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ABSTRACT

A computer model was developed which described salt and water balances for a silt loam soil common to the Grand Praire physiographic region of Arkansas. A ten year period of weather data (1966-75) was used as input data for two divergent cases in regard to salt accumulation. Case one was a rice-soybean rotation with soybean irrigated, while case two was a rice-soybean-soybean rotation with soybean not irrigated. Salts considered were calcium, magnesium, sodium, sulfate and chloride as well as the precipitate, calcium carbonate. Where soybeans were not irrigated less evapotranspiration, more infiltration and less runoff were observed during the fallow season than in the case where soybeans were irrigated. Other differences in the water balances were small. Annual salt additions were substantially larger in the case where soybeans were irrigated and rice occurred more frequently in the rotation. A majority of salt additions were found during the rice season for either case studied. As irrigation water concentration increased for a given salt, the accumulation of that salt in the soil also increased in a linear manner. The rate of this increase was largest for sulfate and chloride, and smallest for magnesium.

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INTRODUCTION

The computer model described below is an updated version of a model developed previously (C. Regan 1978. A Salt and Water Balance for an Irrigated Soil. M.S. Thesis. University of Arkansas). The computer model simulated water and salt balances for Crowley silt loam soil (*Typic Albaqualfs*) found in the Grand Prairie physiographic region of Arkansas cropped to rice (*Oryza sativa* L.) and soybean (*Glycine max* L. Merr). Water inputs (precipitation, irrigation) and outputs (evaporation, transpiration, runoff) as well as redistribution of water within a 158 cm (62 in) soil depth were described. Salt inputs (irrigation, fertilizer) and outputs (crop uptake, erosion, runoff) were used to depict net salt balances. Physical and chemical variables used in computing the water and salt balances were adjusted to values which had been obtained in previous studies or values which were best estimates of a particular phenomenon. Variables which were adjustable were: a) irrigation water quality, b) rate of KCl fertilizer, c) crop rotation, and d) irrigation of soybean. Weather data (mean weekly pan evaporation, weekly precipitation) were used for the 10 year period from 1966 to 1975.

To facilitate computation of water movement through and loss from the soil, the soil profile was divided into 3 main layers given in Table 1 as SMD1, SMD2 and SMD3. These main horizons were further divided into sublayers SEG(1) to SEG(9). The porosities and water contents at saturation of each sublayer are also given in Table 1.

MODEL DESCRIPTION

Aquisition of Input Data and Routing

Overall program control and routing is presented in Fig. 1. After entering initial values and constants for the various portions of the model described below, irrigation water quality (calcium, magnesium, sodium, potassium

Table 1. Description of soil layers.

Main soil layer	Sub-layer	Texture	Depth* (cm)	Porosity (%)	cm H_2O at saturation
SMD1	SEG(1)	sil	2.5	45	1.1
	SEG(2)	sil	5.1	45	2.3
	SEG(3)	sil	5.1	45	2.3
SMD2	SEG(4)	sil	12.7	45	5.7
	SEG(5)	sil	12.7	45	5.7
	SEG(6)	sil	12.7	45	5.7
SMD3	SEG(7)	c	35.6	55	19.6
	SEG(8)	c	35.6	55	19.6
	SEG(9)	c	35.6	55	19.6

*Depth of each soil layer in sequence.

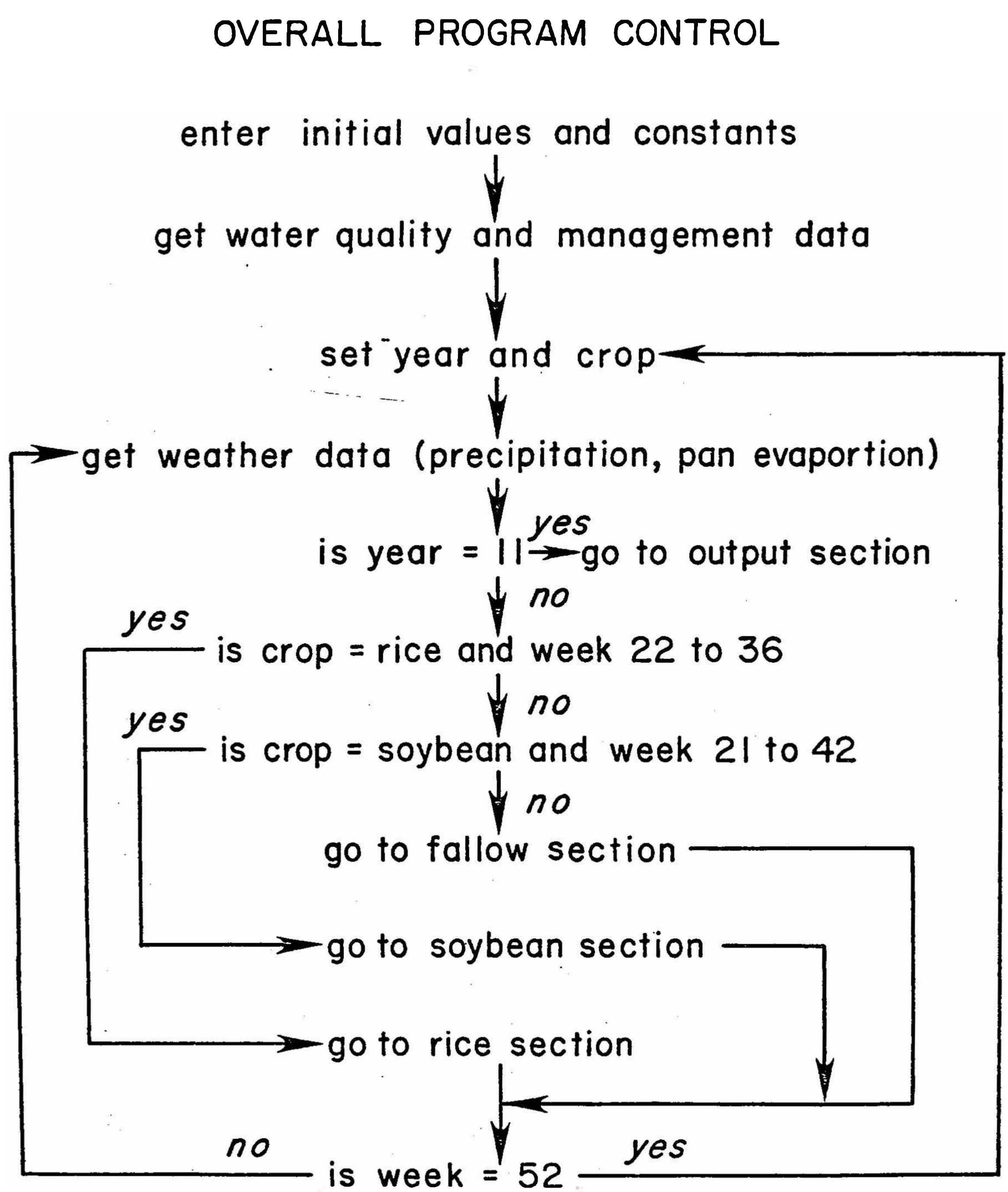


Fig. 1 - Overall program control and routing.

and sulfate in meq/l) and crop management (rate of KCl fertilizer, crop rotation, soybean irrigation instructions) data were obtained. Year and crop were then set (crop = 1 (rice), crop = 2 or 3 (soybean)) and weather data for week 1 obtained from the weather file (see Appendix I). A series of logic steps followed to route the program control to fallow, rice (when crop = 1 and week = 22 to 36) or soybean (crop = 2 or 3, week = 21 to 42) sections. After computations of water and salt balances were made within the appropriate section, either a) new weather data were obtained and routing was followed to fallow, rice or soybean sections as appropriate, or b) crop and/or year were incremented and routing followed as before. With this approach, the same year's weather data were used for a rotation, then the next year's weather data were used for the same rotation and so on. For rice-soybean and rice-soybean-soybean rotations, 20 and 30 years of calculations on a weekly time interval were made, respectively.

Fallow Section

The general routing within the fallow section is presented in Fig. 2. If potash fertilizer (KCl) was specified, a subroutine (FERT) which added both K and Cl to the soil was called. The depth of evapotranspiration (DET) was then computed from pan evaporation (PEVAP) using the soil moisture deficit (SEG(1)) in the surface 2.5 cm (1 in) as the other dependent variable according to Eq. 1 given below;

$$DET = (-1.0 \times SEG(1) + 1.0) \times PEVAP \qquad [1]$$

unless SEG(1) < 0.2 cm or > 0.8 cm where DET was set equal to 0.8 x PEVAP or 0.2 x PEVAP, respectively. In this manner DET was a linear function of PEVAP from the maximum at SEG(1) < 0.2 cm to the minimum at SEG(1) > 0.8 cm. Soil moisture content was decreased to account for evapotranspiration by sequentially adjusting the soil layers given in Table 1 to maximum soil

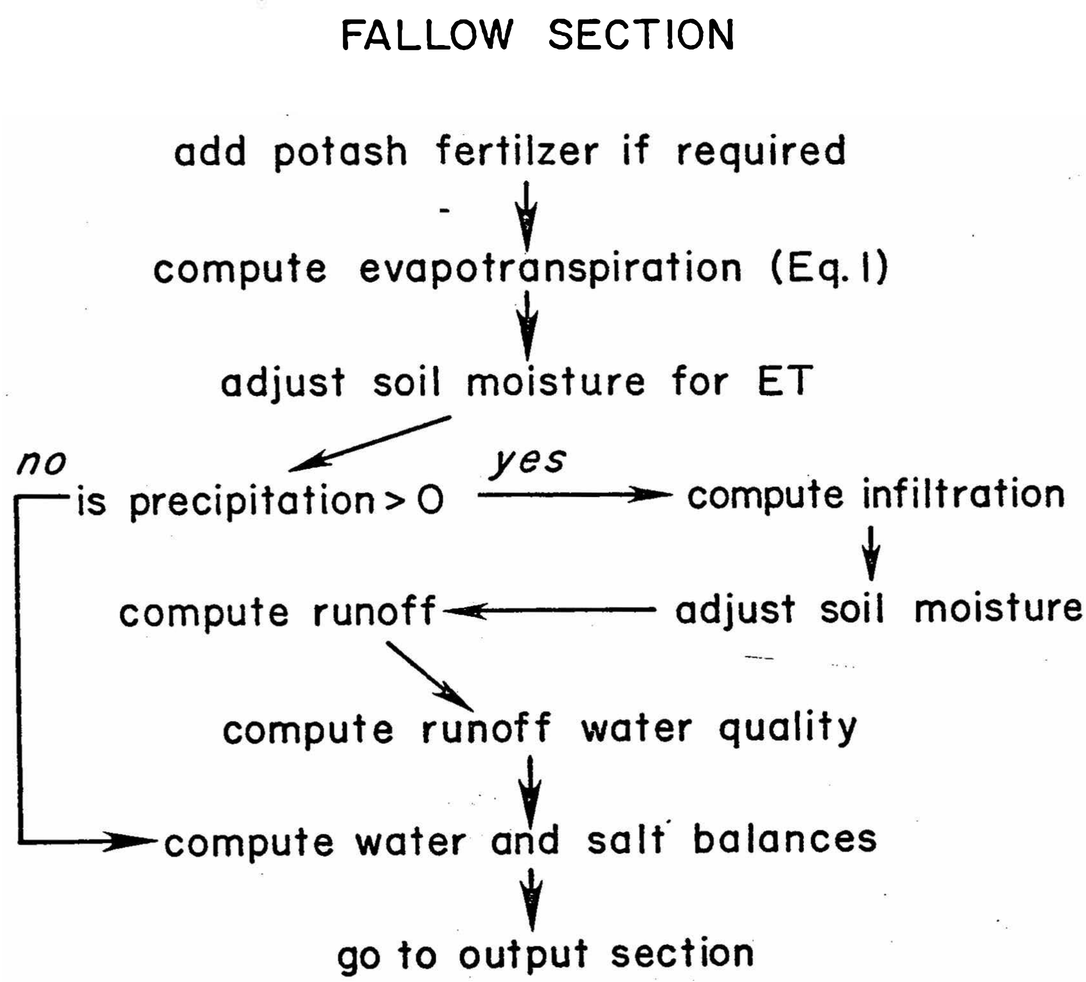


Fig. 2 - Routing during the Fallow section of the program.

moisture deficit (WSAT) until the increase in soil moisture deficit (SMD) of the affected soil layers equalled DET.

If precipitation occurred, a subroutine (RAIN) was called to compute infiltration (DINFIL) and readjust soil moisture. Within RAIN, the water movement subroutine (MOV) was called to further redistribute soil water according to Darcy's law. After infiltration was computed, runoff (DROFF) if any was taken as the difference between precipitation and infiltration. When no precipitation occurred, the MOV subroutine was called and infiltration was set to zero.

Water balances were then adjusted to reflect precipitation, infiltration, runoff and evapotranspiration. Salt balances were adjusted for salt losses in runoff water (see below) as well as erosion (see below).

Rice Section

The general routing within the rice section is presented in Fig. 3. During the first week (week = 22), the rice field was flooded to the maximum depth (DMAX). This depth was adjustable by either altering DMAX or using the same DMAX and overirrigating by a fixed percentage (P1/100). During most simulations DMAX and P1 were 10 cm (4 in) and 0, respectively.

The depth of evapotranspiration (DET) was then computed using Eq. 2 shown below;

$$DET = KRICE \times PEVAP \qquad [2]$$

where: KRICE was ratio of evapotranspiration to PEVAP. The values of KRICE were obtained from J. A. Ferguson (personal communication). From week 22 to 27, the DET was apportioned between evaporation (DE) and transpiration (DT) according to Eqs. 3, 4 and 5 below;

$$FT = (14 \times (week - 22) + 19.5)/100 \qquad [3]$$

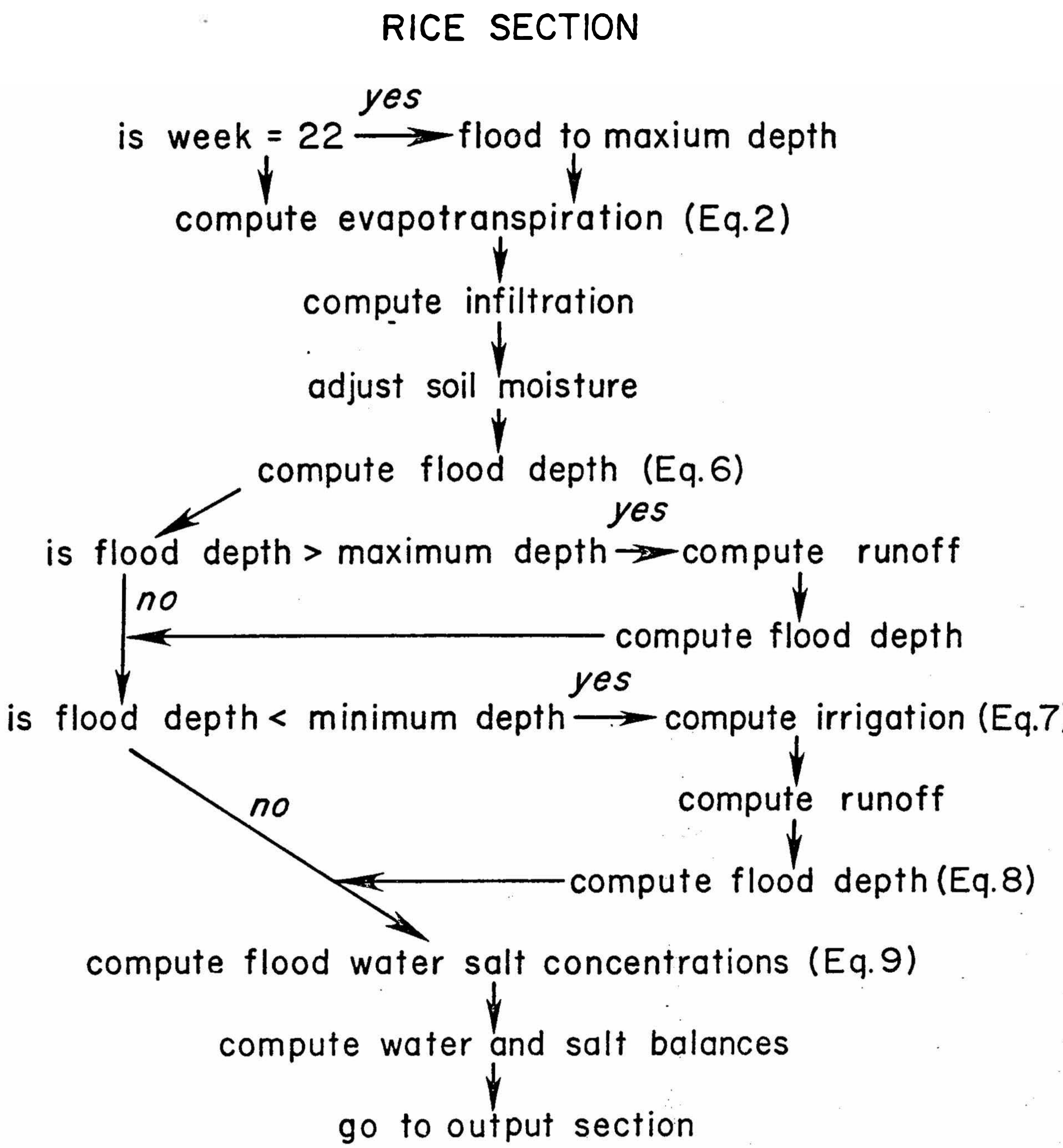


Fig. 3 - Routing during the Rice section of the program.

$$DT = FT \times DET \qquad [4]$$

$$DE = (1 - FT) \times DET \qquad [5]$$

where: FT was the fraction of DET attributable to transpiration. Equation 3 was obtained from J. A. Ferguson (personal communication). After week 27, all DET was assumed to be transpiration (DE = 0). This approach to evapotranspiration also affected the salt concentration in the floodwater because only evaporation was used to adjust concentration.

The infiltration of floodwater (DINFIL) was then computed by the infiltration subroutine (RAIN) and Darcian movement of water within the soil calculated with the subroutine MOV. The new depth of floodwater (D2) was computed from the original depth (D1) as given in Eq. 6 below;

$$D2 = D1 + DRAIN - DE - DT - DINFIL \qquad [6]$$

If the new depth, D2, was greater than DMAX, runoff (DROFF) was calculated as the difference between D2 and DMAX. If the new depth, D2, was less than DMIN (5.0 cm or 2 in), then the irrigation depth (DIRR) was computed from Eq. 7 given below;

$$DIRR = (DMAX - D2) \times (1 + P1/100) \qquad [7]$$

and a new D2 calculated from Eq. 8 below

$$D2 = D1 + DIRR + DRAIN - DE - DT - DINFIL \qquad [8]$$

If runoff occurred (D2 in Eq. 8 $>$ DMAX), runoff depth was calculated and D2 set to DMAX. The concentration of each salt in the floodwater was then adjusted for the above events according to Eq. 9 given below;

$$C2 = (C1 \times D1 + WAT \times DIRR)/(D1 + DRAIN + DIRR - DE) \qquad [9]$$

where: C2 was the new concentration, C1 was the old concentration and WAT was the irrigation water concentration.

Water balances were then adjusted to account for precipitation, irrigation, infiltration, runoff, evaporation and transpiration. Salt balances were adjusted to reflect salt additions via irrigation and infiltration as well as salt losses from runoff. Erosional losses were assumed to be zero. The above salt and water balances were further adjusted during the last week of flooded rice (week = 36) to reflect floodwater removal and crop uptake of salt by the rice grain. Rice yields were set at 4800 kg/ha (95 bu/acre).

Soybean Section

The general routing within the soybean section is presented in Fig. 4. Evapotranspiration depth was computed using Eq. 10 shown below;

$$DET = KSOY \times PEVAP \qquad [10]$$

where: KSOY was the ratio of evapotranspiration to PEVAP. The values of KSOY were obtained from H. D. Scott (personal communication). The value of DET was reduced if the soil moisture deficit of the entire profile was greater that 70 percent of the maximum soil moisture deficit of 81.6 cm using Eq. 11 shown below;

$$DET = ((81.6 - (SMD1 + SMD2 + SMD3))/24.5) \times DET \qquad [11]$$

where: (SMD1 + SMD2 + SMD3) was the soil moisture deficit of the entire soil profile.

When DET was known, soil moisture was adjusted to reflect this water loss. In this computation soil moisture removal was distributed over the soil layers by considering the growth of the soybean root system and the water available for evapotranspiration in a given layer. To compute the water available for transpirational loss, it was assumed that 70 percent of the water content at saturation was available for this loss pathway (H. D. Scott, personal communication) and that the amount lost from a given soil layer would be linearly related to the amount of this available water com-

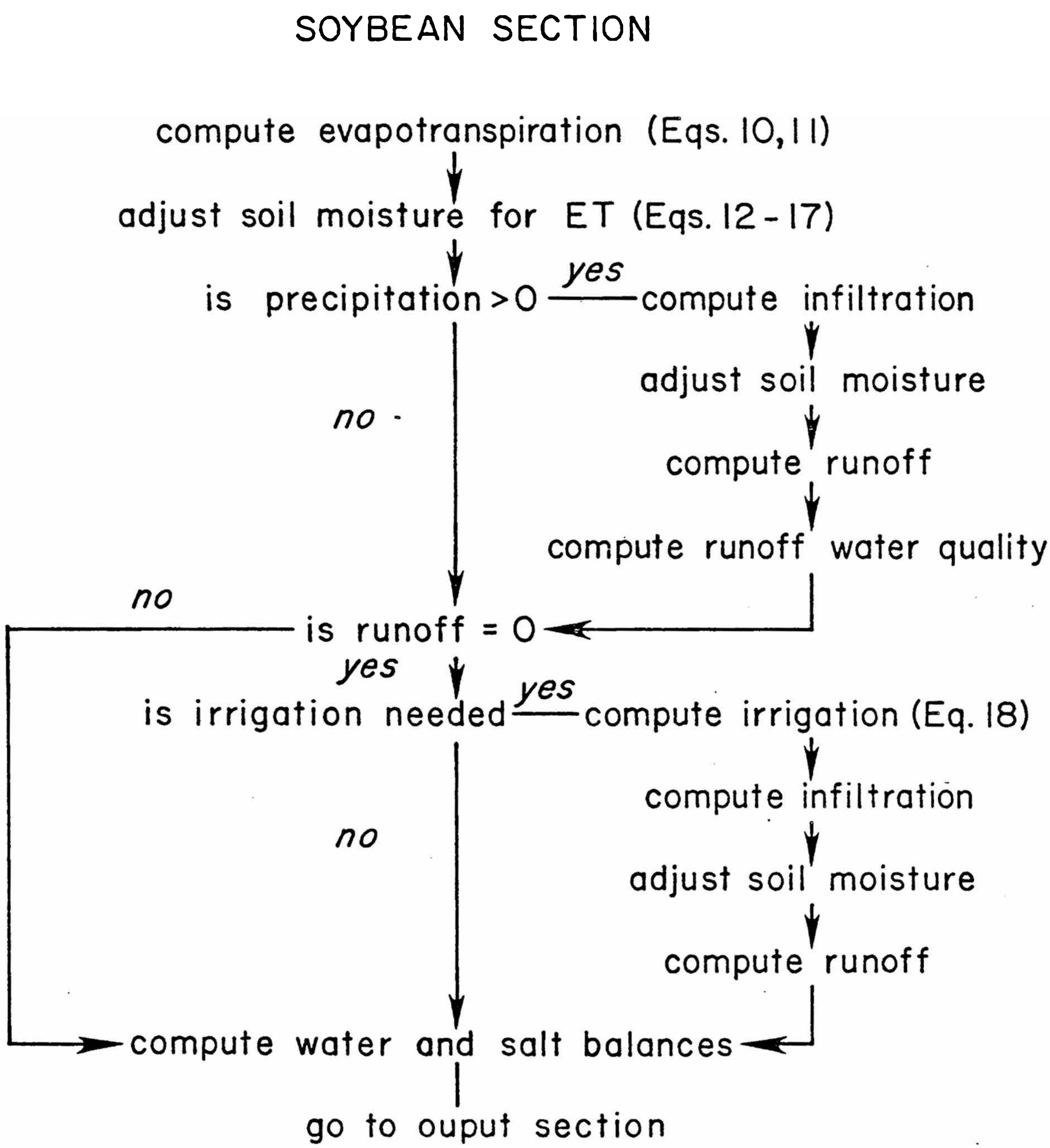


Fig. 4 - Routing during the Soybean section of the program.

ponent within a given soil layer as given in Eqs. 12, 13 and 14 below;

$$SMD1FACT = (4.0 - SMD1)/4.0 \quad [12]$$

$$SMD2FACT = (12.0 - SMD2)/12.0 \quad [13]$$

$$SMD3FACT = (41.1 - SMD3)/41.1 \quad [14]$$

where: SMD1FACT, SMD2FACT and SMD3FACT were used to weight water loss for the availability of water in soil layers SMD1, SMD2 and SMD3, respectively. If the left hand side of Eqs. 12, 13 or 14 was less than zero, the weighting factor was set to zero.

To account for the progressive downward growth of the soybean root system, water was only removed from SMD1 if week $<$ 23. Between weeks 23 and 26 water was removed from SMD1 and SMD2, but not SMD3. From week 27 to 42 all three segments were used in these calculations. Thus, when week $>$ 26, Eqs. 15, 16 and 17 were used to compute the distribution of water loss due to DET within the profile as given below;

$$SMD1DEL = (SMD1FACT/(SMD1FACT + SMD2FACT + SMD3FACT)) \times DET \quad [15]$$

$$SMD2DEL = (SMD2FACT/(SMD1FACT + SMD2FACT + SMD3FACT)) \times DET \quad [16]$$

$$SMD3DEL = (SMD3FACT/(SMD1FACT + SMD2FACT + SMD3FACT)) \times DET \quad [17]$$

where: SMD1DEL, SMD2DEL, and SMD3DEL were the cm of water lost from SMD1, SMD2 and SMD3 via evapotranspiration, respectively. These values were adjusted if sufficient water for loss was not available within a given layer by sequentially removing more water from the next lower layer. For week $<$ 23, both SMD2FACT and SMD3FACT were set to zero, while between week 23 and 26 only SMD3FACT was set to zero. In this manner water removal from the soil profile was both a function of the amount of water present in a given soil layer and the root distribution of the soybean plant. The assumptions with respect to the root distribution were obtained from H. D. Scott (personal communication).

If precipitation occurred the subroutine RAIN was called to compute infiltration (DINFIL) and the subroutine MOV called to redistribute water within the soil profile. Runoff (DROFF) was computed and runoff water quality calculated in the subroutine ROQUAL if DROFF > 0. If DROFF = 0, the soybean irrigation option was selected, SMD1 plus SMD2 was greater than 10.3 cm (4 in), week was less than 37 and less than 4 irrigations had previously been made, an irrigation subroutine, SOYIRR, was called.

In SOYIRR, the depth of irrigation was computed with Eq. 18 given below;

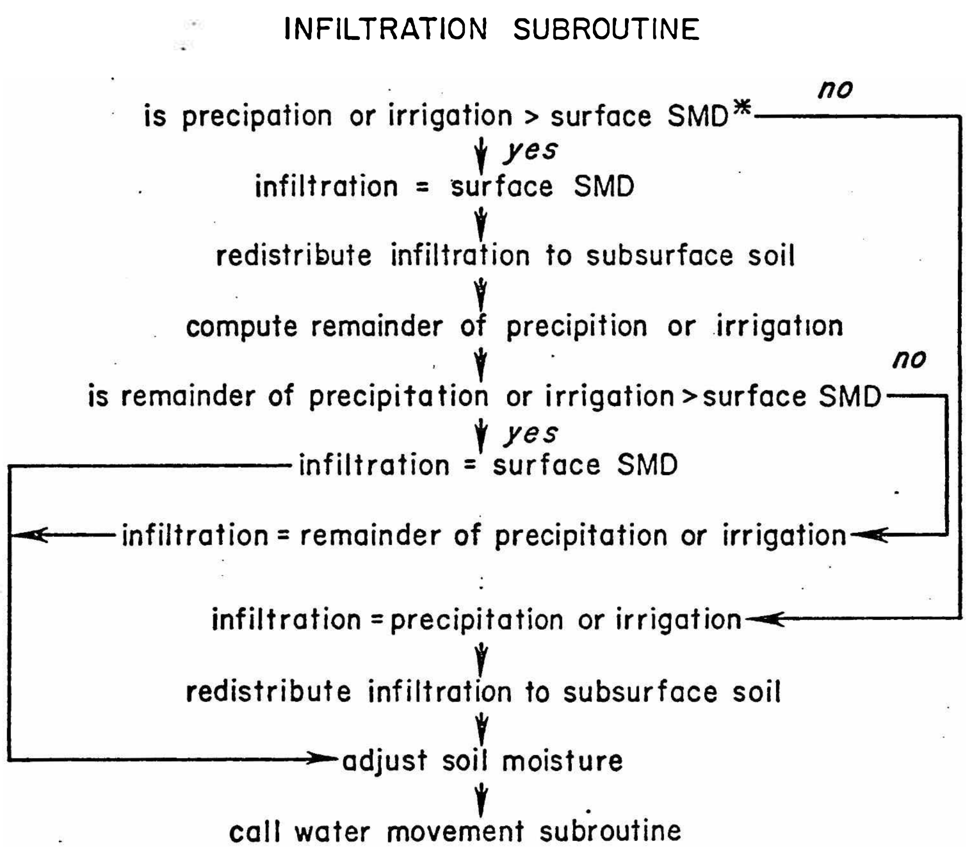
$$\text{DIRR} = \text{DEPTH} \times (1 + \text{P2}/100) \qquad [18]$$

where: DIRR was the irrigation depth (cm) applied, DEPTH was a preset depth of irrigation (3.2 cm or 1.25 in) and P2 was the percentage of excess irrigation (20%). The term P2 was manipulated where an increase in DIRR was desired. The infiltration (DINFIL) of irrigation water was calculated using the subroutine RAIN and water movement computed using the subroutine MOV. Finally, runoff (DROFF) was computed as the difference between DIRR and DINFIL.

Appropriate water and salt balances were then amended to reflect the above. During week 42, salt uptake by the soybean crop was also computed. If soybeans were irrigated,yield was set at 2688 kg/ha (40 bu/acre), with yields of non-irrigated soybeans set at 1680 kg/ha (25 bu/acre).

Infiltration of Precipitation or Irrigation

The subroutine, RAIN, which computed infiltration of precipitation or irrigation water is outlined in Fig.5. If surface water added was greater than the soil moisture deficit in the main surface layer (SMD1), an amount of water equal to the soil moisture deficit was allowed to infiltrate.



*Soil moisture deficit in cm.

Fig. 5 - Routing during the Infiltration section.

Rapid redistribution of the now saturated surface layer was then made to the each sublayer (SEG) of the two main subsurface layers (SMD2, SMD3). A maximum of 33 percent of this water was rapidly redistributed to SMD2, while a maximum of 27 percent was rapidly redistributed to SMD3. The amount of water added to any sublayer was limited by the soil moisture deficit of the sublayer. Any surface water remaining was then added to SMD1 up to the soil moisture deficit in SMD1 which was created due to rapid redistribution described above.

When surface water added was less than or equal to the soil moisture deficit in the main surface layer (SMD1), all the surface water was allowed to infiltrate. A maximum of 30 percent of the water in the first major layer (SMD1) was then rapidly redistributed to the second major layer (SMD2). Again, the amount of water rapidly redistributed to any sublayer (SEG) within SMD2 was limited by the soil moisture deficit of the sublayer.

The percentages of surface water rapidly redistributed was somewhat arbitrary except that the values used were necessary to maintain a zero change in the water balance. When such rapid redistribution was not allowed and only Darcy's law was used to redistribute water, water balances were not zero over the period of computation.

After the rapid infiltration phase was complete soil moisture deficits in the main layers (SMD1, SMD2, SMD2) and sublayers (SEG(1) to SEG(9)) were adjusted and Darcian water movement was computed by the subroutine, MOV.

<u>Water Movement Within Soil</u>

In order to describe the movement of water between the sublayers (SEG(1) to SEG(9)) given in Table 1, the relationship between volumetric water content (θvol) and soil moisture tension presented in Table 2 was

Table 2. Soil physical data for Crowley silt loam soil[1/]

Soil moisture tension ($cm\ H_2O$)	θvol silt loam ($cm^3 H_2O/cm^3$ soil)	θvol clay ($cm^3 H_2O/cm^3$ soil)
1	0.450	0.550
100	0.395	0.460
200	0.375	0.450
300	0.365	0.445
500	0.350	0.430
1000	0.335	0.410

[1/] From P. D. Erstine. 1979. Heat Transfer in Crowley Silt Loam. M.S. Thesis. University of Arkansas.

needed to develop an equation where soil moisture tension could be predicted from θvol. The data were found to follow Eq. 19 given below;

$$SMT = (\theta vol/B)^{1/m} \qquad [19]$$

where: SMT was soil moisture tension (cm H_2O), θvol was volumetric water content and B and m were constants. The values of B and m for the silt loam sublayers were 0.457 and -0.04065, respectively. The values of B and m for the clay sublayers were 0.552 and -0.04036, respectively.

Using the data in Table 2 and estimates of the saturated hydraulic conductivity of the soil (30 cm/week for silt loam and 3 cm/week for clay; H. D. Scott, unpublished data), it was possible to predict unsaturated hydraulic conductivity using the Green-Corey method (1971). The results of the calculation yielded Eq. 20 given below;

$$KTHETA = C \times e^{D \times \theta vol} \qquad [20]$$

where: KTHETA was unsaturated hydraulic conductivity and C and D were constants. The values of C and D for the silt loam soil were 6.21×10^{-22} and 121.1, respectively. The values of C and D for the clay soil were 2.27×10^{-19} and 80.88, respectively.

Water potential gradients were computed from the center of one sublayer to the center of the next according to Eq. 21 below;

$$GRAD = \frac{WPOT1 - WPOT2}{D1 - D2} \qquad [21]$$

where: GRAD was the hydraulic head gradient, WPOT1 and WPOT2 were total water potentials in cm (both SMT and gravimetric components), and D1-D2 was the depth increment in cm. Hydraulic conductivities for each soil sublayer pair were computed using Eq. 22 given below;

$$KSEG = (D1-D2)/(D1/KTHETA1 + D2/KTHETA2) \qquad [22]$$

where: KSEG was the average hydraulic conductivity and the 1 and 2 postscripts refer to soil sublayers in sequence.

With the above discussion as background, the flow diagram for computing Darcian movement of soil water in the subroutine MOV is given in Fig. 6. The rate of water movement was computed from KSEG and GRAD using Eq. 23 presented below;

$$WMOV = -KSEG \times GRAD \qquad [23]$$

where: WMOV was the rate of water movement in cm/week. If insufficient water was available for movement in the soil sublayer losing water or an insufficient soil moisture deficit was available in the soil sublayer receiving water, WMOV was adjusted accordingly.

<u>Precipitation of Calcium Carbonate</u>

A section in the program was developed to compute the calcium concentration in floodwater after $CaCO_3$ precipitation had taken place. The calculation employed a solution of Eq. 24 given below;

$$K_{sp} = a_{Ca}\, a_{CO3} \qquad [23]$$

where: K_{sp} was the solubility product and a_{Ca} and a_{CO3} were activities of calcium and carbonate ions, respectively. The solubility product was set at 10^{-8} which was computed from floodwater measurements made in a previous study (J. T. Gilmour, unpublished data). Other equilibria used to solve for equilibrium calcium concentration are given in Gilmour et al. (1978). Corrections for ion-pair formation were not made.

At the end of each week the soil was flooded the final floodwater calcium concentration was compared to the equilibrium concentration computed using Eq. 23. If the floodwater calcium concentration exceeded the equilibrium value, $CaCO_3$ was formed via a decrease in floodwater calcium concentration to the equilibrium value and the final floodwater calcium concentration was reset to the equilibrium value. This loss of calcium was then added to the appropriate portions of the salt balance. When the flood-

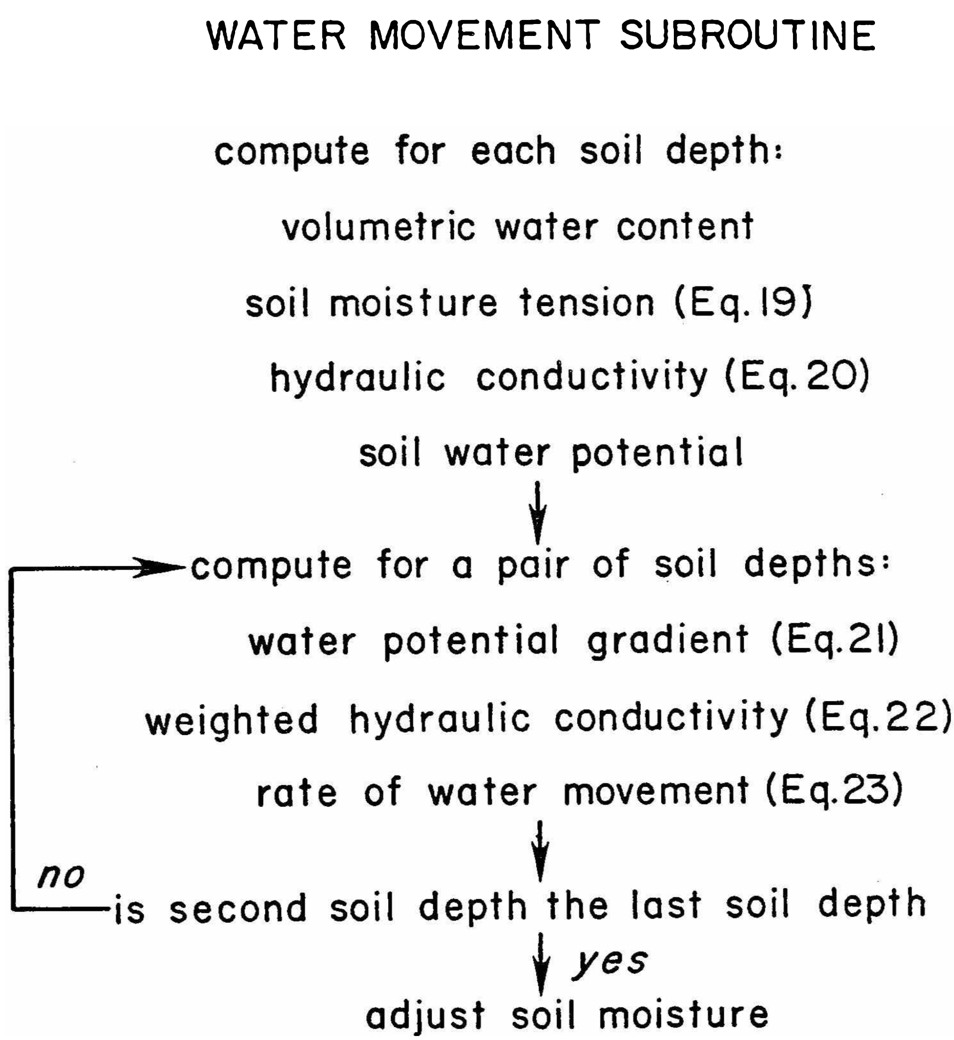


Fig. 6 - Routing during the Water Movement section.

water calcium concentration was less than or equal to the equilibrium value, no adjustment in floodwater calcium or dissolution of $CaCO_3$ was attempted.

Runoff Water Salt Concentrations

When the soil was not flooded and precipitation exceeded infiltration, runoff water salt concentrations were computed using equations from Gilmour and Marx (1981). When cumulative runoff following removal of rice floodwater was less than or equal to 10 cm, Eq. 24 given below was used;

$$RWAT = WAT \times EXP\ (D \times CUMROFF + E) \qquad [24]$$

where: RWAT was runoff water concentration (meq/l), WAT was irrigation water concentration (meq/l), CUMROFF was cumulative runoff (cm), and A and B were constants. The values of D for Ca, Mg, Na, K, SO_4 and Cl were -0.28, -0.27, -0.23, -0.12, -0.44, -0.35 cm^{-1}, respectively. The values of E for Ca, Mg, Na and K were -1.00, -0.45, +0.20 and +0.80, respectively. The E values for SO_4 and Cl were related to irrigation water concentration (WAT) and were computed using Eq. 25 shown below;

$$E = F \times WAT + G \qquad [25]$$

where: F and G were constants equal to -2.43 and 3.44 respectively.

When cumulative runoff following rice floodwater removal was greater than 10 cm, runoff water concentrations were assigned constant values using Eqs. 24 and 25 where CUMROFF = 10 cm.

Runoff water salt concentrations during runoff from soybean irrigation were assumed equal to the irrigation water quality as described by Bondurant (1971).

Erosional Losses

When runoff occurred during fallow and rice sections soil erosion was calculated from the Universal Soil Loss Equation as described by Regan (C. Regan. 1978. A Salt and Water Balance for an Irrigated Soil.

M.S. Thesis. University of Arkansas). When the soil was not cropped (fallow section) and spring field operations were likely (Week 14 to Week 22) the concentration of soil in runoff water was 1660 ppm. At all other times in the fallow section the concentration was 1050 ppm. In the soybean section, soil concentration in runoff water was 1860 ppm, while soil concentration in runoff water was set to zero when soil was flooded.

The aforementioned runoff water soil concentrations were used in conjunction with soil salt concentrations presented in Table 3 in Eq. 26 given below;

$$SEROS = SOIL \times DROFF \times PPM \times 10^{-7} \qquad [26]$$

where: SEROS was erosional salt loss in kg/ha, SOIL was soil salt concentration from Table 3 in ppm, DROFF was runoff depth in cm and PPM was runoff soil concentration given above. Soil salt concentrations were average values obtained from 3 fields which were monitored during the winter-spring period of 1978 and 1979. These data are discussed in detail elsewhere.

Crop Uptake

Crop uptake of salt was initiated during the last week of rice or soybean as described above. Equation 27 given below was used in the calculation;

$$RCROP = YIELD \times SEED/100 \qquad [27]$$

where: RCROP was crop uptake in kg/ha, YIELD was grain yield in kg/ha and SEED was percent salt in grain. The values for percent salt in grain for rice (RISEED) and soybean (SOYSEED are given in Table 3. These salt concentrations were mean values obtained from grain from the field sites discussed below.

Table 3. Constants and conversion factors.

Salt	K1 (kgxl/(haxcmxmeq)	Soil Concentration* (ppm)	Grain Concentration rice (%)	Grain Concentration soybean (%)
calcium	2.0	1280	0.017	0.142
magnesium	1.2	160	0.122	0.216
sodium	2.3	100	0.129	0.548
potassium	3.9	70	0.351	1.648
sulfate	4.8	55	0.346	0.535
chloride	3.5	0	0.257	0.126

*SOIL(I)
RISEED(I)
SOYSEED(I)

Salt Additions and Removals in Water

When salt was added to the soil via infiltration of irrigation water or removed from the soil during runoff, Eq. 28 given below was used to compute salt added or removed;

$$SALT = K1 \times DEPTH \times CONC \quad [28]$$

where: SALT was the amount of salt in kg/ha, DEPTH was the depth of water in cm, CONC was the salt concentration in the water in meg/l and K1 was the conversion factor given in Table 3.

MODEL OUTPUT

General

As described above, the model output provides salt and water balances for various management schemes. To facilitate the presentation of the results, two schemes which represent the extremes with respect to both water and salt balances were selected for detailed discussion. The first was a rice-soybean rotation with soybeans irrigated which represented maximal irrigation water and salt additions to the soil. The second was a rice-soybean-soybean rotation with soybeans not irrigated which represented mininal irrigation water and salt additions to the soil. The addition of KCl fertilizer was omitted from all results presented here as the impact of this salt addition can be assessed by simply adding a given KCl rate to the salt balances presented below.

Since seasonal data are presented on a weekly basis, Fig. 7 was constructed to convert week to month or day if desired.

Finally, the results presented below are mean values for a 10 year period and do not reflect maximum and minimum values for a variable which undoubtedly occur for a given week in a single year.

Rice-Soybean Rotation with Soybean Irrigated

The weekly soil moisture deficits for the 3 main layers (SMD1, SMD2, SMD3) are presented in Fig. 8. Water balance components which altered the soil moisture deficits are given in Fig. 9.

The fallow period which began after the soybean crop and extended between years to the rice crop was a time where a sequential decrease in SMD1, SMD2 and SMD3 occurred. Both SMD1 and SMD2 were small by week 1 of the rice year and fluctuated within a narrow range after that time, while SMD3 continued to decrease throughout this fallow period. Evapotranspiration was small until week 6 prior to the rice crop when a

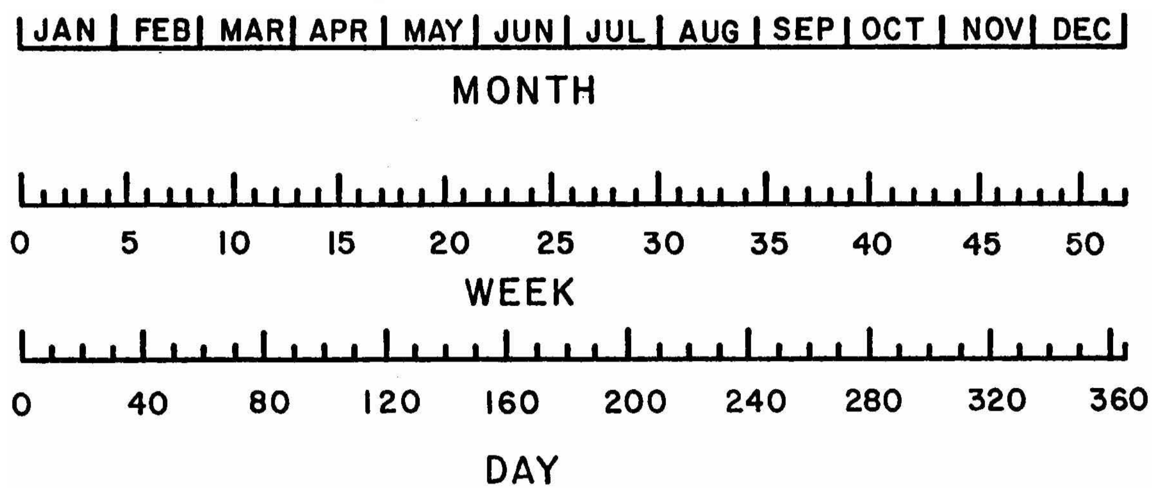


Fig. 7 - Conversion table for day, week and year.

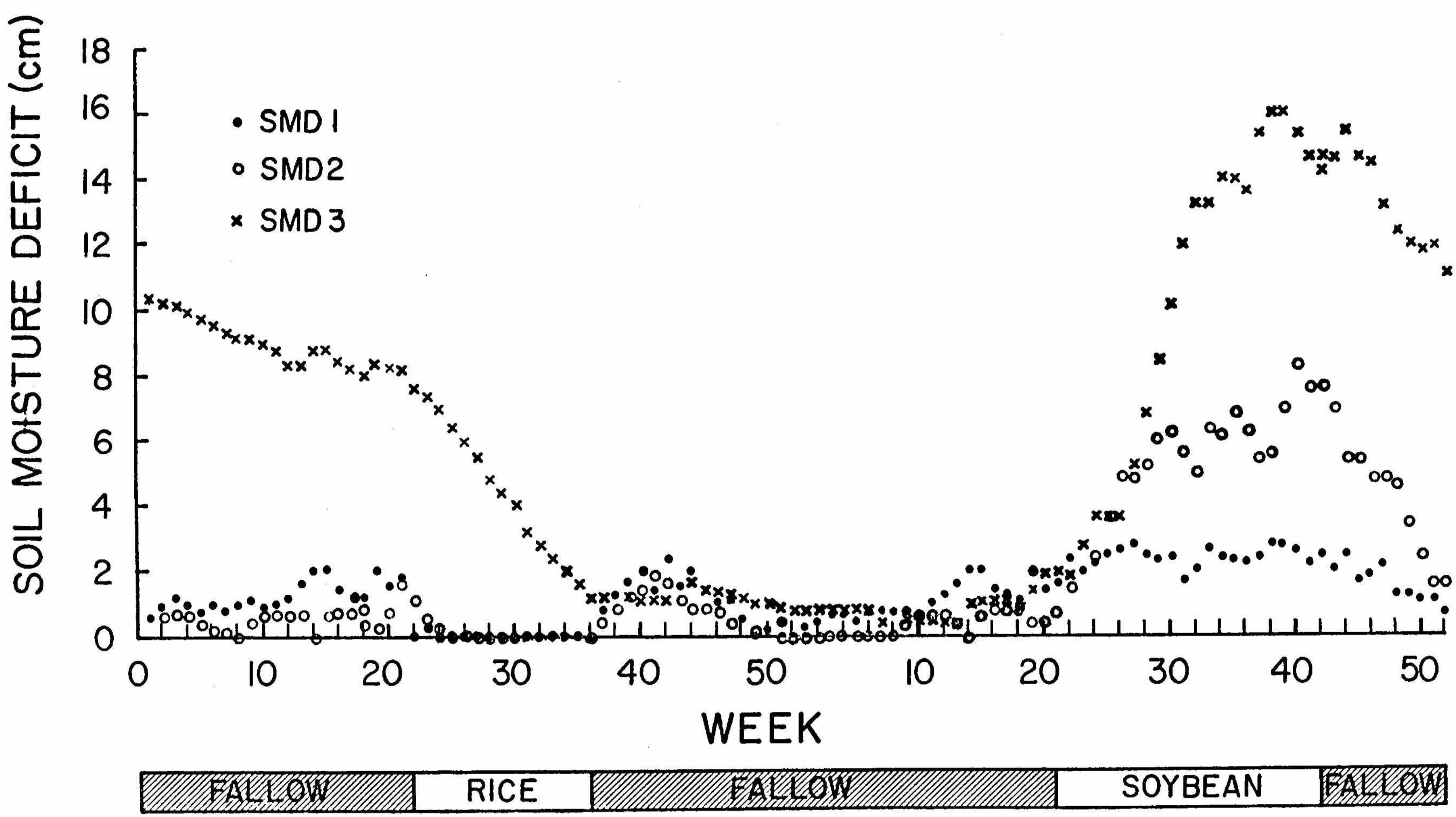


Fig. 8 - Weekly soil moisture deficits for the rice-soybean rotation with soybean irrigated.

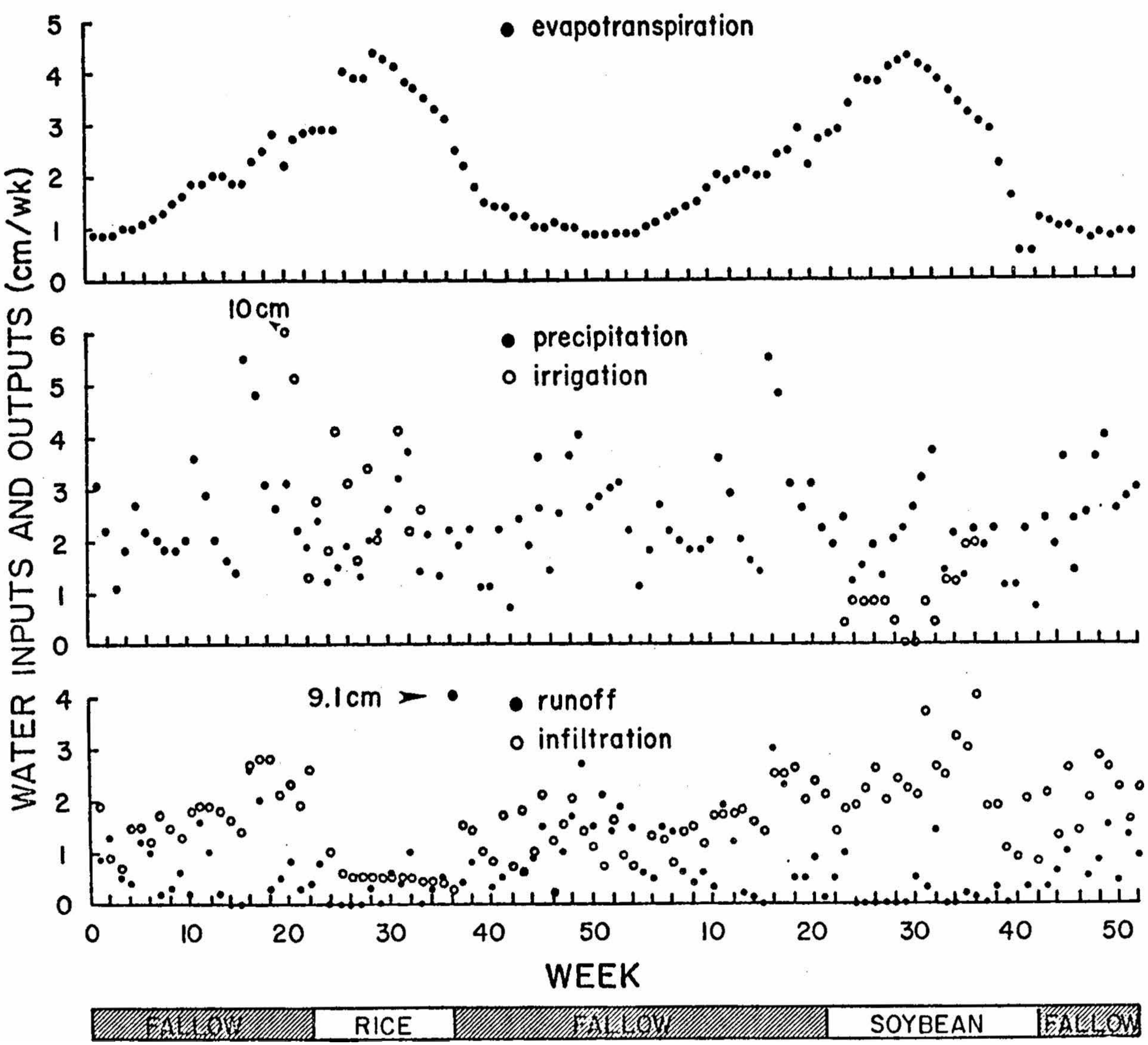


Fig. 9 - Water inputs and outputs for the rice-soybean rotation with soybean irrigated.

progressive increase was found. Precipitation, infiltration and runoff were variable over this fallow period with the largest infiltration amounts coinciding with the most rapid decreases in soil moisture deficit. Infiltration always exceeded runoff and was often large compared to runoff. A runoff peak did appear to occur in week 49 following the soybean crop. In total, this fallow period was a time of high infiltration, low evapotranspiration and reduction of the soil moisture deficit.

During the rice season, SMD1 and SMD2 were zero by the 3rd week after flooding with SMD2 rapidly decreasing to a near zero value at the end of the rice season. Evapotranspiration increased to a maximum at week 29 and thereafter decreased, while a precipitation maximum was found at week 32. Irrigation water applications were erratic in amount and ceased after week 33, three weeks prior to flood removal. Infiltration of floodwater was initially high, decreased rapidly, then decreased very slowly throughout the remainder of the season. Runoff was erratic and coincided with periods of high precipitation except during the last weeks of flooding when the flood was removed. The rice crop water balance was, thus, a period of a rapid lowering of the soil moisture deficit of the surface soil and a gradual lowering of soil moisture deficit of the subsurface layers.

The fallow period between the rice and soybean crops exhibited drying of the surface soil (SMD1 increasing) near week 42 of the rice year and week 15 of the soybean year, while the two lower layers (SMD2 and SMD3) remained at low soil moisture deficits. These increases in SMD1 coincided with higher evapotranspiration and lower precipitation periods. Infiltration was erratic during this period, while runoff increased to peaks near week 51 of the rice year and week 16 of the soybean year. These runoff peaks generally followed precipitation peaks and interestingly, one peak occurred during a period near week 16 prior to soybean when SMD1 was relatively high.

The soybean season was characterized by a sequential increase in soil moisture deficits of the three main layers. The SMD1 was maximal by week 27 and remained near that value throughout the season. The SMD2 generally increased to a maximal value in week 40, while SMD3 increased to a maximum at week 38. Evapotranspiration reached a peak in week 30 and declined thereafter. Substantial irrigation occurred during weeks 24 to 27 when precipitation was low. The increase in precipitation from weeks 28 to 32 was reflected in a lower irrigation requirement followed by increasing irrigation from weeks 33 to 36. Infiltration was high throughout the soybean season with a peak at week 36, while runoff was low or zero except where the precipitation peak occurred. In general, the soybean season was a period of soil drying, low runoff and high infiltration.

Rice-Soybean-Soybean Rotation With Soybean Not Irrigated

The weekly soil moisture deficits for the 3 main layers (SMD1, SMD2 and SMD3) are presented in Fig. 10. Water balance components which altered the soil moisture deficits are given in Fig. 11.

Since the model employed the same weather data for this rotation as the one described above, precipitation patterns were identical and evapotranspiration patterns were similar for the two rotation-irrigation schemes. The data for the soybean year was a mean value of the 2 years of soybean following rice.

The fallow season following soybean and preceeding rice was similar to that of the rice-soybean rotation with soybean irrigated except that soil moisture deficits were larger. Since the first year after soybean was probably similar in this rotation to that shown in Fig. 8, the large relative increases in SMD1, SMD2 and SMD3 appeared to be largely due to soil moisture deficits incurred during the 3rd year of the rotation.

During the rice season, the behavior of soil moisture deficits and

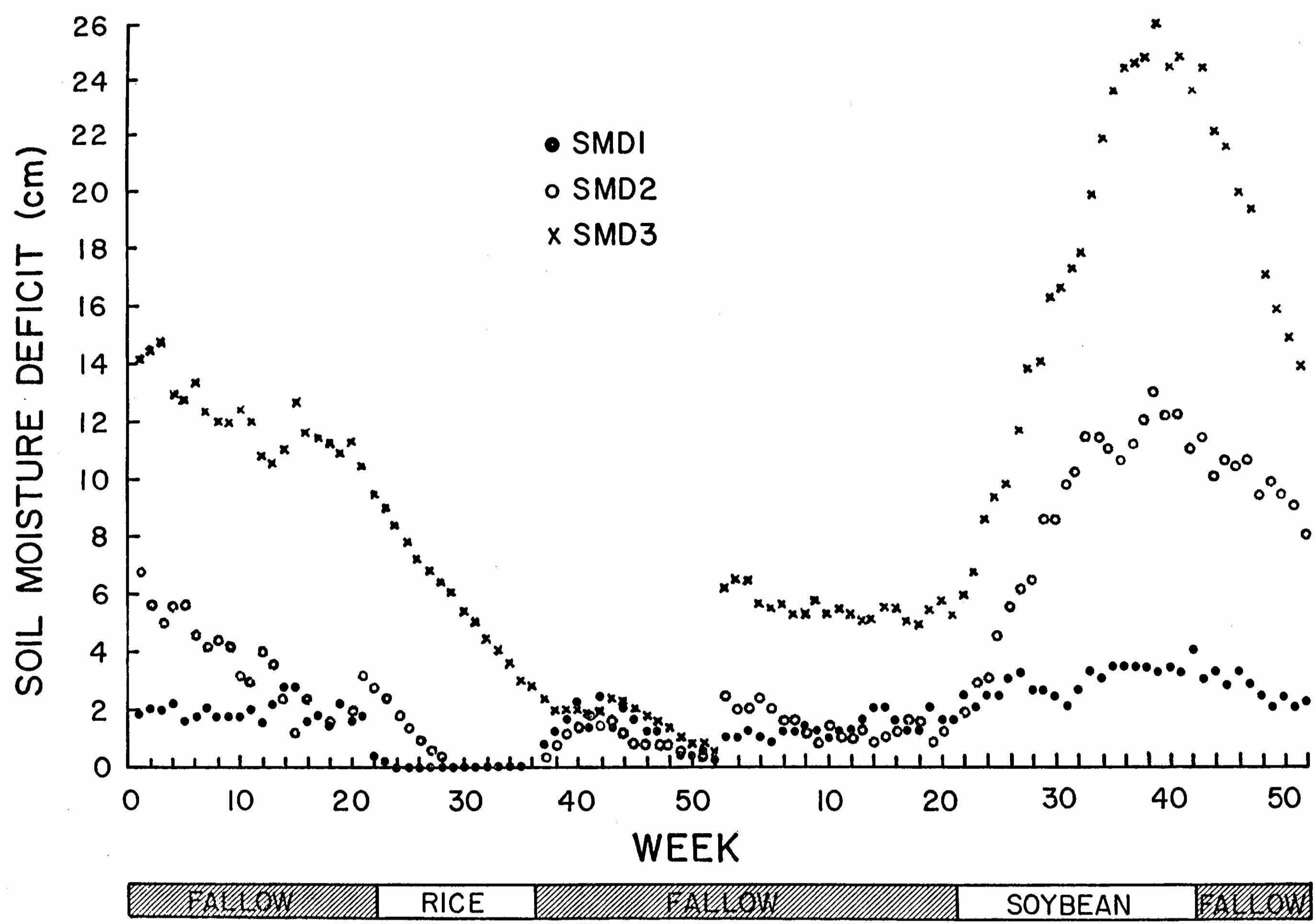


Fig. 10 - Weekly soil moisture deficits for the rice-soybean-soybean rotation with soybean not irrigated.

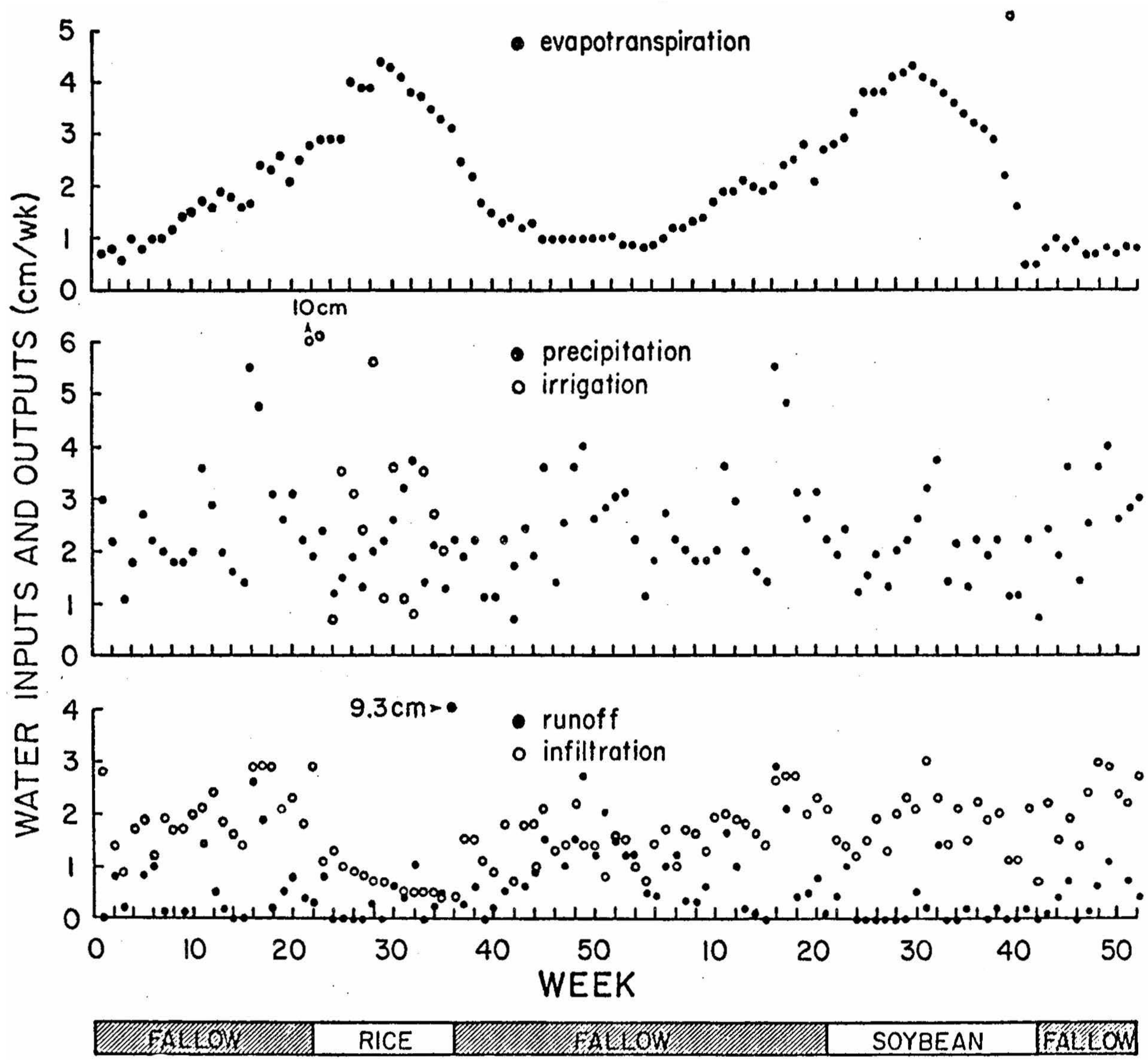


Fig. 11 - Water inputs and outputs for the rice-soybean-soybean rotation with soybean not irrigated.

the water balance components were again similar to that found for the rice-soybean rotation with soybean irrigated. A major difference which did occur was the higher amount of infiltration with this rotation although the pattern was similar to that described previously.

The fallow season between rice and soybean crops appeared to be composed of two periods. The first occurred during the rice year and was essentially the same as that found for the rice-soybean rotation with soybean irrigated. The second which occurred during the soybean year was characterized by a discontinuity in SMD2 and SMD3 and a larger soil moisture deficit throughout the soil due to lower infiltration as compared to the rice-soybean rotation with soybean irrigated. These results reinforced the concept that soil moisture deficits developed during the 3rd year of the rotation were much larger than those which were formed during the 2nd year of the rotation following flooded rice.

The soybean season produced much higher soil moisture deficits and lower amounts of infiltration than those found for the rice-soybean rotation with soybean irrigated. The infiltration peak also occurred earlier than that found for the other rotation. This peak coincided with the precipitation peak as no irrigation water was applied.

Evapotranspiration Details

The layer from which evapotranspiration (largely transpiration) water was extracted as well as total evapotranspiration for soybean are shown in Fig. 12. Total evapotranspiration did not substantially differ between the rice-soybean-soybean rotation without soybean irrigation (Fig. 12a) and the rice-soybean rotation with soybean irrigated (Fig. 12b). There were shifts in water losses among SMD1, SMD2 and SMD3; however, as more water was extracted from SMD3 and less water from SMD1 and SMD2 for the rotation without irrigation as compared to the rotation where irrigation was provided.

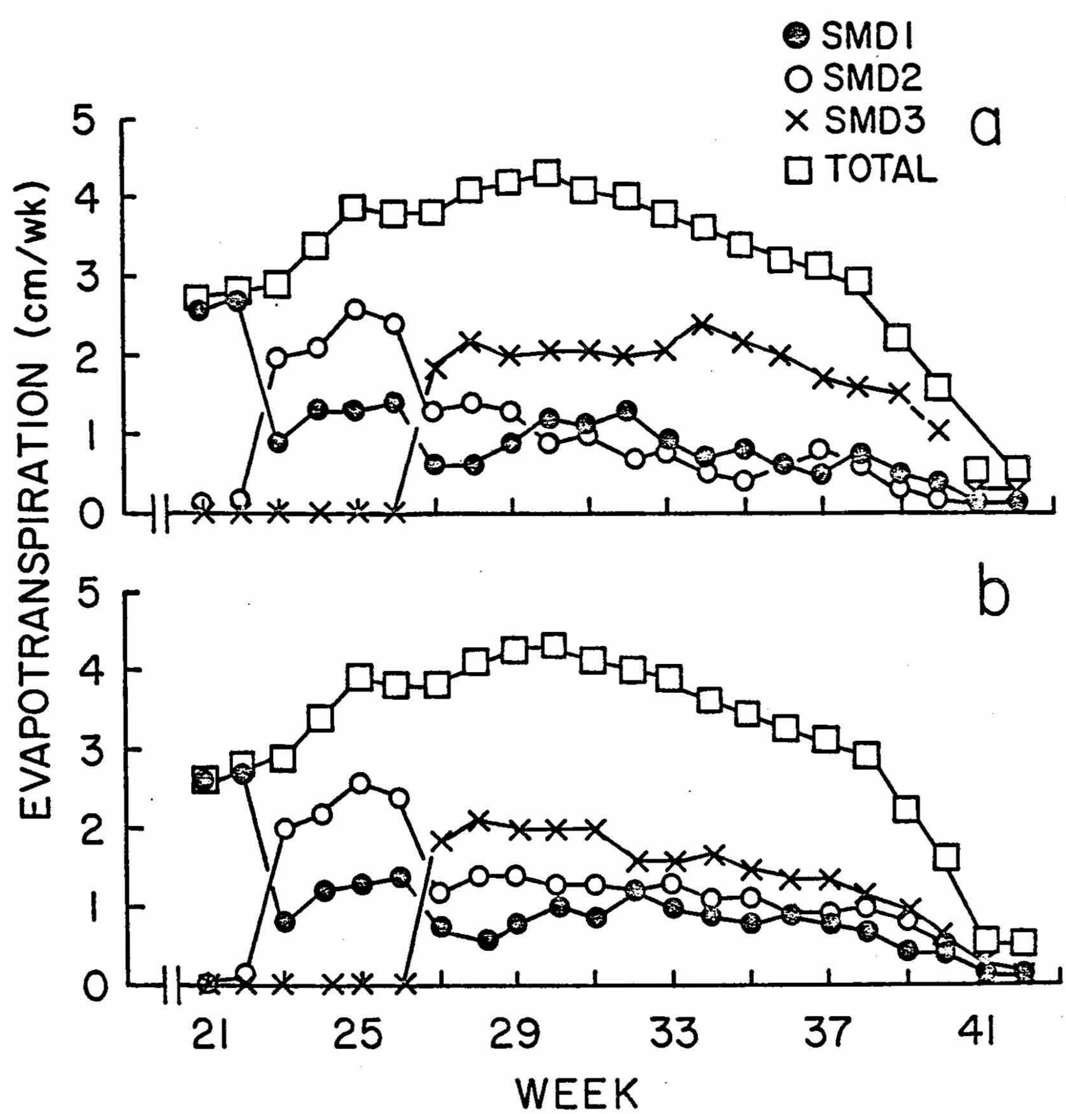


Fig. 12 - Evapotranspiration details during the soybean season where a) rotation was rice-soybean-soybean with soybean not irrigated or b) rotation was rice-soybean with soybean irrigated.

Evapotranspiration during the rice season while the rice was flooded is shown in Fig. 13. These results illustrated the decline in evaporation from the floodwater surface which tended to concentrate floodwater salts and the rise in transpiration which did not alter floodwater salt concentrations.

Floodwater Depth and Concentration Details

Figures 14 and 15 present weekly floodwater depths and ion concentrations during rice for the rice-soybean rotation with irrigation and the rice-soybean-soybean rotation without irrigation, respectively. Floodwater depths were variable for both management regimes. Depth patterns with time were also erratic except for the depth decrease to a minimum at about week 32. This minimum corresponded to a dramatic decrease in precipitation which occurred after week 32 (Fig. 9).

Floodwater ion concentrations also followed similar patterns for the two rotations. The rapid decline in calcium was due to calcium carbonate precipitate formation with the other ions showing similar patterns of decline until week 32 when small increases were noted. While these concentrations reflected the combined influence of several factors outlined in the model description, it would appear that the precipitation increases from week 24 to 32 (Fig. 9) effectively diluted floodwater concentrations, while salt additions via irrigation increased concentrations after that time as evaporation from the floodwater surface was set to zero after week 28.

Mean Yearly Water Balances

Mean yearly water balances for the rice-soybean rotation with soybean irrigated and rice-soybean-soybean rotation with soybean not irrigated are presented in Tables 4 and 5, respectively.

Evapotranspiration was similar for both rotations during rice and

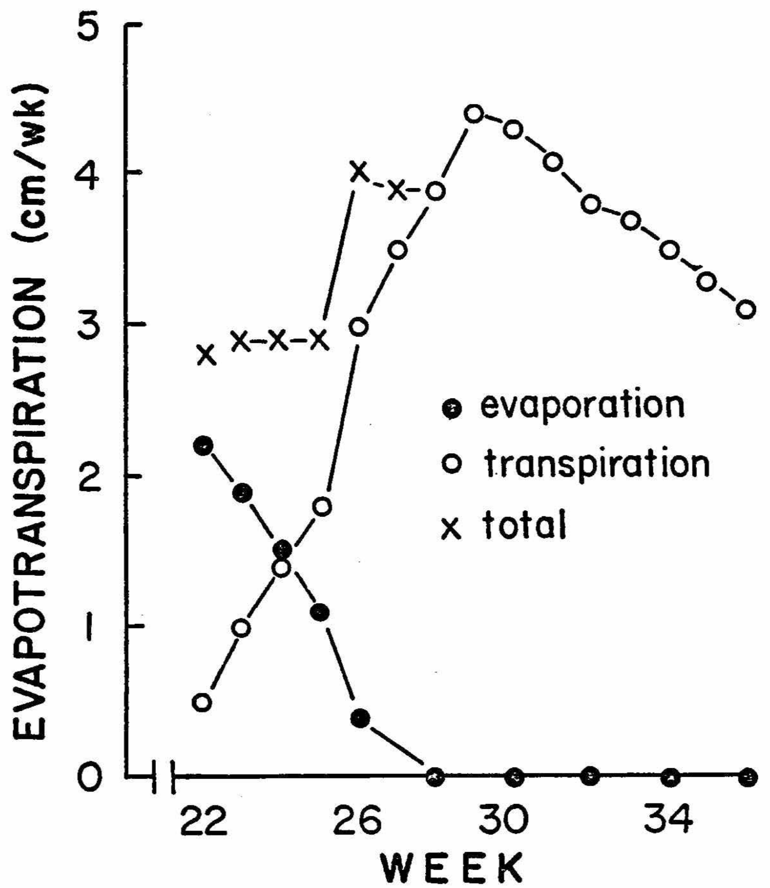


Fig. 13 - Evapotranspiration details during the flooded rice season.

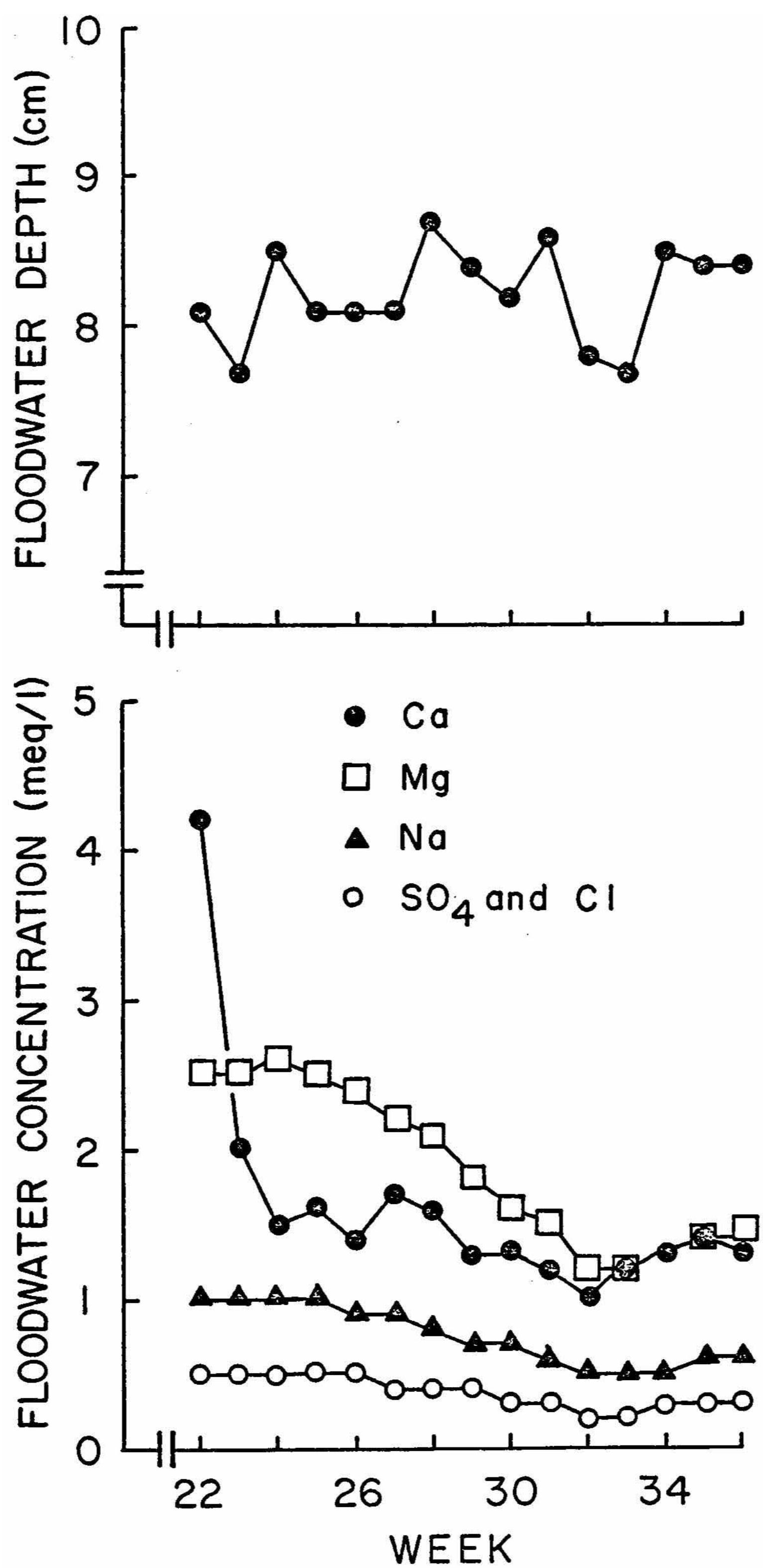


Fig. 14 - Floodwater depths and ion concentrations for rice season when in rice-soybean rotation with soybean irrigated.

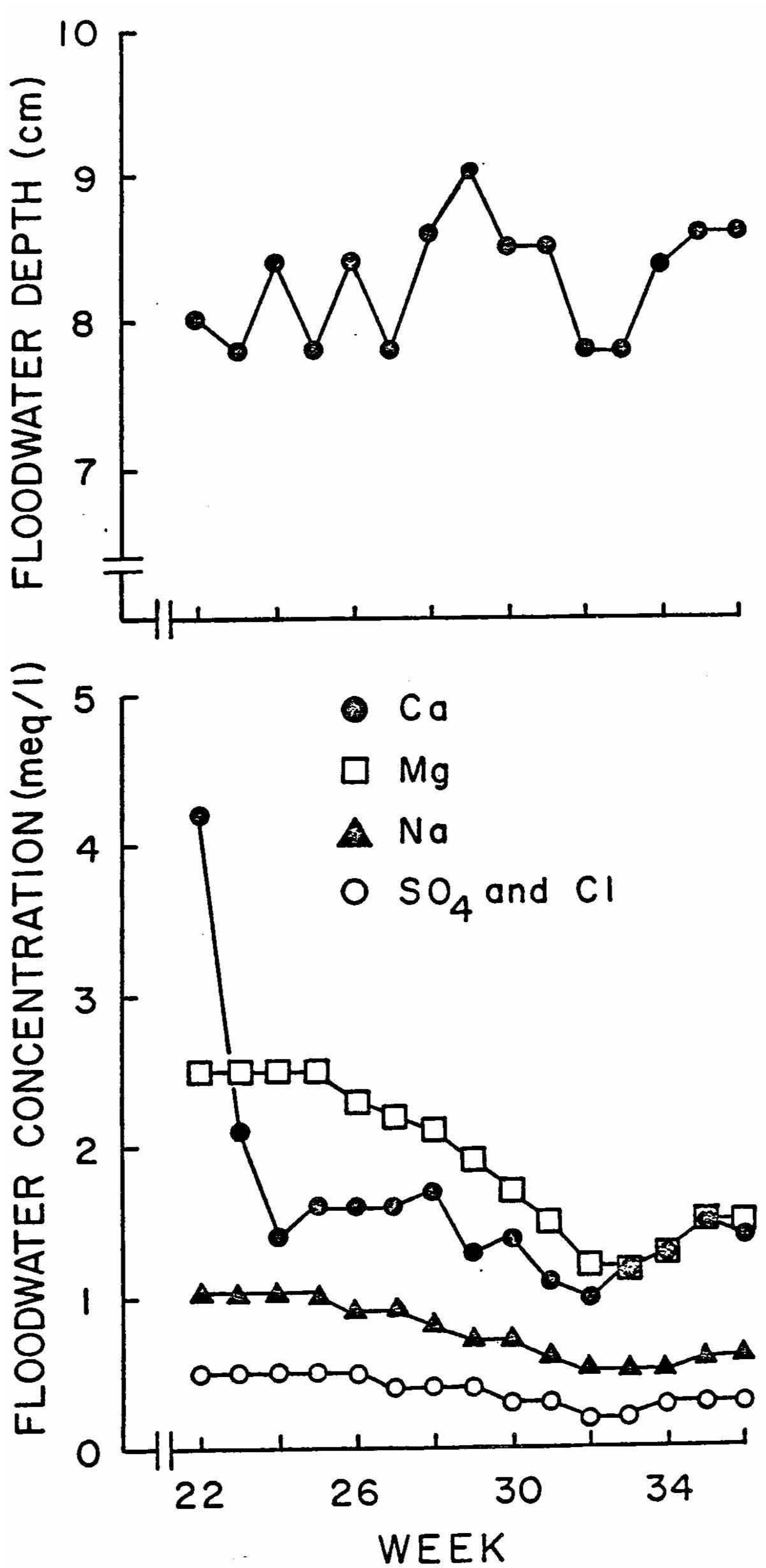


Fig. 15 - Floodwater depths and ion concentrations for rice season when in rice-soybean-soybean rotation with soybean not irrigated.

Table 4 - Mean yearly water and salt balances for the rice-soybean rotation with soybeans irrigated.

WATER BALANCE (cm/yr)

Crop	Evapo-transpiration	Infiltration	Runoff	Precipitation	Irrigation	Change in Storage
Rice	53	10	12	31	46	10
Soybeans	69	48	5	42	11	-21
Fallow	50	55	30	85		5
Annual	111	84	39	121	29	-0

SALT BALANCE (kg/ha/yr)

Salt	Transpi-ration	Infil-tration	Fertil-izer	Surface	Total	Crop Uptake	Erosion	Runoff	Total	Change in Storage
				Rice						
Ca	143	199		35	369	1	0	35	36	334
Mg	92	25		21	138	6	0	21	27	112
K	70	19		16	106	6	0	16	22	84
K	12	3		3	18	17	0	3	20	-2
SO4	73	20		17	111	17	0	17	33	78
CL	53	15		12	81	12	0	12	24	56
				Soybeans						
Ca		89		0	89	4	1	3	8	81
Mg		33		0	33	6	0	3	8	25
NA		26		0	26	15	0	2	17	8
K		4		0	4	44	0	2	47	-42
SO4		27		0	27	14	0	2	17	10
CL		19		0	19	3	0	2	6	14
				Fallow						
Ca			0		0		5	7	12	-12
Mg			0		0		1	5	6	-6
NA			0		0		0	11	11	-11
K			0		0		0	8	9	-9
SO4			0		0		0	19	19	-19
CL			0		0		0	25	25	-25
				Annual						
Ca	71	144	0	18	299	2	5	26	34	196
Mg	46	29	0	10	86	6	1	17	23	63
NA	35	22	0	8	66	10	0	20	31	35
K	6	4	0	1	11	31	0	11	42	-31
SO4	37	23	0	8	69	15	0	29	45	24
CL	27	17	0	6	50	8	0	32	40	10

Table 5 - Mean yearly water and salt balances for the rice-soybean-soybean rotation with soybeans not irrigated.

WATER BALANCE (cm/yr)

Crop	Evapo-transpiration	Infiltration	Runoff	Precipitation	Irrigation	Change in Storage
Rice	53	13	13	31	49	13
Soybeans	69	38	4	42	0	-31
Fallow	45	60	23	83		15
Annual	109	90	30	121	16	-1

SALT BALANCE (kg/ha/yr)

Salt	Transpi-ration	Infil-tration	Fertil-izer	Surface	Total	Crop Uptake	Erosion	Runoff	Total	Change in Storage
					Rice					
Ca	145	218		35	391	1	0	35	35	356
Mg	92	33		21	147	6	0	21	27	120
NA	71	25		16	112	6	0	16	22	90
K	12	4		3	19	17	0	3	20	-1
SO4	74	26		17	117	17	0	17	33	84
CL	54	19		12	86	12	0	12	25	61
					Soybeans					
Ca		0		0	0	2	1	2	5	-5
Mg		0		0	0	4	0	2	6	-6
NA		0		0	0	9	0	2	11	-11
K		0		0	0	28	0	2	30	-30
SO4		0		0	0	9	0	2	11	-11
CL		0		0	0	2	0	2	4	-4
					Fallow					
Ca			0		0		4	5	9	-9
Mg			0		0		0	4	4	-4
NA			0		0		0	8	8	-8
K			0		0		0	6	7	-7
SO4			0		0		0	13	13	-13
CL			0		0		0	17	17	-17
					Annual					
Ca	48	73	0	12	130	2	4	18	24	106
Mg	31	11	0	7	49	4	1	12	17	32
NA	24	8	0	5	37	8	0	14	23	14
K	4	1	0	1	6	24	0	9	33	-27
SO4	25	9	0	6	39	12	0	20	32	7
CL	18	6	0	4	29	6	0	23	28	0

soybean with a 5cm reduction in fallow evapotranspiration occurring where soybeans were not irrigated. Annual evapotranspiration was similar in both cases. Infiltration was greater during the soybean season when soybeans were irrigated and was greater during rice and fallow periods when soybeans were not irrigated. Runoff was similar for both rotations during rice and soybean seasons and was smaller during fallow for the rotation without irrigation. Annual infiltration was higher and runoff lower for the rice-soybean-soybean rotation with soybeans irrigated as compared to the non-irrigated rotation. The irrigation requirement was somewhat less during rice for the rice-soybean rotation with soybeans irrigated than the non-irrigated soybean case. The change in storage component reflected the above differences for the rice, soybean and fallow seasons and yielded a near zero annual value for both rotations.

<u>Mean Yearly Salt Balances</u>

Mean yearly salt balances for the rice-soybean rotation with soybean irrigated and rice-soybean-soybean rotation with soybean not irrigated are also presented in Tables 4 and 5, respectively. Irrigation water calcium, magnesium, sodium, potassium, sulfate and chloride concentrations were set at 4.0, 2.5, 1.0, 0.1, 0.5 and 0.5 meq/l, respectively, for these results.

Salt inputs were via: a) water that infiltrated as a result of transpiration by the rice crop (transpiration), b) direct infiltration of irrigation water during rice and/or soybean crops (infiltration), c) fertilizer additions which were set to zero as discussed above and d) a component which was added as irrigation, but ran off (surface). The deposition of lime during rice was added to the infiltration component. Salt outputs were: a) crop uptake, b) erosion and c) runoff. The difference between total inputs and total outputs was the change in storage.

Salt additions were somewhat higher during the rice season when rice was rotated with 2 years of soybean, while salt losses were comparible for both rotations. Most of the total salt additions during rice were due to infiltration of water to meet transpirational needs except for calcuim where about 40 percent of the direct infiltration component was calcium carbonate. A net increase in the change in storage occurred for calcuim, magnesuim, sodium, sulfate and chloride, while potassium yielded a near zero value.

During the soybean season, salt additions due to irrigation for the rice-soybean-soybean rotation were about 25 percent of the additions of the corresponding rice year. Total salt removals were largest when soybeans were irrigated due to the yield and concomitant crop uptake increases from irrigation. The change in storage for the rotation with soybean irrigated showed net positive values for all salts except potassium, while negative changes in storage were obtained for all salts when soybeans were not irrigated.

The fallow season for both rotations was a period where negative changes in storage were obtained due to runoff. The larger runoff volume during the fallow period for the rice-soybean rotation with soybean irrigated lead to more salt loss and the greatest negative values of change in storage.

The annual salt balances for the two rotations pointed out that much greater accumulations of salt occurred during the rice-soybean rotation with soybean irrigated than the rice-soybean-soybean rotation with soybean not irrigated. In order of amount, net positive accumulations of calcuim, magnesium, sodium and sulfate were found for both rotations with chloride accumulations being small or zero. A net loss in potassium occurred in both rotations as no KCl fertilizer was added.

The salt balances described above were for a given water quality and represented extremes with respect to rotation and water management. When the model was used to evaluate the effect of irrigation water quality upon mean yearly (annual) salt accumulations the results shown in Fig. 16 were obtained. For each ion and calcuim carbonate, a linear increase in net addition to the soil was found as the concentration of the component in question increased. The slopes for the rice-soybean rotation with soybean irrigated were larger than for the rice-soybean-soybean rotation with soybean not irrigated. For the concentration of 2 to 4 meq/l in the irrigation water the net annual addition followed the order sulfate > chloride > calcium > sodium > magnesium.

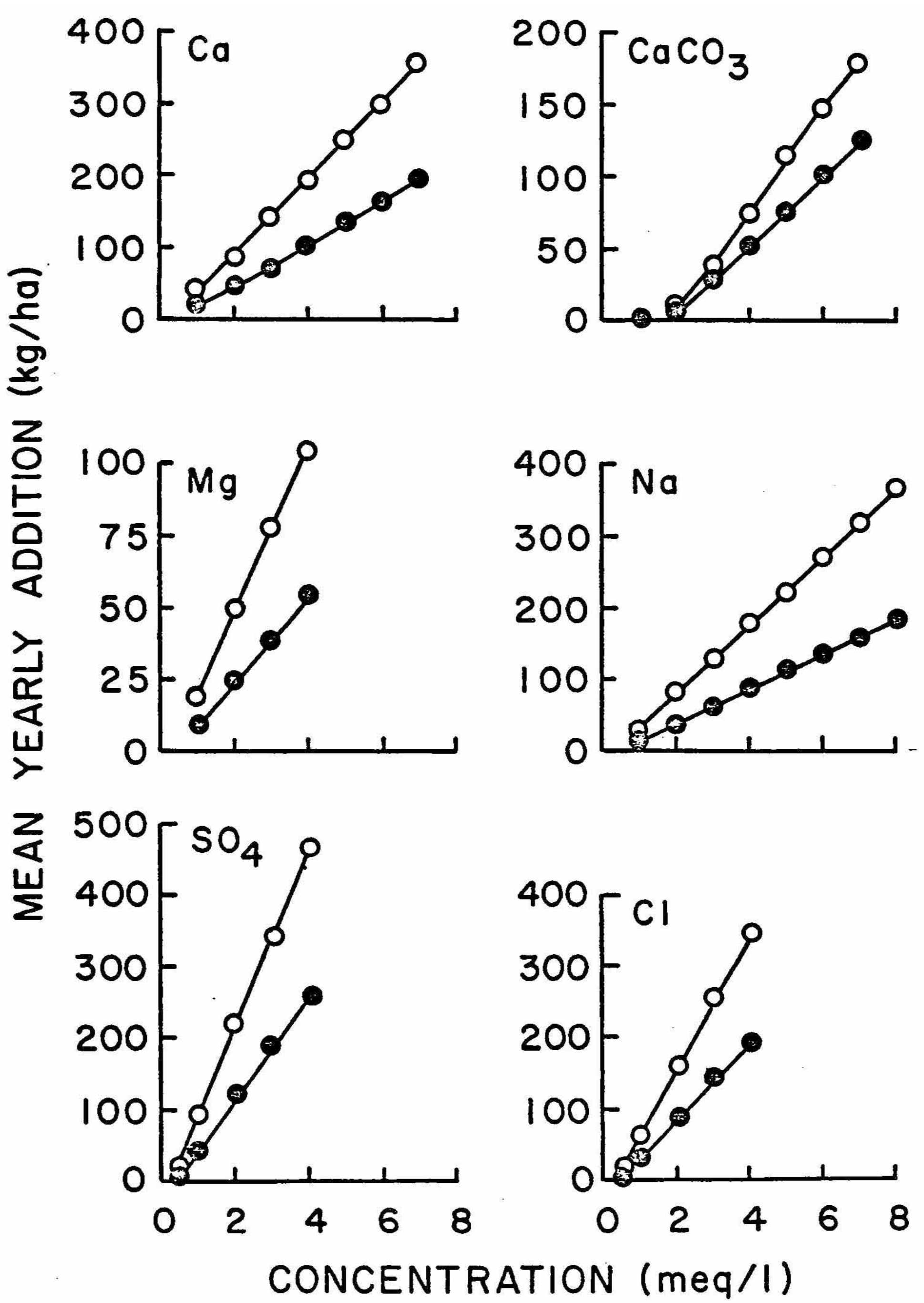


Fig. 16 - Mean yearly(annual)salt additions as a function of irrigation water contraction.

Literature Cited

1. Bondurant, J.A. 1971. Quality of surface irrigation water. Trans. Amer. Soc. Agr. Eng. 14:1001-1003.

2. Gilmour, J.T., K.S. Shirk, J.A. Ferguson, and C.L. Griffis. 1978. A kinetic study of the $CaCO_3$ precipitation reaction. Agri. Water Manag. 1:253-262.

3. Gilmour, J.T. and D.B. Marx. 1981. Soluble salt concentrations in runoff waters from soils previously cropped to rice. Soil Sci. Soc. Amer. Jour. 45(6) in press.

4. Green, R.E. and J.C. Corey. 1971. Calculation of hydraulic conductivity: A further evaluation of some predictive methods. Soil Sci. Soc. Amer. Proc. 35:3-8.

APPENDIX

```
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2 .80 .80 0.47 0.01 0.68 1.99 0.00 0.49 0.23 0.20 0.09 3.82 1.28
3 .80 .80 0.48 0.00 0.11 0.00 0.70 0.12 0.00 0.02 2.82 0.34 0.45
4 .80 .80 0.52 0.43 1.00 0.72 0.36 0.09 0.98 0.78 1.23 1.54 0.17
5 .80 .80 0.56 0.64 0.23 1.06 4.58 1.32 0.24 0.01 1.12 0.01 1.76
6 .80 .80 0.61 4.75 0.00 0.00 0.33 0.18 0.38 0.27 2.03 0.12 0.86
7 .80 .80 0.67 1.44 0.08 0.40 1.07 1.74 1.33 0.13 0.66 0.62 0.44
8 .80 .80 0.76 0.33 1.39 0.04 0.69 0.81 2.01 0.31 0.00 1.04 0.73
9 .80 .80 0.83 0.51 0.58 0.54 0.01 3.17 0.40 1.14 0.95 0.00 0.09
10 .80 .80 0.94 0.00 1.88 1.04 0.44 0.00 0.91 0.59 1.19 0.91 0.99
11 .80 .80 1.02 0.05 0.00 1.63 0.54 1.48 1.26 0.56 2.55 0.24 5.94
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13 .80 .80 1.21 0.16 0.94 0.27 0.22 0.99 0.82 0.75 1.00 0.41 2.36
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15 .80 .80 1.40 0.05 0.22 0.96 1.47 0.11 0.00 0.04 0.48 1.60 0.86
16 .80 .80 1.46 1.30 4.91 0.03 0.42 2.73 1.03 0.36 7.85 3.30 0.10
17 .80 .80 1.52 4.52 4.18 1.44 0.60 1.55 0.56 0.37 4.53 0.07 1.26
18 .80 .80 1.58 1.59 0.46 0.95 0.35 2.30 0.12 1.76 1.14 1.24 2.42
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21 .80 .80 1.78 0.00 2.72 0.27 0.70 0.00 1.60 0.00 2.01 1.41 0.09
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24 .80 .80 1.96 0.00 0.05 0.17 1.34 0.00 1.09 0.12 0.34 0.47 1.03
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26 .84 .80 1.90 0.06 1.57 1.02 0.28 0.47 1.35 1.49 0.44 0.00 0.84
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44 .80 .80 0.79 0.17 0.39 0.05 0.01 0.22 0.02 2.48 0.97 3.27 0.08
45 .80 .80 0.72 0.91 0.10 0.48 2.76 1.14 0.34 5.02 1.55 1.72 0.45
46 .80 .80 0.65 0.09 0.31 0.40 1.13 0.62 0.82 1.22 0.67 0.38 0.00
47 .80 .80 0.60 1.00 0.82 0.52 0.15 0.25 0.48 2.38 2.57 1.54 0.19
48 .80 .80 0.55 0.00 2.00 3.20 1.62 0.00 1.92 0.02 3.40 0.22 2.20
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```

```
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  /**********************************************************************
 ***/
  /**************************************************/
  /*TO CREATE WEATH, SUB SBJCL, THEN SUB SBFILE*/
  /**************************************************/
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 DCL(SUMFAL,SUMRICE,SUMSOY,FALWAT,RICEWAT,SOYWAT)ENTRY;
 DCL(YEAR,WEEK,CROP,POTASH,MOISTURE,PLACE)FIXED;
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 DCL(WATUP1(1:52),WATUP2(1:52),WATUP3(1:52),WATE(1:52),WATT(1:52))FLOAT;

 DCL(TOT(1:52),DTOT(1:52),CONC(1:52,1:6),MU,MGI)FLOAT;
 DCL(ROR(1:52),ROS(1:52),IRRR(1:52),INR(1:52),INS(1:52),IRRS(1:52)
 ,TRAIN(1:52))FLOAT;
 DCL(SMD1,SMD2,SMD3,RAINLEFT,SMD1DEL,SMD2DEL,SMD3DEL)FLOAT;
 DCL(DUMMY,DUMMY1,DUMMY2,DUMMY3,DUMMY4)FLOAT;
 DCL(SMD1FACT,SMD2FACT,SMD3FACT)FLOAT;
 DCL(DEP(1:9),SDEP(1:9),SMT(1:9),WPOT(1:9),THETA(1:9),KTHETA(1:9),SEG(1:
 9))
 FLOAT;
 DCL(KSEG,WSAT(1:9))FLOAT;
 DCL(K1(1:6),C1(1:6),C2(1:6),WAT(1:6),STORAGE(1:6),INPUT(1:6))FLOAT;
 DCL(OUTPUT(1:6),SFERT(1:6),SEROS(1:6),TFERT(1:6),TEROS(1:6))FLOAT;
 DCL(SET(1:6),SINFIL(1:6),SROFF(1:6),SIRR(1:6),SCROP(1:6))FLOAT;;
 DCL(TET(1:6),TINFIL(1:6),TROFF(1:6),TIRR(1:6),TCROP(1:6),TSURF(1:6))FLO
 AT;
 DCL(SE(1:6),ST(1:6),RT(1:6),RE(1:6),RTOTAL(1:6),SSURF(1:6))FLOAT;
 DCL(KRICE,KSOY,INFIL,B,KG)FLOAT;
 DCL(SOIL(1:6),RWAT(1:6),RISEED(1:6),SOYSEED(1:6))FLOAT;
 DCL NAME(1:6) CHAR(11);
 DCL(FFERT(1:6),FROFF(1:6),FEROS(1:6),FINPUT(1:6),FOUTPUT(1:6),FSTORAGE(
 1:6))
 FLOAT;
 DCL(RET(1:6),RINFIL(1:6),RCROP(1:6),REROS(1:6),RROFF(1:6),RINPUT(1:6))F
 LOAT;
 DCL(ROUTPUT(1:6),RSTORAGE(1:6),RIRR(1:6),RSURF(1:6))FLOAT;
 DCL(SOINFIL(1:6),SOCROP(1:6),SOEROS(1:6),SOROFF(1:6))FLOAT;
 DCL(SINPUT(1:6),SOUTPUT(1:6),SSTORAGE(1:6))FLOAT;
 DCL(SOIRR(1:6),SOSURF(1:6))FLOAT;
  /*****************/
  /*INITIAL VALUES*/
  /*****************/
 SR1=0; SR2=0; SR3=0; SB1=0; SB2=0; SB3=0; XCACO3=0;
 WATUP1=0; WATUP2=0; WATUP3=0; WATE=0; WATT=0; DTOT=0; CONC=0;
 ROR=0; ROS=0; IRRR=0; INR=0; INS=0; IRRS=0; TRAIN=0;
 DO I=1 TO 6;
 RET(I)=0; RINFIL(I)=0; RCROP(I)=0; REROS(I)=0; RROFF(I)=0; RIRR(I)=0;
 RSURF(I)=0; SE(I)=0; ST(I)=0; RT(I)=0; RE(I)=0; RTOTAL(I)=0; SSURF(I)=0
```

```
;
SOINFIL(I)=0; SOCROP(I)=0; SOEROS(I)=0; SOROFF(I)=0; SOIRR(I)=0;
FEROS(I)=0; FROFF(I)=0; FFERT(I)=0; SOSURF(I)=0;
END;
RDET=0; RDINFIL=0; RDROFF=0; RDRAIN=0; RDIRR=0;
RDE=0; RDT=0;
SDET=0; SDINFIL=0; SDROFF=0; SDRAIN=0; SDIRR=0;
FDET=0; FDINFIL=0; FDROFF=0; FDRAIN=0;
YEAR=0; CUMROFF=10;
 /***********/
 /*CONSTANTS*/
 /***********/
BSL=0.457; CSL=6.21E-22; DSL=121.1; MSL=-0.04065;
BC=0.552; CC=2.27E-19; DC=80.88; MC=-0.04036;
DEP(1)=-1.25; DEP(2)=-5.05; DEP(3)=-10.15; DEP(4)=-19.05; DEP(5)=-31.75
;
DEP(6)=-44.45; DEP(7)=-68.6; DEP(8)=-104.2; DEP(9)=-139.8;
SDEP(1)=2.5; SDEP(2)=5.1; SDEP(3)=5.1; SDEP(4)=12.7; SDEP(5)=12.7;
SDEP(6)=12.7; SDEP(7)=35.6; SDEP(8)=35.6; SDEP(9)=35.6;
WSAT(1)=1.1; WSAT(2)=2.3; WSAT(3)=2.3; WSAT(4)=5.7; WSAT(5)=5.7;
WSAT(6)=5.7; WSAT(7)=19.6; WSAT(8)=19.6; WSAT(9)=19.6;
K1(1)=2.0;K1(2)=1.2;K1(3)=2.3;K1(4)=3.9;K1(5)=4.8;K1(6)=3.5;
SOIL(1)=1280;SOIL(2)=160;SOIL(3)=100;SOIL(4)=70;SOIL(5)=55;SOIL(6)=0;
RISEED(1)=.017;RISEED(2)=.122;RISEED(3)=.129;RISEED(4)=.351;RISEED(5)=.
346;
RISEED(6)=.257;SOYSEED(1)=.142;SOYSEED(2)=.216;SOYSEED(3)=.548;
SOYSEED(4)=1.648;SOYSEED(5)=.535;SOYSEED(6)=.126;
DMAX=10;DMIN=5; P1=0;P2=20; DEPTH=3.2;
YIELDRI=4800;
NAME(1)='CA'; NAME(2)='MG'; NAME(3)='NA'; NAME(4)='K';
NAME(5)='SO4'; NAME(6)='CL';
SMD1=1.9; SMD2=6.4; SMD3=11.8;
SEG(1)=0.4; SEG(2)=0.75; SEG(3)=0.75; SEG(4)=2.1; SEG(5)=2.1; SEG(6)=2.
1;
SEG(7)=3.9; SEG(8)=3.9; SEG(9)=4.0;
 /***********/
 /*QUESTIONS*/
 /***********/
BEGIN:
GET LIST(WAT(1),WAT(2),WAT(3),WAT(4),WAT(5),WAT(6));
GET LIST(POTASH,RATE);
GET LIST(ROT);
GET LIST(MOISTURE);
GET LIST(INFO);
PUT SKIP LIST('DATA IN');
 /*************************************/
 /*EQUILIBRIUM CALCIUM CONCENTRATION*/
 /*************************************/
ITER=0;
X=0.0001; HCO3=WAT(1)+WAT(2)+WAT(3)+WAT(4)-WAT(5)-WAT(6);
CAI=WAT(1)/2000; MGI=WAT(2)/2000; NAI=(WAT(3)+WAT(4))/1000;
HCO3I=HCO3/1000; SO4I=WAT(5)/2000; CLI=WAT(6)/1000;
INIT: CAI=CAI-X; HCO3I=HCO3I-2*X; ITER=ITER+1;
MU=2*CAI+2*MGI+NAI/2+HCO3I/2+2*SO4I+CLI/2;
```

```
PKSPE=-LOG10(CAI)-LOG10(HCO3I)+2.55*(SQRT(MU)/(1+SQRT(MU))-0.2*MU)+2.3;

IF ITER=1 & PKSPE>8.01 THEN DO; CAEQ=10; GO TO START; END;
IF PKSPE<=8.01 THEN GO TO INIT;
IF PKSPE>8.02 THEN DO; CAI=CAI+X; HCO3I=HCO3I+2*X; X=X/10; GO TO INIT;
END;
CAEQ=CAI*2000;
 /********************/
 /*SET YEAR AND CROP*/
 /********************/
START: YEAR=YEAR+1; CROP=0;
CHANGE: CROP=CROP+1;  IRRIG=0;
OPEN FILE (WEATH)INPUT;  WEEK=1;
 /********************/
 /*WEATHER DATA FILE*/
 /********************/
FALLOW:
IF YEAR=1 THEN GET FILE(WEATH)LIST(WEEK.KRICE,KSOY,PEVAP,DRAIN,A,B.C,D,
E
,F,G,H,X);
IF YEAR=2 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,DRAIN,B.C,D,
E
,F,G,H,X);
IF YEAR=3 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,B,DRAIN,C,D,
E
,F,G,H,X);
IF YEAR=4 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,B,C,DRAIN,D,
E
,F,G,H,X);
IF YEAR=5 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,B,C,D,DRAIN,
E
,F,G,H,X);
IF YEAR=6 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,B,C,D,E,DRAI
N
,F,G,H,X);
IF YEAR=7 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,B,C,D,E,F,
DRAIN,G,H,X);
IF YEAR=8 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,B,C,D,E,F,G,

DRAIN,H,X);
IF YEAR=9 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,B,C,D,E.F,G,
H
,DRAIN,X);
IF YEAR=10 THEN GET FILE(WEATH)LIST(WEEK,KRICE,KSOY,PEVAP,A,B,C,D,E,F
,G,H,X,DRAIN);
DRAIN=DRAIN*2.5; PEVAP=PEVAP*2.5;
TRAIN(WEEK)=TRAIN(WEEK)+DRAIN;
DROFF=0; DINFIL=0;
 /**********************************/
 /*RUNOFF WATER ION CONCENTRATIONS*/
 /**********************************/
ROQUAL: PROC;
IF CUMROFF<10 THEN DO;
```

```
RWAT(1)=WAT(1)*EXP(-0.28*CUMROFF-1.00);
RWAT(2)=WAT(2)*EXP(-0.27*CUMROFF-0.45);
RWAT(3)=WAT(3)*EXP(-0.23*CUMROFF+0.20);
RWAT(4)=WAT(4)*EXP(-0.12*CUMROFF+0.80);
RWAT(5)=WAT(5)*EXP(-0.44*CUMROFF-2.43*WAT(5)+3.44);
RWAT(6)=WAT(6)*EXP(-0.35*CUMROFF-2.43*WAT(6)+3.44);
END; ELSE DO;
RWAT(1)=WAT(1)*0.022; RWAT(2)=WAT(2)*0.043; RWAT(3)=WAT(3)*0.122;
RWAT(4)=WAT(4)*0.670; RWAT(5)=WAT(5)*EXP(-2.43*WAT(5)-0.96);
RWAT(6)=WAT(6)*EXP(-2.43*WAT(6)-0.06); END;
END ROQUAL;
 /*********/
 /*ROUTING*/
 /*********/
IF YEAR=11 THEN GO TO SUMMARY;
IF CROP=1 THEN DO; IF WEEK>21 & WEEK<37 THEN GO TO RICE;  END;
IF CROP>1 THEN DO; IF WEEK>20 & WEEK<43 THEN GO TO SOYBEAN; END;
 /****************************************/
 /*SALT BALANCE WHEN SOIL IS NOT CROPPED*/
 /****************************************/
IF WEEK=17 & POTASH=1 THEN CALL FERT;
DET=(-1.0*SEG(1)+1.0)*PEVAP;
IF SEG(1)<0.2 THEN DET=0.80*PEVAP;
IF SEG(1)>0.8 THEN DET=0.20*PEVAP;
DUMMY4=DET;
DO J=1 TO 9;
SEG(J)=SEG(J)+DET;
IF SEG(J)<=WSAT(J) THEN GO TO PT12;
DET=SEG(J)-WSAT(J); SEG(J)=WSAT(J); END;
PT12: DET=DUMMY4;
SMD1=SEG(1)+SEG(2)+SEG(3);
SMD2=SEG(4)+SEG(5)+SEG(6);
SMD3=SEG(7)+SEG(8)+SEG(9);
IF DRAIN=0 THEN CALL MOV;
IF DRAIN>0 THEN DO; PLACE=1; GO TO RAIN; END;
PT1: IF DRAIN>0 THEN DROFF=DRAIN-DINFIL; ELSE DROFF=0;
CUMROFF=CUMROFF+DROFF;
CALL ROQUAL;
CALL FALWAT;
IF DROFF>0 THEN DO I=1 TO 6;
SROFF(I)=RWAT(I)*DROFF*K1(I);
IF WEEK>13 & WEEK<23 THEN SEROS(I)=SOIL(I)*DROFF*.000166;
ELSE SEROS(I)=SOIL(I)*DROFF*.000105; END;
ELSE DO; SROFF=0; SEROS=0; END;
SIRR=0;  SFERT=0;  CALL SUMFAL;
IF WEEK=52 THEN DO;  CLOSE FILE(WEATH);
IF CROP=(ROT+1) THEN GO TO START;  ELSE GO TO CHANGE;  END;
GO TO FALLOW;
 /*********************************************/
 /*SALT BALANCE WHEN SOIL IS CROPPED TO RICE*/
 /*********************************************/
RICE:
CACO3=0; DIRR=0;
```

```
IF WEEK=22 THEN DO; D1=DMAX*(1+P1/100);  DO I=1 TO 6; C1(I)=WAT(I);
END; END;
DET=KRICE*PEVAP;
IF WEEK<28 THEN DO;  FT=(14*(WEEK-22)+19.5)/100;
DE=DET*(1-FT);  DT=DET*FT;  END;
ELSE DO;  DE=0;  DT=DET;  END;
WATE(WEEK)=WATE(WEEK)+DE; WATT(WEEK)=WATT(WEEK)+DT;
DUMMY2=DRAIN; DRAIN=D1; PLACE=2; GO TO RAIN; PT2: DRAIN=DUMMY2;
D2=D1+DRAIN-DE-DT-DINFIL;
IF D2>DMAX THEN DO; DROFF=D2-DMAX; D2=DMAX; END;
IF D2<DMIN & WEEK>22 THEN DO;
DIRR=(DMAX-D2)*(1+P1/100); D2=D1+DRAIN+DIRR-DE-DT-DINFIL;
IF D2>DMAX THEN DO; DROFF=D2-DMAX; D2=DMAX; END; END;
IF D2<0 THEN PUT EDIT('D2 NEGATIVE')(A);
DO I=1 TO 6  ;
C2(I)=(C1(I)*D1+WAT(I)*DIRR)/(D1+DRAIN+DIRR-DE);
IF C2(I)<0 THEN PUT EDIT('C2 NEGATIVE')(A);
CALL SALTSUB;
END;
DTOT(WEEK)=DTOT(WEEK)+(D1+D2)/2;
IF WEEK=36 THEN CALL RICEUPT; ELSE SCROP=0;
D1=D2;
CALL SUMRICE;
IF WEEK=36 THEN DO; DROFF=DROFF+D2; CUMROFF=0; END;
CALL RICEWAT; GO TO FALLOW;
 /*************************/
 /*WEEKLY SALT IO FOR RICE*/
 /*************************/
SALTSUB: PROC;
ST(I)=K1(I)*DT*C2(I);
SINFIL(I)=K1(I)*DINFIL*C2(I);
SROFF(I)=K1(I)*DROFF*C2(I);
IF WEEK=22 THEN DIRR=DMAX*(1+P1/100);
IF WEEK=36 THEN SROFF(I)=SROFF(I)+K1(I)*C2(I)*D2;
SIRR(I)=K1(I)*DIRR*WAT(I);
SSURF(I)=SROFF(I);
SEROS=0; SCROP=0;
CONC(WEEK,I)=CONC(WEEK,I)+(C1(I)+C2(I))/2;
C1(I)=C2(I);
END SALTSUB;
 /*******************************************/
 /*SALT BALANCE FOR SOIL CROPPED TO SOYBEAN*/
 /*******************************************/
SOYBEAN:
SEROS=0; SROFF=0;  SINFIL=0; SIRR=0;
DIRR=0; DUMMY1=0;
DET=KSOY*PEVAP;
IF (SMD1+SMD2+SMD3)>57.1 THEN DET=((81.6-(SMD1+SMD2+SMD3))/24.5)*DET;
SMD1FACT=(4.0-SMD1)/4.0; IF SMD1FACT<0 THEN SMD1FACT=0;
SMD2FACT=(12.0-SMD2)/12.0; IF SMD2FACT<0 THEN SMD2FACT=0;
SMD3FACT=(41.1-SMD3)/41.1; IF SMD3FACT<0 THEN SMD3FACT=0;
IF WEEK<27 THEN DO;
SMD1DEL=(SMD1FACT/(SMD1FACT+SMD2FACT))*DET;
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SMD2DEL=(SMD2FACT/(SMD1FACT+SMD2FACT))*DET;
SMD3DEL=0; END;
IF WEEK<23 THEN DO;
SMD1DEL=DET; SMD2DEL=0; SMD3DEL=0; END;
IF WEEK>26 THEN DO;
SMD1DEL=(SMD1FACT/(SMD1FACT+SMD2FACT+SMD3FACT))*DET;
SMD2DEL=(SMD2FACT/(SMD1FACT+SMD2FACT+SMD3FACT))*DET;
SMD3DEL=(SMD3FACT/(SMD1FACT+SMD2FACT+SMD3FACT))*DET;
END;
IF SMD1DEL>(5.7-SMD1) THEN DO; SMD2DEL=SMD2DEL+SMD1DEL-5.7+SMD1;
SMD1DEL=5.7-SMD1; END;
IF SMD2DEL>(17.1-SMD2) THEN DO; SMD3DEL=SMD3DEL+SMD2DEL-17.1+SMD2;
SMD2DEL=17.1-SMD2; END;
IF SMD3DEL>(58.7-SMD3)THEN DO; SMD3DEL=58.7-SMD3; END;
IF SMD3DEL<0 THEN PUT SKIP LIST(YEAR,CROP,WEEK,SMD3DEL);
DET=SMD1DEL+SMD2DEL+SMD3DEL;
SMD1=SMD1+SMD1DEL;
SMD2=SMD2+SMD2DEL;
SMD3=SMD3+SMD3DEL;
SEG(1)=SEG(1)+0.20*SMD1DEL; SEG(2)=SEG(2)+0.40*SMD1DEL;
SEG(3)=SEG(3)+0.40*SMD1DEL;
SEG(4)=SEG(4)+0.34*SMD2DEL; SEG(5)=SEG(5)+0.33*SMD2DEL;
SEG(6)=SEG(6)+0.33*SMD2DEL;
SEG(7)=SEG(7)+0.34*SMD3DEL; SEG(8)=SEG(8)+0.33*SMD3DEL;
SEG(9)=SEG(9)+0.33*SMD3DEL;
WATUP1(WEEK)=WATUP1(WEEK)+SMD1DEL;
WATUP2(WEEK)=WATUP2(WEEK)+SMD2DEL;
WATUP3(WEEK)=WATUP3(WEEK)+SMD3DEL;
IF DRAIN>0 THEN DO; PLACE=3; GO TO RAIN; END;
PT3: IF DRAIN>0 THEN DO;
IF DRAIN>DINFIL THEN DROFF=DRAIN-DINFIL; ELSE DROFF=0;
DUMMY1=DINFIL; END;
CUMROFF=CUMROFF+DROFF; CALL ROQUAL;
IF DROFF=0 THEN DO;  IF (SMD1+SMD2)>10.3 & WEEK<37 THEN DO;
IF IRRIG<5 & MOISTURE=1 THEN GO TO SOYIRR;  END; END;
PT5:
IF DIRR=0 & DRAIN=0 THEN CALL MOV;
CALL SOYWAT;
IF DROFF>0 & DIRR=0 THEN DO I=1 TO 6;
SEROS(I)=SOIL(I)*DROFF*0.000186; SROFF=K1(I)*DROFF*RWAT(I);
END;
IF WEEK=42 THEN CALL SOYUPT;   ELSE SCROP=0;
CALL SUMSOY;  GO TO FALLOW;
 /*************************/
 /*SOYBEANS ARE IRRIGATED*/
 /*************************/
SOYIRR:
IRRIG=IRRIG+1;
DIRR=DEPTH*(1+P2/100);
DUMMY3=DRAIN; DRAIN=DIRR; PLACE=4; GO TO RAIN; PT4: DRAIN=DUMMY3;
DROFF=DIRR-DINFIL+DUMMY1;
DO I=1 TO 6;
SEROS(I)=SOIL(I)*DROFF*0.000186; SROFF(I)=K1(I)*DROFF*WAT(I);
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SINFIL(I)=K1(I)*(DINFIL-DUMMY1)*WAT(I); SIRR(I)=K1(I)*DIRR*WAT(I);
SOSURF(I)=SOSURF(I)+SROFF(I); END;
GO TO PT5;
 /***************************************/
 /*INFILTRATION OF RAIN OR IRRIGATION*/
 /***************************************/
RAIN:
IF DRAIN>SMD1 THEN DO;
DUMMY=SMD1; DINFIL=DINFIL+SMD1; SMD1=0;
DO J=4 TO 6;
WMOV=-0.11*5.7; WMOV=-MIN(-WMOV,SEG(J));
SEG(J)=SEG(J)+WMOV; SMD1=SMD1-WMOV; END;
DO J=7 TO 9;
WMOV=-0.09*5.7; WMOV=-MIN(-WMOV,SEG(J));
SEG(J)=SEG(J)+WMOV; SMD1=SMD1-WMOV; END;
RAINLEFT=DRAIN-DUMMY;
IF RAINLEFT>SMD1 THEN DO;
DINFIL=DINFIL+SMD1; SMD1=0; END;
ELSE DO;
DINFIL=DINFIL+RAINLEFT; SMD1=SMD1-RAINLEFT;
END; END;
IF DRAIN<=SMD1 THEN DO;
DINFIL=DINFIL+DRAIN; SMD1=SMD1-DRAIN;
DO J=4 TO 6;
WMOV=-0.10*(5.7-SMD1); WMOV=-MIN(-WMOV,SEG(J));
SEG(J)=SEG(J)+WMOV; SMD1=SMD1-WMOV; END;
END;
SEG(1)=0.2*SMD1; SEG(2)=0.4*SMD1; SEG(3)=0.4*SMD1;
SMD2=SEG(4)+SEG(5)+SEG(6);
SMD3=SEG(7)+SEG(8)+SEG(9);
CALL MOV;
IF PLACE=1 THEN GO TO PT1; IF PLACE=2 THEN GO TO PT2;
IF PLACE=3 THEN GO TO PT3; IF PLACE=4 THEN GO TO PT4;
 /*************************/
 /*WATER MOVEMENT IN SOIL*/
 /*************************/
MOV: PROC;
DO J=1 TO 8;
IF J<6 THEN DO;
THETA(J)=((WSAT(J)-SEG(J))/WSAT(J))*0.45;
THETA(J+1)=((WSAT(J+1)-SEG(J+1))/WSAT(J+1))*0.45;
IF THETA(J)<=0.01 THEN THETA(J)=0.01;
SMT(J)=(THETA(J)/BSL)**(1/MSL);
IF THETA(J+1)<=0.01 THEN THETA(J+1)=0.01;
SMT(J+1)=(THETA(J+1)/BSL)**(1/MSL);
KTHETA(J)=CSL*EXP(DSL*THETA(J));
KTHETA(J+1)=CSL*EXP(DSL*THETA(J+1));
END;
IF J=6 THEN DO;
THETA(J)=((WSAT(J)-SEG(J))/WSAT(J))*0.45;
THETA(J+1)=((WSAT(J+1)-SEG(J+1))/WSAT(J+1))*0.55;
IF THETA(J)<=0.01 THEN THETA(J)=0.01;
SMT(J)=(THETA(J)/BSL)**(1/MSL);
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IF THETA(J+1)<=0.01 THEN THETA(J+1)=0.01;
SMT(J+1)=(THETA(J+1)/BC)**(1/MC);
KTHETA(J)=CSL*EXP(DSL*THETA(J));
KTHETA(J+1)=CC*EXP(DC*THETA(J+1));
END;
IF J>6 THEN DO;
THETA(J)=((WSAT(J)-SEG(J))/WSAT(J))*0.55;
THETA(J+1)=((WSAT(J+1)-SEG(J+1))/WSAT(J+1))*0.55;
IF THETA(J)<=0.01 THEN THETA(J)=0.01;
SMT(J)=(THETA(J)/BC)**(1/MC);
IF THETA(J+1)<=0.01 THEN THETA(J+1)=0.01;
SMT(J+1)=(THETA(J+1)/BC)**(1/MC);
PT11: SMT(J+1)=1E+43; THETA(J+1)=0.01;
KTHETA(J)=CC*EXP(DC*THETA(J));
KTHETA(J+1)=CC*EXP(DC*THETA(J+1));
END;
WPOT(J)=DEP(J)-SMT(J);
WPOT(J+1)=DEP(J+1)-SMT(J+1);
GRAD=(WPOT(J)-WPOT(J+1))/(DEP(J)-DEP(J+1));
KSEG=(DEP(J)-DEP(J+1))/((SDEP(J)/(2*KTHETA(J)))+(SDEP(J+1)/(2*KTHETA(J+
1))));
WMOV=-KSEG*GRAD;
IF WMOV>0 THEN DO;
WMOV1=WSAT(J+1)-SEG(J+1);
WMOV=MIN(WMOV,WMOV1,SEG(J)); END;
IF WMOV<0 THEN DO;
WMOV1=WSAT(J)-SEG(J);
WMOV=-MIN(-WMOV,WMOV1,SEG(J+1)); END;
SEG(J)=SEG(J)-WMOV;
SEG(J+1)=SEG(J+1)+WMOV;
END;
SMD1=SEG(1)+SEG(2)+SEG(3);
SMD2=SEG(4)+SEG(5)+SEG(6);
SMD3=SEG(7)+SEG(8)+SEG(9);
IF SMD1>5.7 THEN PUT LIST('SMD1 DRY');
IF SMD2>17.1 THEN PUT LIST('SMD2 DRY');
IF SMD3>58.7 THEN PUT LIST('SMD3 DRY');
IF SMD1<0 THEN PUT LIST('SMD1 SAT');
IF SMD2<0 THEN PUT LIST('SMD2 SAT');
IF SMD3<0 THEN PUT LIST('SMD2 SAT');
END MOV;
 /******************/
 /*CROP SALT UPTAKE*/
 /******************/
RICEUPT:   PROC;
DO I=1 TO 6;  SCROP(I)=YIELDRI*RISEED(I)/100;  END;  END RICEUPT;
SOYUPT:  PROC;
IF MOISTURE=1 THEN YIELDSOY=2688; ELSE YIELDSOY=1680;
DO I=1 TO 6; SCROP(I)=YIELDSOY*SOYSEED(I)/100;  END; END SOYUPT;
 /**********************/
 /*FERTILIZER ADDITION*/
 /**********************/
FERT: PROC;
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```
SFERT(4)=RATE*.52;  SFERT(6)=RATE*.48;
SINFIL=0;  SCROP=0;  SET=0;  SEROS=0;  SROFF=0;
CALL SUMFAL;  END FERT;
 /**********************/
 /*SALT BALANCE SUMMARY*/
 /**********************/
SUMFAL:  PROC;
DO I=1 TO 6;
FFERT(I)=FFERT(I) + SFERT(I);
FROFF(I)=FROFF(I) + SROFF(I);
FEROS(I)=FEROS(I) + SEROS(I);
END;  END SUMFAL;
SUMRICE:  PROC;
DO I=1 TO 6;
RT(I)=RT(I) + ST(I);
RINFIL(I)=RINFIL(I) + SINFIL(I);
RCROP(I)=RCROP(I) + SCROP(I);
REROS(I)=REROS(I) + SEROS(I);
RROFF(I)=RROFF(I) + SROFF(I);
RIRR(I)=RIRR(I) + SIRR(I);
RSURF(I)=RSURF(I) + SSURF(I);

M"#
SOEROS(I)=SOEROS(I) + SEROS(I);
SOROFF(I)=SOROFF(I) + SROFF(I);
SOIRR(I)=SOIRR(I) + SIRR(I);
END;  END SUMSOY;
 /***********************/
 /*WATER BALANCE SUMMARY*/
 /***********************/
RICEWAT:  PROC;
SR1(WEEK)=SR1(WEEK)+SMD1; SR2(WEEK)=SR2(WEEK)+SMD2; SR3(WEEK)=SR3(WEEK)
+SMD3;
RDE=RDE + DE;  RDT=RDT + DT;
RDROFF=RDROFF + DROFF;     RDINFIL=RDINFIL + DINFIL;
RDRAIN=RDRAIN + DRAIN;     RDIRR=RDIRR + DIRR;
ROR(WEEK)=ROR(WEEK)+DROFF; INR(WEEK)=INR(WEEK)+DINFIL;
IRRR(WEEK)=IRRR(WEEK)+DIRR;
END RICEWAT;
SOYWAT:  PROC;
SB1(WEEK)=SB1(WEEK)+SMD1; SB2(WEEK)=SB2(WEEK)+SMD2; SB3(WEEK)=SB3(WEEK)
+SMD3;
SDET=SDET + DET;           SDINFIL=SDINFIL + DINFIL;
SDROFF=SDROFF + DROFF;
SDRAIN=SDRAIN + DRAIN;     SDIRR=SDIRR + DIRR;
ROS(WEEK)=ROS(WEEK)+DROFF; INS(WEEK)=INS(WEEK)+DINFIL;
IRRS(WEEK)=IRRS(WEEK)+DIRR;
END SOYWAT;
FALWAT:  PROC;
IF CROP>1 THEN DO;
SB1(WEEK)=SB1(WEEK)+SMD1; SB2(WEEK)=SB2(WEEK)+SMD2; SB3(WEEK)=SB3(WEEK)
+SMD3;
ROS(WEEK)=ROS(WEEK)+DROFF; INS(WEEK)=INS(WEEK)+DINFIL;
```

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WATUP1(WEEK)=WATUP1(WEEK)+DET;
END;
ELSE DO;
SR1(WEEK)=SR1(WEEK)+SMD1; SR2(WEEK)=SR2(WEEK)+SMD2; SR3(WEEK)=SR3(WEEK)
+SMD3;
ROR(WEEK)=ROR(WEEK)+DROFF; INR(WEEK)=INR(WEEK)+DINFIL;
WATE(WEEK)=WATE(WEEK)+DET;
END;
FDET=FDET + DET;            FDINFIL=FDINFIL + DINFIL;
IF DROFF<0 THEN DROFF=0;    FDROFF=FDROFF + DROFF;
FDRAIN=FDRAIN+DRAIN;
END FALWAT;
 /*********************************************/
 /*FINAL SUMMARY OF SALT AND WATER BALANCES*/
 /*********************************************/
SUMMARY:
DO I=1 TO 6;
TET(I)= RT(I);
TINFIL(I)= RINFIL(I) + SOINFIL(I);
TFERT(I)= FFERT(I);
TCROP(I)= RCROP(I) + SOCROP(I);
TEROS(I)= FEROS(I) + REROS(I) + SOEROS(I);
TROFF(I)= FROFF(I) + RROFF(I) + SOROFF(I);
TSURF(I)=RSURF(I) + SOSURF(I);
FINPUT(I)= FFERT(I);
FOUTPUT(I)= FROFF(I) + FEROS(I);
FSTORAGE(I)=FINPUT(I) - FOUTPUT(I);
RINPUT(I)= RT(I) + RINFIL(I);
ROUTPUT(I)= RCROP(I) + REROS(I) + RROFF(I);
RSTORAGE(I)=RIRR(I) - ROUTPUT(I);
RTOTAL(I)= RIRR(I);
SINPUT(I)= SOINFIL(I);
SOUTPUT(I)= SOCROP(I) + SOEROS(I) + SOROFF(I);
SSTORAGE(I)=SOIRR(I) - SOUTPUT(I);
INPUT(I)=RIRR(I) + SOIRR(I) + TFERT(I);
OUTPUT(I)= TCROP(I) + TEROS(I) + TROFF(I);
STORAGE(I)=RIRR(I)+SOIRR(I)+TFERT(I)-OUTPUT(I);
END;
XEROS=TEROS(1)*1E+6/(1180*(ROT*10+10));
RWATER=RDINFIL ; SWATER=SDINFIL - SDET; FWATER=FDINFIL - FDET;
RDET=RDE + RDT;
ET=RDE + RDT + SDET + FDET;    INFIL=RDINFIL + SDINFIL + FDINFIL;
ROFF=RDROFF + SDROFF + FDROFF;
TDRAIN=RDRAIN + SDRAIN + FDRAIN;  TDIRR=RDIRR + SDIRR;
WATER=RWATER + SWATER + FWATER;
PRINTIT:
PUT SKIP EDIT('CA IS ',WAT(1))(A,F(4,2));
PUT SKIP EDIT('MG IS ',WAT(2))(A,F(4,2));
PUT SKIP EDIT('NA IS ',WAT(3))(A,F(4,2));
PUT SKIP EDIT('K IS ',WAT(4))(A,F(4,2));
PUT SKIP EDIT('SO4 IS ',WAT(5))(A,F(4,2));
PUT SKIP EDIT('CL IS ',WAT(6))(A,F(4,2));
PUT SKIP EDIT('YRS SOYBEAN',ROT)(A,F(3,0));
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PUT SKIP EDIT('POTASH USED?',POTASH,' RATE ',RATE)(A,F(2,0),A,F(4,0));
PUT SKIP EDIT('SOYBEANS IRRIGATED',MOISTURE)(A,F(2,0));
PUT SKIP EDIT('CAEQ IS ',CAEQ)(A,F(4,2));
IF INFO=1 THEN DO;
PUT SKIP(2) LIST('RICE YEAR DETAILS');
PUT SKIP(2) LIST(' WEEK  IRR RAIN   RO  INF EVAP TRANS  ET SMD1 SMD2 SM
D3');
DO WEEK=1 TO 52;
TOT(WEEK)=WATE(WEEK)+WATT(WEEK);
PUT SKIP EDIT(WEEK,IRRR(WEEK)/10,TRAIN(WEEK)/(10+ROT*10),ROR(WEEK)/10,
INR(WEEK)/10,WATE(WEEK)/10,WATT(WEEK)/10,TOT(WEEK)/10,SR1(WEEK)/10,
SR2(WEEK)/10,SR3(WEEK)/10)((11)(F(5,1)));
END;
PUT SKIP(2) LIST('RICE FLOODWATER DETAILS');
PUT SKIP(2) LIST(' WEEK DEPTH CA   MG   NA   K   SO4   CL');
DO WEEK=22 TO 36;
PUT SKIP EDIT(WEEK,DTOT(WEEK)/10,CONC(WEEK,1)/10,CONC(WEEK,2)/10,
CONC(WEEK,3)/10,CONC(WEEK,4)/10,CONC(WEEK,5)/10,CONC(WEEK,6)/10)
((8)(F(5,1)));
END;
YAR=ROT*10;
PUT SKIP(2) LIST('SOYBEAN YEAR DETAILS');
PUT SKIP(2) LIST(' WEEK  IRR RAIN   RO  INF  ET1  ET2  ET3  TOT SMD1 SM
D2
SMD3');
DO WEEK=1 TO 52;
TOT(WEEK)=WATUP1(WEEK)+WATUP2(WEEK)+WATUP3(WEEK);
PUT SKIP EDIT(WEEK,IRRS(WEEK)/YAR,TRAIN(WEEK)/(10+YAR),ROS(WEEK)/YAR,
INS(WEEK)/YAR,WATUP1(WEEK)/YAR,WATUP2(WEEK)/YAR,WATUP3(WEEK)/YAR,
TOT(WEEK)/YAR,SB1(WEEK)/YAR,SB2(WEEK)/YAR,SB3(WEEK)/YAR)
((12)(F(5,1)));
END;
END;
PUT SKIP(4) LIST('                                 SALT BALANCE(KG/HA/YR)
 );
PUT SKIP EDIT('SALT','INPUTS','OUTPUTS','STORAGE')
(A(4),X(17),A(6),X(28),A(7),X(10),A(7));
PUT SKIP EDIT('TRANS','INFIL','FERT','SURF','TOTAL','CROP','EROS','ROFF

,'TOTAL')(X(7),A(5),X(2),A(5),X(3),A(4),X(3),A(4),X(2),A(5),X(5),A(4)
,X(3),A(4),X(3),A(4),X(2),A(5));
IF INFO=1 THEN DO;
PUT SKIP EDIT('----------RICE----------')(X(27),A(24));
DO I=1 TO 6;
PUT SKIP EDIT(NAME(I),RT(I)/10,RINFIL(I)/10,RSURF(I)/10,RTOTAL(I)/10,
RCROP(I)/10,REROS(I)/10,RROFF(I)/10,ROUTPUT(I)/10,RSTORAGE(I)/10)
(A(4),(2)(F(7)),X(6),F(8),F(7),F(9),F(7),F(8),(2)(F(7)));
END;
PUT SKIP EDIT('----------SOYBEANS----------')(X(25),A(28));
YR=ROT*10;
DO I=1 TO 6;
PUT SKIP EDIT(NAME(I),SOINFIL(I)/YR,SOSURF(I)/YR,SOIRR(I)/YR,SOCROP(I)/
YR
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,SOEROS(I)/YR,SOROFF(I)/YR,SOUTPUT(I)/YR,SSTORAGE(I)/YR)
(A(4),X(7),F(7),X(7),(2)(F(7)),F(9),F(7),F(8),(2)(F(7)));
END;
PUT SKIP EDIT('----------FALLOW----------')(X(26),A(26));
YR=ROT*10+10;
DO I=1 TO 6;
PUT SKIP EDIT(NAME(I),FFERT(I)/YR,FINPUT(I)/YR,FEROS(I)/YR,FROFF(I)/YR
,FOUTPUT(I)/YR,FSTORAGE(I)/YR)
(A(4),X(14),F(7),X(8),F(6),X(9),F(7),F(8),(2)(F(7)));
END;
END;
YR=ROT*10+10;
PUT SKIP EDIT('----------ANNUAL----------')(X(26),A(26));
DO I=1 TO 6;
PUT SKIP EDIT(NAME(I),TET(I)/YR,TINFIL(I)/YR,TFERT(I)/YR,TSURF(I)/YR
,INPUT(I)/YR,TCROP(I)/YR,TEROS(I)/YR,TROFF(I)/YR,OUTPUT(I)/YR
,STORAGE(I)/YR)
(A(4),(3)(F(7)),F(8),F(6),F(9),F(7),F(8),(2)(F(7)));
END;
PUT SKIP(3) LIST('                                        WATER BALANCE (CM/YR)
  ');
PUT SKIP EDIT('CROP','ET','INFIL','ROFF','RAIN','IRR','STORAGE')
(X(3),A(4),X(11),A(2),X(8),A(5),X(6),A(4),X(7),A(4),X(7),A(3),X(6),A(7)
);
PUT SKIP EDIT(' RICE',RDET/10,RDINFIL/10,RDROFF/10,RDRAIN/10,RDIRR/10
,RWATER/10)(A,F(15),(5)(F(11)));
YR=ROT*10;
PUT SKIP EDIT(' SOYBEANS',SDET/YR,SDINFIL/YR,SDROFF/YR,SDRAIN/YR
,SDIRR/YR,SWATER/YR)(A,F(11),(5)(F(11)));
YR=ROT*10+10;
PUT SKIP EDIT(' FALLOW',FDET/YR,FDINFIL/YR,FDROFF/YR,FDRAIN/YR
,FWATER/YR)(A,F(13),(3)(F(11)),X(11),F(11));
PUT SKIP EDIT(' ANNUAL ',ET/YR,INFIL/YR,ROFF/YR,TDRAIN/YR
,TDIRR/YR,WATER/YR)(A,F(12),(4)(F(11)),F(11));
PUT SKIP EDIT('CACO3 PER YEAR OF RICE IN KG/HA IS  ',XCACO3/10)(A,F(6,0
));
PUT SKIP EDIT('EROSION IN KG/HA/YR IS ',XEROS)(A,F(7,0));
END SALTBAL;
//GO.WEATH DD UNIT=SYSDA,VOL=SER=WORK01,DISP=(SHR,KEEP),DSN=WEATH
//GO.SYSIN DD *
4.0 2.5 1.0 .1 .5 .5 0 0 2 0 1
//
```