TR-140
1988

Texas Water
Resources Institute
make every drop count

Furrow Diking Technology for Agricultural Water Conservation and Its Impact on Crop Yields in Texas

J.H. Krishna
G.F. Arkin

Texas Water Resources Institute

Texas A&M University

RESEARCH PROJECT COMPLETION REPORT

FURROW DIKING TECHNOLOGY FOR AGRICULTURAL WATER CONSERVATION AND ITS IMPACT ON CROP YIELDS IN TEXAS

Project Number G-1046-03
(May 17, 1985 - August 31, 1986)

Project Number G-1254-03
(September 1, 1986 - August 31, 1987)

Grant Numbers

14-08-0001 G-1046
14-08-0001 G-1254

by

J. Hari Krishna

and

Gerald F. Arkin

The research on which this report is based, was financed in part by the United States Department of the Interior, Geological Survey, through the Texas Water Resources Institute.

Technical Report No. 140
Texas Water Resources Institute
Texas A&M University
College Station, Texas 77843-2118

July 1988

ABSTRACT

Furrow Diking Technology for Agricultural Water Conservation and Its Impact on Crop Yields in Texas

Furrow diking is a practical, efficient and low-cost technique to conserve water and increase crop yields. Improvements in diker design and the increased use of herbicides have resulted in the rapid spread of furrow diking in the Texas High Plains and other regions.

To quantify the long-term effects of diking on crop yields, a computer simulation approach was used. Three crop models for sorghum, corn and cotton were combined with surface runoff hydrology algorithms, based on the USDA-SCS curve number methodology. The combination models called SORDIKE, CORDIKE and COTDIKE were run to determine the effects of conserving the runoff (by diking) on crop yields. Three scenarios of not diking, diking in the growing season, and diking all year were simulated. Daily weather data for 25 years from five Texas regions were used for the analyses. Depending on the location, furrow diking in the growing season increased average annual sorghum yields by 320 to 570 kg/ha, corn yields by 180 to 570 kg/ha, and cotton lint yields by 10 to 20 kg/ha. Diking the land throughout the year increased mean annual yields by 440 to 1080 kg/ha of sorghum, 210 to 800 kg/ha of corn and 10 to 30 kg/ha of cotton lint. The study indicated that furrow diking can be a valuable management practice for about 3.4 million ha of cropped area in the semi-arid and sub-humid regions of Texas. The practice may be useful in other areas also, to mitigate the effects of short duration moisture stress on crop yields.

ACKNOWLEDGMENTS

Appreciation is expressed to Dr. Wayne R. Jordan, Director, Texas Water Resources Institute and to the TWRI staff for their excellent cooperation during the project duration. Drs. James R. Mulkey and Cleveland J. Gerard provided data from Uvalde and Vernon, respectively, for model validation. Appreciation is expressed to Drs. Clarence W. Richardson and Jimmy R. Williams, USDA-ARS, Temple, for their cooperation in sharing hydrologic data and other related material. Thanks are due to Ms. Pam Vansa for her excellent secretarial assistance in preparing this report.

TABLE OF CONTENTS

SECTION I:

SECTION II:

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

INTRODUCTION

Texas agriculture uses 72% of the state's total water consumption. There are 10.5 million hectares of cropped area in Texas, and approximately one-fourth of it is irrigated. Because of declining ground water levels, increased energy costs for pumping, and competition for water resources from municipal and industrial users, it is projected that approximately one-third less water would be available for agricultural use by the year 2000. To maintain crop production at current levels, it is critical that new and improved agricultural water conservation technologies be applied in dryland and irrigated agriculture. Furrow diking is a practical, efficient and low-cost technique to conserve water in row-crop agriculture. It is also known as row-damming, tied-ridging or basin listing, and is a practice of building small dikes or dams at regular intervals in the furrows to hold runoff or irrigation water for infiltration (Figure 1).

Furrow diking is not a new technology. Practices similar to diking were first attempted in the United States more than fifty years ago (Wood, 1933; Hughes, 1933; Shedd et al., 1935; and Cole and Morgan, 1938). However, the basin lister was used during the 1940's primarily in the fallow period after wheat each year, and very little improvement in yields was noted between basin listing and other conventional treatments (Daniel, 1950; Luebs, 1962). The practice of basin listing was given up in most areas by 1950. Kuska and Mathews (1956) reported that basin listing of wheat did not significantly increase yields. Slow operating speed, poor weed control and difficulty with seedbed preparation were among the reasons given for abandoning the practice. Dagg and Macartney (1967) and Hudson (1971), however, reported successful results with basin tillage in Africa.

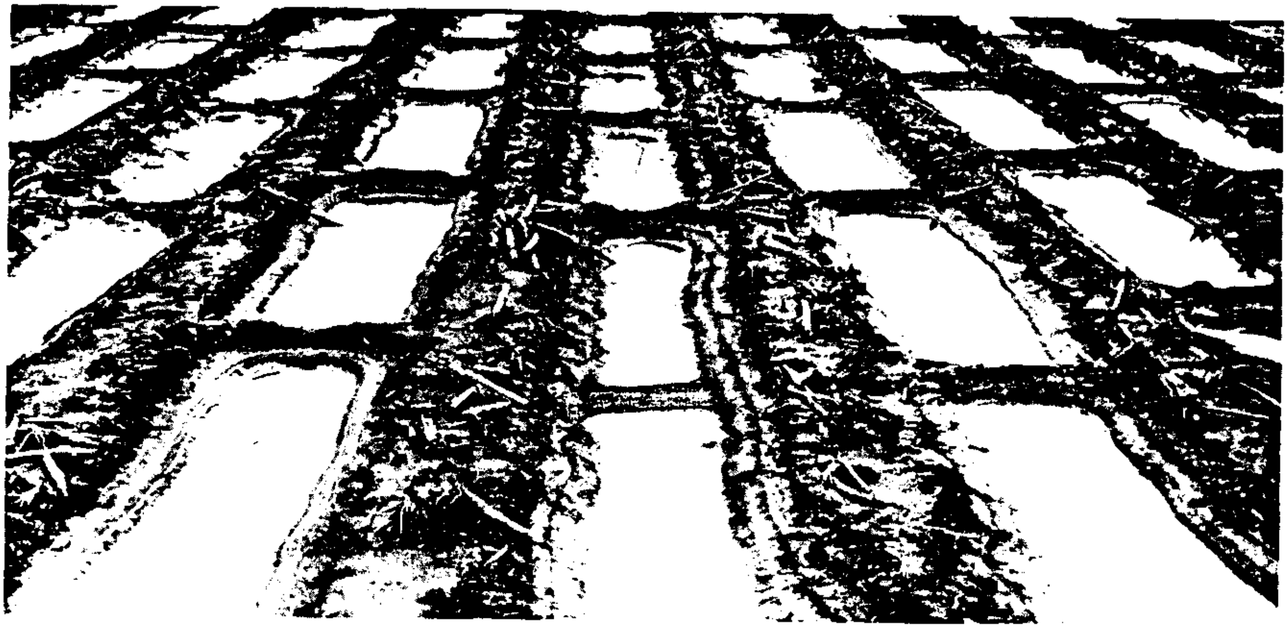

Fig. 1. Furrow dikes to hold runoff (Courtesy: O. R. Jones, USDA-ARS, Bushland, Texas).

The first attempts to systematically study furrow diking in Texas appear to have begun in 1975 with a replicated grain sorghum experiment at the USDA Conservation and Production Research Laboratory at Bushland (Clark and Jones, 1980) and a dryland cotton study at Lubbock (Bilbro and Hudspeth, 1977). Improvement in diker design (Lyle and Dixon, 1977), as well as the development and use of herbicides have resulted in the practice of furrow diking to spread rapidly in the High Plains and other Texas regions. Colburn and Alexander (1986) estimate that approximately 1.6 million ha are currently diked in Texas.

A research review of past furrow diking studies in Texas is included as Section I of this report. Crop yield increases reported earlier have varied considerably between locations and between years at any particular location. Field experiments were limited to a few sites and for relatively short periods of time. Although positive results were obtained, they did not adequately quantify the long-term benefits from furrow-diking. Besides, those results may not be directly transferable to other sites in Texas.

To evaluate the long-term impact of furrow diking, a computer simulation approach combining hydrologic and crop growth models was used. A runoff prediction method based on the USDA-SCS methodology was included with three crop models, validated with field data, and run for a 25 year period. The modeling results are discussed in Section II of this report.

The Soil Conservation Service (SCS) of the U. S. Department of Agriculture in Texas developed technical standards and specifications for furrow diking (USDA/SCS/TX, 1983; Lindemann, 1984). These standards do not consider evaporation or infiltration, but do provide broad specifications for furrow dike spacing and use. The following is the technical standard as developed for Texas:

A. Crops Applicable:

1. Summer growing crops such as: cotton, sunflowers, grain sorghum, corn, soybeans, etc.
2. Applicable to fallow period prior to planting following warm- or cool-season crop.

B. Date and Duration of Installation:

1. As a minimum dikes will be installed between April 1 and no later than July 10 each year.
2. Dikes shall be utilized for at least 90 consecutive days starting anytime between April 1 and July 10.
3. Dikes may be installed prior to April 1 when being used to increase soil water content at planting time.

C. Applicable Slopes:

1. Dikes may be used with up-and-down hill planting where slopes are 1.0% gradient or less.
2. Dikes may be used on all slope ranges where the field is actually worked on the contour.

D. Dike Spacing, Height, and Size:

1. On slopes with less than 1% gradient the spacing between dikes in the furrow can vary from 2.5 feet to 20 feet (0.75 m to 6 m). On slopes with 1% gradient, the optimum spacing is about 10 feet (3 m).
2. On slopes with 1.1% gradient or greater (which requires contour farming), the spacing between dikes in the furrow shall not exceed 12 feet (3.65 m). The normal spacing ideally should not be less than about 8 feet (2.45 m).

OBJECTIVES

The objectives of this research were to determine the feasibility, potential geographic extent and impact of furrow diking in Texas, by

1. consolidating and synthesizing results of previous furrow diking studies conducted in Texas,
2. analyzing rainfall and runoff at representative locations, and
3. assessing the impact of furrow diking on crop yields, using hydrologic and crop modeling techniques.

The following five Texas regions were targeted to determine the effect of conserving runoff (by diking) on crop yields:

High Plains

Rolling Plains

Blackland Prairie

Edwards Plateau

Coastal Bend.

SECTION I

FURROW DIKING IN TEXAS - A RESEARCH REVIEW

High Plains

Bushland: Dryland crop yields in semi-arid climates are generally dependent on available soil water. Even a modest timely increase in soil water can result in a significant yield increase under semi-arid conditions. Furrow diking can retain surface runoff and increase soil moisture availability for crop production. The effectiveness of furrow diking would depend on the timing at which dikes are installed. Runoff data from dryland wheat-fallow-sorghum-fallow plots (Jones et al., 1984) can be used to show that the greatest benefit from diking at Bushland would result if dikes were built in April each year (Figure 2), so that the runoff during the period of May through September could be captured.

Clark and Jones (1980) reported a five-year furrow dike study conducted at the USDA Conservation and Production Research Laboratory at Bushland, Texas. Their replicated study began in 1975 with non-diked furrows, diked furrows, and flat planting to evaluate the diking technique. All plots were on Pullman clay loam which has a low infiltration rate (0.15 cm/hr) and a slope of 0.2%. Furrows were made with a conventional 75-cm lister or a tri-level lister allowing for two 75-cm rows of grain sorghum the first 3 years (1975-1977). In 1975 and 1976, furrow dikes were first made every 15 m with a laboratory designed blade-like scoop. In 1977, a hydraulic tripping diker designed by Lyle and Dixon (1977) was built and used. A commercial dammer was used in 1979 which spaced dams 3.5 m apart. Grain sorghum was planted between June 5 and 15 and harvested in October. Initially dikes were constructed in a separate operation immediately after herbicide application. Later,

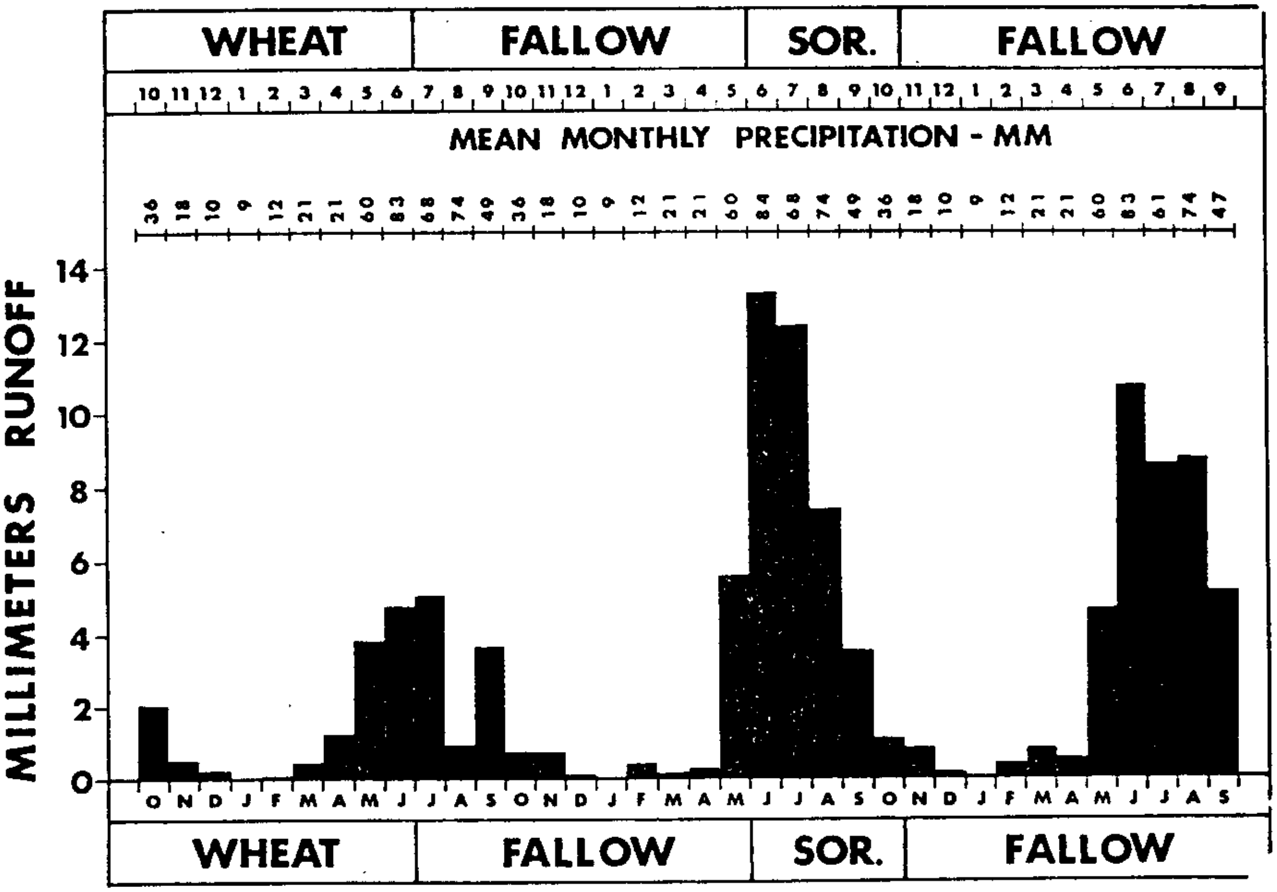

Fig. 2. Twenty-six year (1958-83) mean monthly precipitation and runoff, wheat-sorghum-fallow sequence, Bushland, Texas (Jones et al., 1984).

herbicide was applied as an integral part of the diking operation. Grain yields were obtained by combine harvesting 0.67 ha plots. Storm runoff from the non-diked treatment was measured with 30-cm "H" flumes equipped with water stage recorders. Soil water content was monitored with the neutron method.

Furrow diking benefits in any particular year were shown to depend on the seasonal precipitation and storm runoff. Seasonal (June 1 to October 31) precipitation and runoff are shown in Table 1. Yield increases due to furrow dikes were observed only in years with above average runoff. Only one significant runoff event occurred in 1975 to produce a seasonal runoff of 2.1 cm and no runoff occurred in 1976. In 1977, all four runoff events occurred in August, while in 1978, one event of 3.8 cm occurred in September. Only 0.2 cm of runoff was measured in 1979.

Table 1. Seasonal (June 1 - October 31) rainfall and runoff from non-diked furrows, Bushland, Texas (Clark and Jones, 1980).

Year	Seasonal rainfall (cm)	Seasonal runoff (cm)
1975	21.8	2.1
1976	21.9	0.0
1977	27.5	8.5
1978	35.8	3.8
1979	29.2	0.2
20 yr. Avg.	29.4	3.8

Grain yields were variable, ranging from 0 to 2,900 kg/ha during the 5 year test (Table 2). High yields were produced in 1975 and 1979 because of high levels of soil water stored at planting followed by timely precipitation. Although seasonal precipitation was much below average in 1975, rainfall was adequate during July to maintain a high soil water content in early August. August rainfall was limited, but plants reached maturity using stored soil water. Furrow diked treatment grain yields were increased 340 kg/ha by conserving 2.1 cm of runoff in 1975.

Plot areas for the 1975 and 1979 crops had been fallowed the previous year, resulting in high soil water contents at planting and high grain yields. Plot areas for the 1976, 1977 and 1978 crops had been planted in sorghum the previous year and therefore less soil moisture available at planting time may have lowered yields. In 1976 all sorghum treatments were destroyed by hail. Although seasonal precipitation was near average in 1977, low soil water content and precipitation during June and July resulted in small, severely stressed plants unable to efficiently use the ample August rainfall. Even though 1977 sorghum yields were low, furrow diking increased yields 650 and 870 kg/ha, respectively, compared to the flat and non-diked treatments.

Table 2. Yields of grain sorghum planted in 75-cm rows at Bushland, Texas (Clark and Jones, 1980).

Year	Treatments		
	Diked	Non-Diked	Flat
	----------------	kg/ha	----------------
1975	2,920	2,580	2,470
1976	0	0	0
1977	1,380	510	730
1978	1,050	1,120	---
1979	2,890	2,870	---
Avg.	1,650	1,420	---

Seasonal precipitation in 1978 was above average, however, below average July and August precipitation caused low yields. Runoff in September 1978 occurred too late in the season to benefit the crop and the excess soil water resulting from conserved runoff on the furrow-diked treatment possibly reduced sorghum yields compared to the non-diked treatment (Table 2).

Little difference in sorghum yields should be expected between diked and non-diked treatments in years when adequate moisture is available. However, in dry years, diking can prevent a crop failure, as in 1977. In each of the years when runoff was caught in the diked furrows before August 15, yields were increased. Unger (1972) indicated that each additional 1 cm of stored soil water at planting could increase yields about 275 kg/ha.

Treatment effects on soil water content are shown in Figs. 3-6. All treatments had similar soil water contents at planting in 1975 (Fig. 3) and only small differences were observed until July 10. Runoff caught from rainfall on July 10 and 11 increased the soil water content in the diked treatment by 1.3 cm. This difference continued until all treatments reached a similar dry condition at harvest. A similar condition existed in 1977 (Fig. 4), except all treatments were much drier at planting and remained dry until the large rain on August 11. The diked treatment increased in soil water content after the rainfall on August 11 and August 22, reaching a maximum difference of 5.6 cm by August 24. In 1978, the diked treatment had approximately 1 cm more soil water during most of the season until the large rain in September when the soil water content reached field capacity in both treatments (Fig. 5). In 1979 soil water contents were similar throughout the season because little runoff occurred (Fig. 6).

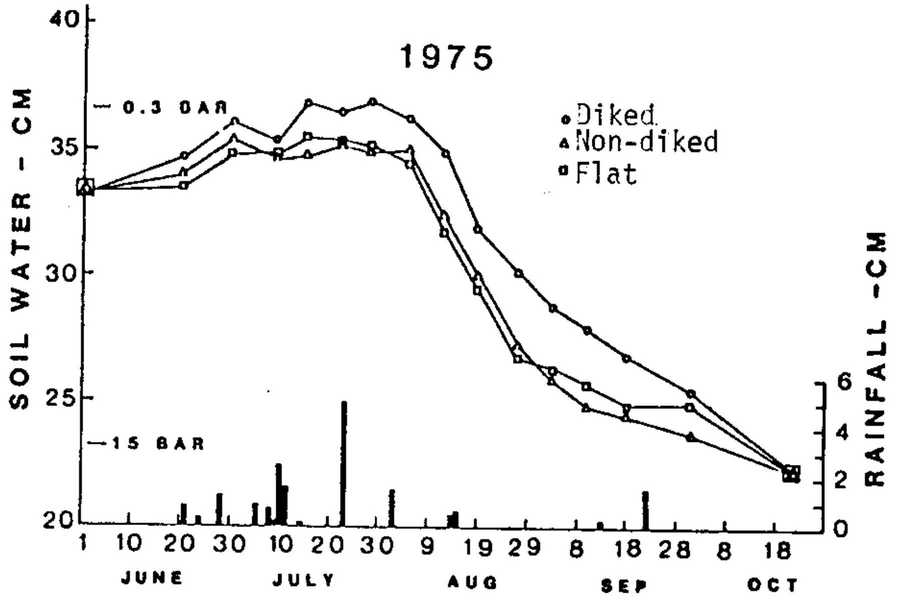

Fig. 3. Soil water content (0-120 cm) and seasonal precipitation for grain sorghum on diked, non-diked and flat tillage treatments, 1975, Bushland, Texas (Clark and Jones, 1980).

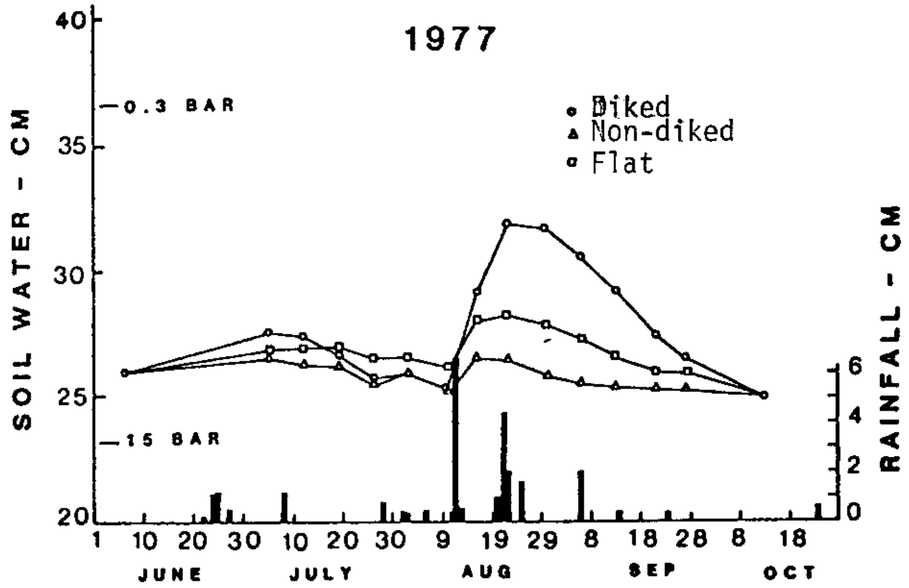

Fig. 4. Soil water content (0-120 cm) and seasonal precipitation for grain sorghum on diked, non-diked and flat tillage treatments, 1977, Bushland, Texas (Clark and Jones, 1980).

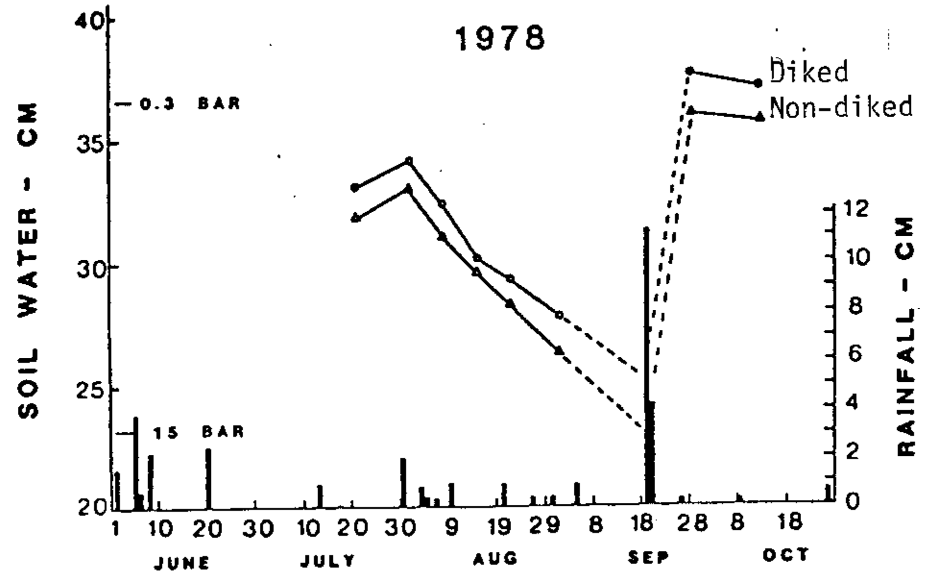

Fig. 5. Soil water content (0-120 cm) and seasonal precipitation for grain sorghum on diked and non-diked treatments, 1978, Bushland, Texas (Clark and Jones, 1980).

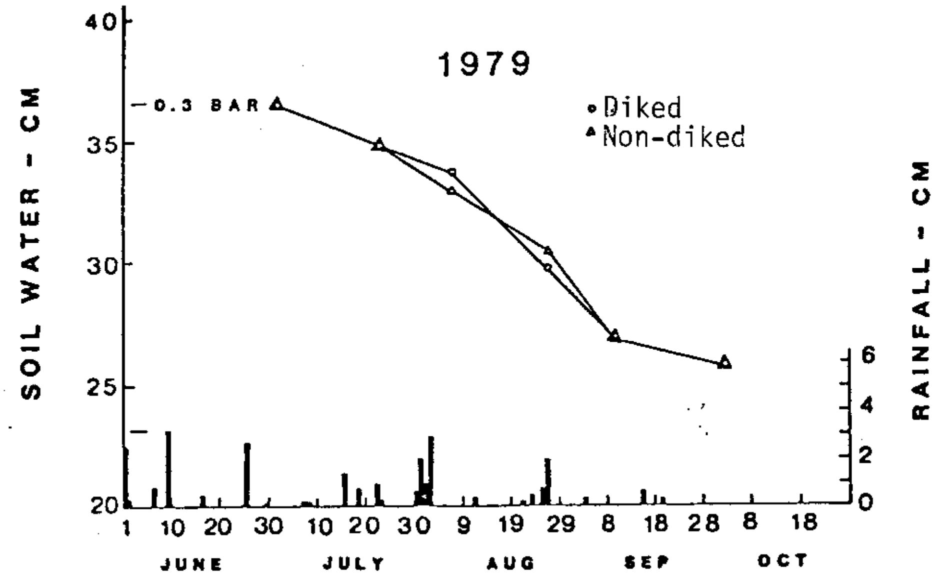

Fig. 6. Soil water content (0-120 cm) and seasonal precipitation for grain sorghum on diked and non-diked treatments, 1979, Bushland, Texas (Clark and Jones, 1980).

Limited Irrigation - Dryland (LID) System:

Stewart et al. (1983) developed a limited irrigation-dryland (LID) farming system using furrow diked land and limited supplies of irrigation water for efficient grain sorghum production. The objective of the LID concept is to maximize the conjunctive use of growing season rainfall with a limited supply of irrigation water. The unique feature of the LID system is the flexible adjustment during the crop growing season of the amount of land irrigated, allowing more land to be irrigated during above average rainfall years than during dry years. Risk is low in the LID system, and response is good in favorable rainfall years.

The LID system concept is illustrated in Fig. 7. A graded furrow field, 600 m long on 0.3 to 0.4% slope, was divided into three water management sections. The upper half of the field was managed as "fully irrigated." The next one-fourth was managed as a "tailwater runoff" section that utilized furrow runoff from the fully irrigated section. Finally, the lower one-fourth was managed as a "dryland" section capable of receiving and utilizing any runoff resulting from either irrigation or rainfall on the wetter, fully irrigated and tailwater runoff sections. Plant densities and fertility were reduced down the field to decrease stress because irrigation water was decreased down the field. Furrow dikes were placed about every 4 m throughout the length of the field. Alternate 76-cm furrows were irrigated, and the dikes in the irrigated furrows were notched to insure that irrigation water moved over the dikes and down the furrow, rather than across the beds. The remaining furrow dikes on the lower part of the field and the dikes in the non-irrigated furrows for the entire length of the field prevented rainfall runoff. A predetermined amount of irrigation water was applied

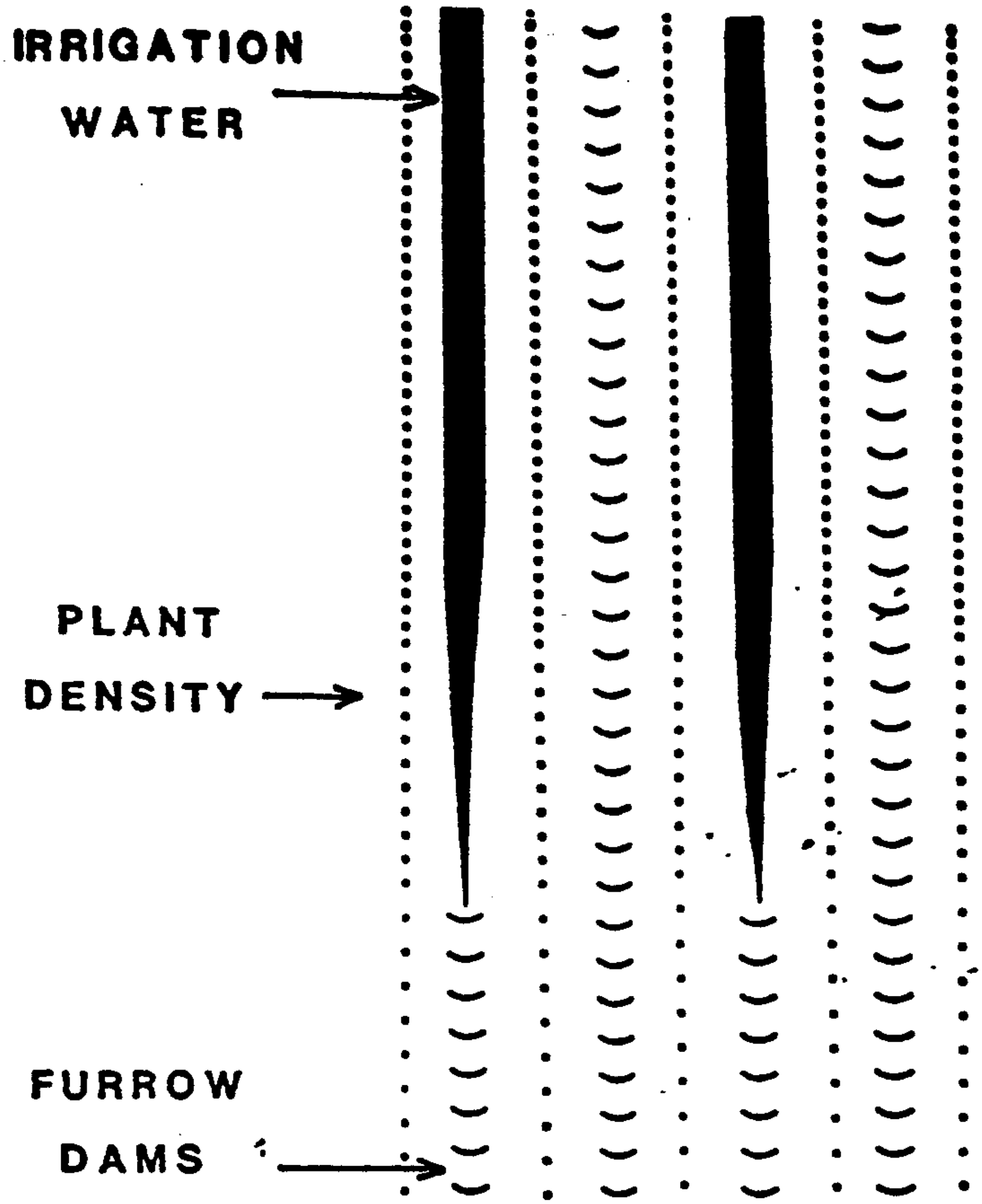

Fig. 7. Schematic drawing of the Limited Irrigation-Dryland (LID) System (Stewart, 1985).

at regular time intervals. The extent to which the entire field was irrigated depended on the rainfall received -- the wetter the year, the greater the advance of a fixed application down the field. The objective was to prevent or minimize any water from rainfall or irrigation from leaving the field. More recent studies with the LID system have utilized a medium seeding rate throughout the field and furrow dikes in only alternate furrows that are not used for irrigation (Stewart, 1985). These changes make the system somewhat easier to manage, and the benefits are similar. The treatments that were compared in the 3 year study (Stewart et al., 1983) and the irrigation water use efficiency achieved in each of the treatments is shown in Table 3.

Table 3. Irrigation water use efficiencies for various treatments, Bushland, Texas.

Treatment	Irrigation water use efficiency kg grain/m^3
Dryland	----
Dryland, diked (4 m intervals)	----
Fully irrigated	0.92
LID - 250 mm	1.36
LID - 185 mm	1.50
LID - 125 mm	1.70
LSD (0.05)	0.64

Even though the fully irrigated treatment may result in the highest yield, the irrigation water use efficiency is the important element to consider when only limited amounts of irrigation water are available. As indicated in Table 3, the highest water use efficiency with limited irrigation application was obtained with the LID-125 mm treatment.

Lubbock: Bilbro and Hudspeth (1977) reported the results of a furrow diking study with cotton at Lubbock in 1975. The dikes were made in three dryland tests in which half of each plot was left non-diked and the other half kept diked from March until October or later. Dikes were spaced about 3 m apart. Rainfall from May through September exceeded the 50-percent probability level each month, but October rainfall was only 2 percent of normal. The total for these 7 months was 30 cm, and the 59-year average was 29.7 cm. Air temperatures were below normal, and the cotton plants were 1-2 weeks behind normal growth by September. Cold, cloudy, windy, wet weather from September 13-15 was followed by several days of hot, dry, windy conditions. Consequently, most cotton leaves were desiccated and later dropped from the plants resulting in lower lint yields. The following three tests were conducted:

Test A: There were four replicated plots (8 m x 94 m) with slopes of 0.9%, row spacing 1 m, and access tubes for periodic soil moisture measurement. The diked and non-diked plots produced 336 kg/ha and 304 kg/ha respectively. The 10.6% lint increase for the diked plots was statistically significant. Moisture measurements about 36 hrs after a 39 mm rain on July 21 showed that the top 30 cm of the soil had 19.2% more total water (6.35 mm) than the non-diked plots. This indicated that considerable runoff occurred from the non-diked rows.

Test B: The plots were 8 m x 18 m replicated on land having 0.2% slope. Row spacing was 1 m. The average lint yields in the diked plots was 383 kg/ha, 14.7% greater than non-diked, which was statistically significant.

Test C: Plots were 8 m x 213 m, replicated four times on a land slope of 0.2%; both 1 m row spacing and 25 cm double row spacing on beds were used. Diked and non-diked plots on 1 m spacing yielded 279 kg/ha and 224 kg/ha while the double row plot yields were 264 kg/ha and 252 kg/ha, respectively. Even though the diked yields were higher, they were not statistically significant in this test.

All fields were observed following each rain, and evidence of runoff from the diked plots was not visible. After some of the heavy rains, considerable soil erosion was noticed in the non-diked rows of the 0.9% slope field (Test A). Erosion was less extensive in non-diked rows of Tests B and C (0.2% slope). These tests revealed that furrow diking could effectively prevent runoff and erosion and increase yields.

Irrigated-dryland basin tillage evaluations were conducted with cotton in 1977 (Lyle and Dixon, 1977), and with sorghum in 1978 at Lubbock (Lyle et al., 1978). The replicated experiments had 8.2m x 335m plots on Olton loam soil with 0.9 m row spacing. The five treatments were:

1. Basin tillage - Alternate Furrow-Irrigated (BT-AF-I)
2. Conventional - Irrigated (C-I)
3. Basin tillage - Every Furrow - Dryland (BT-EF-D)
4. Basin tillage - Alternate Furrow - Dryland (BT-AF-D)
5. Conventional - Dryland (C-D)

Relevant fertilizer application, dike installation, irrigation and rainfall information during the two seasons are given below:

1977

Crop	Cotton
Fertilizer	None
Dikes	Installed - June 17; Removed - September 7
Irrigation	Pre-irrigated March 21-24 with 13.2 cm; alternate furrow irrigation of 3.3 cm on July 4-5
Rainfall	9.4 cm received while dikes were in place

1978

Crop	Sorghum
Fertilizer	180 kg/ha N applied as NH_3 and 45 kg/ha P applied as P_2O_5
Dikes	Installed May 12; remained through harvest
Irrigation	Preplant April 14 with 5.7 cm and four later alternate furrow irrigations of approximately 3.0 cm each
Rainfall	14.4 cm received during the growing season

In 1977, the limited rainfall after diking prevented large yield increases in the diked plots. The date of the runoff producing rain (June 21) was also early and closely followed a spring with adequate soil moisture. However, the retained rainfall supplemented alternate furrow irrigation to the extent that a significant yield increase did result. The results are shown in Table 4.

Table 4. Basin tillage cotton lint yields (kg/ha), 1977, Lubbock, Texas (Lyle and Dixon, 1977).

Treatments	BT-AF-I	C-I	BT-EF-D	C-D	BT-AF-D
Yields	448 a	404 b	319 c	298 c	294 c

$L.S.D_{0.05} = 37.6$ kg/ha

* Yields followed by the same letter are not significantly different at the 5% level.

Results of the basin tillage evaluation with 1978 grain sorghum were similar to those obtained in the 1977 with cotton. Minimal runoff producing rains and little growing season rainfall in both years resulted in failure to produce significant responses from basin tillage on dryland plots. However, furrow dikes placed in alternate furrows both years and irrigated in the open furrow produced significant yield increases at the 5% level compared to conventional tilled plots irrigated every other furrow with an equal water application.

The results of the 1978 basin tillage grain sorghum evaluation are shown in Table 5.

Table 5. Basin tillage grain sorghum yields (kg/ha), 1978, Lubbock, Texas (Lyle et al., 1978).

Treatments	BT-AF-I	C-I	BT-AF-D	BT-EF-D	C-D
Yields*	1540 a	1251 b	303 c	289 c	276 c

$L.S.D_{0.05}$ = 258.3 kg/ha

* Yields followed by the same letter are not significantly different at the 5% level.

Dryland crop yields in the Southern Great Plains are normally dependent upon the available soil water. Grain sorghum is highly responsive to water and in some instances even 1 cm of additional stored water can produce significant yield increases. Most rainfall there occurs from May through September. Rainfall during that time is from thunderstorms which have high intensities and short durations. These storms frequently have intensities greater than the intake rate, thereby causing water to pond and leave the field as storm runoff. Furrow diking, under these circumstances, provides additional opportunity time for ponded runoff to infiltrate and recharge the soil profile.

Low Energy Precision Application (LEPA):

The LEPA (Low Energy Precision Application) irrigation concept and the application system have been described by Lyle and Bordovsky (1981). The system distributes water directly to the furrow at very low pressure through drop tubes and emitters which are located at a height of 5 to 10 cm above the furrow. The system was designed to minimize the effect of soil and climatic variables that adversely influence furrow and sprinkler irrigation efficiencies. It would also maximize rainfall utilization by conjunctive use with microbasin tillage.

Lyle and Bordovsky (1983) describe the results of the LEPA irrigation system evaluation on soybeans. Factors analyzed in comparing the LEPA system with sprinkler and furrow methods included distribution uniformity, application efficiency, water use efficiency and energy savings. Three irrigation systems (LEPA, furrow and sprinkler) and the presence or absence of furrow dikes were compared. Approximately equal amounts of water per unit land area were delivered to each system. Four furrow treatments consisted of eight rows per treatment, each with 305 m length of run. The furrow treatments were (a) furrow irrigated - conventional; (b) furrow dryland - conventional; (c) furrow irrigated - micro-basin; and (d) furrow dryland - micro-basin. Soil surface modification to form micro-basins is considered an integral part of the LEPA system and was found to effectively eliminate runoff.

The irrigation application efficiency was defined by Lyle and Bordovsky, 1983 as:

$$E_a = \frac{W_d - e_a - e_{ws} - e_{ss} - D_p - R}{W_d} (100)$$

where E_a is application efficiency, W_d is water delivered to the field, e_a is spray evaporation in the air, e_{ws} is evaporation from a free water surface, e_{ss} is evaporation from the soil surface during irrigation, D_p is deep percolation and R is runoff.

The application efficiency data are summarized in Table 6. For all three systems, LEPA, sprinkler and furrow, the application efficiencies were higher with basin tillage than with conventional tillage.

Below average rainfall in 1980 and above average rainfall in 1981 resulted in a total of 49.3 cm and 23.6 cm of irrigation water applied in 1980 and 1981, respectively. Total water delivered to the crop (rainfall plus gross irrigation) averaged 66.5 cm in 1980, and 62.0 cm in 1981. The 1980 results should more accurately represent the normal yield responses from the irrigation methods tested. Frequent rainfall late in the 1981 growing season practically masked the response to irrigation and favored furrow treatments where no ponding occurred.

Table 6. Application Efficiency (E_a) summary, Lubbock, Texas (Lyle and Bordovsky, 1983).

	Basin tillage			Conventional tillage		
	LEPA	Sprinkler	Furrow	LEPA	Sprinkler	Furrow
1980						
Average E_a	99	77	91	91	76	89
Range	96 to 100	7 to 97	82 to 99	80 to 100	7 to 97	71 to 99
1981						
Average E_a	99	90	82	84	86	83
Range	96 to 100	79 to 100	58 to 98	69 to 99	71 to 100	66 to 99
Two-year Average E_a	99	84	87	88	81	86

Lyle and Bordovsky (1983) showed that the LEPA system with basin tillage resulted in the lowest irrigation energy expense (2¢/kg). The two-year average grain yields and net returns (after expenses) for the various treatments are shown in Table 7. The LEPA system in conjunction with basin listing (furrow diking) was superior to all the other treatments.

Table 7. Two-year soybean yields and net returns for various treatments, Lubbock, Texas.

	Basin tillage			Conventional tillage		
	LEPA	Sprinkler	Furrow	LEPA	Sprinkler	Furrow
Two-year average yield (kg/ha)	2633	2212	2386	2294	2004	2455
Two-year average net return ($/ha)	546	439	463	445	379	486

Rolling Plains

Gerard et al. (1983) conducted studies in 1980 and 1981 on Miles fine sandy loam soil near Vernon to determine the effect of subsoiling and furrow diking on cotton yields. These cultural practices did not show any effect on cotton yields in 1980 because of low rainfall and extremely high temperatures. However, in 1981, diking prevented runoff and increased yields from 365 Kg/ha to 481 Kg/ha. Yield increases above the non-diked treatment were 15% for the half-diked (alternate row diked), 32% for the fully diked and 38% for the diked-subsoiled treatment. The average non-diked treatment runoff during the 1981 crop season was estimated to be 35% of the rainfall. Gerard et al. (1984) reported 1981 and 1982 studies of sorghum and cotton on an Abilene loam soil and on a Miles fine sandy loam soil respectively. The tillage treatments during 1981 and 1982 are shown in Table 8, and the rainfall received during those two years is shown in Table 9. The slopes in the furrows ranged from 0.1% on the lower half to 0.4% on the upper half of the field.

Table 8. Sorghum and cotton tillage treatments, 1981 and 1982, near Chillicothe, Texas (Gerard et al., 1984).

Treatment No.	Sorghum
1	Conventional beds (check)
2	Half diked [a]
3	Subsoiled 0.4 m deep at 0.5 m intervals
4	Diked [b]
5	Diked [b] and subsoiled 0.4 m deep at 0.5 m intervals

Treatment No.	Cotton
1	Conventional beds (check)
2	Half diked [a]
3	Diked [b]
4	Diked [b] and subsoiled 0.35 m

[a] Half diked refers to diking every other furrow.

[b] Every furrow for Treatments 4 and 5 (sorghum) and 3 and 4 (cotton) was diked.

Table 9. Monthly rainfall for sorghum and cotton, 1981 and 1982, near Chillicothe, Texas (Gerard et al., 1984).

	Sorghum		Cotton	
	Year		Year	
	1981	1982	1981	1982
	mm			
January	1.0	31.5	1.3	33.8
February	20.3	8.5	21.1	6.4
March	39.4	55.1	34.0	42.2
April	81.0	38.9	62.2	43.2
May	132.1	198.6	126.2	227.1
June	98.3	106.7	120.1	120.1
July	17.5	67.6	43.9	62.5
August	21.1	79.0	77.0	37.3
September	18.8	50.5	35.6	19.6
October	57.9	2.8	81.5	3.6
November	16.8	47.5	11.2	58.7
December	7.1	28.4	7.1	26.4
Total	511.3	715.2	621.2	680.9

The sorghum grain and cotton lint yields recorded in 1981 and 1982 are shown in Tables 10 and 11, respectively. Diking and subsoiling reduced runoff and significantly increased yields of sorghum and cotton. Yields of diked sorghum and cotton were 108% and 32% higher than the check, respectively. Yields of sorghum on the diked treatment in 1985 and 1986 however, were only 14% and 8.5% higher than non-diked (Gerard, 1987). These data confirm the high variability that exists from year to year in the yield increases due to furrow diking. The data further establish the need to analyze furrow diking yields on a long term basis, to adequately account for the year to year variability.

Table 10. Grain sorghum yields, treatments and locations along the slope, 1981-82, Chillicothe, Texas (Gerard et al., 1984).

	1981			
Treatments	Upper	Middle	Lower	Average
	kg/ha			
Check	536 a*	1065 a	1887 a	1163 a
Subsoiled	350 a	591 a	2805 a	1249 a
Half diked	1615 b	1995 b	2644 a	2084 b
Diked	2027 b	2579 bc	2872 a	2493 b
Diked and subsoiled	2175 b	2872 c	2507 a	2518 b
Average	1341	1821	2544	

*Values for each location on slope or averages followed by same letter are not significantly different at the 5% level.

	1982				
Treatments	Upper	Middle	Lower	Average	1981/1982 Average
	kg/ha				
Check	735 a	1694 a	3162 a	1864 a	1513 a
Subsoiled	1439 b	2558 a	3799 a	2598 b	1924 b
Half diked	2285 c	2410 a	3273 a	2656 b	2370 c
Diked	3083 d	4036 b	4324 a	3815 c	3154 d
Diked and subsoiled	3827 e	4169 b	3633 a	3876 c	3197 d
Average	2274	2973	3638		

* Values for each location on slope or averages followed by same letter are not significantly different at the 5% level.

Table 11. Lint cotton yields for different treatments and locations along the slope, 1981-82, Chillicothe, Texas (Gerard et al., 1984).

	1981			
Treatments	Upper	Middle	Lower	Average
	kg/ha			
Check	303 a*	370 a	422 a	365 a
Half diked	374 b	404 b	480 a	420 b
Diked	447 c	514 c	482 a	481 b
Diked and subsoiled	445 c	538 c	533 a	506 b
Average	393	457	479	

	1982				
Treatments	Upper	Middle	Lower	Average	1981/1982 Average
	kg/ha				
Check	292 a	381 a	433 a	369 a	367 a
Half diked	436 b	452 ab	488 a	459 b	439 b
Diked	490 c	515 b	468 a	491 b	486 c
Diked and subsoiled	478 c	483 b	438 a	466 b	486 c
Average	424	458	457		

* Values within each location on slope or averages followed by same letter are not significantly different at the 5% level.

Clark (1983) reported the results of a tillage test on an Abilene clay loam soil which compared diked, alternate row diked and non-diked treatments for conventional and reduced tillage systems. Satisfactory rainfall was received during the year (85% of the normal). The yield response of cotton is shown in Table 12. Furrow diking prior to the spring planting resulted in significant yield increases. Diking alternate and every furrow resulted in average yield increases of 16 and 36 percent, respectively.

Table 12. Yield response of cotton to tillage treatments, 1981, Chillicothe, Texas (Clark, 1983).

		Lint yield (kg/ha)			
			Furrows diked		
Tillage System	Subsoiled	None	Alternate	All	Average
Conventional		214	294	314	274 a
Reduced	100 cm	255	261	314	277 a
Reduced	50 cm		259	330	294 a
Average		234 c*	271 b	319 a	

* Means within a row or column followed by the same letter are not significantly different at the 5% probability level.

The gross monetary values from the cotton tillage test (Clark, 1983) are shown in Table 13.

Table 13. Gross value in dollars per hectare of cotton from tillage test, 1981, Chillicothe, Texas (Clark, 1983).

		Value per hectare in dollars			
			Furrows diked		
Tillage System	Subsoiled	None	Alternate	All	Average
Conventional		195	269	287	250 a
Reduced	100 cm	237	242	288	256 a
Reduced	50 cm		250	306	278 a
Average		216 c*	253 b	294 a	

* Means within a row or column followed by the same letter are not significantly different at the 5% probability level.

Bordovsky (1983) reported that cotton grown on furrow diked plots at Munday yielded an average of 10.5% higher than non-diked check plots; however, this increase was not statistically significant at the 5% level of probability. Only 5 cm of rainfall were received from mid-June to mid-September.

Central Texas

Krishna and Arkin (1985) conducted a furrow diking feasibility evaluation for Central Texas by analyzing hydrologic data from two research watersheds monitored by USDA-ARS near Riesel, Texas. Both watersheds are located on Blackland soils and their physical characteristics are shown in Table 14.

Table 14. Physical characteristics and cropping systems of two USDA-ARS watersheds, Riesel, Texas (Krishna and Arkin, 1985).

Watershed	Area (ha)	Average slope (%)	Cropping system
Y-6	6.6	3.2	oats, corn, sorghum (rotation)
Y-7	16.2	1.9	oats, corn, sorghum (not in rotation)

Runoff data for 26 years from watershed Y-6 and 20 years from Y-7 were analyzed and it was determined that there is an 80-90% probability of receiving runoff during the late spring months in Central Texas and, that on average, more than 50 mm of runoff can be expected to occur between March and June in the Waco-Temple area, most of which occurs in April and May. Krishna and Arkin (1985) found that at least 70% of the late spring and/or early summer runoff occurs between April 16 and June 15 and, therefore, an appropriate period to build furrow dikes would be no later than mid-April in the Temple area.

The analysis showed further that while runoff events of 3.80 cm or less contributed the major portion of total runoff, most events were less than 2.54 cm and approximately 75% of these were 1.25 cm or less (Table 15). This indicates that the chances of water ponding in diked furrows for more than a day are low in the Blacklands. The dikes should, however, be at least 7.6 cm high after settling to hold the large and infrequent runoff volumes. Furrow diking appears to be feasible in the Central Texas Blacklands, and field studies have been initiated to ascertain the benefit/cost ratio of adopting this practice in Central Texas.

Table 15. Runoff distribution by amount and month*, Central Texas (Krishna and Arkin, 1985).

Amount (cm)	March	April	May	June	March-June	Total (cm)
			Y-6 runoff events			
0.25-1.25	15	18	19	10	62	37.8
1.26-2.53	2	5	5	4	16	31.7
2.54-3.80	2	3	7	3	15	43.2
3.81-5.06	1	2	1	0	4	16.8
>5.07	1	2	2	1	6	38.1**
			Y-7 runoff events			
0.25-1.25	5	18	9	6	30	18.3
1.26-2.53	0	3	9	4	16	24.9
2.54-3.80	2	1	2	1	6	23.9
3.81-5.06	0	1	2	0	3	17.0
>5.07	0	3	2	0	5	55.9**

* 26 years of data for watershed Y-6 and 20 years of data for Y-7.
** 1957 was an extremely high rainfall year. Runoff events > 5.0 cm contributed 19.0 cm in Y-6 and 27.4 cm in Y-7 in 1957.

Krishna et al. (1987) evaluated the likely long-term impact of furrow diking on sorghum yields by combining SORGF, a grain sorghum simulation model with the surface runoff hydrology from the USDA-ARS model EPIC (Erosion-Productivity Impact Calculator). A twenty-year simulation was conducted using climatic data from Temple, Uvalde, and Lubbock. It was shown that diking during the growing season is likely to increase long-term mean sorghum yields by approximately 350 kg/ha at Temple, 590 kg/ha at Uvalde and 450 kg/ha at Lubbock. The increase in net benefits due to furrow diking in the growing season can therefore range from approximately $20 per ha at Temple to $35 per ha at Uvalde.

Edwards Plateau

Mulkey (1986) reported the results of a furrow diking study at Uvalde during 1985. Sorghum was grown on Uvalde silt loam, with a row spacing of 96 cm and plant population of 124,000 per ha. There were three treatments: non-diked, diked during the fallow season and diked during the growing season. The yields reported were 3,500 kg/ha for non-diked, 4,874 kg/ha for diked during the fallow season, and 4,069 kg/ha for diked during the growing season. The treatment that was diked during the fallow season had the highest yield because at planting time it stored 17.6 cm of water in the root zone (180 cm) compared to only about 12 cm in the other treatments. The treatment that was diked during the growing season, however, had the greatest amount of soil water remaining in the profile (1.4 cm) at harvest. In 1986, diking in the growing season resulted in only 100 kg/ha yield increase over the non-diked treatment. Diking in the fallow season resulted in less yield than non-diked, but this was probably due to a lower plant population in that treatment (66500 plants/ha) as compared to the non-diked treatment (75,100 plants/ha). The Uvalde data for both 1985 and 1986 were used for model validation.

FURROW DIKING COSTS

Furrow diking equipment requires an initial investment of $150 to $300 per row of cultivation, depending upon the design selected. Wistrand (1984) estimated that even with a high financing rate of 14%, the annual cost of owning and operating furrow dike equipment was only about $2.50/hectare (Table 16).

Table 16. Estimated costs of purchasing and operating nine row furrow dike equipment (Wistrand, 1984).

Costs	Dollars
Investment Costs:	
Financed 3 years at 14%	2,541.00
Used on 260 ha, 3 years, cost/ha	9.77
7-year life, cost/ha/year	1.40
Operating Costs/ha:	
Fuel[1]	0.22
Labor[2]	0.13
Maintenance[3]	0.71
Subtotal	1.06
Total Annual Cost/ha ($1.40 +1.06)	2.46

[1] Three passes x 7.0 gallons/hour x 0.198 hr/ha x $1.05/gallon x 0.05 additional fuel.

[2] Three times over x 0.198 hr/ha x $4.50 wage/hr x 0.05 added labor.

[3] Price x 0.65 repair ratio/260 ha x 7 year life.

Fuel costs and interest rates have decreased substantially since 1984, while other costs remain approximately the same. The total annual cost now should therefore be lower than $2.50/ha.

SECTION II

MODEL DEVELOPMENT AND VALIDATION

Three crop growth models, SORGF (Arkin et al., 1976; Maas and Arkin, 1978), CORNF (Stapper and Arkin, 1980), and COTTAM (Jackson et al., 1984) were combined with the surface runoff hydrology algorithms from the Erosion-Productivity Impact Calculator (EPIC) model (Williams et al., 1984). Additional subroutines have been added to the crop models to compute surface runoff, and changes were made in the soil water balance subroutine to include the runoff component. The sorghum, corn and cotton models, modified to evaluate the impact of diking are called SORDIKE, CORDIKE, and COTDIKE, respectively. The input data that are required include soil bulk density and water holding capacity, initial water content, latitude, land slope, curve number (AMC-II), plant population, maturity type, and row spacing. Meteorological data requirements include daily maximum and minimum temperatures, rainfall and solar radiation.

Surface runoff is predicted for daily rainfall using the curve number equation developed by the USDA-Soil Conservation Service (1972):

$$Q = \frac{(P - 0.2s)^2}{(P + 0.8s)} \; ; \; P \geq (0.2)s \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where Q is the daily runoff, P is daily rainfall and s is a retention parameter related to available soil water content SW, as shown below (Williams et al., 1984):

$$s = s_1 \left[1 - \frac{SW}{SW + \exp(w_1 - w_2(SW))} \right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where w_1 and w_2 are shape parameters. The value of s_1 is computed from CN_1 (dry) soil moisture condition curve number as follows:

$$s_1 = 254(100/CN_1-1) \quad \text{[3]}$$

Values of CN_1 and CN_3 corresponding to CN_2 (AMC-II) are tabulated in the SCS Hydrology Handbook (USDA-SCS, 1972) and for computing purposes, CN_1 and CN_3 are related to CN_2 by the following equations:

$$CN_1 = CN_2 - \frac{20(100-CN_2)}{100-CN_2+\exp(2.533-0.063(100-CN_2))} \quad \text{[4]}$$

$$CN_3 = CN_2 \exp(0.00673(100-CN_2)) \quad \text{[5]}$$

The shape parameters w_1 and w_2 are computed as follows:

$$w_1 = \ln\left(\frac{FC}{1-(s_3/s_1)} - FC\right) + W_2 * (FC) \quad \text{[6]}$$

$$w_2 = \frac{\ln\left(\frac{FC}{1-(s_3/s_1)} - FC\right) - \ln\left(\frac{ULM}{1-(2.54/s_1)} - ULM\right)}{ULM - FC} \quad \text{[7]}$$

where FC is the root zone water content at field capacity minus wilting point water content in mm, ULM is the upper limit of water storage in the root zone (porosity minus wilting point) in mm, and s_3 corresponds to the field capacity (wet) moisture condition curve number CN_3.

An adjustment is made to express the slope effect (SL) on runoff by assuming that the handbook CN_2 is appropriate for .05 slope. The equation for slope adjustment is

$$CN_{2a} = (CN_3 - CN_2)\ ((1 - 2\ \exp(-13.86\ SL))/3) + CN_2 \ldots\ldots\ldots\ldots[8]$$

where CN_{2a} is CN_2 adjusted for slope.

When land is not diked, runoff occurs as predicted by the above equations and is considered lost from the daily water budget. When dikes are in place, no runoff is subtracted from the water budget. The soil water subroutine allows the rainfall to recharge the profile consisting of up to ten soil layers. Any soil water in excess of field capacity is lost as deep percolation below the root zone. It is assumed in the model that dikes are large enough to hold any runoff that is generated and no provision is made for overtopping.

The SORDIKE model was tested for the non-diked treatment by comparing simulated sorghum yields and runoff with measured yields and runoff data from two small USDA-ARS research watersheds Y-6 and Y-8, located at Riesel, Texas (Krishna et al., 1987). Both watersheds are located on a Houston black clay vertisol. Watershed Y-6 is 6.6 ha in area with an average slope of 3.2% and Y-8 is 8.4 ha with a slope of 2.2%. Sorghum was grown on watershed Y-6 in 1974, 77, and 80 and on Y-8 in 1972, 75, and 78. The measured and simulated runoff and crop yields are shown in Table 17. The SORDIKE model was also tested with data sets from Uvalde and Vernon, Texas. Replicated field experiments were conducted in 1985 and 1986 on Uvalde silt loam and Abilene Loam at the Texas A&M University Agricultural Research and Extension Centers at Uvalde and Vernon, respectively (Mulkey, 1987; Gerard, 1987). The simulated runoff during the growing season compared well with measured runoff at Vernon in 1985 and 1986. At Uvalde, runoff could not be measured accurately due to overtopping of the dikes. Measured and simulated yields for three treatments at Uvalde, and two at Vernon are shown in Table 18.

Table 17. Measured and simulated runoff during the growing season, and crop yields, Riesel, Texas.

Year	Surface Runoff (mm)		Sorghum Yield (kg/ha)	
	Measured	Simulated	Measured	Simulated
1972	0	0	3870	3690
1974	21	34	2940	2650
1975	54	53	4520	5440
1977	34	46	3030	3810
1978	87	99	4870	6190
1980	76	83	2370	2660
$\bar{X}$:	45	52	3600	4070
s:	33	35	980	1450

Table 18. Measured and simulated sorghum yields at Uvalde, and Vernon, Texas.

Location	Year	Treatment	Measured Yield (kg/ha)	Simulated Yield (kg/ha)
Uvalde	1985	Non-diked	3500	3610
		Diked in growing season	4070	3990
		Diked in fallow season	4870	4960
Uvalde	1986	Non-diked	2540	2810
		Diked in growing season	2640	2980
		Diked in fallow season	2310	2590
Vernon	1985	Non-diked	3440	3280
		Diked	4000	3780
Vernon	1986	Non-diked	3810	3200
		Diked	4130	3310

At Uvalde, the predicted crop yields as well as the yield response to diking were in excellent agreement with measured results, both in

1985 and in 1986. At Vernon too, the simulated yields compared well with measured yields in both the years. The simulated yield response to diking was closer to the observed response in 1985 than in 1986. In all cases, the yields predicted by SORDIKE deviated less than 20% from measured yields.

The corn and cotton models, CORNF and COTTAM respectively, have been tested previously against several sets of non-diked data (Maas and Arkin, 1980; Jackson et al., 1984). Data for 1985 on furrow diked corn at the Stiles Farm Foundation was obtained to validate CORDIKE. The simulated non-diked and diked yields were 7650 kg/ha and 7950 kg/ha against measured yields of 7340 and 7520 kg/ha. Attempts were made to obtain additional furrow diking field data on corn at Temple in 1987, but due to a good rainfall season, no differences were found between diked and non-diked treatments. Inadequate runoff and yield data for cotton were available for conducting a robust validation of COTDIKE. However, the data reported by Gerard et al. (1984) for cotton on a Sandy loam soil at Vernon were used to test the model. The non-diked simulated lint yields in 1981 and 1982 were 372 kg/ha and 319 kg/ha respectively, against measured yields of 365 kg/ha and 369 kg/ha. The simulated diked yields were 429 kg/ha and 346 kg/ha in 1981 and 1982 against reported yields of 481 kg/ha and 491 kg/ha. Under non-diked conditions, the predicted yields agreed well with measured yields, but the simulated lint yield response to diking was less than that reported by Gerard et al. (1984).

METHODOLOGY

Mean annual rainfall in Texas ranges from 200 mm in West Texas to more than 1300 mm in the East (Fig. 8). Five major agricultural areas in the semi-arid and sub-humid (300-800 mm annual rainfall) regions of Texas, viz., The High Plains, Rolling Plains, Blackland Prairie, Edwards Plateau and the Coastal Bend (Fig. 9) were targeted for conducting furrow dike simulation studies. Daily weather data (rainfall, maximum and minimum temperatures and solar radiation) for a 25 year period (1960-84) were obtained for Lubbock, Vernon, Temple, Uvalde and Corpus Christi (Fig. 10) to represent the five targeted regions. For each location, SORDIKE, CORDIKE and COTDIKE were run to predict the surface runoff each year, and the likely effect of conserving it (by diking) on sorghum, corn and cotton yields. Even though dryland corn is not an accepted cultural practice in the High Plains and Rolling Plains, CORDIKE was run for those locations because the weather data and the model were already available, and little additional effort was needed to obtain the simulation results. Besides, there is always a possibility that crops and cropping systems can change in the future.

A diking option enables the user to allow the excess rainfall to either run off, or to dike it and allow it to infiltrate into the soil. Diking can be simulated for any part of the year, or for the entire year. In the analyses conducted, three scenarios were simulated: non-diked (ND), diked in the growing season (DIGS), and diked all year (DAY). For any given location and crop, the same planting date was used each year. A continuous soil water simulation was maintained from 1960 to 1984 at each location for SORDIKE and CORDIKE. For COTDIKE however, the soil water status was reinitialized

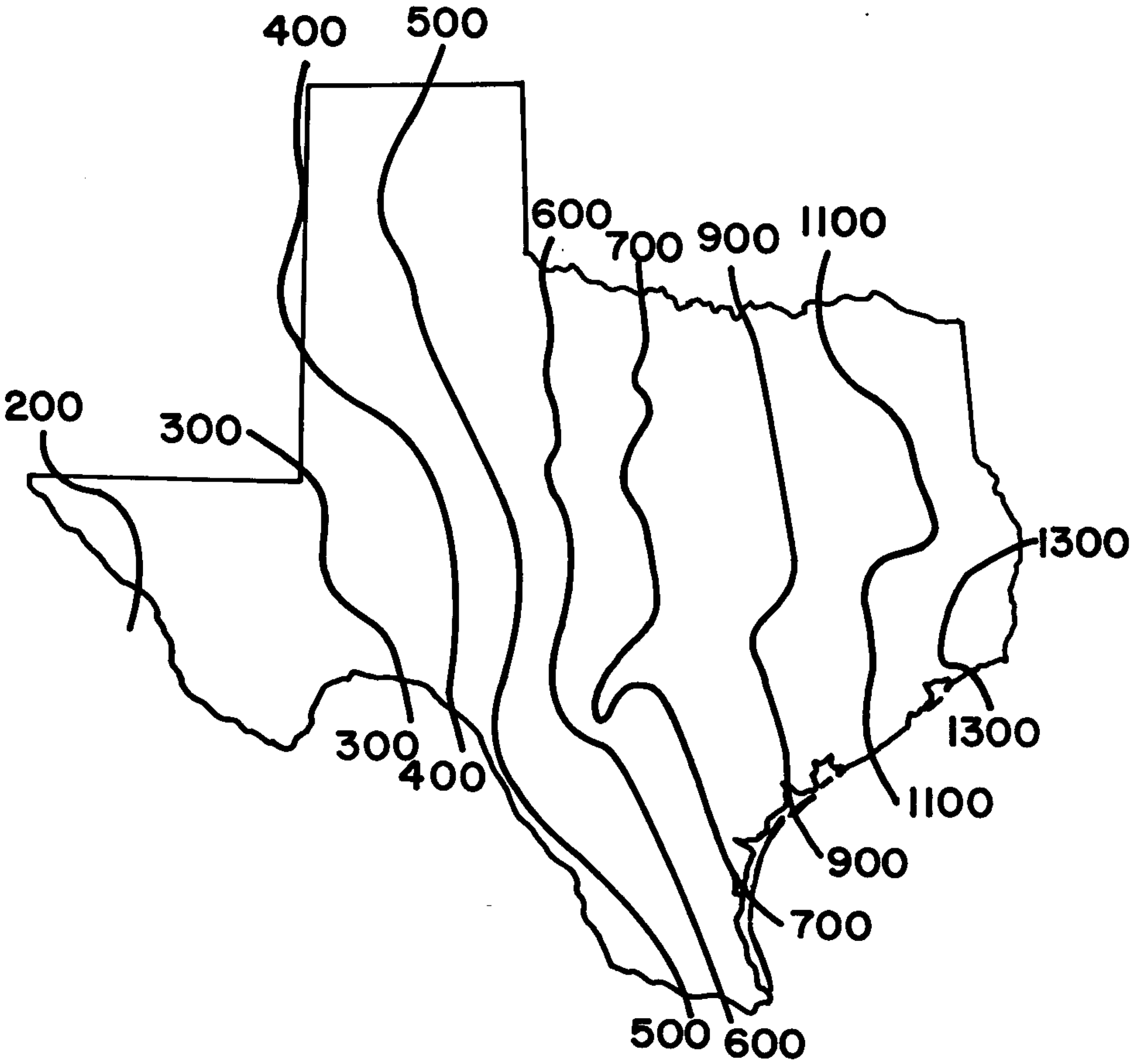

Figure 8. Mean annual rainfall (mm) in Texas.

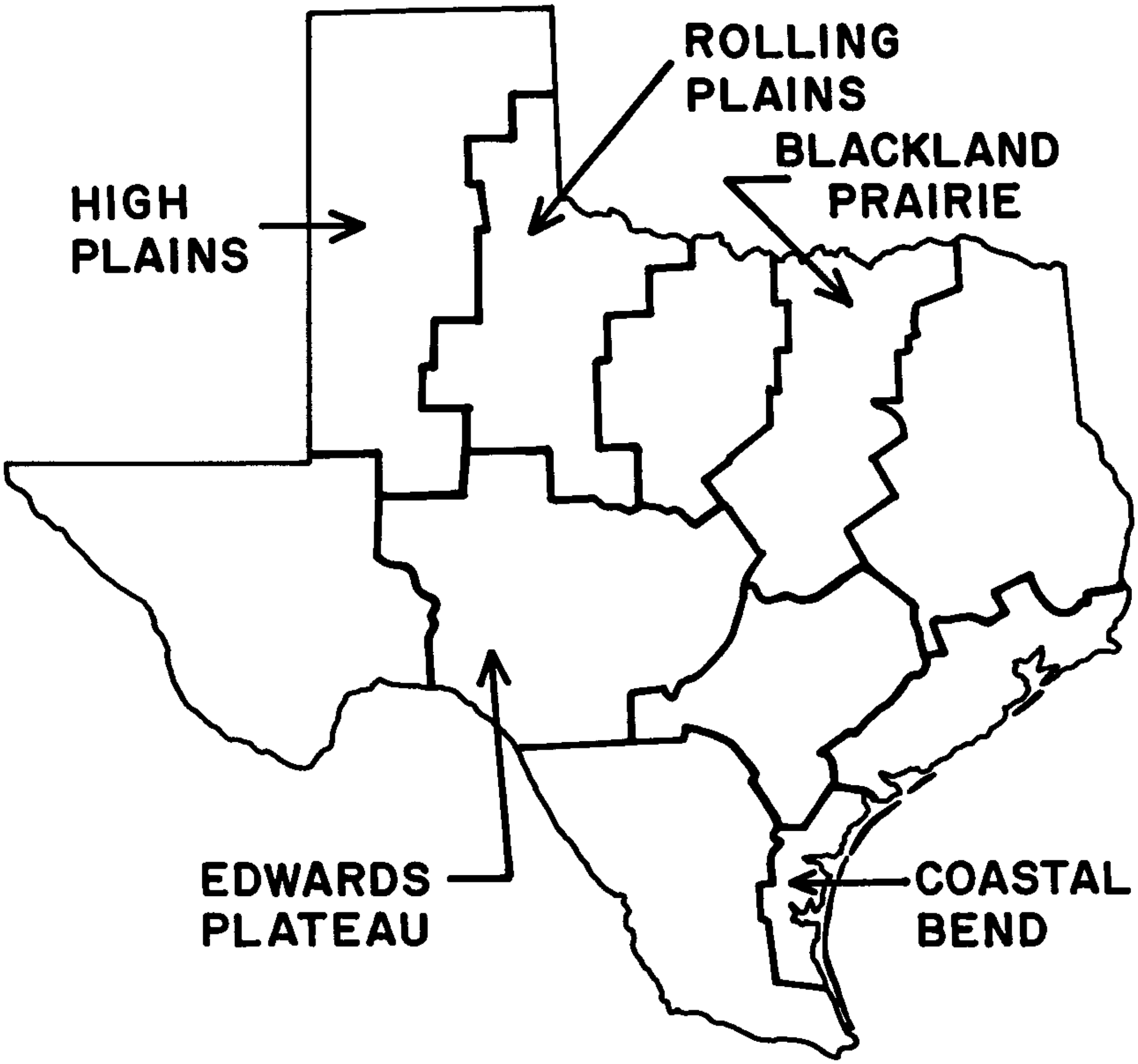

Figure 9. Map of Texas showing crop reporting districts (TDA/USDA, 1986).

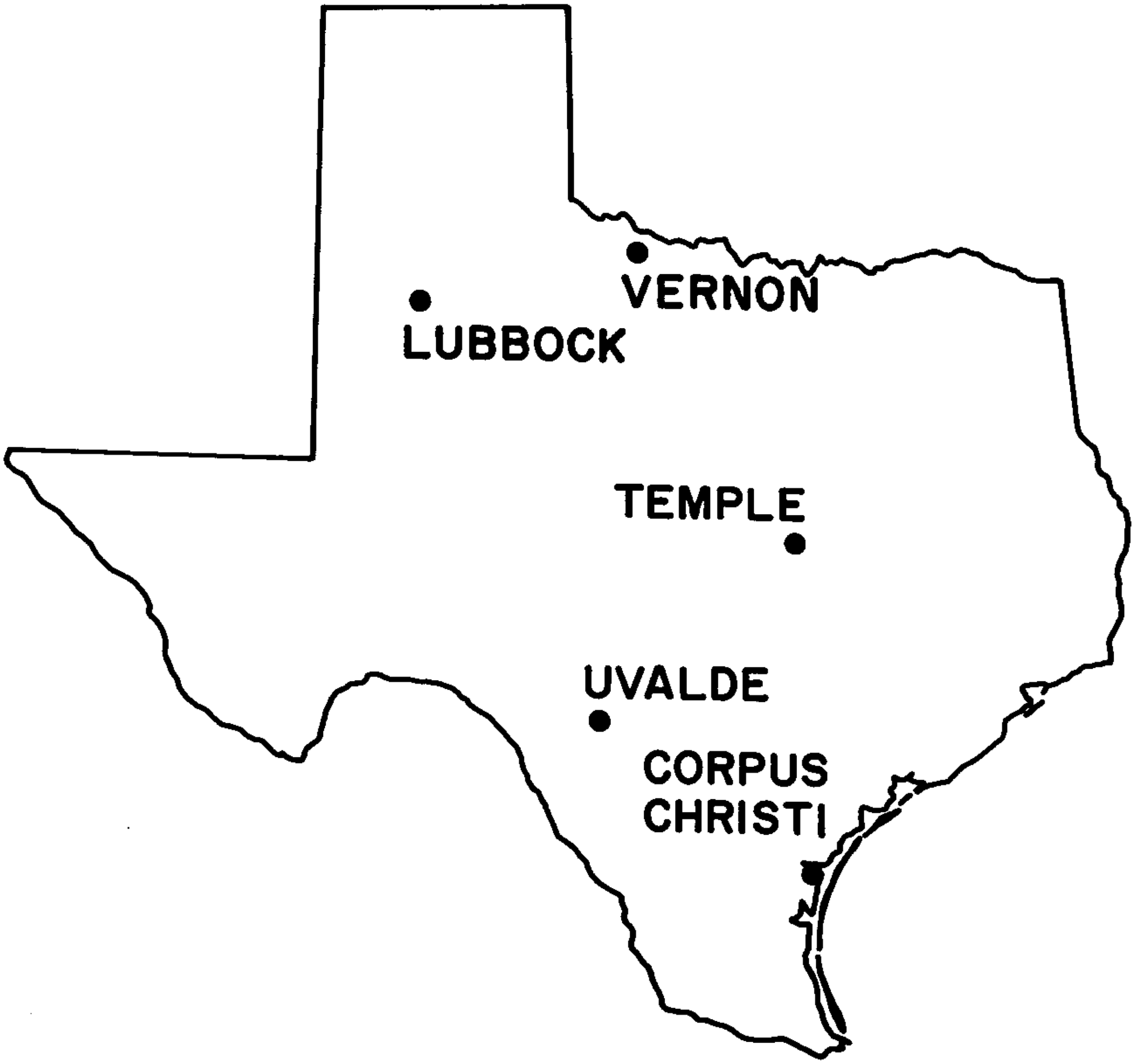

Figure 10. Five Texas locations selected for furrow dike modeling studies.

at the beginning of each year to a preset figure. SORDIKE and CORDIKE were run on a DEC minicomputer while COTDIKE was run on an IBM-AT microcomputer.

The simulated runoff amounts and crop yields were used to determine the Runoff Conservation Efficiency (RCE), defined here as the increase in yield per mm of runoff conserved by diking. The RCE values for the growing season are denoted as RGS and those for the entire year (all year) as RAY. The higher the value of RCE (RGS and RAY), the higher is the value of the runoff water at a given location. The site characteristics and the results of the simulation analyses for each location are described on the following pages.

SIMULATION RESULTS

Lubbock (Southern High Plains):

The mean annual rainfall at Lubbock is 470 mm and the mean monthly rainfall distribution is shown in Figure 11. The soil selected for the simulation analyses was Acuff fine sandy loam. Measured rainfall and simulated non-diked runoff during the sorghum growing season, and for the entire year, are shown in Table 19. Mean runoff of 21 mm were predicted for the growing season, and 29 mm annually at Lubbock. The simulated sorghum yields for non-diked (ND), diked in the growing season (DIGS), and diked all year (DAY) treatments are shown in Table 20. Mean yields of 1260 kg/ha, 1690 kg/ha and 2050 kg/ha were simulated for ND, DIGS and DAY treatments. Diking in the growing season is likely to result in an average annual yield increase of 430 kg/ha of sorghum while year round diking could increase yield by 790 kg/ha.

The runoff and crop yields that are likely under corn, are shown in Tables 21 and 22, respectively. Mean annual corn yields of 1530 kg/ha, 1800 kg/ha and 1950 kg/ha were simulated for ND, DIGS and DAY treatments. Corn yields increased by 270 kg/ha and 420 kg/ha due to diking in the growing season and diking all year, respectively. Both with sorghum and corn, as the mean yields increased due to diking, the standard deviation (s) values also increased, thereby indicating somewhat greater variability associated with the distribution of diked yields over the 25-year period. The runoff conserved and the simulated yields with cotton are shown in Table 23. Mean yields of lint cotton increased from 267 to about 275 kg/ha due to diking. Although crops are planted in May and early June in the Lubbock area, runoff can occur from early May. Diking the land a month ahead of planting may be desirable at Lubbock. At Lubbock, RGS for sorghum, corn and cotton lint are 20.5, 15 and 0.5 kg/ha/mm, respectively. RAY values for the three crops are 27.2, 12.7 and 0.5 kg/ha/mm.

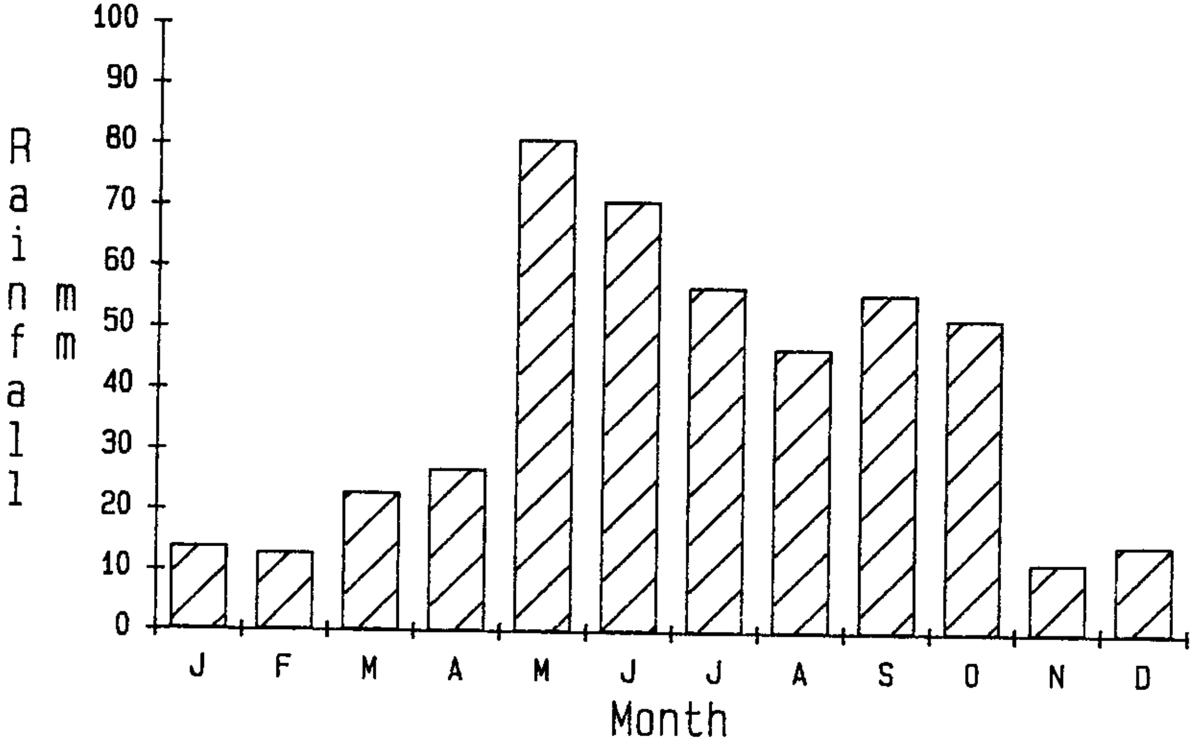

Figure 11. Mean monthly rainfall distribution at Lubbock, Texas.

Table 19. Rainfall (P) and simulated runoff (Q) under non-diked sorghum at Lubbock, Texas.

Year	Growing Season P (mm)	Growing Season Q (mm)	Annual P (mm)	Annual Q (mm)
1960	301	21	562	44
1961	263	26	468	37
1962	335	0	456	0
1963	219	11	382	16
1964	264	8	361	8
1965	299	15	358	15
1966	369	46	468	53
1967	363	120	514	120
1968	227	0	479	1
1969	303	15	741	58
1970	135	2	307	50
1971	375	12	514	13
1972	396	47	632	50
1973	97	1	301	1
1974	499	45	604	45
1975	211	13	443	18
1976	284	12	499	16
1977	243	5	410	5
1978	201	0	315	1
1979	260	19	529	23
1980	193	3	403	9
1981	302	12	584	21
1982	258	6	532	22
1983	370	82	514	82
1984	220	8	369	8
$\bar{x}$:	279	21	470	29
s:	88	28	109	29

Table 20. Simulated sorghum yields at Lubbock, Texas.

Year	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	840	1810	1810
1961	1030	2600	4740
1962	2110	2110	2110
1963	10	80	80
1964	530	600	600
1965	0	0	0
1966	2570	2730	3080
1967	2300	5000	5000
1968	370	390	390
1969	950	950	950
1970	850	850	870
1971	1490	1490	1490
1972	3900	5250	5250
1973	100	1290	2980
1974	1560	1560	1570
1975	4240	4840	5030
1976	1660	2050	2270
1977	2190	2180	2200
1978	150	150	150
1979	700	700	1340
1980	0	0	0
1981	2920	3460	3480
1982	560	1280	2660
1983	0	0	0
1984	500	780	3080
$\bar{x}$:	1260	1690	2050
s:	1210	1570	1700

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year

Table 22. Simulated corn yields at Lubbock, Texas.

YEAR	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	1930	2410	2410
1961	3280	3760	4280
1962	290	290	290
1963	250	280	290
1964	590	620	620
1965	1140	1140	1140
1966	1670	1760	2390
1967	2490	3890	3890
1968	730	740	740
1969	1140	1400	1400
1970	860	870	1180
1971	940	980	980
1972	5580	7760	7800
1973	30	40	40
1974	410	410	410
1975	4910	5440	5520
1976	4470	4990	4990
1977	460	460	470
1978	20	20	20
1979	1540	1570	1720
1980	110	120	130
1981	820	820	820
1982	2500	2810	3470
1983	180	180	220
1984	1960	2220	3550
$\bar{x}$:	1530	1800	1950
s:	1570	1980	2060

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year

Table 21. Rainfall (P) and simulated runoff (Q) under non-diked corn at Lubbock, Texas.

Year	Growing Season		Annual	
	P (mm)	Q (mm)	P (mm)	Q (mm)
1960	307	65	562	94
1961	263	28	468	45
1962	213	0	456	0
1963	129	10	382	13
1964	159	5	361	5
1965	126	0	358	15
1966	314	49	468	64
1967	363	129	514	132
1968	227	0	479	1
1969	114	9	741	50
1970	46	2	307	51
1971	243	2	514	12
1972	465	60	632	64
1973	138	2	301	2
1974	215	4	604	44
1975	211	10	443	16
1976	349	22	499	22
1977	121	2	410	4
1978	67	0	315	1
1979	173	3	529	22
1980	51	2	403	8
1981	249	12	584	30
1982	258	16	532	32
1983	69	1	514	79
1984	220	11	369	11
$\bar{x}$:	204	18	470	33
s:	106	30	109	34

Table 23. Simulated runoff and the impact of diking on cotton lint yields at Lubbock, Texas.

YEAR	ND	DIGS		DAY	
	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)
1960	230	40	230	40	230
1961	245	20	245	20	245
1962	168	0	168	0	168
1963	234	10	234	10	234
1964	212	0	214	0	214
1965	180	10	180	10	180
1966	536	20	547	20	550
1967	255	100	259	100	259
1968	120	0	117	0	119
1969	497	20	556	20	556
1970	179	0	200	10	216
1971	205	0	205	0	213
1972	797	20	801	20	801
1973	129	0	129	0	129
1974	482	10	483	10	483
1975	222	0	222	0	222
1976	412	10	427	10	427
1977	304	0	306	0	309
1978	0	0	0	0	0
1979	248	10	248	30	248
1980	166	0	167	10	169
1981	152	10	169	10	169
1982	257	0	283	10	285
1983	129	50	129	50	129
1984	325	0	326	0	326
$\overline{X}$:	267	13	274	15	275
S:	168	23	173	22	172

ND: Non-Diked
DIGS: Diked in growing season
DAY: Diked all year
RC: Runoff conserved

Vernon (Rolling Plains):

The mean annual rainfall at Vernon is 650 mm and the mean monthly rainfall distribution is shown in Figure 12. The simulation analyses for the Rolling Plains were conducted using the Abilene Loam soil. Daily weather data for 25 years from Vernon were used. There is a bimodal rainfall pattern at Vernon. The long-term rainfall and runoff and the simulated sorghum yields are shown in Tables 24 and 25. Even though crops are planted in June, there may be an advantage in diking ahead of planting, to conserve pre-plant moisture. It can be seen from Table 24 that year round diking, if feasible, will allow an average of 38 mm of runoff to be stored in the soil, against only 11 mm by diking in the growing season. Mean annual sorghum yields increased from 1410 kg/ha to 1900 kg/ha (490 kg/ha increase) by diking in the growing season. Sorghum yields increased by 810 kg/ha from 1410 kg/ha to 2220 kg/ha, by maintaining dikes all year long (Table 25).

The simulation results for corn are shown in Tables 26 and 27. The average runoff that can be conserved during the growing season is 15 mm and that during the entire year is 49 mm. Mean annual corn yields are likely to increase by 570 kg/ha from 3080 kg/ha to 3650 kg/ha by diking in the growing season. Year-round diking could increase average yields by 800 kg/ha to 3880 kg/ha (Table 27).

The runoff conserved and the effect of diking on cotton lint yields are shown in Table 28. Mean annual cotton yields increase from 268 kg/ha to 279 kg/ha by diking in the growing season and to 301 kg/ha by diking all year. RGS at Vernon for sorghum is 44.5 and RAY is 21. The RGS for corn is 38 and RAY is 16. RGS and RAY for cotton are 0.58 and 1.14, respectively.

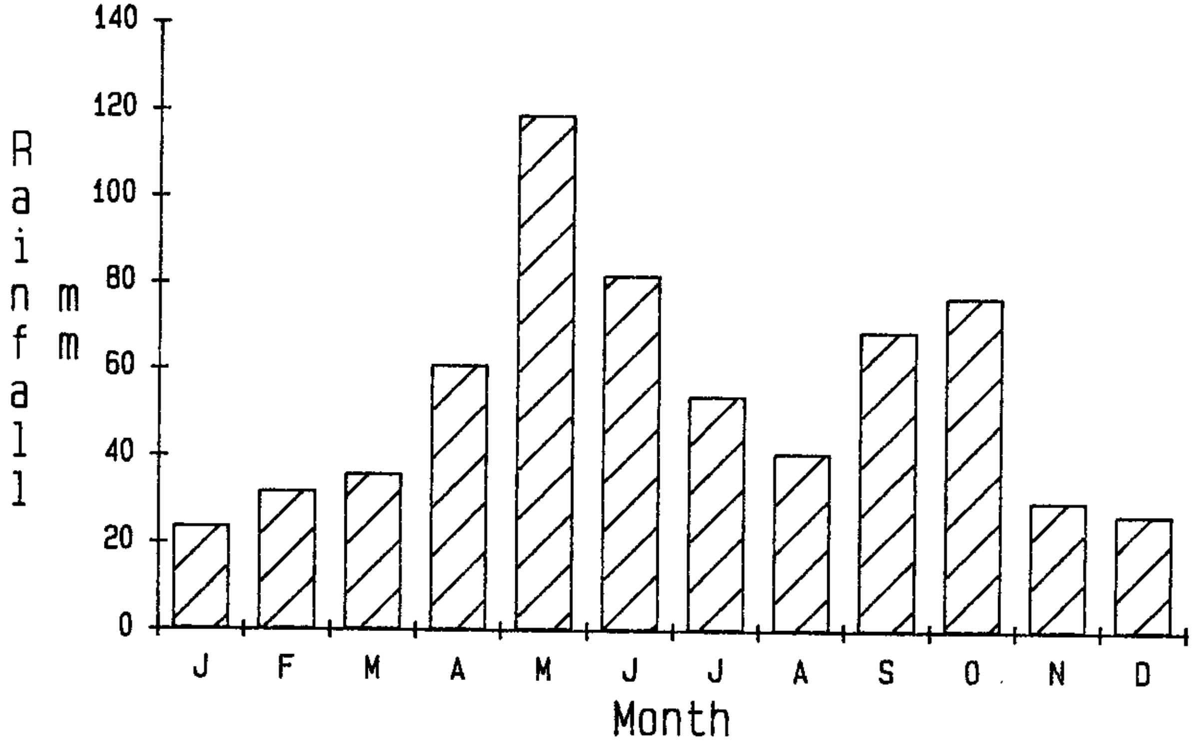

Figure 12. Mean monthly rainfall distribution at Vernon, Texas.

Table 24. Rainfall (P) and simulated runoff (Q) under non-diked sorghum at Vernon, Texas.

Year	Growing Season P (mm)	Q (mm)	Annual P (mm)	Q (mm)
1960	109	1	680	62
1961	239	13	687	55
1962	210	16	741	34
1963	168	30	476	89
1964	333	7	600	14
1965	270	16	496	18
1966	356	20	550	20
1967	190	22	486	62
1968	206	16	726	19
1969	299	1	718	56
1970	166	0	425	3
1971	380	2	614	2
1972	209	12	640	18
1973	202	0	789	45
1974	309	1	636	30
1975	325	30	717	110
1976	294	0	614	6
1977	123	6	668	99
1978	252	5	509	7
1979	219	3	705	29
1980	59	0	411	7
1981	254	3	599	16
1982	111	3	731	43
1983	411	74	832	92
1984	110	2	466	15
$\overline{x}$:	232	11	621	38
s:	92	16	117	32

Table 25. Simulated sorghum yields at Vernon, Texas.

YEAR	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	720	950	1490
1961	2260	4490	4490
1962	190	1060	1310
1963	0	0	0
1964	70	100	100
1965	760	770	820
1966	2100	2640	2640
1967	300	580	1370
1968	1090	2310	2520
1969	2930	3190	5500
1970	260	260	260
1971	3240	3240	3240
1972	200	200	330
1973	3190	3900	3900
1974	4150	4920	5260
1975	3750	5580	5580
1976	800	810	930
1977	1790	2170	2160
1978	0	0	0
1979	4240	4440	6470
1980	0	0	0
1981	1000	1050	1050
1982	1680	1860	3090
1983	250	800	830
1984	160	2100	2250
$\bar{X}$:	1410	1900	2220
s:	1430	1730	2040

ND; Non-diked
DIGS: Diked in growing season
DAY: Diked all year
RC: Runoff conserved

Table 26. Rainfall (P) and simulated runoff (Q) under non-diked corn at Vernon, Texas.

Year	Growing Season P (mm)	Growing Season Q (mm)	Annual P (mm)	Annual Q (mm)
1960	109	3	680	73
1961	246	25	687	67
1962	269	31	741	51
1963	139	59	476	119
1964	127	7	600	17
1965	96	0	496	19
1966	67	0	550	23
1967	106	3	486	43
1968	227	18	726	21
1969	271	14	718	71
1970	34	0	425	4
1971	195	1	614	2
1972	208	6	640	40
1973	321	33	789	80
1974	309	35	636	67
1975	373	86	717	166
1976	91	2	614	9
1977	167	12	668	104
1978	63	1	509	7
1979	219	6	705	39
1980	0	0	411	11
1981	149	3	599	15
1982	154	5	731	48
1983	116	27	832	109
1984	207	3	466	22
$\bar{x}$:	171	15	621	49
s:	94	21	117	42

Table 27. Simulated corn yields at Vernon, Texas.

YEAR	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	2830	2870	2900
1961	6330	6890	6890
1962	3210	3240	3240
1963	2260	2270	2270
1964	600	660	710
1965	1450	1650	1690
1966	250	1800	1800
1967	460	2420	2930
1968	4220	5060	5480
1969	5690	6660	6690
1970	630	1460	1850
1971	1410	1410	1410
1972	4990	5360	5620
1973	6040	6540	6540
1974	2590	3740	3740
1975	6600	8200	8200
1976	1330	4200	4450
1977	4220	4330	4350
1978	90	90	100
1979	7210	7230	8820
1980	550	550	1060
1981	4350	4450	5530
1982	4870	5030	5130
1983	2640	2760	2760
1984	2150	2350	2760
$\overline{X}$:	3080	3650	3880
s:	2230	2280	2380

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year
RC: Runoff conserved

Table 28: Simulated runoff and the impact of diking on cotton lint yields at Vernon, Texas.

YEAR	ND	DIGS		DAY	
	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)
1960	130	30	130	30	130
1961	204	10	207	10	210
1962	136	30	136	40	136
1963	121	70	121	70	120
1964	268	10	282	10	307
1965	0	10	0	10	0
1966	0	20	0	20	0
1967	157	10	163	50	163
1968	388	20	429	20	429
1969	539	30	550	60	575
1970	0	0	0	0	0
1971	166	0	166	0	166
1972	264	0	264	10	266
1973	381	10	405	10	405
1974	527	10	535	10	537
1975	528	90	595	90	595
1976	181	0	181	0	181
1977	219	10	219	80	219
1978	809	0	809	10	1,021
1979	447	10	453	40	453
1980	299	0	301	10	582
1981	436	10	506	10	506
1982	346	20	348	60	348
1983	165	60	177	70	187
1984	0	10	0	10	0
$\overline{X}$:	268	19	279	29	301
S:	203	23	212	28	245

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year
RC: Runoff conserved

Temple (Blackland Prairie):

The mean annual rainfall at Temple is 860 mm and the monthly distribution is shown in Figure 13. Although the rainfall can vary from year to year, there is a 65% probability of receiving at least 750 mm annually at Temple (Tucker and Griffiths, 1965). Houston black clay was chosen as the representative soil for the simulation analyses.

The rainfall and simulated runoff under sorghum are shown in Table 29. Diking in the growing season on average could conserve 70 mm of runoff while year round diking could conserve 129 mm. The predicted sorghum yields are shown in Table 30. They range from less than 1000 to more than 8000 kg/ha. Non-diked mean yield is 5280 kg/ha, that is likely to increase by 320 kg/ha to 5600 kg/ha by diking in the growing season. DAY increases the yield only slightly to 5720 kg/ha at Temple.

The rainfall and runoff under corn (Table 31) follow a similar pattern to that of sorghum, but with somewhat higher annual runoff. The predicted corn yields (Table 32) are also in the same general range of those of sorghum. Diking in the growing season results in 180 kg/ha additional yield on the long-term, while year round diking increases yields by only 210 kg/ha. It appears from this study that corn would not be a suitable crop to grow under diked conditions in the Blacklands. A furrow-dike field experiment at Temple in 1987 with corn further corroborated the modeling results.

Runoff under cotton and predicted lint yields are shown in Table 33. DIGS increased average lint yields from 386 to 406 kg/ha, due to an additional 68 mm of runoff that could be conserved by diking. DAY made little additional difference to the simulated yields.

The RGS values for sorghum, corn and cotton at Temple are 5, 3 and 0.3 kg/ha/mm, respectively. The RAY values for the three crops are 3,

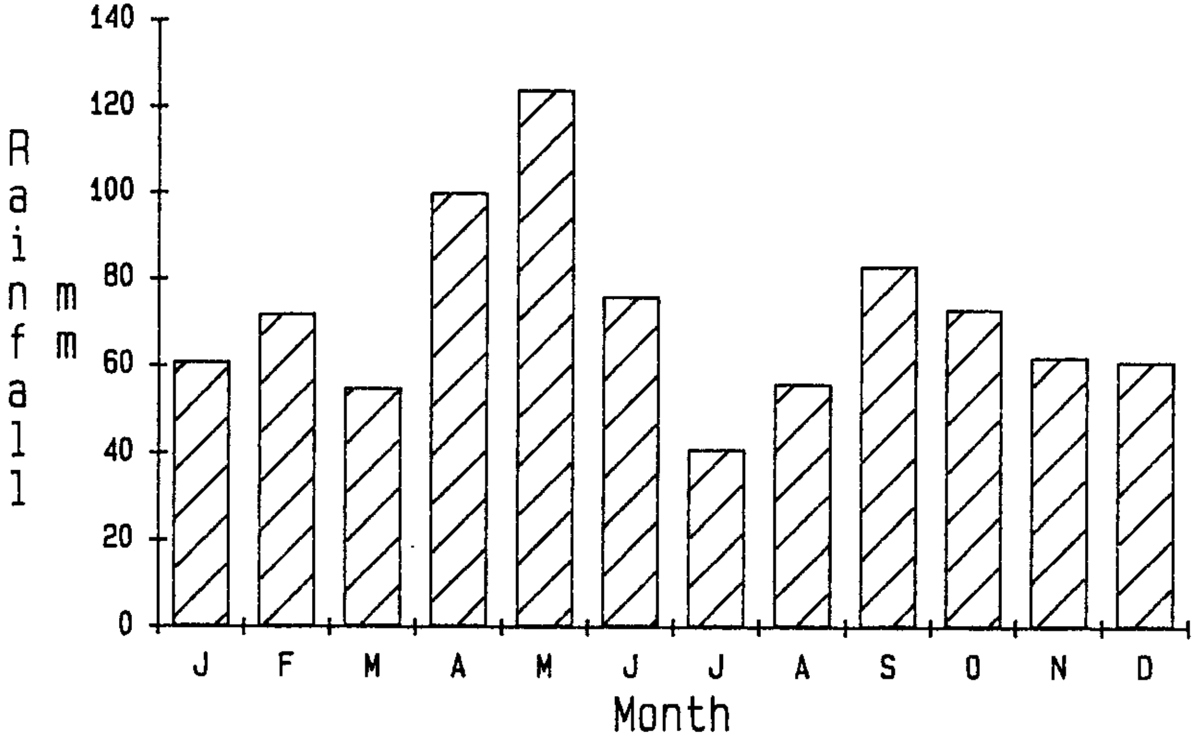

Figure 13. Mean monthly rainfall distribution at Temple, Texas.

Table 29. Rainfall (P) and simulated runoff (Q) under non-diked sorghum at Temple, Texas.

Year	Growing Season		Annual	
	P (mm)	Q (mm)	P (mm)	Q (mm)
1960	232	31	1064	218
1961	219	19	727	87
1962	302	16	769	35
1963	162	2	490	9
1964	259	30	785	44
1965	344	111	1007	220
1966	411	75	807	111
1967	285	41	820	84
1968	370	80	1057	211
1969	203	50	698	76
1970	239	51	690	80
1971	161	2	934	145
1972	211	23	649	27
1973	374	65	1056	139
1974	162	27	756	100
1975	586	192	1048	337
1976	509	176	1048	237
1977	363	142	673	196
1978	225	11	754	35
1979	624	291	1249	331
1980	310	85	660	102
1981	532	54	1169	189
1982	355	18	723	29
1983	329	132	865	142
1984	241	15	859	48
$\bar{x}$:	320	70	854	129
s:	130	70	188	92

Table 30: Simulated sorghum yields at Temple, Texas.

Year	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	5700	5720	5720
1961	6120	6200	6200
1962	7510	8130	8230
1963	2190	2240	3700
1964	2680	4760	5010
1965	7380	7450	7450
1966	7680	7680	7690
1967	7450	8100	8100
1968	8280	8280	8280
1969	1270	1460	1460
1970	4560	4990	4990
1971	250	280	570
1972	5920	6900	6900
1973	6510	7060	7060
1974	2790	3170	3170
1975	7180	7180	7180
1976	6440	6490	6490
1977	6550	6720	6720
1978	5730	6300	7090
1979	7390	7390	7390
1980	1740	1760	1760
1981	8040	8040	8040
1982	8700	8730	8730
1983	3080	3340	3340
1984	760	1640	1830
$\bar{x}$:	5280	5600	5720
s:	2620	2540	2450

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year

Table 31. Rainfall (P) and simulated runoff (Q) under non-diked corn at Temple, Texas.

Year	P (mm)	Q (mm)	P (mm)	Q (mm)
1960	232	3	1064	219
1961	293	20	727	98
1962	302	37	769	98
1963	229	22	490	32
1964	259	44	785	110
1965	344	106	1007	270
1966	411	74	807	112
1967	285	55	820	154
1968	440	81	1057	240
1969	231	57	698	84
1970	243	48	690	113
1971	161	4	934	187
1972	245	19	649	47
1973	376	66	1056	193
1974	163	22	756	139
1975	592	192	1048	334
1976	518	173	1048	270
1977	364	137	673	191
1978	225	33	754	87
1979	660	298	1249	407
1980	310	79	660	96
1981	539	103	1169	239
1982	358	18	723	31
1983	329	92	865	150
1984	241	28	859	106
$\bar{x}$:	334	72	854	160
s:	130	68	188	94

Table 32. Simulated corn yields at Temple, Texas.

YEAR	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	3810	3880	3880
1961	6710	6800	6800
1962	7460	7630	7630
1963	4610	4650	4650
1964	5210	5610	5630
1965	6710	6760	6760
1966	7750	7830	7830
1967	7020	7370	7370
1968	7590	7620	7620
1969	2980	3090	3090
1970	5040	5350	5350
1971	1660	1730	1940
1972	4940	5440	5440
1973	6990	7540	7540
1974	3870	4210	4210
1975	6760	6790	6790
1976	5840	5870	5870
1977	4660	4680	4940
1978	4700	5310	5310
1979	6750	6750	6750
1980	3180	3190	3260
1981	8700	8700	8740
1982	7550	8020	8170
1983	4240	4380	4380
1984	2980	3160	3160
$\bar{x}$:	5510	5690	5720
s:	1840	1850	1830

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year

Table 33. Simulated runoff and the impact of diking on cotton lint yields at Temple, Texas.

YEAR	ND	DIGS		DAY	
	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)
1960	665	130	687	150	687
1961	446	50	446	90	446
1962	204	30	204	60	204
1963	216	10	224	10	227
1964	472	50	473	70	474
1965	291	90	295	170	295
1966	422	30	463	70	463
1967	281	60	314	60	314
1968	468	80	513	180	513
1969	189	0	189	40	194
1970	165	40	165	80	174
1971	713	60	759	60	759
1972	350	10	407	20	407
1973	333	90	333	120	333
1974	292	50	292	50	292
1975	813	200	817	220	818
1976	330	40	339	170	339
1977	201	20	202	150	202
1978	285	40	285	110	285
1979	675	200	725	300	725
1980	206	40	208	60	208
1981	662	190	714	210	721
1982	287	20	287	20	287
1983	422	90	507	130	507
1984	268	80	303	80	303
$\bar{X}$:	386	68	406	107	407
S:	187	58	199	73	199

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year
RC: Runoff conserved

1 and 0.2 kg/ha/mm. The low runoff conservation efficiency values indicate that the yield response to diking (kg/ha/mm of runoff) is lower at Temple than at most other locations selected for this analysis.

Uvalde (Edwards Plateau):

The mean annual rainfall at Uvalde is 590 mm and the monthly distribution of rainfall is shown in Figure 14. Uvalde has a bimodal rainfall pattern with peaks in May and September. The soil used for the simulation study was Uvalde silt loam.

The simulated runoff amounts under sorghum are shown in Table 34. Diking all year is likely to conserve more than twice as much water as diking in the growing season alone. The predicted sorghum yields (Table 35), range from 0 to more than 8000 kg/ha. Mean annual yields increase from 2630 kg/ha for ND, to 3200 kg/ha for DIGS, and to 3710 kg/ha for the DAY treatment. Runoff under corn (Table 36) exhibits a pattern similar to that under sorghum. More than twice the amount of runoff could be conserved by diking all year as compared to diking only in the growing season. Predicted corn yields (Table 37) range from about 300 kg/ha to more than 8000 kg/ha. Mean annual corn yields increased by 430 kg/ha from 3750 kg/ha under non-diked conditions to 4180 kg/ha under diking in the growing season. Yields increased 560 kg/ha by diking all year round. The response of cotton to diking is shown in Table 38. The mean lint yield increased from 331 kg/ha to 352 kg/ha by diking in the growing season, and increased to 359 kg/ha by diking all year.

The RGS and RAY for sorghum are 29 kg/ha/mm and 25 kg/ha/mm, and for corn, 14 and 8 kg/ha/mm, respectively. RGS and RAY for cotton at Uvalde are 0.8 and 1.0, respectively.

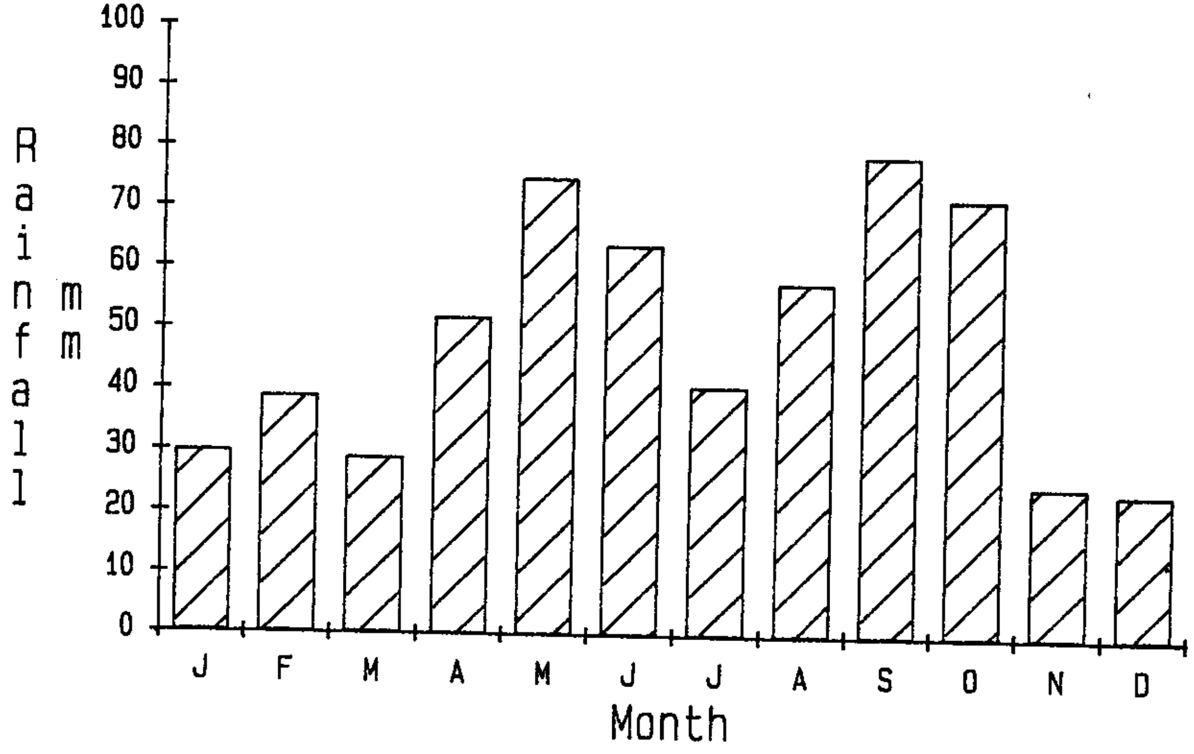

Figure 14. Mean monthly rainfall distribution at Uvalde, Texas.

Table 34. Rainfall (P) and simulated runoff (Q) under non-diked sorghum at Uvalde, Texas.

Year	Growing Season		Annual	
	P (mm)	Q (mm)	P (mm)	Q (mm)
1960	114	5	547	21
1961	284	24	661	96
1962	130	5	359	8
1963	206	28	365	30
1964	126	0	566	20
1965	250	50	666	58
1966	232	43	530	51
1967	116	1	510	5
1968	214	36	640	59
1969	236	7	848	141
1970	92	3	345	17
1971	281	16	788	115
1972	173	2	391	4
1973	226	2	784	63
1974	145	18	784	175
1975	423	113	658	130
1976	627	56	1158	199
1977	210	51	503	57
1978	201	24	434	27
1979	623	167	822	169
1980	239	18	586	70
1981	377	57	662	58
1982	202	6	591	27
1983	256	6	738	52
1984	82	0	377	25
$\bar{x}$:	243	30	613	67
s:	141	39	192	57

Table 35. Simulated sorghum yields at Uvalde, Texas.

YEAR	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	120	870	3580
1961	3290	3370	3530
1962	0	0	580
1963	250	820	820
1964	670	670	670
1965	4680	6290	6990
1966	1170	2720	3970
1967	0	0	0
1968	4130	6090	6430
1969	270	280	320
1970	970	1050	3560
1971	5740	5740	5740
1972	1250	1500	3800
1973	2610	2630	2640
1974	1100	2350	3010
1975	8170	8170	8170
1976	6040	8310	8310
1977	6620	7260	7260
1978	420	420	440
1979	5860	6650	6710
1980	3670	4230	4230
1981	6110	6700	7100
1982	1140	1710	2010
1983	1320	2070	2780
1984	90	90	130
$\bar{x}$:	2630	3200	3710
s:	2570	2840	2730

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year

Table 36. Rainfall (P) and simulated runoff (Q) under non-diked corn at Uvalde, Texas.

Year	Growing Season P (mm)	Growing Season Q (mm)	Annual P (mm)	Annual Q (mm)
1960	114	5	547	21
1961	284	24	661	96
1962	130	5	359	8
1963	206	28	365	30
1964	126	0	566	20
1965	250	50	666	58
1966	232	43	530	51
1967	116	1	510	5
1968	214	36	640	59
1969	236	7	848	141
1970	92	3	345	17
1971	281	16	788	115
1972	173	2	391	4
1973	226	2	784	63
1974	145	18	784	175
1975	423	113	658	130
1976	627	56	1158	199
1977	210	51	503	57
1978	201	24	434	27
1979	623	167	822	169
1980	239	18	586	70
1981	377	57	662	58
1982	202	6	591	27
1983	256	6	738	52
1984	82	0	377	25
$\bar{x}$:	243	30	613	67
s:	141	39	192	57

Table 37. Simulated corn yields at Uvalde, Texas.

YEAR	ND (kg/ha)	DDGS (kg/ha)	DAY (kg/ha)
1960	1970	2010	2010
1961	5440	5660	5940
1962	2870	3010	3640
1963	2020	2480	3010
1964	310	350	380
1965	5660	6480	6480
1966	3920	5050	5050
1967	1620	2100	2170
1968	5450	5790	5790
1969	4760	5310	5460
1970	3770	3900	3960
1971	2770	3230	3260
1972	1380	1430	1440
1973	4030	4050	4090
1974	3530	4520	4850
1975	6490	6940	6940
1976	5670	6380	6380
1977	3530	3580	3580
1978	2630	3330	3390
1979	8480	8650	8650
1980	890	1320	1330
1981	6580	7320	7320
1982	3850	4690	4860
1983	5670	6330	7050
1984	510	550	770
$\bar{x}$:	3750	4180	4310
s:	2100	2220	2220

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year

Table 38. Simulated runoff and the impact of diking on cotton lint yields at Uvalde, Texas.

YEAR	ND	DIGS		DAY	
	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)
1960	308	0	318	0	318
1961	471	30	515	30	515
1962	0	0	0	0	0
1963	229	10	238	10	238
1964	0	10	0	10	0
1965	424	0	424	10	463
1966	400	10	412	10	412
1967	0	0	0	0	0
1968	312	10	325	10	325
1969	245	90	246	90	246
1970	0	0	0	0	0
1971	864	40	941	40	941
1972	0	0	0	0	0
1973	403	20	477	20	477
1974	643	50	655	50	655
1975	649	10	664	20	664
1976	923	60	923	60	923
1977	160	10	166	10	166
1978	365	20	430	20	430
1979	424	210	424	220	424
1980	337	40	432	40	432
1981	342	0	342	20	475
1982	353	10	389	10	389
1983	417	10	482	10	483
1984	0	10	0	10	0
$\overline{X}$:	331	26	352	28	359
S:	258	45	271	46	273

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year
RC: Runoff conserved

Corpus Christi (Coastal Bend):

The mean annual rainfall at Corpus Christi is 720 mm and the mean monthly distribution of rainfall is shown in Figure 15. The Orelia sandy clay loam was used as a representative soil for the Coastal Bend region.

The simulated runoff amounts and crop yields under sorghum are shown in Tables 39 and 40, respectively. Crop yields ranged from 0 to more than 6000 kg/ha. The mean annual sorghum yield of 2610 kg/ha increased by 440 kg/ha to 3050 kg/ha by diking in the growing season. Diking all year increased the yield further to 3240 kg/ha. The simulation results with corn are shown in Tables 41 and 42. Corn yields increased by 460 kg/ha due to DIGS and by 530 kg/ha due to DAY.

Results of the simulation with cotton (Table 43) indicated that diking in the growing season could increase average annual lint yields by 14 kg/ha from 360 to 374 kg/ha. Year round diking appears to be of little further benefit for cotton at Corpus Christi. RGS for sorghum, corn and cotton lint are 10, 7 and 0.14 kg/ha/mm, respectively. The RAY values for the three crops are 4, 3 and 0.13 kg/ha/mm.

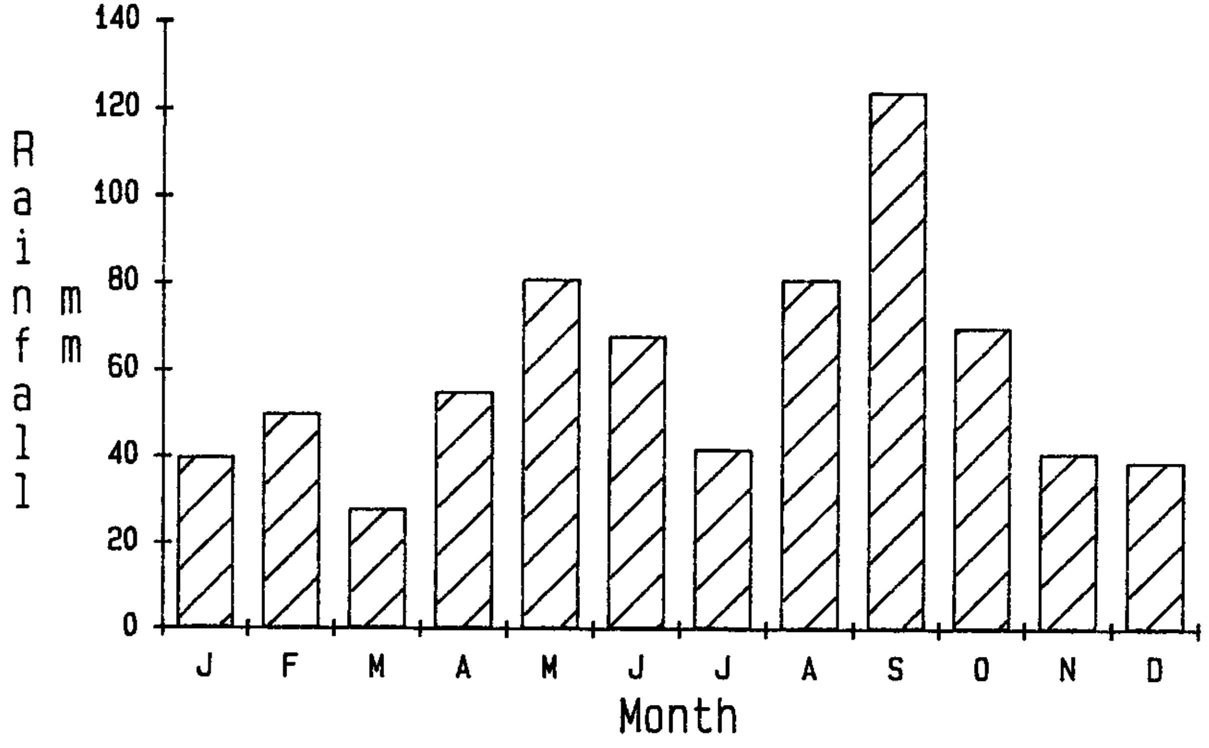

Figure 15. Mean monthly rainfall distribution at Corpus Christi, Texas.

Table 39. Rainfall (P) and simulated runoff (Q) under non-diked sorghum at Corpus Christi, Texas.

Year	Growing Season P (mm)	Growing Season Q (mm)	Annual P (mm)	Annual Q (mm)
1960	283	36	1238	350
1961	125	19	585	119
1962	271	2	462	17
1963	91	1	367	3
1964	206	9	581	24
1965	184	13	696	47
1966	488	135	732	138
1967	135	1	925	300
1968	558	266	1191	413
1969	139	18	683	92
1970	234	19	686	59
1971	177	20	1111	508
1972	301	39	796	157
1973	395	44	1008	212
1974	286	71	629	82
1975	205	25	769	119
1976	298	28	1058	231
1977	209	70	562	90
1978	175	18	608	92
1979	324	62	992	246
1980	88	5	830	292
1981	367	100	1118	354
1982	367	92	1118	348
1983	155	8	561	144
1984	94	10	553	42
$\bar{x}$:	246	44	794	179
s:	122	58	249	139

Table 40. Simulated sorghum yields at Corpus Christi, Texas.

YEAR	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	1470	1470	1470
1961	810	1430	1430
1962	0	0	0
1963	330	350	410
1964	690	1030	1090
1965	3000	3590	4870
1966	5940	6380	6380
1967	0	0	20
1968	5940	6660	6660
1969	2090	2870	2870
1970	5760	6250	6250
1971	430	1440	2550
1972	4930	6100	6240
1973	5620	6070	6300
1974	310	310	310
1975	430	1450	2460
1976	4910	6060	6060
1977	2710	3440	3440
1978	1000	1030	1080
1979	4590	5090	5090
1980	1280	1350	1530
1981	4880	5010	5010
1982	5070	5190	5190
1983	3120	3750	3750
1984	0	0	490
$\bar{x}$:	2610	3050	3240
s:	2240	2410	2370

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year

Table 41. Rainfall (P) and simulated runoff (Q) under non-diked corn at Corpus Christi, Texas.

Year	Growing Season P (mm)	Growing Season Q (mm)	Annual P (mm)	Annual Q (mm)
1960	272	39	1238	391
1961	189	31	585	133
1962	111	0	462	30
1963	105	16	367	40
1964	262	55	581	85
1965	191	44	696	100
1966	522	183	732	191
1967	110	4	925	313
1968	717	335	1191	420
1969	139	22	683	102
1970	234	21	686	93
1971	173	34	1111	551
1972	325	54	796	191
1973	395	99	1008	278
1974	267	75	629	95
1975	273	51	769	148
1976	533	96	1058	261
1977	213	82	562	105
1978	130	24	608	119
1979	324	78	992	283
1980	125	12	830	343
1981	381	128	1118	366
1982	380	127	1118	364
1983	162	26	561	166
1984	90	11	553	86
$\bar{x}$:	265	66	794	210
s:	156	72	249	138

Table 42. Simulated corn yields at Corpus Christi, Texas.

YEAR	ND (kg/ha)	DIGS (kg/ha)	DAY (kg/ha)
1960	3980	4610	4670
1961	3470	3720	3720
1962	2620	2620	3710
1963	100	120	120
1964	1350	1350	1370
1965	1810	2110	2110
1966	4900	5690	5690
1967	360	380	440
1968	5030	5300	5440
1969	1440	1810	1900
1970	7470	7860	7860
1971	5170	6230	6260
1972	7220	8440	8440
1973	7350	7740	7990
1974	4650	4670	4670
1975	2050	2490	2570
1976	5660	7200	7200
1977	2070	2180	2180
1978	1550	2030	2090
1979	6270	7520	7520
1980	390	400	420
1981	7420	8200	8200
1982	7350	8190	8190
1983	1690	1910	1910
1984	220	240	320
$\bar{x}$:	3660	4120	4190
s:	2590	2910	2880

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year

Table 43. Simulated runoff and the impact of diking on cotton lint yields at Corpus Christi, Texas.

YEAR	ND	DIGS		DAY	
	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)	RC (MM)	YIELD (KG/HA)
1960	475	160	509	160	514
1961	248	50	295	60	295
1962	434	0	434	0	434
1963	160	0	164	0	164
1964	176	50	177	50	177
1965	250	50	262	70	262
1966	249	80	249	130	249
1967	549	230	549	260	549
1968	410	320	428	330	428
1969	151	30	151	40	151
1970	203	40	203	40	203
1971	1,031	340	1,031	340	1,031
1972	352	60	353	100	353
1973	580	170	580	170	580
1974	189	10	210	60	210
1975	836	50	950	50	950
1976	459	120	471	130	471
1977	115	0	115	50	115
1978	158	70	158	70	158
1979	230	180	233	200	237
1980	524	150	524	150	524
1981	481	150	522	180	522
1982	404	160	449	180	449
1983	128	20	139	110	139
1984	205	20	205	50	205
$\overline{X}$:	360	100	374	119	375
S:	228	96	239	93	239

ND: Non-diked
DIGS: Diked in growing season
DAY: Diked all year
RC: Runoff conserved

SUMMARY AND CONCLUSIONS

Results of past furrow diking research in the High Plains and Rolling Plains of Texas, have generally indicated a favorable response from diking. The increases in crop yields however varied considerably between locations, and between years at any particular location. Although positive results were obtained, they did not adequately quantify the long-term benefits from furrow diking. Besides, those results may not be transferable to other sites in Texas.

To evaluate likely long-term benefits, a runoff prediction method based on the USDA-ARS curve number methodology, was combined with three crop models for sorghum, corn and cotton. The combined models, SORDIKE, CORDIKE and COTDIKE were validated with data from several Texas sites, and modified to simulate three possible scenarios: no diking, diking in the growing season, and diking all year. The models were run with daily weather data for 25 years (1960-84), from the following five representative Texas locations: Lubbock (Southern High Plains); Vernon (Rolling Plains); Temple (Blackland Prairie); Uvalde (Edwards Plateau); and Corpus Christi (Coastal Bend). Seasonal and annual runoff amounts and crop yields were simulated for sorghum, corn and cotton under diked and non-diked conditions at each of the above locations. Even though corn is normally not grown in the High Plains and Rolling Plains of Texas, the two locations were included in CORDIKE simulations to maintain consistency. Besides, existing cropping systems can change in the future.

At Lubbock, the mean annual non-diked yields of sorghum, corn and cotton lint were 1260 kg/ha, 1530 kg/ha and 267 kg/ha. Diking in the growing season increased mean annual yields of sorghum, corn and cotton lint by 430 kg/ha, 270 kg/ha and 7 kg/ha, respectively. Diking all year resulted in average annual yield increases of 790 kg/ha, 420 kg/ha and 8 kg/ha for the three crops.

At Vernon, average non-diked yields were 1410 kg/ha of sorghum, 3080 kg/ha of corn and 268 kg/ha of lint cotton. These yields increased by 490 kg/ha, 570 kg/ha and 11 kg/ha, respectively, for the three crops, when they were diked in the growing season. Diking all year increased sorghum, corn and cotton lint yields by an average of 810 kg/ha, 800 kg/ha and 33 kg/ha, respectively.

The average non-diked yields at Temple were 5280 kg/ha of sorghum, 5510 kg/ha of corn, and 386 kg/ha of cotton lint. Diking in the growing season increased the yields of those three crops by 320 kg/ha, 180 kg/ha and 20 kg/ha, respectively. Diking all year increases the yields 440 kg/ha, 210 kg/ha and 21 kg/ha over non-diked yields.

At Uvalde, non-diked yields of sorghum, corn and cotton lint were 2630 kg/ha, 3750 kg/ha and 331 kg/ha. Diking in the growing season increased the yields of those crops by 570 kg/ha, 430 kg/ha and 21 kg/ha. Diking all year increased sorghum yields by 1080 kg/ha, corn yields by 560 kg/ha and cotton lint yields by 28 kg/ha.

Simulation results for Corpus Christi indicated average non-diked yields of 2610 kg/ha of sorghum, 3660 kg/ha of corn and 360 kg/ha of cotton lint. Diking in the growing season increased yields of the three crops by 440 kg/ha, 460 kg/ha and 14 kg/ha, respectively. Diking all year resulted in 630 kg/ha of sorghum, 530 kg/ha of corn and 15 kg/ha of lint, over non-diked yields.

The simulated runoff amounts and crop yields were used to determine the Runoff Conservation Efficiency (RCE) for each location. Defined as the increase in crop yield per unit of runoff conserved by diking, RCE is a good measure of the relative value of furrow diking at any given location. For sorghum and corn, the highest RCE values were computed at Vernon, followed by Uvalde, Lubbock, Corpus Christi and Temple. For cotton, Uvalde had the highest RCE, followed by Vernon, Lubbock, Temple and Corpus Christi. Based on the runoff conservation efficiencies computed for the five locations, it appears that the sub-humid region between 500-800 mm annual rainfall would be the most suitable region for furrow diking (Figure 16). Moderate values of RCE were computed in the region that receives less than 500 mm mean annual rainfall, because of lower amounts of runoff generated. The impact of diking is also likely to be moderate (medium) in the region receiving more than 800 mm precipitation, because of generally higher probabilities of receiving that rainfall, resulting in presumably, fewer periods of crop water stress.

Approximately 1.3 million ha of sorghum and 0.3 million ha of corn are grown in the five regions selected for this modeling study. If those 1.6 million ha can be diked just in the growing season, an additional 450,000 tonnes of sorghum and 60,000 tonnes of corn could be produced annually. For cotton, the highest RCE and lint yield increases were computed by diking all year at Vernon and Uvalde. Even if diking is practised only in the growing season in the High Plains, Blacklands and Coastal Bend, it would be desirable to dike the land for cotton in the Rolling Plains and Edwards Plateau early in the year (January/February), to utilize the precipitation that is received ahead of planting. If this can be accomplished, an additional 24,000 tonnes of cotton lint could be produced annually. The combined value of 450,000 tonnes of sorghum, 60,000 tonnes of corn and 24,000 tonnes of lint cotton is approximately $60 million. Furrow diking, being a low cost input (less than $3 per ha), the technology could result in about $50 million as net profit to farmers in the five Texas regions.

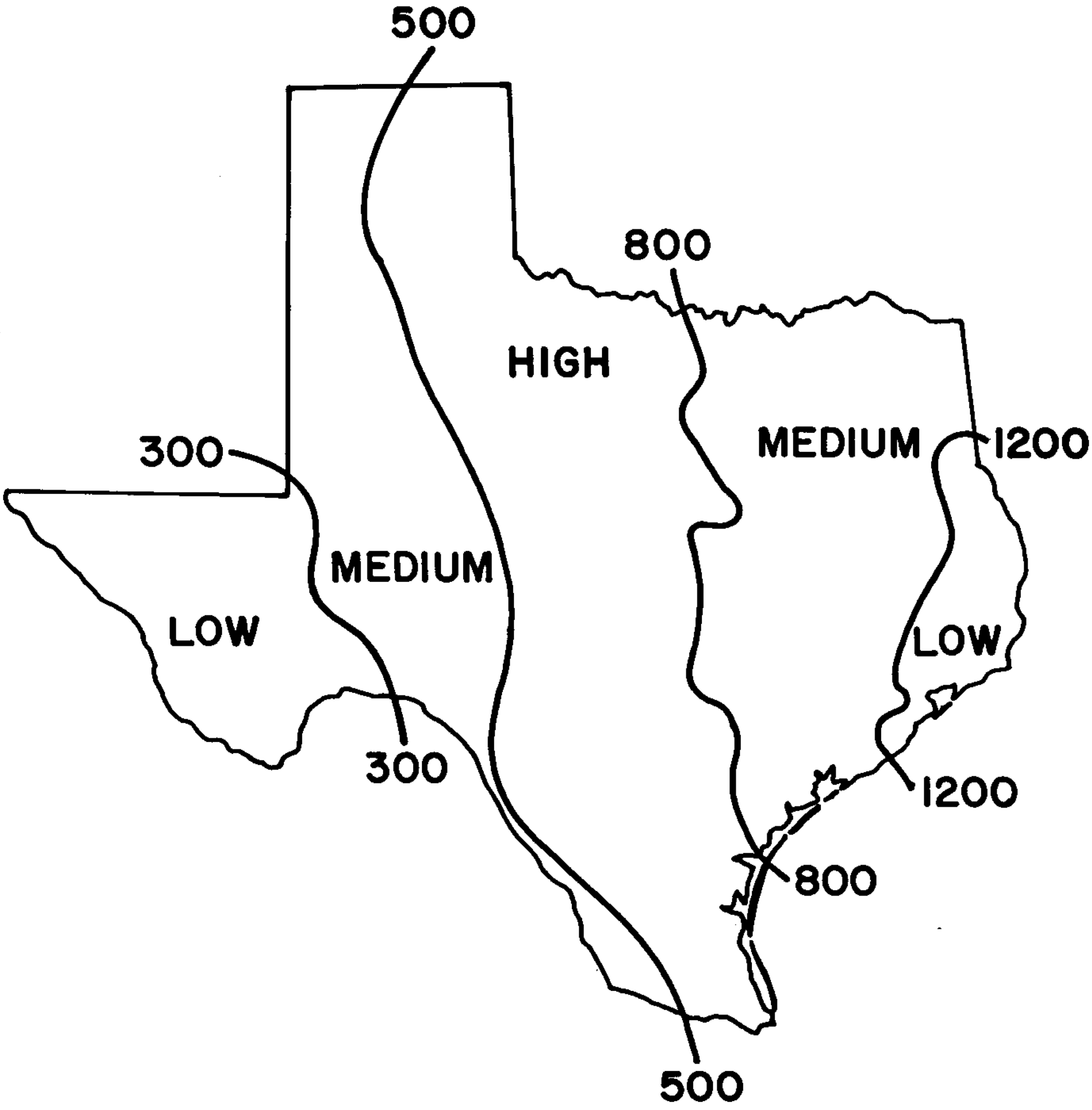

Figure 16. Relative impact of furrow diking on crop yields in Texas.

REFERENCES

Arkin, G. F., R. L. Vanderlip, and J. T. Ritchie. 1976. A dynamic grain sorghum growth model. TRANSACTIONS of the ASAE 19(4):622-626, 630.

Bilbro, J. E. and E. B. Hudspeth. 1977. Furrow diking to prevent runoff and increase yields of cotton. Texas Agric. Expt. Stn. PR-3436.

Bordovsky, D. G. 1983. Effect of furrow diking on cotton in the Rolling Plains. Texas Agric. Expt. Stn. PR-4176.

Chilcott, E. F. 1937. Preventing soil blowing on the Southern Great Plains. USDA Farmers Bull. No. 1771.

Clark, L. E. 1983. Response of cotton to cultural practices. Texas Agric. Expt. Stn. PR-4175.

Clark, R. N. and O. R. Jones. 1980. Furrow dams for conserving rainwater in a semi-arid climate. Proc. of the ASAE Conf. on Crop Production With Conservation in the 80's. pp. 198-206.

Colburn, A. E. and U. U. Alexander. 1986. Furrow diking in Texas, Texas Agricultural Extension Service, B-1539.

Cole, J. S. and G. W. Morgan. 1938. Implements and methods of tillage to control soil blowing on the Northern Great Plains. USDA Farmers Bull. No. 1797.

Dagg, M and J. C. Macartney. 1967. The agronomic efficiency of the N.I.A.E. mechanized tied ridge system of cultivation. Exp. Agric. 4:279-294. Great Britain.

Daniel, H. A. 1950. Water conservation for wheat production in Oklahoma. Soil Sci. Soc. Proc. 15:408-412.

Faulkner, O. T. 1944. Experiments on ridged cultivation in Tanganyika and Nigeria. Tropical Agric. 21(9):177-178.

Gerard, C. J., P. D. Sexton, and D. M. Matus. 1983. Furrow diking for cotton production in the Rolling Plains. Texas Agric. Expt. Stn. PR-4174.

Gerard, C. J., P. D. Sexton, and D. M. Conover. 1984. Effect of furrow diking, subsoiling and slope position on crop yields. Agron. J., 76:945-950.

Gerard, C. J. 1987. Personal Communication. Texas Agric. Expt. Stn., Vernon, TX.

Hudson, N. 1971. Soil Conservation. B. T. Batsford Ltd., London. pp. 320.

Hughes, R. M. 1933. Report on agricultural research for year ending June 30, 1933. Agric. Expt. Stn., Iowa State College of Agriculture and Mechanic Arts.

Jackson, B. S., G. F. Arkin, and A. B. Hearn. 1984. Cotton fruiting model: Calibration and testing. ASAE Technical Paper No. 84-4542.

Jones, O. R. 1975. Yields and water-use efficiencies of dryland winter wheat and grain sorghum production systems in the Southern High Plains. Soil Sci. Soc. of Amer. Proc. 39:98-103.

Jones, O. R., P. W. Unger, and D. W. Fryrear. 1984. Technology effects on soil and water conservation in the Southern High Plains. USDA-ARS, Bushland, TXX.

Krishna, J. H. and G. F. Arkin. 1985. Furrow diking in Central Texas: A hydrologic assessment. Texas Agric. Expt. Stn. PR-4264.

Krishna, J. H., G. F. Arkin, J. R. Williams, and J. R. Mulkey. 1987. Simulating furrow-dike impacts on runoff and sorghum yields. TRANSACTIONS of the ASAE 30(1):143-147.

Kuska, J. R. and O. R. Mathews. 1956. Dryland crop-rotation and tillage experiments at the Colby (Kansas) Branch Experiment Station. USDA Circ. No. 979.

Lascano, R. J. 1986. Personal Communication, Texas Agr. Expt. Stn., Lubbock, Texas.

Lindemann, E. R. 1984. Personal communication. USDA-SCS, Temple, Texas.

Luebs, R. E. 1962. Investigations of cropping systems, tillage methods, and cultural practices for dryland farming at Fort Hays (Kansas) Branch Experiment Station. Kansas Agric. Expt. Stn. Bull. 449.

Lyle, W. M. and O. R. Dixon. 1977. Basin tillage for ranfall retention. TRANSACTIONS of the ASAE 20:1013-1017.

Lyle, W. M., J. P. Bordovsky, and D. R. Dixon. 1978. Irrigation-dryland basin tillage evaluation. TAES Annual Report. High Plains Research Foundation.

Lyle, W. M. and J. P. Bordovsky. 1981. Low energy precision application (LEPA) irrigation system. TRANSACTIONS of the ASAE 24(5):1241-1245.

Lyle, W. M. and J. P. Bordovsky. 1983. LEPA irrigation system evaluation. TRANSACTIONS of the ASAE 26(3):776-781.

Maas, S. J. and G. F. Arkin. 1978. Users' guide to SORGF: A dynamic grain sorghum growth model with feedback capacity. Program and model documentation. No. 78-1. Texas Agric. Expt. Stn., Blackland Research Center.

Mulkey, J. R. 1987. Personal communication. Texas Agric. Exp. Stn., Uvalde, Texas.

Schwab, G. O., R. K. Frevert, T. W. Edminster, and K. K. Barnes. 1981. Soil and Water Conservation Engineering. Third edition. John Wiley and Sons, Inc.

Shedd, C. K., E. V. Collins, and J. B. Davidson. 1935. The basin method of planting row crops and a basin lister planter. Agric. Eng. 16(4):133-136.

Stapper, M. and G. F. Arkin. 1980. CORNF: A dynamic growth and development model for maize. Program and model documentation No. 80-2. Texas Agric. Expt. Stn., Blackland Research Ctr., Temple, TX.

Stewart, B. A. 1985. Limited irrigation-dryland farming system. Paper presented at the Management of Vertisols for Improved Agricultural Production Workshop at ICRISAT, India.

Stewart, B. A., J. T., Musick, and D. A. Dusek. 1983. Yield and water use efficiency of grain sorghum in a limited irrigation-dryland system. Agron. J. 75:629-634.

TDA/USDA. 1986. Texas Field Crop Statistics, 1985. Texas Dept. of Agriculture and U.S. Dept. of Agriculture Bulletin 237.

Tucker, J. E. and J. Griffiths. 1965. Precipitation distribution and the probability of receiving selected amounts over Texas. Texas Agric. Expt. Stn. MP-794, College Station, TX.

Unger, P. W. 1972. Dryland winter wheat and grain sorghum cropping systems -- Northern High Plains of Texas. Texas Agric. Expt. Stn. Bull. 1126.

USDA, Soil Conservation Service. 1972. Natl. Eng. Handbook. Hydrology, Section 4.

USDA-SCS-TX-Area 2. 1983. Technical standard and specifications for furrow diking. Tech. Guide, Section IV.

Williams, J. R., C. A. Jones, and P. T. Dyke. 1984. A modeling approach to determine the relationship between erosion and soil productivity. TRANSACTIONS of the ASAE 27(1):129-144.

Wistrand, G. L. 1984. Furrow dike water conservation practices in the Texas High Plains. Tech. Bull. No. 1691. Economic Research Service, USDA.

Wood, I. D. 1933. The future of moisture conservation. Agric. Eng. 14(6):152.

APPENDICES

(COTDIKE Program is not included because it has four sub-programs, and the cotton model documentation/user manual are not yet available.)

```
C     PROGRAM SORDIKE
C
C                           S  O  R  D  I  K  E
C
C     A FORTRAN PROGRAM COMBINING SORGF AND EPIC RUNOFF ALGORITHMS
C     TO EVALUATE THE IMPACT OF FURROW DIKING ON SORGHUM YIELDS
C     J. H. KRISHNA, BLACKLAND RESEARCH CENTER, TAES, 1987


      INTEGER SUMOPT, STMO, STDAY, STYR, ENMO, ENDAY, ENYR
      INTEGER CHKIRR, IRR, IRRDAY, IRRIG, IRROPT, DAY
      INTEGER TMPMO, TMPDAY
      CHARACTER*14 SUMMRY
      CHARACTER*8 INDAT,INMET,OTDAT
      CHARACTER*4 STA4
      COMMON /BLK1/ GRO(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     *              DLAI(366),RCOUNT(20),ACDAYS(20),DLA,IOPT
      COMMON /BLK2/ ROSPZ,PAREA,N,IDAY3,IDAY6,IDAY9,ISTAGE,SXDIN(20),
     *              SINIT,ACHU,DIFF,DIFF6
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     *              SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/ TEMPCO,SW,WATSCO,EOS,EO,UL,SDEPTH,WATSC2,Q,CN2,SL
      COMMON /BLK5/ WR,WL,WC,WH,WG,DRIWT,DWG,DWH,DWC,DWL,DWR,TOTWT,
     *              WTLF(20)
      COMMON /BLK6/ RLE(30),RLA(30),DLE(30),DILA(30),FSHU(30),AHU(30),
     *              XHU(30),DLHU(30),SHU(30),RXHU(30),RHU(30),EXHU(30),
     *              TLA(30),IPL,IPL4,IPL2,IFLAG(30)
      COMMON /BSOIL/NLAYR,RTDEPM,DLAYR(20),ULAYR(20),SWLAYR(20),SMI,
     *              RTDEP1,W1,W2,S1,SSW,PWC
      COMMON /BLK7/ SUMOPT
      DIMENSION TITLE(20), ICOR(12), IRRDAY(450), IRRIG(450)
      DATA ICOR/1,-1,0,0,1,1,2,3,3,4,4,5/
C
    1 FORMAT(/,1X,'TYPE 1 FOR DRYLAND, 2 FOR IRRIGATED:',$)
    2 FORMAT(I1)
    3 FORMAT(///,1X,'ENTER DATES IRRIGATED.',/,1X,'ENTER 00/00'
     *' WHEN FINISHED.',/)
    4 FORMAT(I2,1X,I2)
    7 FORMAT(/,1X,'DATE (mm/dd):',$)
    8 FORMAT(1X,'AMOUNT OF IRRIGATION (cm):',$)
   11 FORMAT(/,31X,'S  O  R  D  I  K  E',/)
   12 FORMAT(16X,A)
   13 FORMAT(/,20X,'J. H. KRISHNA, BLACKLAND RESEARCH CENTER')
   16 FORMAT(1X,'TYPE 1 FOR DAILY SUMMARY, 2 FOR ANNUAL SUMMARY:',$)
   18 FORMAT(I1)
   43 FORMAT(22X,A)
C
      WRITE(*,11)
      WRITE(*,12) 'A FORTRAN PROGRAM COMBINING SORGF AND EPIC RUNOFF'
      WRITE(*,12) 'TO EVALUATE THE IMPACT OF DIKING ON SORGHUM YIELD'
      WRITE(*,13)
      WRITE(*,43) 'TEXAS AGRICULTURAL EXPERIMENT STATION'
      WRITE(*,43) '808 E.BLACKLAND ROAD, TEMPLE, TEXAS  76503'
      WRITE(*,*) ' '
      WRITE(*,*) ' '
      WRITE(*,101)
  101 FORMAT(1X,'TYPE LOCATION AND YEAR ( T64):',$)
      READ(*,104) STA4
  104 FORMAT(1A4)
```

```
C
      INDAT = '    .DAT'
      OTDAT = '     .OUT'
      INMET = '    .MET'
      INDAT(1:3) = STA4
      INMET(1:3) = STA4
C
      OPEN(UNIT = 1, FILE = INDAT,STATUS = 'OLD')
      OPEN(UNIT = 3, FILE = INMET,STATUS = 'OLD')
C
      DO 77 I = 1,20
      WTLF(I) = 0.
      ACDAYS(I) = 0.
      SXDIN(I) = 0.
      RCOUNT(I) = 0.
   77 CONTINUE
      SPROUT = 0.0
      IDAYFB = 0
      SINIT = 0.
      WR = 0.
      WL = 0.
      WC = 0.
      WH = 0.
      WG = 0.
      TOTWT = 0.
      IDAY3 = 0
      IDAY6 = 0
      IDAY9 = 0
      READ(1,1301) TITLE
 1301 FORMAT(20A4)
      WRITE(*,16)
      READ(*,18) SUMOPT
      IF (SUMOPT .EQ. 1) THEN
      SUMMRY = 'DAILY SUMMARY'
      ELSE
      SUMMRY = 'ANNUAL SUMMARY'
      ENDIF
 1571 FORMAT(1X,20A4,7X,A14,//)
      READ(1,*) KI,N,ROSPZ,P,LAT,PWC,UL,SW,SDEPTH,CN2,SL,IOPT
 1302 FORMAT(2I4,F5.1,F10.0,4F5.2)
      WRITE(*,*) ' '
      WRITE(*,102)
  102 FORMAT(1X,'TYPE 1 IF NON-DIKED, 2 IF DIKED ALL YEAR,'
     *' 3 IF DIKED PART YEAR:',$)
      READ(*,103) L
  103 FORMAT(I1)
      IF (L .EQ. 1) OTDAT(1:1) = '1'
      IF (L .EQ. 2) OTDAT(1:1) = '2'
      IF (L .EQ. 3) OTDAT(1:1) = '3'
      OTDAT(2:4) = STA4
      OPEN(UNIT = 2, FILE = OTDAT,STATUS = 'NEW')
      WRITE(2,300)
  300 FORMAT(1X)
   19 FORMAT(1X,'SORDIKE',/,1X,'SORGHUM FURROW-DIKING PROGRAM',//)
      WRITE(2,19)
      WRITE(2,1571) TITLE, SUMMRY
      IF (L .EQ. 3) THEN
      WRITE(*,701)
  701 FORMAT(1X,'TYPE DATE DIKES INSTALLED (mm/dd/yyyy):',$)
      READ(*,777) MO, ND, IYR
  777 FORMAT(I2,1X,I2,1X,I4)
      STMO = MO
      STDAY = ND
      STYR = IYR
      IF (MO .EQ. 1) THEN
      IDB = ND
```

```
      ELSE
      IDB = 30 * (MO - 1) + ICOR(MO - 1) + ND
      IF (MOD(IYR,4) .EQ. 0) THEN
      IF (MO .GT. 2) THEN
      IDB = IDB + 1
      ENDIF
      ENDIF
      ENDIF
      WRITE(*,702)
  702 FORMAT(1X,'TYPE DATE DIKES REMOVED (mm/dd/yyyy):',$)
      READ(*,777) MO, ND, IYR
      ENMO = MO
      ENDAY = ND
      ENYR = IYR
      IF (MO .EQ. 1) THEN
      IDE = ND
      ELSE
      IDE = 30 * (MO - 1) + ICOR(MO - 1) + ND
      IF (MOD(IYR,4) .EQ. 0) THEN
      IF (MO .GT. 2) THEN
      IDE = IDE + 1
      ENDIF
      ENDIF
      ENDIF
      ENDIF
      READ(1,1003) MO, ND, IYR
      TMPMO = MO
      TMPDAY = ND
      WRITE(*,1)
      READ(*,2) IRROPT
      IF (IRROPT .EQ. 2) THEN
      IRR = 1
      WRITE(*,3)
   29 WRITE(*,7)
      READ(*,4) MO, ND
      IF (MO .NE. 0) THEN
      IF (MO .EQ. 1) THEN
      IRRDAY(IRR) = ND
      ELSE
      IRRDAY(IRR) = 30 * (MO - 1) + ICOR(MO - 1) + ND
      IF (MOD(IYR,4) .EQ. 0) THEN
      IF (MO .GT. 2) THEN
      IRRDAY(IRR) = IRRDAY(IRR) + 1
      ENDIF
      ENDIF
      ENDIF
      WRITE(*,8)
      READ(*,*) IRRIG(IRR)
      IRR = IRR + 1
      GO TO 29
      ENDIF
      ENDIF
      MO = TMPMO
      ND = TMPDAY
      WRITE(*,*) ' '
      WRITE(*,*) ' '
      WRITE(*,*) 'PROGRAM RUNNING, PLEASE WAIT...'
      IOPT = L
      PAREA = 1.E08/P
      R2 = PAREA/ROSPZ
      IPL = N-10
      IPL4 = IPL+4
      IPL1 = IPL-1
      IPL2 = IPL+2
      DO 14 J = 1,N
      AHU(J) = 0.0
```

```
      DLHU(J) = 0.0
      XHU(J) = 0.0
      AHU(J) = 0.0
      FSHU(J) = 0.0
      DILA(J) = 0.0
      SHU(J) = 0.0
      RHU(J) = 0.0
      RXHU(J) = 0.0
      EXHU(J) = 0.0
      TLA(J) = 0.0
      RLA(1) = 10.
      RLA(2) = 55.
      IF (J.LE.16.AND.J.GT.2) RLA(J) = 55.
      IF (J.GT.16) RLA(J) = 7.96*J-70.4
      IF (J.LE.4) RLE(J) = 0.10
      IF (J.GT.4.AND.J.LE.14 ) RLE(J) = 0.28*J-1.16
      IF (J.GT.14) RLE(J) = -0.57*J+10.94
      IF (RLE(J).LT.0.10) RLE(J) = 0.10
      IF (J.LE.7) DLE(J) = 13.45*J+16.91
      IF (J.GT.7.AND.J.LE.IPL4) DLE(J) = 120.
      IF (J.GT.IPL4) DLE(J) = 11.*J+(120.-11.*IPL4)
      DLE(N) = DLE(N-1)-20.
      IF (J.LE.IPL) DILA(J) = 55.25*J+179.09
      IF (J.GT.IPL) DILA(J) = 104.63*J-188.98
 14   CONTINUE
      I = 1
1570  IF (I .EQ. 2) READ(1,1003) MO,ND,IYR
      IF (MO .EQ. 1) THEN
      IDY = ND
      ELSE
      IDY = 30 * (MO - 1) + ICOR(MO - 1) + ND
      IF (MOD(IYR,4) .EQ. 0) THEN
      IF (MO .GT. 2) THEN
      IDY = IDY + 1
      ENDIF
      ENDIF
      ENDIF
      GO TO (65,66),  I
  65  ICDAY = IDY
      WRITE(2,1572) ICDAY, MO, ND, IYR
      I = I + 1
      GO TO 1570
  66  ISOW = IDY
      WRITE(2,1573) ISOW, MO, ND, IYR
1003  FORMAT(3I4)
1572  FORMAT(1X,5X,14HSTARTING DATE=,I4,6X,13HCALENDAR DAY=,3I6)
1573  FORMAT(1X,5X,14HPLANTING DATE=,I4,6X,13HCALENDAR DAY=,3I6)
      IMAX = ICDAY + KI - 1
      READ (1,1231) NLAYR,RTDEPM
1231  FORMAT (I2,1X,F5.0)
      READ (1,1234) (DLAYR(L),ULAYR(L),SWLAYR(L),L = 1,NLAYR)
1234  FORMAT (10F8.3)
      IF (SUMOPT .EQ. 1) WRITE(2,22) P,ROSPZ,R2,PAREA
  22  FORMAT(1X,20HPLANTS PER HECTARE= ,F10.0/13H ROW SPACING=,F6.2/
     * 15H PLANT SPACING=,F6.1/16H AREA PER PLANT=,F8.2)
      WRITE(2,*)
      IF (SUMOPT .EQ. 1) WRITE(2,2000) UL,SW
2000  FORMAT(1X,'SWX=',F5.2,3H CM,5X,'SWA=',F5.2,3H CM)
      IF (IOPT .EQ. 1) WRITE(2,1801)
      IF (IOPT .EQ. 2) WRITE(2,1802)
      IF (IOPT .EQ. 3) WRITE(2,1805) STMO.STDAY.STYR.ENMO,ENDAY,ENYR
1801  FORMAT(1X,'NON-DIKED')
1802  FORMAT(1X,'DIKED')
1805  FORMAT(1X,'DIKED FROM: ',I2,'/',I2,'/',I4,'  TO: ',I2,'/',
     *I2,'/',I4)
      IF (IRROPT .EQ. 2) THEN
```

```
      WRITE(2,7000) 'IRRIGATED'
      ELSE
      WRITE(2,7000) 'DRYLAND  '
      ENDIF
 7000 FORMAT(1X,A9,/)
      IF (SUMOPT .EQ. 1) WRITE(2,1001)
 1001 FORMAT(6X,'DAY',10X,'SW(CM)',10X,'PRECIP(CM)',7X,'RUNOFF(CM)')
      READ(3,*) (RAIN(I),TEMPMX(I),TEMPMN(I),SOLRAD(I),I = ICDAY,IMAX)
      DO 6 I = ICDAY,IMAX
      AVTEMP = (TEMPMX(I) + TEMPMN(I)) / 2.0
      TEMP(I) = (AVTEMP - 32.0) * 5.0 / 9.0
      RAIN(I) = RAIN(I) * 2.54
    6 CONTINUE
      IF (IRROPT .EQ. 2) THEN
      IRR = IRR - 1
 5000 DO 5001 DAY = 1,366
 4000 DO 4001 CHKIRR = 1,IRR
      IF (IRRDAY(CHKIRR) .EQ. DAY) THEN
      RAIN(DAY) = RAIN(DAY) + IRRIG(CHKIRR)
      ENDIF
 4001 CONTINUE
 5001 CONTINUE
      ENDIF
      DO 5 J = 1,N
      GRO(1,J) = 0.0
      GRO(2,J) = 0.0
    5 CONTINUE
      READ(1,1250) IDAYFB
 1250 FORMAT (I4)
      IF (IDAYFB.EQ.0) GO TO 1249
      CALL FDBAK(IDAYFB)
      ICDAY = IDAYFB + 1
      BASET = 7.0
      GO TO 1300
 1249 CONTINUE
      FMRGDA = 0.
      SPROUT = 0.
      CALL RNF
 1300 DO 200 I = ICDAY, IMAX
      IF ((SUMOPT .EQ. 1) .AND. (ISOW .EQ. I)) WRITE(2,1800)I,RT,RFT
 1800 FORMAT(/,1X,'SOWING DATE: ',I3,10X,'RAINFALL TO DATE:',F6.2,
     *5X,'RUNOFF TO DATE: ',F6.2,/)
      CALL RUNOFF(I)
 1305 J = I
      IF (SUMOPT .EQ. 1) WRITE(2,3000) J, SSW, RAIN(I), Q
 3000 FORMAT(6X,I3,11X,F5.2,12X,F5.2,12X,F5.2)
      RT = RT + RAIN(I)
      RFT = RFT + Q
      IF (SPROUT .GT. 0.) GO TO 190
      DLAI(I) = 0.
      IF (I .LT. ISOW) GO TO 191
      CALL EMRGNC (I)
      IF (SPROUT .EQ. 0.) GO TO 191
      RCOUNT(1) = SPROUT
      BASET = 7.0
  190 CALL HFUNC(I,BASET)
      CALL LEAF(I)
      CALL STAGE (I)
  191 CALL EVAP(I)
      CALL SOLWAT (I)
      IF (SPROUT .EQ. 0.) GO TO 200
      IF (DLA .LE. 0.) GO TO 198
      CALL PHOTO (I)
      CALL GROW (I)
  198 IF (TEMPMN(I) .GT. 28.0) GO TO 199
      IF (SUMOPT .EQ. 1) WRITE (2,1222) I
```

```
1222 FORMAT(1X,  'FREEZE ON DAY  ',I4,' KILLED CROP')
     ISTAGE = 5
 199 CONTINUE
     IPRINT = I - IFIX(RCOUNT(1) + 0.5)
     IF(ISTAGE .EQ. 5) GO TO 1006
     IF(I .NE. IDAY6) GO TO 1007
     IF (SUMOPT .EQ. 1) WRITE(2,1005) I
1005 FORMAT(1X,30HANTHESIS OCCURS ON JULIAN DAY    ,I4)
1007 IF(MOD(IPRINT,1)) 200,1006,200
1006 CONTINUE
     IF(ISTAGE .EQ. 5) GO TO 201
     FMRGDA = 1.0
 200 CONTINUE
     IF (ISTAGE .EQ. 5) GO TO 201
     IF (SUMOPT .EQ. 1) WRITE(2,1004) IDAY9
1004 FORMAT(1X,35HPHYSIOLOGICAL MATURITY NOT REACHED. /1X,
    * 23HPREDICTED ON JULIAN DAY  ,2X,I4////)
     GO TO 99
 201 WRITE(2,1002) I
1002 FORMAT(1X,'PHYSIOLOGICAL MATURITY OCCURRED ON DAY' ,I4)
     YLD = WG * P / 1000.
     WRITE(2,1008) YLD
1008 FORMAT(6X,12HFIELD YIELD= ,F10.2,6H KG/HA )
     IF (SUMOPT .EQ. 1) WRITE(2,3500) RT, RFT
3500 FORMAT(7X,'RAINFALL=',F6.2,' CM',5X,'RUNOFF=',F5.2,' CM')
     K = I + 1
     WRITE(2,*)
     T = 0
     FT = 0
     Q = 0
     DO 250 I = K, IMAX
     CALL RUNOFF(I)
     M = I
     IF (SUMOPT .EQ. 1) WRITE(2,3000) M, SSW, RAIN(I), Q
     CALL SOLWAT(I)
     T = T + RAIN(I)
     FT = FT + Q
 250 CONTINUE
  98 WRITE(2,*)
     IF (SUMOPT .EQ. 1) WRITE(2,3600) T, FT
3600 FORMAT(7X,'RAINFALL=',F6.2,' CM',5X,'RUNOFF=',F5.2,' CM')
     TOTR = RT + T
     TORF = RFT + FT
     WRITE(2,*)
     IF (SUMOPT .EQ. 1) WRITE(2,3700) TOTR, TORF
3700 FORMAT(7X,'TOTAL RAINFALL=',F6.2,3X,'TOTAL RUNOFF=',F5.2)
  99 CLOSE(UNIT = 1)
     CLOSE(UNIT = 2)
     CLOSE(UNIT = 3)
     END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE LEAF(I)
      COMMON /BLK1/ GRO(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     2              DLAI(366),RCOUNT(20),ACDAYS(20),DLA,IOPT
      COMMON /BLK2/ ROSPZ,PAREA,N,IDAY3,IDAY6,IDAY9,ISTAGE,SXDIN(20),
     2              SINIT,ACHU,DIFF,DIFF6
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2              SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/ TEMPCO,SW,WATSCO,EOS,EO,UL,SDEPTH,WATSC2,Q,CN2,SL
      COMMON /BLK6/ RLE(30),RLA(30),DLE(30),DILA(30),FSHU(30),AHU(30),
     2        XHU(30),DLHU(30),SHU(30),RXHU(30),RHU(30),EXHU(30),
     3TLA(30),IPL,IPL4,IPL2,IFLAG(30)
      DHU = TEMP(I)-7.
      WSC = 1.0
      SLA = 0.0
      IF (I.LT.ISOW) GO TO 1999
```

```
      IF (SPROOT.EQ.0.) GO TO 1999
      DO 2000 J = 1,N
      IF (J.EQ.1) GO TO 150
      IF (IFLAG(J-1).LT.2) GO TO 1000
  150 GO TO (1,2,3,4),IFLAG(J)
    1 WCO = WATSCO
      IF(ISTAGE.EQ.1) WCO = WATSC2
      AHU(J) = AHU(J)+DHU*WCO
      IF (AHU(J).LT.RLA(J)) GO TO 1000
      RHU(J) = AHU(J)-RLA(J)
      AHU(J+1) = RHU(J)
      IFLAG(J) = 2
      IF (J.EQ.1) GO TO 2
      IF (RHU(J).GT.DHU) RHU(J) = DHU
      RCOUNT(J) = I-RHU(J)/DHU
    2 IF (RHU(J).EQ.0.0) GO TO 23
      EXHU(J) = RHU(J)
      RHU(J) = 0.0
      GO TO 1000
   23 EXHU(J) = EXHU(J)+DHU
      GRD(1,J) = EXHU(J)*RLE(J)*WATSC2
      TLA(J) = GRO(1,J)
      IF(EXHU(J).LT.DLE(J)) GO TO 1000
      IFLAG(J) = 3
      RXHU(J) = EXHU(J)-DLE(J)
      GRO(1,J) = DLE(J)*RLE(J)*WATSC2
      TLA(J) = GRO(1,J)
      ACDAYS(J) = I-RXHU(J)/DHU
    3 IF (RXHU(J).EQ.0.0) GO TO 33
      IF(WATSCO.LT.1.)WSC = -0.1*(SW/UL)+4.0
      RADE = -0.869+0.00284*SOLRAD(I)
      IF (RADE.LE.0.01) RADE = 0.01
      SHU(J) = RXHU(J)+SHU(J)*WSC/RADE
      RXHU(J) = 0.0
      GO TO 1000
   33 SHU(J) = SHU(J)+DHU*WSC
      IF (SHU(J).LT.DILA(J)) GO TO 1000
      IFLAG(J) = 4
      GRD(1,J) = 0.0
      TLA(J) = 0.0
    4 CONTINUE
 1000 CONTINUE
      SLA = TLA(J)+SLA
      DLA = SLA
      DLAI(I) = DLA/PAREA
 2000 CONTINUE
 1999 CONTINUE
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE HFUNC(I,BASET)
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2               SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      PI = 3.14159
      CMIN = (TEMPMN(I)-32.)/1.8
      CMAX = (TEMPMX(I)-32.)/1.8
      AMP = CMAX - TEMP(I)
      IF (CMIN .GE. BASET) GO TO 150
      IF (CMAX .LE. BASET) GO TO 103
      ZETA = ASIN((BASET-TEMP(I)) /AMP)
      HUNITS(I) = 1./PI*(AMP*COS(ZETA) + (TEMP(I)-BASET)*(PI/2.-ZETA))
      GO TO 190
  150 HUNITS(I) = TEMP(I) - BASET
      IF (TEMP(I) .GT. 30.) HUNITS(I) = 30.-BASET
      GO TO 190
  103 HUNITS(I) = 0.
```

```
  190 CONTINUE
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE EMRGNC (I)
      INTEGER SUMOPT
      COMMON /BLK1/ GRD(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     *              DLAI(366),RCOUNT(20),ACDAYS(20),DLA, IOPT
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     *              SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/ TEMPCO, SW, WATSCO, EOS, EO, UL, SDEPTH, WATSC2, Q, CN2, SL
      COMMON /BLK6/ RLE(30),RLA(30),DLE(30),DILA(30),FSHU(30),AHU(30),
     *              XHU(30),DLHU(30),SHU(30),RXHU(30),RHU(30),EXHU(30),
     *              TLA(30),IPL,IPL4,IPL2,IFLAG(30)
      COMMON /BLK7/ SUMOPT
      DATA IGERM/0/
      DCOEF = 2.8
      SUMHU1 = 18.
      SUMHU2 = 51.
      SWLIM = 0.05
      IF (IGERM .NE. 0) GO TO 200
      IF (SW/UL - SWLIM) 999, 10, 10
   10 BASET = 6.3
      DEP = 0.
      CALL HFUNC(I,BASET)
      FMRGDA = FMRGDA+HUNITS(I)
      IF (FMRGDA-SUMHU1) 999, 20, 20
   20 IGERm = 1
      BASET = 11.4
      CALL HFUNC(I,BASET)
      FMRGDA = HUNITS(I)
      RETURN
  200 CALL HFUNC(I,BASET)
      FMRGDA = FMRGDA +HUNITS(I)
      IF (FMRGDA-SUMHU2) 999,999,300
  300 DEP = DEP +HUNITS(I)/DCOEF
      IF (DEP-SDEPTH) 999,400,400
  400 FMRGDA = (DEP-SDEPTH)/(HUNITS(I)/DCOEF)
      SPROUT = I - FMRGDA
      IF (SUMOPT .EQ. 1) WRITE(2,1001)  SPROUT
 1001 FORMAT(5X,'DAY LEAF 1 APPEARS = ',F7.2)
      IFLAG(1) = 2.
      RHU(1) = FMRGDA
      AHU(2) = FMRGDA
  999 RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE PHOTO (I)
      COMMON /BLK1/ GRD(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     2              DLAI(366),RCOUNT(20),ACDAYS(20),DLA, IOPT
      COMMON /BLK2/ ROSPZ, PAREA, N, IDAY3, IDAY6, IDAY9, ISTAGE, SXDIN(20),
     2              SINIT,ACHU,DIFF,DIFF6
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2              SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/ TEMPCO, SW, WATSCO, EOS, EO, UL, SDEPTH, WATSC2, Q, CN2, SL
      COMMON /BLK5/ WR, WL, WC, WH, WG, DRIWT, DWG, DWH, DWC, DWL, DWR, TOTWT,
     2              WTLF(20)
      REAL LITRAN, INTPAR

      IF (ISTAGE.LT.3.AND.ISTAGE.EQ.4) MAXS = 0
      R = ROSPZ/2.54
      X1 = 0.5946*R+67.9915
      X2 = 0.0026*R-.322
  200 LITRAN = X1 * EXP(X2 * DLAI(I))
      TRANLI = 70.1*EXP(-0.612*DLAI(I))
      IF (ISTAGE.LT.3) GO TO 201
```

```
      IF (ISTAGE.EQ.3) MAXS = MAXS+1
      IF (MAXS.GT.7) MAXS = 7
      IF (ISTAGE.GE.4) LITRAN = TRANLI
      IF (ISTAGE.EQ.3) LITRAN = LITRAN-(LITRAN-TRANLI)*(MAXS/7.)
  201 IF (LITRAN.LT.5.)LITRAN = 5.
      IF (TEMP(I).LT.5.0.OR.TEMP(I).GE.45.0) TEMPCO = 0.
      IF (TEMP(I).GE.25.0.AND.TEMP(I).LE.40.0) TEMPCO = 1.
      IF(TEMP(I).GE.5.0.AND.TEMP(I).LE.25.) TEMPCO = .05*TEMP(I)-.25
      IF (TEMP(I).GT.40.0.AND.TEMP(I).LT.45.) TEMPCO = -.2*TEMP(I)+9.
      TOFOTO = TEMPCO*WATSCO*DAYPFO
      INTPAR = 0.50 * SOLRAD(I) * (0.95-(LITRAN/100.))
      ALPHA = 3.2
      DRIWT = 4.2E-6*(ALPHA)*(WATSCO)*(TEMPCO)*(INTPAR)*(PAREA)
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE EVAP (I)
      COMMON /BLK1/ GRO(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     2              DLAI(366),RCOUNT(20),ACDAYS(20),DLA,IOPT
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2              SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/ TEMPCO,SW,WATSCO,EOS,EO,UL,SDEPTH,WATSC2,Q,CN2,SL
      DATA GAMMA/.68/
      TK = TEMP(I)+273.
      DELTA = (EXP(21.255- 5304./TK))*(5304./(TK**2))
      D = DELTA/GAMMA
      ALBEDO = .24
      RO = 520+193*SIN(.0172*(I-80))
      IF(SOLRAD(I).GT.RO) SOLRAD(I) = RO
      R4 = 1.-.261*EXP(-7.77E-04*TEMP(I)**2)
      R6 = (R4-.96)*1.17E-07*TK**4*(.2+.8*(SOLRAD(I)/RO))
      H = (1.-ALBEDO)*SOLRAD(I)+R6
      HO = H/583.
      EO = 1.35*DELTA/(DELTA+GAMMA)*HO
      IF (DLAI(I) .LT. 0.5) EOS = EO
      IF (DLAI(I) .LT. 0.5) GO TO 41
      HOS = HO
      EOS = (D*HOS)/(D+1.)
   41 RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE SOLWAT (I)
      COMMON /BLK1/ GRO(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     2              DLAI(366),RCOUNT(20),ACDAYS(20),DLA,IOPT
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2              SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/ TEMPCO,SW,WATSCO,EOS,EO,UL,SDEPTH,WATSC2,Q,CN2,SL
      COMMON /BSOIL/NLAYR,RTDEPM,DLAYR(20),ULAYR(20),SWLAYR(20),SMI,
     1RTDEP1,W1,W2,S1,SSW,PWC
      DIMENSION STOR(20),SWTR(3)
      DATA U,SUMES1,SUMES2,CONA/.6,2*0.,0.35/DELT/15./
      DATA SWTR/0.30,0.10,0.00/
C
      IF (I.GT.1) GO TO 40
      T = 0.
      SMI = SWLAYR(1)/ULAYR(1)
      SML = SMI
      IF(SMI.GE.0.9) GO TO 20
      SUMES1 = UL1
      SUMES2 = 2.5-2.78*SMI
      GO TO 40
   20 SUMES1 = 10.-SMI*10.
      SUMES2 = 0.
   40 PRECIP = RAIN(I)
      PRECIP = PRECIP-Q
      RAINSI = PRECIP
```

```
      IF (SUMES1.GE.U) GO TO 180
      IF (RAINSI.GE.SUMES1) GO TO 120
      SUMES1 = SUMES1-RAINSI
      GO TO 140
 120  SUMES1 = 0.
 140  SUMES1 = SUMES1+EOS
      IF(SUMES1.GT.U) GO TO 160
      ES = EOS
      GO TO 260
 160  ES = EOS-0.4*(SUMES1-U)
      SUMES2 = 0.6*(SUMES1-U)
      T = (SUMES2/.35)**2
      GO TO 260
 180  IF(RAINSI.LT.SUMES2) GO TO 200
      RAINSI = RAINSI-SUMES2
      SUMES1 = U-RAINSI
      T = 0.
      IF(RAINSI.GT.U) GO TO 120
      GO TO 140
 200  T = T+1.
      ES = CONA*T**0.5-SUMES2
      IF(RAINSI.GT.0.) GO TO 220
      IF(ES.GT.EOS) ES = EOS
      GO TO 240
 220  ESX = 0.8*RAINSI
      IF (ESX.LE.ES) ESX = ES+RAINSI
      IF (ESX.GT.EOS) ESX = EOS
      ES = ESX
 240  SUMES2 = SUMES2+ES-RAINSI
      T = (SUMES2/CONA)**2.
 260  IF (ES.LT.0.) ES = 0.
      IF (DLAI(I).GT.3.0) GO TO 280
      EP = 0.53*EO*DLAI(I)**0.5
      GO TO 300
 280  EP = EO-ES
 300  IF(EP.LT.0.) EP = 0.
      ET = ES+EP
      IF(EO.GE.ET) GO TO 320
      ET = EO
      EP = ET-ES
 320  CONTINUE
C
C   SOIL WATER BALANCE INCLUDING RAIN AND SOIL EVAPORATION,
C   BEGINNING WITH THE TOP SOIL LAYER.
C
       DELTSW = PRECIP-ET
       IF (DELTSW.LE.0.0) GO TO 340
C
       DO 330 L = 1,NLAYR
       SWLAYR(L) = SWLAYR(L)+DELTSW/DLAYR(L)
       IF(SWLAYR(L).GT.ULAYR(L)) GO TO 325
       DELTSW = 0.0
       GO TO 333
C
   325 CONTINUE
       DELTSW = (SWLAYR(L)-ULAYR(L))*DLAYR(L)
       SWLAYR(L) = ULAYR(L)
   330 CONTINUE
   333 CONTINUE
       IF(DELTSW.GE.0.0) GO TO 365
C
   340 CONTINUE
       DO 360 K = 1,3
       DO 350 L = 1,NLAYR
       DMY = ULAYR(L)*SWTR(K)
       IF(SWLAYR(L).LE.DMY) GO TO 350
```

```
C
      DMY1 = -DELTSW/DLAYR(L)
      DMY = SWLAYR(L)-DMY
      IF(DMY.LT.DMY1) GO TO 343
      SWLAYR(L) = SWLAYR(L)-DMY1
      DELTSW = 0.0
      GO TO 365
C
  343 CONTINUE
      SWLAYR(L) = SWLAYR(L)-DMY
      DELTSW = DELTSW+DMY*DLAYR(L)
  350 CONTINUE
  360 CONTINUE
  365 CONTINUE
C
C   CALCULATE SOIL WATER STRESS FACTOR 'SMI'
C
      RTDEP = 12.0+0.403*DLA
      IF(RTDEP.LT.RTDEP1) RTDEP = RTDEP1
      RTDEP1 = RTDEP
      IF(RTDEP.GT.RTDEPM) RTDEP = RTDEPM
      DEPTH = 0.0
      SW = 0.
      UL = 0.0001
      SMI = 0.0
      IF(I.LT.ISOW) GO TO 500
      DO 440 L = 1,NLAYR
      DEPTH = DEPTH+DLAYR(L)
      IF(RTDEP.LE.DEPTH) GO TO 460
      UL = UL+ULAYR(L)*DLAYR(L)
      SW = SW+SWLAYR(L)*DLAYR(L)
  440 CONTINUE
      GO TO 480
  460 SW = SW+SWLAYR(L)*(RTDEP+DLAYR(L)-DEPTH)
      UL = UL+ULAYR(L)*(RTDEP+DLAYR(L)-DEPTH)
      SWUL = SW/UL
      SWI = SWLAYR(1)/ULAYR(1)
  480 IF(SWUL.GT.SWI) SMI = SW/UL
      IF(SWI.GT.SWUL) SMI = SWI
      IF((SMI-SML).GT.0.10) SMI = SML+0.10
      SML = SMI
      WATSC2 = 1.0
      IF(SMI.LE.0.5) WATSC2 = SMI/0.5
      IF (SMI.GT.0.3) WATSCO = 1.0
      IF (SMI.LE.0.3) WATSCO = SMI/0.3
      EP = EP*WATSCO
      ET = ES+EP
C
  500 CONTINUE
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE STAGE (I)
      COMMON /BLK1/ GRD(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     2              DLAI(366),RCOUNT(20),ACDAYS(20),DLA,IOPT
      COMMON /BLK2/ RDSPZ,PAREA,N,IDAY3,IDAY6,IDAY9,ISTAGE,SXDIN(20),
     2              SINIT,ACHU,DIFF,DIFF6
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2              SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/ TEMPCO,SW,WATSCO,EOS,EO,UL,SDEPTH,WATSC2,Q,CN2,SL
      IF(ISTAGE.GE.4) GO TO 25
      ISTAGE = 1
      DIFF = 27.6*N+12.90
      DIFF6 = 45.84*N+289.72
      HUNT = HUNITS(I)*WATSCO
      SINIT = SINIT+HUNT*FMRGDA
```

```
      IF(SINIT-DIFF) 199,10,10
 10   IF(IDAY3.GT.0) GO TO 15
      IDAY3 = I
 15   ISTAGE = 2
      IF(ACDAYS(N).EQ.0.) GO TO 199
      ISTAGE = 3
      IF(SINIT-DIFF6) 199,20,20
 20   IF(IDAY6.GT.0) GO TO 25
      IDAY6 = I
      ISTAGE = 4
 25   BASET = 1.
      CALL HFUNC(I,BASET)
      ACHU = HUNITB(I)+ACHU
      BASET = 7.
      IF(ISTAGE.EQ.5) GO TO 199
      IF(ACHU.LT.741.)GO TO 199
      IDAY9 = I
      ISTAGE = 5
199   CONTINUE
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE GROW (I)
      COMMON /BLK1/ GRO(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     2              DLAI(366),RCOUNT(20),ACDAYS(20),DLA,IOPT
      COMMON /BLK2/ ROSPZ,PAREA,N,IDAY3,IDAY6,IDAY9,ISTAGE,SXDIN(20),
     2              SINIT,ACHU,DIFF,DIFF6
      COMMON /BLK5/ WR,WL,WC,WH,WG,DRIWT,DWG,DWH,DWC,DWL,DWR,TOTWT,
     2              WTLF(20)
      DATA PL,SLW/1.,200./
      IF(DLA.LE.0.) GO TO 5
      IF(DRIWT.LE.0.0) GO TO 5
      IF(I-RCOUNT(1).LT.1.)PL = 1.
      YDLA = 0.
      IF (I-RCOUNT(1) .GE. 1.) YDLA = DLAI(I-1)*PAREA
      DDLA = DLA-YDLA
      SLW = 200.
      IF (WL .GE. 0.1) SLW = YDLA/WL
      GO TO (1,2,2,4,4), ISTAGE
    1 IF(SLW.GT.200.) SLW = 200.
      IF(SLW.LT.160.) SLW = 160.
      PDWL = DDLA/SLW
      IF(DDLA.EQ.0.) GO TO 100
      PDWA = (-0.13*(SINIT/DIFF)+0.60)*DRIWT
      IF(PDWA.LT.PDWL.OR.PDWA.GT.PDWL)PDWA = PDWL
  100 DWL = PDWA
      DWC = DRIWT-DWL
      DWR = (-0.25*(SINIT/DIFF6)+0.50)*DRIWT
      GO TO 602
    2 IF(SLW.GT.160.) SLW = 160.
      IF(SLW.LT.140.) SLW = 140.
      PDWL = DDLA/SLW
      IF(DDLA.EQ.0.) GO TO 202
      PDWA = (-0.47*(SINIT-DIFF)/(DIFF6-DIFF)+0.50)*DRIWT
      IF (PDWA.LT.0.) PDWA = 0.
      IF (PDWA.LT.PDWL.OR.PDWA.GT.PDWL) PDWA = PDWL
      PDWL = PDWA
  202 DWL = PDWL
      DWH = 0.375*(SINIT-DIFF)/(DIFF6-DIFF)*DRIWT
      DWC = DRIWT-DWL-DWH
      DWR = (-0.25*(SINIT/DIFF6)+0.50)*DRIWT
      IF(ISTAGE.LT.3) GO TO 602
    3 DWL = 0.
      GO TO 602
    4 IF(ACHU.GT.100.) GO TO 580
      DWR = (-0.25*(ACHU/100.)+0.25)*DRIWT
```

```
      DWG = (0.9*(ACHU/100.))*DRIWT
      DWH = (0.375*(ACHU/100.)+0.375)*DRIWT
      DWC = DRIWT-DWH-DWG
      GO TO 599
  580 DWC = 0.1*DRIWT
      DWG = 0.9*DRIWT
      DWH = 0.
  599 DWL = 0.0
      WG = WG+DWG
  602 WH = WH+DWH
  601 WC = WC+DWC
      IF(WC.LT.0) WC = 0
  600 WR = WR+DWR
      IF(DLA.LE.0.) GO TO 5
      WL = 0.
      DO 800 J = 1,N
      IF(GRO(1,J).LE.0.) WTLF(J) = 0.
      WTLF(J) = WTLF(J)+DWL*GRO(1,J)/DLA
  800 WL = WL+WTLF(J)
    5 TOTWT = WL+WC+WH+WG
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE FDBAK (IDAYFB)
      COMMON /BLK1/ GRO(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     2              DLAI(366),RCOUNT(20),ACDAYS(20),DLA,IOPT
      COMMON /BLK2/ ROSPI,PAREA,N,IDAY3,IDAY6,IDAY9,ISTAGE,SXDIN(20),
     2              SINIT,ACHU,DIFF,DIFF6
      COMMON /BLK3/ DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2              SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/ TEMPCO,SW,WATSCO,EOS,EO,UL,SDEPTH,WATSC2,Q,CN2,SL
      COMMON /BLK5/ WR,WL,WC,WH,WG,DRIWT,DWG,DWH,DWC,DWL,DWR,TOTWT,
     2              WTLF(20)
      DLA = 0.
      HTOTAL = 50.
      READ(1,2001) NLF,NFULL,IDAY3,IDAY6,IDAY9,SPROUT
 2001 FORMAT(5I4,F7.2)
      READ(1,2002) (RCOUNT(J), J = 1,NLF)
 2002 FORMAT( 8F10.2)
      IF (NFULL .EQ. 0) GO TO 105
      READ(1,2002) (ACDAYS(J), J = 1,NFULL)
  105 CONTINUE
      READ(1,2002) (GRO(1,J), J = 1,NLF)
      DO 110 J = 1,NLF
      DLA = DLA + GRO(1,J)
      PDAYS(J) = 1.
      IF (J .GT. 1) SXDIN(J) = HTOTAL
  110 SINIT = SINIT + SXDIN(J)
      DLAI(IDAYFB) = DLA /PAREA
      HUNITS(IDAYFB) = 0.
      IF (NFULL .EQ. N) GO TO 120
      IF (NLF .LT. 2) GO TO 120
      T1 = RCOUNT(NLF)-RCOUNT(NLF-1)
      T2 = IDAYFB-RCOUNT(NLF)
      HUNITS(IDAYFB) = HTOTAL* T2/T1
      IF (HUNITS(IDAYFB) .GT. HTOTAL) HUNITS(IDAYFB) = HTOTAL
      IF (NLF-NFULL)  112,112,115
  112 SXDIN(NLF+1) = HUNITS(IDAYFB)
      GO TO 120
  115 SXDIN(NFULL+1) = HUNITS(IDAYFB)
  120 CONTINUE
      FMRGDA = 1.0
      CALL STAGE(IDAYFB)
      READ(1,2002) WR,WL,WC,WH,WG
      TOTWT = WL+WC+WH+WG
      IF (WL .LE. 0.) GO TO 150
```

```
      DO 130 J = 1, NLF
      WTLF(J) = WL*GRO(1,J)/DLA
  130 CONTINUE
  150 RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE RNF
      COMMON /BLK3/  DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2               SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/  TEMPCO,SW,WATSCO,EOS,EO,UL,SDEPTH,WATSC2,Q,CN2,SL
      COMMON /BSOIL/NLAYR,RTDEPM,DLAYR(20),ULAYR(20),SWLAYR(20),SMI,
     1RTDEP1,W1,W2,S1,SSW,PWC
      SUL = 0
      DO 100 N = 1,NLAYR
      SUL = SUL+ULAYR(N)*DLAYR(N)
 100  CONTINUE
      C = 100-CN2
      D = C*0.063
      E = 2.533-D
      F = EXP(E)
      G = C+F
      H = (20*C)/G
      CN1 = CN2-H
      CN3 = CN2*EXP(.00673*(100-CN2))
      IF(SL.EQ.0.05) GO TO 150
      CN2A = (CN3-CN2)*((1-2*EXP(-13.86*SL))/3)+CN2
      CN2 = CN2A
      C = 100-CN2
      D = C*0.063
      E = 2.533-D
      F = EXP(E)
      G = C+F
      H = (20*C)/G
      CN1 = CN2-H
      CN3 = CN2*EXP(.00673*(100-CN2))
 150  S1 = 254*((100/CN1)-1)
      S3 = 254*((100/CN3)-1)
      FC = SUL*10
      ULM = PWC*10
      P = 2.54/S1
      P1 = 1-P
      P2 = ULM/P1
      P3 = P2-ULM
      Q1 = S3/S1
      Q2 = 1-Q1
      Q3 = FC/Q2
      Q4 = Q3-FC
      Q5 = ALOG(Q4)-ALOG(P3)
      W2 = Q5/(ULM-FC)
      W1 = ALOG(Q4)+(W2*FC)
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE RUNOFF(I)
      COMMON /BLK1/  GRO(2,20),XMAX(20),PDAYS(20),SPROUT,FMRGDA,
     2               DLAI(366),RCOUNT(20),ACDAYS(20),DLA,IOPT
      COMMON /BLK3/  DAYPFO,LAT,TEMPMX(366),TEMPMN(366),TEMP(366),
     2               SOLRAD(366),RAIN(366),HUNITS(366),INTPAR,LITRAN
      COMMON /BLK4/  TEMPCO,SW,WATSCO,EOS,EO,UL,SDEPTH,WATSC2,Q,CN2,SL
      COMMON /BSOIL/NLAYR,RTDEPM,DLAYR(20),ULAYR(20),SWLAYR(20),SMI,
     1  RTDEP1,W1,W2,S1,SSW,PWC
      SSW = 0
      DO 100 N = 1,NLAYR
      SSW = SSW+SWLAYR(N)*DLAYR(N)
  100 CONTINUE
      SSW = SSW*10
```

```
      S = S1*(1-(SSW/(SSW+EXP(W1-(W2*SSW)))))
      CN = 25400/(S+254)
      R = RAIN(I)
      R = R*10
      Z = 0.2*S
      IF(R.LT.Z) GO TO 200
      Q = (R-0.2*S)**2/(R+0.8*S)
      Q = Q/10
      IF(IOPT.NE.3) GO TO 230
      IOP = IOPT
      IF(I.LT.90) IOP = 1
      IF(I.GE.90 .AND. I.LE.213) IOP = 2
      IF(I.GT.213)IOP = 1
      IF(IOP.EQ.2) Q = 0
      GO TO 240
230   CONTINUE
      IF(IOPT.EQ.2) Q = 0
240   SSW = SSW/10
      CONTINUE
      GO TO 250
200   Q = 0
      CONTINUE
      SSW = SSW/10
250   RETURN
      END
```

```
      PROGRAM CORDIKE
C
C                         C  O  R  D  I  K  E
C
C     A FORTRAN PROGRAM COMBINING CORNF AND EPIC RUNOFF ALGORITHMS
C     TO EVALUATE THE IMPACT OF FURROW DIKING ON CORN YIELDS
C     J. H. KRISHNA, BLACKLAND RESEARCH CENTER, TAES, 1987
C
C
      REAL IPAR
      INTEGER SUMOPT, STMO, STDAY, STYR, ENMO, ENDAY, ENYR
      INTEGER CHKIRR, IRR, IRRDAY, IRRIG, IRROPT, DAY
      INTEGER TMPMO, TMPDAY
      CHARACTER*4 FMT
      CHARACTER*9 OTFIL
      CHARACTER*10 INFIL
      CHARACTER*14 SUMMRY
C
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     *               CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     *               IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     *               IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     *               PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,ED,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     *               LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
      COMMON /BLK5/DRIWT,TOTWT,RSRVS,GRNWT,TOTGRN,GRNMST,KRNLS,IPAR
      COMMON /BSOIL/ CN2,SL,PWC,W1,W2,SSW,Q,IOPT,IDB,IDE,S1
      COMMON /BLK7/ SUMOPT
      DIMENSION ICOR(12),STOR(20),TITLE(20),FMT(20)
      DIMENSION IRRDAY(450), IRRIG(450)
      DATA ICOR/1,-1,0,0,1,1,2,3,3,4,4,5/
*
*  Format Section
*
    1 FORMAT(/,1X,'TYPE 1 FOR DRYLAND, 2 FOR IRRIGATED:',$)
    2 FORMAT(I1)
    3 FORMAT(///,1X,'ENTER DATES IRRIGATED.',/,1X,'ENTER 00/00'
     *' WHEN FINISHED.',/)
    4 FORMAT(I2,1X,I2)
    7 FORMAT(/,1X,'DATE (mm/dd):',$)
    8 FORMAT(1X,'AMOUNT OF IRRIGATION (mm):',$)
   11 FORMAT(/,31X,'C  O  R  D  I  K  E',/)
   12 FORMAT(16X,A)
   13 FORMAT(/,20X,'J. H. KRISHNA, BLACKLAND RESEARCH CENTER')
   16 FORMAT(/,1X,'TYPE 1 FOR DAILY SUMMARY, 2 FOR ANNUAL SUMMARY:',$)
   18 FORMAT(I1)
   19 FORMAT(1X,'CORDIKE',/,1X,'CORN FURROW-DIKING PROGRAM',//)
   43 FORMAT(22X,A)
  101 FORMAT(1H ,'Type in station code (1A20): ',$)
  102 FORMAT(/,1X,'TYPE 1 IF NON-DIKED, 2 IF DIKED ALL YEAR,'
     *' 3 IF DIKED PART YEAR:',$)
  104 FORMAT(1A10)
  200 FORMAT(1X,20A4,7X,A14,//)
  201 FORMAT(20A4)
  300 FORMAT(/1X,20A4//)
  505 FORMAT(//,11H LATITUDE =,F6.2,8H  DEGREE)
  570 FORMAT(3I4)
```

```
 580 FORMAT(//1X,'STARTING DATE  =',I4,6X,'CALENDAR DAY =',3I6)
 590 FORMAT(/1X,'PLANTING DATE  =',I4,6X,'CALENDAR DAY =',3I6)
 699 FORMAT(3F6.2)
 701 FORMAT(/,1X,'TYPE DATE DIKES INSTALLED (mm/dd/yyyy):',$)
 702 FORMAT(/,1X,'TYPE DATE DIKES REMOVED (mm/dd/yyyy):',$)
 731 FORMAT(///,16H SOIL DEPTH (CM),5X,24H INITIAL SOIL WATER (CM),5X,
    *28H EXTRACTABLE SOIL WATER (CM)/)
 732 FORMAT(2X,F4.0,' - ',F4.0,16X,F6.1,28X,F6.1)
 733 FORMAT(//,' POTENTIAL DEPTH OF ROOTZONE =',F6.0,/,' EXTRACTABLE '
    *'SOIL WATER WHEN ROOTZONE IS FILLED =',F6.1,/,' INITIAL SOIL'
    *' WATER CONTENT IN ROOTZONE =',F6.1)
 777 FORMAT(I2,1X,I2,1X,I4)
 790 FORMAT(14H ROW SPACING =,F6.1/
    *16H PLANT SPACING =,F6.1/21H PLANTS PER HECTARE =,F7.0/
    *17H AREA PER PLANT =,F8.2/18H PLANTING DEPTH  =,F5.1/
    *,/,' DIKING OPTION =',I2)

 800 FORMAT(///,1X,' DAY',20X,' SW',17X,' PRECIP',17X,' RUNOFF')
 950 FORMAT(I4,20X,F6.2,16X,F6.2,19X,F6.2)
 975 FORMAT(47H PHYSIOLOGICAL MATURITY OCCURRED ON JULIAN DAY ,I4,
    */,1H ,'GRAIN YIELD =',F6.0,'KG/HA',
    *'  RAINFALL TO DATE:',F6.2,'   RUNOFF TO DATE: '
    *,F6.2)
1010 FORMAT(/,36H PHYSIOLOGICAL MATURITY NOT REACHED. /1X,
    */25HPREDICTED ON JULIAN DAY  ,I4)
1111 FORMAT(/,1H ,28X,'TOTAL RAINFALL:',F6.2,'     TOTAL RUNOFF: '
    *,F6.2)
1571 FORMAT(1X,20A4,7X,A14,//)
5800 FORMAT(/,1X,A9)
5900 FORMAT(/,1X,'DIKED FROM: ',I2,'/',I2,'/',I4,'  TO: ',I2,'/',
    *I2,'/',I4)
7777 FORMAT(1H ,'SOWING DATE: ',I3,'          RAINFALL TO DATE:'
    *,F6.2,'   RUNOFF TO DATE: ',F6.2)
8000 FORMAT(1H ,23X,'(CM)',18X,'(CM)',20X,'(CM)')
C
      WRITE(*,11)
      WRITE(*,12) 'A FORTRAN PROGRAM COMBINING CORNF & EPIC RUNOFF'
      WRITE(*,12) 'TO EVALUATE THE IMPACT OF DIKING ON CORN YIELD'
      WRITE(*,13)
      WRITE(*,43) 'TEXAS AGRICULTURAL EXPERIMENT STATION'
      WRITE(*,43) '808 E.BLACKLAND ROAD, TEMPLE, TEXAS  76503'
      WRITE(*,*) ' '
      WRITE(*,*) ' '
*
      WRITE(*,101)
      READ(*,104) INFIL
C
      DO 641 I=1,365
      SOLRAD(I)=0.
      RAIN(I)=0.0
 641  CONTINUE
C
C  INPUT NORMAL TEMPS AND PCPN.
C
*
      WRITE(*,16)
      READ(*,18) SUMOPT
      IF (SUMOPT .EQ. 1) THEN
      SUMMRY = 'DAILY SUMMARY'
      ELSE
      SUMMRY = 'ANNUAL SUMMARY'
      ENDIF
      WRITE(*,*) ' '
      WRITE(*,102)
      READ(*,18) L
      IF (L .EQ. 1) OTFIL(1:1) = '1'
```

```
      IF (L .EQ. 2) OTFIL(1:1) = '2'
      IF (L .EQ. 3) OTFIL(1:1) = '3'
      OTFIL(2:2) = 'C'
      OTFIL(3:3) = INFIL(1:1)
      OTFIL(4:5) = INFIL(5:6)
      OTFIL(6:9) = '.OUT'
      INFIL(7:10) = '.DAT'
      OPEN(UNIT = 1,FILE = INFIL,STATUS = 'OLD')
      OPEN(UNIT = 3,FILE = OTFIL,STATUS = 'NEW')
      READ(1,201) TITLE
      WRITE(3,19)
      WRITE(3,1571) TITLE, SUMMRY
      IF (L .EQ. 3) THEN
      WRITE(*,701)
      READ(*,777) MO, ND, IYR
      STMO = MO
      STDAY = ND
      STYR = IYR
      IF (MO .EQ. 1) THEN
      IDB = ND
      ELSE
      IDB = 30 * (MO - 1) + ICOR(MO - 1) + ND
      IF (MOD(IYR,4) .EQ. 0) THEN
      IF (MO .GT. 2) THEN
      IDB = IDB + 1
      ENDIF
      ENDIF
      ENDIF
      WRITE(*,702)
      READ(*,777) MO, ND, IYR
      ENMO = MO
      ENDAY = ND
      ENYR = IYR
      IF (MO .EQ. 1) THEN
      IDE = ND
      ELSE
      IDE = 30 * (MO - 1) + ICOR(MO - 1) + ND
      IF (MOD(IYR,4) .EQ. 0) THEN
      IF (MO .GT. 2) THEN
      IDE = IDE + 1
      ENDIF
      ENDIF
      ENDIF
      ENDIF
*
      READ(1,*) KDAY,ROSPZ,PP,SDEPTH,ALAT,LAYRS,UL1,ASOILT
     $ ,XMAX(1),MCLASS
      READ(1,*) CN2,SL,PWC,IOPT
      IF (SUMOPT .EQ. 1) WRITE(3,505) ALAT
      PAREA=1.E08/PP
      R2=PAREA/ROSPZ
*
      READ(1,570) MO, ND, IYR
      TMPMO = MO
      TMPDAY = ND
      WRITE(*,1)
      READ(*,2) IRROPT
      IF (IRROPT .EQ. 2) THEN
      IRR = 1
      WRITE(*,3)
   29 WRITE(*,7)
      READ(*,4) MO, ND
      IF (MO .NE. 0) THEN
      IF (MO .EQ. 1) THEN
      IRRDAY(IRR) = ND
      ELSE
```

```
      IRRDAY(IRR) = 30 * (MO - 1) + ICOR(MO - 1) + ND
      IF (MOD(IYR,4) .EQ. 0) THEN
      IF (MO .GT. 2) THEN
      IRRDAY(IRR) = IRRDAY(IRR) + 1
      ENDIF
      ENDIF
      ENDIF
      WRITE(*,8)
      READ(*,*) IRRIG(IRR)
      IRR = IRR + 1
      GO TO 29
      ENDIF
      ENDIF
      MO = TMPMO
      ND = TMPDAY
      WRITE(*,*) ' '
      WRITE(*,*) ' '
      WRITE(*,*) 'PROGRAM RUNNING, PLEASE WAIT...'
      IOPT = L
      I = 1
  510 IF (I .EQ. 2) READ(1,570) MO, ND, IYR
      IF (MO .EQ. 1) THEN
      IDY = ND
      ELSE
      IDY = 30 * (MO - 1) + ICOR(MO - 1) + ND
      IF (MOD(IYR,4) .EQ. 0) THEN
      IF (MO .GT. 2) THEN
      IDY = IDY + 1
      ENDIF
      ENDIF
      ENDIF
      GO TO (511,512),  I
  511 IBEGIN = IDY
      WRITE(3,580) IBEGIN, MO, ND, IYR
      I = I + 1
      GO TO 510
  512 IDAY0 = IDY
      WRITE(3,590) IDAY0, MO, ND, IYR
      IF (IOPT .EQ. 1) WRITE(3,5800) 'NON-DIKED'
      IF (IOPT .EQ. 2) WRITE(3,5800) 'DIKED    '
      IF (IOPT .EQ. 3) WRITE(3,5900) STMO,STDAY,STYR,ENMO,ENDAY,ENYR
      IF (IRROPT .EQ. 2) THEN
      WRITE(3,5800) 'IRRIGATED'
      ELSE
      WRITE(3,5800) 'DRYLAND  '
      ENDIF
      READ(1,570) MO, ND, IYR
      READ(1,570) MO, ND, IYR
*
      DO 700 L=1,LAYRS
      READ(1,699)DLAYR(L),SWLAYR(L),ULLAYR(L)
  700 CONTINUE
      DL1=0.
      RTDEPM=0.
      SW=0.
      UL=0.
      IF (SUMOPT .EQ. 1) WRITE(3,731)
      DO 730 L=1,LAYRS
      DL2=DL1+DLAYR(L)
      SWLR=SWLAYR(L)*DLAYR(L)
      ULLR=ULLAYR(L)*DLAYR(L)
      IF (SUMOPT .EQ. 1) WRITE(3,732) DL1,DL2,SWLR,ULLR
      DL1=DL2
      RTDEPM=RTDEPM+DLAYR(L)
      SW=SW+SWLR
      UL=UL+ULLR
```

```
  730 CONTINUE
      IF (SUMOPT .EQ. 1) WRITE(3,733)RTDEPM,UL,SW
      DO 750 L=1,LAYRS
      STOR(L)=ULLAYR(L)-SWLAYR(L)
  750 CONTINUE
      IEND = IBEGIN + KDAY - 1
 2000 DO 2001 I = IBEGIN,IEND
      READ(1,*) RAIN(I), TEMPMX(I), TEMPMN(I), SOLRAD(I)
      RAIN(I) = RAIN(I) * 25.4
      TEMPMX(I) = (TEMPMX(I) - 32) * 5 / 9
      TEMPMN(I) = (TEMPMN(I) - 32) * 5 / 9
 2001 CONTINUE
*
      IF (IRROPT .EQ. 2) THEN
      IRR = IRR - 1
 5000 DO 5001 DAY = 1,366
 4000 DO 4001 CHKIRR = 1,IRR
      IF (IRRDAY(CHKIRR) .EQ. DAY) THEN
      RAIN(DAY) = RAIN(DAY) + IRRIG(CHKIRR)
      ENDIF
 4001 CONTINUE
 5001 CONTINUE
      ENDIF
*
      DO 753 L=1,LAYRS
      SWLAYR(L)=ULLAYR(L)-STOR(L)
 753  CONTINUE
      DO 780 J=1,30
      IF(J.EQ.1) GO TO 754
      XMAX(J)=0.
 754  FLEAF(J)=0.
      PDAYS(J)=0.
      RCOUNT(J)=0.
 780  CONTINUE
      TRAIN=0.
      TRUN=0.
      SUMHU=0.
      RTDEP=0.
      SPROUT=0.
      FEMRGN=0.
      FTASIN=0.
      FANTH=0.
      FSILK=0.
      FBLIST=0.
      FDENT=0.
      IPAR=0.
      TOTWT=0.
      DRIWT=0.
      RSRVS=0.
      GRNWT=0.
      GRNMST=0.
      TOTGRN=0.
      ISTAGE=-1
      IDAY1=0
      IDAY2=0
      IDAY3=0
      IDAY4=0
      IDAY5=0
      IDAY6=0
      IDAY7=0
      IDAY8=0
      IDAY9=0
      WRITE(3,790) ROSPI,R2,PP,PAREA,SDEPTH,IOPT
      IF (SUMOPT .EQ. 1) THEN
      WRITE(3,800)
      WRITE(3,8000)
```

```
      ENDIF
      WRITE(3,*)
C
      CALL RNF
C
      DO 1000 I = IBEGIN,365
      IF (I .EQ. IDAY0) THEN
      WRITE(3,7777) I,TRAIN,TRUN
      END IF
      I1 = I
      CALL RUNOFF(I)
      IF(I1 .GT. 365) I1 = I1 - 365
      DECDAY = I1 + 100
      DECLIN = SIN((DECDAY*360./365.)/180.*3.141593)*(-23.47)
      SUNRIS = 12.-ACOS(-TAN(ALAT/180.*3.141593)*TAN(DECLIN/180.*
     $3.141593))/0.2618
      DAYLN=2.*(12.-SUNRIS)
      CALL HFUNC(I)
      IF(SPROUT.GT.0.) GO TO 910
      DLA(I)=0.
      DLAI(I)=0.
      IF(I .LT. IDAY0) GO TO 930
      CALL EMRGNC(I)
      IF(SPROUT .EQ. 0.0) GO TO 920
  910 CALL LEAF(I)
  920 CALL STAGE(I)
  930 CALL EVAP(I)
      CALL SOLWAT(I)
      IF(SPROUT .EQ. 0.0) GO TO 940
      CALL PHOTO(I)
      IF(IDAY3 .EQ. 0) GO TO 940
      CALL EAR(I)
  940 IPRINT = I1 - IDAY0 + 1
      RAINT = RAIN(I) / 10
      TRAIN = TRAIN + RAINT
      TRUN = TRUN + Q
      IF (SUMOPT .EQ. 1) WRITE(3,950) I1, SSW, RAINT, Q
      IF(SPROUT .EQ. 0.0) GO TO 999
      IF(I .NE. IDAY5) GO TO 971
  971 IF(I .NE. IDAY9) GO TO 980
      YLD=TOTGRN*1.18*PP/1000.
      WRITE(3,975) I,YLD,TRAIN,TRUN
  980 PDAY=1.0
  999 CONTINUE
 1000 CONTINUE
      IF(I.GT.IDAY9) GO TO 1050
      IF (SUMOPT .EQ. 1) WRITE(3,1010) IDAY9
 1050 CONTINUE
      WRITE(3,1111) TRAIN,TRUN
      TYLD = TOTWT * PP / 1000.0
      WTKRNL = TOTGRN / KRNLS
      CLOSE(UNIT = 1)
      CLOSE(UNIT = 3)
      STOP
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE HFUNC(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2            CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     2            IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     3            IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2            PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,EO,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     2            LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
```

```
      PI=3.14159
      IF(I.GT.IBEGIN) GO TO 5
      SMI=SWLAYR(1)/ULLAYR(1)
5     CUTOFT=30.
      IF(SPROUT.NE.0.) GO TO 10
      BASET=8.7
      GO TO 20
10    BASET=10.
20    CMIN=TEMPMN(I)
      CMAX=TEMPMX(I)
      CAVG=(CMIN+CMAX)/2.
      AMP=CMAX-CAVG
      IF (AMP .LE. .01) AMP = .01
      CMAXI=CMAX
      IF(CMAXI.GE.CUTOFT) CMAXI=CUTOFT
      IF(CMIN.GE.BASET) GO TO 100
      IF(CMAXI.LE.BASET) GO TO 200
      ZETA=ASIN((BASET-CAVG)/AMP)
      HUNITS(I)=1./PI*(AMP*COS(ZETA)+(CAVG-BASET)*(PI/2.-ZETA))
      GO TO 300
 100  HUNITS(I)=(CMAX+CMIN)/2.-BASET
      GO TO 300
 200  HUNITS(I)=0.
 300  HUDAYL=1.-(13.-DAYLN)*0.10
      HURED=1.0
      IF(SOLRAD(I).LT.200..AND.SMI.GT.0.8) HURED=SOLRAD(I)/200.
      IF(ISTAGE.GT.2) HURED=1.0
      HUNITS(I)=HUNITS(I)*HUDAYL*HURED
      IF(I.LT.IDAY0) GO TO 400
      SUMHU=SUMHU+HUNITS(I)
 400  RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE EMRGNC(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     *              CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     *              PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,EO,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     *              LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
      COMMON /BLK7/ SUMOPT
C
      RTDEP=RTDEP+HUNITS(I)/7.0
      IF(I.EQ.IDAY0) RTDEP=SDEPTH
      SW=SWLAYR(1)*RTDEP
      UL=ULLAYR(1)*RTDEP
      IF(SW/UL.LT.0.2) RTDEP=SDEPTH
      IF(SW/UL.LT.0.2) GO TO 900
      SOILHU=75.
      TEMRGN=ASOILT*SOILHU
      FEMRGN=FEMRGN+HUNITS(I)
      IF(FEMRGN-TEMRGN)900,200,200
 200  PDAY=(FEMRGN-TEMRGN)/HUNITS(I)
      SPROUT=I-PDAY
 900  RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE LEAF(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2              CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     2              IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     3              IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2              PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,EO,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
```

```
     2               LAYRS,DLAYR(20),RIDEP,RIDEPM,ASUILT
      IF(ISTAGE.GE.5) GO TO 500
      IF(I.LE.SPROUT+1.) CALL STAGE(I)
      N=XN+0.5
      NMAX=0.46*XN+4.03
      NTHREE=NEARIN+2
      DO 100 J=1,N
      I1=I
      IF(I1-1.EQ.IFIX(RCOUNT(J))) GO TO 45
      IF(FLOAT(I1-1).LT.RCOUNT(J)) GO TO 200
      IF(RCOUNT(J).NE.0.) GO TO 100
      IF(J.GT.NEARIN) GO TO 20
      IF(J.GE.3) GO TO 10
      HTOTAL(J)=22.*J-7.
      GO TO 30
10    HTOTAL(J)=58.
      GO TO 30
20    HTOTAL(J)=HTOTAL(J-1)-38./(N-NEARIN)
30    FLEAF(J)=FLEAF(J)+PDAY*HUNITS(I)
      IF(FLEAF(J)-HTOTAL(J)) 35,40,40
35    I=I+1
      IF(I-1.GT.SPROUT) PDAY=1.0
      CALL HFUNC(I)
      SUMHU=SUMHU-HUNITS(I)
      GO TO 30
40    PDAYS(J)=(FLEAF(J)-HTOTAL(J))/HUNITS(I)
      RCOUNT(J)=I-PDAYS(J)
      FLEAF(J+1)=FLEAF(J)-HTOTAL(J)
45    IF(FLOAT(I1).LT.RCOUNT(J)) GO TO 200
46    CONTINUE
      IF(J.EQ.NEARIN) IDAY3=I
      IF(J+1.NE.N) GO TO 200
      PDAY=0.
100   CONTINUE
200   I=I1
      IF(DLAI(I-2).LT.0.8.AND.DLAI(I-1).GE.0.8) GO TO 202
      IF(DLAI(I-1).GE.0.8) GO TO 204
      DLARED=1.
      GO TO 204
202   DLARED= 2.5063-0.1613*ALOG(1.E08/PAREA)
      IF(DLARED.GT.1.) DLARED=1.0
      XMAX(J)=XMAX(J)*DLARED
      XMAX(J+1)=0.
      XMAX(J+2)=0.
      XMAX(J+3)=0.
204   DO 300 J=2,N
      IF(XMAX(J).NE.0.) GO TO 300
      IF(J.LE.3) GO TO 205
      IF(RCOUNT(J-3).EQ.0.) GO TO 301
      IF(J.EQ.N) GO TO 220
      IF(J.GT.NMAX) GO TO 215
      IF(J.GT.NTHREE) GO TO 210
      IF(J.GT.4) GO TO 206
205   XMAX(J)=1.63*XMAX(J-1)+XMAX(1)
      GO TO 300
206   XMAX(J)=1.13*XMAX(J-1)+66.5*DLARED
      GO TO 300
210   IF(N.GE.23) GO TO 213
      IF(N.GE.17) GO TO 212
      IF(N.GE.14) GO TO 211
      XMAX(J)=0.60*XMAX(J-1)+320.*DLARED
      GO TO 300
211   XMAX(J)=0.65*XMAX(J-1)+330.*DLARED
      GO TO 300
212   XMAX(J)=0.70*XMAX(J-1)+340.*DLARED
      GO TO 300
```

```
213   XMAX(J)=0.75*XMAX(J-1)+350.*DLARED
      GO TO 300
215   IF(XMAX(J-1).LE.870.*DLARED.AND.XMAX(NMAX).GE.870.*DLARED)GOTO 217
      XMAX(J)=XMAX(J-1)-80.*DLARED
      GO TO 300
217   XMAX(J)=1.21*XMAX(J-1)-263.*DLARED
      GO TO 300
220   XMAX(J)=0.44*XMAX(J-1)-26.*DLARED
300   CONTINUE
301   DO 400 J=1,N
      IF(J.GT.NEARIN) GO TO 330
      IF(I.LE.SPROUT+PDAY+0.1) SUMLA=0.
      IF(J.GT.1) GO TO 320
      DELTLA=XMAX(J)+0.7*XMAX(J+1)+0.3*XMAX(J+2)
      GO TO 350
320   DELTLA=0.3*XMAX(J)+0.4*XMAX(J+1)+0.3*XMAX(J+2)
      GO TO 350
330   IF(J.GT.NEARIN+1) GO TO 340
      DELTLA=0.3*XMAX(J)+0.45*XMAX(J+1)+0.5*XMAX(J+2)+0.25*XMAX(J+3)
      GO TO 350
340   DELTLA=0.25*XMAX(J)+0.25*XMAX(J+1)+0.25*XMAX(J+2)+0.25*XMAX(J+3)
350   IF(RCOUNT(J+1).EQ.0.) GO TO 405
400   CONTINUE
405   IF(J.EQ.1) I2=SPROUT
      IF(J.GT.1) I2=RCOUNT(J-1)+PDAYS(J-1)+0.1
      I3=RCOUNT(J)+PDAYS(J)+0.1
      IF(I3.EQ.I2) I3=I2+1
      RATELA=DELTLA/(I3-I2)
      SUMLA=SUMLA+RATELA
      IF(IDAY2.NE.0) GO TO 500
      K=1
      M1=0
      M2=0
      SF=0.
      CORR=0.
      GO TO 545
500   IF(K.EQ.N) GO TO 600
      K=K+1
      SUMWAT=SUMWAT+WATCO(SMI,.40,0.)
      TIME=TIME+1.
      AVWAT=SUMWAT/TIME
      IF(IDAY7.EQ.0) GO TO 520
      IF(AVWAT.LT.0.95) M1=M1+1
      IF(IDAY8.EQ.0) GO TO 520
      IF(ISTAGE.EQ.8) SF=70.
      IF(ISTAGE.EQ.9) SF=120.
      M2=M2+1
520   SENES=TASINI+K*120.-M1*20.-M2*SF-155.+CORR
530   IF(SUMHU-SENES) 550,540,540
540   SUMLA=SUMLA-XMAX(K)
      IF(ISTAGE.EQ.7) K1=K
      IF(IDAY8.EQ.0) GO TO 545
      IF(K.GT.K1+1) GO TO 545
      SENES1=SENES
      IF(SUMHU-HUNITS(I).GT.SENES1) CORR=SUMHU-HUNITS(I)-SENES1
545   TIME=0.
      SUMWAT=0.
      GO TO 600
550   K=K-1
      IF(AVWAT.LT.0.95.AND.IDAY7.NE.0) M1=M1-1
      IF(IDAY8.NE.0) M2=M2-1
600   IF(K.EQ.N) SUMLA=0.
      DLA(I)=SUMLA
      IF(DLA(I).LT.0.) DLA(I)=0.
      DLAI(I)=DLA(I)/PAREA
      RETURN
      END
```

```
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE STAGE(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2             CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     2             IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     3             IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2             PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      REAL NTASIN
      IF(I-1.EQ.SPROUT) GO TO 2
      IF(SPROUT.NE.0.) GO TO 1
      ISTAGE=0
      GO TO 903
 1    GO TO (2,100,150,200,300,400,500,600,801),ISTAGE
 2    ISTAGE=1
      IF(I-1.GT.SPROUT) GO TO 3
      SDAYLN=0.
      FTASIN=0.
 3    SDAYLN=SDAYLN+DAYLN
      ADAYLN=SDAYLN/(I-IFIX(SPROUT))
      IF(ADAYLN.GT.12.5) GO TO 6
      IF(MCLASS.GE.7) GO TO 4
      XN=MCLASS+9.
      GO TO 40
 4    XN=2.*MCLASS+3.
      GO TO 40
 6    GO TO (10,10,10,10,10,10,20,25,30),MCLASS
 10   A1=0.24*MCLASS+0.47
      A0=-2.0*MCLASS+3.12
      XN=A1*ADAYLN+A0
      GO TO 40
 20   XN=2.14*ADAYLN-9.75
      GO TO 40
 25   XN=2.5*ADAYLN-12.25
      GO TO 40
 30   XN=2.98*ADAYLN-16.25
 40   NTASIN=0.584*XN-4.4
      IF(NTASIN.GE.2.) GO TO 42
      IF(NTASIN.GE.1.) GO TO 41
      NTASIN=1.
 41   TASINI=15.*NTASIN
      GO TO 50
 42   TASINI=45.+(NTASIN-2.)*58.
 50   FTASIN=FTASIN+PDAY*HUNITS(I)
      IF(FTASIN-TASINI)101,60,60
 60   CONTINUE
      IDAY2=I
 100  ISTAGE=2
 101  N=XN+0.5
      NEARIN=0.45*XN+0.5
      NFIVE=0.8*XN+0.5
 150  IF(I.GE.IDAY3.AND.IDAY3.NE.0) ISTAGE=3
      IF(RCOUNT(NFIVE).EQ.0.) GO TO 903
      IDAY4=IFIX(RCOUNT(NFIVE))+1
      IF(I.LT.IDAY4) GO TO 903
 200  ISTAGE=4
      IF(I.LE.RCOUNT(N).OR.RCOUNT(N).EQ.0.) GO TO 903
      IDAY5 =IFIX(RCOUNT(N))+1
      HUANTH=SUMHU
 300  ISTAGE=5
      FSILK=FSILK+PDAY*HUNITS(I)
      TSILK=5.*10000./PAREA
      IF(FSILK-TSILK)900,310,310
 310  PDAY=(FSILK-TSILK)/HUNITS(I)
```

```
      IDAY6=I
400   ISTAGE=6
      TBLIST=0.22*(HUANTH-85.)
      FBLIST=FBLIST+PDAY*HUNITS(I)
      IF(FBLIST-TBLIST)900,410,410
410   PDAY=(FBLIST-TBLIST)/HUNITS(I)
      IDAY7=I
500   ISTAGE=7
      TDENT=0.53*(HUANTH-85.)-TSILK
      FDENT=FDENT+PDAY*HUNITS(I)
      IF(FDENT-TDENT)505,510,510
505   IF(I-IDAY5.LT.60) GO TO 900
510   IDAY8=I
600   ISTAGE=8
      HUPM=2.*HUANTH-85.
      IF(SUMHU-HUPM)700,800,800
700   IF(I.LT.IEND) GO TO 900
      IDAY9=I+(HUPM-SUMHU)/HUNITS(I)
      IF(IDAY9-IDAY5.GT.65) IDAY9=IDAY5+65
      GO TO 900
800   IDAY9=I
801   ISTAGE=9
900   PDAY=1.
903   RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE EVAP(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2               CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2               PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,EO,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     2               LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
      DATA GAMMA/.68/
      TK=CAVG + 273.
      DELTA=(EXP(21.255-5304./TK))*(5304./(TK**2))
      D=DELTA/GAMMA
      ALBEDO=.3367-.1867*EXP(-.6*DLAI(I))
      RO=520+193*SIN(.0172*(I-80))
      IF(SOLRAD(I).GT.RO) SOLRAD(I)=RO
      R4=1.-.261*EXP(-7.77E-04*CAVG**2)
      R6=(R4-.96)*1.17E-07*TK**4*(.2+.8*(SOLRAD(I)/RO))
      H=(1.-ALBEDO)*SOLRAD(I)+R6
      HO=H/583.
      EO=1.35*D/(D+1.)*HO
      IF(DLAI(I).LT.0.5) EOS=EO
      IF(DLAI(I).LT.0.5) GO TO 41
      HOS=HO*EXP(-0.398*DLAI(I))
      EOS=D/(D+1.)*HOS
41    RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE SOLWAT(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2               CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     2               IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     3               IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2               PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,EO,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     2               LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
      COMMON /BSOIL/ CN2,SL,PWC,W1,W2,SSW,Q,IOPT,IDB,IDE,S1
      DIMENSION STOR(20)
      DATA DELT,CF/15.,2.54/
      IF(I.GT.IBEGIN) GO TO 110
```

```
      I=0.
      SMI=SWLAYR(1)/ULLAYR(1)
      IF(SMI-0.9) 101,102,102
 101  SUMES1=UL1
      SUMES2=2.5-2.78*SMI
      GO TO 110
 102  SUMES1=10.-SMI*10.
      SUMES2=0.
 110  RAINSI = RAIN(I) / 10
C       IF(RAINSI.LE.2.5) Q=0.
C       IF(RAINSI.LE.2.5) GO TO 111
C       STORE=0.
C       DO 113 L=1,LAYRS
C       STOR(L)=(ULLAYR(L)-SWLAYR(L))*DLAYR(L)
C       STORE=STORE+STOR(L)
 113  CONTINUE
C       Q=(ABS(RAINSI-0.2*STORE))**2./(RAINSI+0.8*STORE)
 111  RAINEF=RAINSI-Q
      IF(SUMES1-UL1) 1,2,2
 1    IF(RAINSI-SUMES1)3,4,4
 3    SUMES1=SUMES1-RAINSI
      GO TO 5
 4    SUMES1=0.
 5    SUMES1=SUMES1+EOS
      IF(SUMES1-UL1) 6,6,7
 6    ES=EOS
      GO TO 24
 7    ES=EOS-0.4*(SUMES1-UL1)
      SUMES2=0.6*(SUMES1-UL1)
      T=(SUMES2/.35)**2
      GO TO 24
 2    IF(RAINSI-SUMES2)9,8,8
 8    RAINSI=RAINSI-SUMES2
      SUMES1=UL1-RAINSI
      T=0.
      IF(RAINSI-UL1) 5,5,4
 9    T=T+1.
      ES=.35*T**0.5-SUMES2
      IF(RAINSI.GT.0.) GO TO 10
      IF(ES.GT.EOS) ES=EOS
      GO TO 11
 10   ESX=0.8*RAINSI
      IF(ESX.LE.ES) ESX=ES+RAINSI
      IF(ESX.GT.EOS) ESX=EOS
      ES=ESX
 11   SUMES2=SUMES2+ES-RAINSI
      T=(SUMES2/.35)**2
 24   IF(ES.LT.0.) ES=0.
      IF(DLAI(I).GT.3.) GO TO 26
      EP=.53*DLAI(I)**.5*EO
      GO TO 27
 26   EP=EO-ES
 27   IF(EP.LT.0.) EP=0.
      ET=ES+EP
      IF(EO-ET) 39,41,41
 39   ET=EO
      EP=ET-ES
 41   CONTINUE
      EP=EP*WATCO(SMI,.40,0.)
      ET=ES+EP
      IF(I.LE.IDAY0) SUMET=0.
      SUMET=SUMET+ET
      IF(SPROUT.EQ.0.) GO TO 200
      IF(IDAY7.NE.0) GO TO 200
      RTGROW=HUNITS(I)*(0.2-0.0008*RTDEP)*WATCO(SMI,.15,0.)
      RTDEP=RTDEP+RTGROW
```

```
      IF(RTDEP.GT.RTDEPM) RTDEP=RTDEPM
  200 DELTSW=RAINEF-ET
      DO 300 L=1,LAYRS
      IF(DELTSW.EQ.0.) GO TO 301
      SWLR=SWLAYR(L)*DLAYR(L)+DELTSW
      SWMAX=ULLAYR(L)*DLAYR(L)
      IF(SWLR.GE.0.) GO TO 210
      DELTSW=DELTSW+SWLAYR(L)*DLAYR(L)
      SWLAYR(L)=0.
      GO TO 300
  210 IF(SWLR.LE.SWMAX) GO TO 220
      DELTSW=DELTSW-SWMAX+SWLAYR(L)*DLAYR(L)
      SWLAYR(L)=ULLAYR(L)
      GO TO 300
  220 SWLAYR(L)=SWLR/DLAYR(L)
      DELTSW=0.
  300 CONTINUE
  301 DEPTH=0.
      SW=0.
      UL=0.
      DO 400 L=1,LAYRS
      DEPTH=DEPTH+DLAYR(L)
      IF(I.LT.IDAY0) DEPTH=0.
      IF(RTDEP.LE.DEPTH) GO TO 410
      UL=UL+ULLAYR(L)*DLAYR(L)
      SW=SW+SWLAYR(L)*DLAYR(L)
  400 CONTINUE
  410 SW=SW+SWLAYR(L)*(RTDEP+DLAYR(L)-DEPTH)
      UL=UL+ULLAYR(L)*(RTDEP+DLAYR(L)-DEPTH)
      SWI=SWLAYR(1)/ULLAYR(1)
      IF(DLAYR(1).GE.30.) GO TO 450
      SWI=(SWI*DLAYR(1)+(SWLAYR(2)/ULLAYR(2))*(30.-DLAYR(1)))/30.
  450 SMI=AMAX1(SW/UL,SWI)
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE PHOTO(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2                CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     2                IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     3                IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2                PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,ED,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     2                LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
      COMMON /BLK5/DRIWT,TOTWT,RSRVS,GRNWT,TOTGRN,GRNMST,KRNLS,IPAR
      REAL IPAR
      EXTINC=0.65
      IPAR=0.5*SOLRAD(I)*(1.-EXP(-EXTINC*DLAI(I)))
      ALPHA=3.2
      IF(ISTAGE.GE.5) ALPHA=2.57
      DRIWT=4.2E-6*ALPHA*IPAR*PAREA*WATCO(SMI,.40,0.)
      IF(I.GT.IDAY9.AND.IDAY9.NE.0) DRIWT=0.
      TOTWT=TOTWT+DRIWT
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE EAR(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2                CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     2                IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     3                IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2                PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
```

```
      COMMON /BLK4/EOS,EO,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     2             LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
      COMMON /BLK5/DRIWT,TOTWT,RSRVS,GRNWT,TOTGRN,GRNMST,KRNLS,IPAR
      REAL KRNRED
      IF(IDAY6.EQ.IDAY5.AND.I.EQ.IDAY6) GO TO 9
      GO TO  (900,900,900,6,8,10,15,20,25), ISTAGE
6     IF(I-IDAY4) 900,7,14
7     KRNRED=1.
      GO TO 14
8     IF(I-IDAY5) 900,9,14
9     RSFRAC=0.20
      DMANTH=TOTWT
10    IF(I-IDAY6) 900,12,14
12    K=0
      GRNWT1=0.
      GRNRED=1.
14    KRNRED=KRNRED-(1.-WATCO(SMI,.50,0.))*0.04
      IF(ISTAGE.EQ.4) GO TO 900
      GO TO 30
15    IF(I-IDAY7) 900,17,30
17    RSRVS=RSFRAC*TOTWT
      GRNMST=90.
      GO TO 30
20    K=K+1
      GRNRED=0.5*TANH(2.4-0.4*K)+0.5
      GO TO 30
25    GRNRED=0.
      GO TO 100
30    IF(CMAX.LT.30.) CMAX=30.
      IF(I.GE.IDAY7.AND.IDAY7.NE.0) GO TO 31
      RSFRAC=RSFRAC*(1.-(CMAX-30.)/50.)
      GO TO 900
31    RSFRAC=1-(CMAX-30.)/50.
32    RSRVS=RSFRAC*RSRVS
      IF(DMANTH.GT.160.) GO TO 35
      KRNLS=(5.*DMANTH-50.)*KRNRED
      GO TO 40
35    KRNLS=750.*KRNRED
40    GRNWT=0.00065*HUNITS(I)*KRNLS
      IF(RSRVS.LE.0.AND.GRNWT.GT.DRIWT) GRNWT=DRIWT
      RSRVS=RSRVS+DRIWT-GRNWT
      IF(RSRVS.GE.0.) GO TO 100
      GRNWT=GRNWT+RSRVS
      RSRVS=0.
100   GRNWT=GRNRED*GRNWT
      IF(ISTAGE.EQ.8) RSRVS=RSRVS+GRNWT/GRNRED-GRNWT
      TOTGRN=TOTGRN+GRNWT
      IF(ISTAGE.EQ.9) GO TO 210
      IF(GRNWT1.LT.0.1.AND.GRNWT.LT.0.1) IDAY9=I
      IF(I.EQ.IDAY9) ISTAGE=9
      GRNWT1=GRNWT
      GMSTLS=60.*HUNITS(I)/(0.75*(HUANTH-85.))
      GO TO 220
210   GMSTLS=EO/.4
220   IF(RAIN(I).GT.0.AND.ISTAGE.GT.8) GMSTLS=0.
      GRNMST=GRNMST-GMSTLS
900   RETURN
      END
      REAL FUNCTION WATCO(C1,C3,C5)
      C4=1.0
      IF(C1.LT.C3) GO TO 100
      WATCO=C4
      RETURN
100   WATCO=C1*(C4-C5)/C3+C5
      RETURN
      END
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE RNF
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2               CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     2               IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     3               IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2               PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,EO,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     2               LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
      COMMON /BLK5/DRIWT,TOTWT,RSRVS,GRNWT,TOTGRN,GRNMST,KRNLS,IPAR
      COMMON /BSOIL/ CN2,SL,PWC,W1,W2,SSW,Q,IOPT,IDB,IDE,S1
      SUL=0
      DO 100 N=1,LAYRS
      SUL=SUL+ULLAYR(N)*DLAYR(N)
  100 CONTINUE
      C=100-CN2
      D=C*0.063
      E=2.533-D
      F=EXP(E)
      G=C+F
      H=(20*C)/G
      CN1=CN2-H
      CN3=CN2*EXP(.00673*(100-CN2))
      IF(SL.EQ.0.05) GO TO 150
      CN2A=(CN3-CN2)*((1-2*EXP(-13.86*SL))/3)+CN2
      CN2=CN2A
      C=100-CN2
      D=C*0.063
      E=2.533-D
      F=EXP(E)
      G=C+F
      H=(20*C)/G
      CN1=CN2-H
      CN3=CN2*EXP(.00673*(100-CN2))
  150 S1=254*((100/CN1)-1)
      S3=254*((100/CN3)-1)
      FC=SUL*10
      ULM=PWC*10
      P=2.54/S1
      P1=1-P
      P2=ULM/P1
      P3=P2-ULM
      Q1=S3/S1
      Q2=1-Q1
      Q3=FC/Q2
      Q4=Q3-FC
      Q5=ALOG(Q4)-ALOG(P3)
      W2=Q5/(ULM-FC)
      W1=ALOG(Q4)+(W2*FC)
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE RUNOFF(I)
      COMMON/BLK1/ALAT,TEMPMX(500),TEMPMN(500),SOLRAD(500),RAIN(500),
     2               CMAX,CAVG,DAYLN,HUNITS(500),SUMHU,IBEGIN,IEND
      COMMON/BLK2/MCLASS,XMAX(30),XN,NEARIN,FTASIN,FANTH,FSILK,FBLIST,
     2               IDAY1,IDAY2,IDAY3,IDAY4,IDAY5,IDAY6,IDAY7,IDAY8,
     3               IDAY9,ISTAGE,FDENT,HUANTH,TASINI
      COMMON /BLK3/HTOTAL(30),FEMRGN,SPROUT,RCOUNT(30),FLEAF(30),
     2               PDAY,PDAYS(30),DLA(500),DLAI(500),PAREA,SDEPTH,IDAY0
      COMMON /BLK4/EOS,EO,SWLAYR(20),SW,ULLAYR(20),UL,UL1,SUMET,SMI,
     2               LAYRS,DLAYR(20),RTDEP,RTDEPM,ASOILT
      COMMON /BLK5/DRIWT,TOTWT,RSRVS,GRNWT,TOTGRN,GRNMST,KRNLS,IPAR
      COMMON /BSOIL/ CN2,SL,PWC,W1,W2,SSW,Q,IOPT,IDB,IDE,S1
```

```
      SSW=0
      DO 100 N=1,LAYRS
      SSW=SSW+SWLAYR(N)*DLAYR(N)
100   CONTINUE
      SSW=SSW*10
      S=S1*(1-(SSW/(SSW+EXP(W1-(W2*SSW)))))
      IF (S .LE. 0.01) S = 0.01
      CN=25400/(S+254)
      R=RAIN(I)
      Z=0.2*S
      IF(R.LT.Z) GO TO 200
      Q=(R-0.2*S)**2/(R+0.8*S)
      Q=Q/10
      IF(IOPT.NE.3) GO TO 230
      IOP=IOPT
      IF(I.LT.IDB) IOP=1
      IF(I.GE.IDB .AND. I.LE.IDE) IOP=2
      IF(I.GT.IDE) IOP=1
      IF (IOP.EQ.2) Q=0
      GO TO 240
230   CONTINUE
      IF(IOPT.EQ.2) Q=0
240   SSW=SSW/10
      CONTINUE
      GO TO 250
200   Q=0
      SSW=SSW/10
250   RETURN
      END
```