

**A SOIL WATER MODEL FOR TWO
CONTRASTING TILLAGE SYSTEMS**

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pg 27

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COMPARTMENT CELL SYSTEMS

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JULIE
WATER CONTROL

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TABLE OF CONTENTS

ABSTRACT	1
INTRODUCTION	3
General	3
Objective	3
Data for Model Development	8
REVIEW OF LITERATURE	9
Soil Water Balance	9
Watershed Models	12
Evapotranspiration Concepts	13
Empirical Evapotranspiration Methods	14
Theoretical Methods	15
Other Methods	18
DEVELOPMENT OF SOIL WATER PREDICTION MODEL	19
General Soil-Plant Environment	19
Soil Water Accretion Period	21
Plant Interception	22
Plant Height	23
Surface Runoff	26
Retention Storage	28
Plant Available Water	29
Depletion Periods	29
Evaporation	30
Evapotranspiration	33
Soil Water Content Relationships	33
Root Depth	36
Withdrawal Distribution Patterns	39
SOIL WATER PREDICTION MODEL	43
General Program Design	43
General Assumption	43
Model Input	45
Climatological Data	45
Program Control Data	45
Computational Procedure	64
Rain Period	64
Rainless Period	64
Typical Model Output	65

MODEL CALIBRATION	67
General Procedure	67
Goodness of Fit	67
Parameter Adjustment	69
Comparison with 1966 and 1967 Data	69
Observed versus Simulated Results	93
Estimates of Rainfall Excess and Plant Interception	94
Comparison of Synthesized Results with Independent Data	94
Comparison with Mulch Study	105
MODEL SIMULATION	113
General	113
Selection of Soil Types	114
Results of Model Simulation with Different Soil Types	114
Different Rainfall and Pan Evaporation Distribution	116
SUMMARY AND CONCLUSION	119
Model Development	119
Compatibility of Results	120
Applicability	120
Irrigation Requirements	121
APPENDIX A	125
APPENDIX B	127
APPENDIX C	129
APPENDIX D	131
APPENDIX E	133
APPENDIX F	135
APPENDIX G	138
APPENDIX H	141
APPENDIX I	144

APPENDIX J149

LIST OF REFERENCES211

LIST OF FIGURES

1. Typical surface conditions	4
2. Dense mulch resulting from chemically killed sod	5
3. Mulch late in the growing season	6
4. Differences in growth	7
5. Schematic illustrations of the hydrologic system used to simulate the soil water status in conventional or no-tillage methods of corn production	20
6. Typical non-dimensional corn growth curve	24
7. Comparison of measured and synthesized corn growth for conventional and no-tillage systems of corn production	27
8. Typical evaporation relationship for bare soil and killed sod mulch with E_p equal to 0.17 inch/day and W_p in the 0-12 inch profile equal to 3.02 inches	32
9. Relative evapotranspiration rates from conventional-tillage areas for different atmospheric demand rates	34
10. Relative evapotranspiration rates on no-tillage areas for different atmospheric demand rates	35
11. Typical potential available and saturated soil water content versus depth relation- ships for Groseclose silt loam	37
12. Vertical advancement of corn plant roots	40
13. Schematic flow chart illustrating	

	the general flow process in the soil water prediction algorithm	44
14.	Schematic illustration of the order of input data required by the soil water model	46
15.	Evaporation versus evaporation recession constant	71
16.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the conventional-tillage system during the 1966 growing season	73
17.	Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the conventional- tillage system during the 1966 growing season	74
18.	Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for conventional- tillage system during the 1966 growing season	75
19.	Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for conventional- tillage system during the 1966 growing season	76
20.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the no-tillage system	77
21.	Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the no-tillage system	78

22.	Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the no-tillage system .....	.79
23.	Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the no-tillage system .....	.80
24.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the conventional- tillage system .....	.81
25.	Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the conventional- tillage system .....	.82
26.	Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the conventional- tillage system .....	.83
27.	Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the conventional- tillage system .....	.84
28.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the no-tillage system .....	.85
29.	Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the no-tillage system .....	.86
30.	Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the no-tillage system .....	.87

31.	Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the no-tillage system .....	.88
32.	Comparison of estimated evapotrans- piration from no-tillage and conventional-tillage areas during the 1966 growing season .....	.89
33.	Comparison of estimated evapotrans- piration from no-tillage and conventional-tillage areas during the 1967 growing season .....	.90
34.	Accumulated daily rainfall during the 1966, 1967, and 1968 growing seasons .....	.91
35.	Accumulated daily pan evaporation during the 1966, 1967, and 1968 growing seasons .....	.92
36.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the conventional- tillage system during the 1968 growing season .....	.96
37.	Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the conventional- tillage system during the 1968 growing season .....	.97
38.	Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the conventional- tillage system during the 1968 growing season .....	.98
39.	Comparison of simulated versus measured 0-36 inch depth for the conventional-	

	tillage system during the 1968 growing season	99
40.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the no-tillage system during the 1968 growing season	100
41.	Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the no-tillage system during the 1968 growing season	101
42.	Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the no-tillage system during the 1968 growing season	102
43.	Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the no-tillage system during the 1968 growing season	103
44.	Comparison of estimated evapotranspiration and rainfall from n-tillage and conventional-tillage areas during the 1968 growing season	104
45.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the conventional-tillage system. Data courtesy of J. N. Jones, Jr., Blacksburg, Virginia	108
46.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the no-tillage system. Data courtesy of J. N. Jones, Jr., Blacksburg, Virginia	109
47.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth. Area mulched with 3 tons of straw per acre. (1959). Data courtesy of J. N. Jones, Jr., Blacksburg, Virginia	110

48.	Comparison of simulated versus measured plant available soil water in the 0-12 inch depth. Area mulched with 3 tons of straw per acre. (1960). Data courtesy of J. N. Jones, Jr., Blacksburg, Virginia	111
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LIST OF TABLES

I.	Comparison of computed and measured potential soil water content in Groseclose silt loam	38
II.	Format and data description of climatological data required by the soil water model	48
III.	Percentage soil water by volume for indicated depth and tension	68
IV.	Summary of soil water prediction model parameters for the 1966 and 1967 growing seasons	72
V.	Monthly rainfall distribution expressed as a percentage of the total for the growing season	70
VI.	Distribution of daily pan evaporation during the April through September growing season at Blacksburg, Virginia	93
VII.	Summary of soil water prediction model parameters for the 1968 growing season	95
VIII.	Summary of soil water prediction model parameters for the 1965 growing season	107
IX.	Summary of soil water prediction model parameters for corn grown on straw-mulched areas during the 1959 and 1960 growing seasons	112
X.	Model response to the soil types listed in Appendix F. Data subjected to two different climatological distributions	115
XI.	Response of the soil water prediction model to different climatological distributions. Soil parameters are assumed constant	117

ABSTRACT

Techniques were developed to simulate the soil-plant environment as a semi-dynamic hydrologic system. Exponential expressions were found to give reasonable estimates of soil evaporation prior to corn plant emergence. A family of non-linear curves were used to estimate evapotranspiration after corn plant emergence. These curves assumed that pan evaporation was the integrated result of atmospheric demands and was therefore defined as the potential condition. Precipitation excess was estimated from an exponential expression that was developed by Holtan⁴⁵ from the total water storage capacity in the A_p or A soil horizon. Corn plant heights were simulated with a 2-part non-dimensional exponential relationship. Rainfall interception by the corn plant canopy was assumed to be a function of rainfall, plant height, and density of cover with the maximum allowable quantity at full tassel limited to 0.03 inch per storm per 15,000 plants. Vertical water movement through the soil was assumed to be related to its saturated hydraulic conductivity.

The soil profile was subdivided into seven zones with the first zone terminating at the bottom of the A_p or A horizon and the seventh zone terminating at maximum root depth. Intermediate zones were arbitrarily spaced at 6 and 12 inch intervals. The potential water holding capacity of each zone was further categorized as free water and plant available water. All recharge of the system took place in zone one. Subsequent recharge of lower depths or zones were allowed when free water existed in the zone immediately above.

All aspects of the model were programmed in the Fortran language for an IBM 360 Computer. Each logical segment of the model was sub-routined to allow minimum effort for changes and/or modification.

A comparison of simulated with observed data indicates very good agreement. With few exceptions, the simulated results were well within sampling variation.

INTRODUCTION

General

For many years one of the goals of the tillage research at Virginia Polytechnic Institute and State University has been to develop a system which (a) reduces the amount of tillage required, (b) maintains an open soil structure conducive to optimum seed germination and plant development and to good rainfall intake and storage, and (c) makes more beneficial use of residues of preceding crops for minimizing evaporation, soil erosion, and surface runoff losses. From these investigations evolved the no-tillage system. With this system the crop is planted directly into a chemically killed sod with no prior mechanical seedbed preparation, thereby utilizing vegetation from the preceding crop for surface mulch. Typical surface conditions are compared in Figure 1. The mulch is typically dense (Figure 2) and is fastened in place by its own root system. Hence, it is not readily dislodged by weather elements, thereby resulting in a good mulch late in the growing season (Figure 3).

The no-tillage concept was initiated at Virginia Tech in 1960. Early experiments were encouraging; however, many difficulties relating to the control of preceding vegetation, control of regrowth, and planting techniques required basic research before the practice could be implemented or full-scale field testing or experimentation made.

In general, the no-tillage system gave better crop yield and more vigorous plant growth than the conventional system where the seedbed was prepared by turn plowing and discing the land. Typical differences in growth are portrayed in Figure 4. In later research, e.g., Shanholtz et al.⁴³ it was found that for the most part these advantages were related to the improved hydrologic performance of the area and were attributable to the no-tillage system.

Objective

The present work was an extension of this tillage research and was directed towards the development of a mathematical model to simulate the soil water status under these two contrasting tillage systems with sufficient generality to allow its use for studying the hydrologic response of different soil types when subjected to a wide variety of climatological distributions. A knowledge of each system's reaction will allow inferences to be made about potential yields, and the relative efficiencies of the various soil types. The present study

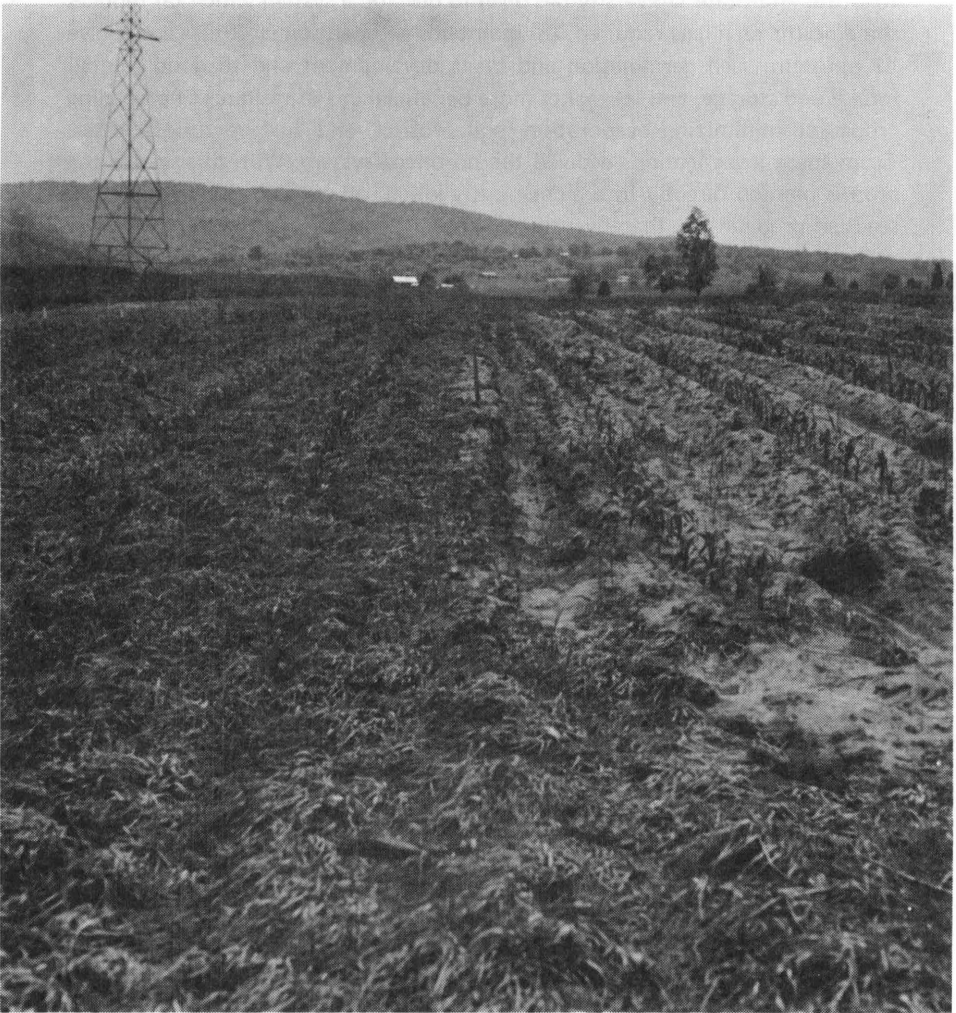


Figure 1. Typical Surface Conditions



Figure 2. Dense Mulch Resulting From
Chemically Killed Sod.



Figure 3. Mulch Late In The Growing Season.

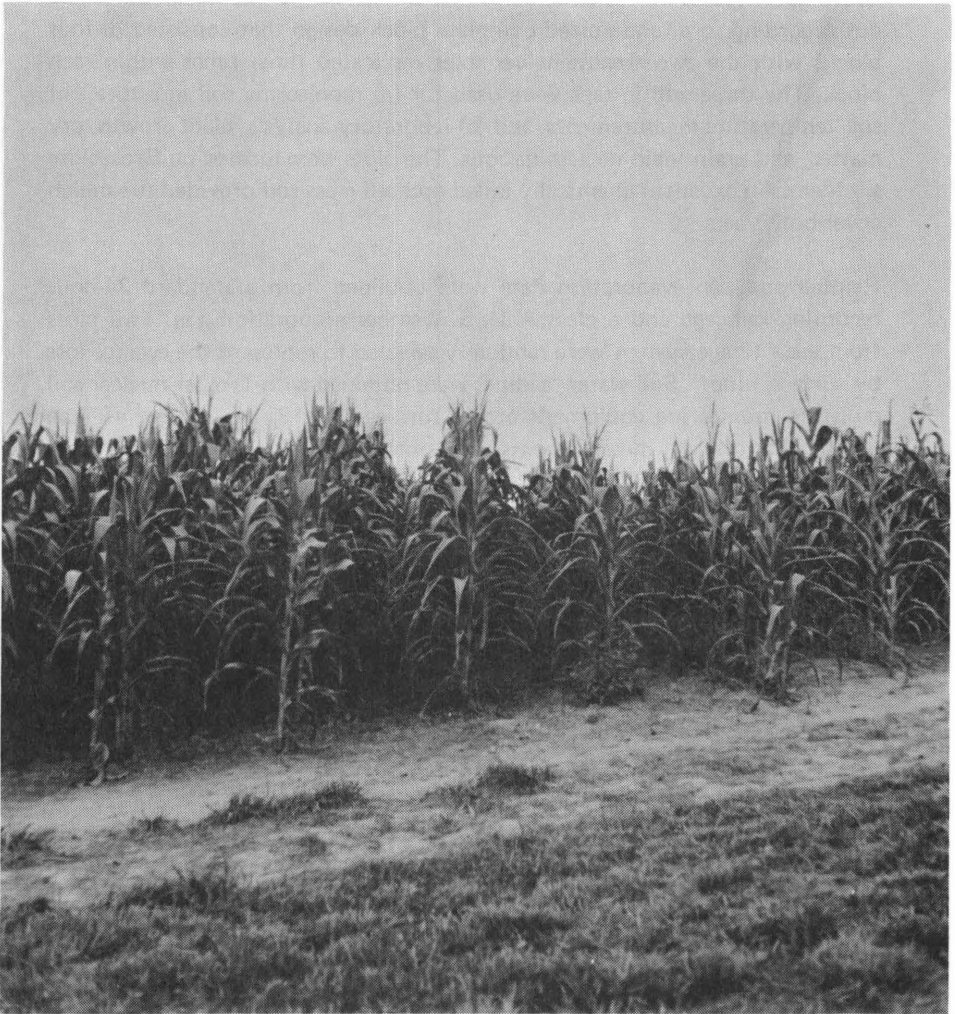


Figure 4. Differences in Growth No-Tillage on the Left.

was concerned primarily with the development, testing, and verification of the soil water prediction model.

Data for Model Development

The data for the development of some phases of the model were obtained from a two-year statistically designed experiment that was set up to study the hydrologic aspects of the two tillage systems. The experimental area was laid out according to a randomized complete block design that consisted of four blocks with the two treatment variables replicated three times within each block. The three within reps were used for (a) monitoring soil moisture, (b) soil temperature measurements, and (c) laboratory analysis, plant growth, dry matter, and grain yield determinations. The plots were located on Groseclose silt loam. An excellent chemically killed orchard grass sod provided the mulch cover both years.

Rainfall and pan evaporation data were obtained from a standard 24-hour recording raingage and a class A U. S. Weather evaporation pan. Two plots from each tillage system were randomly selected to represent the average loss by surface runoff. Soil water readings were obtained with Troxler nuclear soil moisture monitoring equipment at the surface, 12, 18, 24, 36, and 48-inch depths. Plant height measurements were obtained weekly from 40 plants per plot selected randomly from 4 test rows.

REVIEW OF LITERATURE

In past years considerable research has been undertaken to determine means of estimating the amount of water contained in the soil profile at any given time. This research has been centered in two basic areas. The first deals with in situ measurements and the second is concerned with the use of climatological data with appropriately derived theoretical or empirical formulas. Eastwell¹ has made an extensive review of those methods which involve the measurement of some physical property of the soil which is dependent on its moisture content. All moisture sampling techniques would be included in this category. The climatological approach is discussed in some detail by Smith.²

Soil Water Balance

The soil water balance in a given soil profile involves a systematic evaluation of the gains and losses to the moisture reservoir. This process in its basic form can be represented by an equation of the form⁴³

$$SM_t = SM_{t-1} + P_t + I_t \pm ML_t - Q_t - PC_t - ET_t \quad (1)$$

where

SM = soil moisture status at time t in inches

P = precipitation in inches

Q = surface runoff in inches

I = artificially applied water (usually irrigation)

PC = deep seepage in inches

ET = evapotranspiration in inches

ML = minor gains or losses (dew, evaporation and condensation within the soil, upward flow from groundwater, plant interception, etc.)

Van Bavel^{3,4,5} was one of the first to make extensive use of the soil water balance as a tool in estimating drought. In a study conducted for the Lower Mississippi Valley³ the soil water balance was used to predict the occurrence of water surplus as well as drought. His method involved a simple bookkeeping of the soil water status. Analyses were run for several values of available soil moisture. Each day an estimated value for potential evapotranspiration (PE) was subtracted from soil moisture storage and precipitation for the day was added. Moisture accretion beyond the available

water capacity was considered as excess moisture and assumed to be runoff, otherwise all precipitation was assumed to go into storage. Days in which available moisture capacity went to zero were considered as drought days. Actual evapotranspiration (ET) was assumed equal to PE until wilting point.

There is considerable disagreement in the literature concerning the disposition of ET as soil moisture decreases.⁶ Among the many theories advanced are (a) depletion by PE until wilting point at which time the rate abruptly drops to zero, (b) a linear depletion rate from field capacity to wilting point, and (c) non-linear depletion rates between a and b. Thornthwaite and Mather⁷ assumed daily ET proportional to the available moisture remaining in the soil.

Marlatt et al.⁸ compared four methods for calculating soil moisture under irrigated snap beans. All methods utilized PE as determined from Thornthwaite's equation. Available moisture holding capacity was increased as roots penetrated to deeper depths. The major difference in the four methods lay in the manner for accounting for change in ratio of ET to PE with increasing soil moisture deficit. The methods compared were: (a) constant ratio of 1.0 throughout available range, (b) ratio decreasing linearly from unity at field capacity to zero at permanent wilting point, (c) ratio decreasing linearly from unity at field capacity to zero at oven dryness and (d) a constant ratio of 1.0 during the depletion of the first inch of soil moisture below field capacity and beyond that assuming proportionately (as in method 2) to the available moisture remaining. Method 4 was found to give good results between measured and estimated soil moisture.

The 1.00 inch value for soil moisture utilized at the potential rate was justified as being the approximate amount of moisture held in the upper foot of soil between field capacity and 1 atmosphere tension. This figure is generally assumed to be correct for a wide range of soil conditions ranging from very fine sand to silty clay loam.^{9,10}

Shaw¹¹ and Denmead et al.¹³ report using evaporation-pan data as the measure of the evaporation potential. They also stated that the study could have utilized any of the methods available for estimating evaporation potential. Shaw obtained an estimate of ET by applying a crop development factor in per cent to pan evaporation. This result represented ET when soil moisture was not limiting.

Data obtained by Denmead and Shaw¹² show that, under conditions of high atmospheric demand, transpiration from a plant will decrease at a relatively high soil-moisture content because the plant cannot supply water fast enough to meet the high demand. At low atmospheric demand there will be no reduction in water loss until a relatively low moisture content is reached. Three curves were used to represent different stress days: (a) days when pan evaporation was above 0.30 inch were considered as high stress (transpiration rate 0.22 inch/day), (b) days when pan evaporation was between 0.20 inch and 0.30 inch were classified as average (transpiration rate 0.16 inch/day), and (c) days when pan evaporation was below 0.20 inch were classed as low stress days (transpiration rate 0.08 inch/day). The product of pan evaporation, crop development factor, and stress factor represented ET in Shaw's¹¹ work.

Pengra¹⁴ used an adaptation of the method of Thornthwaite and Mather to characterize seasonal variations of soil moisture in South Dakota. Comparisons of estimated versus measured soil moisture were not made. Shaw^{15,16} reports success in using the same procedure for predicting moisture under a permanent grass sod and spring oats.

Pierce¹⁷ developed a procedure for estimating ET, utilizing lysimetry data collected at Coshocton, Ohio. His procedure involved the use of a potential evapotranspiration figure derived from Thornthwaite's¹⁸ procedure which was modified by factors for crop stage, soil dryness, and a "rainy day" correction to arrive at actual daily ET. His soil dryness correction factor had a value of 1.0 for an initial period and then was reduced as soil moisture was further depleted. Holmes and Robertson^{20,21} investigating evapotranspiration rates from columns of three different soil types reported that actual ET took place at the PE rate during an initial period when the soil was near field capacity. After the soil water was depleted to a point where the ability of the soil to transmit moisture was sharply reduced, it continued to diminish approximately exponentially as the soil dried out further. The authors incorporated this concept into a soil moisture budget for dry-land wheat and reported that this approach for estimating soil moisture gave better results than the approach which assumes soil moisture depletion at the potential rate throughout the drying cycle.

Palmer¹⁹ reported a method for estimating the occurrence of meteorological drought which involved a soil moisture balance containing essentially the same principles as used by Holmes and Robertson.^{20,21} In 1964, Ligon et al.²² presented a procedure for determining the probability of soil moisture deficiency and excess. They used PE as computed by Thornthwaite's

method¹⁸ and the graphical aids by Palmer and Havens.²³ Actual ET was assumed to be equivalent to PE for the first 1.00 inch of available moisture, thereafter it was assumed to be a function of the moisture remaining. No provisions were made for varying the root zone nor for runoff which may occur when the moisture content of the soil profile is below field capacity.

Rosenberg et al.²⁴ reporting on work by Baier et al.²⁵ proposed a versatile soil moisture budget in which soil moisture is estimated from standard meteorological data. Simultaneous moisture withdrawal from different depths of the soil is accounted for in this method. Adjustments are made for runoff and different drying characteristics of various soil types. Further examples of bookkeeping methods for the purpose of estimating evapotranspiration or for irrigation scheduling are discussed in papers by Staple and Lehane,²⁶ Allred and Chen,²⁷ McQuigy,²⁹ and Pruitt.²⁸

Watershed Models

In watershed studies Knisel et al.³⁰ reported a two-soil-moisture-reservoir model to improve the estimate accuracy of a runoff-volume-prediction model. A decay type function was used to describe the moisture depletion between days of rainfall with the moisture depletion constant varying by season with soil moisture, pan evaporation, and mean daily temperature.

The present state of the art in models to predict runoff includes two-level and multi-capacity accounting models. In these models the soil mantle is divided into layers, and each layer is represented as a reservoir in an effort to account for the complex effects of soils. Haman³¹ used two layers; one the active root zone of most rapidly changing moisture and the other a lower zone that contributed some moisture to evapotranspiration. Crawford and Linsley³² utilized two hypothetical dimensionless storage reservoirs--upper zone and lower zone together with groundwater storage to represent soil moisture profiles and groundwater conditions. The upper zone storage was used to simulate the dynamic hydrologic processes occurring on and very near the soil surface, whereas the lower zone storage was used to model conditions between the soil surface and the water table. Multi-capacity basin accounting was reported by Kohler and Richards.³³ In this procedure the surface-runoff quadrant relations of the coaxial method were replaced by mathematical relationships. Saxton et al.³⁴ reported on the use of antecedent indexes to estimate soil water conditions.

Evapotranspiration Concepts

In the previous discussions the concept of potential evaporation or evapotranspiration (PE) was used repeatedly. All water budget studies result in the use of some facet of this concept. As a result of its importance a brief resume of methods available for determining PE will be given. The reader is referred to Rosenberg's et al.²⁴ classic for a more thorough review of evapotranspiration.

In 1948 Thornthwaite¹⁸ introduced the concept of potential evapotranspiration as a means of estimating the evapotranspiration loss from the ground surface. Later Thornthwaite et al.³⁵ defined potential evapotranspiration with the following commendable statement.

It is necessary to distinguish between the evapotranspiration where soil moisture is limiting and the evapotranspiration where moisture is available as needed. A further distinction must be made between evapotranspiration from the small isolated 'oases' provided by evaporation pans, pots, tanks, etc. In the latter case, an inordinate supply of energy may be derived from the ambient air by reason of the locally superior utilization of energy for evapotranspiration at a point. The only standard measure of evapotranspiration are those from a large, vegetation-covered land surface with adequate moisture at all times. This condition defines potential evapotranspiration or water need; since moisture is not restricted potential evapotranspiration is limited solely by available energy. When there is a shortage of moisture, actual evapotranspiration falls short of potential evapotranspiration.

In essence the above definition says that potential ET is not affected by moisture content but is dependent on the energy available for the ET process. Penman et al.³⁶ states that this mechanism is composed of an energy balance and a transport process. The aerodynamic aspect is supposedly self-contained, whereas the energy balance aspect must utilize some aerodynamic principles to make it complete.

Methods for estimating evapotranspiration as a result have been grouped by Levine³⁷ into three broad categories: (a) empirical methods, (b) theoretical methods based upon a balance of energies available and used in the evaporation process.

Empirical Evapotranspiration Methods

One of the earliest empirical approaches was proposed by Dalton and took the form²⁴

$$E = C(e_s - e_d) \quad (2)$$

where E is the evaporation in unit time and e_s is the vapor pressure at the evaporating surface, e_d is the vapor pressure at some height above ground and C is an empirically determined constant which includes a function of horizontal wind velocity. The equation provides estimates from a water surface but has not been widely used because constants vary from location to location and until the advent of infrared thermometry it has been extremely difficult to obtain accurate surface temperatures.

A more recent empirical equation which has been used in the western United States with considerable success is the Blaney-Criddle Formula.³⁸ The equation is expressed mathematically as

$$U = KF = \sum kf \quad (3)$$

where U is the consumptive use of a crop in inches for any period; f is the monthly consumptive use factor which is equal to the product of the mean monthly temperature and monthly percentage of daylight hours per year; k is an empirical consumptive use coefficient for the month; F is the sum of the monthly consumptive use factors; and K is the overall consumptive use coefficient for the period.

Another very important empirical equation was developed by Thornthwaite¹⁸ in which he advanced the concept of potential evaporation (maximum evaporation) with the equation

$$e = ct^a \quad (4)$$

where e is the monthly evaporation in cm, t is the mean monthly temperature in degrees C and a and c are coefficients which vary from locality to locality.

To evaluate a the following equation was developed:

$$a = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 17.92 \times 10^{-3} I + 0.49239 \quad (5)$$

where I is an annual heat flux and is equal to the sum of monthly heat indexes i where $i = (t/5)^{1.514}$. The coefficient c varies inversely with I . Upon substitution his equation becomes

$$c = 1.6 (10t/I)^a. \quad (6)$$

The formula is similar in some respects to the Blaney-Cridde expression. Emphasis is placed upon mean monthly temperature and an estimate of radiation energy available is implicitly applied by adjusting the values to standard conditions by day length. Where temperature and radiation are correlated, the method works well, particularly on long periods. The equation was developed primarily in the central and eastern United States.

Theoretical Methods

One of the best known formulas based upon the theory of vapor diffusion was developed by Thornthwaite and Holzman.³⁹ The formula is expressed as

$$E = \rho k^2 (q_1 - q_2) (U_2 - U_1) / (\text{Log}_e z_2/z_1)^2 \quad (7)$$

where E = rate of evaporation, q_1, q_2 and U_1, U_2 , are the specific humidities and mean velocities respectively at heights z_1 and z_2 and k is Karmans constant.

The equation in this form requires extreme precision in measurements which imposes considerable restriction on its practical use. As a consequence Pasquill⁴⁰ has suggested a more convenient form:

$E = BU_2 (e_1 - e_2)$ where

$$B = \frac{k^2 M}{RT} \frac{(1 - U_1/U_2)}{(\text{Log}_e Z_2/Z_1)^2}$$

(where M = molecular weight of water, R = gas constant, T = absolute temperature, e_1 and e_2 = vapor pressure) and is essentially constant for any site of fixed roughness.

The energy balance method is based upon the principal of conservation of energy and is represented by the form

$$F_1 = F_r + F_b + F_h - F_s + F_e \quad (8)$$

where F_1 = incoming radiation from the sun, F_r = reflected solar radiation, F_b = upward flux of long wave radiation, F_h = flux of energy from the surface as sensible heat (heating of air), F_s = flux of heat into and stored by body, and F_e = heat used in evaporation process, all expressed in gram cal per cm^2 min. The primary difficulty in using this method has been the accurate determination of F_h and F_e .

Penman⁴¹ developed a method to estimate ET by combining the energy theory and the theory of diffusion. Two basic steps are involved; first the evaluation of the net gain of radiation energy ($H = F_i - F_r - F_b$); and, second, determining how this energy is divided in heating the air and evaporation. Two assumptions are made: (a) the gain in heat by soil is relatively small over short periods, and (b) advective heat transfer is negligible. The basic equation then becomes $H = F_e + F_h$ where H is estimated by the relationship

$$H = R_a(1-r)(0.18+0.55 n/N) - \sigma T_a^4(0.56-0.92 e_d)(0.10+0.90 n/N)$$

where

R_a = mean monthly extraterrestrial radiation in mm per day.

r = radiation reflection coefficient

n/N = ratio of actual to possible sunshine

T = Stefan Boltzman constant

2.01×10^{-9} mm per day

T_a = absolute air temperature in degree (Kelvin)

e_d = actual vapor pressure of the air in mm of mercury

After H is determined Penman assumes that it is partitioned between heating of air and evaporation by the Bowen ratio which is given by $F_h/F_e = B =$

$$\frac{\gamma(T_s - T_a)}{e_s - e_d} \quad \text{where } \gamma \text{ is the constant in the wet and dry bulb}$$

hygrometer equation and for degree F and mm of mercury it is equal to 0.27. The quantity e_s is unmeasurable at ground surface therefore it must be estimated.

Penman suggests using the principles of aerodynamics to obtain

$$E = (\Delta H + E_a \gamma) / (\Delta + \gamma)$$

where Δ is the slope of the e:t curve at $T = T_a$ and is equal to de/dt , and E_a is a measure of the diffusion of vapor given by

$$E_a = 0.35 (e_a - e_d) (1 + 0.0098 U_2) \text{ mm per day}$$

with e_a being the saturation vapor pressure of the air and U_2 being the wind speed at 2 meters in miles per day. Using the foregoing equations the evaporation from a free water surface can be estimated.

One of the most recent approaches is attributed to Van Bavel.⁴² Expanding on Penman's concepts and introducing aerodynamics principles Van Bavel developed the so-called combination method for estimating potential evaporation.

Potential evaporation is given by

$$LE_o = \frac{\frac{m}{\gamma} H + L B_v d_a}{\frac{m}{\gamma} + 1} \text{ cal cm}^{-2} \text{ min}^{-1} \quad (9)$$

where H is the sum of energy input excluding the heat flux to air and evaporation; d_a is the vapor pressure deficit in mb at some elevation above the surface; γ is the psychrometric constant; L is latent heat of evaporation of water; m is the slope of saturation vapor pressure versus temperature curve at mean wet bulb temperature; and B_v is a transfer coefficient for water vapor in $\text{cal cm}^{-2} \text{ min}^{-1} \text{ mb}^{-1}$ and is defined by

$$B_v = \frac{\rho e k^2}{P} \frac{U_a}{[\text{Log}_e (Z_a/Z_o)]^2} \text{ g cm}^{-2} \text{ min}^{-1} \text{ mb}^{-1} \quad (10)$$

where ρ is the air density; e is the ratio of molecular weight of water to air; k is Von Karmans' constant = 0.40; P is atmospheric pressure; U_a is horizontal wind speed; g is acceleration of gravity; Z_o is the aerodynamic roughness parameter (zero plane); and Z_a is vertical distance above surface.

Other Methods

Numerous other methods have been employed by investigators to estimate potential evaporation.²⁴ These include pan evaporation, bookkeeping methods, streamflow analysis, and net radiation.

DEVELOPMENT OF SOIL WATER PREDICTION MODEL

General Soil-Plant Environment

An algorithm was developed to simulate the hydrologic characteristics of the soil-plant environment in two contrasting tillage systems. Such a model requires accurate estimates of the plant available soil water within each system at any specific time. The flow process can best be visualized by considering the soil-plant environment as a finite hydrologic system such as the schematic given in Figure 5. For this system, continuity requires that inflow minus outflow must equal the change in storage. Inflow to the system represents recharge or soil water accretion, while outflow represents discharge or soil water depletion. In general

$$\frac{\partial SM}{\partial t} = \frac{\partial R}{\partial t} - \frac{\partial D}{\partial t} \quad (11)$$

where

R = soil water accretion

D = soil water depletion

SM = soil water

The general expression of continuity for the hydrologic process given in Figure 1 becomes, with the substitution of the water budget relationship,

$$\frac{\partial SM}{\partial t} = \frac{\partial(I+P)}{\partial t} - \frac{\partial}{\partial t} (Q + PC + ET + IC) \quad (12)$$

Equation (12) can best be solved by using the simple bookkeeping formulation

$$SM_t = SM_{t-1} + I_t + P_t - ML_t - Q_t - PC_t - ET_t \quad (13)$$

A solution to equation (12) and (13) was obtained by solving for the individual components over a variable time interval Δt . The time intervals during rain periods were selected such that

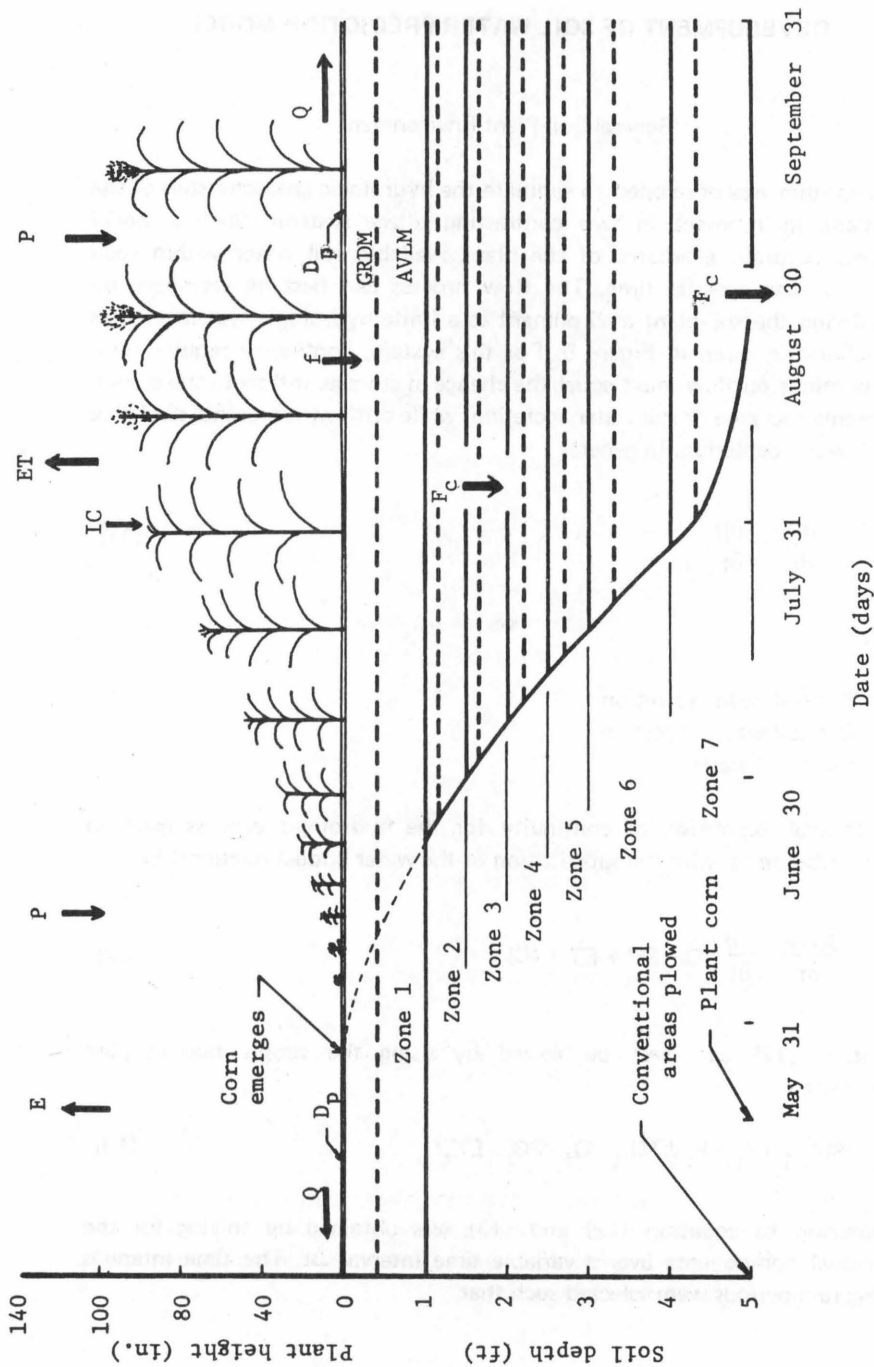


Figure 5. Schematic illustration of the hydrologic system used to simulate the soil water status in conventional- or no-tillage methods of corn production.

$$\Delta t_i = \frac{P_i}{RI_i} \leq 24 \text{ hours} \quad (14)$$

where

Δt = time interval in hours

P_i = rainfall during time interval Δt in inches

RI_i = rainfall intensity

$i = 1, 2, 3, \dots$

During rainless periods Δt was always ≤ 24 hours.

It was assumed throughout the development of the model that P and I were known inputs. The only minor gain or loss considered was interception of water by the plant canopy. Deep seepage was assumed to occur at a rate equal to the saturated hydraulic conductivity of the soil profile being investigated. Runoff was estimated using an infiltration approach and ET was estimated using empirically derived evaporation formula and potential evapotranspiration concepts.

During the development of the model, attempts were made to simulate soil water status through the use of a semi-dynamic environment in contrast to a simple static situation. Mathematical expressions were developed to approximate the growth of corn plants, root development, plant interception, potential plant available soil water, potential soil water at saturation, evaporation, evapotranspiration, infiltration and soil water withdrawal distribution patterns. The development of these expressions are discussed in the following sections.

Soil Water Accretion Period

Soil water accretion periods are intervals during which water is being applied to the system by either natural (p) or artificial (I) methods. The model's function during this period was to determine plant interception, precipitation excess, and the distribution of infiltrated water in the soil profile. Increments of rainfall minus plant interception were reduced by an infiltration model to ascertain the magnitude of these processes.

Plant Interception

Interception in some phases of hydrology, for example, flood flow estimates, can probably be considered as an insignificant factor. In contrast, since most storm events yield small amounts of rain and interception storage is satisfied early in the event, interception can amount to a significant proportion of the total input on some cover conditions. Interception by dense cover commonly amounts to 25 per cent of the annual rainfall.

The storage capacity of vegetation varies with plant growth or leaf development, wind velocity, rain intensity, and raindrop size.⁴⁹ Stoltenberg et al.⁵⁰ classified storage capacity into two categories. The first was termed residual interception storage and was defined as that proportion that stayed on the plant after cessation of rainfall, and the second category was temporary or transitory interception and was defined as that proportion that dripped off or flowed down the stem to the ground. In very detailed experiments with corn, he found the maximum residual interception storage for mature corn plants to be 0.025 inches for a corn plant population of 15,000 plants/acre. This amount was satisfied within a few minutes after the start of rain, and intensity and amount had little effect thereafter.

The amounts suggested by Stoltenberg et al.⁵⁰ are somewhat lower than estimates reported by other investigators. For example, using an empirical equation proposed by Horton,⁵¹ estimates of 0.06 inches were obtained for a mature corn crop subjected to a rainfall of 1.00 inches.

The procedure used in this study was a modification of Horton's⁵¹ suggested equation combined with the interception limits found by Stoltenberg et al.⁵⁰ A basic assumption was that both interception and the projection factor (aerial coverage of projected leaves) were functions of plant height. The basic form is

$$IC = \phi(H,P) \quad IC \leq IC_{\max} \leq F(P) \quad (15)$$

$$F_P = \phi(H) \quad F_P \leq F_{\max} \quad (16)$$

where

IC = interception (inches)

IC_{max} = maximum interception at full tassel (inches)

F_p = projection factor

F_{max} = maximum projection factor at full tassel

H = plant height (inches)

P = total storm precipitation (inches)

ϕ = function

The following form was assumed

$$IC = aH \leq IC_{max} \leq bH(P) \quad (17)$$

where

$$a = \text{constant} = \frac{IC_{max}}{H_m}$$

$$b = \text{constant} = \frac{F_{max}}{H_m}$$

H_m = plant height at full tassel in inches

Plant Height

Since plant growth can exert a tremendous influence on interception magnitudes, mathematical functions depicting changes in height with time were found necessary. Many factors tend to affect day to day plant growth such as amount of sunlight, soil type, corn variety, genetic classification, etc. Despite the many variations that may occur, Kiesselbach⁵² reported that late maturing varieties tend to grow taller than do early ripening varieties. He further stated that the increased height was not due to more rapid growth in the early stages but rather longer continued growth. Average growth rates were found to be 1.9 in./day or 13.3 in./week. As a result of Kiesselbach's⁵² findings and utilizing actual field measurements plant height variations with time were characterized by a non-dimensional plot of height versus duration from plant emergence (Figure 6). The height and duration scales were non-dimensionalized using maximum height and duration at maturity respectively.

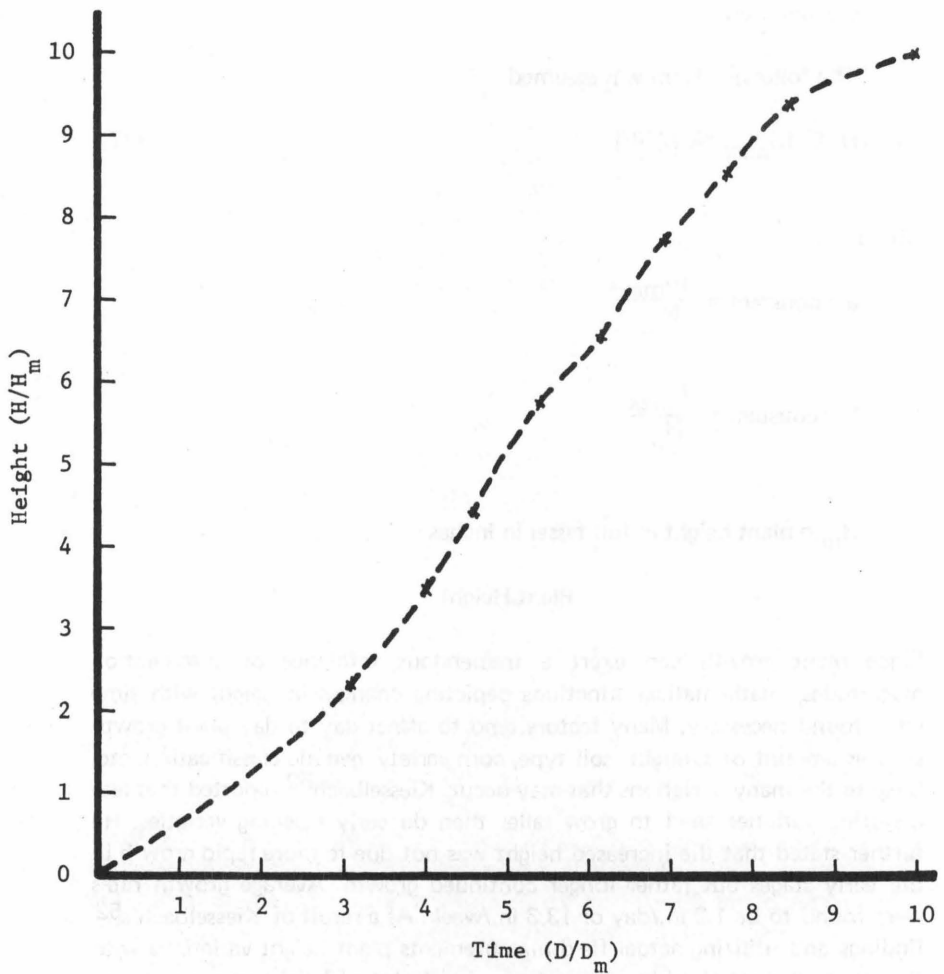


Figure 6. Typical non-dimensional corn growth curve.

The growth curves for both the no-tillage and conventional-tillage systems were assumed to follow a two part exponential of the form

$$H = aH_m \left(\frac{D}{D_m}\right)^b + cH_m \left(\frac{D}{D_m}\right)^d \quad (18)$$

where

H = plant height (inches)

H_m = maximum plant height at maturity (inches)

D = duration measured from plant emergence (weeks)

D_m = duration at maximum plant height (weeks)

Equation (18) depicts two stages during the corn growth cycle. The first stage given by

$$H = aH_m \left(\frac{D}{D_m}\right)^b \quad (19)$$

represents the period during which the corn plant is growing most rapidly. Near maturity the corn undergoes a decrease in plant growth. This stage is represented by the relationship

$$H = cH_m \left(\frac{D}{D_m}\right)^d \quad (20)$$

The transition from equation (19) to (20) was accomplished at the duration common to both equations.

The constants for equations (19) and (20) were evaluated using actual field measurements of plant heights that were collected on a statistically designed tillage experiment during the 1967 growing season. Each point on the non-dimensional curve represented an average of 160 corn height measurements. With numerical estimates for the constants, the equations became

$$H_1 = 1.46 H_m \left(\frac{D}{D_m}\right)^{1.63} \quad (21)$$

and

$$H_2 = H_m \left(\frac{D}{D_m} \right)^{0.410} \quad (22)$$

where

H_1 = height of corn plant (inches) during stage one

H_2 = height of corn plant (inches) during stage two

Corn growth curves were synthesized for both no-tillage and conventional-tillage systems using equations (21) and (22). With D_m equal to 13 weeks, H_m equal to 84 inches and 115 inches for conventional tillage and no tillage respectively, the simulated results for the 1967 growing season are shown in Figure 7. The mean corn height, which is an arithmetic average of 160 separate readings, at the end of each week is shown for comparison.

Surface Runoff

Surface runoff was defined by the expression

$$Q = P - IC - D_p - F \quad (23)$$

where

Q = unrouted surface runoff (inches)

P = precipitation (inches)

IC = plant interception (inches)

D_p = depression storage (inches)

F = infiltrated volume (inches)

Numerical estimates for F were obtained with a modified version of an infiltration equation developed by Holtan⁴⁵ and was expressed as

$$f = aS^n \quad (24)$$

where

f = infiltration rate (in./hr)

S = remaining unfilled pore space above some datum (inches)

a and n = constants

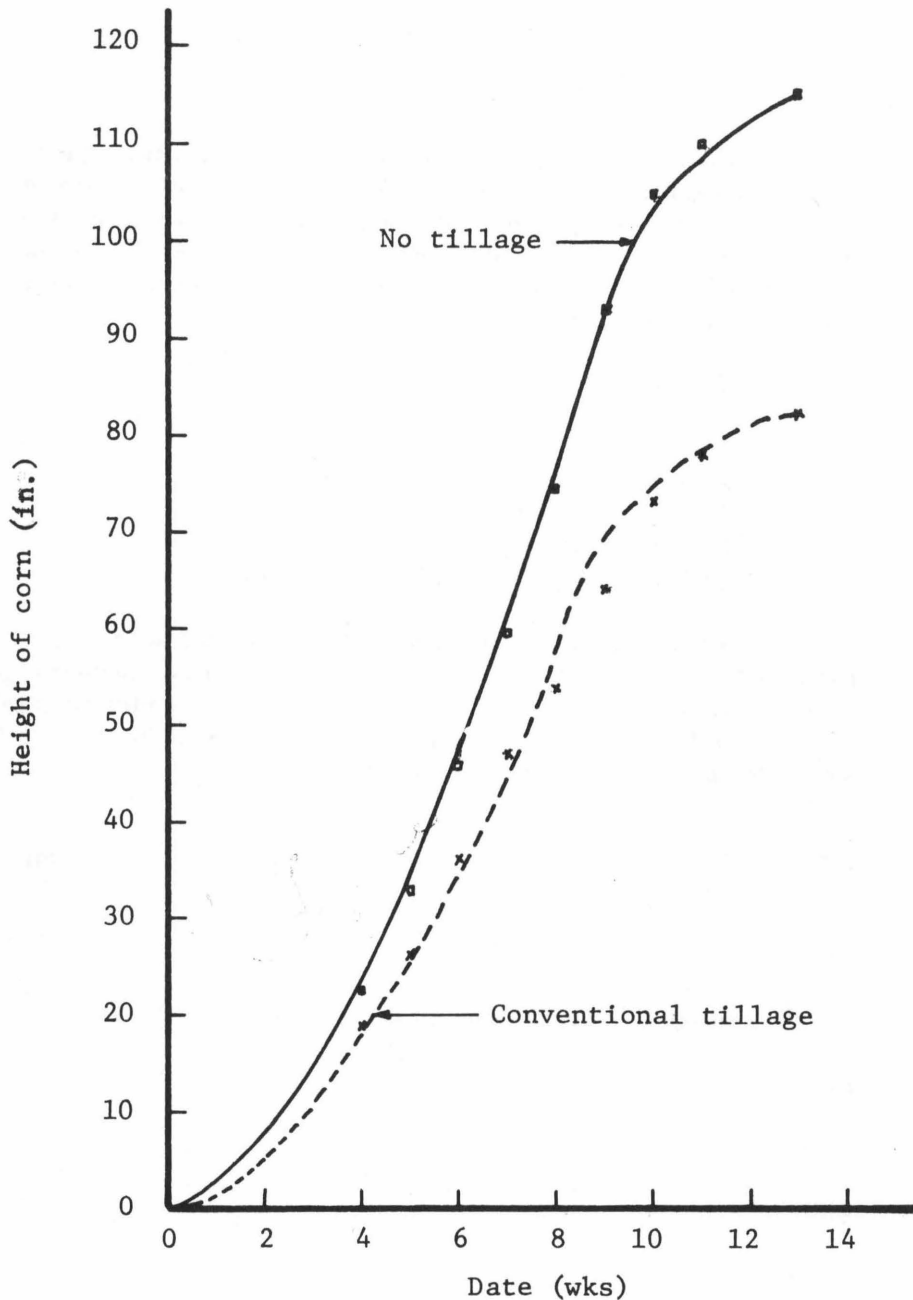


Figure 7. Comparison of measured and synthesized corn growth for no-tillage and conventional-tillage systems of corn production.

Holtan's equation has been shown to give very close approximations of both temporal and spatial variations of runoff.^{46,47,48} The equation assumes that infiltration is a function of storage remaining, which is generally assumed to be closely associated with the plow layer or A_p horizon. At the start of rainfall potential storage is subsequently depleted by infiltration. The status of unused storage is given by

$$S = TP - GRDM - AVL M \quad (25)$$

where

GRDM = gravitational water (inches)

AVLM = plant available water (inches)

TP = total soil porosity above wilting point (inches)

With time in hours, rainfall in inches, maximum value of depression storage in inches, and initial values for S, GRDM, AVL M, a and n, the distribution of rainfall increments are determined as follows. The volume of infiltration (F) is computed for each time increment (Δt) by a series of iterations to determine the infiltrated volumes (ΔF) such that

$$\left(\frac{\Delta F}{\Delta t}\right) \leq \frac{f_1 + f_2}{2} = f_a \quad (26)$$

where

f_a = average infiltration rate for the period (in./hr)

and

$$f_i = aS^n \quad (27)$$

with

$$i = 1, 2$$

Retention Storage

Retention storage (D_p) was defined as precipitation excess required to satisfy the requirements of surface irregularities. The maximum amount of retention or depression storage was assumed to be a constant for a given growing season. Since this water is ponded on the surface, it can either infiltrate into

the soil or evaporate. Infiltration of depression storage was allowed during either the depletion or accretion periods depending on the conditions that existed. Evaporation was allowed only during rainless daylight hours. The magnitude of depression storage infiltrating during Δt was found from an iterative solution of equation (24).

Plant Available Water

The residual after the requirements of interception, surface runoff, and depression storage was added to the soil water reservoir as potential plant available soil water. The distribution of this water is discussed more thoroughly under the headings "Root Depth" and "Withdrawal Distribution Patterns" which follow.

Depletion Periods

The depletion period is characterized by soil water withdrawals by the processes of evapotranspiration. These intervals also included the redistribution of depression storage that accumulated during previous rain periods, the increase in potential total and potential plant available soil water due to the downward progression of the plant root system and the distribution of withdrawals with depth.

The two tillage systems investigated represented two contrasting soil surface conditions. In the conventional-tillage system bare soil was exposed for approximately 40-50 days after plowing, whereas, in the no-tillage system a heavy grass sod was killed by spraying which resulted in a heavy mulch over the entire area. During the first 40-50 days after plowing or approximately two weeks after corn plant emergence, the loss of soil water was due to the evaporation process. Transpiration became the primary mechanism by which soil water was lost when the corn crop developed its root system and its top growth to the extent that a canopy was developed over most of the area. Research^{53,54,55} indicates that losses from the two processes are approximately equal when averaged over the growing season. No data were available for the no-tillage system of corn production, however, previous work by Shanholtz and Lillard⁵⁴ indicated that transpiration would be greater in this system because of the increased demands for water as a result of more vigorous growth. Because of these two distinct periods, separate procedures were developed for approximating evaporation and evapotranspiration.

Evaporation

Veihmeyer et al.⁵⁷ studied evaporation losses from bare soil by the use of tanks and concluded after an analysis of these data that an average curve of evaporation loss versus time may be useful for specific situations. He further reported that his studies revealed that evaporation decreased quite rapidly after initial saturation followed by a much slower depletion rate. The rapid decrease of evaporation after a rain or artificial wetting has been observed by numerous researchers, e.g., Amemeya et al.⁵⁸ and Abrams.⁵⁹

Evaporation from the no-tillage area may be compared to a heavy mulch. The mulch from the killed sod is in effect fastened in place by its own root system and thereby acts as an excellent insulator over the surface, which results in less evaporation from the no-tillage area. These losses are most prevalent early in the growing season.⁴⁶ In general, any material placed over a surface that will reduce temperature will tend to suppress evaporation.^{60,61,62,63,64,65,66,67,68,69,70,71,72,73} A study of the results of various mulch studies led to the hypothesis that the evaporation from the killed sod seedbed would follow an exponential depletion rate, but at a much slower rate than for the bare soil situation.

Evaporation formula for Groseclose silt loam soil was developed from actual field measurements of pan evaporation, soil water, precipitation, and surface runoff. The ratio of actual plant available soil water to potential plant available soil water in the 0-12 inch soil profile plotted versus the duration from field capacity indicated an exponential decay relationship of the form

$$\frac{W_a}{W_p} = -B^t \quad (28)$$

where

$\frac{W_a}{W_p}$ = ratio of actual plant available soil water to potential plant available soil water.

t = time since the soil was at field capacity in days, i.e.,

the time since the ratio $\frac{W_a}{W_p}$ was unity.

B = evaporation decay constant.

The value of B was found to be 0.95 and 0.975 for the conventional-tillage and no-tillage systems, respectively.

By assuming unsaturated flow as insignificant over time interval Δt , the rate of change of soil water loss by the two tillage systems was expressed by (also Figure 8)

$$\left(\frac{W_a}{W_p}\right)' = \text{Log}_e (B)B^t \quad (29)$$

where

$$\left(\frac{W_a}{W_p}\right)' = \text{rate of change of the soil water ratio with respect to a given time in days.}$$

From the basic assumption that no soil water was added to the system during Δt and unsaturated flow was insignificant, the average evaporation rate during time interval Δt was found to be

$$E = W_p \text{Log}_e (B)B^{t_a} \quad (30)$$

where

E = evaporation rate in inches/day.

W_p = potential plant available water in the 0-12 inch soil horizon in inches (defined as the soil water held between 1/3 and 15 atmosphere tension).

t_a = average time since the soil was at field capacity in days.

To allow variations from the climatic conditions implicit in the derivation of equation (30) the relationship was modified by the ratio E_{pa}/E_{pt} where E_{pa} was defined as the daily pan evaporation on the date E was being determined and E_{pt} was defined as equal to the average daily pan evaporation for the period used in the derivation of equation (30). A plot of accumulated pan evaporation versus time during the test period revealed a linear relationship. The slope of this regression line was found to be 0.17 inch/day and this value was substituted for E_{pt} .

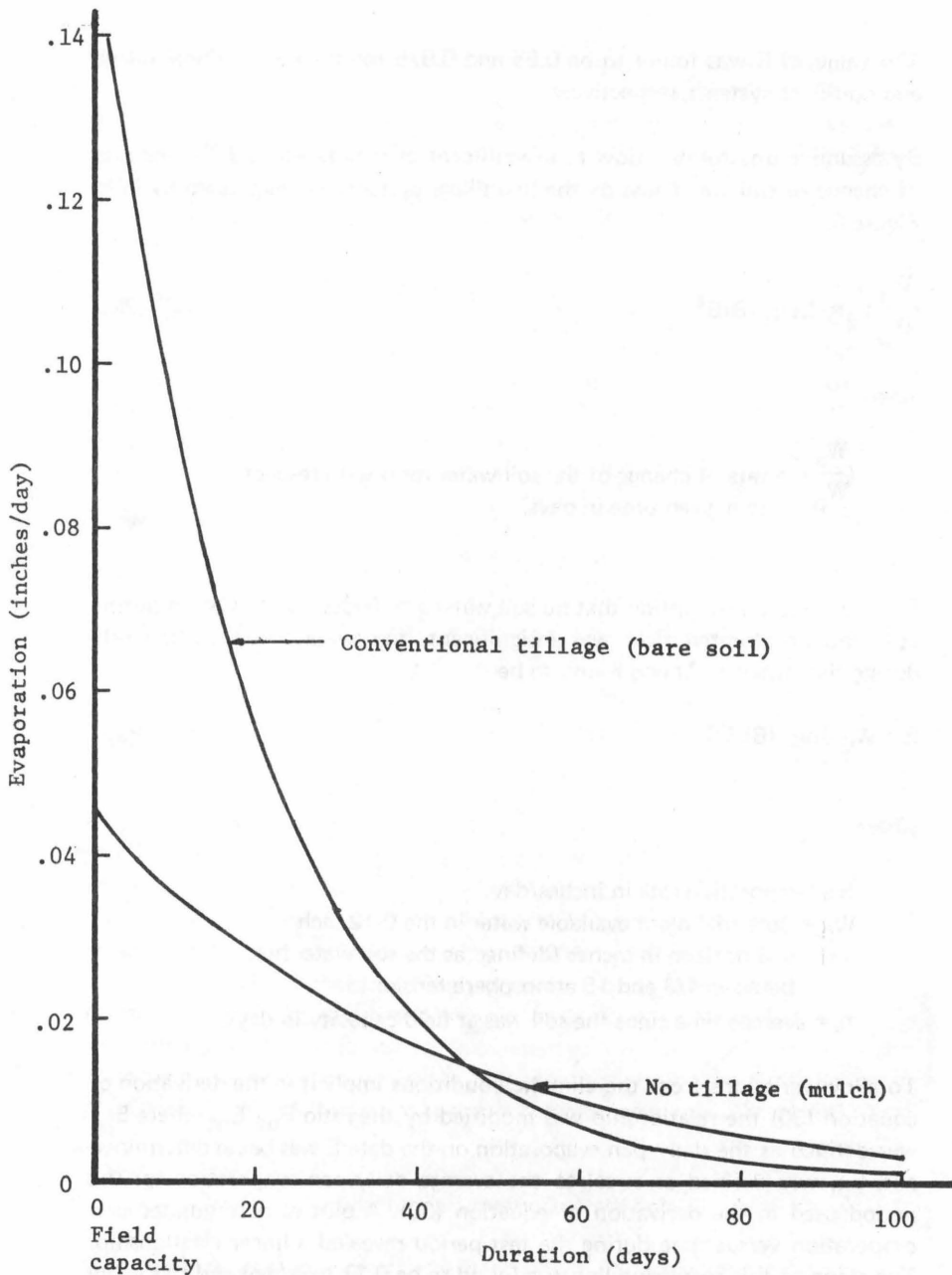


Figure 8. Typical evaporation relationship for bare soil and killed sod mulch with pan E_p equal to 0.17 inch/day and W_p in the 0-12 inch soil depth equal to 3.02 inches.

The final working equation upon substitution became

$$E = 2.94 E_{pa} W_p \text{Log}_e (B)B^t_a \quad (31)$$

Evapotranspiration

Evapotranspiration relationships were developed using the concept of potential evaporation as defined by Thornthwaite et al.³⁵ In this study pan evaporation was assumed to represent the integrated effects of climatic and meteorologic experiences and was thereby designated as the potential condition. The potential value was modified by a stress factor in an effort to simulate field conditions. The stress factor was defined as a percentage of the potential value and depicted the change in potential rate with a decrease in plant available soil water. Analytically, evapotranspiration is given by

$$ET = S(E_{pa}) \quad (32)$$

where

ET = evapotranspiration in inches/day
S = stress factor

The stress factor was determined from the appropriate curve given in Figures 9 and 10. These curves were developed from two years of soil moisture data that was collected from a statistically designed experiment to study the hydrologic aspects of conventional-tillage and no-tillage systems of corn production. The ratio, water utilized to pan evaporation, was plotted against the ratio, plant available soil water to potential plant available soil water. Envelope curves were constructed around the group of plotted points. A transition between the two extreme curves was obtained by constructing intermediate curves through points that represented the same pan evaporation. This family of curves reflected a change in potential ET with decreasing soil water content.

Soil Water Content Relationships

The downward advance of the corn root system increases the potential available soil water supply simply because a greater absorbing volume is involved. Transpiration may be near maximum although the surface conditions may be such that evaporation rates are very low. Mathematical

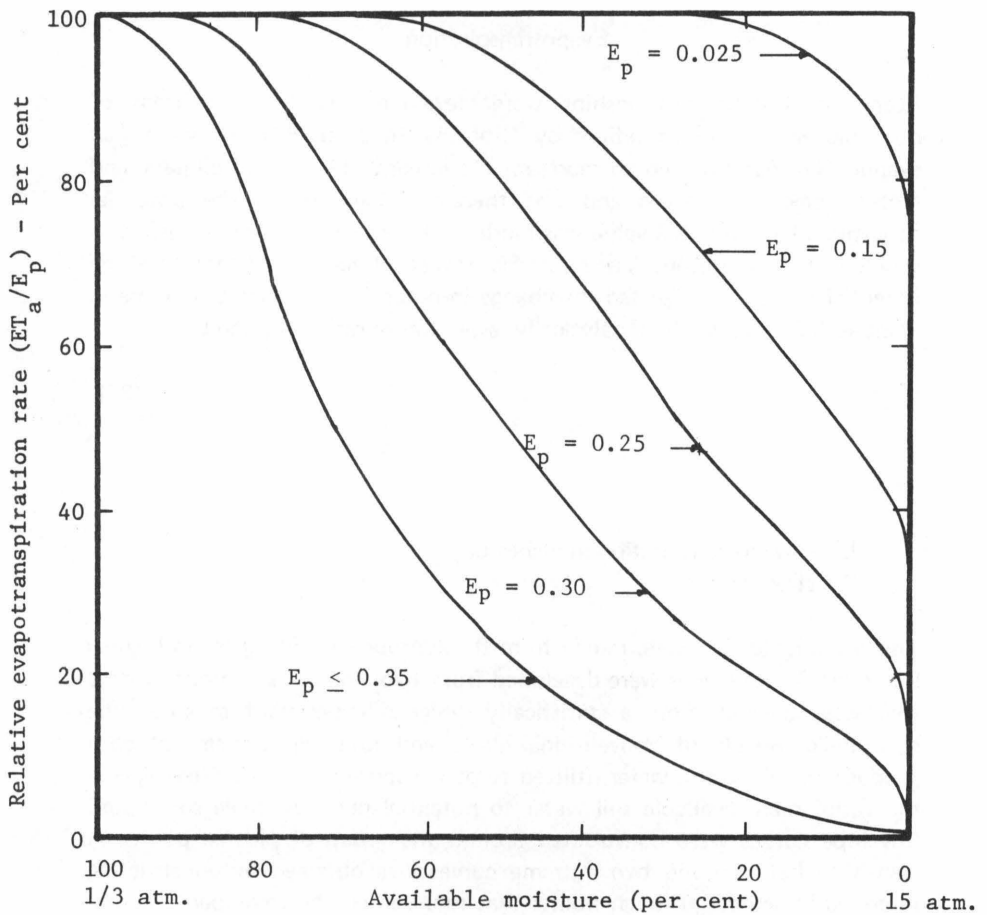


Figure 9. Relative evapotranspiration rates from conventional tillage areas for different atmospheric demand rates.

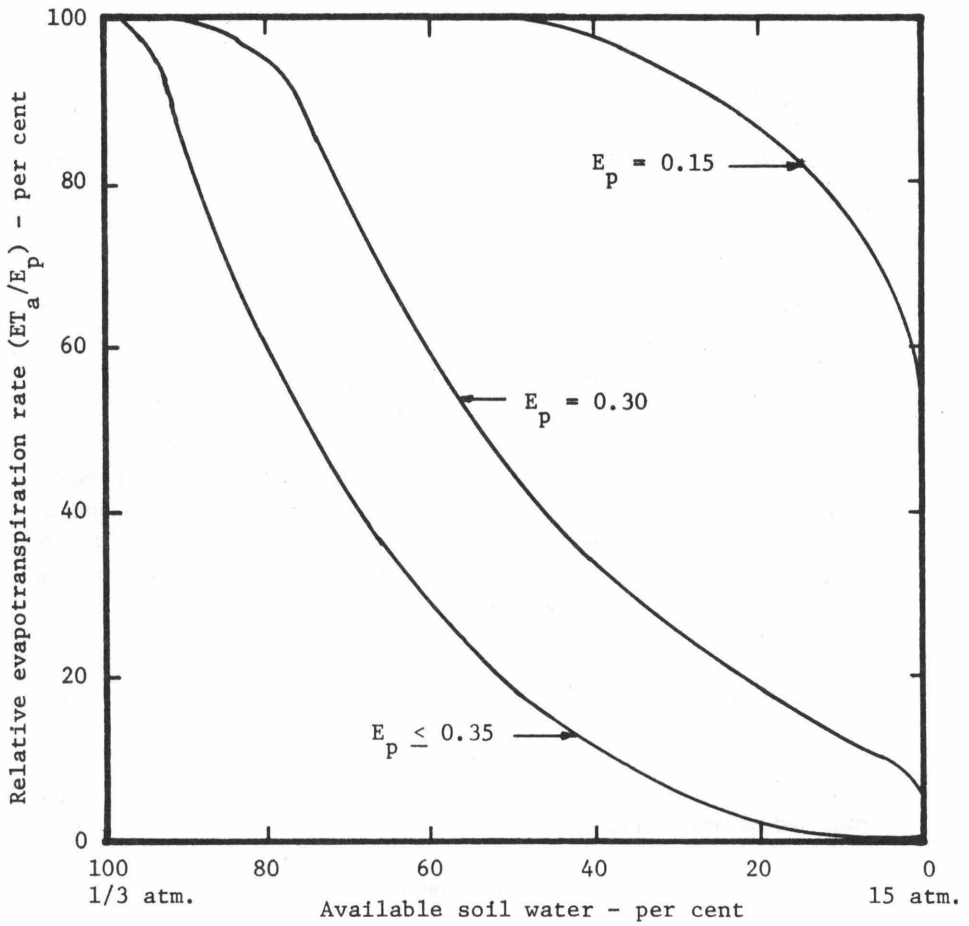


Figure 10. Relative evapotranspiration rates on no-tillage areas for different atmospheric demand rates.

expressions were developed to estimate either the potential plant available soil water and/or the saturated water content from soil profile data. Groseclose silt loam was represented by the analytical expression

$$W_p^2 + W_p - a(RD)^b = 0 \quad (33)$$

which reduces to

$$W_p = 0.5 [-1 + (1 + 4aRD^b)^{1/2}] \quad (34)$$

where

W_p = potential plant available soil water or saturated water content in inches

RD = soil profile depth or root depth in inches

a and b = constants

Equation (34) was used to compute either potential plant available soil water or saturated water content by changing the value of constants a and b . Typical curves for Groseclose silt loam are presented in Figure 11. A comparison of observed versus computed data are presented in Table I. The percentage error was determined by

$$\% \text{ Error} = 100(W_m - W_e)/W_e \quad (35)$$

where W_m is the observed accumulated soil water and W_e is the water estimated by equation (34).

A knowledge of the absorbing area of roots was necessary for the spatial simulation of soil water under given conditions. The downward progression of the root system can be affected by innumerable factors and combinations thereof. The absorbing area of roots in wet soil is less than when the soil is dry.⁷¹ Weaver⁷¹ reports, however, that the total length of the roots remain approximately the same. Other factors which may completely overshadow the plants' genetic capability for root development include soil density, soil aeration, nutrient status, textural or structural stratification, and water table.

Soil water - inches (W)

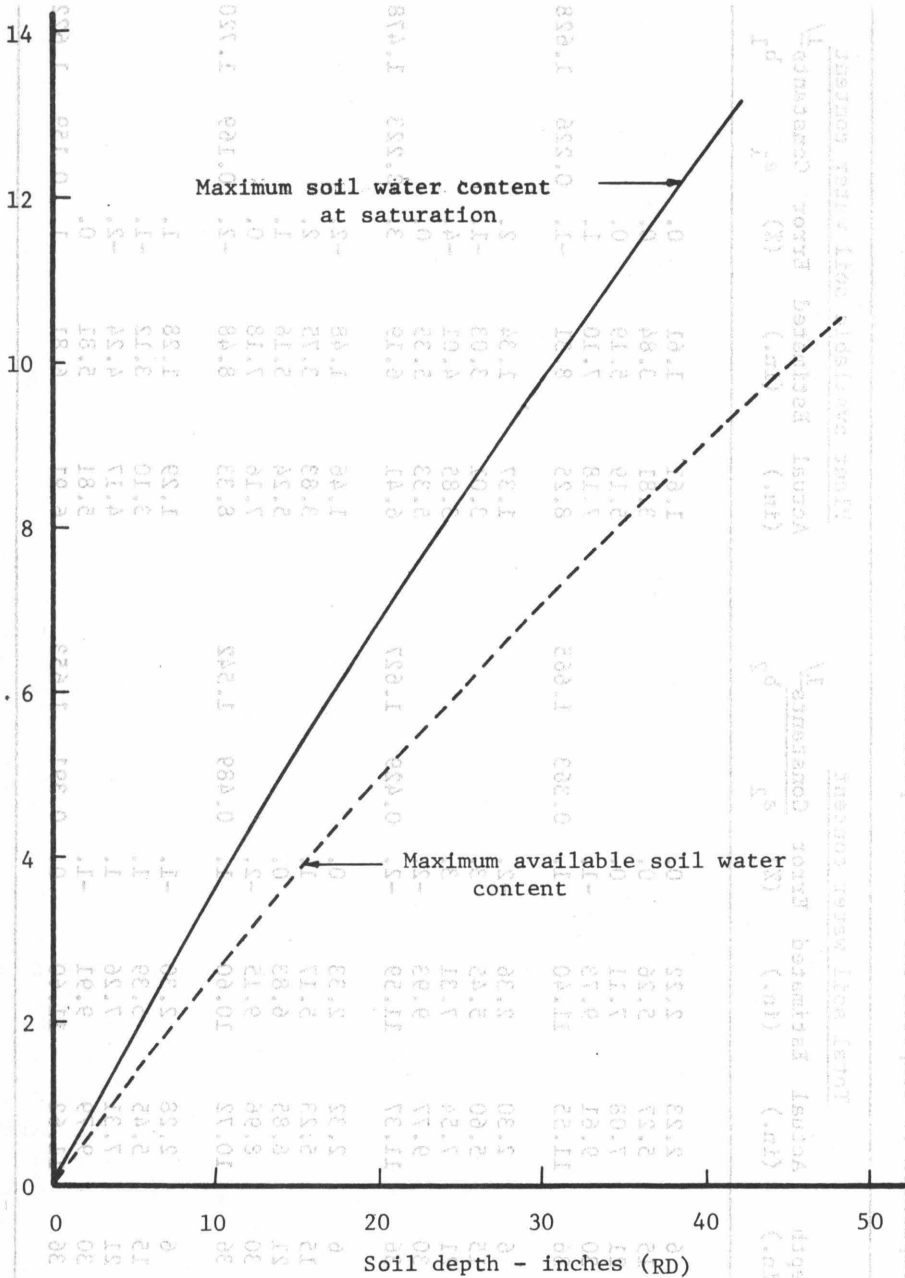


Figure 11. Typical potential available and saturated soil water content versus depth relationships for Groseclose silt loam.

Table I. Comparison of computed and measured potential soil water content in Groseclose silt loam.

Sample No.	Depth (in.)	Total soil water content				Plant available soil water content			
		Actual (in.)	Estimated (in.)	Error (%)	Constants $\frac{1}{b_2}$	Actual (in.)	Estimated (in.)	Error (%)	Constants $\frac{1}{b_1}$
1	6	2.23	2.22	0.		1.61	1.61	0.	
	15	5.27	5.26	0.		3.81	3.84	0.	
	21	7.08	7.11	0.		5.19	5.19	0.	
	30	9.61	9.73	-1.		7.18	7.10	1.	
	36	11.55	11.40	1.	0.363	8.25	8.31	-1.	0.226
2	6	2.30	2.36	-2.		1.37	1.34	2.	
	15	5.60	5.45	3.		3.01	3.03	-1.	
	21	7.54	7.31	3.		3.85	4.01	-4.	
	30	9.77	9.93	-2.		5.33	5.35	0.	
	36	11.37	11.59	-2.	0.429	6.41	6.19	3.	0.223
3	6	2.32	2.33	0.		1.46	1.48	-2.	
	15	5.23	5.17	1.		3.83	3.75	2.	
	21	6.85	6.83	0.		5.24	5.16	1.	
	30	8.96	9.15	-2.		7.16	7.18	0.	
	36	10.72	10.60	1.	0.489	8.33	8.48	-2.	0.169
4	6	2.28	2.30	-1.		1.29	1.28	1.	
	15	5.45	5.39	1.		3.10	3.12	-1.	
	21	7.31	7.26	1.		4.17	4.24	-2.	
	30	9.79	9.91	-1.		5.81	5.81	0.	
	36	11.62	11.60	0.	0.391	6.91	6.81	1.	0.159
									1.622

$\frac{1}{b}$ Constants a and b of equation (34).

An approximation of the downward progression of the corn root system was made by assuming root depth (RD) a function of plant height (Figure 12). The advancement of the roots was given by

$$RD = aH \quad RD \leq RD_{\max} \leq 5 \text{ feet} \quad (36)$$

where

RD = root depth in feet

$$a = \text{constant} = \frac{RD_{\max}}{H_{\max}}$$

RD_{\max} = maximum allowable root penetration in feet

Withdrawal Distribution Patterns

A trial and error solution was used to arrive at a proper soil water withdrawal distribution pattern. The first trials used the relationship

$$W_i = \frac{\int_{RD_{i-1}}^{RD_i} \frac{RD_i^{b-1} dRD_i}{(1 + 4aRD_i^b)^{1/2}}}{\int_0^{RD_i} \frac{RD_i^{b-1} dRD_i}{(1 + 4aRD_i^b)^{1/2}}} \quad (37)$$

where

W_i = percentage extraction

$i = 1, 2, 3, \dots$

This relationship assumed that the extraction of soil water by the process of evapotranspiration was a function of the potential plant available water in the

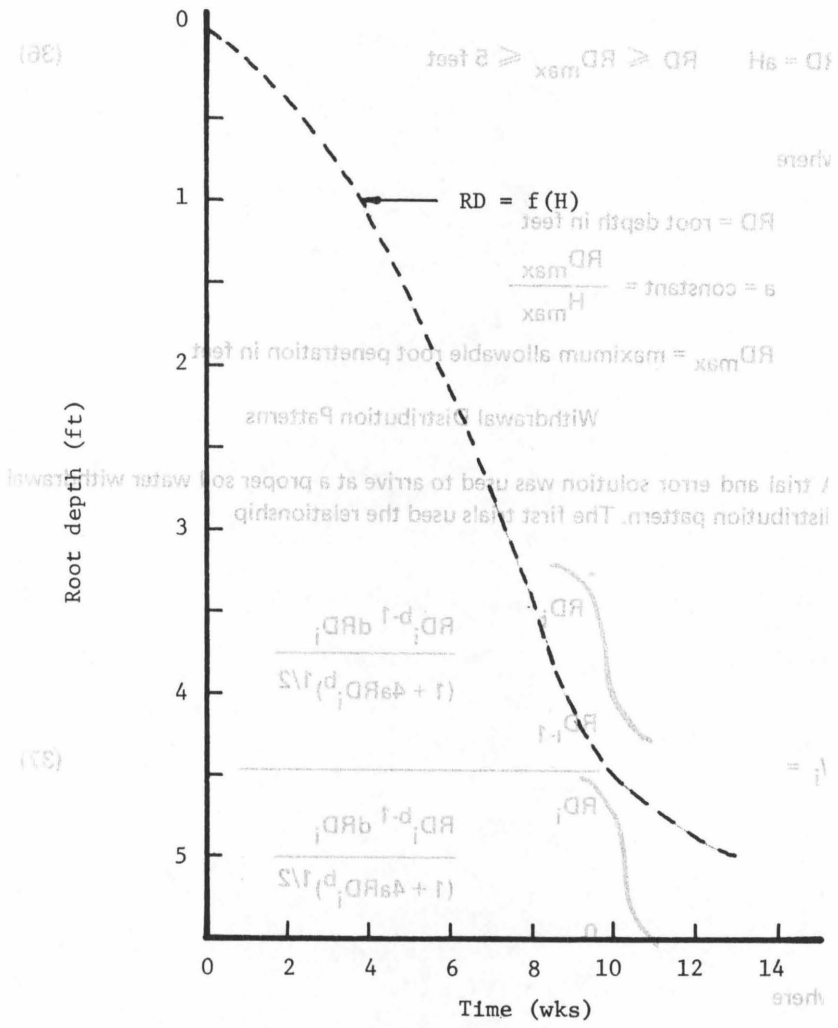


Figure 12. Vertical advancement of corn plant roots.

soil profile. This procedure resulted in excessive withdrawals at deeper depths.

A modification of equation (37) which gave better results is given by

$$W_i = k_1 \text{ AVL M} \int_{RD_{i-1}}^{RD_i} \frac{RD_i^{b-1} dRD_i}{(1 + k_2 RD_i^b)^{1/2}} \quad (38)$$

where

$$k_1 = ab$$

$$k_2 = 4a$$

In equation (38) withdrawals were assumed to occur from each soil horizon as a function of the plant available water remaining. The less soil water available, the greater the tension and the more difficult it becomes for the plant to extract moisture at the potential rate.

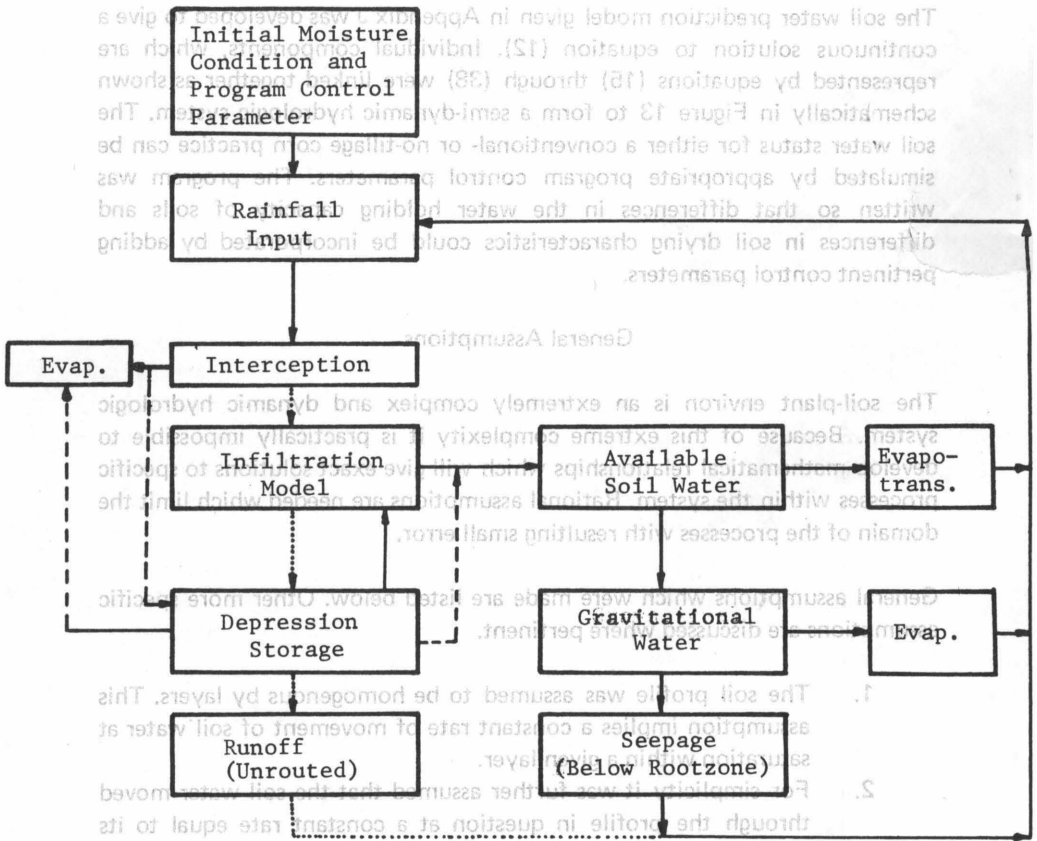


Figure 13. Schematic flowchart illustrating the general flow process in the soil water prediction algorithm.

SOIL WATER PREDICTION MODEL

General Program Design

The soil water prediction model given in Appendix J was developed to give a continuous solution to equation (12). Individual components, which are represented by equations (15) through (38) were linked together as shown schematically in Figure 13 to form a semi-dynamic hydrologic system. The soil water status for either a conventional- or no-tillage corn practice can be simulated by appropriate program control parameters. The program was written so that differences in the water holding capacity of soils and differences in soil drying characteristics could be incorporated by adding pertinent control parameters.

General Assumptions

The soil-plant environ is an extremely complex and dynamic hydrologic system. Because of this extreme complexity it is practically impossible to develop mathematical relationships which will give exact solutions to specific processes within the system. Rational assumptions are needed which limit the domain of the processes with resulting small error.

General assumptions which were made are listed below. Other more specific assumptions are discussed where pertinent.

1. The soil profile was assumed to be homogenous by layers. This assumption implies a constant rate of movement of soil water at saturation within a given layer.
2. For simplicity it was further assumed that the soil water moved through the profile in question at a constant rate equal to its saturated hydrologic conductivity.
3. The soil water content was assumed to be uniform over the area for which it was being estimated. Areal random variations in soil water content, which actually occur in nature, were not attempted. Estimated values were assumed to represent the expected values for the moisture content at the point in question.
4. Capillary movement from a permanent water table was assumed to be zero for Groseclose silt loam soils.
5. Different reactions in the system were assumed to occur in a sequential order with the quantitative estimates of each process being additive to represent the total effect at the end of a given time period.

ERRATUM

Page 43, "General Assumptions," No. 2, last line--Delete the word "hydrologic," insert in its place "hydraulic."

6. During calibration of the model estimated soil water content values were assumed to have acceptable accuracy if they fell within sampling variations of the measured value.
7. The evapotranspiration process was assumed to function only during daylight hours and rainless periods.

Model Input

The inputs are categorized in two general areas: (a) climatological data, and (b) program control data. A schematic illustrating the stacking order of all input data for subsequent computer processing is given in Figure 14.

Climatological Data

The two types of climatological data required are rainfall and pan evaporation. The format of the rainfall data is given in detail by Shanholtz et al.⁴⁴ Preferably rainfall inputs should be in sufficient detail to characterize the rainfall distribution during a given storm event so that better estimates can be made of precipitation excess and plant interception storage. To allow for efficient computation during the execution phase of the soil water model, the basic rainfall data were further reduced by subroutines NEWDAT, RDATA, OUTSKP, OUTDAT, and PAGE to the form given in Appendix A. The format and identification of each data field are given in Table II. The data specification represents the field position, format, and variable name respectively. Decimal points which are indicated must be either punched or all data fields must be right justified.

Program Control Data

The program control data include all data tables and index parameters that are required for proper program execution. These data are summarized below by groups. The position of each group in the input stream can also be obtained from Figure 14.

Reduction of Basic Rainfall and Pan Evaporation Data

Data in groups 1 through 1f are associated with the reduction of basic rainfall and pan evaporation data of the form given in Appendix A. When these data have been created in a previous job step, data groups 1a through 1f are omitted from the input stream. A description of each data group follows.

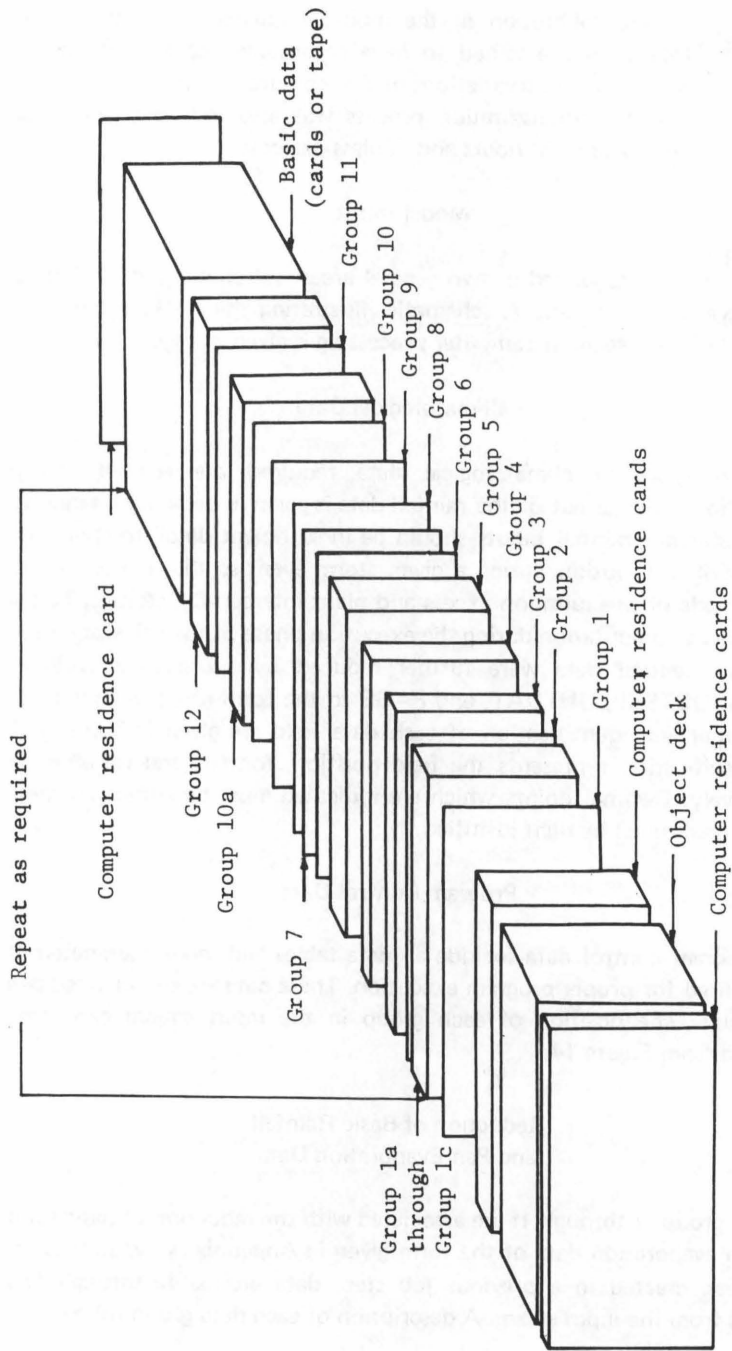


Figure 14. Schematic illustration of the order of input data required by the soil water model.

Group I (1 card)

<u>1-2</u>	(card column)
<u>XX</u>	(data format)
NDASET	(variable name)

Symbol

Description of Variables

NDASET

Index code that indicates the status of basic rainfall data.

NDASET = 0: The rainfall and pan evaporation data have been reduced in a previous job step.

NDASET = 1: The data illustrated in Appendix A must be created before control is transferred to the soil water model. Data Groups 1a through 1f are required.

Group 1a (1 card)

<u>1</u>
<u>X</u>
NL

Symbol

Description of Variables

NL

Index code that is used to list various input data for error check.

NL = 0: Sunrise, sunset, and daylight tables, along with parameter cards and pan evaporation data are listed for error checks.

NL = 1: Listing option is bypassed.

Table II. Format and data description of climatological data required by the soil water model.

3-4	6-7	9-10	12-18	22-28	32-36
XX	XX	XX	XX.XXXX	XX.XXXX	XX.XX
MONTH	NDAY	NYEAR	HR	TI	ACP
39	44-47	51-57	61-65	69-70	
XX	X.XX	XX.XXXX	XX.XX	XX	

KODE	EPA	EFTIME	STACO	NSTNO
KODE	EPA	EFTIME	STACO	NSTNO

<u>Variable Name</u>	<u>Description</u>
MONTH	Numeric identification for month
NDAY	Day
NYEAR	Last two digits in year identification
HR	Time of day (military)
TI	Δt
ACP	ΔP
KODE	KODE = 2 signals end of rainfall data
EPA	Daily pan evaporation (in./hr)
EFTIME	The actual time during Δt that the ET process < is active. $EFTIME \leq TI$
STACO	Total storm rainfall (in.)
NSTNO	Storm number

XX.XXX X.XXX X.XXX
 Data group 1e and 1d are comprised of the basic rainfall data and the time of day that sun sets at a given location. The form of each table follows.

DAYL(J,I)	DAYL(J+I,I)	DAYL(J+II,I)
XXX.X	Description of Variables	XXX.X
DAYL	Number of hours of daylight.	

Group 1e (1 card)

Data group 1e contains the program control information that is required for the reduction of the basic rainfall data. One card will be needed for each rainfall dataset, where a dataset is defined as the rainfall data for a specific growing season.

1-3	4-8	9-11	12-16	12-18	19-20	22-23
XX	XXXXX	XXX	XXXXX	XX	XX	XX
UPC	NSEQ	END1	ND2	L	LAST	NYA
24-25	26-27	80				
XX	XX	X				
NCOV	NWRED	DUMMY				

Symbol **Description of Variables**
 UPC Update code associated with the first line of basic rainfall data that is to be obtained from input unit L.

Groups 1b, 1c, and 1d

Data groups 1b, 1c, and 1d are comprised of sunrise, sunset, and daylight hours tables, respectively. The form of each table follows.

5-9	10-14		59-64
X.XXX	X.XXX	.....	X.XXX
SUNRIS(J,I)	SUNRIS(J+1,I)		SUNRIS(J+11,I)

Symbol

Description of Variables

SUNRIS

Time of day that the sun rises at a given location.

J

Month of year where January is coded as 1, February as 2, and so on.

I

Day of month.

4-9	10-15		69-75
X.XXX	X.XXX	.....	X.XXX
SUNSET(J,I)	SUNSET(J+1,I)		SUNSET(J+11,I)

Symbol

Description of Variables

SUNSET

Time of day that sun sets at a given location. This information can be obtained in abbreviated form from meteorological tables.

NSEQ	Data sequence number. UPC and NSEQ are required to locate the beginning of the rainfall dataset.
END1	Update code associated with the last line of rainfall data that is to be obtained from input unit L.
ND2	Ending data sequence number. END1 and ND2 are required to locate the termination of the dataset.
L	Logical device number assigned to the input dataset.
LAST	Index code for terminating processing.
	<p>LAST: 0: Proceed to the next dataset. A new set of control parameters (Data Group 1e must be read).</p> <p>LAST: 9: Signals the last dataset to be reduced.</p>
NY	The last two digits of the calendar year.
NCOV	Index code that gives the form of the input dataset.
	<p>NCOV = 1: The input dataset resides on a 7 channel tape that was created by an IBM 7040 Computer. These data contain a 6 digit number at the beginning of each record that must be bypassed.</p> <p>NCOV = 2: Normal format assumed.</p>
NWRED	Index code that gives the location status of the magnetic tape being used for input.
	NWRED = 0: Input tape is not rewind.

NWRED = 1: Input unit designated by L is
rewound.

Group 1f

Data group 1f consists of the rainfall data prior to its reduction to the form given in Appendix A. The format of this data is given in detail by Shanholtz et al.⁴⁴

$$\frac{1}{X}$$

NCONTR

<u>Symbol</u>	<u>Description of Variables</u>
NCONTR	Index code used for listing input data tables for error check.
	NCONTR = 0: Listing for error check bypassed.
	NCONTR = 1: Listings are made.

Groups 3, 4, and 5

Data groups 3 and 4 report the stress curves for conventional-tillage and no-tillage systems, respectively. Group 5 is a table of daylight hours and has been identified previously. The form of groups 3 and 4 are listed below. The decimal points that are indicated in the format specification are not to be punched. They simply indicate the orientation of the data field. Data fields are continued as shown until all coordinate points have been punched. Additional cards are used as required.

1-2	3-6	7-11	12-15	16-21
XX	XX.XX	XX.XXX	XX.XX	XX.XXX
N	DCONT1(N,I)	DCONT2(N,I)	DCONT1(N,L+1)	DCONT2(N,I+1)

<u>Symbol</u>	<u>Description of Variables</u>			
DCONT1	Ratio of actual plant available water to potential plant available water in the 0-18 inch soil profile of conventional-tillage areas (See Figure 9).			
DCONT2	Corresponding ratio of actual evapotranspiration to potential evapotranspiration.			
N	Stress or demand curve number starting with one at the top of Figure 9.			
I	Data field number which varies from 1 to K for each curve, where K represents the maximum number of points per curve.			
1-2	3-6	7-11	12-15	16-21
XX	XX.XX	XX.XXX	XX.XX	XX.XXX
N	DNOTI1(N,I)	DNOTI2(N,I)	DNOTI1(N,I+1)	DNOTI2(N,L+1)

<u>Symbol</u>	<u>Description of Variables</u>
N	Stress or demand curve number starting with one at the top of Figure 10.
DNOTI1	Ratio of actual plant available water to the potential plant available water in the 0-18 inch soil profile of no-tillage areas (see Figure 10).
DNOTI2	Corresponding ratio of actual evapotranspiration to potential evapotranspiration.
I	Data field number which varies from 1 to K.

Group 6 (1 card)

The function of data group 6 is simply to furnish control information specifying when succeeding data groups must be included for a given analysis.

1-2	3-4	5-6	7-8	9-10
XX	XX	XX	XX	XX
NDA1	NDA2	NDA3	NDA4	NDA5

Symbol

Description of Variables

NDA1

Index code that gives the status of data group 7.

NDA1 = 1: Data group 7 required.

NDA1 = 2: Data group 7 omitted.

NDA2

Index code that gives the status of data group 8.

NDA2 = 1: Data group 8 required.

NDA2 = 2: Data group 8 omitted.

NDA3

Index code that gives the status of data group 9.

NDA3 = 1: Data group 9 required.

NDA3 = 2: Data group 9 omitted.

NDA4

Index code that gives the status of data group 10.

NDA4 = 1: Data group 10 required.

NDA4 = 2: Data group 10 omitted.

NDA5 Index code that gives the status of data group 11.

NDA5 = 1: Data group 11 required.

NDA5 = 2: Data group 11 omitted.

Group 7 (1 card)

The soil profile is subdivided into seven zones to a maximum of 5 feet. The first zone represents the depth of the Ap or A horizon. Succeeding zones may be arbitrarily selected. The distance from the soil surface to the bottom of each zone is punched according to the following format.

1-10	11-20	.....	61-70
XX.X	XX.X		XX.X
ADEP(1)	ADEP(I+1)	.....	ADEP(I+6)

<u>Symbol</u>	<u>Description of Variables</u>
ADEP	Depth to lower limit of the zones given in Figure 5. Decimal points must be punched.
I	Zone number beginning with 1 for the top level.

Groups 8, 9, 10

The following data groups represent the various parameters and control options that are required for proper execution of the soil water model.

The form of group 8 is given by:

1-10	11-20	21-30	31-40	41-50	51-60
X.XX	X.XX	X.XX	X.XX	X.XX	X.XX
FC	A	POWER	RET	COEFA1	COEFA2

61-70 71-80

X.XX X.XX

COEFB1 COEFB2

<u>Symbol</u>	<u>Description of Variables</u>
FC	Saturated hydraulic conductivity (in./hr)
A	Constant a in equation (24).
POWER	Constant b in equation (24).
RET	Maximum allowable retention storage (in.).
COEFA1	Constant a in equation (34) when potential plant available water computations are performed. Left blank if tabular data are used.
COEFA2	Constant a in equation (34) when saturated conditions are determined. Left blank if tabular data are used.
COEFB1	Constant b in equation (34) when potential plant available water computations are performed. Left blank if tabular data are used.
COEFB2	Constant b in equation (34) when saturated conditions are determined. Left blank if tabular data are used.

Input data group 9 is represented by:

1-10	11-20	21-30	31-40	41-50	51-60	61-70
XX.X	XXX.X	XXX.X	X.XX	X.XX	X.XXX	X.XXX
DTM	HNTM	NCTM	HNMIN	HNFAC	EXBASE	CXBASE

<u>Symbol</u>	<u>Description of Variables</u>
DTM	Time from plant emergence to full tassel (wks).
HNTM	Height of corn grown on no-tillage areas when at full tassel (in.).
NCTM	Height of corn grown on conventional-tillage areas when at full tassel (in.).
HNMINT	Maximum allowable plant interception storage for a given storm when corn on no tillage areas is at full tassel.
HNFAC	Maximum areal coverage of the corn plant at full tassel.
EXBASE	Evaporation recession coefficient for either the no-tillage or conventional-tillage system.
CXBASE	Evaporation recession coefficient for short periods immediately after large rains.

Data group 10 is given by:

1-2	3-4	5-6	7-8	9-10	11-12
XX	XX	XX	XX	XX	XX
NTILL	NPRINT	NREWD	LEND	MEMERG	NEMERG
13-14	15-16	17-18	19-20	21-22	23-34
XX	XX	XX	XX	XX	XX
NY	NCREAT	M	NPLOT	LENGTH	NCOMP

25-26	27-28	29-30	31-32	33-34
XX	XX	XX	XX	XX
NBM	NBD	NSTAT	LIMIT	INTERP

<u>Symbol</u>	<u>Description of Variables</u>
NTILL	<p>Index code giving the tillage system for which the computations are to be made.</p> <p>NTILL = 1: Conventional Tillage</p> <p>NTILL = 2: No tillage</p>
NPRINT	<p>Index code giving different output options.</p> <p>NPRINT = 0: Soil water status listed for each time increment (see Appendix B).</p> <p>NPRINT = 1: The soil water status listed at the end of each day.</p> <p>NPRINT = 2: Only the daily summaries by zones are listed. Note that the daily summary by zones are given for all options.</p>
NREWD	<p>Index code indicating when the unit containing the input dataset must be rewind.</p> <p>NREWD = 0: Input unit is not rewind.</p> <p>NREWD = 1: Rewind logical unit M.</p>
LEND	<p>Index code which signals the end of an analysis.</p>

	LEND = 0:	A new analysis to follow.
	LEND = 9:	Signals the end of all analyses.
MEMERG		Month of plant emergence.
NEMERG		Day of plant emergence.
NY		Year of analysis.
NCREAT		Index code used to specify when a duplicate dataset must be created for subsequent analysis with the same rainfall and pan evaporation data.
	NCREAT = 0:	No duplicate dataset.
	NCREAT = 1:	Create a duplicate dataset.
M		The logical device number that has been assigned to the input unit.
NPLOT		Index code indicating different plotting options.
	NPLOT = 0:	No plot of output data.
	NPLOT = 1:	Daily simulated soil water, measured soil water, and sampling range for measured data are plotted. When NPLOT = 1, a table of measured soil water data must be entered.
	NPLOT = 2:	Same as NPLOT = 1, except the table of measured values is not required.
LENGTH		Number of zones for which daily summaries and plottings are to be made.

NCOMP	Index code specifying optional comparison between the two tillage systems.
NCOMP = 0:	No comparisons.
NCOMP = 1:	A coordinate plot is given of the soil water status in the two tillage system.
NCOMP = 2:	Simulated and measured data are retained so that they can be compared by plotting in succeeding step.
NCOMP = 3:	Monthly and seasonal summaries of the frequency of occurrence of the simulated soil water at selected levels is determined for both tillage systems.
NBM	Beginning month for plotting of the first zone.
NBD	Beginning day for plotting the first zone.
NSTAT	Index code for statistical analysis.
NSTAT = 0:	No statistical summaries are made.
NSTAT = 1:	Linear correlation determined between the measured and simulated daily soil water content.
LIMIT	The range of the sampling variation expressed as a percentage of potential available soil water. A range of 10 to 20 per cent is not uncommon.

INTERP Index code used to specify when tabular data required for potential soil water content computations.

INTERP = 0: No tabular data required.

INTERP = 1: Tabular data required.

Group 10a

Group 10a is required when INTERP = 1, i.e., tabular data are required for potential soil water determinations. The data are punched in 5 column fields according to the following format.

1-5	6-10	11-15	(5L+1)-(5L+5)
XXXXX	XX.XX	XX.XX	.... XX.XX
L	SMTAB1(J)	SMTAB1(J+1)	SMTAB1(L)
(5L+6)-(5L+10)		(5L+11)-(5L+15)	(10L+1)-(10L+5)
XX.XX		XX.XX	.... XX.XX
SMTAB2(L+1)		SMTAB2(L+2)	SMTAB2(2L)
(10L+6)-(10L+10)		(10L+11)-(10L+15)	(15L+1)-(15L+5)
XX.XX		XX.XX	XX.XX
SMTAB3(2L+1)		SMTAB3(2L+2)	SMTAB3(3L)

<u>Symbol</u>	<u>Description of Variables</u>
L	Number of values in each table
SMTAB1	Accumulated soil depth from surface (in.).
SMTAB2	Corresponding accumulated plant available soil water (in.).
SMTAB3	Corresponding total soil water (in.).
J	Index code which varies from 1 to L.

Group 11 (1 card)

1-10	11-20	61-70
X.XX	X.XX	X.XX
PERC(I)	PERC(I+1)	PERC(I+6)

<u>Symbol</u>	<u>Description of Variables</u>
PERC	Initial plant available soil water expressed as a percentage of potential plant available soil water in the respective zones.
I	Index ranging from 1 to 7.

Group 12

This data group is required when NPLOT is equal to 1.

1-2	3-4	5-9	10-14
XX	XX	XX.XX	XX.XX
MO	NO	ACMOST(NT,L,MO,NO)	ACMOST(NT,L+1,MO,NO)

35-39

XX.XX

ACMOST(NT,L+6,NO,MO)

<u>Symbol</u>	<u>Description</u>
MO	Month
NO	Day
ACMOST	Measured soil water content
NT	Tillage system
	NT = 1: Conventional Tillage
	NT = 2: No tillage
L	Zone

Computational Procedure

The soil profile was subdivided into 7 zones. The upper zone (zone 1, Figure 5) terminates at the lower edge of the A_p or A horizon. Zone 7 ends at maximum expected root penetration. The intermediate zones were arbitrarily selected at 6- and 12-inch increments. The total storage capacity above wilting point for each zone was categorized as gravitational water or plant available soil water. Gravitational water was free to move to succeeding layers by a rate equal to its saturated hydraulic conductivity. Flow below the root zone was assumed to be lost to the plant for the time in question. Plant available soil water remained in place until depleted by the evapotranspiration process.

Rain Period

A rain period was defined as a Δt interval with continuous natural or artificial rainfall. These periods represent a recharge to the soil profile with the magnitude regulated by the processes of plant interception, rainfall amount, and intensity and soil infiltration capacity. Interception is a function of plant physiology and rainfall and was determined from equations (17), (21), and (22). The infiltration capacity of the soil was determined by equation (24). Rainfall that could not be infiltrated during Δt was termed precipitation excess, which was subsequently subdivided into unrouted surface runoff and retention storage. Retention storage was allowed to infiltrate and evaporate during a succeeding Δt .

All recharge was assumed to take place in zone one. Recharge of adjacent zones was initiated when the requirements of plant available water in the zone immediately above was satisfied. Gravity water was moved through the soil profile at the beginning of each Δt .

Rainless Period

The rainless periods were defined to include all time increments during which rainfall was equal to zero. Therefore, this period may be considered as predominantly a period of infiltration recovery. Soil water was depleted from all zones by the process of evapotranspiration and moved vertically downward where appropriate by saturated porous media flow relationships. The total ET loss from all zones was estimated by the relationships (31) and (32) and the withdrawal from each zone was dictated by expression (38).

Although the rainless period represented, in general, withdrawal from the system, recharge of the top zone was possible from retention storage that remained from a previous rain period. The volume and the time required for this recharge was determined by equation (24). Evapotranspiration from the soil profile was assumed to be zero when the time required to infiltrate retention storage exceeded Δt .

Typical Model Output

With rainfall, pan evaporation and appropriate control parameters, the model determines the soil water status for each time increment. Typical results are given in Appendix B. This output resulted from the data presented in abbreviated form in Appendix A. The daily soil water content of each zone is summarized and stored for subsequent listing in tabular form. A quick check on the seasonal distribution of simulated values can be obtained by specifying a coordinate plot of the daily soil water content.

MODEL CALIBRATION

General Procedure

Calibration procedures involved the comparison of simulated and observed soil water values for the 1966 and 1967 growing seasons. These two years were selected because detailed soil moisture data were available for calibrating the model and segments of the soil moisture, and plant physiological data from these two years were used in the development of evapotranspiration and interception formula.

Goodness of Fit

The most difficult task during calibration was ascertaining "goodness of fit." The normal procedure in these circumstances would involve the placing of confidence limits around the mean, which requires an estimate of the sample standard error given by

$$S_{\bar{x}} = s / \sqrt{n} \quad (39)$$

where $S_{\bar{x}}$ is the sample standard error, S is the standard deviation, and n is sample size.

Three types of errors were associated with the mean of each set of measured points that were used to represent the actual plant available soil water content. These errors were categorized as sampling errors, instrument errors from nuclear soil moisture monitoring equipment, and laboratory errors, which included all sampling and equipment errors related to the determination of points on the soil moisture depletion curve.

A randomized complete block design containing 24 plots was used to measure the hydrologic response of the two tillage systems. Random soil samples were taken from all plots and desorption curves developed for each. The results from the twelve no-tillage and conventional-tillage areas were averaged as shown in Table III. Although some variation is still apparent, potential erroneous laboratory errors have been greatly minimized due to the number of replications.

Table III. Percentage soil water by volume for indicated depth and tension.

Growing Season	Tillage system	Depth (in.)	Percentage soil water by volume					
			1/3Atm	1Atm	2Atm	4Atm	6Atm	15Atm
1966	No tillage	0-6	35.39	24.58	17.79	13.06	10.75	8.55
		6-15	37.65	28.23	22.48	18.64	16.22	13.21
		15-21	44.25	34.92	30.59	27.31	24.81	21.18
		21-30	46.53	37.31	32.84	30.40	27.21	24.49
		30-	42.43	35.52	32.18	30.05	27.19	24.50
	Conventional tillage	0-6	31.36	21.48	15.85	11.85	9.80	7.02
		6-15	40.93	29.14	23.75	19.43	17.07	14.64
		15-21	47.87	38.00	33.09	29.63	27.08	24.36
		21-30	50.52	41.51	37.35	34.49	31.88	29.13
		30-	47.17	39.29	35.82	33.19	30.41	27.67
1967	No tillage	0-6	30.08	22.78	17.79	12.22	10.15	7.27
		6-15	28.54	23.26	19.31	15.13	13.01	10.34
		15-21	33.13	30.53	26.94	24.35	21.86	19.05
		21-30	44.38	38.78	35.28	32.82	30.28	27.91
		30-	47.99	40.90	37.60	35.04	32.36	30.13
	Conventional tillage	0-6	29.13	22.29	17.76	13.27	10.48	7.65
		6-15	31.94	24.62	20.61	16.52	14.35	11.80
		15-21	38.17	31.78	28.69	24.78	23.00	20.38
		21-30	43.20	36.12	33.09	29.78	27.86	25.00
		30-	44.77	37.31	34.39	31.50	29.26	26.38

Instrument errors were due to the random emission of fast neutrons from a radioactive source. This random variation has been given considerable attention by research consultants and staff working for industry involved in the production of nuclear soil moisture monitoring equipment. From statistical theory they recommend that duplicate readings be obtained at each soil moisture site and that the readings be within 200 counts for a 95 per cent confidence that the actual soil water content will fall within this range. All measurements were subsequently obtained following these guidelines.

The third error involved sampling variation. The relative magnitude of this variation can be viewed by computing the sample standard error. However, consultation with statisticians revealed that an unbiased estimate of sample standard error was not possible because instrument and laboratory errors could not be correctly evaluated. Instrument errors in particular lost their random variation when the readings were forced to fall within a predetermined range.

After an evaluation of the errors, the procedure finally adopted was to construct a range about the mean estimate. The extent of this range was measured by the difference between the maximum and minimum estimates obtained over the experimental area. An acceptable calibration was assumed when 95 per cent of the computed values were within this range.

Parameter Adjustment

The parameters which were subject to adjustment during calibration were the evaporation recession constant (equation 31), infiltration parameter (equation 24), potential interception storage (equation 17), and potential retention storage discussed under "Retention Storage" in the section on "Development of Soil Water Prediction Model." The evaporation recession constant affected the simulation by increasing or decreasing soil water withdrawals during the period between seedbed preparation and corn plant emergence, and for short intervals after rainfall.

The variation of the evaporation recession constant with time from field capacity is illustrated in Figure 15. The stress constant affected the withdrawal rate during the predominant transpiration period. The infiltration and retention storage parameters regulated the volumes of water appearing as direct infiltration, delayed infiltration, and surface runoff. A decrease in the infiltration constant results in an increase in the surface runoff estimate. The magnitude of water interception by the plant canopy was determined by the interception parameter. Optimization of those parameters can only be achieved by trial and error when experimental data are not available to derive more exacting values.

Comparison with 1966 and 1967 Data

A summary of the model parameters that were used to synthesize the soil water status during the 1966 and 1967 growing seasons is given in Table IV. Computed and observed values are compared in Figures 16 through 31. Evapotranspiration estimates are accumulated for comparison in Figures 32 and 33, and mass curves of rainfall and pan evaporation are presented in Figures 34 and 35.

An inspection of Figure 34 shows different rainfall distributions for the 1966 and 1967 growing seasons. In 1966 a drought occurred during June and July which was followed by heavy rains, while, in contrast, the 1967 growing season was characterized by a relatively uniform rainfall distribution. The

monthly rainfall distributions expressed as a percentage of the total for the growing season was compared with the long term average in Table V.

In 1966 only 18.4 per cent of the rainfall occurred during the period May 1 to July 29 while in 1967, 53.1 per cent was recorded during the same period. The effect of these two climatological patterns on the magnitude and seasonal distribution of the soil water content in the top one foot can be observed in Figures 16 and 24.

Pan evaporation was assumed to be an indicator of atmospheric demand, i.e., the potential evaporative capacity of the atmosphere. The magnitude and distribution of pan evaporation therefore becomes quite important in the interpretation and outcome of simulation results. In general, there will be an inverse relationship between pan evaporation and rainfall, i.e., the higher the rainfall the lower the pan evaporation rate. If all rainfall occurs at night followed by clear, hot days, then this relationship has no meaning.

Table V. Monthly rainfall distribution expressed as a percentage of the total for the growing season.

Year	May		June		July		Aug.		Sept.	
	P	%	P	%	P	%	P	%	P	%
1966	1.58	10.4	0.26	1.7	4.19	27.6	4.00	26.3	5.16	34.0
1967	4.54	27.9	1.80	11.1	3.13	19.2	4.22	25.9	2.45	15.0
68 yr. avg.	4.49	22.1	4.20	20.6	4.82	23.7	3.82	18.8	3.01	14.8

The seasonal distribution of pan evaporation for a 20-year period beginning with the 1946 growing season and including comparative values for the 1966 and 1967 growing seasons are presented in Table VI. In 1966 E_p exceeded 0.20 inch/day 29 per cent of the time, while in 1967 it was only exceeded 7 per cent of the time. The higher values reflect potential drought conditions which are characterized by high E_p rates for extended periods. The daily distributions can be viewed in Figure 35.

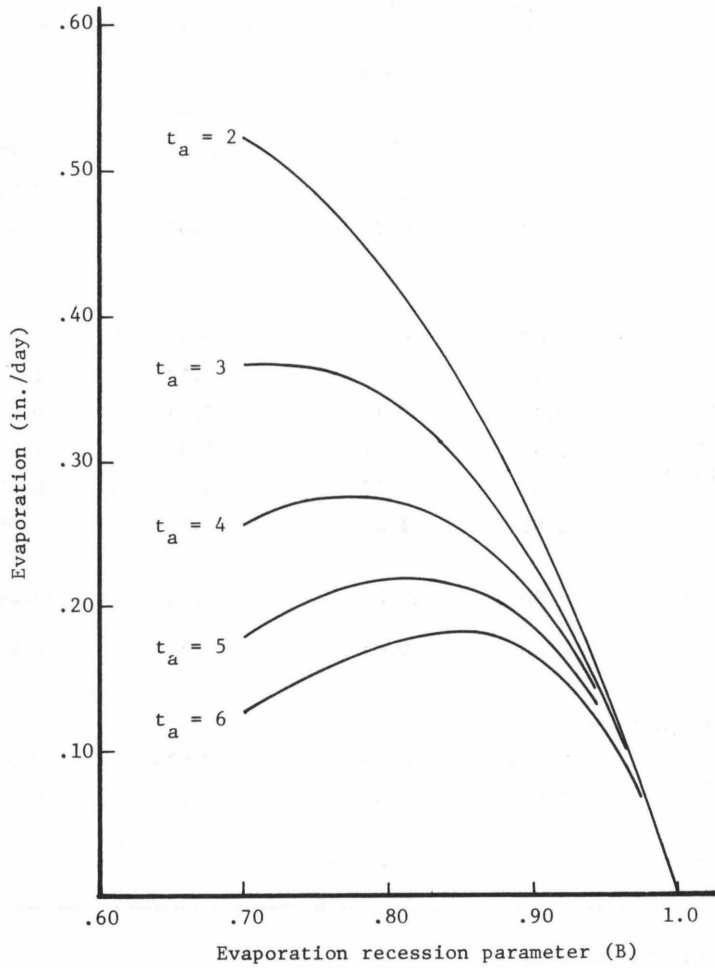


Figure 15. Evaporation versus evaporation recession constant.

Table IV. Summary of soil water prediction model parameters for the 1966 and 1967 growing seasons.

Parameter	1966		1967	
	No tillage	Conventional tillage	No tillage	Conventional tillage
<u>Plant</u>				
IC _m	0.03	0.029	0.03	0.02
F _m	0.98	0.93	0.98	0.70
D _m	13.00	13.00	13.00	13.00
H _m	116.00	110.00	116.00	82.00
<u>Soil:</u>				
a ^{1/}	0.40	0.20	0.40	0.20
b ^{1/}	1.67	1.67	1.67	1.67
a ^{2/}	0.23	0.17	0.17	0.15
b ^{1 2/}	1.62	1.71	1.61	1.63
a ^{2 2/}	0.35	0.47	0.54	0.38
b ^{2 2/}	1.68	1.56	1.63	1.66
ADEP(1)	12.00	12.00	12.00	12.00
D _p	0.30	0.05	0.30	0.05
<u>Evapotranspiration:</u>				
B ^{3/}	0.975	0.95	0.975	0.95
B ^{3/}	0.93	0.93	0.93	0.93
Tables	see Figures 9 and 10			

^{1/} Constants for equation (27)

^{2/} Constants for equation (34)

^{3/} Constants for equation (31)

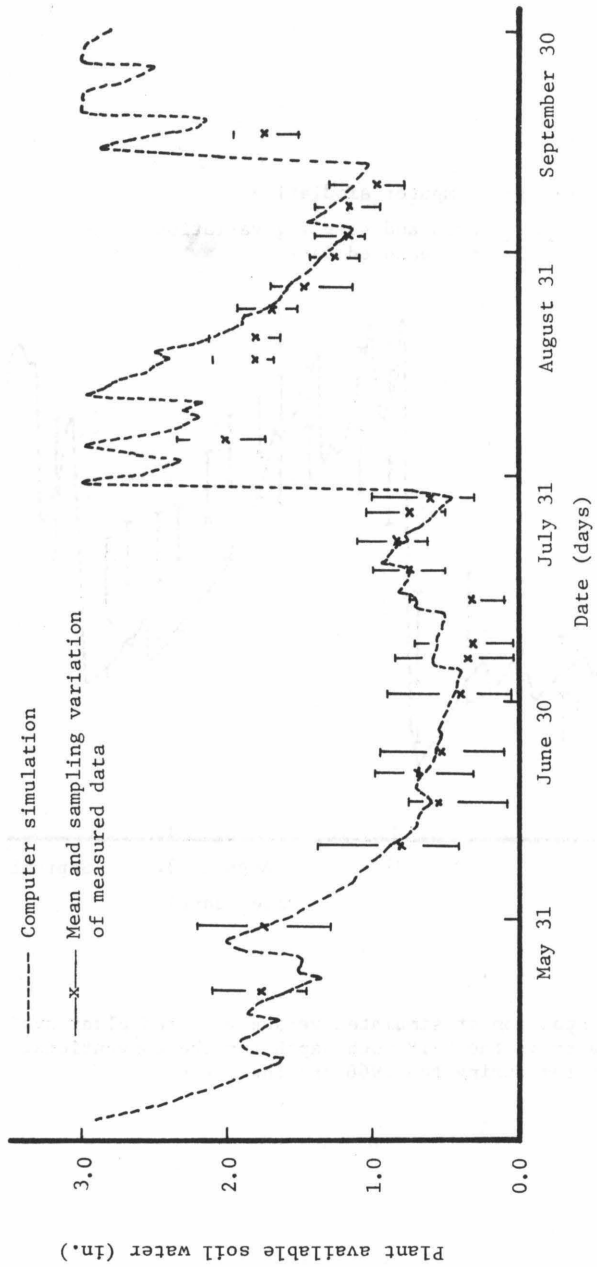


Figure 16. Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the conventional tillage system during the 1966 growing season.

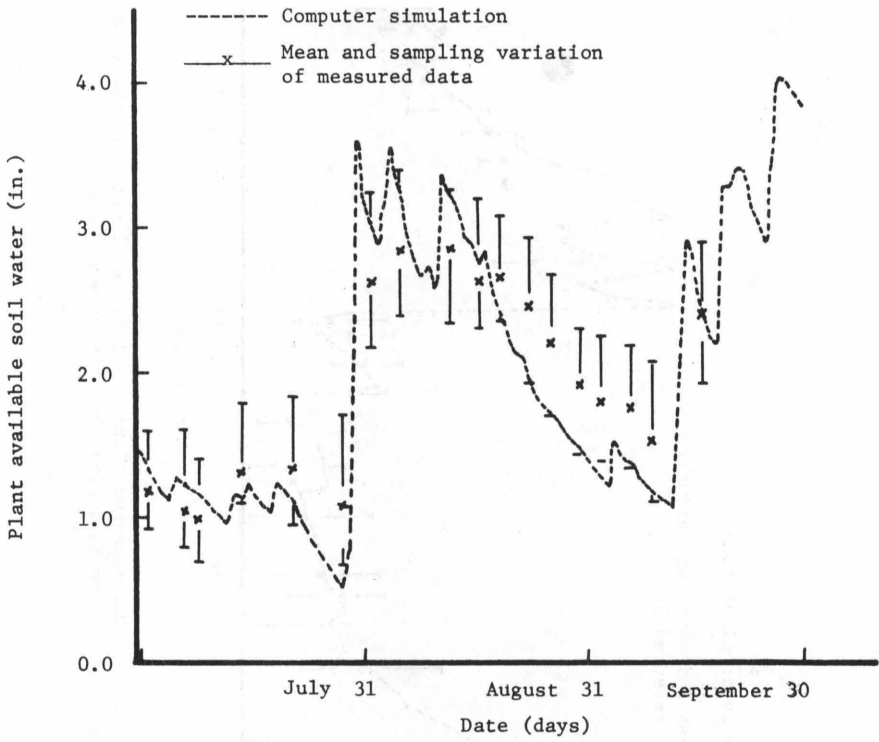


Figure 17. Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the conventional tillage system during the 1966 growing season.

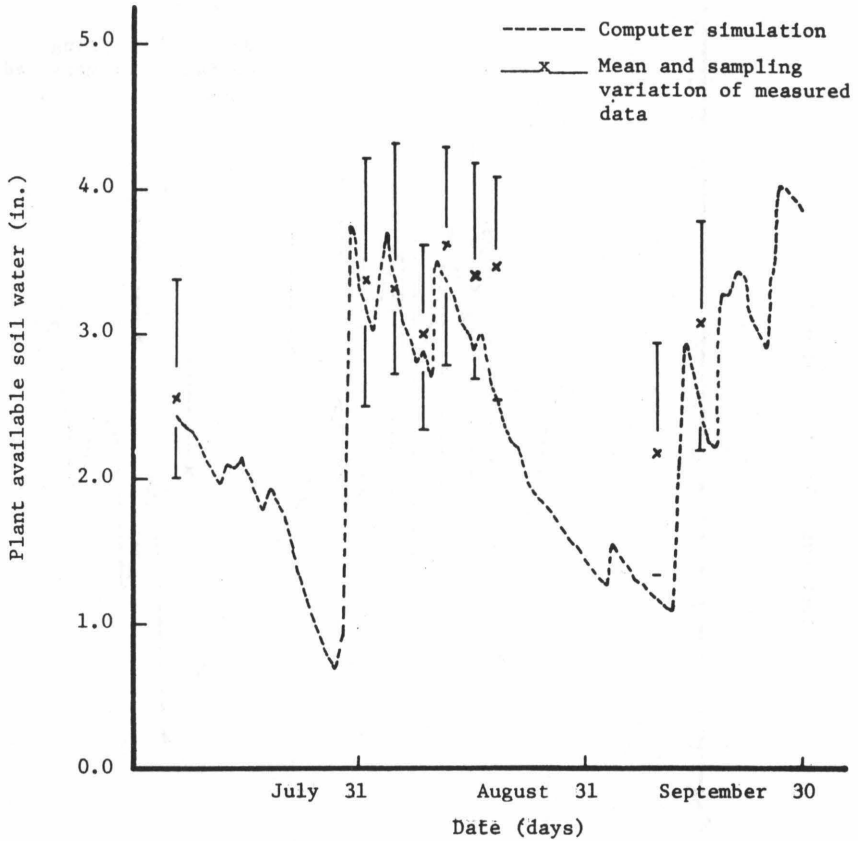


Figure 18. Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the conventional-tillage system during the 1966 growing season.

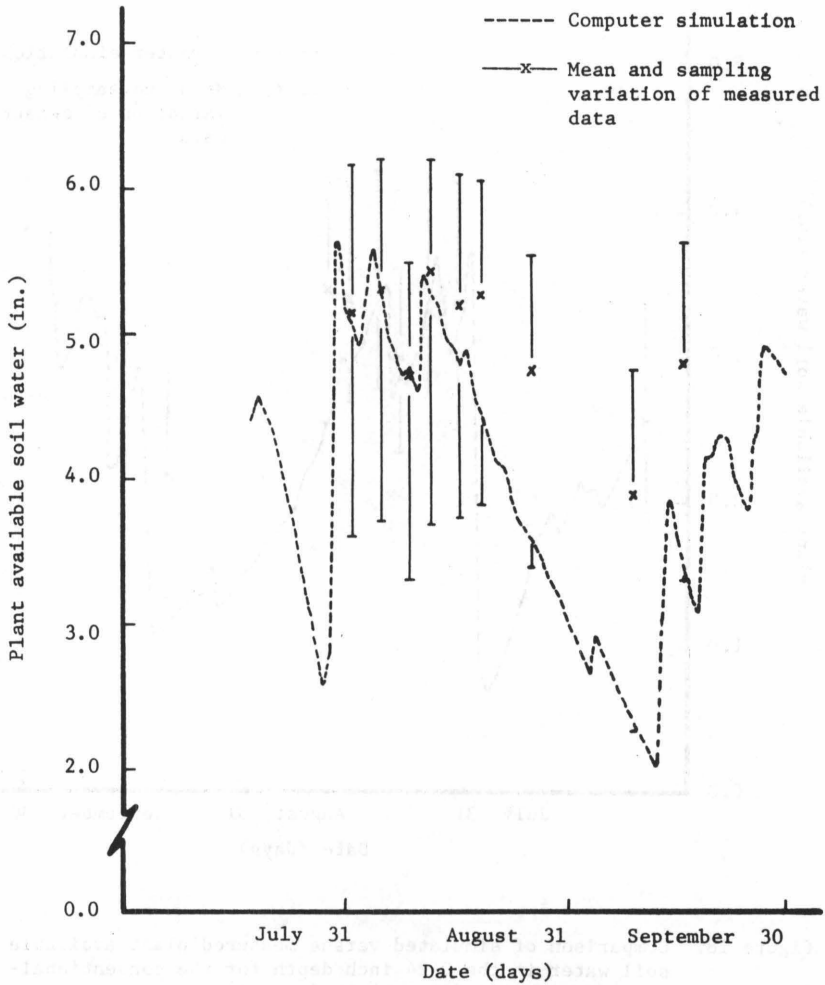


Figure 19. Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the conventional-tillage system during the 1966 growing season.

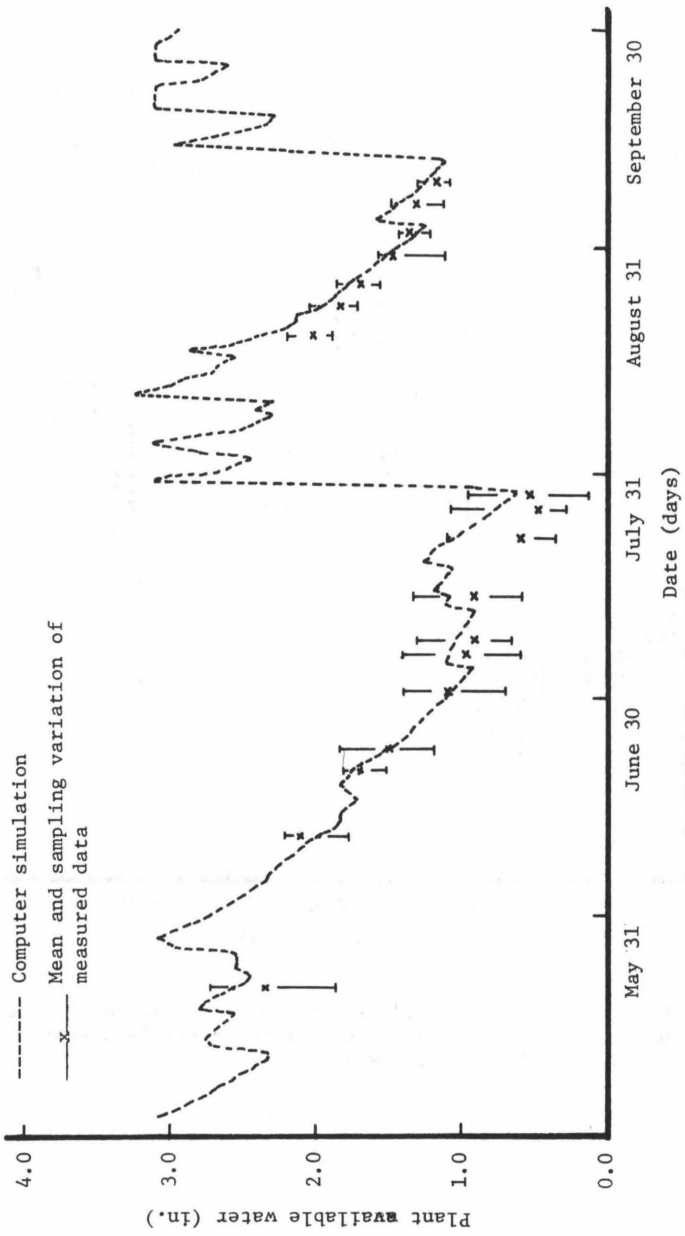


Figure 20. Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the no-tillage system during the 1966 growing season.

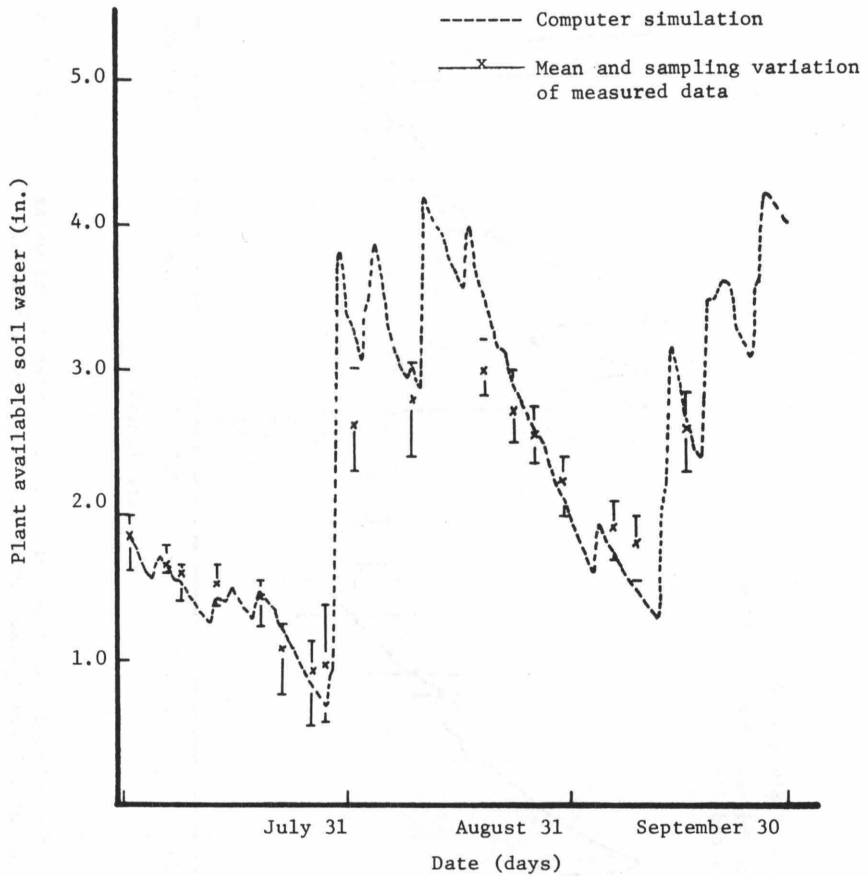


Figure 21. Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the no-tillage system during the 1966 growing season.

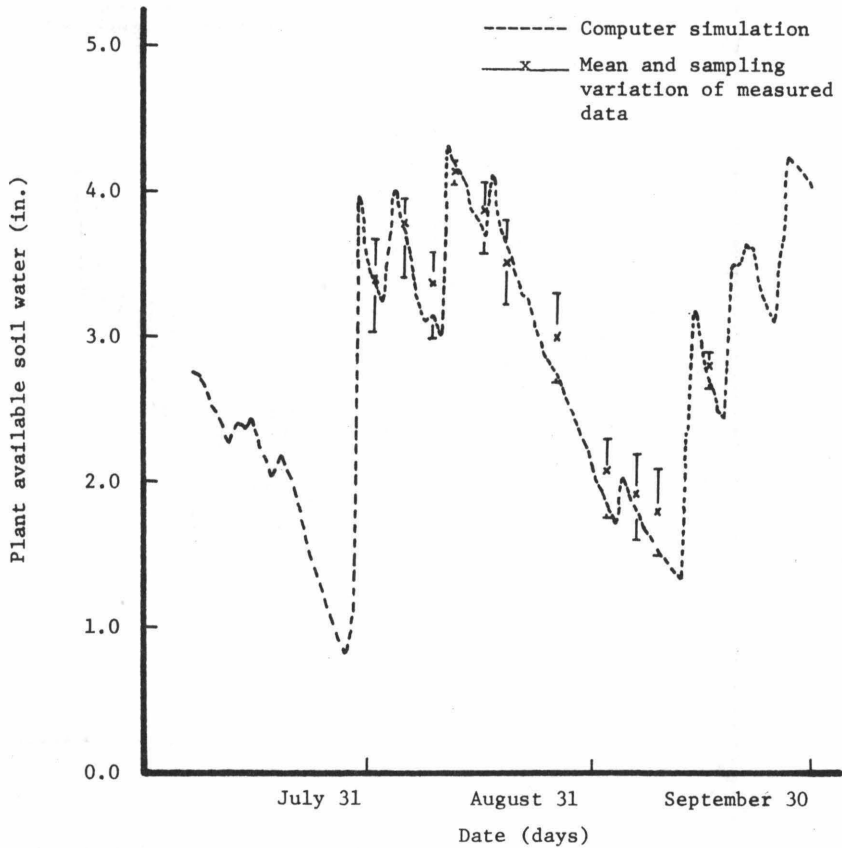


Figure 22. Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the no-tillage system during the 1966 growing season.

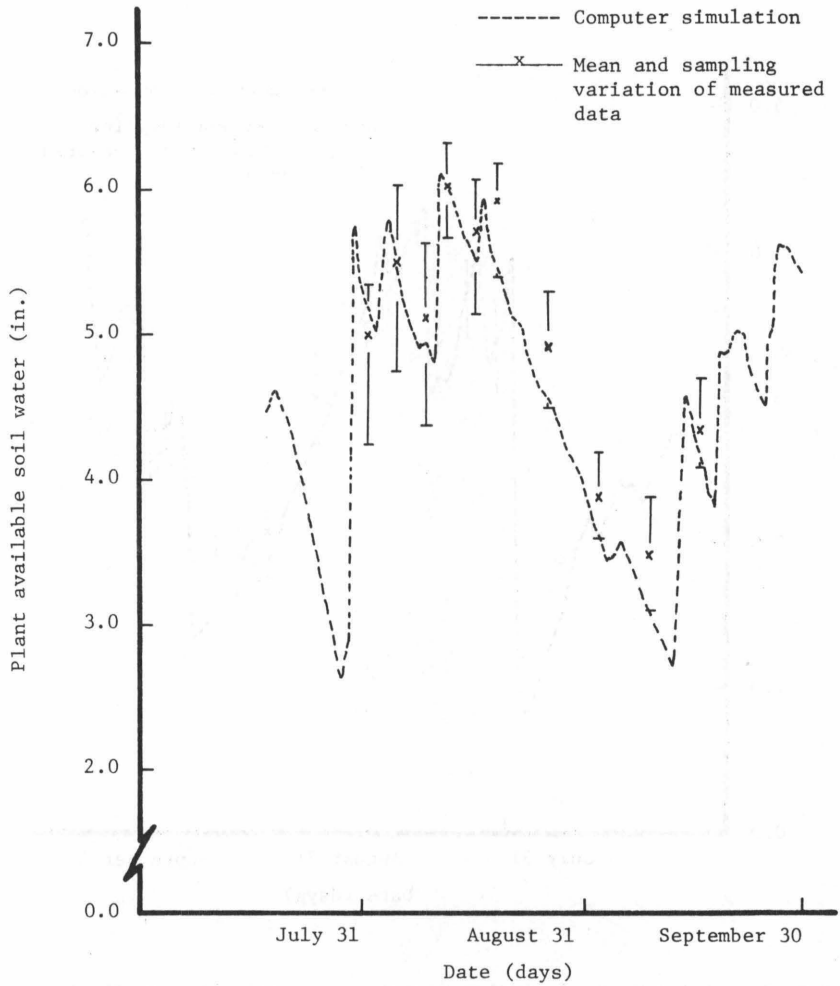


Figure 23. Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the no-tillage system during the 1966 growing season.

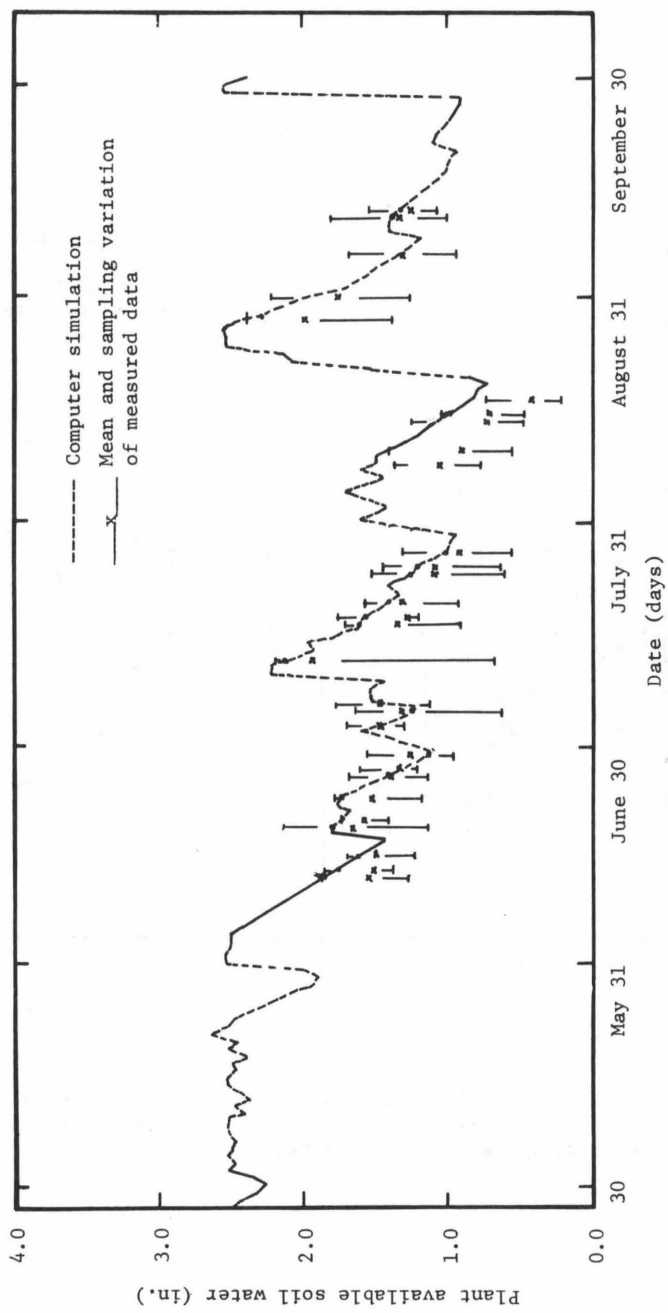


Figure 24. Comparison of simulated versus measured plant available soil water in 0-12 inch depth for the conventional-tillage system during the 1967 growing season.

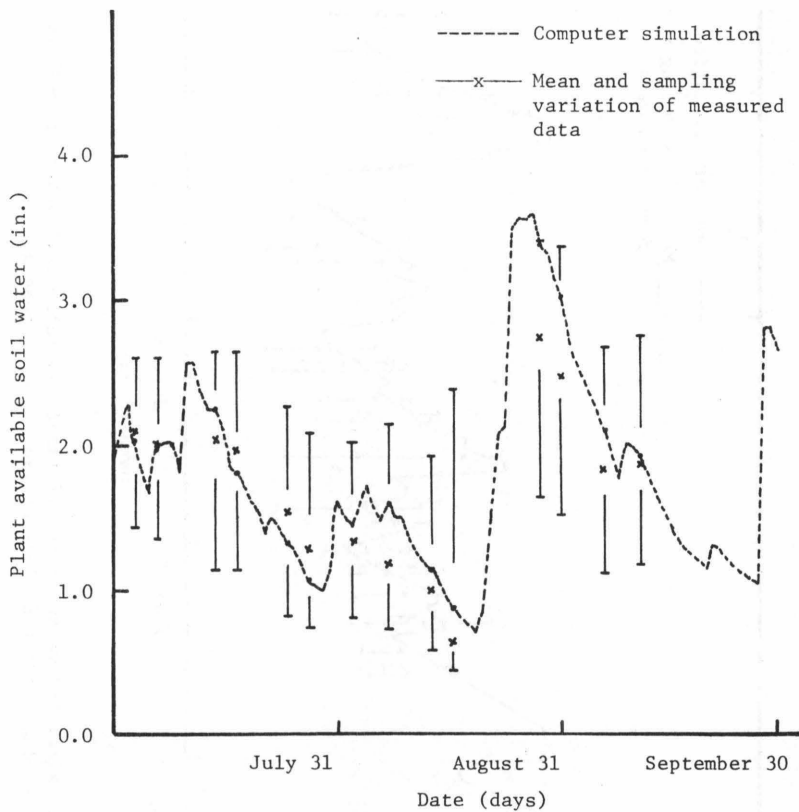


Figure 25. Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the conventional-tillage system during the 1967 growing season.

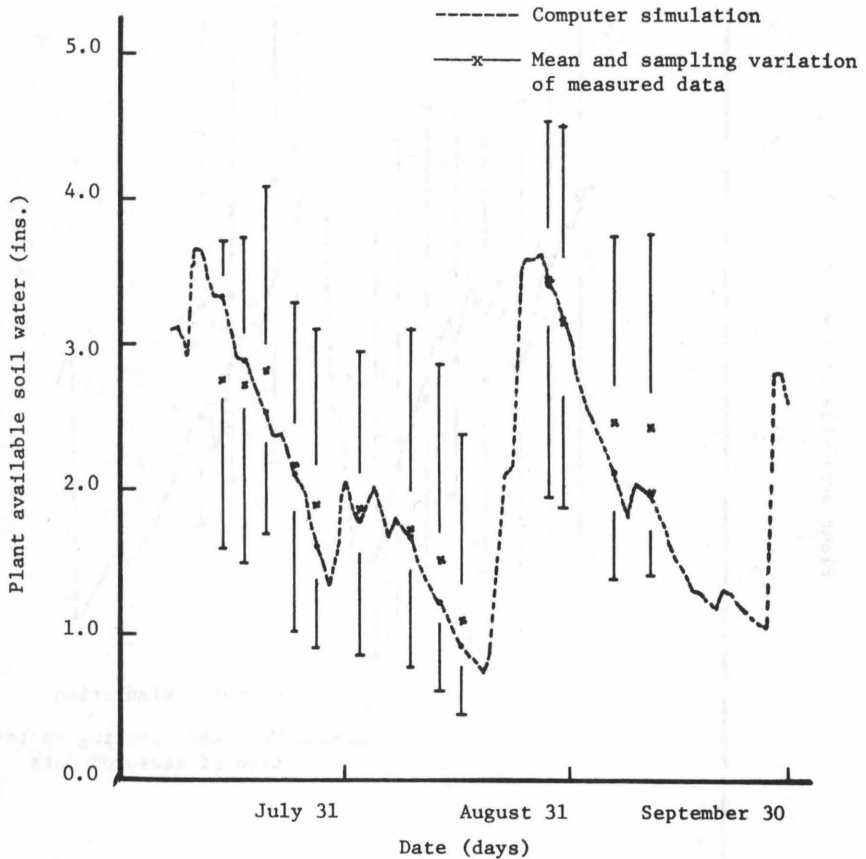


Figure 26. Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the conventional-tillage system during the 1967 growing season.

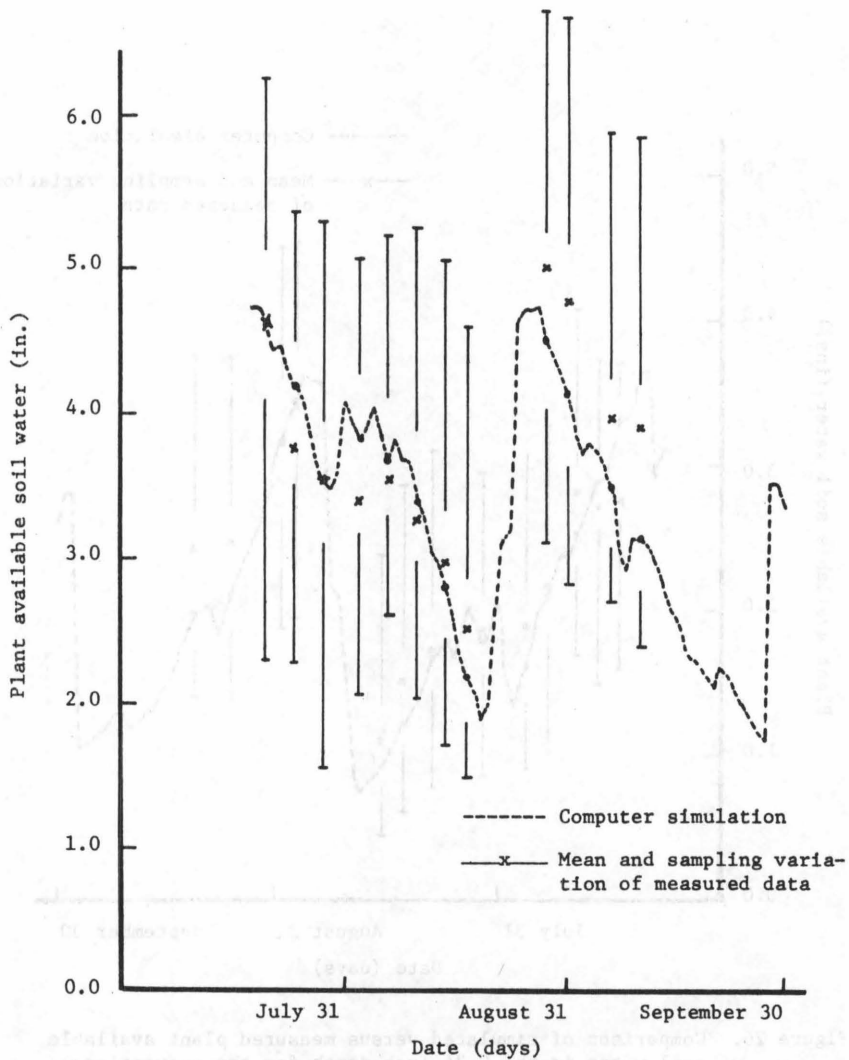


Figure 27. Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the conventional-tillage system during the 1967 growing season.

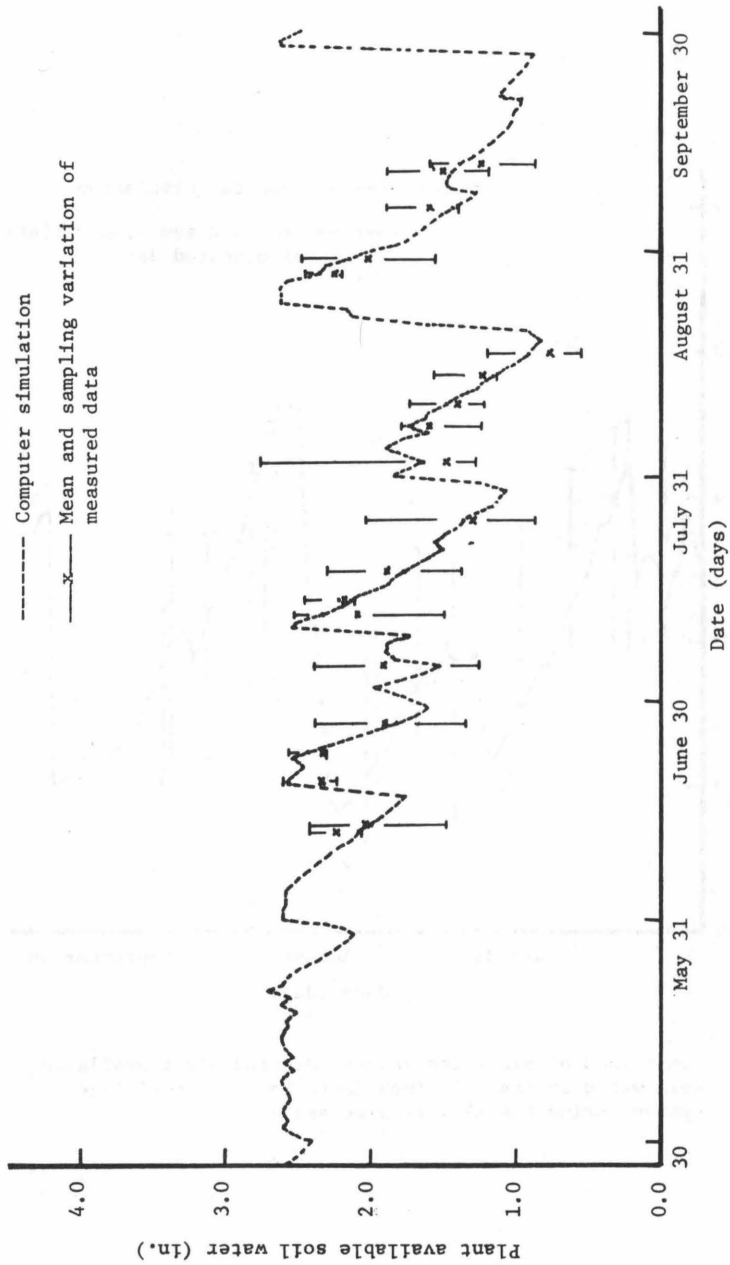


Figure 28. Comparison of simulated versus measured plant available soil water in 0-12 inch depth for the no-tillage system during the 1967 growing season.

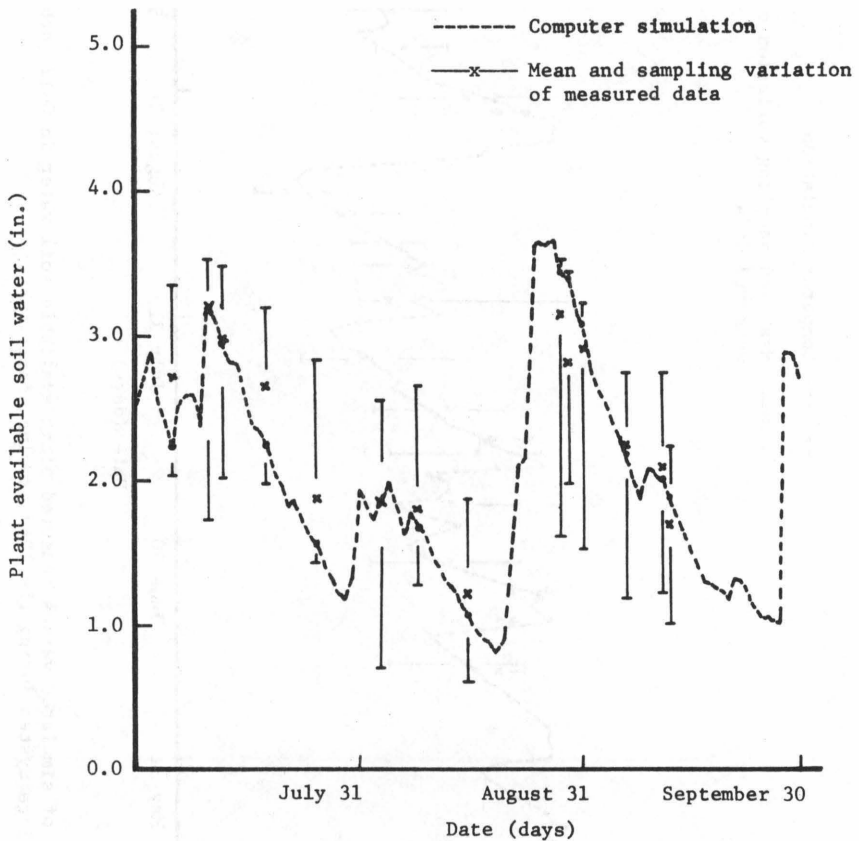


Figure 29. Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the no-tillage system during the 1967 growing season.

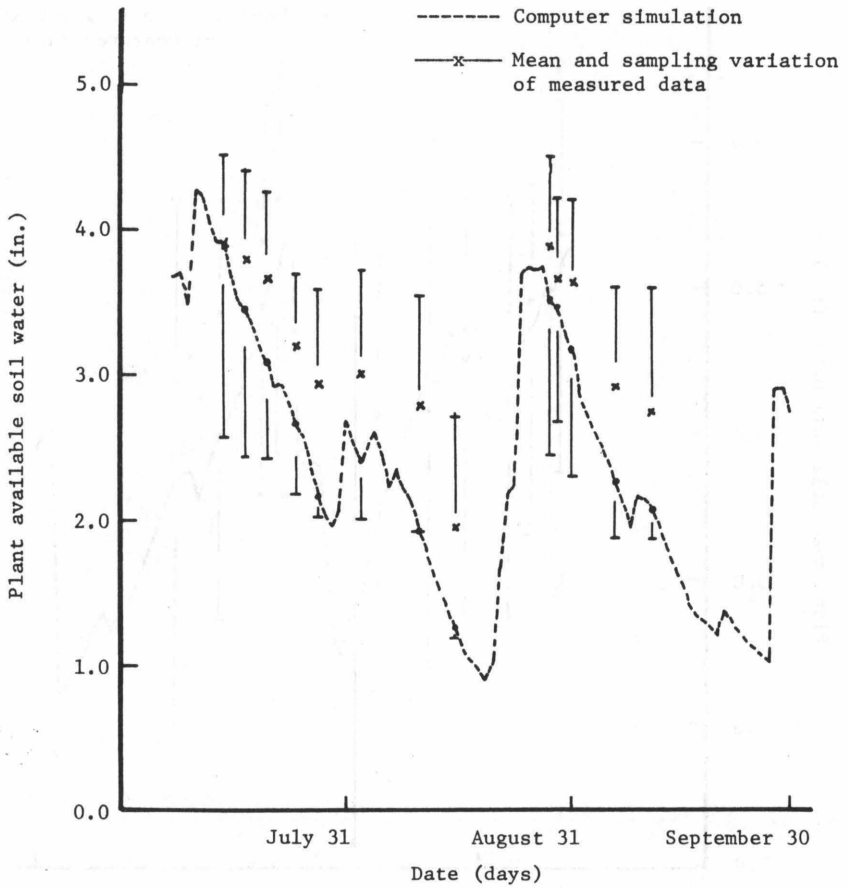


Figure 30. Comparison of simulated measured plant available soil water in the 0-24 inch depth for the no-tillage system during the 1967 growing season.

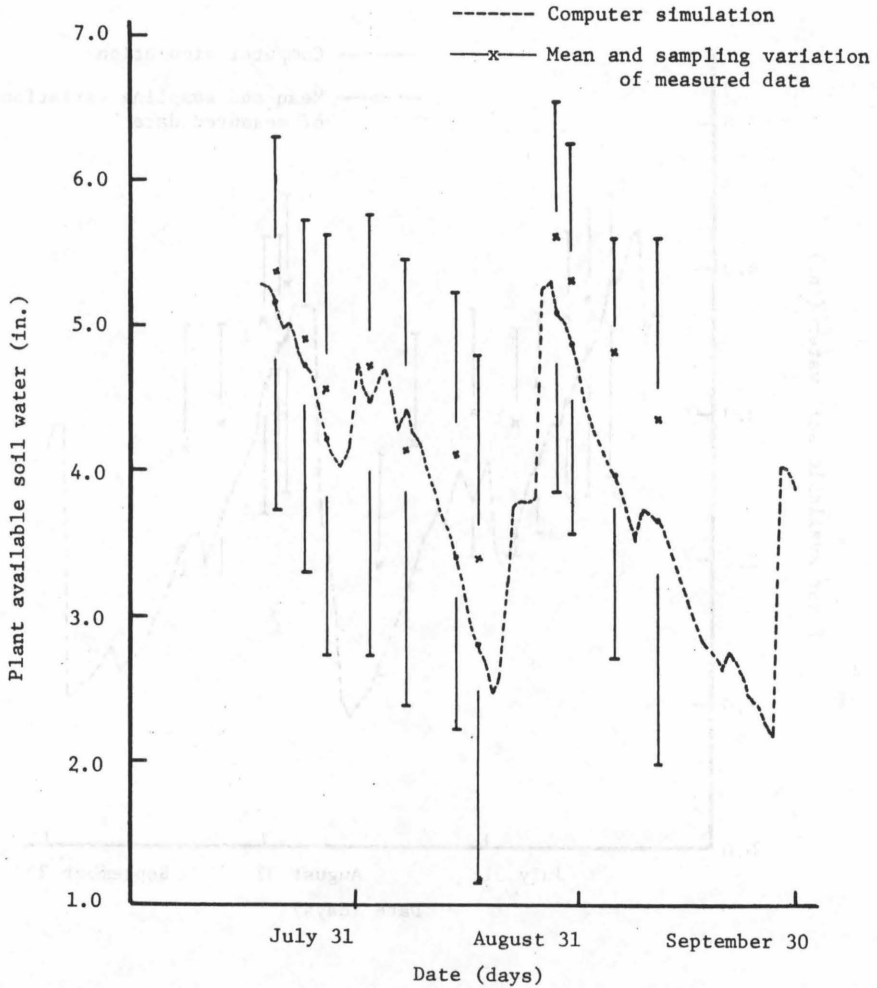


Figure 31. Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the no-tillage system during the 1967 growing season.

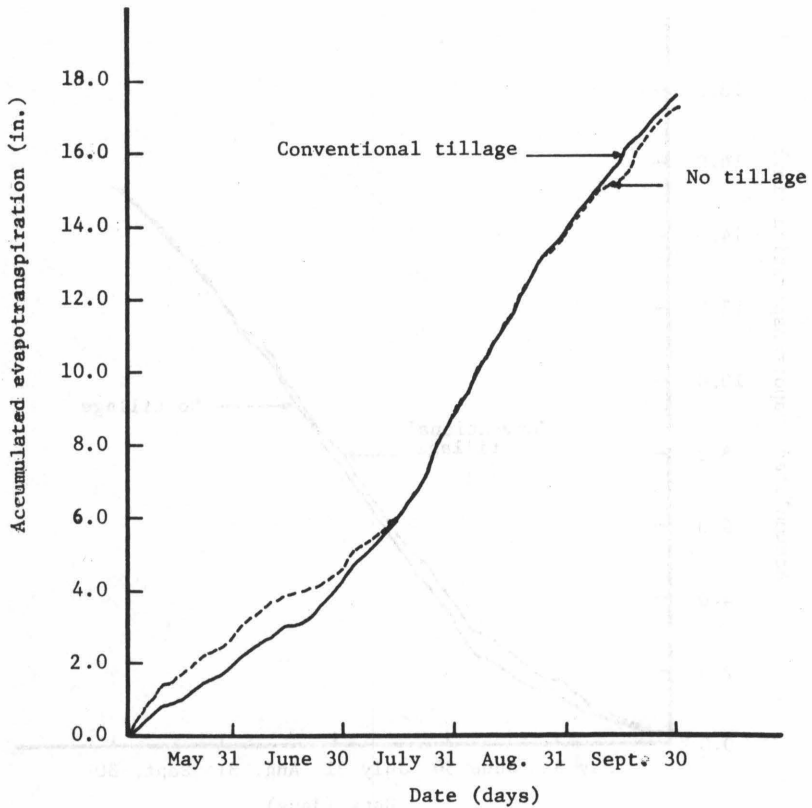


Figure 32. Comparison of estimated evapotranspiration from no-tillage and conventional-tillage areas during the 1966 growing season.

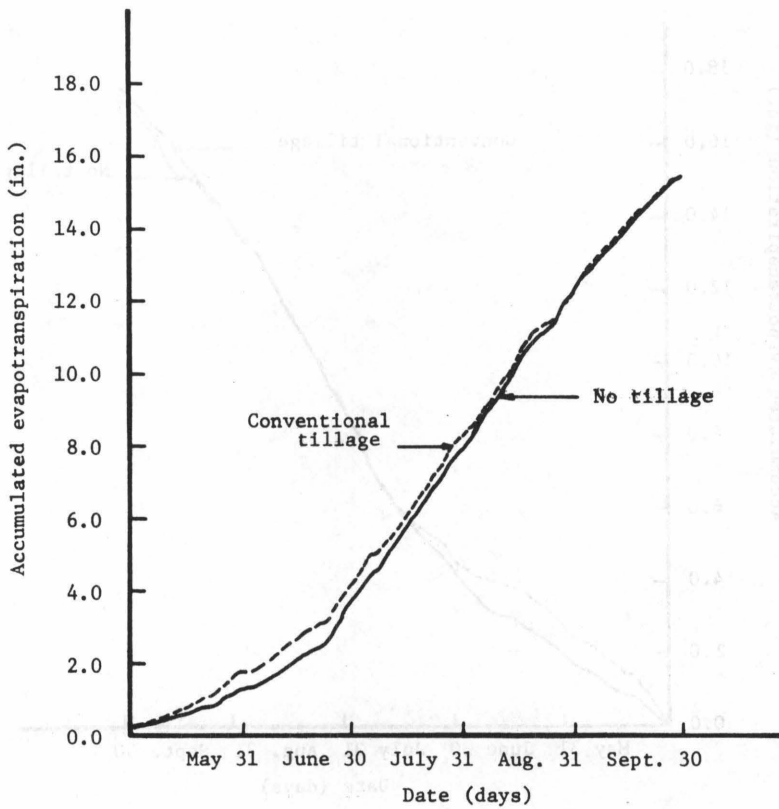


Figure 33. Comparison of estimated evapotranspiration from no-tillage and conventional tillage areas during the 1967 growing season.

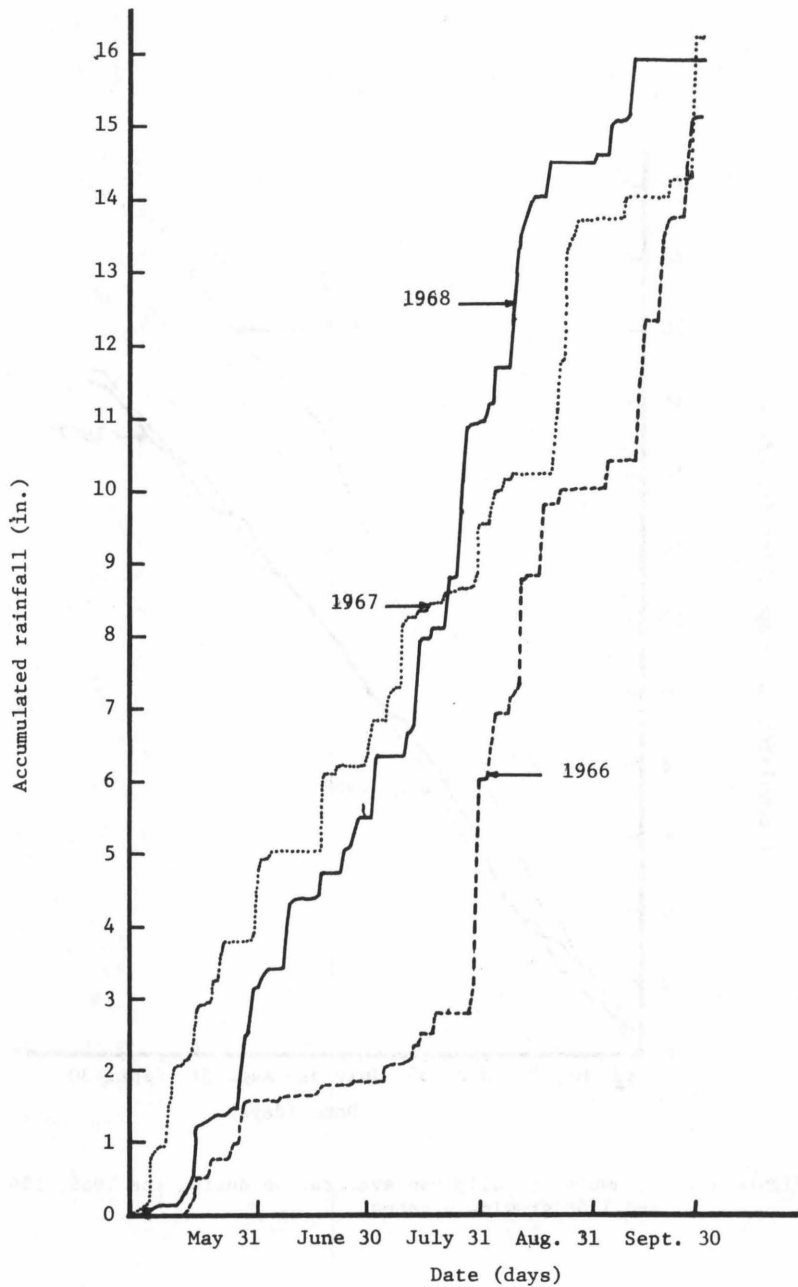


Figure 34. Accumulated daily rainfall during the 1966, 1967, and 1968 growing season.

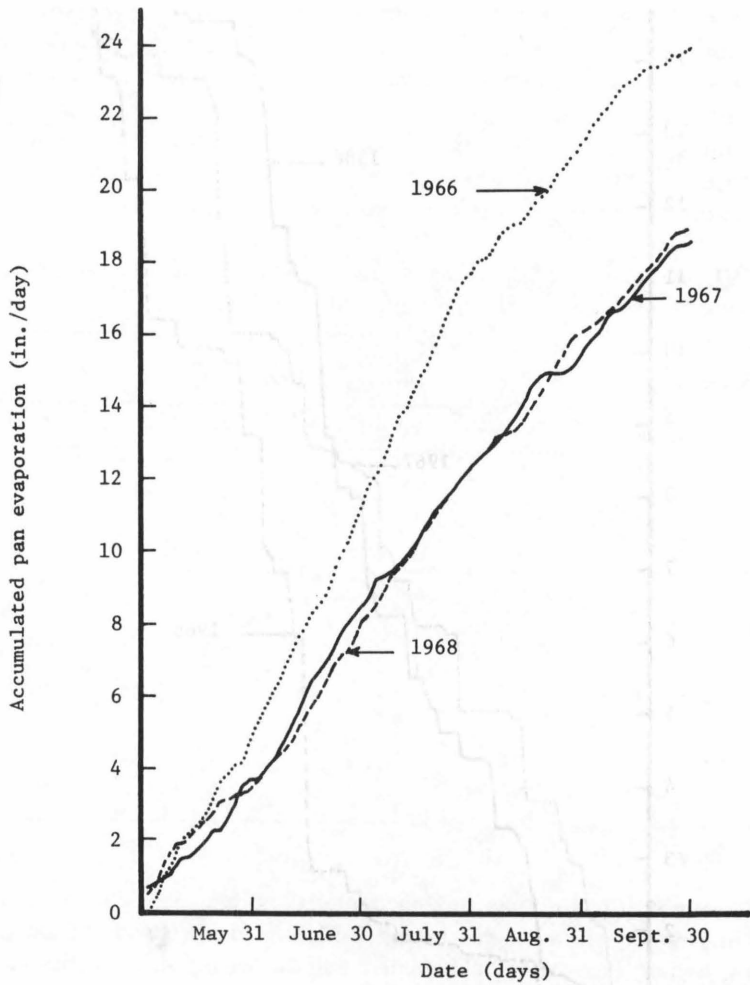


Figure 35. Accumulated daily pan evaporation during the 1966, 1967, and 1968 growing seasons.

Observed Versus Simulated Results

The simulation results that are presented in Figures 16 through 31 indicate reasonable success in synthesizing actual field conditions. The soil type in all cases was Groseclose silt loam with slopes less than 5 per cent. The continuous or dashed lines represent the soil water content at the end of the respective days. The arithmetic average of 24 to 40 field observations is represented by a x. The sampling variation is denoted by the dash at the extremities of the vertical solid lines. As would be expected, the magnitude of this range is quite variable, which is due to random variation of the soil and other errors that have been previously discussed.

Table VI. Distribution of daily pan evaporation during the April through September growing season at Blacksburg, Virginia.

Interval of E_p		Percentage frequency for:			
From	To	20 year avg.	1966	1967	1968
0.00	0.05	0.18	0.13	0.20	0.17
0.05	0.10	0.20	0.13	0.19	0.19
0.10	0.15	0.25	0.23	0.31	0.32
0.15	0.20	0.23	0.22	0.23	0.23
0.20	0.25	0.10	0.15	0.05	0.07
0.25	0.30	0.03	0.11	0.02	0.01
0.30	....	0.01	0.03	0.00	0.00

The greatest difficulty that was encountered during each simulation was obtaining reasonable estimates in the 0-12 inch depth shortly after large storms. At first thought, it would appear that surface runoff predictions were wrong. However, with supposedly correct surface runoff estimates the problem still pertained. As can be noted in Figure 16, for example, an acceptable result was achieved shortly after these excessive rain periods. This would indicate a timing error, which in this model, could only be accounted for by assuming greater amounts of precipitation excess. Since surface runoff estimates were in agreement the increase would have to be considered as delayed infiltration that would occur randomly down slope.

Data were plotted for the 0-12, 0-18, 0-24, and 0-36 inch depths. Sampling variation increases considerably with depth because (a) the soils tend to deviate further from the homogenous assumption with depth, and (b) the textural and structural patterns vary in their distance from the surface. These variations can cause a considerable problem in clay subsoils, because clays are characterized by high total water content with relatively low plant available water. The results emanating from using a desorption curve developed from sandy or silty soils to process data obtained from a clay horizon are quite obvious.

Inspection of Figures 32 and 33 show greater withdrawals from the conventional-tillage areas for a period after plowing. During the predominant transpiration interval, withdrawals are greater from the no-tillage system with the evapotranspiration estimates being approximately equal at the end of the season. Another important point to be gained from Figure 32 is that the soil water will be depleted from both systems during an extended drought. It is depleted more rapidly from the conventional-tillage areas (see Figure 8). Later in the growing season, due to greater demands by the more vigorous growth on the no-tillage areas, the available water can be depleted at a faster rate. This faster depletion rate is offset to some extent by more effective water conservation, i.e., more potential recharge from normally runoff producing events.

Estimates of Rainfall Excess and Plant Interception

In general, increments of rainfall were distributed relative to the requirements of plant interception, soil water storage, and rainfall excess. The requirements of interception were satisfied first, followed by the requirements of soil water storage as augmented by the soils' infiltration rate, with any residual termed as unrouted rainfall excess. Rainfall excess was further categorized as unrouted surface runoff and retention storage. Retention storage volumes were allowed to infiltrate into the soil water reservoir at a later time. Typical daily accumulations are portrayed in Appendixes C and D.

Comparison of Synthesized Results with Independent Data

The model parameters given in Table VII were used to synthesize the soil water status under the two tillage systems during the 1968 growing season. The soil type was Groseclose silt loam and the soil parameters a_1 , a_2 , b_1 and b_2 were averages of their respective 1966 and 1967 values. Corn plants were slightly taller, however, all other parameters remained identical to those used in the 1966 and 1967 simulations. No refinements in the first trials were

attempted. The results are shown in Figures 36 through 43. The climatological distributions are compared with the calibration period in Figures 34 and 35. Evapotranspiration estimates are presented in Figure 44.

Table VII. Summary of soil water prediction model parameters for the 1968 growing season.

Parameter	No Tillage	Conventional Tillage
Plant:		
IC_m	0.03	0.027
F_m	0.98	0.89
D_m	13.0	13.0
H_m	124.0	112.0
Soil:		
$a_1^1/$	0.40	0.20
$b_1^1/$	1.67	1.67
$a_1^2/$	0.163	0.163
$b_1^2/$	1.673	1.673
$a_2^3/$	0.424	0.424
$b_2^3/$	1.613	1.613
ADEP (1)	12.0	12.0
D_p	0.30	0.05
Evapotranspiration		
$B^4/$	0.975	0.95
$B^4/$	0.93	0.93
Tables	see Figures 9 and 10	

^{1/}Constants for equation (27)

^{2/}Constants for equation (34) - potential plant available water

^{3/}Constants for equation (34) - saturated water content

^{4/}Constants for equation (31)

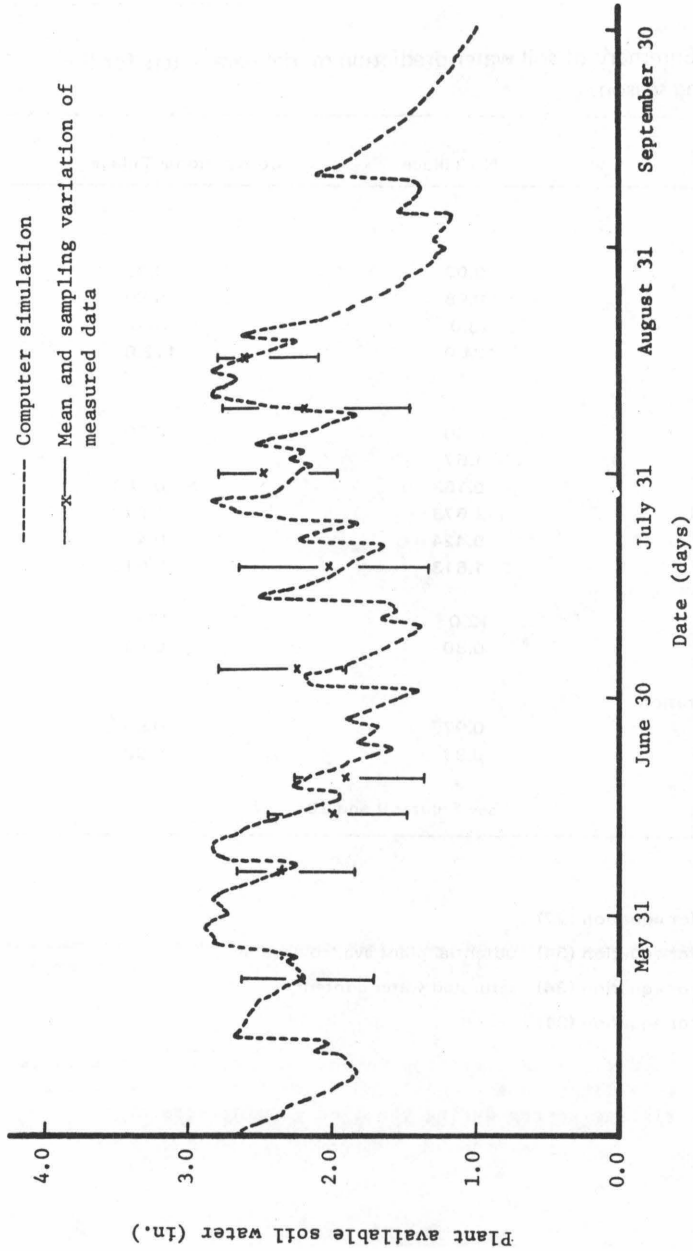


Figure 36. Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the conventional-tillage system during the 1968 growing season.

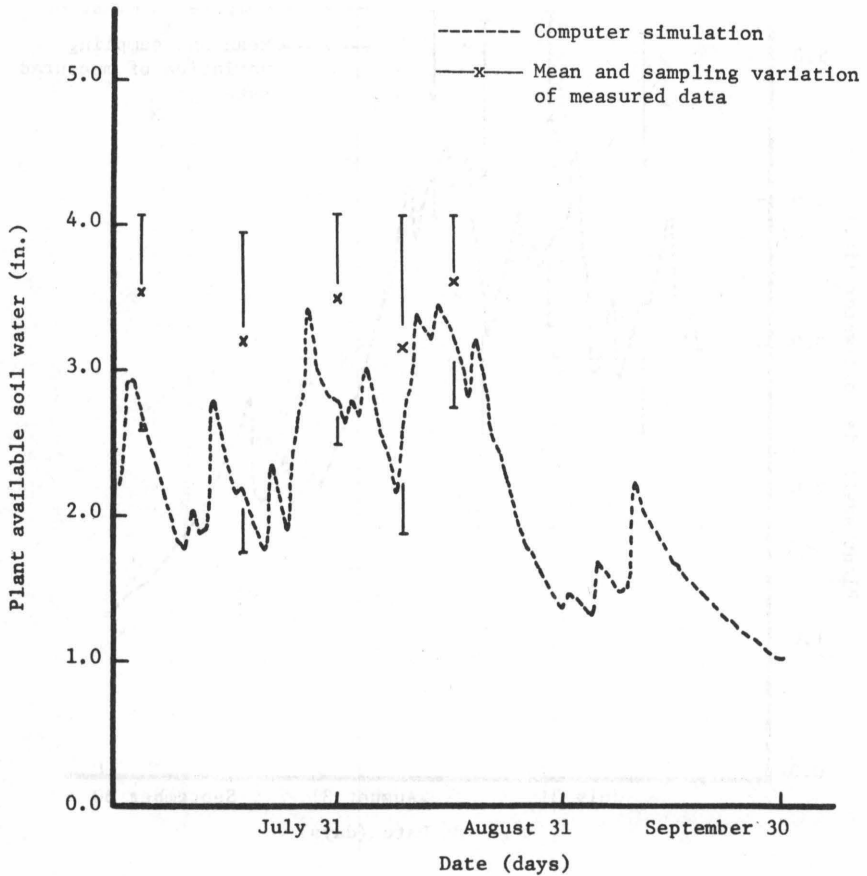


Figure 37. Comparison of simulated versus measured plant available soil water in the 0-18 inch depth for the conventional-tillage system during the 1968 growing season.

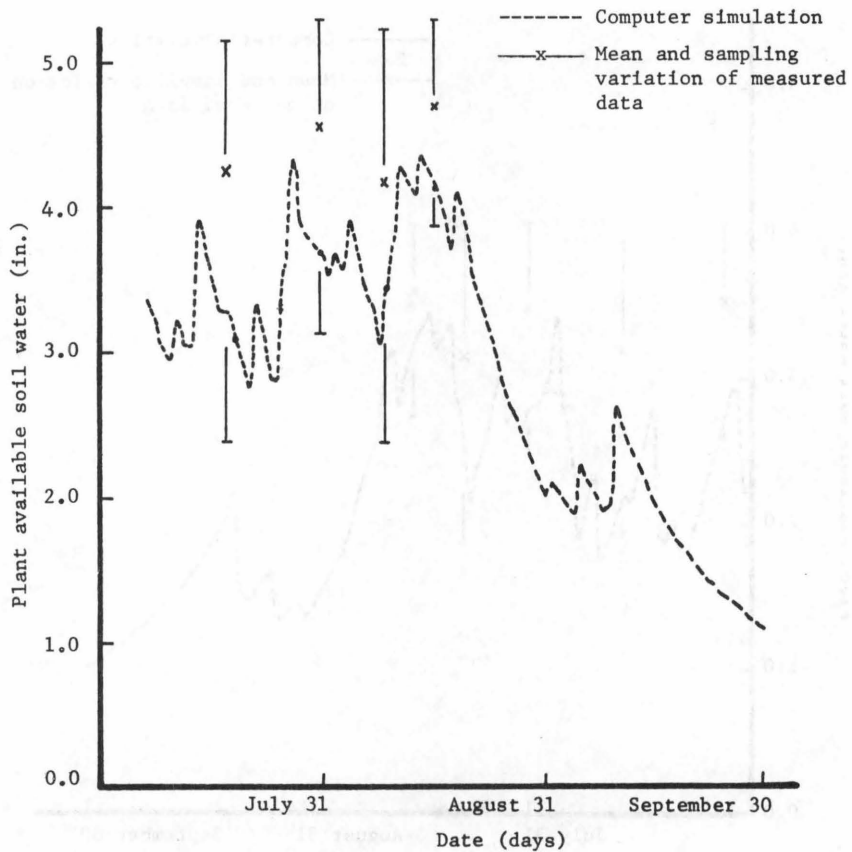


Figure 38. Comparison of simulated versus measured plant available soil water in the 0-24 inch depth for the conventional-tillage system during the 1968 growing season.

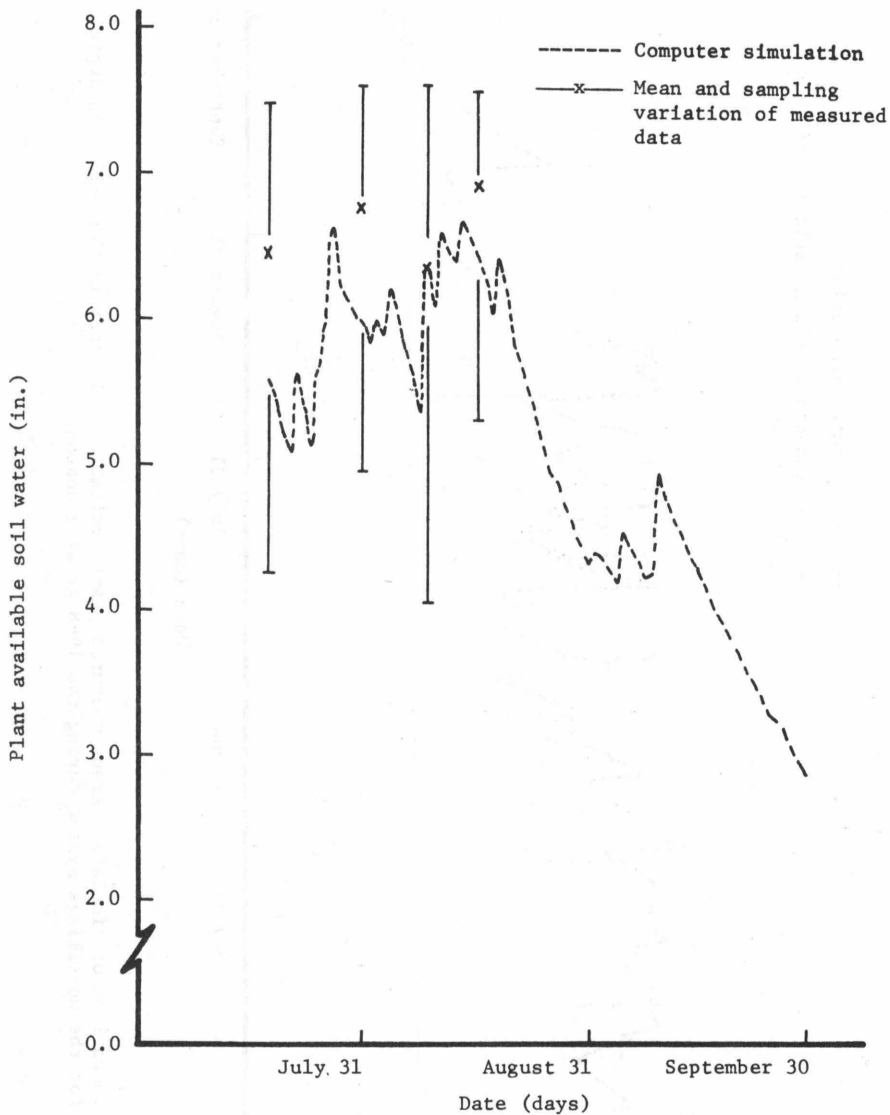


Figure 39. Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the conventional-tillage system during the 1968 growing season.

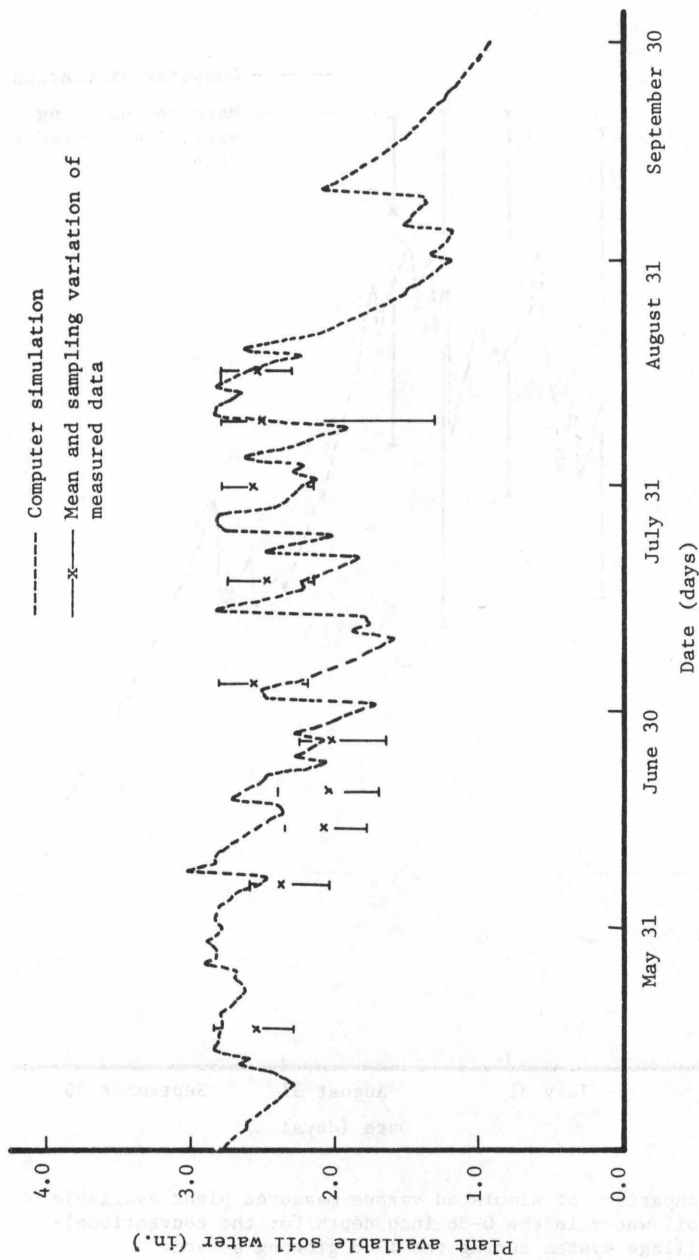


Figure 40. Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the no-tillage system during the 1968 growing season.

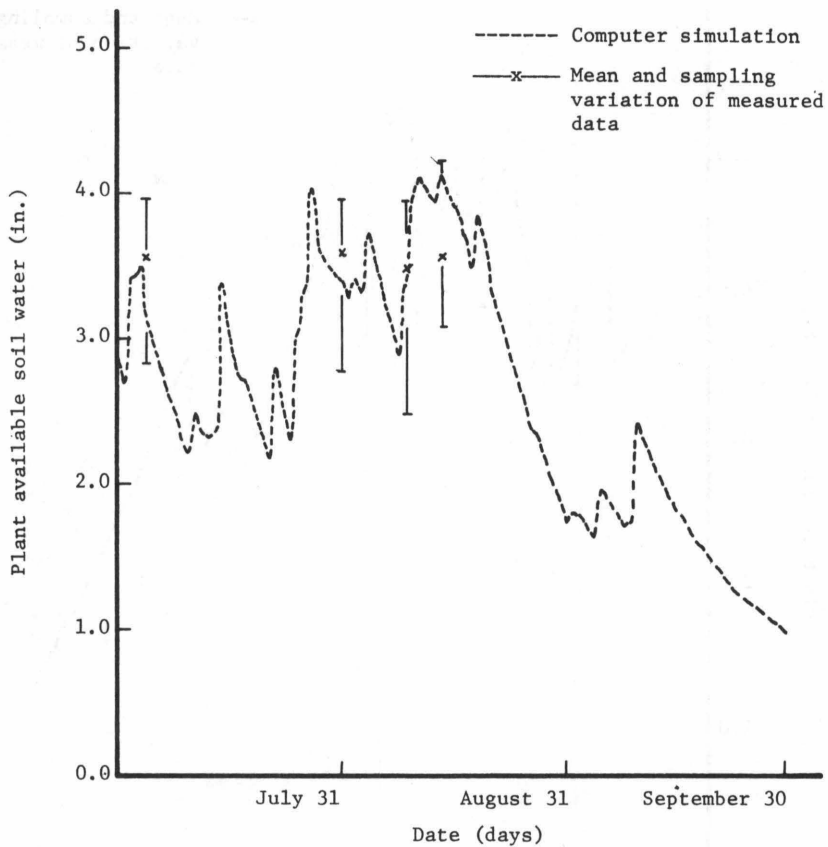


Figure 41. Comparison of simulated versus measured plant available soil water in 0-18 inch depth for the no-tillage system during the 1968 growing season.

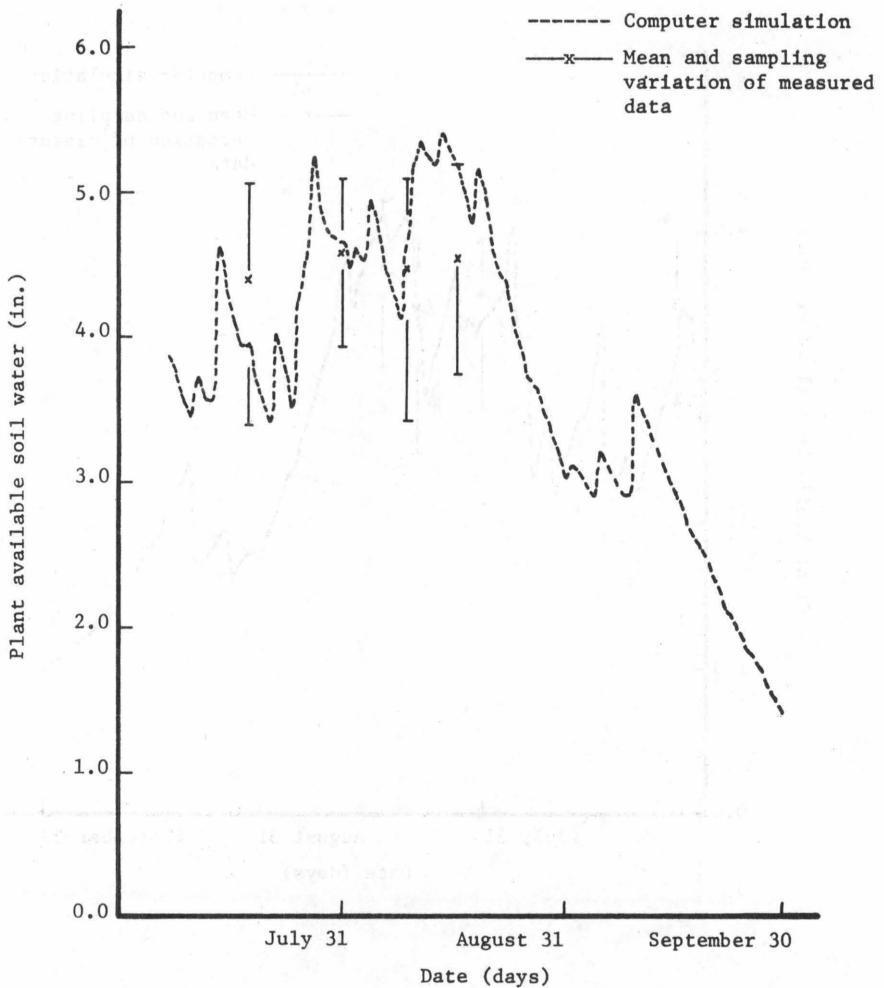


Figure 42. Comparison of simulated versus measured plant available soil water in 0-24 inch depth for the no-tillage system during the 1968 growing season.

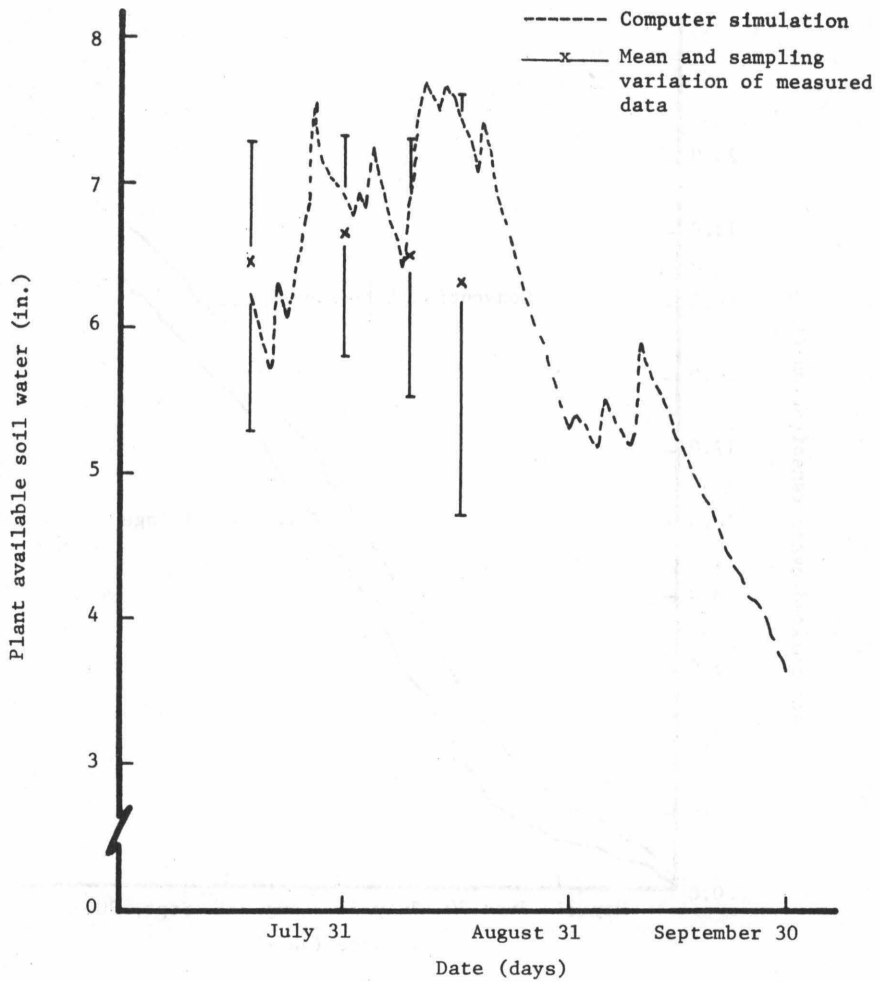


Figure 43. Comparison of simulated versus measured plant available soil water in the 0-36 inch depth for the no-tillage system during the 1968 growing season.

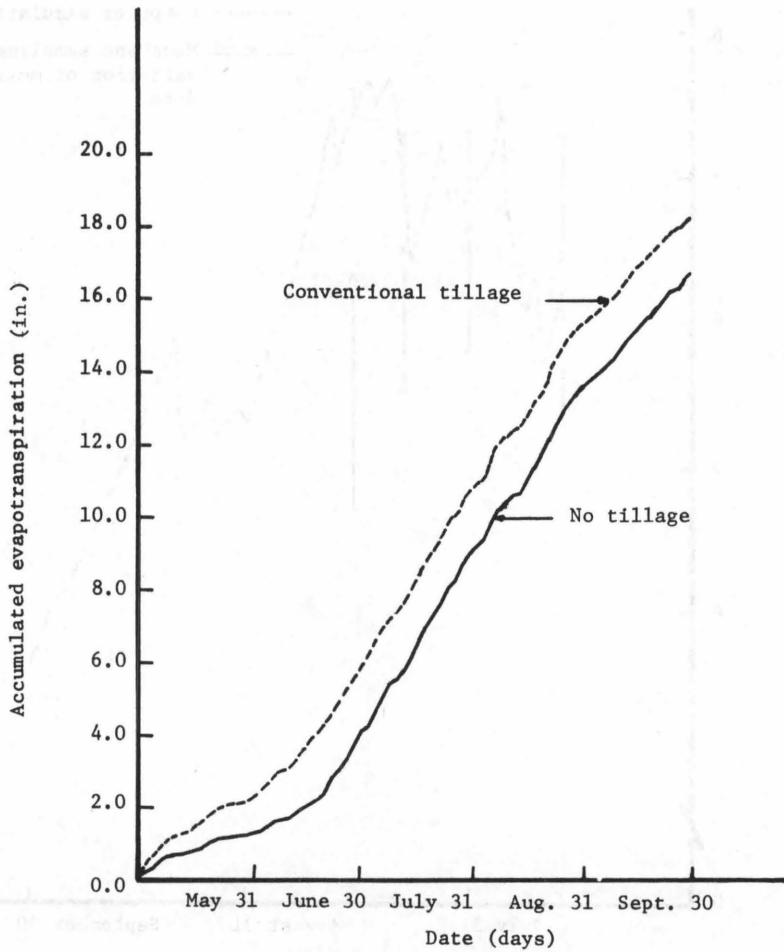


Figure 44. Comparison of estimated evapotranspiration from no-tillage and conventional-tillage areas during the 1968 growing season.

The comparison represents very good agreement between the synthesized and observed data with the exception of two points in Figure 40. The simulation was 0.18 inch beyond the acceptable range on June 9 and 0.25 inch high on June 14. In all probability the soil water variation is greater than that shown because the mean value given represents an average of only 4 locations. Also, these readings do not appear to be typical when compared to corresponding readings obtained from conventional tillage areas. Very little difference can be detected which is not typical of no tillage this early in the growing season.

Inspection of Figure 34 shows relatively high rainfall in midseason, while Figure 35 indicates that the atmospheric demand rates were typical of those that occurred during the previous growing season. The evapotranspiration estimates in Figure 44 indicate approximately equal withdrawals after plant emergence. These data also indicate no significant drought periods early in the growing season.

Data supplied by J. N. Jones, Blacksburg, Virginia, for the 1965 growing season were also used to check the adequacy of the model. The model parameters are given in Table VIII. Again, no refinements in initial estimates were attempted.

Comparisons of simulated and measured field data for the two tillage systems are presented in Figures 45 and 46, respectively. The 1965 growing season was characterized by 20.58 inches of rainfall and 23.78 inches of evaporation. Corn plant heights at full tassel were significantly different. The same soil type was assumed for both systems. The sampling variation is represented by the mean of 4 points.

Inspection of Figures 45 and 46 again reflect reasonable success in synthesizing field conditions. In Figure 45 the simulated value for August 11 lies 0.08 inch beyond the acceptable range and in Figure 46 and value for August 23 is 0.20 inch high.

Comparisons with Mulch Study

The no-tillage system is analogous to straw mulch in that both tillage methods tend to suppress evaporation and retard surface runoff. Since the two methods are closely related, it was felt that the model should give at least approximations to the soil water status. Following these thoughts and utilizing soil moisture data collected during the 1959 and 1960 growing season by gravimetric plugs, the comparisons in Figures 47 and 48 were made.

The model parameters are presented in Table IX. The soil type was Groseclose silt loam, gently sloping phase.

Agreement between simulated and observed data was quite reasonable for the 1959 data and for most of the 1960 data. Because the data were obtained by gravimetric plugs at a limited number of locations the observed data cannot be considered to be extremely accurate. Although the gravimetric sampling technique for determining soil moisture is quite accurate for the plugs obtained, it does not necessarily give an integrated average of the soil water content over a large area.

With proper soil moisture data it appears that the model could easily be calibrated or adjusted to give representative results under straw mulch areas.

Table VIII. Summary of soil water prediction model parameters for the 1965 growing season. Data courtesy of J. N. Jones.

Parameter	No tillage	Conventional tillage
<u>Plant:</u>		
IC_m	0.07	0.07
F_m	0.98	0.98
D_m	10.0	10.0
H_m	112.0	112.0
<u>Soil:</u>		
$a_{1/}$	0.50	0.08
$b_{1/}$	1.67	1.67
$a_{12/}$	0.738	0.738
$b_{12/}$	0.932	0.932
$a_{23/}$	0.674	0.674
$b_{23/}$	1.170	1.170
ADEP(1)	6.0	6.0
Π_p	0.30	0.05
<u>Evapotranspiration:</u>		
$B_{4/}$	0.95	0.91
$B'_{4/}$	0.91	0.91
Tables	see Figures 9 and 10	

$\underline{1/}$ Constants for equation (27)

$\underline{2/}$ Constants for equation (34) - potential plant available water

$\underline{3/}$ Constants for equation (34) - saturated water content

$\underline{4/}$ Constants for equation (31)

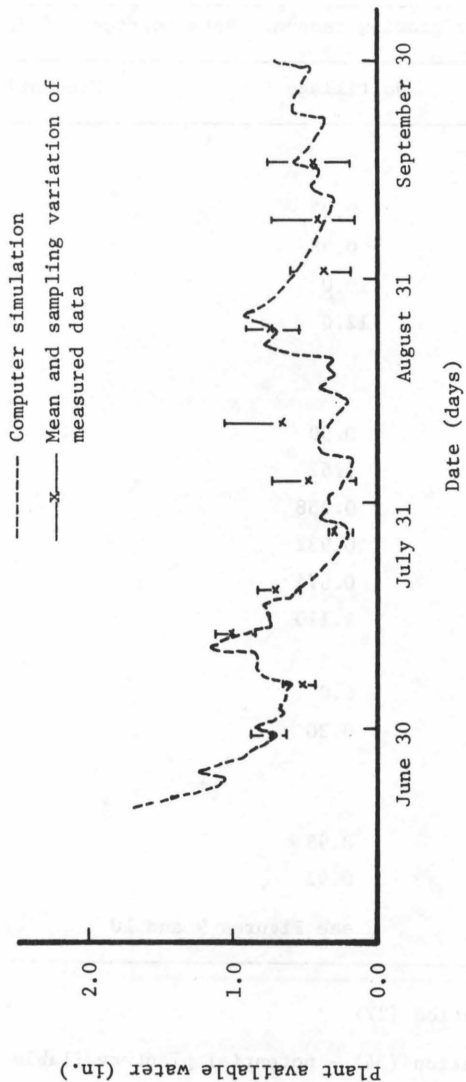


Figure 45. Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the conventional-tillage system. Data courtesy of J. N. Jones, Jr. Blacksburg, Virginia.

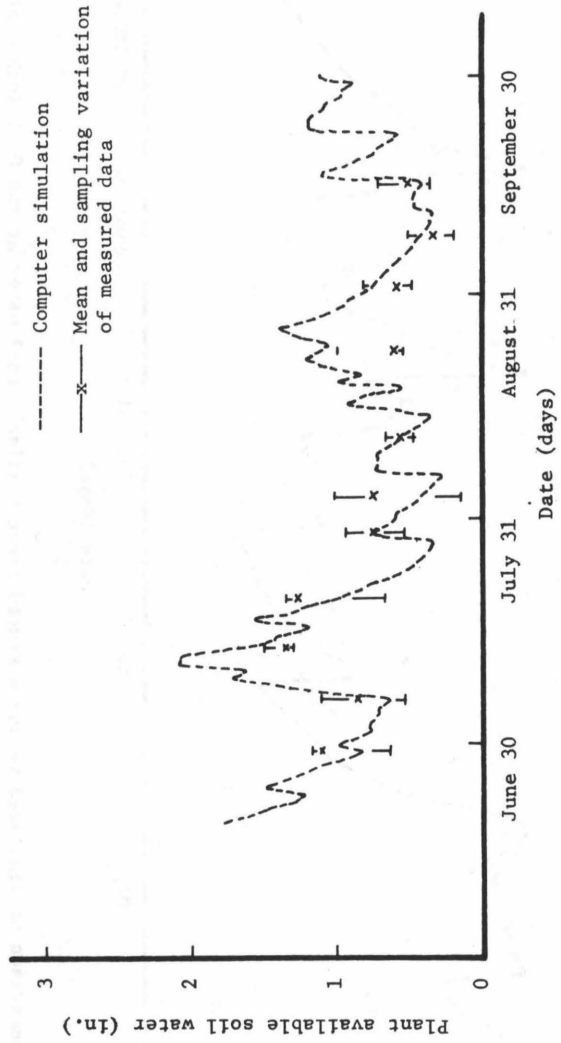


Figure 46. Comparison of simulated versus measured plant available soil water in the 0-12 inch depth for the no-tillage system. Data courtesy of J. N. Jones, Jr., Blacksburg, Virginia.

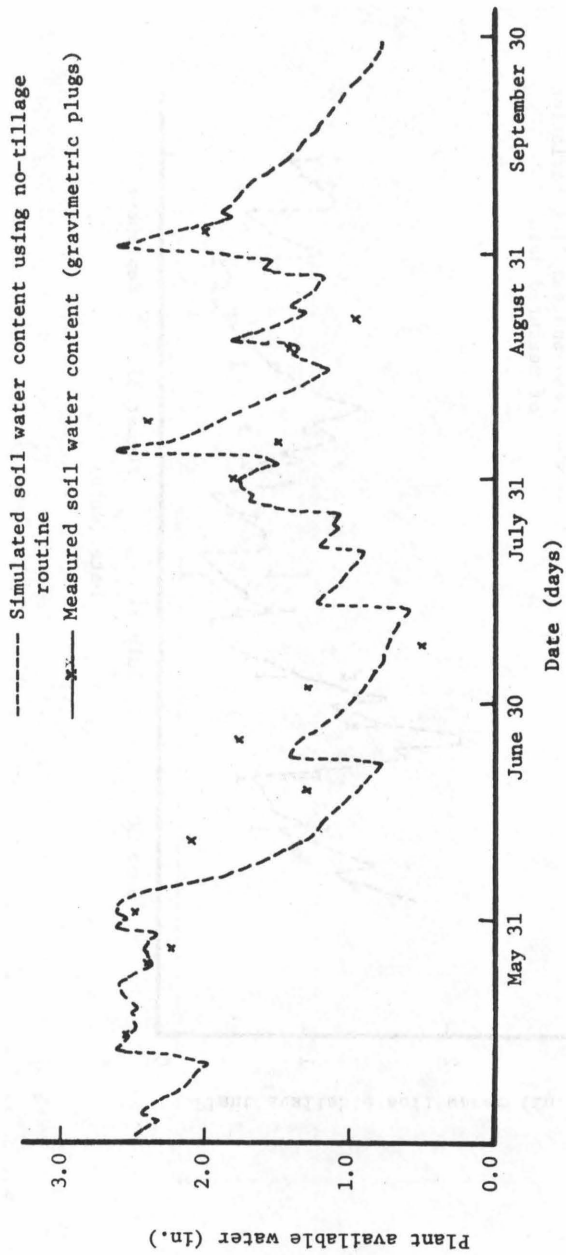


Figure 47. Comparison of simulated versus measured plant available soil water at the 0-12 inch depth. Area mulched with 3 tons of straw per acre (1959). Data courtesy of J. N. Jones, Jr., Blacksburg, Virginia.

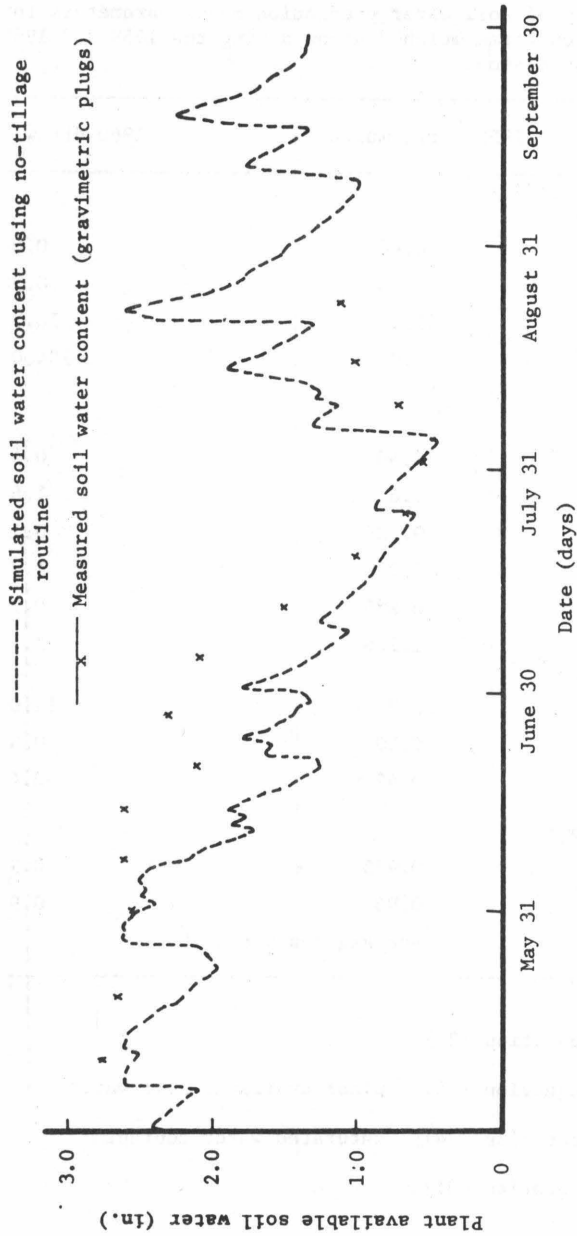


Figure 48. Comparison of simulated versus measured plant available soil water at the 0-12 inch depth. Area mulched with 3 tons of straw per acre (1960). Data courtesy of J. N. Jones, Jr., Blacksburg, Virginia.

Table IX. Summary of soil water prediction model parameters for corn grown on straw mulched areas during the 1959 and 1960 growing seasons.

Parameter	1959 straw mulch	1960 straw mulch
<u>Plant:</u>		
IC _m	0.06	0.06
F _m	0.98	0.98
D _m	11.1	10.3
H _m	98.0	104.0
<u>Soil:</u>		
a ₁ ^{1/}	0.40	0.40
b ₁ ^{1/}	1.67	1.67
a ₁ ^{2/}	0.134	0.134
b ₁ ^{2/}	1.712	1.712
a ₂ ^{3/}	0.285	0.285
b ₂ ^{3/}	1.726	1.726
ADEP (1)	12.0	12.0
D _p	0.30	0.30
F _c	0.42	0.42
<u>Evapotranspiration:</u>		
B ^{4/}	0.975	0.975
B' ^{4/}	0.93	0.93
Tables	see Figures 9 and 10	

^{1/} Constants for equation (27)

^{2/} Constants for equation (34) - plant available soil water

^{3/} Constants for equation (34) - saturated water content

^{4/} Constants for equation (31)

MODEL SIMULATIONS

General

A very important aspect of any model is its ability to react or respond to a wide range of conditions. Models that can be developed on sound mathematical theory, including accurate or exact functions of all variables in the system in question can be expected to react near perfectly to changes within the system. In extremely complex environments for which exacting mathematical theory is not or cannot be developed for all variables, empirical approaches are deemed necessary. The ultimate goal of empirical simulations in hydrology is to define the most significant variables of the process and relate their response to some measurable quantity. In essence this procedure develops into a trial and error solution over a wide environment or a range sufficient to test its applicability in the regions for which it is intended. Exacting tests can probably never be achieved, but many replications with independent data should tend towards a correct solution, or at least show fallacies in the original development.

The model discussed previously has not been tested over an extremely wide range of climatic conditions. However, its development and subsequent testing covered climatological data that deviated considerably from expected mean values. Both drought and excessive rainfall distributions were encountered with reasonable responses predicted by the model.

All testing and subsequent verification dealt with one soil type—Groseclose silt loam. The immediate question is how well will the model respond with different soil types. This question is not and will not be unequivocally answered in this report. However, the model has been so designed (see Appendix J) that it should not be difficult to calibrate for a given soil. The soil's evaporation recession parameter, infiltration parameter, and water holding capacity would have to be arrived at through appropriate procedures. The water holding capacity of a given soil type can vary considerably over small areas and since this factor is very important in simulations, better accuracy can be achieved by developing soil desorption curves that represent the soil type in question. Typical variations that can be expected in Groseclose silt loam are given in Appendix E.

Selection of Soil Types

A wide range of soils were selected to test the model's response with potential soil water content and saturated hydraulic conductivity the only variables. No attempt was made to define the drying characteristics of these soils. This could have been accomplished only through detailed experiments on each. The main objective was simply to observe differences, if any, in the hydrologic response of each soil type when subjected to the same climatological distributions. The selection was limited to soils in Virginia and included only those soils that had moisture-tension data available and were being used for agricultural production.⁷⁵

The constants for equation (34) were evaluated for each soil type. The errors associated with the estimated values were in general slightly higher than corresponding estimates in Groseclose silt loam. With few exceptions, errors for individual estimates were less than 10 per cent. Equation (34) was not used if the estimated error for the plant available water exceeded 10 per cent at the 24-inch depth. In general, errors at this depth were less than 5 per cent. Soils characterized by hardpans or highly non-homogenous profiles completely voided the use of equation (34) and were not included in Appendix F.

Results of Model Simulations with Different Soil Types

The potential soil water coefficients given in Appendix F and the remaining parameters given in Table VII were used to simulate the soil water status over the growing season for all soil types. The 1966 and 1967 rainfall and pan evaporation data were used to represent two different climatological distributions.

The results are presented in Tables X, Appendix G, and Appendix H. The variations in estimates of surface runoff, evapotranspiration, and seepage below the root zone are listed in Table X. The maximum and minimum value in each group has been underscored. In general, the estimates simply reflect the difference in potential storage. For example, Wilkes fine sandy loam has a potential plant available soil water storage capacity of 1.32 inches in the 0-12 inch depth as compared to 3.61 inches for Tatum silt loam. As a consequence, when the two soils are subjected to the same climatic conditions evapotranspiration will generally be less on the Wilkes soil. In contrast, the potential total water content was higher in Wilkes soil, which resulted in lower rainfall excess estimates because infiltration is a direct function of total storage, i.e., as storage increases, infiltration will increase

Table X. Model response to the soil types listed in Appendix F. Data subjected to two different climatological distributions.

Soil type	No tillage				Conventional tillage							
	$\Sigma P=15.19''; \Sigma Ep=23.88''$	$\Sigma P=16.26''; \Sigma Ep=18.59''$	$\Sigma P=15.19''; \Sigma Ep=23.88''$	$\Sigma P=16.26''; \Sigma Ep=18.59''$	ET	Q	PC	ET	Q	PC		
Brandywine loam	15.87	0.09	0.37	14.77	0.20	2.27	15.88	1.24	0.00	15.88	0.91	1.59
Catlett silt loam	16.20	0.44	0.31	14.96	0.32	2.28	15.95	2.26	0.00	16.12	1.61	1.65
Croton silt loam	15.07	<u>0.85</u>	0.41	14.46	<u>0.45</u>	<u>1.78</u>	13.99	<u>3.28</u>	<u>0.00</u>	14.96	<u>2.63</u>	<u>1.10</u>
Edneyville fine sandy loam	15.30	<u>0.00</u>	0.53	14.37	0.13	2.71	15.51	0.99	<u>0.00</u>	15.55	0.70	1.94
Frederick silt loam	15.70	0.14	0.30	14.98	0.21	1.90	15.63	1.30	<u>0.00</u>	15.90	0.96	1.26
Glengel loam	15.60	0.45	0.45	14.52	0.33	2.21	15.43	2.41	<u>0.00</u>	15.46	1.72	1.59
Greendale silt loam	14.69	<u>0.00</u>	0.67	13.90	<u>0.02</u>	3.01	14.92	<u>0.69</u>	0.05	14.73	<u>0.55</u>	<u>2.05</u>
Litz silt loam	<u>17.38</u>	0.12	<u>0.03</u>	<u>15.79</u>	0.18	<u>2.69</u>	<u>17.25</u>	1.18	<u>0.00</u>	<u>17.44</u>	0.86	1.72
Lodi loam	14.64	0.05	0.69	13.86	0.20	2.24	14.81	1.26	0.02	14.59	0.88	1.74
Nason silt loam	13.28	0.16	0.70	<u>13.21</u>	0.26	2.25	13.32	1.67	0.14	13.62	1.11	1.52
Penn silt loam	15.35	0.38	0.51	14.42	0.32	2.46	15.23	2.28	<u>0.00</u>	15.29	1.57	1.65
Tatum silt loam	16.48	0.37	0.25	15.14	0.03	2.18	16.29	1.98	<u>0.00</u>	16.40	1.37	1.81
Wilkes fine sandy loam	<u>12.77</u>	<u>0.00</u>	<u>0.74</u>	13.59	0.16	2.29	<u>12.85</u>	1.10	<u>0.28</u>	<u>13.42</u>	0.76	1.61

and rainfall excess will decrease. Seepage below the root zone is a function of free water and saturated hydraulic conductivity and as a consequence is more difficult to generalize.

The 1966 and 1967 rainfall and pan evaporation data were used to obtain the seasonal distribution of plant available soil water for selected soil types and the data which resulted are given in Appendixes G and H, respectively. Both tables show the number of days per month that the water content in the 0-12 inch depth was within a predetermined moisture range computed from the ratio W_a/W_p . These data are indicative of possible drought conditions. Extreme droughts would be represented by the first range and to a lesser degree by the second range.

For optimum corn production, ample moisture must be available during the silking and tasseling stage. Robbins et al.⁷³ reports that deficits near wilting point for periods of 1-2 days resulted in 22 per cent yield reduction and periods of 6 to 8 days gave a yield reduction of about 50 per cent. Relatively severe water deficits can be endured by the corn plant at other times. In this area, the corn pollination period occurs in a two-week period beginning approximately August 1. Inspection of the data in Appendix G shows extreme deficits in June and July for all soil types where the conventional-tillage system was used. However, with the exception of two soil types the deficits occurred early in the growing season, which, if followed by seasonable weather, do not in general have severe detrimental effects on grain yields. Extremely severe drought days were much fewer on the no-tillage system with the exception of Fluvanna fine sandy loam and Wilkes fine sandy loam. Both of these soils have very low potential plant available soil water storage in the 0-12 inch depth. The data would indicate no significant advantage to be derived from the use of the no-tillage system in these soil types. Inspection of the data in Appendix H indicates that the same two soil types would be classified as droughty. Also, the data for Nason silt loam indicate that possible severe yield reductions would have occurred.

Different Rainfall and Pan Evaporation Distributions

Utilizing rainfall and pan evaporation distributions from 20 separate growing seasons, the model was used to simulate possible soil water deficits in corn grown on Groseclose silt loam. The model parameters are given in Table VII. The results are presented in Table XI and Appendix I. In Table XI the maximum and minimum values for each column are underlined.

Table XI. Response of soil water prediction model to different climatological distributions. Soil parameters are assumed constant.

No.	EP (in.)	No tillage				Conventional tillage					
		ΣETp (in.)	ΣET (in.)	ΣQ (in.)	ΣPC (in.)	ΣET (in.)	ΣQ (in.)	ΣPC (in.)	ΣIC (in.)		
1	16.03	11.61	10.67	0.00	4.77	0.53	11.61	2.07	3.80	(in.)	(in.)
2	22.39	19.14	16.53	0.15	5.40	0.91	19.14	2.60	2.66	0.43	0.74
3	22.96	17.51	14.93	0.07	6.23	1.02	17.25	3.88	3.70	0.91	0.91
4	22.76	16.48	14.99	0.33	6.01	1.01	16.48	2.92	3.96	0.83	0.83
5	19.74	13.89	12.69	0.08	5.63	1.08	13.89	2.46	4.47	0.88	0.88
6	17.53	17.91	14.60	0.83	4.38	0.57	16.58	2.04	2.93	0.49	0.49
7	18.54	20.74	18.56	0.40	2.79	1.09	20.51	2.55	0.67	0.93	0.93
8	14.29	26.88	18.66	0.14	3.50	0.60	20.67	1.35	1.92	0.51	0.51
9	12.96	25.43	17.59	0.00	2.18	0.50	18.63	0.55	0.91	0.45	0.45
10	13.14	27.21	18.10	0.01	2.36	0.56	19.66	0.59	0.82	0.49	0.49
11	19.09	22.81	18.05	0.07	3.83	0.83	20.05	1.28	1.84	0.67	0.67
12	19.98	26.50	18.24	0.12	2.63	0.98	19.40	1.34	1.57	0.80	0.80
13	20.52	24.43	17.23	0.55	2.87	0.88	18.77	1.45	1.52	0.74	0.74
14	15.65	25.06	18.89	0.80	2.60	0.77	20.52	2.12	0.61	0.63	0.63
15	16.18	20.46	16.12	0.00	3.53	0.83	18.45	2.35	0.77	0.70	0.70
16	17.75	22.17	17.15	0.00	2.31	0.77	19.23	0.57	1.53	0.62	0.62
17	14.09	28.55	18.80	0.00	0.88	0.73	19.82	0.34	0.00	0.60	0.60
18	15.38	25.59	17.46	0.00	1.37	0.96	18.82	0.59	0.10	0.83	0.83
19	20.58	23.76	19.44	1.07	3.18	0.88	22.27	2.80	1.46	0.72	0.72
20	18.14	23.88	17.47	0.27	0.00	1.06	17.73	2.12	0.00	0.87	0.87

A survey of Table XI indicates a wide range of rainfall and pan evaporation inputs. In turn, the model estimates for evapotranspiration, surface runoff, seepage, and plant interception vary considerably. The effect of these weather patterns on the soil water status can be observed in Appendix I. A severe moisture deficit was indicated for event 8 on both tillage systems and since it occurred in midseason, a significant reduction in grain yield would probably have resulted. In general, the data showed higher soil water contents early in the growing season for the no tillage, but as the season progressed, differences decreased depending on climatic conditions.

SUMMARY AND CONCLUSIONS

Model Development

The purpose of this phase of the study was to develop analytical relationships that would, when linked together, give a reasonable representation of the soil water status under the no-tillage and conventional-tillage systems of corn production. This phase of the work was at least moderately successful.

Exponential relationships were found to give reasonable estimates of soil evaporation prior to corn plant emergence. Precipitation excess was estimated using an exponential expression, which was a function of the total water storage capacity in the A_p or A horizon. Corn plant heights were simulated from a two-part, non-dimensional exponential, which was a function of duration and plant height at full tassel. Very good agreement was found with field measurements. Rainfall intercepted by the plant canopy was assumed to be a function of rainfall, plant height, and density of cover with the maximum allowable magnitude at full tassel being limited to 0.03 inches per storm per 15,000 plants. This figure was verified by Stoltenberg et al.⁵⁰

Evapotranspiration was assumed to take place according to the non-linear functions given in Figures 9 and 10. These figures were developed from field data and represent the approximate withdrawal rate at a given soil water content and atmospheric demand rate. Vertical water movement through the soil profile was accomplished by the use of the soils' saturated hydraulic conductivity.

The soil profile was subdivided into 7 zones where the first zone was terminated at the bottom of the A_p or A horizon, and the seventh zone was terminated at maximum root depth. The potential water-holding capacity of each zone was partitioned into free water and plant available water. Free water was allowed to evaporate and/or drain through the profile. Recharge always occurred in zone one. The storage requirements of plant available soil water were satisfied first followed by the requirements of the free water reservoir. Recharge of lower depths emanated from this free water reservoir.

All aspects of the soil water model were programmed in the Fortran language for an IBM 360 Computer. This program gives a continuous solution of equation (12), given rainfall, pan evaporation, and specific program control parameters. The program has been subroutined so that each logical facet in the model can be modified or replaced with minimum effort.

Compatibility of Results

Comparison of simulated results with field measurements were very encouraging. Statistical evaluation of predicted versus measured values gave correlations ranging from 0.88 to 0.99. With few exceptions simulated data were within the bounds of sampling variation. The most difficulty was encountered immediately after large storms, which were defined as storm rainfall in excess of 1.50 inches. The difficulty appeared to be both a spatial distribution and a soil moisture sampling problem when the soil water content was near saturation.

Simulations with different soils indicate that only nominal soil water conservation benefits will be derived if the no-tillage system is used on shallow soils with low water holding capacities. Sandy soils which are characterized by low plant available soil water would be included in this group.

The no-tillage system conserves more water early in the growing season, but due to increased plant growth it requires greater quantities as the season progresses.

Applicability

The model was developed with a two-fold purpose; (a) to study the hydrologic aspects of the no-tillage and conventional-tillage systems when selected soil types were subjected to wide ranges of climatic conditions, and (b) to evaluate the soil water balance of different land-use patterns to be incorporated at a later date in a more comprehensive watershed model. To both of these objectives the author feels moderate success has been achieved. The study presented has dealt with testing on only one soil type. However, it is felt that the principles for other soil types will be little different than for Groseclose silt loam. Differences in the evaporativity of the soil, infiltration, potential soil water, precipitation excess, and evapotranspiration can be obtained by simply changing the appropriate program parameters. The difficulty, of course, is involved with the placing of a numerical quantity to the above parameters where in many instances they can only be verified or obtained through experiments and/or laboratory analysis.

The success of using the model for other cover conditions also requires additional experimental verification to obtain reasonable estimates for the pertinent program control parameters.

Irrigation Requirements

Irrigation is used by many farmers to circumvent the drought problem. This practice is quite expensive and time consuming to apply. As a consequence, it becomes very important to know when and how much water to apply for optimum growing conditions. The determination of these requirements is most difficult and has thereby resulted in most farmers using rule-of-thumb techniques.

This model answers the question when and how much water to apply. However, from a practical standpoint, it would be useless to the farmer because the computations would be overwhelming if they were performed by hand. This should not deter thought towards future use since it is not inconceivable that in the not too distant future farmers will have ready access to high speed digital equipment which would make the computational problem nil. In fact, many aspects of farming are now being computerized and future requirements for optimum production will no doubt dictate further use of the computer in reaching this goal.

The present model would require little effort by the farmer to completely classify his crop fields. Measurements of daily rainfall and pan evaporation would be required to give a continuous update to the soil water status.

APPENDICES

APPENDIX A. Abbreviated table of rainfall and pan evaporation data reduced to the input form required by the soil water model.

Date	Time of day (hrs)	Δt (hrs)	ΔP (in.)	Code	E_p (in./day)	$\Delta t'$ (hrs)	Storm rainfall (in.)	Storm number
5-3-66	24.0000	24.0000	0.00	0	0.12	13.7900	0.05	1
5-4-66	24.0000	24.0000	0.00	0	0.28	13.8230	0.05	1
5-13-66	15.3667	15.3667	0.00	0	0.04	10.4227	0.40	2
5-13-66	16.0333	0.6667	0.01	0	0.04	00.0000	0.40	2
5-13-66	16.3333	0.3000	0.00	0	0.04	0.3000	0.40	2
5-13-66	16.3500	0.0167	0.01	0	0.04	0.0000	0.40	2
5-13-66	16.3667	0.0167	0.03	0	0.04	0.0000	0.40	2
5-13-66	16.3833	0.0167	0.05	0	0.04	0.0000	0.40	2
5-13-66	16.4000	0.0167	0.07	0	0.04	0.0000	0.40	2
5-13-66	16.4167	0.0167	0.03	0	0.04	0.0000	0.40	2
5-13-66	16.4333	0.0167	0.05	0	0.04	0.0000	0.40	2
5-13-66	16.4500	0.0167	0.04	0	0.04	0.0000	0.40	2
5-13-66	16.4667	0.0167	0.04	0	0.04	0.0000	0.40	2
5-27-66	1.7500	1.7500	0.00	0	0.00	0.0000	0.01	16
5-27-66	2.7667	1.0167	0.01	0	0.00	0.0000	0.01	16
5-27-66	5.0667	2.3000	0.00	0	0.00	0.2997	0.06	17
5-27-66	5.6667	0.6000	0.06	0	0.00	0.0000	0.06	17
5-27-66	9.4500	3.7833	0.00	0	0.00	3.7833	0.01	18
5-27-66	10.1000	0.6500	0.01	0	0.00	0.0000	0.01	18
7-30-66	4.8500	0.1836	0.04	0	0.01	0.0000	2.90	40
7-30-66	4.8833	0.0352	0.02	0	0.01	0.0000	2.90	40
7-30-66	4.9333	0.0469	0.02	0	0.01	0.0000	2.90	40
7-30-66	4.9500	0.0195	0.03	0	0.01	0.0000	2.90	40

APPENDIX A (Continued)

Date	Time of day (hrs)	Δt (hrs)	ΔP (in.)	Code	E_p (in./day)	$\Delta t'$ (hrs)	Storm rainfall (in.)	Storm number
7-30-66	5.0000	0.0508	0.03	0	0.01	0.0000	2.90	40
7-30-66	5.0500	0.0469	0.02	0	0.01	0.0000	2.90	40
7-30-66	5.1333	0.0859	0.02	0	0.01	0.0000	2.90	40
7-30-66	5.2500	0.1172	0.03	0	0.01	0.0000	2.90	40
7-30-66	5.3333	0.0820	0.02	0	0.01	0.0000	2.90	40
7-30-66	5.4333	0.0977	0.03	0	0.01	0.0000	2.90	40
7-30-66	5.5000	0.0703	0.00	0	0.01	0.0000	2.90	40
7-30-66	5.6167	0.1133	0.02	0	0.01	0.0000	2.90	40
7-30-66	5.6833	0.0664	0.01	0	0.01	0.0000	2.90	40
7-30-66	5.8500	0.1680	0.01	0	0.01	0.0000	2.90	40
7-30-66	6.0000	0.1523	0.01	0	0.01	0.0000	2.90	40
9-29-66	0.3333	0.3333	0.00	0	0.04	0.0000	0.03	85
9-29-66	1.7500	1.4180	0.03	0	0.04	0.0000	0.03	85
9-29-66	24.0000	22.2500	0.00	0	0.04	11.8860	0.03	85
9-30-66	24.0000	24.0000	0.00	0	0.07	11.8610	0.03	85
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APPENDIX B. Output from soil water model using the input data given in Appendix A.

Date	Time	ΔP	ΔF	S	D_p	ΣE_p	GRDM	AVLM	SM_t	ΣP	ΣQ	ΣET	ΣIC	t_a	D	H	RD
5-3-66	0.0000	0.00	0.00	1.26	0.00	0.00	0.00	3.02	3.02	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0
5-3-66	24.0000	0.00	0.00	1.37	0.00	0.12	0.00	2.92	2.92	0.00	0.00	0.10	0.00	24.0	0.0	0.0	0.0
5-4-66	24.0000	0.00	0.00	1.60	0.00	0.40	0.00	2.68	2.68	0.00	0.00	0.34	0.00	48.0	0.0	0.0	0.0
5-13-66	15.3667	0.00	0.00	2.67	0.00	2.06	0.00	1.61	1.61	0.05	0.00	1.46	0.00	307.9	0.0	0.0	0.0
5-13-66	16.0333	0.01	0.00	2.66	0.00	2.06	0.00	1.62	1.62	0.06	0.00	1.46	0.00	290.2	0.0	0.0	0.0
5-13-66	16.3333	0.00	0.01	2.66	0.00	2.06	0.00	1.62	1.62	0.06	0.00	1.46	0.00	290.5	0.0	0.0	0.0
5-13-66	16.3500	0.01	0.00	2.64	0.00	2.06	0.00	1.63	1.63	0.07	0.00	1.46	0.00	287.4	0.0	0.0	0.0
5-13-66	16.3667	0.03	0.01	2.63	0.01	2.06	0.00	1.65	1.65	0.10	0.00	1.46	0.00	281.7	0.0	0.0	0.0
5-13-66	16.3833	0.05	0.02	2.61	0.04	2.06	0.00	1.68	1.68	0.15	0.00	1.46	0.00	275.9	0.0	0.0	0.0
5-13-66	16.4000	0.07	0.02	2.59	0.05	2.06	0.00	1.69	1.69	0.22	0.04	1.46	0.00	270.4	0.0	0.0	0.0
5-13-66	16.4167	0.03	0.02	2.57	0.05	2.06	0.00	1.71	1.71	0.25	0.05	1.46	0.00	265.0	0.0	0.0	0.0
5-13-66	16.4333	0.05	0.02	2.55	0.05	2.06	0.00	1.73	1.73	0.30	0.08	1.46	0.00	259.5	0.0	0.0	0.0
5-13-66	16.4500	0.04	0.02	2.53	0.05	2.06	0.00	1.75	1.75	0.34	0.10	1.46	0.00	254.5	0.0	0.0	0.0
5-13-66	16.4667	0.04	0.02	2.51	0.05	2.06	0.00	1.77	1.77	0.38	0.12	1.46	0.00	249.5	0.0	0.0	0.0
5-27-66	1.7500	0.00	0.00	2.78	0.00	4.08	0.00	1.51	1.51	1.03	0.12	2.42	0.00	382.2	0.0	0.0	0.0
5-27-66	2.7667	0.01	0.01	2.77	0.00	4.08	0.00	1.52	1.52	1.04	0.12	2.42	0.00	322.1	0.0	0.0	0.0
5-27-66	5.0667	0.00	0.00	2.77	0.00	4.08	0.00	1.52	1.52	1.04	0.12	2.42	0.00	324.4	0.0	0.0	0.0
5-27-66	5.6667	0.06	0.06	2.71	0.00	4.08	0.00	1.58	1.58	1.10	0.12	2.42	0.00	304.0	0.0	0.0	0.0
5-27-66	9.4500	0.00	0.00	2.70	0.00	4.08	0.00	1.58	1.58	1.10	0.12	2.42	0.00	307.8	0.1	0.0	0.0
5-27-66	10.1000	0.01	0.01	2.70	0.00	4.08	0.00	1.59	1.59	1.11	0.12	2.42	0.00	301.0	0.1	0.0	0.0
7-30-66	4.8500	0.04	0.04	1.47	0.00	17.55	0.00	7.72	7.72	5.26	0.18	8.59	0.15	32.5	9.2	90.8	4.1
7-30-66	4.8833	0.02	0.01	1.45	0.01	17.55	0.00	7.74	7.74	5.28	0.18	8.59	0.15	30.0	9.2	90.8	4.1
7-30-66	4.9333	0.02	0.02	1.43	0.01	17.55	0.00	7.76	7.76	5.30	0.18	8.59	0.15	27.0	9.2	90.8	4.1
7-30-66	4.9500	0.03	0.01	1.42	0.03	17.55	0.00	7.76	7.76	5.33	0.18	8.59	0.15	25.6	9.2	90.8	4.1
7-30-66	5.0000	0.03	0.02	1.40	0.04	17.55	0.00	7.78	7.78	5.36	0.18	8.59	0.15	22.4	9.2	90.8	4.1

APPENDIX B (Continued)

Date	Time	ΔP	ΔF	S	D_p	ΣE_p	.GRDM	AVLM	SM t	ΣP	ΣQ	ΣET	IC	t_g	D	H	RD
7-30-66	5.0500	0.02	0.02	1.39	0.04	17.55	0.00	7.80	7.80	5.38	0.18	8.59	0.15	22.4	9.2	90.8	4.1
7-30-66	5.1333	0.02	0.03	1.36	0.03	17.55	0.00	7.83	7.83	5.40	0.18	8.59	0.15	14.8	9.2	90.8	4.1
7-30-66	5.2500	0.03	0.04	1.32	0.02	17.55	0.00	7.87	7.87	5.43	0.18	8.59	0.15	8.5	9.2	90.8	4.1
7-30-66	5.3333	0.02	0.03	1.29	0.02	17.55	0.00	7.90	7.90	5.45	0.18	8.59	0.15	4.4	9.2	90.8	4.1
7-30-66	5.4333	0.03	0.03	1.26	0.02	17.55	0.00	7.93	7.93	5.48	0.18	8.59	0.15	0.0	9.2	90.8	4.1
7-30-66	5.5000	0.00	0.02	1.25	0.00	17.55	0.02	7.93	7.95	5.48	0.18	8.59	0.15	0.1	9.2	90.9	4.1
7-30-66	5.6167	0.02	0.02	1.24	0.00	17.55	0.02	7.95	7.97	5.50	0.18	8.59	0.15	0.0	9.2	90.9	4.1
7-30-66	5.6833	0.01	0.01	1.24	0.00	17.55	0.02	7.96	7.98	5.51	0.18	8.59	0.15	0.0	9.2	90.9	4.1
7-30-66	5.8500	0.01	0.01	1.25	0.00	17.55	0.01	7.98	7.99	5.52	0.18	8.59	0.15	0.0	9.2	90.9	4.1
7-30-66	6.0000	0.01	0.01	1.25	0.00	17.55	0.01	7.99	8.00	5.53	0.18	8.59	0.15	0.0	9.2	90.9	4.1
9-29-66	0.3333	0.00	0.00	1.28	0.00	23.81	0.00	9.79	9.79	15.16	1.57	17.12	0.95	3.9	17.9	110.0	5.0
9-29-66	1.7500	0.03	0.00	1.28	0.00	23.81	0.00	9.79	9.79	15.19	1.57	17.15	0.98	3.9	17.9	110.0	5.0
9-29-66	24.0000	0.00	0.00	1.37	0.00	23.81	0.00	9.70	9.70	15.19	1.57	17.24	0.98	24.8	18.0	110.0	5.0
9-30-66	24.0000	0.00	0.00	1.44	0.00	23.88	0.00	9.63	9.63	15.19	1.57	17.31	0.98	48.8	18.1	110.0	5.0

APPENDIX C. Accumulated estimate of retention storage, surface runoff, and plant interception storage on conventional-tillage and no-tillage systems of corn production during 1966 growing Season.

Date	Precipitation excess					
	Retention storage		Surface runoff		Plant interception	
	No tillage (in.)	Conventional tillage (in.)	No tillage (in.)	Conventional tillage (in.)	No tillage (in.)	Conventional tillage (in.)
May 2	0.00	0.00	0.00	0.00	0.00	0.00
13	0.15	0.05	0.00	0.12	0.00	0.00
	0.15	0.05	0.00	0.12	0.00	0.00
July 5	0.15	0.05	0.00	0.12	0.01	0.01
6	0.15	0.05	0.00	0.12	0.02	0.02
11	0.15	0.05	0.00	0.12	0.03	0.03
12	0.15	0.05	0.00	0.12	0.04	0.04
13	0.15	0.05	0.00	0.12	0.06	0.06
15	0.15	0.05	0.00	0.12	0.08	0.07
19	0.16	0.09	0.00	0.12	0.11	0.11
29	0.16	0.09	0.00	0.12	0.16	0.15
30	0.23	0.32	0.00	0.18	0.18	0.17
Aug. 3	0.31	0.43	0.00	0.18	0.21	0.20
4	0.34	0.49	0.00	0.18	0.23	0.22
9	0.34	0.49	0.00	0.18	0.26	0.25
10	0.34	0.49	0.00	0.18	0.26	0.25
11	0.88	0.16	0.10	0.89	0.32	0.30
13	0.88	0.68	0.10	0.89	0.34	0.33
16	0.88	0.68	0.10	0.89	0.35	0.34
17	1.18	0.73	0.35	1.51	0.37	0.36
21	1.18	0.73	0.35	1.51	0.38	0.36
22	1.18	0.73	0.35	1.51	0.43	0.41

APPENDIX C (Continued)

Date	Precipitation excess					
	Retention storage		Surface runoff			
	No tillage (in.)	Conventional tillage (in.)	No tillage (in.)	Conventional tillage (in.)		
				No tillage (in.)	Conventional tillage (in.)	
Sept. 4	1.19	0.78	0.35	1.55	0.46	0.44
12	1.19	0.78	0.35	1.55	0.48	0.46
13	1.19	0.78	0.35	1.55	0.55	0.53
14	1.22	0.84	0.35	1.57	0.55	0.53
19	1.22	0.86	0.35	1.57	0.58	0.55
21	1.22	0.86	0.35	1.57	0.73	0.70
22	1.22	0.86	0.35	1.57	0.75	0.72
25	1.22	0.86	0.35	1.57	0.76	0.73
26	1.23	0.92	0.35	1.57	0.88	0.84
27	1.26	0.96	0.35	1.57	0.95	0.91
28	1.26	0.96	0.35	1.57	1.00	0.95
29	1.26	0.96	0.35	1.57	1.03	0.98

APPENDIX D. Accumulated estimate of retention storage, surface runoff, and plant interception storage on conventional-tillage and no-tillage systems of corn production during 1967 growing season.

Date	Precipitation storage				Surface runoff		Plant interception	
	Retention storage		No		Conventional		No	
	tillage	(in.)	tillage	(in.)	tillage	(in.)	tillage	(in.)
April 26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.07	0.11	0.00	0.00	0.27	0.00	0.00	0.00
7	0.07	0.18	0.00	0.00	0.27	0.00	0.00	0.00
8	0.07	0.22	0.00	0.00	0.27	0.00	0.00	0.00
14	0.10	0.27	0.00	0.00	0.49	0.00	0.00	0.00
19	0.10	0.33	0.00	0.00	0.52	0.00	0.00	0.00
30	0.10	0.34	0.00	0.00	0.52	0.00	0.00	0.00
31	0.10	0.40	0.00	0.00	0.52	0.00	0.00	0.00
June 18	0.40	0.49	0.05	0.05	1.17	0.00	0.00	0.00
30	0.40	0.49	0.05	0.05	1.17	0.03	0.02	0.02
July 1	0.40	0.54	0.05	0.05	1.17	0.04	0.03	0.03
2	0.40	0.54	0.05	0.05	1.17	0.07	0.05	0.05
6	0.40	0.54	0.05	0.05	1.17	0.09	0.07	0.07
7	0.40	0.54	0.05	0.05	1.17	0.10	0.08	0.08
8	0.40	0.54	0.05	0.05	1.17	0.13	0.10	0.10
10	0.40	0.65	0.05	0.05	1.22	0.14	0.11	0.11
11	0.40	0.65	0.05	0.05	1.22	0.15	0.12	0.12
14	0.40	0.65	0.05	0.05	1.22	0.18	0.14	0.14
17	0.40	0.65	0.05	0.05	1.22	0.21	0.16	0.16
22	0.40	0.65	0.05	0.05	1.22	0.23	0.17	0.17

APPENDIX D (Continued)

Date	Precipitation excess					
	Retention storage		Surface runoff		Plant interception	
	No tillage (in.)	Conventional tillage (in.)	No tillage (in.)	Conventional tillage (in.)	No tillage (in.)	Conventional tillage (in.)
July Cont.						
25	0.40	0.65	0.05	1.22	0.25	0.19
28	0.40	0.65	0.05	1.22	0.27	0.20
29	0.40	0.65	0.05	1.22	0.28	0.21
30	0.40	0.65	0.05	1.22	0.30	0.22
31	0.40	0.78	0.05	1.35	0.32	0.24
Aug. 2	0.40	0.78	0.05	1.35	0.33	0.25
3	0.40	0.80	0.05	1.35	0.35	0.25
4	0.40	0.80	0.05	1.35	0.37	0.27
7	0.40	0.80	0.05	1.35	0.40	0.29
9	0.40	0.80	0.05	1.35	0.43	0.31
20	0.40	0.80	0.05	1.35	0.46	0.33
21	0.40	0.82	0.05	1.35	0.51	0.37
22	0.40	0.82	0.05	1.35	0.64	0.47
23	0.40	0.82	0.05	1.35	0.66	0.48
24	0.40	0.98	0.05	1.46	0.71	0.52
25	0.40	0.98	0.05	1.46	0.78	0.56
26	0.40	0.98	0.05	1.46	0.81	0.58
27	0.40	0.98	0.05	1.46	0.87	0.63
31	0.40	0.98	0.05	1.46	0.89	0.65
Sept. 9	0.40	0.98	0.05	1.46	0.95	0.69
10	0.40	0.98	0.05	1.46	0.96	0.69
19	0.40	0.98	0.05	1.46	0.97	0.70
21	0.40	0.98	0.05	1.46	1.00	0.72
22	0.40	0.98	0.05	1.46	1.02	0.75
27	0.40	0.98	0.05	1.46	1.05	0.75
28	0.40	1.20	0.05	1.58	1.08	0.78

APPENDIX E. Variation of water content in Groseclose silt loam at field capacity and saturation.

Sample No.	Accumulated Depth (in.)	Accumulated water content at	
		Saturation (in.)	Field capacity (in.)
1	6	2.23	1.61
	15	5.27	3.81
	21	7.08	5.19
	30	9.61	7.18
	36	11.55	8.25
2	6	2.30	1.37
	15	5.60	3.01
	21	7.54	3.85
	30	9.77	5.33
	36	11.37	6.41
3	6	2.32	1.46
	15	5.23	3.83
	21	6.85	5.24
	30	8.96	7.16
	36	10.72	8.33
4	6	2.28	1.29
	15	5.45	3.10
	21	7.31	4.17
	30	9.79	5.81
	36	11.62	6.91
5	6	1.95	1.51
	11	2.95	2.24
	21	4.23	3.18
	26	4.67	3.39
	40	6.66	4.08
	57	8.76	5.35
6	6	2.14	1.42
	11	3.86	2.38
	21	6.60	3.53
	26	7.82	3.92
	40	10.04	4.93
7	9	2.71	2.23
	16	4.62	3.58
	24	6.00	4.56
	31	7.22	5.33
	37	8.96	6.61

APPENDIX E (Continued)

Sample No.	Accumulated depth (in.)	Accumulated water content at	
		Saturation (in.)	Field capacity (in.)
8	8	3.05	2.25
	15	5.57	3.84
	27	9.23	5.35
	37	11.24	6.42
	43	13.08	7.53
9	6	2.15	1.26
	18	6.74	4.28
	30	10.72	6.79
	42	13.86	8.96
	54	17.73	11.06
10	6	1.99	1.21
	15	4.59	2.95
	21	6.12	3.98
	27	7.70	4.99
	33	9.36	6.09
	39	10.93	7.21
	45	12.63	8.26
	51	14.57	9.31

APPENDIX F (Continued)

Soil type	Depth (in.)	Total soil water				Plant available soil water			
		Actual (in.)	Estimated (in.)	Error (%)	Constants ¹ / a ₂ b ₂	Actual (in.)	Estimated (in.)	Error (%)	Constants ¹ / a ₁ b ₁
Fluvanna fine sandy loam	7	1.69	1.94	-15		0.73	0.70	3	
	10	2.54	2.53	1		1.01	0.98	3	
	15	3.87	3.38	13		1.43	1.40	2	
	24	5.25	4.69	11		1.89	2.07	-10	
	43	6.38	6.95	-9		2.94	3.29	-12	
	60	8.35	8.67	-4		4.27	4.24	1	
	70	9.62	9.60	0	0.502 1.250	5.31	4.75	10	0.084 1.362
Frederick silt loam	7	2.68	2.93	-10		1.68	1.76	-5	
	15	5.18	4.79	8		2.91	2.73	6	
	23	6.83	6.25	9		3.53	3.45	2	
	44	8.96	9.28	-4		4.65	4.88	-5	
	60	10.68	11.18	-5	1.233 1.149	5.79	5.74	1	0.743 0.966
Gleneig loam	7	1.79	1.63	9		1.14	1.09	5	
	20	4.86	5.44	-12		2.99	3.23	-8	
	30	7.84	8.40	-7		4.82	4.76	1	
	41	11.68	11.66	0		6.26	6.63	-2	
	65	20.57	18.77	9	0.087 2.002	10.05	9.67	4	0.081 1.713
Greendale silt loam	7	2.68	2.73	-2		0.90	0.92	-1	
	38	13.81	12.87	7		5.41	5.10	6	
	44	15.06	14.64	3		5.87	5.84	1	
	57	16.91	18.34	-8	0.380 1.692	7.03	7.39	15	0.064 1.700
Litz silt loam	6	2.52	2.52	0		1.50	1.50	0	
	24	8.64	8.64	0	0.488 1.617	5.67	5.67	0	0.190 1.666

APPENDIX F (Continued)

Soil type	Depth (in.)	Total soil water			Plant available soil water			
		Actual (in.)	Estimated (in.)	Error (%)	Actual (in.)	Estimated (in.)	Error (%)	
							Constants	1/
							a ₁	b ₁
							a ₂	b ₂
Lodi loam	7	2.47	2.52	-2	0.85	0.89	-5	
	13	4.05	3.92	3	1.76	1.77	-1	
	30	7.00	6.95	1	4.68	4.10	12	
	42	8.41	8.70	-4	5.62	5.64	0	
	62	11.43	11.26	2	7.48	8.09	8	0.058 1.731
Mason silt loam	7	2.03	2.12	-5	0.91	0.98	-7	
	11	3.18	3.00	5	1.45	1.36	6	
	15	3.87	3.79	2	1.79	1.68	6	
	23	5.00	5.17	-3	2.11	2.24	-6	0.220 1.115
Penn silt loam	7	1.68	1.67	1	1.19	1.15	3	
	13	3.46	3.49	-1	2.03	2.13	-5	
	38	11.30	11.27	0	5.68	5.60	2	0.110 1.598
Tatum silt loam	6	2.07	1.93	7	1.11	1.14	-3	
	21	6.08	6.06	0	4.93	4.48	9	
	27	6.97	7.53	-8	5.64	5.76	-2	
	35	8.43	9.40	-11	7.07	7.44	-5	
	70	18.99	16.82	11	14.52	14.49	0	0.091 1.838
Wilkes fine sandy loam	4	1.18	1.12	5	0.53	0.54	-2	
	7	1.98	2.10	-6	0.87	0.85	2	
	60	17.63	17.18	1	3.77	3.78	0	0.173 1.135

5 APPENDIX G. Seasonal distribution of plant available soil water in the 0-12 inch depth for selected soil types. The data represent the number of days per month that the simulated soil water content fell within the indicated range of available soil water. 1966 climatological data used.

Soil type	Available water ₁ (interval)	No tillage			Conventional tillage						
		May (days)	June (days)	July (days)	Aug. (days)	Sept. (days)	May (days)	June (days)	July (days)	Aug. (days)	Sept. (days)
Brandywine loam	0.00-0.25	0	0	4	0	0	0	11	17	0	0
	0.25-0.50	0	8	25	5	12	7	0	16	12	12
	0.50-0.75	1	16	0	13	2	2	23	3	0	11
	0.75-1.00	28	6	2	13	16	6	0	0	2	13
Cattlett silt loam	0.00-0.25	0	0	3	0	0	0	0	12	17	0
	0.25-0.50	0	8	26	5	12	7	1	16	12	12
	0.50-0.75	1	17	0	13	3	2	23	2	0	12
	0.75-1.00	28	5	2	13	15	5	0	0	2	12
Croton silt loam	0.00-0.25	0	0	4	0	0	0	0	10	17	0
	0.25-0.50	0	8	25	5	12	8	1	17	12	12
	0.50-0.75	1	16	0	13	2	2	22	3	0	12
	0.75-1.00	28	6	2	13	16	6	0	0	2	11
Edneyville fine sandy loam	0.00-0.25	0	0	6	0	0	0	0	7	17	0
	0.25-0.50	0	8	23	7	12	8	0	18	12	12
	0.50-0.75	1	16	0	11	2	2	21	5	0	10
	0.75-1.00	28	6	2	13	16	8	0	0	2	13
Fluvanna fine sandy loam	0.00-0.25	0	1	12	3	6	6	0	6	13	2
	0.25-0.50	0	7	16	8	6	6	0	17	16	9
	0.50-0.75	1	16	2	12	5	5	10	7	1	12
	0.75-1.00	28	6	1	8	13	19	0	0	1	8

1/Available water represents the ratio of actual soil water (W_a) to the potential soil water (W_p) in the 0-12 inch depth.

APPENDIX G (Continued)

Soil type	Available water/interval	No tillage			Conventional tillage							
		May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.	
	(interval)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)
Frederick silt loam	0.00-0.25	0	0	3	0	0	0	11	17	0	0	0
	0.25-0.50	0	8	26	5	12	1	17	12	6	12	12
	0.50-0.75	1	17	0	13	3	23	2	0	12	3	3
	0.75-1.00	28	5	2	13	15	5	0	2	13	15	15
Glencelg loam	0.00-0.25	0	0	6	0	0	0	7	17	0	0	0
	0.25-0.50	0	8	23	7	12	0	19	12	8	12	12
	0.50-0.75	1	16	0	11	2	21	4	0	11	2	2
	0.75-1.00	28	6	2	13	16	8	0	2	12	16	16
Greendale silt loam	0.00-0.25	0	0	8	0	3	0	6	15	0	1	1
	0.25-0.50	0	8	21	8	9	0	17	14	8	11	11
	0.50-0.75	1	16	0	14	2	16	7	0	14	2	2
	0.75-1.00	28	6	2	9	16	13	0	2	9	16	16
Litz silt loam	0.00-0.25	0	0	3	0	0	0	19	19	0	0	0
	0.25-0.50	0	8	26	3	12	2	10	10	4	12	12
	0.50-0.75	2	17	0	11	3	23	1	0	11	3	3
	0.75-1.00	27	5	2	17	15	4	0	2	16	15	15
Lodi loam	0.00-0.25	0	0	8	0	3	0	6	15	0	1	1
	0.25-0.50	0	8	21	8	9	0	17	14	8	11	11
	0.50-0.75	1	16	0	14	3	18	7	0	14	2	2
	0.75-1.00	28	6	2	9	15	11	0	2	9	16	16
Nason silt loam	0.00-0.25	0	0	10	0	5	0	6	13	0	4	4
	0.25-0.50	0	8	19	8	7	0	17	16	9	8	8
	0.50-0.75	1	16	0	14	4	17	7	0	13	4	4
	0.75-1.00	28	6	2	9	14	12	0	2	9	14	14

APPENDIX G (Continued)

Soil type	Available water ₁ / (interval)	No tillage				Conventional tillage				
		May	June	July	Aug. Sept.	May	June	July	Aug. Sept.	
	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	
Penn silt loam	0.00-0.25	0	0	5	0	0	8	17	0	0
	0.25-0.50	0	8	24	7	12	0	18	12	8
	0.50-0.75	1	16	0	11	2	4	0	11	2
	0.75-1.00	28	6	2	13	16	7	0	2	12
Tatum silt loam	0.00-0.25	0	0	3	0	0	0	14	17	0
	0.25-0.50	0	8	26	4	12	1	14	12	6
	0.50-0.75	4	0	2	12	15	24	2	0	13
	0.75-1.00	28	5	2	13	15	4	0	2	12
Wilkes fine sandy loam	0.00-0.25	0	1	11	1	6	0	6	13	1
	0.25-0.50	0	7	17	8	6	0	17	16	9
	0.50-0.75	1	16	1	13	4	9	7	0	12
	0.75-1.00	28	6	2	9	14	20	0	2	9

APPENDIX H. Seasonal distribution of plant available soil water in the 0-12 inch depth for selected soil types. The data represent the number of days per month that the simulated soil water content fell within the indicated range of available soil water. 1967 climatological data used.

Soil type	Available water ^{1/} (interval)	No tillage			Conventional tillage								
		May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.		
		(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)
Brandywine loam	0.00-0.25	0	0	0	0	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	6	9	19	0	7	9	9	19	0	19
	0.50-0.75	0	9	17	11	8	4	14	17	13	8	0	8
	0.75-1.00	31	21	8	11	3	27	9	5	9	3	0	3
Catlett silt loam	0.00-0.25	0	0	0	0	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	5	9	18	0	8	9	10	18	0	18
	0.50-0.75	0	9	19	12	9	4	13	17	11	9	0	9
	0.75-1.00	31	21	7	10	3	27	9	5	10	3	0	3
Croton silt loam	0.00-0.25	0	0	0	0	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	7	9	19	0	8	13	10	19	0	19
	0.50-0.75	0	9	16	12	8	4	13	16	11	8	0	8
	0.75-1.00	31	21	8	10	3	27	9	2	9	3	0	3
Edneyville fine sandy loam	0.00-0.25	0	0	0	1	0	0	0	0	0	1	0	0
	0.25-0.50	0	0	9	8	23	0	7	12	9	23	0	23
	0.50-0.75	0	9	16	12	4	4	14	16	11	4	0	4
	0.75-1.00	31	21	6	10	3	27	9	3	10	3	0	3
Fluvanna fine sandy loam	0.00-0.25	0	0	3	6	10	0	0	3	6	5	0	5
	0.25-0.50	0	4	13	4	16	0	7	14	5	22	0	22
	0.50-0.75	0	6	8	8	1	4	9	8	9	0	0	0
	0.75-1.00	31	20	7	13	3	27	14	6	11	3	0	3

^{1/}Available water represents the ratio of actual soil water (W_a) to the potential soil water (W_p) in the 0-12 inch depth.

APPENDIX H (Continued)

Soil type	Available water/ (interval)	No tillage			Conventional tillage							
		May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.	
	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)
Frederick silt loam	0.00-0.25	0	0	0	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	5	9	17	0	7	9	9	18	18
	0.50-0.75	0	9	17	12	10	4	14	17	12	9	9
	0.75-1.00	31	21	9	10	3	27	9	5	10	3	3
Gleneig loam	0.00-0.25	0	0	0	1	0	0	0	0	0	1	0
	0.25-0.50	0	0	9	8	23	0	7	11	9	23	23
	0.50-0.75	0	9	16	12	4	4	14	15	12	4	4
	0.75-1.00	31	21	6	10	3	27	9	5	9	3	3
Greendale silt loam	0.00-0.25	0	0	0	3	1	0	0	0	0	3	0
	0.25-0.50	0	0	12	7	23	0	6	13	7	25	25
	0.50-0.75	0	9	13	11	3	4	12	15	12	2	2
	0.75-1.00	31	21	6	10	3	27	12	3	9	3	3
Litz silt loam	0.00-0.25	0	0	0	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	4	7	13	0	9	10	9	14	14
	0.50-0.75	0	9	20	14	14	4	12	18	12	13	13
	0.75-1.00	31	21	7	10	3	27	9	3	10	3	3
Lodi loam	0.00-0.25	0	0	0	3	1	0	0	0	0	3	0
	0.25-0.50	0	0	12	7	23	0	7	14	7	25	25
	0.50-0.75	0	10	12	12	3	4	14	14	12	2	2
	0.75-1.00	31	20	7	9	3	27	9	3	9	3	3

APPENDIX H (Continued)

Soil type	Available water ¹ / (interval)	No tillage			Conventional tillage								
		May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.		
		(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)
Nason silt loam	0.00-0.25	0	0	1	4	6	0	0	2	5	1		
	0.25-0.50	0	2	11	6	19	0	7	13	6	25		
	0.50-0.75	0	8	13	12	2	4	14	14	11	1		
	0.75-1.00	31	20	6	9	3	27	9	2	9	3		
Penn silt loam	0.00-0.25	0	0	0	1	0	0	0	0	1	0		
	0.25-0.50	0	0	9	8	23	0	7	11	9	23		
	0.50-0.75	0	9	16	12	4	4	14	17	12	4		
	0.75-1.00	31	21	6	10	3	27	9	3	9	3		
Tatum silt loam	0.00-0.25	0	0	0	0	0	0	0	0	0	0		
	0.25-0.50	0	0	5	9	17	0	8	9	10	17		
	0.50-0.75	0	9	19	12	10	4	13	17	11	10		
	0.75-1.00	31	21	7	10	3	27	9	5	10	3		
Wilkes fine sandy loam	0.00-0.25	0	0	3	5	8	0	0	3	6	3		
	0.25-0.50	0	2	10	5	18	0	7	13	5	23		
	0.50-0.75	0	8	11	11	1	4	9	11	9	1		
	0.75-1.00	31	20	7	10	3	27	14	4	11	3		

APPENDIX I. Seasonal distribution of plant available soil water in the 0-12 inch depth for Groseclouse silt loam subjected to various rainfall patterns. The data represent the number of days per month that the simulated soil water content fell within the indicated range of available soil water.

Event	Available water ^{1/} (interval)	No tillage				Conventional tillage			
		May	June	July	Aug. Sept.	May	June	July	Aug. Sept.
	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)
1	0.00-0.25	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	0	9	10	0	0	16
	0.50-0.75	0	1	8	17	14	0	4	11
	0.75-1.00	31	29	23	5	6	31	26	20
2	0.00-0.25	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	0	0	0	0	0	1
	0.50-0.75	0	3	14	4	9	7	7	15
	0.75-1.00	31	27	17	27	21	24	23	15
3	0.00-0.25	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	0	5	7	0	0	6
	0.50-0.75	0	0	17	13	23	12	0	18
	0.75-1.00	31	30	14	13	0	19	30	13
4	0.00-0.25	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	0	5	0	0	6	0
	0.50-0.75	0	11	8	12	21	2	15	8
	0.75-1.00	30	19	23	14	9	28	9	23
5	0.00-0.25	0	0	0	0	0	0	0	1
	0.25-0.50	0	0	0	0	0	0	0	0
	0.50-0.75	0	3	3	12	14	0	3	9
	0.75-1.00	31	27	28	19	16	31	27	22

^{1/}Available water represents the ratio of actual soil water (W_a) to the potential soil water (W_p) in the 0-12 inch depth.

APPENDIX I (Continued)

Event	Available Water/ (interval)	No tillage				Conventional tillage			
		May	June	July	Aug. Sept.	May	June	July	Aug. Sept.
	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)
6	0.00-0.25	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	1	3	0	0	1	2
	0.50-0.75	0	0	19	23	16	3	20	25
	0.75-1.00	31	30	12	11	4	15	27	11
7	0.00-0.25	0	0	1	0	0	0	2	0
	0.25-0.50	0	0	8	0	4	0	8	5
	0.50-0.75	6	2	12	18	23	4	14	17
	0.75-1.00	25	28	10	13	3	21	16	13
8	0.00-0.25	0	0	3	5	12	0	0	7
	0.25-0.50	0	0	14	19	18	0	4	23
	0.50-0.75	0	9	9	7	0	5	11	0
	0.75-1.00	31	21	5	0	0	26	15	0
9	0.00-0.25	0	0	0	0	1	0	0	0
	0.25-0.50	0	1	11	17	24	0	11	26
	0.50-0.75	0	8	13	14	5	7	18	4
	0.75-1.00	31	21	7	0	0	24	1	0
10	0.00-0.25	0	0	0	0	0	0	5	0
	0.25-0.50	0	0	14	16	21	25	6	23
	0.50-0.75	22	11	17	10	9	6	11	7
	0.75-1.00	9	19	0	5	0	0	8	0

APPENDIX I (Continued)

Event	Available water/ (interval)	No tillage				Conventional tillage				
		May	June	July	Aug. Sept.	May	June	July	Aug. Sept.	
	(interval)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	
11	0.00-0.25	0	0	0	3	0	0	0	4	0
	0.25-0.50	0	0	0	12	0	1	0	12	2
	0.50-0.75	2	1	23	15	19	15	29	15	20
	0.75-1.00	29	29	8	1	11	8	14	2	0
12	0.00-0.25	0	0	0	4	5	1	0	6	5
	0.25-0.50	0	0	11	26	2	25	3	18	2
	0.50-0.75	18	1	16	1	10	5	13	11	0
	0.75-1.00	13	29	4	0	13	0	14	2	13
13	0.00-0.25	0	0	0	0	0	0	3	11	0
	0.25-0.50	0	3	25	4	11	1	15	15	7
	0.50-0.75	1	16	6	22	13	26	6	5	19
	0.75-1.00	30	11	0	5	6	4	6	0	5
14	0.00-0.25	0	0	0	4	0	0	0	5	0
	0.25-0.50	0	0	21	2	6	1	0	27	9
	0.50-0.75	1	3	8	20	22	15	24	4	16
	0.75-1.00	30	27	2	5	2	15	6	0	1
15	0.00-0.25	0	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	3	5	18	1	4	3	8
	0.50-0.75	2	4	25	20	12	10	8	27	17
	0.75-1.00	29	26	3	6	0	20	18	1	6

APPENDIX I (Continued)

Event	Available water/ (interval)	No tillage				Conventional tillage			
		May	June	July	Aug. Sept.	May	June	July	Aug. Sept.
	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)	(days)
16	0.00-0.25	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	0	11	4	2	11	5
	0.50-0.75	3	3	15	12	12	22	10	12
	0.75-1.00	28	27	16	8	14	7	20	13
17	0.00-0.25	0	0	0	5	0	5	0	7
	0.25-0.50	0	0	5	18	7	10	14	18
	0.50-0.75	13	10	26	8	9	12	9	11
	0.75-1.00	18	20	0	0	14	4	7	0
18	0.00-0.25	0	0	0	2	0	0	0	4
	0.25-0.50	0	1	16	17	8	8	15	17
	0.50-0.75	4	9	6	10	17	17	11	8
	0.75-1.00	27	20	9	2	5	6	4	2
19	0.00-0.25	0	0	0	0	0	0	0	0
	0.25-0.50	0	0	7	12	10	2	0	15
	0.50-0.75	2	4	16	16	18	22	13	15
	0.75-1.00	29	26	8	3	2	7	17	1
20	0.00-0.25	0	0	0	0	0	0	10	0
	0.25-0.50	0	7	21	1	12	8	18	3
	0.50-0.75	0	18	8	10	1	17	2	12
	0.75-1.00	20	5	2	20	17	4	0	2

APPENDIX J
COMPUTER PROGRAM


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C * * * * * CALL TABLES SHA 30
10001 CONTINUE SHA 31
20000 WRITE(6,20000) SHA 32
C * * * * * FORMAT('1 PARAMETER DATA') SHA 33
C * * * * * INPUT DATA GROUP NUMBER 3. CODE=1 -- READ CODE=2 NO READ SHA 34
C * * * * * NDA1 INDEX CODE FOR INPUT OF DATA GROUP 4 SHA 35
C * * * * * NDA2 INDEX CODE FOR INPUT OF DATA GROUP 5 SHA 36
C * * * * * NDA3 INDEX CODE FOR INPUT OF DATA GROUP 6 SHA 37
C * * * * * NDA4 INDEX CODE FOR INPUT OF DATA GROUP 7 SHA 38
C * * * * * NDA5 INDEX CODE FOR INPUT OF DATA GROUP 8 SHA 39
C * * * * * READ(5,1002)NDA1,NDA2,NDA3,NDA4,NDA5 SHA 40
C * * * * * WRITE(6,20002)NDA1,NDA2,NDA3,NDA4,NDA5 SHA 41
C * * * * * INPUT DATA GROUP NUMBER 4 SHA 42
C * * * * * ADEP= SOIL PROFILE DEPTHS FOR WHICH MOISTURE SUMMARIES ARE TO SHA 43
C * * * * * BE DETERMINED(INCHES) SHA 44
C * * * * * GO TO(825,826).NDA1 SHA 45
825 CONTINUE SHA 46
826 CONTINUE SHA 47
WRITE(6,20001)(ADEP(I),I=1,7) SHA 48
C * * * * * INPUT DATA GROUP NUMBER 5 -- SEE SUBROUTINE TABLES FOR INPUT SHA 49
C * * * * * DATA GROUPS 1-4 SHA 50
C * * * * * SHA 51
C * * * * * SHA 52
C * * * * * SHA 53
C * * * * * SHA 54
C * * * * * SHA 55
C * * * * * INPUT DATA GROUP NUMBER 5 -- SEE SUBROUTINE TABLES FOR INPUT SHA 56
C * * * * * DATA GROUPS 1-4 SHA 57
C * * * * * SHA 58

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829      GO TO(829,830),NDA3
      CONTINUE
      READ(5,1000)DTM,HCIM,HNTM,HNMINT,HNFAC,EXBASE,CXBASE
      * * * * *
      PERH=(HNTM-HCTM)/HNTM
      HCMINT=HNMINT*(1.-PERH)
      HCFAC=HNFAC*(1.-PERH)
830      CONTINUE
      WRITE(6,2000)DTM,HCIM,HNTM,HNMINT,HNFAC,HCMINT,HCFAC,EXBASE,
      1CXBASE
C
C----- INPUT DATA GROUP NUMBER 7
C----- NTILL= INDEX, CODE INDICATING TILLAGE SYSTEM
C          NTILL=1 CONVENTIONAL TILLAGE PRACTICE
C          NTILL=2 NO TILLAGE PRACTICE
C----- NPRINT= INDEX CODE FOR TYPE OF OUTPUT
C          NPRINT=0 NORMAL OUTPUT -- ALL TIME INTERVALS
C          NPRINT=1 24 HR READINGS PRINTED
C          NPRINT=2 NO OUTPUT EXCEPT SUMMARIES
C----- NREWD= INDEX CODE FOR REWINDING INPUT TAPE
C          NREWD=0 NO REWIND
C          NREWD=1 REWIND INPUT TAPE(GIVEN BY VARIABLE M)
C----- LEND= INDEX CODE FOR TERMINATING PROCESSING
C          LEND=0 CONTINUE PROCESSING WITH A NEW DATA SET
C          LEND=9 TERMINATE PROCESSING
C----- MEMERG= MONTH OF CORN PLANT EMERGENCE
C----- NEMERG= DAY OF CORN PLANT EMERGENCE
C----- NY= YEAR FOR WHICH ANALYSIS ARE BEING RUN
C----- NCREAT= INDEX CODE FOR BUILDING A SECONDARY INPUT TAPE FOR

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SHA 88
SHA 89
SHA 90
SHA 91 * * * * *
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SHA 102
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SHA 112
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SHA 114
SHA 115
SHA 116

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C----- REPEATITIVE OPERATIONS WITH THE SAME DATA SET.
C      NCREAT=0  NEW DATA SET NOT BUILT
C      NCREAT=1  DUPLICATE DATA SET BUILT
C----- M= INPUT DEVICE NUMBER
C----- NPLOT= INDEX CODE FOR PLOTTING OPTIONS
C      NPLOT=0  NO PLOT
C      NPLOT=1  COORDINATE PLOT OF COMPUTED VERSUS ACTUAL DATA
C----- NPLOT=2  COORDINATE PLOT OF COMPUTED VERSUS ACTUAL DATA.
C----- ACTUAL SOIL WATER DATA TABLE READ WHEN NPLOT=1.
C----- THIS TABLE IS NOT READ WHEN NPLOT=2.
C * * * * *
NCREAO=NCREAT
GO TO (831,832),NDA4
831 CONTINUE
1002 FORMAT(20I2)
IF(INTERP.EQ.0)GO TO 832
C * * * * *
C----- L= TOTAL NUMBER OF 5 CHARACTERK DATA FIELDS FOR BOTH DEPTH AND
C----- AVAILABLE WATER TABLES
C----- SMTAB1= PROFILE DEPTH TABLE IN INCHES.
C----- SMTAB2= CORRESPONDING ACCUMULATED PLANT AVAILABLE WATER(IN.)
C----- SMTAB3= CORRESPONDING TOTAL SOIL WATER(IN.)
C * * * * *
READ(5,846)L,(SMTAB1(J),J=1,L),(SMTAB2(J),J=1,L),(SMTAB3(J),J=1,L)
846 FURMAT(15,19F5.0/5X,19F5.0/5X,19F5.0/5X,19F5.0)
832 CONTINUE
IF(NCREAT.EQ.1.AND.NCREAO.EQ.0)REWIND 10

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SHA 117
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SHA 142
SHA 143
SHA 144
SHA 145

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833 GO TO(833,834),NDA5
CONTINUE
READ(5,1000)(PERC(I),I=1,7)
834 CONTINUE
WRITE(6,20003)(PERC(I),I=1,7)
20003 FORMAT(8F10.2)
DO 40021 I=1,7
PROFV(I)=0.
ET(I)=0.
40021 PROFGR(I)=0.
CALL WATER(COEF1,COEF2,COEFB1,COEFB2,INTERP)
IF((NPLT.EQ.0.OR.NPLOT.EQ.2).AND.NCOMP.EQ.0)GO TO 6
NSB=1
IF(NCOMP.EQ.3.OR.NCOMP.EQ.1)NSB=3
DO 3 I=NSB,4
DO 3 II=1,7
DO 3 J=1,12
DO 3 MM=1,31
IF(I.LE.2)AVGM(I,II,J,MM)=0.
3 ACMOST(I,II,J,MM)=0.
CONTINUE
C * * * * * INPUT DATA GROUP NUMBER 9
C----- MD = MONTH
C----- NO = DAY
C----- ACMOST = ACTUAL AVAILABLE SOIL WATER IN 0-12" DEPTH FOR CONV.
AND NO TILLAGE SYSTEMS
C----- NCODE = CODE FOR TERMINATING THE LOADING OF ACMOST TABLE
C----- NCODE=0 CONTINUE LOADING

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SHA 175
SHA 176
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SHA 199
SHA 200
SHA 201
SHA 202
SHA 203

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6 CONTINUE
  IF(NPLOT.EQ.2)NPLOT=1
  IF(NREWD.EQ.1.AND.M.NE.5)REWIND M
  NBR=0
  DET=0.
  NN=0
  DT=0.
  FDEL=0.
  FAVG=0.
  DELPE=0.
  DEPST=0.
  Q=0.
  N=0
  PEA=0.
  PET=0.
  SUMCEP=0.
  SUMET=0.
  SUMACP=0.
  RDEPTH=ADEP(1)/12.
  ETA=0.
  ETC=0.
  CEPT=0.
  HEIGHT=0.
  SUMTIB=0.
  SUMTB=0.
  ANUM=0.
  SINTO=0.
  SINT=0.
  ACCP=0.

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SHA 233
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SHA 260
SHA 261

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STORM=0.
TIACP=0.
TIACPO=0.
SUMP=0.
SUMFC=0.
PCDIST(1)=1.
SAVG=0.
LKKK=0
CL=CLAV(1)
TP=TPAV(1)
GR=TP-CL
SAV12=TPAV(1)-PROFVAV(1)
W36=CLAV(1)
AV36=PROFVAV(1)
AVLM=PROFVAV(1)
GRDM=PROFGR(1)
FRATE=A*SAV12**POWER
IF(PERC(1).NE.1.0)CALL RECRAN(NTILL,SUMTB,SAV12,1,FC,TI,SUMFC,
1RDEPTH,HR,MONTH,NDAY,CL,GR,EXBASE)
DO 99890 I=1,7
99890 WRITE(6,20001)TPAV(I),CLAV(I),GRAV(I),PROFVAV(I),PROFGR(I)
CALL AINTCP(HNTM,HCTM,DTM,DT,STACO,NTILL,CEPT,HEIGHT,2,BASDT,
1HNMINT,HNFAC,HCMINT,HCFAC,RDEPTH)
WRITE(6,20001)BASDT
IF(NPRINT.EQ.2)GO TO 1
CALL OUTPT(NPLOT,HR,MONTH,NDAY,CMAX,NPRINT,NYEAR,P, FDEL,SAV12,
1FAVG,DEPST,Q,GRDM,AVLM,ETC,EPA,RDEPTH,SINT, SUMACP,SUMET,
2SUMCEP,HEIGHT,2, DT,SUMTB,SUMP,SUMFC,NTILL,LENGTH,NCOMP,NBM,NBD,
3NSTAT)

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SHA 262
SHA 263
SHA 264
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SHA 290

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1 READ(M,1011)MONTH,NDAY,NYEAR,HR,TI,ACP,KODE,EPA,EFTIME,STACO,NSTNDSHA 320
1011 FORMAT(IX,3I3,F8.4,F10.4,F8.4,I3,F8.2,F10.4,F8.2,I5) SHA 321
      IF(NY.EQ.NYEAR)NBR=1 SHA 322
      IF(NBR.EQ.0)GO TO 1 SHA 323
      IF(NCREAT.EQ.1)WRITE(10,1011)MONTH,NDAY,NYEAR,HR,TI,ACP,KODE,EPA,ESHA 324
1FTIME,STACO,NSTNO SHA 325
      IF(KODE.EQ.2)GO TO 26 SHA 326
      P=ACP SHA 327
      SUMACP=SUMACP+P SHA 328
      IF(N.NE.0)GO TO 40 SHA 329
      SEPA=EPA SHA 330
      N=1 SHA 331
      GO TO 23 SHA 332
40 K=1 SHA 333
      IF(NDAY.NE.NDAYO)SEPA=SEPA+EPA SHA 334
      J=1 SHA 335
      N=2 SHA 336
      SUMTB=SUMTB+TI SHA 337
      IF(NEMERG.EQ.NDAY.AND.MEMERG.EQ.MONTH)GO TO 50 SHA 338
      IF(NN.EQ.0)GO TO 51 SHA 339
50 CALL CTIMB(MONTH,NDAY,HR,NN,DT) SHA 340
      NN=1 SHA 341
      CALL AINTCP(HNTM,HCTM,DTM,DT,STACO,NTILL,SEPT,HEIGHT,3,BASDT, SHA 342
1HNMINT,HNFAC,HCMINT,HCFAC,RDEPTH) SHA 343
      IF(RDEPTH#12.LE.ADEP(1))GO TO 51 SHA 344
      CALL AVWATR(RDEPTH#12.,CL,TP,COEFA),COEFA2,COEFB1,COEFB2,INTERP) SHA 345
      W36=CL SHA 346
      IF(RDEPTH.GE.1.5)W36=CLAV(1)+CLAV(2) SHA 347
      GR=TP-CL SHA 348

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DELWAT=CL-CL0
DO 40050 I=1,7
IF(RDEPTH#12.-ADEP(I))40051,40053,40050
40050 CONTINUE
40051 IF(RDEPO#12.0.GE.ADEP(I-1))GO TO 40053
PROPI=(ADEP(I-1)-RDEPO#12.)/(12.*(RDEPTH-RDEPO))
PROFV(I-1)=PROFV(I-1)+PERC(I-1)*PROPI*DELWAT
PROFV(I)=PROFV(I)+PERC(I)*DELWAT*(1.-PROPI)
GO TO 51
40053 PROFV(I)=DELWAT*PERC(I)+PROFV(I)
51 CONTINUE
IF(ACP.LE.0.)GO TO 35
ETC=0.
IF(MN.EQ.0.AND.RDEPTH#12..LE.ADEP(1))GO TO 34
60 CONTINUE
IF(LKKK.EQ.0)CALL AINTCP(HNTM,HCTM,DTM,DT,STACO,NTILL,CEPT,HEIGHT,
1 1,BASDT,HNMINT,HNFAC,HCMINT,HCFAC,RDEPTH)
LKKK=1
IF(NSTNOB.EQ.NSTNO)GO TO 65
LKK=0
CALL AINTCP(HNTM,HCTM,DTM,DT,STACO,NTILL,CEPT,HEIGHT,1,BASDT,
1HNMINT,HNFAC,HCMINT,HCFAC,RDEPTH)
SUMCEP=SUMCEP+CEPT
65 CONTINUE
IF(LKK.EQ.1)GO TO 34
DEL=ACP
SINT=SINTO+DEL
IF(SINT.LE.CEPT)GO TO 33
DEL=CEPT-SINTO

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SINT=0.
LKK=1
33 SAVG=SAVG+DEL
SUMET=SUMET+DEL
ACP=ACP-DEL
34 FDEL=ACP
ACCP=0.
STORM=STACO
TIACP=0.
CALL FILTRA(SAV122,FDEL,A,POWER,FC,FRATE,FRATE2,J,K,II,DEPSTE,
1FAVG,X,DELTC,SAV12)
CALL RECRAN(NTILL,SUMTB,SAV12,0,FC,II,SUMFC,
IRDEPTH,HR,MONTH,NDAY,CL,GR,EXBASE)
GO TO 140
35 CONTINUE
IF(NN.GT.0.AND.RDEPTH#12..GT.ADEP(1))GO TO 37
36 CALL BJUNE(SUMTB,SUMTIB,
INDAY,PET,II,ETC,EXBASE)
GO TO 38
37 CONTINUE
IF(LKK.EQ.0)CALL AINTCP(HNTM,HCTM,DT,STACO,NTILL,CEPT,HEIGHT,
1 1,BASDT,HNFAC,HCMINT,HCFAC,RDEPTH)
LKK=1
IF(NSINOB.EQ.NSTNO)GO TO 11137
LKK=0
CALL AINTCP(HNTM,HCTM,DT,STACO,NTILL,CEPT,HEIGHT,1,BASDT,
1HNMINT,HNFAC,HCMINT,HCFAC,RDEPTH)
SUMCEP=SUMCEP+CEPT
11137 CONTINUE

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TIACP=TIACP+TI
IF(TIACP.GT.96.)TIACP=0.
IF(TIACP.EQ.0.)GO TO 11237
IF(ACCP.GT.STORM)GO TO 11237
CALL BJUNE(SUMTB,SUMTIB,EPA,CLAV(1),EFTIME,MONTH,NDAY,PEA,TI,ETA,
1CXBASE)
GO TO 11239
11237 CONTINUE
PEA=0.
ETA=0.
11239 CONTINUE
CALL AJUNE(MONTH,NDAY,NTILL,EPA,AV36,W36,PET,TI,EFTIME,NDAYO,
1ETC,DET)
ETC=ETC+ETA
ACCP=ACCP+ETC
CALL ADJUST(RDEPTH*12.,CL,GR,MONTH)
38 CALL RECOVY(DEPSTE,RDEPTH*12., FDEL,NTILL,PEA, DEPST,
1FC,PI,X,DELTC,PET, A,POWER,FRATE,FRATE2,K,FAVG,J,SAV12,
2SAV122,SUMFC,MONTH,NDAY,HR,SUMET,CL,GR)
FRATE=A*SAV12**POWER
FAVG=(FRATE+FRATE2)/2.
140 CONTINUE
DELPE=ACP-FDEL
DEPST=DEPSTE+DELPE
IF(DEPST.LT.RET)GO TO 22
Q=QE+DEPST-RET
DEPST=RET
GO TO 23
22 Q=QE

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23 CONTINUE
SUMP=SUMP+ACP
25 CONTINUE
AV36=0.
GRDM=0.
AVLM=0.
IF(RDEPTH*12. LE.ADEP(I))GO TO 27
DO 11140 I=1,7
GRDM=GRDM+PROFGR(I)
IF(I.LE.2)AV36=AV36+PROFAV(I)
11140 AVLM=AVLM+PROFAV(I)
GO TO 28
27 AVLM=PROFAV(I)
GRDM=PROFGR(I)
AV36=PROFAV(I)
28 CMAX=AVLM+GRDM
IF(NPRINT.EQ.2)GO TO 2
SUMCEA=PCDIST(I)
CALL OUTPT(NPLOT,HR,MONTH,NDAY,CMAX,NPRINT,NYEAR,P,FDEL,SAV12,
IETA,DEPST,Q,GRDM,AVLM,ETC,SEPA,RDEPTH,SAVG,SUMACP,SUMET,
2SUMCEA,HEIGHT,1,DT,SUMTB,SUMP,SUMFC,NTILL,LENGTH,NCOMP,NBM,NBD,
3NSTAT)
GO TO 2
26 CONTINUE
CALL OUTPT(NPLOT,HR,MONTH,NDAY,CMAX,NPRINT,NYEAR,P,FDEL,SAV12,
1FAVG,DEPST,Q,GRDM,AVLM,ETC,SEPA,RDEPTH,SAVG,SUMACP,SUMET,
2SUMCEP,HEIGHT,3,DT,SUMTB,SUMP,SUMFC,NTILL,LENGTH,NCOMP,NBM,NBD,
3NSTAT)
IF(LEND.EQ.9)STOP

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GO TO 10001
END
C * * * * * SUBROUTINE TO COMPUTE THE PLANT AVAILABLE SOIL WATER AND THE
C * * * * * TOTAL SOIL WATER IN ZONES 1 THRU 7.
C * * * * * SUBROUTINE WATER(COEF1,COEFA2,COEFB1,COEFB2,INTERP)
COMMON/BLK2/ADEP(7)
COMMON/BLK10/SMTAB1(20),SMTAB2(20),SMTAB3(20)
COMMON/BLK7/PROFV(7),PROFGR(7),PERC(7),CLAV(7),TPAV(7),GRAV(7),
1 EI(7),PCDIST(7)
DO 10 I=1,7
CALL AVWATR(ADEP(I),CL,TP,COEF1,COEFA2,COEFB1,COEFB2,INTERP)
IF(I.GT.1)GO TO 2
PROFV(I)=CL*PERC(I)
CLAV(I)=CL
TPAV(I)=TP
GRAV(I)=TP-CL
GO TO 9
2 CLAV(I)=CL-CLO
TPAV(I)=TP-TPO
GRAV(I)=(TP-CL)-GRO
IF(GRAV(I).LE.0.)GRAV(I)=0.
9 CLO=CL
TPO=TP
GRO=TP-CL
10 CONTINUE
RETURN
END
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C * * * * * SUBROUTINE TO COMPUTE THE AVAILABLE SOIL WATER AND TOTAL SOIL          SHA 494
C * * * * * WATER FROM THE SOIL SURFACE TO PLANT ROOT DEPTH.                      SHA 495
C * * * * * SUBROUTINE AVMATR(RDEPTH,CL,TP,COEF1,COEF2,COEFB1,COEFB2,INTERP)SHA 496
C * * * * * COMMON/BLK10/SMTAB1(20),SMTAB2(20),SMTAB3(20)                          SHA 497
C * * * * * IF(INTERP.EQ.1)GO TO 30                                               SHA 498
C * * * * * CL=-0.5+0.5*((1.+4.*COEF1*RDEPTH**COEFB1)**0.5)                       SHA 499
C * * * * * TP=-0.5+0.5*((1.+4.*COEF2*RDEPTH**COEFB2)**0.5)                       SHA 500
C * * * * * RETURN                                                                SHA 501
30 DO 35 I=1,20                                                                    SHA 502
C * * * * * IF(RDEPTH-SMTAB1(I))39,40,35                                         SHA 503
35 CONTINUE                                                                           SHA 504
39 A= RDEPTH-SMTAB1(I-1)                                                            SHA 505
B=SMTAB1(I)-SMTAB1(I-1)                                                            SHA 506
C=SMTAB2(I)-SMTAB2(I-1)                                                            SHA 507
D=A#C/B                                                                              SHA 508
CL=SMTAB2(I-1)+D                                                                    SHA 509
C=SMTAB3(I)-SMTAB3(I-1)                                                            SHA 510
D=A#C/B                                                                              SHA 511
TP=SMTAB3(I-1)+D                                                                    SHA 512
RETURN                                                                                SHA 513
40 CL=SMTAB2(I)                                                                      SHA 514
TP=SMTAB3(I)                                                                        SHA 515
RETURN                                                                                SHA 516
END                                                                                    SHA 517
C * * * * * SUBROUTINE TO REDUCE BASIC RAINFALL DATA INTO A FORM MORE          SHA 518
C * * * * * EFFICIENT FOR USE IN THE SOIL WATER MODEL AND TO MERGE DAILY PAN     SHA 519
C * * * * * SHA 520
C * * * * * SHA 521
C * * * * * SHA 522

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KLM=0	SHA	552
LB=0	SHA	553
NSTP=0	SHA	554
CALL RDATA(UPC,NSEQ,END1,ND2,L,NCOV,NSTNO,STACO,KLM,NY)	SHA	555
READ(10,1020)MONTH,NDAY,NYEAR,HR,TI,ACP,KODE,UPD,NEQ1	SHA	556
1020 FORMAT(7X,3I3,F8.4,F10.4,8X,F8.4,19X,I3,2X,A3,I5)	SHA	557
20 READ(K,1030)MON,ND,PE,NEND,DUMMY	SHA	558
1030 FORMAT(2I2,2X,F5.2,I2,66X,A1)	SHA	559
EFTIME=TI	SHA	560
IF(MON.EQ.MONTH.AND.ND.EQ.NDAY.AND.NSTP.EQ.0)GO TO 30	SHA	561
EFTIME=DAYL(MON,ND)	SHA	562
TI=24.	SHA	563
AHR=24.	SHA	564
ACP=0.	SHA	565
CALL OUTSKP(MON,ND,NY,AHR,TI,ACP,0,PE,EFTIME,STACO,NSTNO,NCONT)	SHA	566
IF(NEND.EQ.9)GO TO 210	SHA	567
IF(NEND.EQ.8)GO TO 11	SHA	568
GO TO 20	SHA	569
30 CONTINUE	SHA	570
TI=HR	SHA	571
IF(HR.LE.SUNRIS(MONTH,NDAY))GO TO 40	SHA	572
IF(HR.GE.SUNSET(MONTH,NDAY))GO TO 50	SHA	573
EFTIME=HR-SUNRIS(MONTH,NDAY)	SHA	574
GO TO 60	SHA	575
40 EFTIME=0.	SHA	576
GO TO 60	SHA	577
50 IF(LB.GT.0)EFTIME=DAYL(MONTH,NDAY)	SHA	578
60 CALL OUTSKP(MON,ND,NY,HR,TI,ACP,0,PE,EFTIME,STACO,NSTNO,NCONT)	SHA	579
70 CONTINUE	SHA	580

NDAYO=NDAY	SHA	581
HRO=HR	SHA	582
MONTHO=MONTH	SHA	583
80 CONTINUE	SHA	584
READ(10,1020)MONTH,NDAY,NYEAR,HR,TI,ACP,KODE,UPD,NEQ1	SHA	585
IF(KODE.NE.99)GO TO 90	SHA	586
CALL RDATA(UPC,NSEQ,END1,ND2,L,NCOV,NSTNO,STACO,KLM,NY)	SHA	587
GO TO 80	SHA	588
90 CONTINUE	SHA	589
IF(KODE.NE.2)GO TO 100	SHA	590
ACP=0.	SHA	591
NSTP=1	SHA	592
GO TO 160	SHA	593
100 IF(NDAY.NE.NDAYO)GO TO 150	SHA	594
EFTIME=0.	SHA	595
IF(ACP.GT.0.)GO TO 170	SHA	596
IF(HR.GT.SUNRIS(MONTH,NDAY).AND.HRO.GE.SUNRIS(MONTH,NDAY))GOTO 110	SHA	597
IF(HR.GT.SUNRIS(MONTH,NDAY).AND.HRO.LT.SUNRIS(MONTH,NDAY))GOTO 120	SHA	598
GO TO 170	SHA	599
110 IF(HR.LE.SUNSET(MONTH,NDAY))GO TO 140	SHA	600
IF(HRO.LT.SUNSET(MONTH,NDAY).AND.HR.GT.SUNSET(MONTH,NDAY))GOTO 130	SHA	601
GO TO 170	SHA	602
120 EFTIME=HR-SUNRIS(MONTH,NDAY)	SHA	603
GO TO 171	SHA	604
130 EFTIME=SUNSET(MONTH,NDAY)-HRO	SHA	605
GO TO 171	SHA	606
140 EFTIME=TI	SHA	607
GO TO 171	SHA	608
150 IF(HRO.EQ.24.)GO TO 200	SHA	609

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160 AHR=24.
    TI=24.-HRO
    EFTIME=C.
    IF(HRO.GT.SUNSET(MONTHO,NDAYO))GO TO 190
    IF(HRO.LE.SUNRIS(MONTHO,NDAYO))GO TO 180
    EFTIME=SUNSET(MONTHO,NDAYO)-HRO
    GO TO 190
170 EFTIME=0.
171 CONTINUE
    CALL OUTSKP(MONTH,NDAY,NY,HR,TI,ACP,0,PE,
    INT)
    GO TO 70
180 EFTIME=DAYL(MONTHO,NDAYO)
190 CALL OUTSKP(MONTHO,NDAYO,NY,AHR,TI,ACP,0,
    INCONT)
    LB=1
200 IF(NEND.EQ.8)GO TO 11
    IF(NEND.NE.9)GO TO 20
210 CONTINUE
    CALL OUTSKP(MONTHO,NDAYO,NY,AHR,TI,ACP,2,PE,EFTIME,STACO,
    INT)
    IF(LAST.NE.9)GO TO 10
    REWIND 8
    RETURN
    END
    SUBROUTINE RDATA(UPC,NSEQ,END1,ND2,L,NCOV,NSTNO,STACO,KLM,NY)
    REWIND 10
    IF(KLM.EQ.0)GO TO 2
    WRITE(10,2000)M1,N1,NY1,H1,T1,A1,K1,U1,N11

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2000 FORMAT(7X,3I3,F8.4,F10.4,8X,F8.4,19X,I3,2X,A3,I5)
      STACO=S1
      GO TO 2
      1 STACO=STAC
      2 GO TO(20,10),NCOV
      10 READ(L,1000)MONTH,NDAY,NYEAR,HR,TI,ACP,STAC,KODE,UPD,NEQ1
      1000 FORMAT(7X,3I3,F8.4,F10.4,8X,2F8.4,19X,I3,2X,A3,I5)
      GO TO 30
      20 READ(L,1001)MONTH,NDAY,NYEAR,HR,TI,ACP,STAC,KODE,UPD,NEQ1
      1001 FORMAT(13X3I3,F8.4,F10.4,8X,2F8.4,19X,I3,2X,A3,I5)
      30 IF((UPC.EQ.UPD.AND.NSEQ.EQ.NEQ1.AND.NY.EQ.NYEAR)KLM=1
      IF(KLM.EQ.0)GO TO 2
      IF(KODE.NE.0)GO TO 2
      IF(STAC.EQ.0.AND.KLM.EQ.2)KODE=99
      KLM=2
      IF(ENDI.EQ.UPD.AND.NEQ1.EQ.ND2)KODE=2
      WRITE(10,2000)MONTH,NDAY,NYEAR,HR,TI,ACP,KODE,UPD,NEQ1
      IF(KODE.EQ.2)GO TO 39
      IF(KODE.EQ.99)GO TO 40
      GO TO 1
      39 STACO=STAC
      GO TO 41
      40 M1=MONTH
      N1=NDAY
      NY1=NYEAR
      H1=HR
      T1=TI
      A1=ACP
      K1=0
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      SHA 640
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      SHA 643
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      SHA 665
      SHA 666
      SHA 667

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U1=UPD
N11=NEQ1
41 REWIND 10
NSTNO=NSTNO+1
RETURN
END
C * * * * *
C * SUBROUTINE TO WRITE THE DATA CREATED BY NEWDAT
C *
C * SUBROUTINE OUTSKP(M,N,NY,HR,TI,ACP,KODE,PE,EFTIME,STACO,NSTNO,NC)
WRITE(8,200)M,N,NY,HR,TI,ACP,KODE,PE,EFTIME,STACO,NSTNO
WRITE(6,200)M,N,NY,HR,TI,ACP,KODE,PE,EFTIME,STACO,NSTNO
200 FORMAT(1X,3I3,F8.4,F10.4,I3,F8.4,I3,F8.4,F10.4,F8.2,I5)
NC=NC+1
IF(NC.LT.56)RETURN
WRITE(6,201)
201 FORMAT(1H1)
RETURN
END
C * * * * *
C * SUBROUTINE TO READ AND ALL INPUT DATA TO NEWDAT SUBROUTINE FOR
C * ERROR CHECKS.
C *
C * SUBROUTINE OUTDAT(K)
DIMENSION A(20)
COMMON/BLK8/SUNRIS(12,31),SUNSET(12,31),DAYL(12,31)
DATA B/4H****/
REWIND 9

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NPAGE=0
C----- LOAD DAYLIGHT HOUR,SUNRIS AND SUNSET TABLES
C
1000 READ(5,1000)NL
      FORMAT(I1)
      IF(NL.EQ.0)GO TO 1
      WRITE(6,2005)NL
2005  FORMAT('1 BASIC INPUT DATA',/I3)
      CALL PAGE(NPAGE)
      1 DO 10 I=1,31
        READ(5,1010)(SUNRIS(J,I),J=1,12)
1010  FORMAT(4X,12F5.3)
      IF(NL.EQ.0)GO TO 10
      WRITE(6,2010)(SUNRIS(J,I),J=1,12)
2010  FORMAT(4X,12F7.3)
      CALL PAGE(NPAGE)
      10 CONTINUE
      DO 20 I=1,31
        READ(5,1020)(SUNSET(J,I),J=1,12)
1020  FORMAT(3X,12F6.3)
      IF(NL.EQ.0)GO TO 20
      WRITE(6,2010)(SUNSET(J,I),J=1,12)
      CALL PAGE(NPAGE)
      20 CONTINUE
      DO 30 I=1,31
        READ(5,1020)(DAYL(J,I),J=1,12)
        IF(NL.EQ.0)GO TO 30
        WRITE(6,2010)(DAYL(J,I),J=1,12)

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784 SHA B=CXY2/CX2
785 SHA A=YBAR-B*XBAR
786 SHA R=CXY2/SQRT(CX2*CXY2)
787 SHA DYX=CX2-((CXY2*CXY2)/CX2)
788 SHA SYX=DYX/(ANUM-2.)
789 SHA SB=SQRT(SYX2/CX2)
790 SHA T=B/SB
791 SHA WRITE(6,100)XBAR,YBAR,ANUM,NTILL,A,B,R,SB,T
792 SHA 100 FORMAT(10XBAR=,F10.4/,YBAR=,F10.4/,ANUM=,F10.4/,TREATMENT=,
793 SHA 1I3/,A=,F10.4/,B=,F10.4/,R=,F10.4/,SB=,F10.4/,T=,F10.4)
794 SHA 55 CONTINUE
795 SHA RETURN
796 SHA END
797 SHA C * * * * *
798 SHA C SUBROUTINE TO DETERMINE SOIL WATER BALANCE DURING RAIN PERIODS
799 SHA C * * * * *
800 SHA C SUBROUTINE RECRAN(NTILL,SUMTI,SAV12,NDELL,FC,II,SUMFC,RDEPTH,HR,
801 SHA 1MDNTH,NDAY,CL,GR,EXBASE)
802 SHA C COMMON/BLK7/PROFVAV(7),PROFGR(7),PERC(7),CLAV(7),TPAV(7),GRAV(7),
803 SHA 1 ET(7),PCDIST(7)
804 SHA C COMMON/BLK1/ACMOST(4,7,12,31),AVGM(2,7,12,31)
805 SHA C COMMON/BLK2/ADEP(7)
806 SHA C IF(NDELL.EQ.1)GO TO 21
807 SHA C SUMGR=0.
808 SHA C NUMB=1
809 SHA C SUMAV=0.
810 SHA C IF(RDEPTH*12..LE.ADEP(1))GO TO 70
811 SHA C NUMB=NUMB+1
812 SHA C SUMGR=SUMGR+GRAV(1)

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SUMAV=SUMAV+CLAV(1)
IF(RDEPTH#12..GT.ADEP(1).AND.RDEPTH#12..LE.ADEP(2))GO TO 70
NUMB=NUMB+1
SUMAV=SUMAV+CLAV(2)
SUMGR=SUMGR+GRAV(2)
IF(RDEPTH#12..GT.ADEP(2).AND.RDEPTH#12..LE.ADEP(3))GO TO 70
NUMB=NUMB+1
SUMGR=SUMGR+GRAV(3)
SUMAV=SUMAV+CLAV(3)
IF(RDEPTH#12..GT.ADEP(3).AND.RDEPTH#12..LE.ADEP(4))GO TO 70
NUMB=NUMB+1
SUMGR=SUMGR+GRAV(4)
SUMAV=SUMAV+CLAV(4)
IF(RDEPTH#12..GT.ADEP(4).AND.RDEPTH#12..LE.ADEP(5))GO TO 70
NUMB=NUMB+1
SUMGR=SUMGR+GRAV(5)
SUMAV=SUMAV+CLAV(5)
IF(RDEPTH#12..GT.ADEP(5).AND.RDEPTH#12..LE.ADEP(6))GO TO 70
NUMB=NUMB+1
SUMAV=SUMAV+CLAV(6)
SUMGR=SUMGR+GRAV(6)
70 CONTINUE
SUMAV=CL-SUMAV
SUMGR=GR-SUMGR
AMT=FC*TI
DRAINQ=0.
MLLL=NUMB+1
DO 7 I=1,NUMB
MLL=MLLL-I

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SHA 813
SHA 814
SHA 815
SHA 816
SHA 817
SHA 818
SHA 819
SHA 820
SHA 821
SHA 822
SHA 823
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SHA 839
SHA 840
SHA 841

```

IF (PROFGR (MLL).EQ.0.)GO TO 4
IF (AMT.GE.PROFGR (MLL))GO TO 1
DRAIN=AMT
PROFGR (MLL)=PROFGR (MLL)-AMT
GO TO 2
1 DRAIN=PROFGR (MLL)
PROFGR (MLL)=0.
2 L=MLL+1
IF (I.EQ.NUMB)DRAIN=DRAIN
IF (L.EQ.MLL)GO TO 6
DO 3 JJ=L,NUMB
COMPGR=GRAV (JJ)
COMPAV=CLAV (JJ)
IF (JJ.NE.NUMB)GO TO 16
COMPAV=SUMAV
COMPGR=SUMGR
16 CONTINUE
PROFAV (JJ)=PROFAV (JJ)+DRAIN
IF (PROFAV (JJ).LE.COMPAV)GO TO 4
PROFGR (JJ)=PROFAV (JJ)-COMPAV
PROFAV (JJ)=COMPAV
IF (PROFGR (JJ).LE.COMPGR)GO TO 4
DRAIN=PROFGR (JJ)-COMPGR
PROFGR (JJ)=COMPGR
3 CONTINUE
4 DRAIN=0.
6 SUMFC=SUMFC+DRAIN
7 CONTINUE
SAV12=SAV12+DRAIN

```

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SHA 842
SHA 843
SHA 844
SHA 845
SHA 846
SHA 847
SHA 848
SHA 849
SHA 850
SHA 851
SHA 852
SHA 853
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SHA 867
SHA 868
SHA 869
SHA 870

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IF(HR.EQ.24.)AVGM(NTILL,1,MONTH,NDAY)=PROFVAV(1)+PROFGR(1)
IF(RDEPTH*12..LE.ADEP(1))GO TO 569
DO 568 I=2,NUMB
IF(HR.EQ.24.)AVGM(NTILL,I,MONTH,NDAY)=AVGM(NTILL,I-1,MONTH,NDAY)+
1PROFVAV(I)+PROFGR(I)
568 CONTINUE
569 CONTINUE
IF(SAV12-GRV(1))5,10,15
5 PROFGR(1)=GRV(1)-SAV12
PROFVAV(1)=CLAV(1)
GO TO 20
10 PROFGR(1)=0.
PROFVAV(1)=CLAV(1)
GO TO 20
15 PROFGR(1)=0.
PROFVAV(1)=TPAV(1)-SAV12
20 CONTINUE
IF(HR.EQ.24.)AVGM(NTILL,1,MONTH,NDAY)=PROFVAV(1)+PROFGR(1)
21 CONTINUE
RATIO=PROFVAV(1)/CLAV(1)
IF(RATIO.GT.1.)RATIO=1.
IF(RATIO.LE.0.)RATIO=0.001
TDAYS=ALOG(RATIO)/ALOG(EXBASE)
50 CONTINUE
IF(TDAYS.LE.0.)TDAYS=0.
SUMTI=TDAYS*24.
55 RETURN
END
C * * * * *

```

SHA 871
SHA 872
SHA 873
SHA 874
SHA 875
SHA 876
SHA 877
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SHA 885
SHA 886
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SHA 888
SHA 889
SHA 890
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SHA 893
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SHA 897
SHA 898
SHA 899

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C * * * * * SUBROUTINE TO COMPUTE THE EVAPORATION FROM EITHER TILLAGE SYSTEM          SHA 900
C * * * * * SUBROUTINE BJUNE(SUMTI, SUMTIO, EPA, WTC, EFTIME, MONTH, NDAY, PET, TI,      SHA 901
C * * * * * ITOET, EXBASE)                                                           SHA 902
C * * * * * COMMON/BLK3/DCONT1(5,32), DCONT2(5,32), DNOTI1(3,32), DNOTI2(3,32),     SHA 903
C * * * * * DAYL(12,31)                                                            SHA 904
C * * * * * T1=SUMTI/24.                                                            SHA 905
C * * * * * T2=SUMTIO/24.                                                           SHA 906
C * * * * * IF(T2.EQ.0.)T2=1.0                                                       SHA 907
C * * * * * ETC=ABS(EPA*WTC*ALOG(EXBASE)*(EXBASE**T1+EXBASE**T2)/0.34)             SHA 908
C * * * * * 5 DET=ETC/DAYL(MONTH, NDAY)                                             SHA 909
C * * * * * TOET=DET*EFTIME                                                         SHA 910
C * * * * * PET=0.                                                                   SHA 911
C * * * * * IF(TI.EQ.0.)RETURN                                                       SHA 912
C * * * * * IF(TOET.GT.0.)PET=TOET/TI                                               SHA 913
C * * * * * RETURN                                                                    SHA 914
C * * * * * END                                                                      SHA 915
C * * * * * SUBROUTINE TO DETERMINE THE SOIL WATER BALANCE DURING RAINLESS        SHA 916
C * * * * * PERIODS.                                                                SHA 917
C * * * * * SUBROUTINE RECOVERY(DEPSIE, RDEPTH, FDEL, NTILL, PEA, DEPSHA 918
C * * * * * 1ST, FC, TI, X, DELTC, PET, A, POWER, FRATE, FRATE2, K, FAVG, J,          SHA 919
C * * * * * 2SAV12, SAV122, SUMFC, MONTH, NDAY, HR, SUMET, CL, GR)                 SHA 920
C * * * * * COMMON/BLK2/ADEP(7)                                                     SHA 921
C * * * * * COMMON/BLK1/ACMOST(4,7,12,31), AVGM(2,7,12,31)                         SHA 922
C * * * * * COMMON/BLK3/DCONT1(5,32), DCONT2(5,32), DNOTI1(3,32), DNOTI2(3,32),     SHA 923
C * * * * * DAYL(12,31)                                                            SHA 924
C * * * * * 1 COMMON/BLK7/PROFAV(7), PROFGR(7), PERC(7), CLAV(7), TPAV(7), GRAV(7),   SHA 925
C * * * * * SHA 926
C * * * * * SHA 927
C * * * * * SHA 928

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```

1 ET(7),PCDIST(7)
TEMP=PET
PET=PEA+PET
DRAIN=0.
DEPSTP=0.
IF(DEPSTE.GT.0.)GO TO 60
IF(SAV122.LT.GRAV(1))GO TO 62
PROFGR(1)=0.
SREC=(PET#I)*PCDIST(1)
FDEL=0.
ET(1)=SREC
PROFV(1)=PROFV(1)-ET(1)
IF(PROFV(1).GE.0.)GO TO 75
SREC=ET(1)-ABS(PROFV(1))
PROFV(1)=0.
GO TO 75
60 CONTINUE
IF(DEPSTE.GT.0..AND.SAV122.EQ.0.)GO TO 70
J=2
K=2
FDEL=DEPSTE
IF(DEPSTE.GT.SAV122)FDEL=SAV122
CALL FILTRA(SAV122,FDEL,A,POWER,FC,FRATE,FRATE2,J,K,TI,DEPSTE,
1 FAVG,X,DELTC,SAV12)
DEPSTP=DEPST
DEPST=DEPSTE-FDEL
IF(DEPST.LT.0.)DEPST=0.
IF(DEPST.GT.0..AND.SAV12.LT.GRAV(1))GO TO 50
IF(DEPST.GT.0..AND.SAV12.GE.GRAV(1))GO TO 59
SHA 929
SHA 930
SHA 931
SHA 932
SHA 933
SHA 934
SHA 935
SHA 936
SHA 937
SHA 938
SHA 939
SHA 940
SHA 941
SHA 942
SHA 943
SHA 944
SHA 945
SHA 946
SHA 947
SHA 948
SHA 949
SHA 950
SHA 951
SHA 952
SHA 953
SHA 954
SHA 955
SHA 956
SHA 957

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```

IF(DEPST.EQ.0.0..AND.SAV12.LT.GRAV(1))GO TO 53
IF(DEPST.EQ.0.0..AND.SAV12.GE.GRAV(1))GO TO 52
WRITE(6,3000)
3000 FORMAT(' ERROR AFTER STATEMENT 18')
50 SREC=0.
ET(1)=0.
PROFGR(1)=FDEL+GRAV(1)-SAV12
PROFAV(1)=CLAV(1)
GO TO 75
59 SREC=0.
ET(1)=0.
PROFGR(1)=0.
PROFAV(1)=TPAV(1)-SAV12
GO TO 75
52 CONTINUE
IF(ABS(X).LE.0.005)GO TO 56
TIME=(TI-DELTC)-0.005
SREC=PET*TIME
PROFGR(1)=0.
ET(1)=SREC
PROFAV(1)=PROFAV(1)-ET(1)
IF(PROFAV(1).GE.0.)GO TO 75
SREC=ET(1)-ABS(PROFAV(1))
PROFAV(1)=0.
GO TO 75
56 ET(1)=0.
SREC=0.
PROFGR(1)=0.
PROFAV(1)=TPAV(1)-SAV12

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SHA 958
SHA 959
SHA 960
SHA 961
SHA 962
SHA 963
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SHA 971
SHA 972
SHA 973
SHA 974
SHA 975
SHA 976
SHA 977
SHA 978
SHA 979
SHA 980
SHA 981
SHA 982
SHA 983
SHA 984
SHA 985
SHA 986

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```

GO TO 75
53 IF(ABS(X).LE.0.005)GO TO 80
   TIME=(TI-DELTC)-0.005
65 CONTINUE
   TDPEXC=(GRAV(1)-SAV12)/(FC+PET)
   IF(TDPEXC.GE.TIME)GO TO 54
   TDET=TIME-TDPEXC
   PROFGR(1)=0.
   ET(1)=PET*TDET
   PROFAV(1)=CLAV(1)-ET(1)
   SREC=ET(1)+TDPEXC*(PET+FC)
   DRAIN=FC*TDPEXC
   GO TO 75
54 PROFGR(1)=(GRAV(1)-SAV12)-TIME*(PET+FC)
   PROFAV(1)=CLAV(1)
   ET(1)=PET*TIME
   SREC=TIME*(FC+PET)
   DRAIN=FC*TIME
   GO TO 75
80 PROFGR(1)=GRAV(1)-SAV12
   PROFAV(1)=CLAV(1)
   ET(1)=0.
   SREC=0.
   GO TO 75
62 TIME=TI
   FDEL=0.
   GO TO 65
70 TDPEXC=(GRAV(1)+DEPSTE)/(FC+PET)
   IF(TDPEXC.GE.TI)GO TO 71

```

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SHA 987
SHA 988
SHA 989
SHA 990
SHA 991
SHA 992
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SHA 998
SHA 999
SHA 1000
SHA 1001
SHA 1002
SHA 1003
SHA 1004
SHA 1005
SHA 1006
SHA 1007
SHA 1008
SHA 1009
SHA 1010
SHA 1011
SHA 1012
SHA 1013
SHA 1014
SHA 1015

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```

TDET=TI-TDPEXC
FDEL=DEPSTE
PROFGR(1)=0.
PROFV(1)=CLAV(1)-(TDET*PET)
SREC=GRAV(1)+(FC+PET)*TDPEXC+TDET*PET
ET(1)=TI*PET
DRAIN=FC*TDPEXC
GO TO 75
71 PROFGR(1)=GRAV(1)+DEPSTE-TI*(FC+PET)
PROFV(1)=CLAV(1)
SREC=(FC+PET)*TI-DEPSTE
IF(SREC.LI.0.)GO TO 72
FDEL=DEPSTE
ET(1)=PET*TI
DRAIN=FC*TI
GO TO 75
72 FDEL=DEPSTE-(FC+PET)*TI
ET(1)=PET*TI
DRAIN=FC*TI
75 SAVI2=SAV12+SREC
PET=TEMP
DEPST=DEPST+DEPSTP
SUMGR=0.
NUMB=1
SUMAV=0.
IF(SAVI2.GT.TPAV(1))SAV12=TPAV(1)
IF(DRAIN.EQ.0..AND.RDEPTH.LE.ADEP(1))GO TO 510
RDEPTH=RDEPTH/12.
IF(RDEPTH#12..LE.ADEP(1))GO TO 701
SHA 1016
SHA 1017
SHA 1018
SHA 1019
SHA 1020
SHA 1021
SHA 1022
SHA 1023
SHA 1024
SHA 1025
SHA 1026
SHA 1027
SHA 1028
SHA 1029
SHA 1030
SHA 1031
SHA 1032
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SHA 1035
SHA 1036
SHA 1037
SHA 1038
SHA 1039
SHA 1040
SHA 1041
SHA 1042
SHA 1043
SHA 1044

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NUMB=NUMB+1
SUMGR=SUMGR+GRAV(1)
SUMAV=SUMAV+CLAV(1)
IF (RDEPTH*12..GT.ADEP(1).AND.RDEPTH*12..LE.ADEP(2))GO TO 701
NUMB=NUMB+1
SUMAV=SUMAV+CLAV(2)
SUMGR=SUMGR+GRAV(2)
IF (RDEPTH*12..GT.ADEP(2).AND.RDEPTH*12..LE.ADEP(3))GO TO 701
NUMB=NUMB+1
SUMGR=SUMGR+GRAV(3)
SUMAV=SUMAV+CLAV(3)
IF (RDEPTH*12..GT.ADEP(3).AND.RDEPTH*12..LE.ADEP(4))GO TO 701
NUMB=NUMB+1
SUMGR=SUMGR+GRAV(4)
SUMAV=SUMAV+CLAV(4)
IF (RDEPTH*12..GT.ADEP(4).AND.RDEPTH*12..LE.ADEP(5))GO TO 701
NUMB=NUMB+1
SUMGR=SUMGR+GRAV(5)
SUMAV=SUMAV+CLAV(5)
IF (RDEPTH*12..GT.ADEP(5).AND.RDEPTH*12..LE.ADEP(6))GO TO 701
NUMB=NUMB+1
SUMAV=SUMAV+CLAV(6)
SUMGR=SUMGR+GRAV(6)
CONTINUE
SUMAV=CL-SUMAV
SUMGR=GR-SUMGR
RDEPTH=RDEPTH*12.
DO 505 I=2,NUMB
COMPGR=GRAV(I)

```

701

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SHA 1045
SHA 1046
SHA 1047
SHA 1048
SHA 1049
SHA 1050
SHA 1051
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SHA 1061
SHA 1062
SHA 1063
SHA 1064
SHA 1065
SHA 1066
SHA 1067
SHA 1068
SHA 1069
SHA 1070
SHA 1071
SHA 1072
SHA 1073

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```

COMPV=CLAV(I)
IF(I.NE.NUMB)GO TO 503
COMPV=SUMAV
COMPGR=SUMGR
503 CONTINUE
PROFV(I)=PROFV(I)+DRAIN
IF(PROFV(I).LE.COMPV)GO TO 506
PROFGR(I)=PROFV(I)-COMPV
PROFV(I)=COMPV
IF(PROFGR(I).LE.COMPGR)GO TO 506
DRAIN=PROFGR(I)-COMPGR
PROFGR(I)=COMPGR
505 CONTINUE
SUMFC=SUMFC+DRAIN
506 CONTINUE
IF(RDEPTH.LE.ADEP(I))GO TO 510
DO 507 I=2,NUMB
COMPGR=GRAV(I)
COMPV=CLAV(I)
IF(I.NE.NUMB)GO TO 567
COMPGR=SUMGR
COMPV=SUMAV
567 CONTINUE
AD=PCDIST(I)
IF(AD.EQ.0.)GO TO 510
ADD=AD*PET
IF(PROFGR(I).GT.0.)GO TO 508
SREC=TI#ADD
ET(I)=SREC
SHA 1074
SHA 1075
SHA 1076
SHA 1077
SHA 1078
SHA 1079
SHA 1080
SHA 1081
SHA 1082
SHA 1083
SHA 1084
SHA 1085
SHA 1086
SHA 1087
SHA 1088
SHA 1089
SHA 1090
SHA 1091
SHA 1092
SHA 1093
SHA 1094
SHA 1095
SHA 1096
SHA 1097
SHA 1098
SHA 1099
SHA 1100
SHA 1101
SHA 1102

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PROFGR(I)=0.
PROFV(I)=PROFV(I)-SREC
IF (PROFV(I).GE.0.)GO TO 507
ET(I)=ET(I)-ABS(PROFV(I))
PROFV(I)=0.
GO TO 507
508 TIM=PROFGR(I)/(FC+ADD)
IF (TIM.LE.TI)GO TG 509
PROFGR(I)=PROFGR(I)-(FC+ADD)*TI
ET(I)=ADD*TI
DRAIN=FC*TI
GO TO 519
509 ET(I)=(TI-TIM)*ADD
PROFGR(I)=0.
IF (ET(I).GT.PROFV(I))GO TO 517
PROFV(I)=PROFV(I)-ET(I)
GO TO 518
517 ET(I)=ET(I)-PROFV(I)
PROFV(I)=0.
518 DRAIN=TIM*FC
519 CONTINUE
IF (DRAIN.EQ.0..OR.I.EQ.NUMB)GO TO 507
L=L+1
DO 520 JJ=L,NUMB
PROFV(JJ)=PROFV(JJ)+DRAIN
PROFV(JJ)=CCMPV
IF (PROFV(JJ).LE.COMPAV)GO TO 507
PROFGR(JJ)=PROFV(JJ)-COMPAV
IF (PROFGR(JJ).LE.COMPGR)GO TO 507

```

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SHA 1103
SHA 1104
SHA 1105
SHA 1106
SHA 1107
SHA 1108
SHA 1109
SHA 1110
SHA 1111
SHA 1112
SHA 1113
SHA 1114
SHA 1115
SHA 1116
SHA 1117
SHA 1118
SHA 1119
SHA 1120
SHA 1121
SHA 1122
SHA 1123
SHA 1124
SHA 1125
SHA 1126
SHA 1127
SHA 1128
SHA 1129
SHA 1130
SHA 1131

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```

DRAIN=PROFGR(JJ)-COMPGR
PROFGR(JJ)=COMPGR
520 CONTINUE
SUMFC=SUMFC+DRAIN
507 CONTINUE
510 CONTINUE
IF(HR.EQ.24.)AVGM(NTILL,1,MONTH,NDAY)=PROFV(1)+PROFGR(1)
SUMET=SUMET+ET(1)
ET(1)=0.
IF(RDEPTH.LE.ADEP(1))RETURN
DD 530 I=2,NUMB
IF(HR.EQ.24.)AVGM(NTILL,I,MONTH,NDAY)=AVGM(NTILL,I-1,MONTH,NDAY)+
1 PROFV(I)+PROFGR(I)
SUMET=SUMET+ET(I)
ET(I)=0.
530 CONTINUE
RETURN
END
C * * * * *
C * * * * * SUBROUTINE TO COMPUTE INFILTRATION VOLUMES AND PRECIPITATION
C * * * * * EXCESS.
C * * * * *
12 SAV12=SAV122-FDEL
SUBROUTINE FILTRA(SAV122,FDEL,A,POWER,FC,FRATE,FRATE2,J,K,II,
1 DEPSTE,FAVG,X,DELTC,SAV12)
IF(SAV12.LT.0.)SAV12=0.
FRATE=A*SAV12**POWER
FAVG=(FRATE+FRATE2)/2.
DELTC=FDEL/FAVG
SHA 1132
SHA 1133
SHA 1134
SHA 1135
SHA 1136
SHA 1137
SHA 1138
SHA 1139
SHA 1140
SHA 1141
SHA 1142
SHA 1143
SHA 1144
SHA 1145
SHA 1146
SHA 1147
SHA 1148
SHA 1149
SHA 1150
SHA 1151
SHA 1152
SHA 1153
SHA 1154
SHA 1155
SHA 1156
SHA 1157
SHA 1158
SHA 1159
SHA 1160

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```

X=DELIC-TI
IF(J.NE.2)GO TO 16
IF(X.GT.0.)J=3
16 GO TO(17,10,17),J
17 IF(X-0.005)8,10,9
8 IF(0.005.GE.ABS(X))RETURN
GO TO(31,10),K
31 IF(DEPSTE.EQ.0.)RETURN
FDEL=FDEL+DEPSTE
IF(FDEL.GT.SAV12)FDEL=SAV12
K=2
GO TO 12
9 FDEL=(FDEL+TI*FAVG)/2.
GO TO 12
10 RETURN
END
C * * * * *
C * SUBROUTINE TO DETERMINE ACCUMULATED TIME FROM SOME PREDETERMINED
C * DATE.
C * * * * *
SUBROUTINE CTIMB(MONTH,NDAY,HR,N,DT)
DIMENSION NTIME(12)
DATA NTIME/31,59,90,120,151,181,212,243,273,304,334,365/
IF(N.EQ.1)GO TO 5
BASET=(FLOAT(NTIME(MONTH-1))+FLOAT(NDAY-1))+HR/24.) / 7.
RETURN
5 DT=(FLOAT(NTIME(MONTH-1))+FLOAT(NDAY-1))+HR/24.) / 7.-BASET
RETURN
END

```

```

SHA 1161
SHA 1162
SHA 1163
SHA 1164
SHA 1165
SHA 1166
SHA 1167
SHA 1168
SHA 1169
SHA 1170
SHA 1171
SHA 1172
SHA 1173
SHA 1174
SHA 1175
SHA 1176
SHA 1177
SHA 1178
SHA 1179
SHA 1180
SHA 1181
SHA 1182
SHA 1183
SHA 1184
SHA 1185
SHA 1186
SHA 1187
SHA 1188
SHA 1189

```

```

C * * * * * SUBROUTINE TO LOAD BASIC TABLES REQUIRED IN THE SOIL WATER MODEL. * * * * * SHA 1190
C * * * * * SUBROUTINE TABLES * * * * * SHA 1191
C * * * * * COMMON/BLK3/DCONT1(5,32), DCONT2(5,32), DNOTI1(3,32), DNOTI2(3,32), * * * * * SHA 1192
C * * * * * DAYL(12,31) * * * * * SHA 1193
C * * * * * INPUT DATA CARD NUMBER 1 * * * * * SHA 1194
C * * * * * INPUT DATA CARD NUMBER 1 * * * * * SHA 1195
C * * * * * INPUT DATA CARD NUMBER 1 * * * * * SHA 1196
C * * * * * INPUT DATA CARD NUMBER 1 * * * * * SHA 1197
C * * * * * NCONTR= CONTROL INDEX FOR LISTING INPUT DATA SETS * * * * * SHA 1198
C * * * * * NCONTR=0 NO LISTING * * * * * SHA 1199
C * * * * * NCONTR=1 LISTING OF INPUT TABLES * * * * * SHA 1200
C * * * * * READ(5,900)NCONTR * * * * * SHA 1201
C * * * * * FORMAT(I1) * * * * * SHA 1202
C * * * * * IF(NCONTR.EQ.1)WRITE(6,1000)NCONTR * * * * * SHA 1203
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1204
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1205
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1206
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1207
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1208
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1209
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1210
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1211
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1212
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1213
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1214
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1215
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1216
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1217
C * * * * * INPUT DATA GROUP NUMBER 2 * * * * * SHA 1218

```

```

1
900
1000
1010
1001
1011

```



```

C * * * * * RETURN
C * * * * * END
C * * * * * SUBROUTINE TO DETERMINE THE DISTRIBUTION OF EVAPOTRANSPIRATION
C * * * * * WITHDRAWALS FROM THE INDIVIDUAL ZONES.
C * * * * * SUBROUTINE ADJUST(RDEPTH,CL,GR,MONTH)
COMMON/BLK7/PROFAV(7),PROFGR(7),PERC(7),CLAV(7),TPAV(7),GRAV(7),
1 ET(7),PCDIST(7)
COMMON/BLK2/ADEP(7)
DO 5 I=1,7
5 PCDIST(I)=0.
IF(RDEPTH.LE.ADEP(1))GO TO 20
SUMC=0.
SUMCO=0.
AMT=1.-PCDIST(1)
DO 27 I=2,7
PCDIST(I)=PROFAV(I)/CLAV(I)
SUMC=SUMC+PCDIST(I)
IF(SUMC.GE.AMT)GO TO 28
SUMCO=SUMC
27 CONTINUE
I=I-1
28 PCDIST(I)=AMT-SUMCO
RETURN
20 PCDIST(1)=1.
RETURN
END
SHA 1248
SHA 1249
SHA 1250
SHA 1251
SHA 1252
SHA 1253
SHA 1254
SHA 1255
SHA 1256
SHA 1257
SHA 1258
SHA 1259
SHA 1260
SHA 1261
SHA 1262
SHA 1263
SHA 1264
SHA 1265
SHA 1266
SHA 1267
SHA 1268
SHA 1269
SHA 1270
SHA 1271
SHA 1272
SHA 1273
SHA 1274
SHA 1275
SHA 1276
PCDIST(1)=PROFAV(1)/CLAV(1)

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```

C * * * * * SUBROUTINE TO DETERMINE PLANT HEIGHT, INTERCEPTION AND ROOT DEPTH. SHA 1277
C * * * * * SUBROUTINE AINTCP(HNTM,HCTM,DTM,DT,STACO,NTILL,CEPT,HEIGHT, KOD)SHA 1278
C * * * * * SUBROUTINE AINTCP(HNTM,HCTM,DTM,DT,STACO,NTILL,CEPT,HEIGHT, KOD)SHA 1279
C * * * * * SUBROUTINE AINTCP(HNTM,HCTM,DTM,DT,STACO,NTILL,CEPT,HEIGHT, KOD)SHA 1280
C * * * * * SUBROUTINE AINTCP(HNTM,HCTM,DTM,DT,STACO,NTILL,CEPT,HEIGHT, KOD)SHA 1281
C * * * * * GO TO(4,20,4),KOD SHA 1282
C * * * * * 4 GO TO(5,10),NTILL SHA 1283
C * * * * * 5 CONTINUE SHA 1284
C * * * * * HM=HCTM SHA 1285
C * * * * * RAT1=HCMINT/HCTM SHA 1286
C * * * * * RAT2=HCFAC/HCTM SHA 1287
C * * * * * GO TO 11 SHA 1288
C * * * * * 10 HM=HNTM SHA 1289
C * * * * * RAT1=HNMINT/HNTM SHA 1290
C * * * * * RAT2=HNFAC/HNTM SHA 1291
C * * * * * 11 CONTINUE SHA 1292
C * * * * * IF(DT.GE.BASDT)GO TO 6 SHA 1293
C * * * * * HEIGHT=1.46*HM*(DT/DTM)**1.63 SHA 1294
C * * * * * GO TO 15 SHA 1295
C * * * * * 6 HEIGHT=HM*(DT/DTM)**0.41 SHA 1296
C * * * * * IF(HEIGHT.LE.HM)GO TO 15 SHA 1297
C * * * * * HEIGHT=HM SHA 1298
C * * * * * 15 CONTINUE SHA 1299
C * * * * * RDEPTH=5.0*HEIGHT/HM SHA 1300
C * * * * * IF(KOD.NE.1)RETURN SHA 1301
C * * * * * F=RAT2*HEIGHT SHA 1302
C * * * * * CEPT=RAT1*HEIGHT*F SHA 1303
C * * * * * RETURN SHA 1304
C * * * * * 20 CONTINUE SHA 1305

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SHA 1306
SHA 1307
SHA 1308
SHA 1309
SHA 1310
SHA 1311
SHA 1312
SHA 1313
SHA 1314
SHA 1315
SHA 1316
SHA 1317
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SHA 1319
SHA 1320
SHA 1321
SHA 1322
SHA 1323
SHA 1324
SHA 1325
SHA 1326
SHA 1327
SHA 1328
SHA 1329
SHA 1330
SHA 1331
SHA 1332
SHA 1333
SHA 1334

SINC=1.
K=1
ST=3.
21 ST=ST+SINC
A=ST/DTM
GO TO(22,23),NTILL
22 HM=HCTM
GO TO I8
23 HM=HNTM
18 H1=1.46*HM*A**1.63
H2=HM*A**0.41
24 IF(ABS(H1-H2).LE.0.005)GD TO 40
IF(H1.LT.H2)GO TO 29
K=K+1
ST=ST-SINC
29 GO TO(21,30,31,32,33,34,35,36,37,38,39,40),K
30 SINC=0.5
GO TO 21
31 SINC=0.1
GO TO 21
32 SINC=0.05
GO TO 21
33 SINC=0.01
GO TO 21
34 SINC=0.005
GO TO 21
35 SINC=0.001
GO TO 21
36 SINC=0.0005

```

GO TO 21
37 SINC=0.0001
GO TO 21
38 SINC=0.00005
GO TO 21
39 SINC=0.00001
GO TO 21
40 BASDT=ST
RETURN
END
C * * * * *
C * SUBROUTINE TO DETERMINE THE EVAPOTRANSPIRATION RATE FROM EITHER
C * TILLAGE SYSTEM.
C * * * * *
C * SUBROUTINE AJUNE(M,N,NTILL,EPA,AVLM,WTC,WTN,PET,TI,EFTIME,NO,TOET,
1 DET)
COMMON/BLK3/DCONT1(5,32),DCONT2(5,32),DNOTI1(3,32),DNOTI2(3,32),
1 DAYL(12,31)
1 IF(NO.EQ.N)GO TO 53
KOD=0
IF(M.LT.7)GO TO 18
IF(M.EQ.7.AND.N.LE.21)GO TO 18
IF(M.GT.8)GO TO 18
IF(M.EQ.8.AND.N.GT.21)GO TO 18
GO TO 43
18 CONTINUE
GO TO(5,15),NTILL
5 CONTINUE
PERAV=AVLM/WTC

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SHA 1335
SHA 1336
SHA 1337
SHA 1338
SHA 1339
SHA 1340
SHA 1341
SHA 1342
SHA 1343
SHA 1344
SHA 1345
SHA 1346
SHA 1347
SHA 1348
SHA 1349
SHA 1350
SHA 1351
SHA 1352
SHA 1353
SHA 1354
SHA 1355
SHA 1356
SHA 1357
SHA 1358
SHA 1359
SHA 1360
SHA 1361
SHA 1362
SHA 1363

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IF(PERAV.GE.1.0.OR.PERAV.LE.0.)GO TO 43
IF(EPA.EQ.0.)GO TO 38
NC=1
IF(EPA-0.025)30,37,20
20 NC=2
IF(EPA-0.15)31,37,21
21 NC=3
IF(EPA-0.25)33,37,22
22 NC=4
IF(EPA-0.30)34,37,23
23 NC=5
IF(EPA-0.35)35,37,37
30 BEPA=0.
TOTD=0.025
32 DO 10 I=1,32
IF(DCONT1(NC,I).GT.PERAV)GO TO 13
10 CONTINUE
13 A=DCONT1(NC,I)-DCONT1(NC,I-1)
B=DCONT2(NC,I)-DCONT2(NC,I-1)
C=DCONT1(NC,I)-PERAV
RAT1=DCONT2(NC,I)-B*C/A
IF(KOD.EQ.1)GO TO 39
IF(NC.GT.1)GO TO 51
RAT2=1.0
GO TO 78
31 TOTD=0.125
BEPA=0.025
GO TO 32
51 DO 41 I=1,32

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SHA 1364
SHA 1365
SHA 1366
SHA 1367
SHA 1368
SHA 1369
SHA 1370
SHA 1371
SHA 1372
SHA 1373
SHA 1374
SHA 1375
SHA 1376
SHA 1377
SHA 1378
SHA 1379
SHA 1380
SHA 1381
SHA 1382
SHA 1383
SHA 1384
SHA 1385
SHA 1386
SHA 1387
SHA 1388
SHA 1389
SHA 1390
SHA 1391
SHA 1392

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IF(DCONT1(NC-1,I).GT.PERAV)GO TO 70
41 CONTINUE
70 AA=DCONT1(NC-1,I)-DCONT1(NC-1,I-1)
BB=DCONT2(NC-1,I)-DCONT2(NC-1,I-1)
CC=DCONT1(NC-1,I)-PERAV
RAT2=DCONT2(NC-1,I)-BB*CC/AA
78 ACTD=(EPA-BEPA)/TOTD
DIN=RAT2-(RAT2-RAT1)*ACTD
GO TO 50
33 TOTD=0.10
BEPA=0.15
GO TO 32
34 TOTD=0.05
BEPA=0.25
GO TO 32
43 DIN=1.0
GO TO 50
35 TOTD=0.05
BEPA=0.30
GO TO 32
37 KOD=1
GO TO 32
39 DIN=RAT1
GO TO 50
38 DIN=0.
GO TO 50
15 CONTINUE
PERAV=AVLM/WTN
IF(PERAV.GE.1.0.OR.PERAV.LE.0.)GO TO 43

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SHA 1393
SHA 1394
SHA 1395
SHA 1396
SHA 1397
SHA 1398
SHA 1399
SHA 1400
SHA 1401
SHA 1402
SHA 1403
SHA 1404
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SHA 1406
SHA 1407
SHA 1408
SHA 1409
SHA 1410
SHA 1411
SHA 1412
SHA 1413
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SHA 1415
SHA 1416
SHA 1417
SHA 1418
SHA 1419
SHA 1420
SHA 1421

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IF(EPA.EQ.0.)GO TO 38
NC=1
IF(EPA-0.15)130,137,120
120 NC=2
IF(EPA-0.30)131,137,121
121 NC=3
IF(EPA-0.35)133,137,137
130 NC=1
BPA=0.0
TOTD=0.15
132 CONTINUE
DO 17 I=1,32
IF(DNOTI1(NC,I).GT.PERAV)GO TO 19
17 CONTINUE
19 A=DNOTI1(NC,I)-DNOTI1(NC,I-1)
B=DNOTI2(NC,I)-DNOTI2(NC,I-1)
C=DNOTI1(NC,I)-PERAV
RAT1=DNOTI2(NC,I)-B*C/A
IF(KOD.EQ.1)GO TO 39
IF(NC.GT.1)GO TO 151
RAT2=1.0
GO TO 185
131 TOTD=0.15
BPA=0.15
GO TO 132
151 DO 140 I=1,32
IF(DNOTI1(NC-1,I).GT.PERAV)GO TO 170
140 CONTINUE
170 AA=DNOTI1(NC-1,I)-DNOTI1(NC-1,I-1)
SHA 1422
SHA 1423
SHA 1424
SHA 1425
SHA 1426
SHA 1427
SHA 1428
SHA 1429
SHA 1430
SHA 1431
SHA 1432
SHA 1433
SHA 1434
SHA 1435
SHA 1436
SHA 1437
SHA 1438
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SHA 1441
SHA 1442
SHA 1443
SHA 1444
SHA 1445
SHA 1446
SHA 1447
SHA 1448
SHA 1449
SHA 1450

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GO TO(5,11,12),NGO
5 CONTINUE
IF(NPRINT.EQ.0)GO TO 10
IF(HR.NE.24.)GO TO 20
10 CONTINUE
WRITE(6,3005)MONTH,NDAY,NYEAR,HR,ACP,FDEL,SAV,FAVG,DEPST,EPA,ETC,
1GRDM,AVLM,CMAX,SUMACP,Q,SUMET,SUMTB,DT,HEIGHT,RDEPTH,SUMCEP,SINT
3005 FORMAT(3I3,F8.4,2F5.2,F6.3,F6.2,2F5.2,F6.3,3F5.2,F6.2,F5.2,F6.2,
1F8.2,F6.2,F7.2,F6.2,2X,F8.4,F7.4)
LIST=LIST+1
IF(LIST.LE.56)GO TO 20
11 WRITE(6,3004)
3004 FORMAT('1MO DA YR TIME P FDEL SAV FAVG DPST EPA ETC GRSHA 1492
1DM AVLM CMAX SUMP SUMQ SUMET SUMTB DT HEIGHT RDEPTH SUMCEP SHA 1493
2 SINT')
LIST=0
20 RETURN
12 CONTINUE
IF(NPRINT.NE.2)WRITE(6,30081)
30081 FORMAT(1H1)
WRITE(6,30027)SUMACP,EPA,SUMET,SUMCEP,SINT,SUMFC,Q,RDEPTH,HEIGHT
30027 FORMAT('0 PERIOD END SUMMARIES',F8.4,' TOTAL PRECIPITATION=',F8.4,' INSHA 1501
1CHES',F8.4,' POTENTIAL EVAPOTRANSPIRATION=',F8.4,' INCHES',F8.4,' ESTIMATED SHA 1502
2EVAPOTRANSPIRATION=',F8.4,' INCHES',F8.4,' POTENTIAL INTERCEPTION=',F8.4,' F8.4,' SHA 1503
34,' INCHES',F8.4,' ESTIMATED INTERCEPTION=',F8.4,' INCHES',F8.4,' SEEPAGE BE SHA 1504
4LOW ROOTZONE=',F8.4,' INCHES',F8.4,' SURFACE RUNOFF=',F8.4,' INCHES',F8.4,' SHA 1505
5ROOT DEPTH=',F8.4,' FEET',F8.4,' PLANT HEIGHT=',F8.4,' INCHES')
DO 30 L=1,LENGTH
IF(NPRINT.NE.2)GO TO 28
SHA 1480
SHA 1481
SHA 1482
SHA 1483
SHA 1484
SHA 1485
SHA 1486
SHA 1487
SHA 1488
SHA 1489
SHA 1490
SHA 1491
SHA 1492
SHA 1493
SHA 1494
SHA 1495
SHA 1496
SHA 1497
SHA 1498
SHA 1499
SHA 1500
SHA 1501
SHA 1502
SHA 1503
SHA 1504
SHA 1505
SHA 1506
SHA 1507
SHA 1508

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IF(L.NE.1)GO TO 28
WRITE(6,30040)ADEP(L)
30040 FORMAT('0MOISTURE SUMMARY FOR 0 -',F5.1,' INCH DEPTH','0',7X'DAY
1 JAN FEB SEPT OCT MAR APR MAY JUNE JULSHA 1512
2Y AUG SEPT OCT MAR APR MAY JUNE JULSHA 1513
GO TO 29
28 CONTINUE
WRITE(6,30029)ADEP(L)
30029 FORMAT('1MOISTURE SUMMARY FOR 0 -',F5.1,' INCH DEPTH','0',7X'DAY
1 JAN FEB SEPT OCT MAR APR MAY JUNE JULSHA 1518
2Y AUG SEPT OCT MAR APR MAY DEC')
29 CONTINUE
DC 30 I=1,31
WRITE(6,30028)NTILL, I,(AVGM(NTILL,L,J,I),J=1,12)
30028 FORMAT(3X,I4, I4,12F10.4)
30 CONTINUE
IF(NPLOT.EQ.0.AND.(NCOMP.EQ.0.OR.NCOMP.EQ.2))RETURN
CALL PLOTM(MONTH,NDAY,NTILL,LENGTH,NBM,NBD,NCOMP,
INSTAT,NPLOT)
RETURN
END
C * * * * *
C * * * * * SUBROUTINE TO GIVE SELECTED COORDINATE PLOT OF TWO TILLAGE
C * * * * * SYSTEMS.
C * * * * * SUBROUTINE PLOTM(MONTH,NDAY,NTILL,LENGTH,NBM,NBD,NCOMP,NSTAT,
1 NPLOT)
DIMENSION VERT(120),SCALE(120)
DIMENSION SUM(8),NDATE(12),SSUM(4,12)

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SHA 1509
SHA 1510
SHA 1511
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SHA 1534
SHA 1535
SHA 1536
SHA 1537

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COMMON/BLK2/ADEP(7)
COMMON/BLK7/PROFAV(7), PROFGR(7), PERC(7), CLAV(7), TPAV(7), GRAV(7),
1 ET(7), PCDIST(7)
COMMON/BLK1/ACMOST(4,7,12,31), AVGM(2,7,12,31)
DATA BLK/1H /, PLUS/1H+/, STAR/1H*/
DATA XXX/'X' /
DATA NDATE/31,28,31,30,31,30,31,31,30,31,30,31,30,31/
IF(NSSTAT.EQ.1)CALL STAT(LENGTH,NTILL)
NP1=1
NP2=1
NP3=1
NP4=1
DO 75 LL=1,2
IF(LL.EQ.1.AND.NPLOT.EQ.0)GO TO 75
IF(LL.EQ.2.AND.(NCOMP.EQ.0.OR.NCOMP.EQ.2))RETURN
DO 70 JJ=1,LENGTH
DO 628 KJ=1,4
DO 628 LKJ=1,12
628 SSUM(JKJ,LKJ)=0.
KKK=0
IF(LL.EQ.1)GO TO 3
DO 2 IJ=1,8
2 SUM(IJ)=0.
IF(NCOMP.EQ.3)GO TO 106
3 DO 5 I=1,120
5 VERT(I)=BLK
GO TO(101,101,102,102,102,103,103),JJ
101 AT=0.05
AI=-0.05

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SHA 1538
SHA 1539
SHA 1540
SHA 1541
SHA 1542
SHA 1543
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SHA 1546
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SHA 1563
SHA 1564
SHA 1565
SHA 1566

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IF(MMM.EQ.NBM)NBG=NBD
DO 65 JJJ=NBG,NEN
GO TO(6,7),LL
6 CONTINUE
IF((JJ.GT.1.AND.ACMOST(NTILL,JJ,MMM,JJJ).GT.0.0).OR.(JJ.EQ.1)KKK=1)
IF(KKK.EQ.0)GO TO 65
IF(ACMOST(NTILL,JJ,MMM,JJJ).EQ.0.)GO TO 8
NBR=1
AV=ACMOST(NTILL,JJ,MMM,JJJ)
GO TO 9
8 CONTINUE
NBR=2
AV=AVGM(NTILL,JJ,MMM,JJJ)
GO TO 9
7 CONTINUE
NBR=1
AV=AVGM(1,JJ,MMM,JJJ)
CMAX=AV
N=1
IF(CMAX.GE.0..AND.CMAX.LT.(CLAV(JJ)/4.))GO TO 622
N=2
IF(CMAX.GE.(CLAV(JJ)/4.).AND.CMAX.LT.(CLAV(JJ)/2.))GO TO 622
N=3
IF(CMAX.GE.(CLAV(JJ)/2.).AND.CMAX.LT.(0.75*CLAV(JJ)))GO TO 622
N=4
IF(CMAX.GE.(0.75*CLAV(JJ)))GO TO 622
IF(NCOMP.EQ.3)GO TO 11
GO TO 9
622 SUM(N)=SUM(N)+1.

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SHA 1596
SHA 1597
SHA 1598
SHA 1599
SHA 1600
SHA 1601
SHA 1602
SHA 1603
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SHA 1620
SHA 1621
SHA 1622
SHA 1623
SHA 1624

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SSUM(N,MMM-3)=SSUM(N,MMM-3)+1.
IF(NCOMP.NE.3)GO TO 9
11 NBR=2
AV=AVGH(2,JJ,MMM,JJJ)
CMAX=AV
NNN=1
N=5
IF(CMAX.GE.0..AND.CMAX.LT.(CLAV(JJ)/4.))GO TO 623
NNN=2
N=6
IF(CMAX.GE.(CLAV(JJ)/4.).AND.CMAX.LT.(CLAV(JJ)/2.))GO TO 623
NNN=3
N=7
IF(CMAX.GE.(CLAV(JJ)/2.).AND.CMAX.LT.(0.75*CLAV(JJ)))GO TO 623
NNN=4
N=8
IF(CMAX.GE.(0.75*CLAV(JJ)))GO TO 623
GO TO 9
623 SUM(N)=SUM(N)+1.
SSUM(NNN,MMM+3)=SSUM(NNN,MMM+3)+1.
9 CONTINUE
IF(NCOMP.EQ.3.AND.LL.EQ.2)GO TO 65
DO 10 L=2,120
IF(AV.GE.SCALE(L-1).AND.AV.LE.SCALE(L))GO TO 15
10 CONTINUE
NPLT=120
GO TO 20
15 CONTINUE
NPLT=L
SHA 1625
SHA 1626
SHA 1627
SHA 1628
SHA 1629
SHA 1630
SHA 1631
SHA 1632
SHA 1633
SHA 1634
SHA 1635
SHA 1636
SHA 1637
SHA 1638
SHA 1639
SHA 1640
SHA 1641
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SHA 1645
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SHA 1648
SHA 1649
SHA 1650
SHA 1651
SHA 1652
SHA 1653

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IF((AV-SCALE(L-1)).LT.SCAL)NPLT=L-1
20 CONTINUE
GO TO (21,22,23,24),NBR
21 VERT(NPLT)=PLUS
NP1=NPLT
IF(LL.EQ.2)GO TO 11
GO TO 8
22 VERT(NPLT)=STAR
NP2=NPLT
IF(LL.NE.1)GO TO 29
NBR=3
AV=ACMOST(3,JJ,MMM,JJJ)
IF(AV.GT.0.)GO TO 9
NP3=1
NP4=1
GO TO 29
23 VERT(NPLT)=XXX
NP3=NPLT
30 NBR=4
AV=ACMOST(4,J,J,MMM,JJJ)
GO TO 9
24 VERT(NPLT)=XXX
NP4=NPLT
29 CONTINUE
WRITE(6,30030)MMM,JJJ, (VERT(I),I=1,120)
30030 FORMAT(2I3,3X,120A1)
VERT(NP1)=BLK
VERT(NP2)=BLK
VERT(NP3)=BLK

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SHA 1654
SHA 1655
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SHA 1680
SHA 1681
SHA 1682

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VERT(NP4)=8LK
65 CONTINUE
  IF(LL.EQ.1)GO TO 70
  WRITE(6,82)
82 FORMAT('0 CONVENTIONAL TILLAGE -- FREQUENCY OF OCCURRENCE AT SPECIFIED MOISTURE RANGES')
  WRITE(6,81)(SUM(I),I=1,4)
81 FORMAT('0 0.00 - 0.25=',F7.0/'0 0.25 - 0.50=',F7.0/'0 0.50 - 0.75=',F7.0/'0 0.75 - 1.00=',F7.0)
  WRITE(6,880)
880 FORMAT('1 NO TILLAGE -- FREQUENCY OF OCCURRENCE AT SPECIFIED MOISTURE RANGES')
  WRITE(6,81)(SUM(I),I=5,8)
  IF(NCOMP.NE.3)GO TO 70
  WRITE(6,634)
634 FORMAT('0 FREQUENCY BREAKDOWN BY MONTH',/0 DEPTH TREATMENT PERCENT)
  I1=1
  I2=2
  DO 633 N5=1,4
    PERCT=FLOAT(N5)/4.
    720 WRITE(6,630)ADEP(JJ),I1,PERCT,(SSUM(N5,N6),N6=1,6),I2,(SSUM(N5,N6),N6=1,6)
    I,N6=7,12)
    630 FORMAT(F6.1,I8,F11.2,I8,6F7.0/6X,I8,12X,6F7.0)
    633 CONTINUE
  70 CONTINUE
  75 CONTINUE
  RETURN
  END
SHA 1683
SHA 1684
SHA 1685
SHA 1686
SHA 1687
SHA 1688
SHA 1689
SHA 1690
SHA 1691
SHA 1692
SHA 1693
SHA 1694
SHA 1695
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SHA 1700
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SHA 1703
SHA 1704
SHA 1705
SHA 1706
SHA 1707
SHA 1708
SHA 1709
SHA 1710
SHA 1711

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