2	2	4
CrC ST		79	76	73	70	66	64	62	60	68	66	64	60
AE		5	3	3	3	4	2	2	2	2	2	2	4
WaB ST		49	44	41	36	33	30	26	23	28	26	24	21
AE		5	5	3	5	3	3	4	3	4	2	2	3
LnA ST		86	81	78	75	71	67	64	61	66	64	62	59
AE		5	5	3	3	4	4	3	3	4	2	2	3
Tu ST		76	71	67	63	58	54	51	46	51	49	46	44
AE		5	5	4	4	5	4	3	5	4	2	3	3
Pa ST		43	39	36	33	30	27	23	21	26	24	22	20
AE		5	4	3	3	3	3	4	2	4	2	2	2
Po ST		93	88	85	81	77	74	70	66	71	68	66	63
AE		5	5	3	4	4	3	4	4	4	3	2	3
AgB ST		43	39	36	33	30	27	23	21	26	24	22	20
AE		5	4	3	3	3	3	4	2	4	2	2	2
WkB ST		81	77	74	71	68	64	60	58	63	60	59	56
AE		5	4	3	3	3	4	4	2	4	3	1	3

July	29	30	31	August	1	2	3	4	5	6	7
Temp. °F	80	78	80		77	76	80	85	84	81	71
PE mm	5	5	5		5	5	5	6	6	5	4
PPT mm		14								22	
OcB ST	19	29	27		24	22	20	18	16	34	32
AE	2	4	2		3	2	2	2	2	3	2
NrB2 ST	58	68	65		62	59	56	53	50	68	66
AE	2	4	3		3	3	3	3	3	4	2
CrC ST	58	68	65		62	59	56	53	50	68	66
AE	2	4	3		3	3	3	3	3	4	2
WaB ST	19	29	26		23	21	19	17	15	33	31
AE	2	4	3		3	2	2	2	2	4	2
LnA ST	56	66	63		60	58	54	51	49	67	64
AE	3	4	3		3	2	4	3	2	4	3
Tu ST	41	51	48		45	43	39	36	34	52	50
AE	3	4	3		3	2	4	3	2	4	2
Pa ST	18	28	25		23	21	19	17	15	33	31
AE	2	4	3		2	2	2	2	2	4	2
Po ST	60	70	67		64	61	58	54	51	69	66
AE	3	4	3		3	3	3	4	3	4	3
AgB ST	18	28	25		23	21	19	17	15	33	31
AE	2	4	3		2	2	2	2	2	4	2
WkB ST	53	63	60		58	55	52	49	46	64	62
AE	3	4	3		2	3	3	3	3	4	2

August		8	9	10	11	12	13	14	15	16	17	18	19
Temp. °F		75	76	74	80	76	77	79	79	79	77	77	70
PE mm		5	5	4	5	5	5	5	5	5	5	5	4
PPT mm												9	
OcB ST		29	26	24	21	19	17	16	14	13	11	16	15
AE		3	3	2	3	2	2	1	2	1	2	4	1
NrB2 ST		63	60	58	54	52	49	47	44	42	40	45	44
AE		3	3	2	4	2	3	2	3	2	2	4	1
CrC ST		63	60	58	54	52	49	47	44	42	40	45	44
AE		3	3	2	4	2	3	2	3	2	2	4	1
WaB ST		28	25	23	20	18	17	15	13	12	11	16	15
AE		3	3	2	3	2	1	2	2	1	1	4	1
LnA ST		61	58	56	53	50	48	46	44	41	39	44	43
AE		3	3	2	3	3	2	2	2	3	2	4	1
Tu ST		46	44	41	38	36	34	32	30	28	26	31	30
AE		4	2	3	3	2	2	2	2	2	2	4	1
Pa ST		28	25	23	21	19	17	15	14	12	11	16	15
AE		3	3	2	2	2	2	2	1	2	1	4	1
Po ST		64	60	58	55	52	50	47	45	43	40	45	44
AE		2	4	2	3	3	2	3	2	2	3	4	1
AgB ST		28	25	23	21	19	17	15	14	12	11	16	15
AE		3	3	2	2	2	2	2	1	2	1	4	1
WkB ST		59	56	53	51	48	46	44	41	39	37	42	40
AE		3	3	3	2	3	2	2	3	2	2	4	2

August		20	21	22	23	24	25	26	27	28	29	30	31
Temp. °F		74	74	76	78	78	83	85	83	78	74	80	69
PE mm		4	4	5	5	5	6	6	6	5	4	5	4
PPT mm								17					
OcB ST		14	13	11	10	9	8	21	19	17	16	14	13
AE		1	1	2	1	1	1	4	2	2	1	2	1
NrB2 ST		42	40	38	36	34	32	45	43	40	39	37	35
AE		2	2	2	2	2	2	4	2	3	1	2	2
CrC ST		42	40	38	36	34	32	45	43	40	39	37	35
AE		2	2	2	2	2	2	4	2	3	1	2	2
WaB ST		14	13	11	10	9	8	21	19	17	16	14	13
AE		1	1	2	1	1	1	4	2	2	1	2	1
LnA ST		41	39	37	35	34	32	45	43	40	39	37	35
AE		2	2	2	2	1	2	4	2	3	1	2	2
Tu ST		28	27	25	23	22	20	33	31	29	27	25	24
AE		2	1	2	2	1	2	4	2	2	2	2	1
Pa ST		14	12	11	10	9	8	21	19	17	16	14	13
AE		1	2	1	1	1	1	4	2	2	1	2	1
Po ST		42	40	38	36	34	32	45	43	40	39	37	35
AE		2	2	2	2	2	2	4	2	3	1	2	2
AgB ST		14	12	11	10	9	8	21	19	17	16	14	13
AE		1	2	1	1	1	1	4	2	2	1	2	1
WkB ST		39	37	35	34	32	30	43	40	38	37	35	34
AE		1	2	2	1	2	2	4	3	2	1	2	1

Sept.	1	2	3	4	5	6	7	8	June 1976	1
Temp. °F	78	75	78	77	79	78	73	77		55
PE mm	4	4	4	4	4	4	4	4		2
PPT mm	24									
OcB ST	33	30	28	25	23	21	19	18		45
AE	4	3	2	3	2	2	2	1		
NrB2 ST	55	53	51	49	47	45	43	41		80
AE	4	2	2	2	2	2	2	2		
CrC ST	55	53	51	49	47	45	43	41		79
AE	4	2	2	2	2	2	2	2		
WaB ST	33	31	28	26	24	22	20	18		49
AE	4	2	3	2	2	2	2	2		
LnA ST	55	53	51	49	47	45	43	41		86
AE	4	2	2	2	2	2	2	2		
Tu ST	44	42	39	38	35	34	32	30		76
AE	4	2	3	1	3	1	2	2		
Pa ST	33	31	28	26	24	22	20	18		43
AE	4	2	3	2	2	2	2	2		
Po ST	55	53	51	49	47	45	43	41		93
AE	4	2	2	2	2	2	2	2		
AgB ST	33	31	28	26	24	22	20	18		43
AE	4	2	3	2	2	2	2	2		
WkB ST	54	52	50	48	46	44	43	41		81
AE	4	2	2	2	2	2	1	2		

June		2	3	4	5	6	7	8	9	10	11	12	13
Temp. °F		55	54	54	54	56	61	63	64	63	68	66	70
PE mm		2	2	2	2	2	3	3	3	3	3	3	3
PPT mm			52	6							4		
OcB ST		43	45	45	41	39	36	34	33	31	33	32	30
AE		2	2	2	4	2	3	2	1	2	2	1	2
NrB2 ST		78	80	78	77	74	72	70	68	70	68	66	64
AE		2	2	2	2	1	3	2	2	2	2	2	2
CrC ST		78	79	79	78	77	74	72	70	68	70	68	66
AE		1	2	2	1	1	3	2	2	2	2	2	2
WaB ST		47	49	49	47	44	41	39	36	34	35	33	31
AE		2	2	2	2	2	3	2	3	2	2	2	2
LnA ST		86	84	86	86	84	82	80	77	75	73	70	67
AE		2	2	2	2	2	2	2	3	2	2	2	3
Tu ST		74	76	76	74	72	69	66	64	61	62	59	57
AE		2	2	2	2	2	3	3	2	3	2	3	2
Pa ST		41	43	43	41	40	37	35	33	32	33	32	30
AE		2	2	2	2	1	3	2	2	1	2	1	2
Po ST		91	93	93	91	89	87	84	81	79	80	77	75
AE		2	2	2	2	2	2	3	2	2	2	3	2
AgB ST		41	43	43	41	40	37	35	33	32	33	32	30
AE		2	2	2	2	1	3	2	2	1	2	1	2
WkB ST		80	81	81	80	78	76	74	71	69	70	68	66
AE		1	2	2	1	2	2	2	3	2	2	2	2

June		14	15	16	17	18	19	20	21	22	23	24	25
Temp. °F		66	67	68	66	70	72	72	67	67	67	68	71
PE mm		3	3	3	3	3	4	4	3	3	3	3	3
PPT mm					9			6		27			9
OcB ST		28	26	24	30	28	27	30	28	45	42	40	45
AE		2	2	2	3	2	1	3	2	3	3	2	3
NrB2 ST		64	62	60	66	64	62	65	63	80	77	75	80
AE		2	2	2	3	2	2	3	2	3	3	2	3
CrC ST		64	62	60	66	64	62	65	63	79	77	75	79
AE		2	2	2	3	2	2	3	2	3	2	2	3
WaB ST		29	27	25	31	29	27	30	28	49	46	43	49
AE		2	2	2	3	2	2	3	2	3	3	3	3
LnA ST		64	62	60	66	64	62	65	63	86	83	81	86
AE		2	2	2	3	2	2	3	2	3	3	2	3
Tu ST		55	53	51	57	55	53	56	53	76	73	70	76
AE		2	2	2	3	2	2	3	3	3	3	3	3
Pa ST		28	26	24	30	28	26	29	27	43	41	38	43
AE		2	2	2	3	2	2	3	2	3	2	3	3
Po ST		73	70	68	74	72	69	72	70	93	90	88	93
AE		2	3	2	3	2	3	3	2	3	3	2	3
AgB ST		28	26	24	30	28	26	29	27	43	41	38	43
AE		2	2	2	3	2	2	3	2	3	2	3	3
WkB ST		64	62	60	66	64	62	65	63	81	79	77	81
AE		2	2	2	3	2	2	3	2	3	2	2	3

June	26	27	28	29	30	July	1	2	3	4	5
Temp. °F	73	72	71	72	72		72	71	68	72	74
PE mm	4	4	3	3	3		4	4	4	4	4
PPT mm							25	37			
OcB ST	41	38	36	33	31		45	45	41	38	35
AE	4	3	2	3	2		4	4	4	3	3
NrB2 ST	77	74	71	68	66		80	80	77	74	71
AE	3	3	3	3	2		4	4	3	3	3
CrC ST	77	74	71	68	66		79	79	77	74	71
AE	2	3	3	3	2		4	4	2	3	3
WaB ST	45	42	39	36	33		49	49	45	41	38
AE	4	3	3	3	3		4	4	4	4	3
LnA ST	82	80	77	74	72		86	86	82	79	76
AE	4	2	3	3	2		4	4	4	3	3
Tu ST	72	69	66	63	60		76	76	72	68	64
AE	4	3	3	3	3		4	4	4	4	4
Pa ST	40	37	34	32	30		43	43	40	36	33
AE	3	3	3	2	2		4	4	3	4	3
Po ST	89	87	84	81	78		93	93	89	86	82
AE	4	2	3	3	3		4	4	4	3	4
AgB ST	40	37	34	32	30		43	43	40	36	33
AE	3	3	3	2	2		4	4	3	4	3
WkB ST	78	75	73	70	68		81	81	78	75	72
AE	3	3	3	3	3		4	4	3	3	3

July		6	7	8	9	10	11	12	13	14
Temp. °F		71	65	70	76	68	69	66	64	68
PE mm		4	3	4	5	4	4	3	3	4
PPT mm			13							
OcB ST		32	42	39	36	33	31	28	26	24
AE		3	3	3	3	3	2	3	2	2
NrB2 ST		68	78	75	72	69	66	64	62	60
AE		3	3	3	3	3	3	2	2	2
CrC ST		68	78	75	72	69	66	64	62	60
AE		3	3	3	3	3	3	2	2	2
WaB ST		35	45	41	37	35	32	30	28	27
AE		3	3	4	4	2	3	2	2	1
LnA ST		73	83	80	77	74	70	68	66	64
AE		3	3	3	3	3	4	2	2	2
Tu ST		60	70	66	61	58	56	53	51	50
AE		4	3	4	5	3	2	3	2	2
Pa ST		31	41	38	34	32	30	28	26	24
AE		2	3	3	4	2	2	2	2	2
Po ST		79	89	86	81	79	76	74	71	68
AE		3	3	3	5	2	3	2	3	3
AgB ST		31	41	38	34	32	30	28	26	24
AE		2	3	3	4	2	2	2	2	2
WkB ST		69	79	76	72	70	67	65	63	60
AE		3	3	3	4	2	3	2	2	3

APPENDIX 3 TABLE C

WATER BUDGET UTILIZING THE THORNTHWAITE PE DATA*

May		20	21	22	23	24	25	26	27	28	29	30	31
Temp. °C		22	24	25	26	22	22	23	25	23	23	23	25
PE mm		3	4	4	4	3	3	4	4	4	4	4	4
PPT mm								12	9			9	
OcB ST		45	41	38	35	33	31	39	44	41	37	43	41
AE			4	3	3	2	2	4	4	3	4	3	2
NrB2 ST		80	78	77	74	72	70	78	80	77	74	80	77
AE			2	1	3	2	2	4	4	3	3	3	3
CrC ST		79	77	74	70	68	66	74	79	77	74	79	77
AE			2	3	4	2	2	4	4	2	3	3	2
WaB ST		49	45	41	38	36	33	41	47	43	40	48	44
AE			4	4	3	2	3	4	4	4	3	3	4
LnA ST		85	81	78	75	73	70	78	83	80	77	85	81
AE			4	3	3	2	3	4	4	3	3	3	4
Tu ST		75	72	69	66	64	62	70	75	72	69	76	73
AE			3	3	3	2	2	4	4	3	3	3	3
Pa ST		43	40	36	33	32	30	38	43	40	36	43	40
AE			3	4	3	1	2	4	4	3	4	3	3
Po ST		93	89	86	82	80	77	85	90	87	83	91	88
AE			4	3	4	2	3	4	4	3	4	3	3
AgB ST		43	40	36	33	32	30	38	43	40	36	43	40
AE			3	4	3	1	2	4	4	3	4	3	3
WkB ST		81	78	75	72	70	68	76	81	78	75	81	78
AE			3	3	3	2	2	4	4	3	3	3	3

*Storage and Actual Evapotranspiration given in mm and missing Precipitation data represents non-rain days

June	1	2	3	4	5	6	7	8	9	10	11	12
Temp. °C	23	23	23	22	24	26	26	18	20	21	21	21
PE mm	4	4	4	4	4	5	5	3	3	3	3	3
PPT mm		10										16
OcB ST	38	45	41	38	35	32	28	27	25	23	22	35
AE	3	4	4	3	3	3	3	1	2	2	1	3
NrB2 ST	74	80	77	74	70	67	66	65	63	62	61	75
AE	3	4	3	3	4	3	1	1	2	1	1	3
CrC ST	74	79	77	74	70	67	70	68	66	64	62	75
AE	3	4	2	3	4	3	3	2	2	2	2	3
WaB ST	41	49	45	41	38	34	32	30	28	26	24	37
AE	3	4	4	4	3	4	2	2	2	2	2	3
LnA ST	78	86	82	79	76	72	68	66	64	62	60	73
AE	3	4	4	3	3	4	4	2	2	2	2	3
Tu ST	70	76	73	70	67	64	60	59	57	55	53	66
AE	3	4	3	3	3	3	4	1	2	2	2	3
Pa ST	36	43	40	36	33	30	27	25	24	22	21	24
AE	4	4	3	4	3	3	3	2	1	2	1	3
Po ST	85	93	89	86	82	78	74	72	70	68	66	79
AE	3	4	4	3	4	4	4	2	2	2	2	3
AgB ST	36	43	40	36	33	30	27	25	24	22	21	24
AE	4	4	3	4	3	3	3	2	1	2	1	3
WkB ST	75	81	78	75	72	68	65	63	61	59	58	71
AE	3	4	3	3	3	4	3	2	2	2	1	3

June		13	14	15	16	17	18	19	20	21	22	23	24
Temp. °C		26	22	23	27	26	27	27	28	22	20	22	23
PE mm		5	4	4	5	5	6	6	6	4	3	4	4
PPT mm					6								
OcB	ST	32	29	27	30	27	24	21	18	17	16	15	13
AE		3	3	2	3	3	3	3	3	1	1	1	2
NrB2	ST	71	68	66	69	66	62	58	54	52	51	49	47
AE		4	3	2	3	3	4	4	4	2	1	2	2
CrC	ST	71	68	66	69	66	62	58	54	52	51	49	47
AE		4	3	2	3	3	4	4	4	2	1	2	2
WaB	ST	33	28	31	28	24	21	19	17	16	15	14	12
AE		4	2	3	3	3	4	3	2	2	1	1	1
LnA	ST	69	66	64	67	64	60	56	53	51	49	47	45
AE		4	3	2	3	3	4	4	3	2	2	2	2
Tu	ST	63	60	58	61	58	54	51	53	48	47	45	43
AE		3	3	2	3	3	4	3	2	5	1	2	2
Pa	ST	22	20	18	21	19	17	15	13	12	11	10	9
AE		2	2	2	3	2	2	2	2	1	1	1	1
Po	ST	75	72	69	71	68	64	60	56	54	52	50	48
AE		4	3	3	3	3	4	4	4	2	2	2	2
AgB	ST	22	20	18	21	19	17	15	13	12	11	10	9
AE		2	2	2	3	2	2	2	2	1	1	1	1
WkB	ST	68	65	62	64	61	58	54	51	49	47	45	44
AE		3	3	3	3	3	3	4	3	2	2	2	1

June	25	26	27	28	29	30	July	1	2	3	4
Temp. °C	26	26	24	22	22	24		23	21	25	24
PE mm	5	5	4	4	4	5		4	4	5	5
PPT mm			21								9
OcB ST	12	10	28	26	24	21		19	18	16	21
AE	1	2	3	2	2	3		2	1	2	4
NrB2 ST	44	42	60	58	56	53		51	49	47	52
AE	3	2	3	2	2	3		2	2	2	4
CrC ST	44	42	60	58	56	53		51	49	47	52
AE	3	2	3	2	2	3		2	2	2	4
WaB ST	12	11	29	27	24	22		20	18	17	22
AE	2	1	3	2	3	2		2	2	1	4
LnA ST	43	41	59	57	54	52		50	48	46	51
AE	2	2	3	2	3	2		2	2	2	4
Tu ST	41	39	57	54	52	50		48	46	44	49
AE	2	2	3	3	2	2		2	2	2	4
Pa ST	8	8	26	24	22	19		18	17	15	20
AE	1	0	3	2	2	3		1	1	2	4
Po ST	46	44	62	60	58	54		52	50	48	53
AE	2	2	3	2	2	4		2	2	2	4
AgB ST	8	8	26	24	22	19		18	17	15	20
AE	1	0	3	2	2	3		1	1	2	4
WkB ST	41	39	57	54	52	50		48	46	44	49
AE	3	2	3	3	2	2		2	2	2	4

July		5	6	7	8	9	10	11	12	13	14	15	16
Temp. °C		22	22	24	24	26	26	26	22	23	24	25	25
PE mm		4	4	5	5	5	5	5	4	4	4	5	5
PPT mm			12	17				7		41	67		10
OcB ST		19	26	39	35	32	28	31	28	45	45	41	45
AE		2	4	4	4	3	4	4	3	4	4	4	5
NrB2 ST		50	58	71	68	64	61	64	62	80	80	76	80
AE		2	4	4	3	4	3	4	2	4	4	4	5
CrC ST		50	58	71	68	64	61	64	62	79	79	76	79
AE		2	4	4	3	4	3	4	2	4	4	3	5
WaB ST		20	28	41	37	33	30	33	30	49	49	44	49
AE		2	4	4	4	4	3	4	3	4	4	5	5
LnA ST		49	57	70	67	64	60	63	60	86	86	81	86
AE		2	4	4	3	3	4	4	3	4	4	5	5
Tu ST		47	55	68	65	62	59	62	60	76	76	72	76
Pa ST		19	27	40	36	32	29	34	32	43	43	39	43
AE		1	4	4	4	4	3	4	2	4	4	4	5
Po ST		51	59	72	68	65	62	65	62	93	93	88	93
AE		2	4	4	4	3	3	4	3	4	4	5	5
AgB ST		19	27	40	36	32	29	34	32	43	43	39	43
AE		1	4	4	4	4	3	4	2	4	4	4	5
WkB ST		47	55	68	65	62	59	62	60	81	81	77	81
AE		2	4	4	3	3	3	4	2	4	4	4	5

July		17	18	19	20	21	22	23	24	25	26	27	28
Temp. °C		24	25	22	24	27	28	28	28	27	22	19	25
PE mm		5	5	4	4	5	6	6	6	5	4	3	5
PPT mm		13								9			
OcB ST		45	41	37	34	31	27	24	21	26	24	22	20
AE		5	4	4	3	3	4	3	3	4	2	2	2
NrB2 ST		80	76	73	70	66	62	59	55	60	58	56	53
AE		5	4	3	3	4	4	3	4	4	2	2	3
CrC ST		79	76	73	70	66	62	59	55	60	58	56	53
AE		5	3	3	3	4	4	3	4	4	2	2	3
WaB ST		49	44	41	37	33	30	26	23	28	26	24	22
AE		5	5	3	4	4	3	4	3	4	2	2	2
LnA ST		86	81	78	75	71	67	63	59	64	62	60	57
AE		5	5	3	3	4	4	4	4	4	2	2	3
Tu ST		76	72	69	66	63	59	56	52	57	54	53	50
AE		5	4	3	3	3	4	3	4	4	3	1	3
Pa ST		43	39	36	33	30	26	23	20	25	23	22	19
AE		5	4	3	3	3	4	3	3	4	2	1	3
Po ST		93	88	85	81	77	73	68	64	69	66	64	61
AE		5	5	3	4	4	4	5	4	4	3	2	3
AgB ST		43	39	36	33	30	26	23	20	25	23	22	19
AE		5	4	3	3	3	4	3	3	4	2	1	3
WkB ST		81	77	74	71	68	64	60	56	61	59	57	54
AE		5	4	3	3	3	4	4	4	4	2	2	3

July	29	30	31	August	1	2	3	4	5	6	7
Temp. °C	27	26	27		25	24	27	29	29	27	22
PE mm	5	5	5		5	5	5	6	6	5	4
PPT mm		14								22	
OcB ST	18	28	25		23	20	18	16	14	32	30
AE	2	5	3		2	3	2	2	2	4	2
NrB2 ST	51	61	58		55	52	50	47	44	62	60
AE	2	5	3		3	3	2	3	3	4	2
CrC ST	51	61	58		55	52	50	47	44	62	60
AE	2	5	3		3	3	2	3	3	4	2
WaB ST	19	29	26		23	21	19	17	15	38	35
AE	3	5	3		3	2	2	2	2	4	3
LnA ST	54	64	61		58	55	52	49	46	64	62
AE	3	5	3		3	3	3	3	3	4	2
Tu ST	48	58	55		52	50	47	44	42	60	58
AE	2	5	3		3	2	3	3	2	4	2
Pa ST	18	28	25		23	20	18	16	14	32	30
AE	1	5	3		2	3	2	2	2	4	2
Po ST	58	68	65		62	59	56	52	49	67	64
AE	3	5	3		3	3	3	4	3	4	3
AgB ST	18	28	25		23	20	18	16	14	32	30
AE	1	5	3		2	3	2	2	2	4	2
WkB ST	51	61	58		55	52	50	47	44	62	60
AE	3	5	3		3	3	2	3	3	4	2

August		8	9	10	11	12	13	14	15	16	17	18	19
Temp. °C		24	24	23	27	24	25	26	26	26	25	25	21
PE mm		4	4	4	5	4	4	5	5	5	4	4	3
PPT mm												9	
OcB ST		27	25	23	20	19	17	16	14	13	11	16	15
AE		3	2	2	3	1	2	1	2	1	2	4	1
NrB2 ST		58	55	53	50	48	46	44	42	40	38	43	42
AE		2	3	2	3	2	2	2	2	2	2	4	1
CrC ST		58	55	53	50	48	46	44	42	40	38	43	42
AE		2	3	2	3	2	2	2	2	2	2	4	1
WaB ST		32	30	27	24	22	20	18	17	15	14	19	18
AE		3	2	3	3	2	2	2	1	2	1	4	1
LnA ST		59	57	54	52	50	48	45	43	41	39	44	43
AE		3	2	2	2	2	2	3	2	2	2	4	1
Tu ST		56	53	51	49	47	45	43	40	39	37	42	41
AE		2	3	2	2	2	2	2	3	1	2	4	1
Pa ST		27	25	23	20	19	17	16	14	13	11	16	15
AE		3	2	2	3	1	2	1	2	1	2	4	1
Po ST		62	59	57	54	52	50	47	45	43	41	46	45
AE		2	3	2	3	2	2	3	2	2	2	4	1
AgB ST		27	25	23	20	19	17	16	14	13	11	16	15
AE		3	2	2	3	1	2	1	2	1	2	4	1
WkB ST		58	55	53	50	48	46	44	42	40	38	43	42
AE		2	3	2	3	2	2	2	2	2	2	4	1

August		20	21	22	23	24	25	26	27	28	29	30	31
Temp. °C		23	23	24	26	26	28	29	28	26	23	27	26
PE mm		4	4	4	5	5	5	6	5	5	4	5	5
PPT mm								17					
OcB ST		14	13	11	10	9	8	21	19	17	16	14	13
AE		1	1	2	1	1	1	4	2	2	1	2	1
NrB2 ST		40	38	37	35	33	32	45	43	41	39	37	35
AE		2	2	1	2	2	1	4	2	2	2	2	2
CrC ST		40	38	37	35	33	32	45	43	41	39	37	35
AE		2	2	1	2	2	1	4	2	2	2	2	2
WaB ST		17	16	14	13	11	10	23	21	19	17	16	14
AE		1	1	2	1	2	1	4	2	2	2	1	2
LnA ST		41	39	38	36	34	32	45	43	41	39	37	35
AE		2	2	1	2	2	2	4	2	2	2	2	2
Tu ST		39	38	36	34	31	30	44	42	40	38	36	34
AE		2	1	2	2	3	1	4	2	2	2	2	2
Pa ST		14	13	11	10	9	8	21	19	17	16	14	13
AE		1	1	2	1	1	1	4	2	2	1	2	1
Po ST		43	41	40	38	36	34	47	45	43	41	39	37
AE		2	2	1	2	2	2	4	2	2	2	2	2
AgB ST		14	13	11	10	9	8	21	19	17	16	14	13
AE		1	1	2	1	1	1	4	2	2	1	2	1
WkB ST		40	38	37	35	33	32	45	43	41	39	37	35
AE		2	2	1	2	2	1	4	2	2	2	2	2

Sept.		1	2	3	4	5	6	7	8	June 1976	1
Temp. °C		26	24	26	25	26	26	23	25		13
PE mm		5	4	4	4	5	4	4	4		1
PPT mm		24									
OcB ST		33	31	28	26	23	21	19	18		45
AE		4	2	3	2	3	2	2	1		
NrB2 ST		55	53	51	49	46	44	43	41		80
AE		4	2	2	2	3	2	1	2		
CrC ST		55	53	51	49	46	44	43	41		79
AE		4	2	2	2	3	3	1	2		
WaB ST		34	32	29	27	24	22	20	18		49
AE		4	2	3	2	3	2	2	2		
LnA ST		55	53	51	49	46	44	43	41		86
AE		4	2	2	2	3	2	1	2		
Tu ST		54	52	50	48	45	43	42	40		76
AE		4	2	2	2	3	2	1	2		
Pa ST		33	31	28	26	23	21	19	18		43
AE		4	2	3	2	3	2	2	1		
Po ST		57	54	52	50	48	46	44	42		93
AE		4	3	2	2	2	2	2	2		
AgB ST		33	31	28	26	23	21	19	18		43
AE		4	2	3	2	3	2	2	1		
WkB ST		55	53	51	49	46	44	43	41		81
AE		4	2	2	2	3	2	1	2		

June		2	3	4	5	6	7	8	9	10	11	12	13
Temp. °C		12	12	12	13	16	17	18	17	20	19	21	19
PE mm		1	1	1	2	2	3	3	3	3	3	3	3
PPT mm			52	6							4		
OcB	ST	44	45	45	43	41	39	36	34	32	33	32	30
AE		1	1	1	2	2	2	3	2	2	3	1	2
NrB2	ST	79	80	80	78	77	74	72	70	68	69	67	65
AE		1	1	1	2	1	3	2	2	2	3	2	2
CrC	ST	78	79	79	78	77	74	72	70	68	69	67	65
AE		1	1	1	1	1	3	2	2	2	3	2	2
WaB	ST	48	49	47	45	42	40	37	35	36	34	32	30
AE		1	1	2	2	3	2	3	2	3	2	2	2
LnA	ST	85	86	86	84	82	80	77	75	73	74	71	69
AE		1	1	1	2	2	2	3	2	2	3	3	2
Tu	ST	75	76	76	74	73	70	68	66	64	65	63	61
AE		1	1	1	2	1	3	2	2	2	3	2	2
Pa	ST	42	43	43	41	40	37	35	33	31	32	30	28
AE		1	1	1	2	1	3	2	2	2	3	2	2
Po	ST	92	93	93	91	89	87	84	81	79	80	77	75
AE		1	1	1	2	2	2	3	3	2	3	3	2
AgB	ST	42	43	43	41	40	37	35	33	31	32	30	28
AE		1	1	1	2	1	3	2	2	2	3	2	2
WkB	ST	80	81	81	78	76	74	71	69	70	68	66	64
AE		1	1	1	1	2	2	2	2	3	2	2	2

June		14	15	16	17	18	19	20	21	22	23	24	25
Temp. °C		19	20	20	19	21	22	22	20	20	20	20	25
PE mm		3	3	3	3	4	4	4	3	3	3	3	4
PPT mm					9			6					9
OcB	ST	28	26	24	30	28	25	28	27	45	42	40	45
AE		2	2	2	3	2	3	3	1	3	3	2	4
NrB2	ST	63	61	59	65	62	60	63	61	80	77	75	80
AE		2	2	2	3	3	2	3	2	3	3	2	4
CrC	ST	63	61	59	65	62	60	63	61	79	77	75	79
AE		2	2	2	3	3	2	3	2	3	2	2	4
WaB	ST	30	28	27	33	31	28	31	29	49	46	43	49
AE		2	2	1	3	2	3	3	2	3	3	3	4
LnA	ST	67	65	63	69	66	64	66	64	86	83	81	86
AE		2	2	2	3	3	2	3	2	3	3	2	4
Tu	ST	59	58	56	62	60	58	61	59	76	74	71	76
AE		2	1	2	3	2	2	3	2	3	2	3	4
Pa	ST	27	25	23	29	27	24	26	24	43	41	38	43
AE		1	2	2	3	2	3	3	2	3	2	3	4
Po	ST	73	70	68	74	71	68	71	69	93	90	88	93
AE		2	3	2	3	3	3	3	2	3	3	2	4
AgB	ST	27	25	23	29	27	24	26	24	43	41	38	43
AE		1	2	2	3	2	3	3	2	3	2	3	4
WkB	ST	64	62	60	66	64	61	63	61	81	79	77	81
AE		2	2	2	3	2	3	3	2	3	2	2	4

June	26	27	28	29	30	July	1	2	3	4	5
Temp. °C	23	22	22	22	22		22	22	20	21	24
PE mm	4	4	4	4	4		4	4	3	4	4
PPT mm							25	37			
OcB ST	41	38	35	32	30		45	45	42	39	36
AE	4	3	3	3	2		4	4	3	3	3
NrB2 ST	77	74	70	68	65		80	80	77	74	71
AE	3	3	4	2	3		4	4	3	3	3
CrC ST	77	74	70	68	65		79	79	77	74	71
AE	2	3	4	2	3		4	4	2	3	3
WaB ST	45	41	38	35	32		49	49	46	42	39
AE	4	4	3	3	3		4	4	3	4	3
LnA ST	82	79	76	73	70		86	86	83	80	77
AE	4	3	3	3	3		4	4	3	3	3
Tu ST	73	70	67	64	61		76	76	74	70	68
AE	3	3	3	3	3		4	4	2	4	2
Pa ST	40	36	33	31	28		43	43	41	37	34
AE	3	4	3	2	3		4	4	2	4	3
Po ST	89	86	82	79	76		93	93	89	86	82
AE	4	3	4	3	3		4	4	4	3	4
AgB ST	40	36	33	31	28		43	43	41	37	34
AE	3	4	3	2	3		4	4	2	4	3
WkB ST	78	75	72	69	66		81	81	79	76	73
AE	3	3	3	3	3		4	4	2	3	3

REFERENCES

- American Society Of Agronomy. 1965. Methods Of Soil Analysis, Physical And Mineralogical Properties, Including Statistics Of Measurement And Sampling. Agronomy #9. Madison, Wisconsin.
- Black, Peter E. 1967. Thorntwaite's Mean Annual Water Balance. Silviculture General Utility Library Program GU-101, State Univ. Col. Forest. Syracuse, N.Y.
- Blaney, Harry F. 1955. Climate As An Index Of Irrigation Needs. 1955 Yearbook Of Agriculture. Dept. Of Agriculture, Washington, D.C.
- Blaney, Harry F., and Criddle Wayne D. 1962. Determining Consumptive Use And Irrigation Water Requirements. U.S. Dept. Agricultural Technical Bulletin 1275.
- Blaney, H.F., and Criddle, W.D. 1950. Determining Water Requirements In Irrigated Areas From Climatological And Irrigation Data. U.S. Dept. Agric. Soil Conserv. Service.
- Blaney, Harry F., and Hanson, Eldon G. 1965. Consumptive Use And Water Requirements In New Mexico. Technical Report 32. New Mexico State Engineer, Santa Fe, New Mexico.
- Chang, Jen-Hu. 1968. Climate And Agriculture: An Ecological Survey. Chicago: Aldine Publishing Co.
- Chang, Jen-Hu. 1970. Potential Photosynthesis And Crop Productivity. Annals Of The Association Of American Geographers. Vol. 60.
- Cruff, R.W., and Thompson, T.H. 1967. A Comparison Of Methods Of Estimating Potential Evapotranspiration From Climatological Data In Arid And Subhumid Environments. U.S. Geological Survey Water Supply Paper 1839-M.
- Denmead, O.T., and Shaw, R.H. 1962. Availability Of Soil Water To Plants As Affected By Soil Moisture Content. Agronomy Journal, 54.

- Hamon, W. Russell. 1966. Evapotranspiration From Temperature And Day Length Functions. Methods For Estimating Evapotranspiration. Irrig. And Drain. Speciality Confer., Amer. Soc. Civ. Engin., Las Vegas, Nev.
- Holdridge, L.R. 1959. A Simple Method For Determining Potential Evapotranspiration From Temperature Data. Science, 130.
- Jackson, R.D. 1973. Diurnal Changes In Soil Water Content During Drying. Field Soil Water Regime. Soil Society Of America, Inc. #5, Madison, Wis.
- Jensen, Marvin E., and Haise, Howard R. 1963. Estimating Evapotranspiration From Solar Radiation. Amer. Soc. Civ. Engin. Proc., Journal Irrigation And Drainage Division 89 (IR-4).
- Mustonen, Seppo E., and McGuinness, J.L. 1968. Estimating Evapotranspiration In a Humid Region. U.S. Dept. Agr. Tech. Bul. 1389.
- New Mexico Water Conference. 1964. Research-The Key To The Future In Water Management. University Park, New Mexico.
- Omar, M.H. 1968. Potential Evapotranspiration In A Warm Arid Climate. Agroclimatological Methods, Proc. Of The Reading Symposium, Natural Resources Research Pub. 7, UNESCO, Paris France.
- Penman, H.L. 1956. Estimating Evapotranspiration. American Geophysical Union Trans.
- Rijtema, P.E. 1959. Calculation Methods Of Potential Evapotranspiration. Technical Bulletin 7, Institute For Land And Water Management Research, Wageningen, Netherlands.
- Sellers, W. 1964. Potential Evapotranspiration In Arid Regions. Journal Of Applied Meteorology. Volumn 3.
- Smith, K. 1964. A Long-Period Assessment Of The Penman And Thornthwaite Potential Evapotranspiration Formulae. Journal Of Hydrology 2 (4).
- Sokolov, A.A., and Chapman, T.G. 1974. Methods For Water Balance Computations: An International Guide For Research And Practice. UNESCO Press, New York.

- Stanhill, G. 1961. A Comparison Of Methods Of Calculating Potential Evapotranspiration From Climatic Data. Israel Journal Agricultural Research 11 (3-4).
- Stephens, John C., and Stewart, Ernest H. 1963. A Comparison Of Procedures For Computing Evaporation And Evapotranspiration. Publ. 62, International Association Of Science Hydrology, International Union Of Geodesy And Geophysics, Berkeley, California.
- Thornthwaite, C.W. 1948. An Approach Toward A Rational Classification Of Climate. Geographical Review. Volumn 38.
- Thornthwaite, C.W. 1954. A Reexamination Of The Concept And Measurement Of Potential Evapotranspiration. Publications In Climatology, 7, No. 1. Centerton, N.J.
- Thornthwaite, C.W., and Mather, J.R. 1957. Instructions And Tables For Computing Potential Evapotranspiration And The Water Balance. Publications In Climatology: Volumn X, No. 3. Drexel Institute Of Technology, Centerton, N.J.
- Thornthwaite, E.W., and Mather, J.R. 1955. The Water Balance. Climatology. Drexel Institute Of Technology, Volumn 8, No. 1.
- Thornthwaite, C.W., and Mather, J.R. 1955 The Water Budget And Its Use In Irrigation. The 1955 Yearbook Of Agriculture. Dept. Of Agriculture, Washington, D.C.
- UNESCO. 1968. Agroclimatological Methods. New York.
- van Bavel, C.H.M. 1966. Potential Evapotranspiration: The Combination Concept And Its Experimental Verification. Water Resources Research 2 (3).
- Veihmeyer, F.J., and Hendrickson, A.H. 1955. Does Transpiration Decrease As Soil Moisture Decreases? Trans. American Geophysical Union, 36.
- World Meteorological Organization. 1972. Agricultural Meteorology. W.M.O. # 310. Geneva, Switzerland.
- World Meteorological Organization. 1968. Practical Soil Moisture Problems In Agricultural. Technical Note No. 97. W.M.O. No. 235. TP-128. Geneva, Switzerland.

MCU LIBRARY

UNPUBLISHED PAPER

Hsu, Shin-Yi, Maxfield, Donald, W., and Stephenson,
Richard A. 1969. To Log Or Not To Log. Univ. Of
Georgia, Athens, Ga.