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CROPWAT

A computer program for irrigation planning and management

FAO IRRIGATION AND DRAINAGE PAPER

46

Food and Agriculture Organization of the United Nations

CROPWAT

A computer program for irrigation planning and management

Developed by

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Water Resources, Development and Management Service
FAO Land and Water Development Division

FAO
IRRIGATION
AND DRAINAGE
PAPER

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Organisation
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FOREWORD

CROPWAT is a computer program for IBM-PCs or compatibles:

To calculate:	•	Reference evapotranspiration
	•	Crop water requirements
	•	Irrigation requirements
	•	Scheme water supply
To develop:	•	Irrigation schedules under various management conditions
To estimate:	•	Rainfed production and drought effects

To provide users with directions in the use of the CROPWAT program, a manual and guidelines have been prepared, contained in this publication.

PART 1 MANUAL OF CROPWAT

Provides directions on the various procedures of the computer program: how to install, to set up the program on a computer system, how to print and how to manage the various data files.

The procedures for the various program elements are explained, as well as the input of data, the concept of the calculations and the various printouts.

PART 2 GUIDELINES FOR CROPWAT

Provides a detailed example on the use of CROPWAT for the planning and management of irrigation projects.

Adequate attention is given to the collection and processing of data for input in CROPWAT.

Examples are given of the analysis of the printouts for planning, management and evaluation of irrigation systems.

Adequate attention is given to demonstration of the various applications of the Scheduling Program in:

- Indicative Irrigation Scheduling
- Evaluation of Irrigation Practices
- Rainfed Production and Supplementary Irrigation
- Deficit Irrigation

In the annexes the results of the various calculations are provided in a range of CROPWAT printouts.

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PART 1 MANUAL OF CROPWAT

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PART 1

MANUAL OF CROPWAT

1. INTRODUCTION

**************** WELCOME TO CROPWAT ******************

PROGRAM TO CALCULATE IRRIGATION REQUIREMENTS
AND
GENERATE IRRIGATION SCHEDULES

FOOD AND AGRICULTURE ORGANIZATION

LAND AND WATER DEVELOPMENT DIVISION

**************** VERSION 5.7 - OCTOBER 1991 ****************

CROPWAT is a computer program to calculate crop water requirements and irrigation requirements from climatic and crop data. Furthermore, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying cropping patterns. The program will run on any IBM-PC type of computer with a minimum of 360 Kb.

Procedures for calculation of the crop water requirements and irrigation requirements are mainly based on methodologies presented in FAO Irrigation and Drainage Papers No. 24 "Crop water requirements" and No. 33 "Yield response to water". Concepts and calculation procedures for the irrigation schedules will be presented in a FAO publication on irrigation scheduling, presently in preparation.

The program is meant as a practical tool to help both the Irrigation Engineer and Irrigation Agronomist to carry out standard calculations for design and management of irrigation schemes. It will further help in the development of recommendations for improved irrigation practices and the planning of irrigation schedules under varying water supply conditions.

CROPWAT version 5.6 is an update of earlier versions and includes a revised method for estimating reference crop evapotranspiration, adopting the approach of Penman-Monteith as recommended by the FAO Expert Consultation held in May 1990 in Rome. For further details, reference is made to the report of the concerned meeting.

CROPWAT version 5.7, based on the 5.6 version, facilitates the linkage to the CLIMWAT program, a climatic data base of 3261 stations of 144 countries worldwide in Asia, Africa, Near East, South Europe, Middle and South America.

The many positive comments and suggestions received on earlier versions have been an important encouragement to enhance the program further. Any further suggestions and comments are very much welcomed, to be directed to:

Water Resources, Development and Management Service/AGLW
FAO, Via delle Terme di Caracalla, 00100 Rome, Italy

2. SETTING UP CROPWAT

2.1 Conditions of Use and Distribution

****** FAO COPYRIGHT AND WARRANTY ******

All rights reserved. No part of the procedures or program may be reproduced, altered or transmitted in any form or by any means without the prior permission of the copyright holder, except in the cases of copies intended for security backups or for internal uses (i.e. not for distribution with or without a fee to third parties). Applications for such permission, explaining the purpose and extent, should be addressed to the Director, Publications Division, FAO, Via delle Terme di Caracalla, 00100 Rome, Italy.

However, data generated by the program may be used freely, provided that FAO can be cited as the source.

FAO declines all responsibility for any software errors or deficiencies, or for any damages arising from them, as well for program maintenance and upgrading, and documentation. However, users are encouraged to report any such errors or deficiencies of this product to FAO.

*************** CROPWAT / Version 5.7 ***************

Computer System: IBM-PC XT/AT or Compatibles

Developed by: Martin Smith
Land and Water Development Division

Literature: FAO Irrigation and Drainage Papers:
- CROPWAT Manual and Guidelines
- Crop Water Requirements
- Yield Response to Water

For Information: Land and Water Development Division, FAO, ROME

2.2 Installation

The CROPWAT 5.7 program comes on one disk (1.2 Mb, 5 1/4") which contains both program files and utilities and a range of data files. The program files included on the disk permit a direct start-up of CROPWAT when the computer is running under MSDOS (version 3.2). The program is called up by typing, after the system prompt, the name CROPWAT:

```
A:> cropwat
```

The program disk contains sufficient space to accommodate additional data files, and the program can run on a computer with only one drive. A two disk system is convenient to separate programs and data files, and will allow the effective storage of data on separate disks.

If the PC system is equipped with a hard disk, the CROPWAT program can be installed on the hard disk by copying the files from the floppy disk. This can be done by calling up the installation program (INSTALLH), which is included specifically for this purpose on the disk:

```
A:> installh
```

The installation program creates a subdirectory named CROPWAT to which the program and data files are copied in the respective directories. The installation program can also be used to copy CROPWAT conveniently to differently formatted diskettes, high density and 3½" diskettes.

2.3 File structure

The different program files are protected and cannot be addressed directly.

The CROPWAT data files are stored in different directories under different names. According to the type of data the files are distinguished by their extensions and arranged on three directories:

On the Climate Directory: A:\CLIMATE

- *.PEN climatic data file with monthly data on temperature, humidity, wind and sunshine as well as evapotranspiration calculated according to modified Penman

- *.CLI climatic data file with monthly data on reference evapotranspiration and rainfall together with calculated values of effective rainfall according to four possible methodologies

On the Crop Directory: A:\CROPS

- *.CRO crop data file containing data on length of growth stages, crop coefficients, rooting depth, depletion levels and yield response factors

On the Field Directory: A:\FIELDS

- *.SOL soil data file with data on available soil moisture

- *.FLD field data file containing date of planting and data on crop irrigation requirements.

The creation and modification of the different data files are done from within the CROPWAT program.

The deletion, copying or renaming of the data files, however, has to be carried out in the MS-DOS system environment, using the appropriate DOS commands, e.g.:

A:\CROPS> del c-cotton.cro	to delete the crop data file c-cotton.crop in the crop data directory
A:\CROP> copy cotton.cro b:\PROJECT	to copy the data of the crop file cotton.cro to the directory in drive b:\PROJECT
A:\CROP> ren cotton.cro c-cotton.cro	to rename the cotton.cro file in c.cotton.cro etc.

To allow a systematic storage and overview of the different data files, the files are alphabetically sorted each time the CROPWAT program is closed.

By typing in the respective data directories the command:

A:\CLIMATE> *dir *.CLI\w*

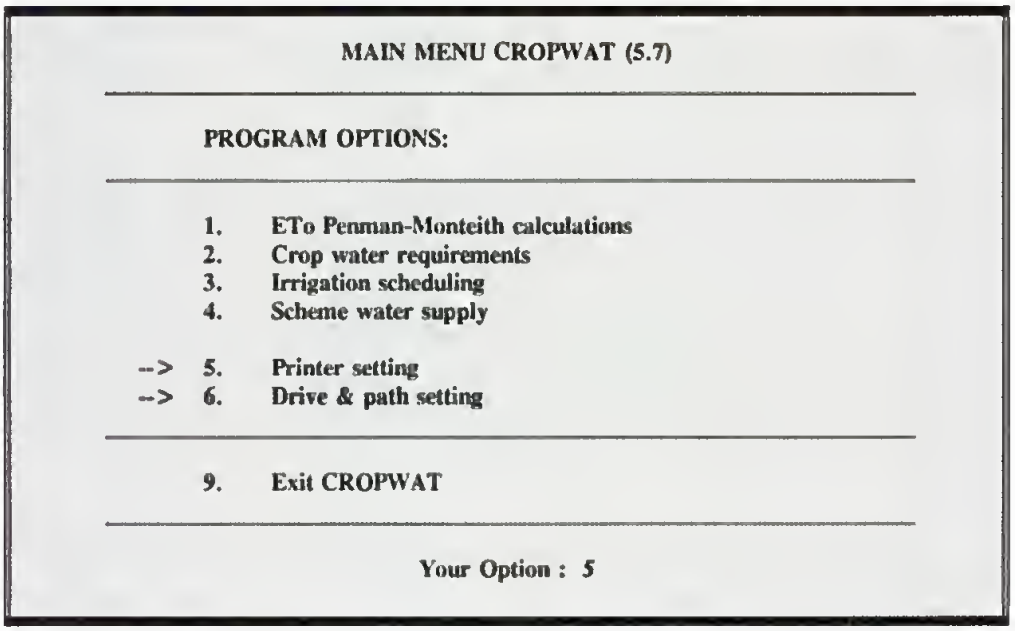
an outprint of all files will be presented arranged according the file extension and file names:

```
Climate files in Climate Directory A:\CLIMATE:
AL_JOUF  CLI        BERN-DRY CLI        BERN-NOR CLI        BERN-WET CLI        BERNARD  CLI
HAVA-834 CLI        HAVA-DRY CLI        HAVA-NOR CLI        HAVA-WET CLI        KURN-79  CLI
KURN-82  CLI        KURN-AV  CLI        KURN-DRY CLI        KURN-NOR CLI        KURN-WET CLI
MELAWER  CLI        MOSH-ACT CLI        MOSHI-AV CLI

Penman files in Climate Directory A:\CLIMATE:
BERNART  PEN        HAVANA   PEN        KURNOOL  PEN        LODWAR   PEN        MELKAWER PEN
MOSHI    PEN

Crop files in Crops Directory A:\CROPS:
ALFALFA  CRO        BANANA   CRO        BEANS    CRO        CITRUS   CRO        COTTON   CRO
DATES    CRO        GRAINS   CRO        GRONONUT CRO        MAIZE    CRO        MANGO    CRO
PADDY    CRO        PASTURE  CRO        PULSES   CRO        R-COTT   CRO        R-GRNONK CRO
R-GRNONR CRO        R-PADDY  CRO        R-SORGHU CRO        RICE     CRO        SORGHUM  CRO
SUGARBET CRO        SUGARCAN CRO        TOBACCO  CRO        TOMATOES CRO        VEGETABL CRO
W-WHEAT  CRO

Field files in Fields Directory A:\FIELDS:
RN-CT081 FLD        RN-GRD11 FLD        RN-GR012 FLD        RN-GR072 FLD        RN-GR081 FLD
RN-GR082 FLD        RN-GR122 FLD        RN-PD011 FLD        RN-PD072 FLD        RN-PD073 FLD
RN-PD081 FLD        RN-PD082 FLD        RN-PD122 FLD        RN-PD123 FLD        RN-SC011 FLD
RN-SO072 FLD        RN-SO081 FLD

Soil files in Fields Directory A:\FIELDS:
BLCKCLAY SOL        COARSTEX SOL        FINETEX  SOL        HEAVY    SOL        LIGHT    SOL
LOAM     SOL        MEDITEX  SOL        MEDIUM   SOL        REDCLAY  SOL        SANDLOAM SOL
```

3. GETTING STARTED ON CROPWAT

3.1 Main Menu

After loading the program, the title and information page appear successively on the screen. These are followed by the Main Menu, presenting the different program options of CROPWAT:



Selection of one of the options directs the program to one of the following procedures:

1. Calculation of Reference Evapotranspiration, ETo, according to the Penman-Monteith approach

2. Calculation of Crop Water Requirements, Effective Rain and Irrigation Requirements as well as the Rice Water Requirements calculation

3. Calculation of Irrigation Schedules

4. Calculation of Scheme Water Supply

5. Initialization of the printer for different print modes or writing of files to a special print file on disk

6. Setting of the default drive and directory for the different data files

The options 1 to 4 are discussed in the next chapters. The printer and drive initialization are to be executed at the beginning of the program and are discussed in this chapter.

3.2 Printer Setting

During program execution the results of the various calculations can be printed on a connected printer or can be written to a separate diskfile, by responding with Y(es) to the following question:

```
Do you want to PRINT (Y/N) : Y
```

1. Printer Initialization

Program option 5 'Printer setting' of the Main Menu allows to set and test the printing mode of the lineprinter, which should be set in the IBM printing mode for drawing of boxes. Unfortunately some printers have deviating codes for the different printing modes and some settings may not work properly with your printer.

```
                    PRINTER SETTING
                    ---------------

To modify the print setting choose one of these options:

    1.   Standard PICA print     (10 characters/inch)
    2.   ELITE print             (12 characters/inch)
    3.   CONDENSED print         (17 characters/inch)

    4.   Print to DISK FILE

    5.   Return to Main Menu

              Give your choice  (1-5) : 1
```

In addition the letter quality can be set:

```
          Choose for print setting one of these options

              1. Draft print
              2. Letter quality

              Give your choice (1-2) : 1
```

A test print allows the evaluation of the different print options before a final choice is made.

2. Printer file

Instead of writing the results directly to the printer the output tables can be more conveniently written to a separate diskfile on a selected directory and drive. This would allow later editing of the tables and inclusion in reports.

The path and a convenient file name needs to be given.

PRINTER SETTING

To modify the print setting choose one of these options

Print to DISKFILE selected

Give the PATH : *C:\WP51\DOC*
(return for default path A:\)

Give the FILE-NAME : *Project.OUT*
(max 8 characters; without extension !!)

All print files are given the standard extension ***.OUT** and are written in ASCII format and can be retrieved in the DOS environment by any editor or word processor.

3.3 Default drive and path for data input and retrieval

To facilitate data saving and retrieval, the various data files can be stored on default drives and directories, allowing access to extensive data bases. This is of importance in particular for the linkage to the CLIMWAT data base where data are stored in 144 country-based directories on a series of disks.

The default directory can be easily modified within the program and a review of file listings provides an extra check on the availability of the correct data files.

The directories are grouped according to the type of files in climatic data files (*.PEN and *.CLI), crop data files (*.CRO) and field data files (*/SOL and */FLD).

Default DRIVE and PATH setting

Default Drive and Path for data input and retrieval

Climatic Data Files	:	A:\CLIMATE\
Crop Data Files	:	A:\CROPS\
Soil & Field Data Files	:	A:\FIELD\

(Press Return for NO change to default setting ..)

Change any of the Directories (Y/N) : *N*

When modifying drive and directory, the program will check the existence and readiness of drive and directory, and provides an option to view the file listing.

Once set, each saving and retrieval operation will automatically access the default drive and path.

Saving

After each input of a new set of data (climate, crop, soil) or when modifications are made to existing data files, the user is asked if the data need to be saved on the disk:

Do you want to SAVE data on DISK (Y/N) : *Y*

Care should be taken in naming the data file to be saved. A file name can have a maximum of eight characters. Points, commas and blanks are not accepted. No check is made on existing file names and a new filename may overwrite an existing file if an identical name is given. Try to find a logical, recognizable file name, for instance HAVA-AVE may denote climatic data of Havana, Cuba, for an average year, while HAVA-84 contains the climatic data of 1984.

Retrieving

Retrieval of previously-saved data is carried out from the default directory. A listing of all corresponding files on the screen allows selection and the correct orthographic input.

RETRIEVE CROP DATA

The following .CRO files are on C:\CROPWAT\CROPS\ :

ALFALFA	CRO	BANANA	CRO	BEANS	CRO	CABBAGE	CRO	CITRUS	CRO
COTTON	CRO	DATAPALM	CRO	GRAINS	CRO	GRAPE	CRO	GRASS	CRO
GROUNDNUT	CRO	MAIZE	CRO	MANGO	CRO	ONION	CRO	PADDY	CRO
PASTURE	CRO	PEPPERS	CRO	POTATO	CRO	PULSES	CRO	RICE	CRO
SILOMAIS	CRO	SORGHUM	CRO	SOYBEAN	CRO	SUGARBET	CRO	SUGARCAN	CRO
SUNFLOWR	CRO	SW-MELON	CRO	TOBACCO	CRO	TOMATO	CRO	VEGETABL	CRO
W-WHEAT	CRO	WHEAT	CRO						

Please enter file name (without .CRO) : *groundnut*

4. ETo CALCULATIONS

The calculation of reference evapotranspiration from monthly climatic data, according to the FAO adapted Penman-Monteith approach, can be made by choosing option 1 in the Main Menu:

```
                    MAIN MENU CROPWAT (5.7)

        PROGRAM OPTIONS:

  -->   1.   ETo Penman-Monteith calculations
        2.   Crop water requirements
        3.   Irrigation scheduling
        4.   Scheme water supply

        5.   Printer setting
        6.   Drive & path setting

        9.   Exit CROPWAT

                    Your option : 1
```

The program allows both the input of new climatic data for the Penman-Monteith calculations as well as the retrieval of an existing data set:

```
                    DATA INPUT ETo

        Input Climate Data for ETo calc.    1
        Retrieval of ETo data from disk     2

        Return to Main Menu                 3

                    Your Choice (1-3) : 1
```

4.1 Input climatic data

If Penman-Monteith calculations are to be carried out, data are requested on the following:

1. Basic information on the climatic station: country name, station name, altitude, latitude and longitude.

2. Monthly climatic data on temperature, relative humidity, daily sunshine and windspeed.

4.1.1 Identification of climatic station

Information is required on the latitude and altitude of the climatological station from which the climatic data are collected. Data on country, climatic station and longitude is optional, as they do not affect calculations. The input of the information is presented as in the following example.

```
                    Input Climate Station
-------------------------------------------------------

Name Country                :   KENYA
Climatological station      :   LODWAR
Altitude (metres)           :   506 metres
Latitude (0 - 80 °L)        :   3.08 N.L.
Longitude (0 - 180 °L)      :   35.37 E.L.
```

NOTE: If in the southern hemisphere, the latitude should be given as a negative value, likewise the longitude is noted negative for the western hemisphere.

Although by default the calculations will be carried out over all 12 months of the year, the data input may be restricted to a limited number of months, in response to the following questions:

```
How many months to calculate          (1-12) :  12
Give first month for data input  (1-12) :  1
                                                (January - Dec)
```

Mean monthly temperatures can be given as average daily temperature or as separate maximum and minimum temperatures. For one data set, this option should be set in advance:

```
        Mean monthly temperatures can be given as:

            1.   Average daily temperature
            2.   Max. and min daily temperature
```

If mistakes have been made or to modify any information given on the climatic station, respond 'Y'(es) to the next question:

```
        Any correction on Climatic Station (Y/N) : Y
```

4.1.2 Climate data input

After the information on the meteorological station has been provided, the input of climatic data on temperature, humidity, sunshine and windspeed is requested for each month.

Temperature: Temperature data are provided in degrees Celsius either as average temperature or as maximum and minimum temperature data from which the average is calculated.

Air humidity: Air humidity can he given as:

- Relative humidity expressed in percent (10-100); or as
- Vapour pressure in kPa (1-9);

The program automatically distinguishes between vapour pressure values (< 10 kPa) and relative humidity (10-100%)[1].

Daily sunshine: The daily sunshine can he given as:

- percentage (20-100) of the ratio sunshine/daylength;
- fraction (0-1) sunshine/day length; or as
- hours sunshine (1-20).

Values > 20 are interpreted as daily sunshine in %.
Values < 1 as daily sunshine as fraction.
Values > 1 and < 20 as sunshine in hours.

Windspeed: Windspeed can he given in km/day (10-500) or in m/s (0 -10).

Values > 10 are interpreted as windspeed in km/day.
Values < 10 are interpreted as windspeed in m/sec.

All values concern averages of daily windrun measured over 24 hours.

Climatic Data Input

Data for April

Mean maximum temperature (°C)	:	*32.6*	°C
Mean minimum temperature (°C)	:	*23.2*	°C
Air humidity (% or kPa)	:	*50*	%
Windspeed (km/day or m/s)	:	*129*	*km/day*
Daily sunshine (hours or %)	:	*8.4*	*hours*

1 If vapour pressure (e_d) is given, RH_{mean} is calculated according to $RH_{mean} = 50\ e_d\ (1/e_{a(Tmin)} + 1/e_{a(Tmax)})$.

After completion of the data input, possible corrections can be made, followed by a display of the input data and calculated reference evapotranspiration.

Month	MaxTemp °C	MinTemp °C	Humid %	Wind km/day	Sunshine hours	Radiation MJ/m²/day	ETo-PenMon mm/day
January	32.6	23.2	50	129	8.4	22.3	5.49

Any corrections ... ? (Y/N) : *N*

Calculation of reference evapotranspiration is carried out according to the PenMon method as recommended by the FAO Expert Consultation held in Rome in May 1990. For details on the calculation procedures, reference is made to the concerned report of the meeting.

4.2 Retrieval of ETo data from disk

Option 2 in the ETo data input of the Penman subprogram allows the retrieval of previously-saved data (files with extension PEN). A display of all concerned data files is shown from which the desired data file can be selected:

Retrieve ETo & Climate Data

The following .PEN files are on C:\CROPWAT\CLIMATE\ :

BERNART PEN HAVANA PEN KURNOOL PEN LODWAR PEN MELKA-WE PEN

Please enter file name (without .PEN) : *lodwar*

4.3 Output

The results of ETo calculations are presented together with the climatic data[1] in a table, as shown. The table can be printed on the line printer (make sure the printer is properly connected !!) written to the printfile on a selected directory by answering Y(es) to following question:

Do you want to PRINT the climatic data (Y/N) : *N*

[1] Data from the CLIMWAT data base are given a reference to the source of climatic data as well as information on the length of the climatic data records.

Reference Evapotranspiration ETo according Penman-Monteith

Country : Ethiopia Meteo Station : Melka Werer (13 yr)
Altitude : 737 metres Coordinates : 9.28 N.L. 40.23 E.L.

Month	MaxTemp °C	MinTemp °C	Ilumid. %	Wind km/day	Sunshine hours	Radiation MJ/m²/day	ETo-PenMon mm/day
January	31.6	15.7	55	147	8.4	19.7	4.8
February	32.8	16.5	55	121	8.5	21.2	4.9
March	34.3	18.7	52	112	8.5	22.4	5.3
April	36.0	19.7	53	104	8.4	22.5	5.4
May	36.4	20.5	47	112	8.3	21.8	5.5
June	37.4	22.7	42	181	8.5	21.6	6.6
July	35.0	21.3	56	181	7.2	19.9	5.8
August	33.3	20.0	62	147	7.0	20.0	5.2
September	35.1	20.2	54	130	7.8	21.3	5.4
October	34.6	16.9	47	112	9.1	22.4	5.3
November	32.5	14.4	49	121	9.5	21.6	5.0
December	31.5	13.3	40	104	9.3	20.5	4.4
YEAR	34.2	18.3	51	131	8.4	21.4	1933

Climatic data compiled by FAO Agro-meteorological unit

Possible modifications can be made:

Any modification (Y/N) : *N*

which allow any individual month to be recalculated. Incorrect data for April for instance, can be modified by responding:

How many months to recalculate (1-12) : *1*
Give first month for data input (1-12) : *4 (April)*

A new set of climatic data and ETo values or a possible modification of the climatic data can be saved on disk for future reference:

Do you want to SAVE the ETo data (Y/N) : *Y*

The user will be asked to provide an appropriate name for the data file.

The program will proceed to the Main Menu of CROPWAT:

Return to Main Menu (Y/N) : *Y*

or will be directed again to the ETo input menu when responding N(o).

5. CROP WATER REQUIREMENTS

Option 2 from the Main Menu should be selected to proceed to the calculation of crop water requirements:

```
                    MAIN MENU CROPWAT (5.7)

                    PROGRAM OPTIONS:

                    1. ETo Penman-Monteith calculations
                -->  2. Crop water requirements
                    3. Irrigation scheduling
                    4. Scheme water supply

                    5. Printer setting
                    6. Drive & path setting

                    9. Exit CROPWAT

                    Your Option : 2
```

This program element forms the central part of the CROPWAT program and is subdivided into three distinct parts:

5.1 the input and processing of monthly evaporation and rainfall data
5.2 the input of crop data and planting date
5.3 the calculation and output of crop water requirements.

The different program steps will be discussed in the following chapters.

5.1 Input Climate data

For the calculation of crop water requirements monthly data on reference evapotranspiration (ETo) and rainfall are required. For the input, the following options are given:

```
                    INPUT ETo and RAIN DATA

                    ETo and rainfall for CWR calculation

                    1.  Input of ETo and rainfall data
                    2.  Retrieve ETo and rain data from disk
                    3.  Retrieve ETo data from disk, rain new input
                    4.  Calculate ETo - PenMon from climatic data

                    5.  Return to Main Menu

                    Your Choice (1-4) : 1
```

The input of data on reference evapotranspiration (ETo) and rainfall (P_{tot}), can be carried out either as:

1. Input of both ETo and rain monthly values from keyboard;

2. Retrieval from disk of both ETo and Rain values from previously saved climate file (*.CLI). A listing of available climate files on disk will be displayed.

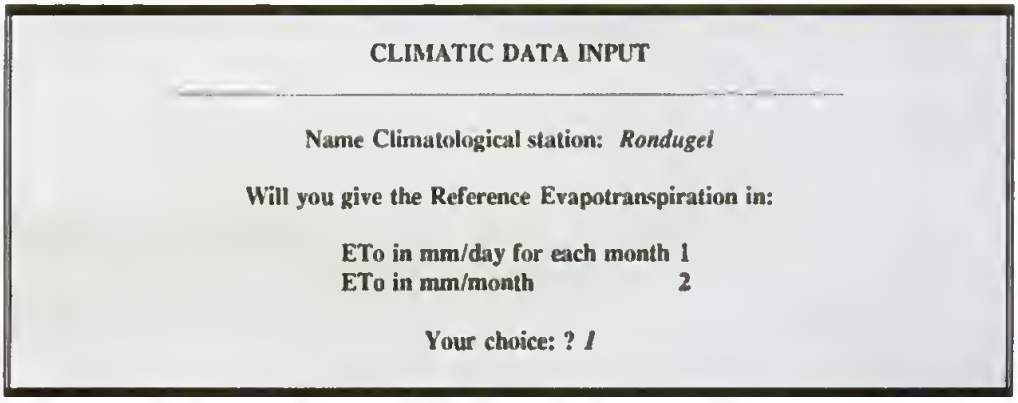
3. Retrieval of ETo values from disk on Penman files (*.PEN) and input of monthly rain values from the keyboard. A listing of available ETo files will be displayed.

4. Return to PENMAN program to calculate ETo from climate data, for which data on temperature, humidity, sunshine and wind are required.

In the selection of the monthly climatic data, special consideration should be given to the type of rainfall data. For planning purposes, average monthly values are normally taken, while for design purposes more extreme values corresponding with a certain probability of exceedance (70 - 80 %) are used. Analyses of long term data sets are required for this. For further details reference is made to the concerned literature and the examples given in the CROPWAT guidelines.

5.1.1 Input of ETo and rainfall from keyboard

The monthly ETo values identified by the name of the climatological station can be given in mm/day or in mm/month. The ETo data can be calculated according to Penman-Monteith using the PENMAN program section of CROPWAT, but can be obtained also through separate calculations using one of the correlation formulas such as Penman, Radiation, Blaney-Criddle from Evaporation Pan data or any other ETo method.



For the calculation of irrigation requirements an input of monthly rainfall data is required. The rainfall data used can be :

- average data
- actual or historical data;
- dependable rainfall;

For the latter type a statistical analysis has been carried out from a long term series of historical data. Rainfall data related to a certain probability of exceedance are thus defined and used in the calculations.

REFERENCE EVAPOTRANSPIRATION (ETo) INPUT

Reference Evapotranspiration in mm/day

ETo January	? *6.1*
ETo February	? *6.3*
ETo March	? *6.1*
ETo April	? *5.4*
ETo May	? *4.4*
ETo June	? *4.0*
ETo July	? *4.0*
ETo August	? *4.6*
ETo September	? *5.5*
ETo October	? *6.0*
ETo November	? *6.2*
ETo December	? *6.4*

Any changes in ETo input (Y/N): *N*

RAINFALL DATA INPUT

Give Monthly Rainfall in mm/month

Rainfall in January	? *31*
Rainfall in February	? *38*
Rainfall in March	? *75*
Rainfall in April	? *204*
Rainfall in May	? *115*
Rainfall in June	? *15*
Rainfall in July	? *6*
Rainfall in August	? *10*
Rainfall in September	? *12*
Rainfall in October	? *23*
Rainfall in November	? *30*
Rainfall in December	? *41*

Any changes in Rain input (Y/N): *N*

If only crop water requirements are required, the input of rainfall data can be set to ZERO, which effectively makes crop water requirements equal to irrigation requirements.

After input of data from the keyboard, the program will continue with the calculation of the effective rainfall as explained in section 5.1.3. A set of climatic data can be saved on disk and retrieved at a later program session:

Do you want to SAVE data on DISK ? (Y/N): *Y*

The file name may include a reference to both the climatic station and to the type of data as shown in disk file table below. Notations like -NOR, -AVG, -DRY, -WET or -87 refer to statistically processed rainfall data with normal, average, 80%, 20% probability of exceedance or to historical data sets (for instance 1987).

5.1.2 Retrieval ETo and rain data from disk

The different climatic data files on disk, saved after earlier sessions or from the CLIMWAT data base, will be shown on screen from which a choice can be made:

RETRIEVE CLIMATIC DATA

The following files are on the data-disk:

AL-JOUF CLI	BERN-DRY CLI	BERN-NOR CLI	BERN-WET CLI
BERNARD CLI	AVA-834 CLI	HAVA-DRY CLI	HAVA-NOR CLI
HAVA-WET CLI	KURN-79 CLI	KURN-82 CLI	KURN-AV CLI
KURN-NOR CLI	KURN-WET CLI	MELAWER CLI	MOSH-ACT CLI
MOSHI-AV CLI			

Please enter your file name (without ext. !): *kurn-av*

5.1.3 Effective rainfall options

As input of monthly rainfall, the average, dependable or actual rainfall data can be given. Care should be taken in selecting appropriate values for the dependable rainfall, based on separately carried out statistical analyses of long-term rainfall records.

EFFECTIVE RAINFALL

Effective rainfall calculated according to:

Fixed percentage of rainfall	1
Dependable Rain (empirical form)	2
Empirical formula (locally dev)	3
USDA Soil Conservation Service	4
Rainfall not considered	5
Return to climate data screen	6
INFORMATION on effective rain	0

Your option (0-6): *1*

Give percentage of effective rainfall: ? *80*

Dependable rainfall is defined as rainfall with a probability of exceedance of respectively :

- **80 % probability of exceedance,** characterizing a "dry" year with rainfall in 4 out of 5 years exceeding, used as criteria for dimensioning of the irrigation system as well as for irrigation management to simulate a dry year supply schedule,

- **50 % probability,** representing a "normal" year, approaching the average value,

- **20 % probability** representing a "wet" year, used in irrigation management to simulate a wet year supply schedule.

To account for losses due to surface runoff and deep percolation the effective rainfall is used.

Four different methodologies are given to determine the effective rainfall. The different options are:

1. **Fixed percentage of rainfall:** effective rainfall is calculated according to:

$$P_{eff} = a.P_{tot}$$

where a is a fixed percentage to be given by the user to account for losses from runoff and deep percolation. Normally losses are around 10 to 30%, thus a = 0.7 - 0.9.

2. **Dependable Rain:** based on an analysis carried out for different arid and sub-humid climates an empirical formula was developed in FAO/AGLW to estimate dependable rainfall, the combined effect of dependable rainfall (80% prob.exc.) and estimated losses due to runoff and percolation. This formula may be used for design purposes where 80% probability of exceedance is required.

Calculation according to:

$$P_{eff} = 0.6\ P_{tot} - 10 \text{ for } P_{tot} < 70 \text{ mm}$$
$$P_{eff} = 0.8\ P_{tot} - 24 \text{ for } P_{tot} > 70 \text{ mm}$$

3. **Empirical formula:** The parameters may be determined from an analysis of local climatic records. An analysis of local climatic records may allow an estimation of effective rainfall. The relationship can, in most cases, be simplified by the following equations:

$$P_{eff} = a\ P_{tot} + b \text{ for } P_{tot} < z \text{ mm}$$
$$P_{eff} = c\ P_{tot} + d \text{ for } P_{tot} > z \text{ mm}$$

values for a, b, c and z are correlation coefficients.

4. **USDA Soil Conservation Service Method:** where effective rainfall can be calculated according to:

$$P_{eff} = P_{tot}\ (125 - 0.2\ P_{tot})/125 \quad \text{for } P_{tot} < 250 \text{ mm} \quad \text{and}$$
$$P_{eff} = 125 + 0.1\ P_{tot} \quad \text{for } P_{tot} > 250 \text{ mm}$$

Note: In the water balance calculations, carried out for the irrigation scheduling (Chapter 7), the intake of rain into the soil is determined on a daily basis and rainfall losses due to deep percolation and surface runoff are estimated according to actual soil moisture content in the root zone. Total rainfall and not effective rainfall is therefore used for the water balance calculations; effective rainfall is calculated over the total growing season.

5.1.4 Processing of climatic data

Calculation of effective rainfall is carried out according to any of the four indicated methodologies. For the crop water requirement calculations, 10-day values of ETo and Peff are used. To convert monthly data to 10-day values, a linear interpolation is carried out.

Values for first and third decades are found by interpolation with the preceding and successive month respectively. To compensate for deviations in the maximum and minimum months, a reiteration is carried out to fulfil the condition that the 3 decade values average the given monthly average. The reiteration will take some seconds and the following message appears briefly on the screen:

> Calculating decades .... Wait

5.1.5 Output

The climatic input data are presented in a table of monthly values of ETo, P_{tot} and P_{eff} with information on the climatic station and the effective rainfall method used.

Country : Burundi Climate Station: Rondugei

	ETo (mm/day)	Rainfall (mm/month)	Eff. Rain (mm/month)
January	6.1	31.0	24.8
February	6.3	38.0	30.4
March	6.1	75.0	60.0
April	5.4	204.0	163.2
May	4.4	115.0	92.0
June	4.0	15.0	12.0
July	4.0	6.0	4.8
August	4.6	10.0	8.0
September	5.5	12.0	9.6
October	6.0	23.0	18.4
November	6.2	30.0	24.0
December	6.4	41.0	32.8
YEAR Total	1975.0	600.0	480.0 mm

Effective Rainfall: 80%

The results can be at this stage printed to printer or printfile and saved if they concern a new data input or a modified data file.

Revise Data input or Eff. Rainfall method (Y/N) : *N*

Revise Effective Rainfall method (Y/N) : *N*

Do you want a PRINTOUT of climatic data (Y/N) : *N*

Do you want to SAVE the climatic data input (Y/N) : *N*

In a separate menu the climatic data are saved under an appropriate name to be given by the user.

SAVE CLIMATIC DATA

Climate File: kurn-nor Climate Station: KURNOOL

Give the FILE-NAME : *kurn-nor*
(max 8 characters; without extension !!)

Also modifications of the effective rainfall method or of another climate file can be done which will bring the user back to the concerned program sections.

5.2 Input of crop data

The input of crop data may concern either the input of new data (option 1) or the retrieval of data saved earlier (option 2).

CROP DATA INPUT

Crop data from keyboard	1
Retrieve crop data from disk	2
Return to main menu	3

Your choice ? *N*

The program disk contains data files for a range of over 30 crops with general data based on global values (see FAO Irrigation and Drainage Paper No 24 'Crop water requirements' and No 33 'Yield response to water'). The crop data should be adjusted to local available data obtained through surveys or from recommendations of agricultural research stations.

5.2.1 Input of crop data from keyboard

The input of crop data required for crop water requirement calculations is carried out with the help of an input table as shown below. Either an empty table is given (option 1) or an existing crop data table is modified and separately saved.

Note: For the input of rice data a different procedure is followed, described in chapter 6:

CROP DATA INPUT

Crop : GROUNDNUT — Crop file : grondnut

Growth stage		Initial	Devel	Mid	Late	Total
Crop stage	[days]	20	40	45	30	130
Crop coefficient	[coeff.]	0.40	->	1.10	0.70	
Rooting depth	[metre]	0.30	->	0.80	0.80	
Depletion level	[fract.]	0.45	->	0.45	0.50	
Yield response f.	[coeff.]	0.40	0.60	1.00	0.80	0.80

1. **Lengths of the individual growing stages**: Initial phase (A), development stage (B), mid-season (C) and late season (D). The length of the total growing season is calculated and can be used to check the input. The length of the growing stages will depend mainly on variety and growth conditions, in particular temperature. Values need therefore to be checked and adjusted for each location and growing season.

2. **Crop factors** (Kc) for initial stage, mid-season stage and at harvest are to be given. Kc values for development stage are interpolated. Indicative values for lengths of growing stages and Kc values can be found in Annex 1. A range of crop files are included with CROPWAT which can be used as reference values.

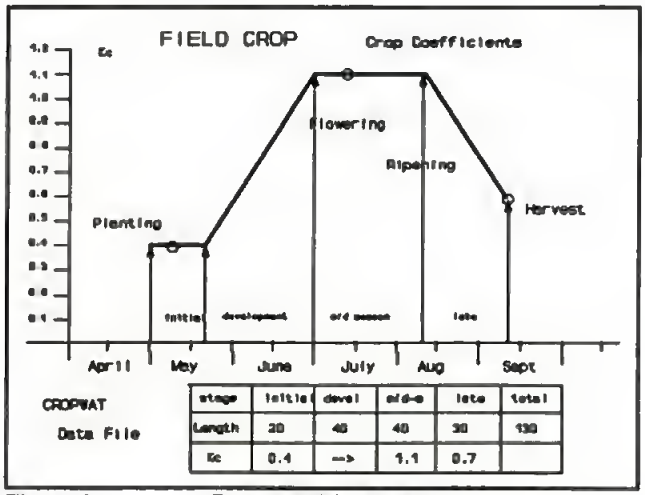


Figure 1 **Crop coefficient curve**

For calculation of irrigation schedules, additional inputs are required on rooting depth, depletion levels and yield response factors.

3. **Rooting depth (D)**: The depth of soil water which can be used effectively by the crop, defined as the Readily Available Soil Moisture (RAM), depends directly on the rooting depth of the crop. Two values are required:

   - rooting depth of initial stage, normally taken as 0.25 - 0.30 m, representing the effective soil depth from which the small seedling abstracts its water;
   - rooting depth at full development at start of mid-season. For most irrigated field crops values vary between 1 and 1.40, vegetable crops 0.50 - 1.00.

   Rooting depth at development and late season are interpolated values and no input is required.

4. **Allowable depletion (p)** represents the critical soil moisture level where first drought stress occurs affecting evapotranspiration and crop production. Values are expressed as a fraction of total available soil moisture and normally vary between 0.4 and 0.6, with lower values taken for sensitive crops with limited root systems under high evaporative conditions, and higher values for deep and densely rooting crops and low evaporation rates.

5. **Yield response factor (Ky)** to estimate yield reductions due to drought stress; yield response factors have to be given for each growth stages.

Values for the different crop characteristics can be found in Annex 1. For further details, reference is made to Irrigation and Drainage Papers 24 and 33.

For **perennial** crops a somewhat different procedure needs to be followed as the four growth stages as distinguished for seasonal crops do not normally coincide with those of the perennial crops. For CROPWAT calculations, Kc can be taken constant over the year (four stages of 90 days) with planting date 1 January or four stages can be distinguished in the growing season and a convenient planting date selected. To illustrate the procedures, reference is made to the examples given in Annex 4.

5.2.2 Retrieval of crop data from disk

Input of crop data can be made from files previously saved on disk. A list of the available crop files is presented from which a choice can be made:

RETRIEVE CROP DATA

The following .CRO files are on C:\CROPWAT\CROPS\ :

ALFALFA	CRO	BANANA	CRO	BEANS	CRO	CABBAGE	CRO	CITRUS	CRO
COTTON	CRO	DATEPALM	CRO	GRAINS	CRO	GRAPE	CRO	GRASS	CRO
GROUNDNUT	CRO	MAIZE	CRO	MANGO	CRO	ONION	CRO	PADDY	CRO
PASTURE	CRO	PEPPERS	CRO	POTATO	CRO	PULSES	CRO	RICE	CRO
SILOMAIS	CRO	SORGHUM	CRO	SOYBEAN	CRO	SUGARBET	CRO	SUGARCAN	CRO
SUNFLOWR	CRO	SW-MELON	CRO	TOBACCO	CRO	TOMATO	CRO	VEGETABL	CRO
W-WHEAT	CRO	WHEAT	CRO						

Please enter file name (without .CRO): *grondnut*

5.2.3 Printing and saving of crop data

To allow a quick overview of the crop data, data are displayed. Possible modifications of any crop data can be conveniently carried out at any stage of data input. For any modification in crop data the user is prompted for a saving under a separate file name:

Any modifications on crop data	(Y/N) *Y*
- Revise length growth stages	(Y/N) *Y*
- Revise Crop Coefficient	(Y/N) *N*
- Revise Rooting Depth	(Y/N) *N*
- Revise Allowable Depletion	(Y/N) *N*
- Revise Yield Response Factor	(Y/N) *N*
Other Crop Input	(Y/N) *N*

Also a printout of the crop data table is possible:

Do you want to PRINT the crop data (Y/N) *Y*

If a new set of data has been given, or if crop data have been modified, the user is prompted for saving under a separate file name:

Do you want to SAVE the crop data (Y/N) *Y*

Care should be taken in naming the crop file. The program disk contains a series of standard crop files which may be used as a reference. To distinguish the standard files from future crop files, a clear notification should be used. It is recommended to use a one or two letter prefix code (C-COTTON) to distinguish typical project crop files which, through the automatic sorting routine, can be easily identified.

SAVE CROP DATA

Crop File : r-grondn Crop: GROUNDNUT

Give the FILE NAME : *r-grondn*
(max 8 characters; without extension !!)

5.2.4 Planting date

The date of planting is a separate crop data input, normally to be determined from climatic conditions (for instance rainy season) and local agricultural practices. The user can, for the same crop and the same climatological station, choose different planting dates. This is useful for the study of different cropping patterns and the calculation of scheme water supply schedules.

PLANTING DATE

Climate File : kurn-nor Cl. Station : KURNOOL
Crop File : r-grondn Crop Name : GROUNDNUT

For ETcrop calculations give PLANTING DATE :

Planting month (1-12) : *11 (November)*
Planting day (1-30) : *20*
Harvest on : 10 March

Any changes in the planting date (Y/N) : *N*

5.3 Crop water requirements results

5.3.1 CWR calculations

The calculation of crop water requirements is carried out per decade. For reasons of simplicity all months are taken to have 30 days, subdivided into 3 decades of 10 days. ETo and Peff values are determined as indicated in section 4.1.

The crop factor, Kc, is determined for each decade following the procedure as shown in Figure 1 and Annex 1. Values in the initial and midseason stages are constant as given in crop data input. Values in the development stage and late season stage are calculated by linear interpolation. The average daily crop evapotranspiration (ETcrop) is determined according to:

$$ETcrop = Kc \cdot ETo$$

Crop evapotranspiration per decade is calculated by multiplication of the number of effective crop days. This will normally be 10, except in the first and last decade when planting date and harvest date do not necessarily coincide with the beginning or end of the decade.

Irrigation requirements (In) are determined by:

$$IRReq = ETcrop - Peff$$

calculated similarly to ETcrop, as average per day and decade as well as for the total season.

5.3.2 Output and print of CWR

The results of the calculations are presented in table form on screen.

Crop Evapotranspiration and Irrigation Requirements

Climate File : kurn-nor Climate Station : KURNOOL
Crop : GROUNDNUT Planting Date : 20 November

Month	Dec	Stage	Coeff Ke	ETerop mm/day	ETerop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	tRReq. mm/dec
Nov	3	init	0.40	1.42	14.2	3.6	1.06	10.6
Dec	1	init	0.40	1.38	t3.8	2.t	t.t7	tt.7
Dec	2	deve	0.50	1.68	t6.8	0.5	1.63	16.3
Dec	3	deve	0.70	2.46	24.6	0.4	2.42	24.2
Jan	1	deve	0.90	3.30	33.0	0.2	3.28	32.8
Jan	2	mid	1.00	3.82	38.2	0.0	3.82	38.2
Jan	3	mid	t.00	4.t6	4t.6	0.4	4.t3	4t.3
Feb	1	mid	1.00	4.5t	45.1	0.7	4.44	44.4
Feb	2	mi/lt	0.97	4.70	47.0	1.1	4.60	46.0
Feb	3	late	0.88	4.56	45.6	0.9	4.48	44.8
Mar	t	late	0.76	4.20	42.0	0.7	4.t3	4t.3
TOTAL					362.0	t0.5		351.5

The output of Crop Water Requirement can be sent to printer or printfile:

Do you want a PRINTOUT of the data output (Y/N) : *Y*

5.3.3 Saving of CWR

The saving of the crop water requirements is needed when scheme water supply calculations (option 4 Main Menu CROPWAT, see chapter 8) or irrigation scheduling (option 3 Main Menu CROPWAT) are to be carried out. The results of the CWR calculations can therefore be saved on a so-called field file (*.FLD).

Save Irrigation Requirement data as FIELD-File on disk for FUTURE calculations on SCHEME WATER REQUIREMENTS : *Y*

Any name can be given to the field file, but as crop water requirements are specific to the planting data, the crop type and the climate, the name of the field file should preferably provide an adequate reference to crop, climate and planting date in order to allow easy identification. The following 8-digit codification of the field files is therefore proposed:

1. **Scheme code**: 2 characters or digits e.g. scheme name RAJOLIBANDA: code RA or R-

2. **A climatic data code** can be given if calculations are to be carried out for different types of climatic data, e.g. for average, wet or dry years a one-letter code can be used while for historical data of a certain year a two digit code can be used, such as:

SAVE ETCrop & IRR.REQ

Climate file	: KURN-AV	Climatic station	: KURNOOL
Crop file	: GRONDNUT	Plant date	: 1 November

To save the calculated crop water requirement data for the given planting date, give an identifiable file name. Notations such as RA-GN112 may be used for GROUNDNUTS planted 2nd decade of NOVEMBER (11) using Average climatic data of the Rajolibanda project.

Give the FILE-NAME : ? *RA-GN112*
(max 8 characters; without extension !!)

average data:	A	wet year:	W
dry year:	D	actual data 1986:	86 or 6

3. **Crop code**: 2 characters or digits

Alfalfa:	AL	Banana:	BA	Cabbage:	CA
Citrus:	CI	Cotton:	CT	Grape:	GP
Groundnut:	GN	Maize:	MZ	Melon:	ML
Olive:	OL	Onion:	ON	Pea:	PE
Pepper:	PP	Pineapple:	PA	Potato:	PO
Rice:	RC	Sunflower:	SF	Sorghum:	SO
Soybean:	SY	Sugarbeet:	SB	Sugarcane:	SC
Sunflower:	SU	Tobacco:	TB	Tomato:	TM
Watermelon:	WM	Wheat:	WH		

4. **Planting date**: 3 digits e.g. Month: Jan - Dec: 01 - 12 Decade: 1 - 3

Examples of field files for a certain cropping pattern may be as follows:

Project:	Rajolibanda		
Climatic Data:	Normal Data		
Cropping Pattern:	Crop	Pl. Date	Field-File
	Rice	1 July	RN-RC071
	Rice	10 July	RN-RC072
	Rice	20 July	RN-RC073
	Cotton	15 June	RN-CT062
	Sorghum	15 June	RN-SO062
	Groundnut	1 November	RN-GN111
	Groundnut	1 December	RN-GN121
	Maize	10 November	RN-MZ112

The automatic sorting will conveniently group identical files together.

5.4 Program continuation

Several options exist at this stage to continue the program:

1. Proceed with the calculated irrigation requirement of the concerned crop to the irrigation scheduling program.

2. Calculate crop water requirements for the same crop and climatic data set but for another planting date.

3. Calculate crop water requirements for the same climatic data set but for another crop and another planting date.

4. Take another climatic data set and restart crop water requirement calculations for a new crop and new planting date.

5. Return to main menu.

```
                    CONTINUE CALCULATIONS

-------------------------------------------------------------

Climate File    : kurn-nor  Cl. Station  : KURNOOL
Crop file       : r-grondn  Plant date   : 20 November

-------------------------------------------------------------

        To continue the program you have the following Options:

        1. Proceed to irr. scheduling of GROUNDNUT
        2. Revise PLANTING date of GROUNDNUT
        3. Take another CROP
        4. Take NEW set of CLIMATIC data

        5. Return to MAIN MENU

                    Give your option (1 - 5) : 3
```

Reference is made to the concerned chapters for continuation of the program.

6. RICE WATER REQUIREMENTS

The calculation of the irrigation requirements of wetland rice is different from other field crops. Extra irrigation water is required not only to cover evaporation losses but also to compensate for the percolation losses in the inundated fields. Furthermore, prior to transplanting, substantial irrigation water is required for the land preparation and the nursery. Input and calculation procedures will therefore differ from those of other crops for which a separate program is included in CROPWAT.

The rice program is called up automatically whenever the crop name (both for new data input and for input from disk) RICE or PADDY is given. Also names like R-Rice or T-Paddy referring to specific project crop files and names like RICERABI or PADDY2 are accepted and will call up the rice program. REDRICE and ARICE however will be conceived as normal field crops.

6.1 Input of rice data from keyboard

Data input required for rice include:

RICE DATA INPUT

Crop : RICE

Growth period	Length stage	Crop coefficient
Nursery	30 days	1.20
Land preparation	20 days	---
Initial stage (A)	20 days	1.00
Development stage (B)	30 days	---
Mid season (C)	40 days	1.05
Late season (D)	30 days	0.80
Total	150 days	
Nursery area	10 %	
Land preparation	180 mm	
Percolation rate	1.5 mm/day	

Any modifications (Y/N) : *N*

1. **Length of 6 growth stages**: Normally upland crops will have 4 growth stages. In wetland rice this is extended to 6 stages to include the nursery and land preparation periods (see Fig. 2).

   The length of the different stages is defined as follows:

   - **Length of nursery period**: number of nursery days starting from land preparation nursery area to transplanting of rice.

   - **Length of land preparation**: number of days required to carry out land preparation and inundation prior to transplantation for given irrigation unit. Normally land preparation will fall within the nursery period.

- **Lengths of initial period (A), development stage (B), mid-season (C) and late season (D)** are defined similarly to those for field crops.

2. **Crop factors (Kc)**: each of the 6 growth stages will be allocated a crop factor. As rice is permanently inundated, the crop factor represents values for the combined effect of crop transpiration and open water evaporation. Values will vary from 1.0 to 1.2. In late season a lower value (0.9) can be taken to account for the drying out of the soil profile.

3. **Nursery area**: the area covered by the rice nurseries will occupy only a fraction of the total area. Crop water requirements will be proportionally reduced. An input is therefore required of the area covered by the nursery area as a percentage of total cultivated area.

4. **Land preparation depth**: for land preparation and inundation a considerable amount of irrigation water is normally required, normally given in two irrigations. A first application to bring the soil to saturation (+/- 100 to 150 mm), after which puddling and land cultivation are carried out. Prior to transplanting, a second irrigation for inundation of a water layer to 100 mm is effected.

   The total irrigation requirements for land preparation amount to 200-300 mm. This high momentary irrigation requirement for inundation and land preparation for a given rice area is spread over the land preparation period by rotating irrigation supply over the fields. A longer land preparation period will result therefore in lower daily irrigation requirements.

5. **Percolation rate**: depending on soil type and groundwater levels, the inundated rice fields will have a continuous water percolation to the deeper layers. This percolation process is favourable for plant growth as the water movement will keep oxygen content within the soil at a reasonable level.

   Normal percolation rates are 1-3 mm/day, but rice fields on light soils and slopes may have as much as 10-20 mm/day.

6.2 Saving of rice data

After input or modification of the rice data the user can SAVE the input of rice data:

```
Do you want to SAVE data on DISK (Y/N) : Y
```

To be able to retrieve the rice data afterwards and run the rice program, the name of the rice file should contain the words RICE or PADDY.

The rice water requirements sub program is automatically called up when the file name begins with 'RICE' or 'PADD' or when the name starts with a two letter code and then 'RICE' or 'PADD': Names like C-RICE, RICE2 or PADDY are allowed. A name such as REDRICE will be considered as a field crop and the data input will be incorrectly stored.

6.3 Retrieval of rice data from disk

Selection of RICE or PADDY files can be made from the previously saved file, and is called up from the CROP input menu, as has been explained in section 5.2.2. The file name containing RICE or PADD will automatically call up the rice program.

6.4 Date of transplanting

The procedures for input of the transplanting data are as shown in the following screen print.

TRANSPLANTING DATE

Climate file : kurn-nor Cl. station : KURNOOL
Crop file : rice Crop name : RICE

For ET-rice calculations give DATE of TRANSplanting:

Month of TRANS-Plant (1-12) : *July*
Day of TRANS-Plant (1-30) : *20*
Date of nursery preparation : 20 June
Date of harvest : 20 November

Any changes in the Planting Date (Y/N) : *N*

6.5 Rice irrigation calculations

Rice irrigation requirements include the combined effect of evapotranspiration and percolation and the requirements for land preparation and nursery before transplanting.

Evapotranspiration and percolation occur as soon as the fields are inundated. During the nursery period ETo and percolation are accounted for only over that area covered by the nursery. During the land preparation this area increases daily with more land being inundated until the area is fully covered at transplanting. The area factor in the printout shows the average area coverage over the 10-day period.

Figure 2 illustrates the calculation procedures for rice irrigation requirements during nursery and land preparation periods and after transplanting.

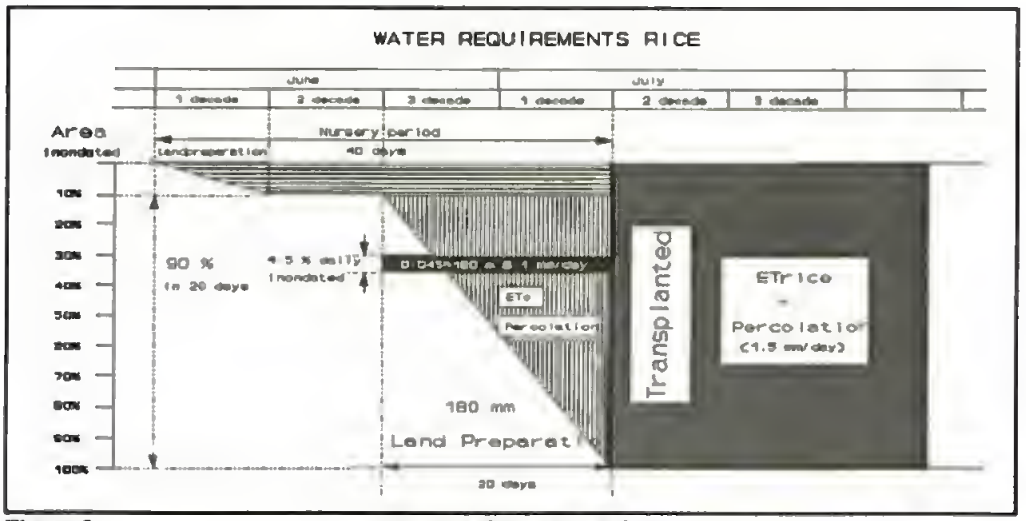


Figure 2 **Water requirements of rice**

6.6 Rice irrigation output

Results of the rice irrigation requirements are presented on screen and if desired on the printer. An example of the results is given below.

Rice Evapotranspiration and Irrigation Requirements

Climate : kurn-nor Station : KURNOOL
Crop : RICE Date of Transplant : 20 July
Effective Rainfall : 80%

Month	Dec	Stage	Area %	Coeff	ETcrop mm/day	Perc. mm/dy	LPrep mm/day	RiceRq mm/day	EffRain mm/dec	IRReq. mm/day	IRReq mm/dec
June	3	NUR	0.10	1.20	0.77	0.2	1.8	2.7	2.1	2.51	25.1
Jul	1	LP	0.33	1.15	2.23	0.5	8.1	10.8	7.5	10.07	100.7
Jul	2	LP	0.78	1.15	4.52	1.2	8.1	13.8	19.6	11.02	118.2
Jul	3	A	1.00	1.00	5.54	1.5	0.0	7.0	25.6	4.48	44.8
Aug	1	A	1.00	1.00	5.55	1.5	0.0	7.1	25.9	4.47	44.7
Aug	2	B	1.00	1.01	5.55	1.5	0.0	7.0	26.1	4.43	44.3
Aug	3	B	1.00	1.03	5.44	1.5	0.0	6.9	27.6	4.18	41.8
Sep	1	B	1.00	1.04	5.32	1.5	0.0	6.8	29.6	3.85	38.6
Sep	2	C	1.00	1.05	5.16	1.5	0.0	6.7	31.4	3.52	35.2
Sep	3	C	1.00	1.05	4.93	1.5	0.0	6.4	28.8	3.55	35.5
Oct	1	C	1.00	1.05	4.70	1.5	0.0	6.2	26.8	3.52	35.2
Oct	2	C	1.00	1.05	4.47	1.5	0.0	6.0	24.5	3.53	35.3
Oct	3	D	1.00	1.01	4.09	1.3	0.0	5.3	18.4	3.50	35.0
Nov	1	D	1.00	0.92	3.56	0.9	0.0	4.4	11.6	3.28	32.8
Nov	2	D	1.00	0.84	3.06	0.4	0.0	3.5	5.1	2.99	29.9
Totals					649	179	180	1007	311		697

A printout of the rice requirements can be made by answering Y(es) to the next question:

Do you want PRINT OUT of the RICE-requirements (Y/N) : *Y*

Rice irrigation requirements can be SAVED as a field file for scheme water requirement calculations:

Save future requirement data as FIELD-File on disk for FUTURE calculations on SCHEME WATER REQUIREMENTS ? : *Y*

For the naming of the rice field file reference is made to section 5.3.3

6.7 Program continuation

As in chapter 5, the program con be continued with a revision of the planting date, the crop or climate.

NOTE: The present CROPWAT version does not yet include an option for irrigation scheduling of wetland rice.

7. IRRIGATION SCHEDULING

The irrigation scheduling program cannot be addressed directly from the main program, but is reached after completion of the crop water requirement calculations (option 2, Main Menu):

```
                    CONTINUE CALCULATIONS

Climate File    : KURN-NOR  Cl. Station  : KURNOOL
Crop file       : GRONDNUT  Plant date   : 20 November

          To continue the program you have the following Options:

 --> 1. Proceed to irr. scheduling of GROUNDNUT
     2. Revise PLANTING date of GROUNDNUT
     3. Take another CROP
     4. Take NEW set of CLIMATIC data

     5. Return to MAIN MENU

                  Give your option (1-5) : 1
```

The irrigation scheduling program provides the possibility to:

- develop and plan indicative irrigation schedules adapted to field operational conditions;
- evaluate field irrigation programs in terms of efficiency of water use and yield production;
- simulate field irrigation programs under water deficiency conditions, rainfed conditions, supplementary irrigation, etc.

7.1 Data input for irrigation scheduling

The calculation of the irrigation schedules is based on the water balance in which on a daily basis, the incoming and outgoing water flow (evaporation, rain, irrigation) in the rootzone of the soil profile is being monitored. For the calculations, data on crop evapotranspiration, rainfall, crop and soil are required:

7.1.1 Crop water requirements

The crop water requirements, defined as the daily water needs of crops, have been calculated previously from climatic data (ETo) and crop data (Kc, length of growth stages). They represent the daily uptake of soil moisture from the root zone due to evapotranspiration of the crop.

7.1.2 Rainfall

Rainfall data are included at the input of climate data. Depending on the objective of the irrigation scheduling calculations, the rainfall data given concern:

- monthly averages
- rainfall with a 80% (dry) or 20% (wet) probability of exceedance, representing respectively a dry or wet year
- historical or actual data.

7.1.3 Crop data

The crop data required for irrigation scheduling concern the data on **rooting depth** and **allowable depletion** which allow the calculation of the readily available soil moisture content in the rootzone (RAM). Furthermore, to assess the effect of water stress on yield, the **yield response factor** is required.

The input of the crop data has been carried out earlier (chapter 5.2).

7.1.4 Soil data

The soil parameters important for irrigation scheduling are :

INPUT SOIL DATA

For scheduling ENTER your soil data:

From keyboard	**1**
From diskette	**2**
Back to Start-up CROPWAT	**3**

Your choice : *2*

- **Total Available Soil Moisture Content** (TAM), defined as the difference in soil moisture content between field capacity and wilting point. It represents the ultimate amount of water available to the crop and depends on texture, structure and organic matter content of the soil, expressed in mm/metre. Indicative values for different texture class are:

	Coarse	Sandy	Loamy	Clayey
TAM	60	100	140	180 mm/m

- **Initial Soil Moisture Depletion** (% TAM), indicating the dryness of the soil at the start of the growing season. The initial soil moisture is expressed as a depletion percentage from field capacity. Default value of 0 % represents a fully wetted soil profile, 100 % is a soil at wilting point. In most cases only an estimate can be made of the initial soil moisture condition, depending on previous crop and periods of a preceding fallow or dry season period.

- **Maximum Rooting Depth**, although in most cases the genetic characteristics of the crop will determine the rooting depth, in some cases the soil and certain disturbing soil layers may restrict the maximum soil depth. Default value is set arbitrarily on 900 cm, indicating no soil depth limitation.

- **Maximum Rain Infiltration Rate**, to allow an estimate of the *surface runoff* for the effective rain calculation, the maximum rain infiltration rate expressed in mm/day, can be set, limiting the maximum amount of rain which can infiltrate the soil on any one day, as a function of rain intensity, soil type and slope class. Default value is set at 30 mm/day.

Data input can concern new data or previously saved data. The procedure to input new data or to retrieve data saved earlier is similar to that for climate and crop data.

INPUT SOIL DATA

Soil type description (max. 15 char.) : *sandy loam*

Total Available Soil Moisture (mm/m) : *140* mm/metre

Maximum Rain Infiltration Rate : *40* mm/day

Maximum Rooting Depth : *900* centimetres

Initial Soil Moisture Depletion (% TAM) : *40* percent
–> Initial Available Soil Moisture : 84 mm/metre

Any changes in Input Soil Data (Y/N) : *N*

In the case of new soil data, the soil type description should be given. The different soil data files on disk, saved in earlier sessions, will be shown on screen from whicb a choice can be made:

RETRIEVE SOIL DATA

The following files are on the data disk:

BLCKCLAY	SOL	COARSE	SOL	COARSTEX	SOL	FINETEX	SOL
HEAVY	SOL	LIGHT	SOL	LOAM	SOL	MEDITEX	SOL
MEDIUM	SOL	REDCLAY	SOL	SANDLOAM	SOL		

Please enter your file name (without extension !) : ? *sandloam*

7.2 Irrigation scheduling options

The irrigation scheduling program allows a range of options, depending on the specific application the user is aiming at and the conditions and restrictions the field irrigation system imposes.

The scheduling option refers to two different categories:

1. Timing Options - related to WHEN irrigation is to be applied.

2. Application Options - HOW MUCH water is to be given per irrigation turn.

7.2.1 Timing options

The user can select the following irrigation TIMING OPTIONS, determining wben an irrigation is to be given:

Options Irrigation Timing

Objective	Timing Option
EVAL. & SIMUL.	1. Each irrigation defined by user
OPTIMAL IRRIGATION	2. Irrigation at CRITICAL depletion (100% RAM) 3. Irr. below or above critical depl. (% RAM)
PRACTICAL IRRIG.	4. Irrigation at fixed intervals per stage 5. Irrigation at fixed depletion (mm)
DEFICIT IRRIGATION	6. Irrigation at given ETcrop reduction (%) 7. Irrigation at given YIELD reduction (%)
RAINFED	8. No irrigation, only rainfall
	0. Revise data input

Give your option : *1*

For EVALUATION AND SIMULATION:

Option 1 Irrigation turns are defined by the user and can be either historical irrigation dates from actual field data or simulated dates. This option is used to evaluate irrigation practices, to simulate any alternative irrigation schedule and in particular to refine the programming of irrigation schedules, developed in other options. The input of the individual dates is carried out as shown in the screen print.

INPUT INDIVIDUAL IRRIGATIONS

Irrigation dates defined by user

Type 0 (zero) to terminate the input

Application no 1: Days after planting: *20*
Application Depth (mm): *40*
Application no 2: Days after planting: *40*
Application Depth (mm): *40*
Application no 3: Days after planting: *50*
Application Depth (mm): *50*
Application no 4: Days after planting: *70*
Application Depth (mm): *50*
Application no 5: Days after planting: *85*
Application Depth (mm): *50*
Application no 6: Days after planting: *0*

Any corrections in input irrigation dates (Y/N) : *N*

For **OPTIMAL IRRIGATION**, where no restrictions are set on timing and availability of water supply:

Option 2 Irrigation water applied whenever the critical soil moisture level is reached and readily available soil moisture is depleted, defined as 100% RAM. The classical way to determine irrigation schedules, resulting in minimum irrigations, but irregular and therefore unpractical irrigation intervals.

> Irrigation at 100% Depletion of Readily Available Soil Moisture

Option 3 Irrigation water applied whenever a certain soil moisture level is reached defined as percentage of RAM. Useful to set a safety level above critical soil moisture (for instance 80% RAM) or to allow a certain stress level (for instance 120% RAM).

> Fixed % of RAM on which irrigation is required (%) ? *80*

For **PRACTICAL IRRIGATION** where the scheduling is adjusted to the field irrigation method and the water supply conditions:

Option 4 Irrigation water applied on fixed interval turns, suitable in particular in a gravity system with **rotational water distribution** as found in a majority of irrigation schemes. Although it may result in some over-irrigation in the initial stages and under-irrigation in the peak season, the fixed irrigation turns have great operational advantages.

> Interval length stage A (days) : *10* stage B (days) : *10*
> stage C (days) : *7* stage D (days) : *10*

Option 5 Irrigation water applied whenever a predetermined amount of water has been depleted, suitable in particular to adjust the irrigation schedule to the field irrigation method, and a fixed water application is given in each irrigation turn.

> **Give fixed depletion in mm : ? *40***

For **DEFICIT IRRIGATION**, where in view of shortages of water supply we aim at restricting water supply while minimizing yield reductions:

Option 6 Irrigation water applied whenever a critical reduction in evapotranspiration is reached, predetermined by user for each stage in percentage of the reduction in evaporation:

Deficit = 100 * (1-ETa/ETmax),

where ETa = actual evapotranspiration
ETmax = ETcrop = crop evapotranspiration.

```
ETc reduction  stage A (%) : ? 10      stage B (%) : 10
               stage C (%) : ?  0      stage D (%) : 10
```

Option 7 Irrigation water applied whenever a critical yield reduction level is reached, determined by sensitivity of concerned growing stage, according to:

$$(1 - Ya / Ymax) = Ky * (1 - ETa / ETmax)$$

where Ya = actual yield and Ymax = maximum yield
Ky = Yield response factor

```
Give yield deficit level (%) : ? 10
```

Option 8 Rainfed. No irrigation is applied, only the monthly rainfall as given in the climatic data is considered, spread regularly over the month, in six rainfall showers. The printout gives a 10-day overview on deficit, evapotranspiration and rainfall losses.

7.2.2 Application option

Similarly the user must select one of the following irrigation application options:

```
                Irrigation Application Options

Objective            Application Option
-------------------------------------------------
EVAL. & SIMUL.       1. Each irrigation depth defined by user
OPTIMAL IRRIG.       2. Refill soil to FIELD CAPACITY
                     3. Refill below or above field capacity
PRACTICAL IRRIG.     4. Irrigation depth fixed acc. irr. method
-------------------------------------------------
                     0. BACK TO TIMING OPTIONS
```

For **EVALUATION AND SIMULATION:**

Option 1 Application depth is specified by user for each irrigation turn as determined from field data or simulated data. The input of irrigation depth is carried out in combination with Timing Option 1, as shown on page 38:

```
Return to timing menu option 1 to define each irrigation depth!
```

For **OPTIMAL IRRIGATION:**

Option 2 The application depth will bring soil moisture content back to field capacity, thus equal to the depleted soil moisture in the root zone. As the depletion in the root zone will normally vary over the growing season with changing root depth and allowable depletion levels, the application gifts may vary substantially over the season.

Option 3 The application depth will bring soil moisture content back to a fixed amount above or below field capacity. Useful to allow for leaching for salinity control (application larger than field capacity) or to accommodate possible rainfall (application below field capacity).

Give Irrigation depth (+) or (-) mm from field capacity : ? *20*

For **PRACTICAL IRRIGATION**, where application is restricted by one or more conditions set by the irrigation system:

Option 4 Application depth is fixed by the user, and normally adapted to the irrigation method. Predominant condition in most gravity systems, where irrigation depths allow little variation; in addition fixed irrigation depth offers considerable operational advantages.

Give fixed irrigation depth (mm) ? *40*

Fixed Irrigation Depth:Indicative values for different irrigation methods are given below:

Surface irrigation:	basin irrigation	: 50 - 150 mm
	furrow irrigation	: 30 - 60 mm
	border irrigation	: 40 - 80 mm
Sprinkler irrigation	: 30 - 80 mm	
Drip irrigation	: 10 - 30 mm	

7.2.3 Field irrigation efficiency

The application depth concerns the net irrigation depth, the amount of water effectively infiltrated in the root zone. Inadequacies in the irrigation system and in particular in the field layout (poor land levelling, poor practices) will cause losses. To account for these system losses, the program allows an input on the estimated irrigation efficiency.

A default value of 70% is recommended for normal well-managed gravity irrigation methods.

Estimate field application efficiency (%) ? *70*

NOTE: A distinction should be made between the 'scheduling' efficiency, which is calculated in the water balance as water lost due to deep percolation and is a consequence of inadequate scheduling, and the system irrigation efficiency estimated on the basis of inadequacies in the field irrigation system.

7.3 Irrigation scheduling calculations

The calculation of the scheduling program is based on a soil water balance, where the soil moisture status is determined based on a daily accounting of all ingoing and outgoing water in the root zone, according to:

$$SMDi = SMDi\text{-}1 + ETa - P_{tot} - Irr.Appl. + RO + DP$$

where:
- SMDi = soil moisture depletion at day i
- ETa = actual crop evapotranspiration
- P_{tot} = effective rainfall
- Irr.Appl. = irrigation depth
- RO = runoff
- DP = deep percolation

Figure 3 illustrates graphically the soil water balance over the growing season.

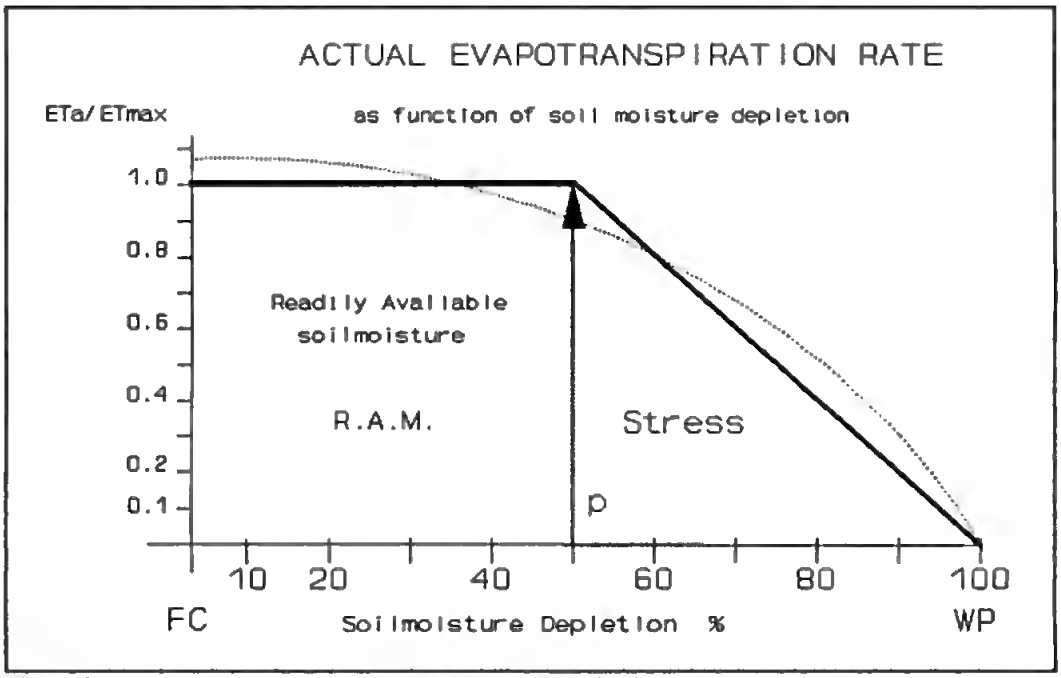


Figure 3 **Actual evapotranspiration**

The budget calculation in CROPWAT assumes a soil moisture content at field capacity at planting, unless modified in the soil input file (see 7.1.4).

Rainfall data are given as monthly values and the program converts the monthly values into 10-daily values (see CWR calculations). For the water balance calculation, total rainfall is taken and rainfall applications are simulated by two applications for each decade on day 3 and day 7 of half the 10 daily rainfall. For each rainfall an account is kept of which part of the rainfall has been lost by **runoff** determined by the maximum rain infiltration rate (see input soil data 7.1.4) and the **deep percolation** determined by the soil moisture depletion in the root zone.

Actual evapotranspiration will be equal to the calculated crop evapotranspiration as long as soil moisture content has not reached the critical level as given by the allowable depletion (p). Beyond this

level actual crop evapotranspiration will be reduced proportionally to soil moisture depletion as illustrated in Figure 4.

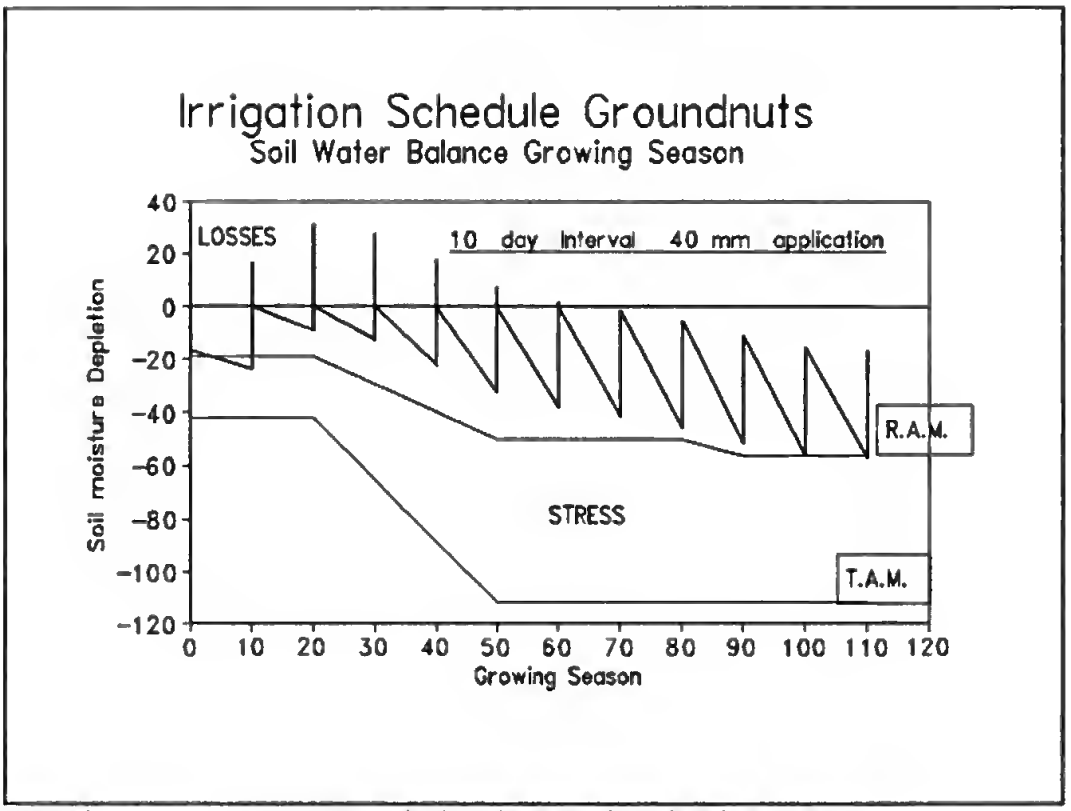


Figure 4 **Actual evapotranspiration with decreasing soil moisture content**

Values for total and readily available soil moisture, as determined by root depth, allowable depletion and total available soil moisture, are calculated on a daily basis.

Furthermore, by summation of daily values, an account is kept of actual and potential evapotranspiration for each growing stage and the total growing period.

Timing and application of irrigation are incorporated in the calculation as determined by the user.

For the final output accounts are kept on the number of irrigations, interval periods and irrigation losses and yield reductions due to stress as presented in Output.

Gross irrigation application depth is determined from given irrigation efficiency and converted into a permanent field supply in l/sec/ha over the irrigation interval period.

7.4 Irrigation scheduling output

The results of the scheduling calculations are presented on the screen and can subsequently be printed on a connected printer or to a disk file.

The output includes information on the irrigation calendar, the total water use and production and allows evaluations of the scheduling efficiency.

IRRIGATION SCHEDULING GROUNDNUT 20 November

Climate Station : KURNOOL
Crop : GROUNDNUT
Soil : sandy loam
Climate File : kurn-nor
Planting date : 20 November
Available Soil moisture : 140 mm/m
Initial Soil moisture : 84 mm/m

Irrigation Options selected:

Timing : Fixed Interval of 10 (A) / 10 (B) / 10 (C) / 10 (D) days
Application : Fixed Irrigation Depth of 40 mm

Field Application Efficiency 70 %

No. Irr.	Int days	Date	Stage	Deplet %	TX %	ETA %	Net Depth mm	Deficit mm	Loss mm	Gr. Depth mm	Flow l/s/ha
1	10	1 Dec	A	56	85	94	40.0	0.0	0.0	57.1	0.66
2	10	10 Dec	A	21	100	100	40.0	0.0	15.4	57.1	0.66
3	10	20 Dec	B	19	100	100	40.0	0.0	23.9	57.1	0.66
4	10	1 Jan	B	25	100	100	40.0	0.0	15.9	57.1	0.66
5	10	10 Jan	B	29	100	100	40.0	0.0	7.2	57.1	0.66
6	10	20 Jan	C	34	100	100	40.0	0.0	1.8	57.1	0.66
7	10	1 Feb	C	37	100	100	40.0	1.2	0.0	57.1	0.66
8	10	10 Feb	C	41	100	100	40.0	5.4	0.0	57.1	0.66
9	10	20 Feb	D	46	100	100	40.0	11.1	0.0	57.1	0.66
10	10	1 Mar	D	50	100	100	40.0	15.6	0.0	57.1	0.66
11	10	10 Mar	D	51	100	100	40.0	16.7	0.0	57.1	0.66
END	1	11 Mar	D	15	100	0					

7.4.1 Irrigation calendar

General information on the data used includes:

- details on crop, planting date and soil data
- timing and application criteria selected.

For each irrigation event an account of:

- number of the irrigation turn (**No. Irr.**)
- interval period (**Int**)
- DATE of irrigation turn (**Date**)
- crop STAGE in which irrigation turn occurs (**Stage**):

  A: initial phase
  B: development stage
  C: mid-season
  D: late season

- depletion level (**Depl**) as percentage of total available soil moisture (TAM)
- actual evapotranspiration rate (TX) on the day before irrigation, expressed as percentage of potential crop evapotranspiration

- average actual evapotranspiration (**ETa**) calculated over the irrigation interval period, and expressed as percentage of potential crop evapotranspiration

- deficit (**Deficit**), indicates the soil moisture depletion level after irrigation:

  ... a zero value represents a refill to field capacity;
  ... a positive value represents an under-irrigation, equal to the amount needed to refill the root zone to field capacity

- loss (**Loss**) the excess water lost to deep percolation of any irrigation depth or rain exceeding refill to field capacity.

- net and gross irrigation depths as defined by application option (**Net Depth and Gross Depth**)

- the gross depth converted into a permanent flow (**Flow**), representing a continuous discharge to satisfy irrigation requirements over the concerned interval period.

7.4.2 Total water use and yield reductions

The output is concluded with a presentation of total water use and yield reductions as shown in the printout.

Total Gross Irrigation	628.6 mm	Total Rainfall	13.3 mm
Total Net Irrigation	440.0 mm	Effective Rain	13.3 mm
Total Irrigation Losses	64.1 mm	Total Rain Loss	0.0 mm
Moist Deficit at harvest	16.7 mm		
Actual Water Use by Crop	361.1 mm	Actual Irrig. Req.	348.6 mm
Potential Water Use by Crop	362.0 mm		
Efficiency Irr. Schedule	85.4 %	Efficiency Rain	100.0 %
Deficiency Irr. Schedule	0.2 %		

YIELD REDUCTIONS	Stage	A	B	C	D	Season	
Reductions in ETC		3.1	0.0	0.0	0.0	0.2	%
Yield Response factor		0.40	0.60	1.00	0.80	0.80	
Reductions in Yield		1.2	0.0	0.0	0.0	0.2	%
Cumulative Yield reduct.		1.2	1.2	1.2	1.2		%

i. The **efficiency of the irrigation supply** can be evaluated from:

   - total net and gross irrigation supply

   - total net irrigation losses as sum of excess irrigation applications; these do not account for the irrigation efficiency defined in input (see chapter 7.2.4)

   - soil moisture deficit at harvest, representing the soil moisture depletion at the end of the season, a check if the last irrigation was really required or could be possibly suppressed

- total net supply + soil retention, representing the total water use by the crop plus possible water losses

- total net water use of the crop

- potential total irrigation requirement, which is equal to the earlier calculated total crop water requirements minus effective rainfall

- efficiency of supplied irrigation water, which is expressed as the ratio water use crop over net supply

- deficiency of the irrigation supply, which is a measure of crop water stress determined as ratio actual crop water use over potential crop water use.

ii. **Reductions in yield** due to soil moisture stress are indicated per season and per growing stage:

- if no stress occurred table will be suppressed

- reductions in Evapotranspiration are calculated for each growing stage and over the total growing season, expressed as percentage of potential crop evapotranspiration.

- reductions in Yield are expressed in two ways:

  ... for each growth stage separately according to:

$$(1-Ya/Ymax)=Ky*(1- ETa/ETm)$$

  ... cumulative yield reduction where each yield reduction for a given stage is carried over to the next stage according to:

$$(1 - Ya/Ym)i = 1 - (Ya/Ym)1 * (Ya/Ym)2 * .. *(Ya/Ym)i$$

The yield reduction values will only provide an indication of possible yield reductions and it will be up to the user to interpret the actual accuracy of the values based on his experience.

iii. The **efficiency of rainfall** can be evaluated from the information on:

- total rainfall

- rain losses as determined from rainfall exceeding refill capacity of the soil (deep percolation) and rainfall exceeding the maximum daily infiltration rate (runoff losses)

- effective rain as total rain - losses

- rain efficiency as percentage of the ratio effective and total rainfall. The evaluation of the rainfall efficiency provides a way to establish effective rainfall correlations (see section 5.1.3).

7.4.3 Evaluation of the irrigation schedule

The efficiency of the irrigation schedule can be judged in particular from:

i. Efficiency of supplied irrigation water
ii. Yield reduction due to moisture stress.

The user has to evaluate the different efficiency factors and compare these to the set timing and application options. By varying the options and input parameters, better efficiencies can possibly be achieved.

Normally a number of runs is necessary before a satisfactory irrigation schedule can be found. A typical sequence will be:

1. Optimal irrigation scheduling with timing option 100% RAM and application to field capacity.

2. Practical irrigation scheduling with timing option fixed interval, for instance 10 days or 7 days and an application option set at fixed irrigation depth as determined by the irrigation method. Several intervals and applications may be tried.

   The output shows a pattern which is typical of many field irrigation systems: an over irrigation in the early season and an under irrigation during mid season, leading to mild stress. This is also illustrated in Figure 2.

3. Simulated schedule where further refinements can be applied by varying timing and applications over the growing season.

```
                          1. Print Irrigation Schedule
Give your option : 2      2. Modify Scheduling Options
                          3. Revise Input data
                          4. Return Main Menu
```

7.5 Program continuation

To continue, a new scheduling option can be chosen, or the data set in use can be renewed. If modifications in the data set are required, option 0 (zero) from the irrigation timing menu has to be selected. The following options are available to revise the data:

1. A new soil type to be used for the soil water balance calculations for same crop and climate

2. Revision of certain soil parameters such as the initial soil moisture content

3. Revise planting date of crop used. A recalculation of the CWR will follow after which soil data have to be re-entered.

4. Revise crop input: a completely new crop can be taken or certain crop parameters can be modified.

5. Revise climatic data set: will bring user back to climate data input from where either another climate file can be called up or a new data set can be typed in. To return to the scheduling program, crop data, planting date and soil data will have to re-entered.

6. Return to scheduling options for revision of timing or application options.

7. Return to Main Menu.

DATA REVISION

Climate File	**: kurn-nor**	**Soil Type**	**: sandy loam**
Crop File	**: grondnut**	**Plant date**	**: 20 November**

To continue the program you have the following options:

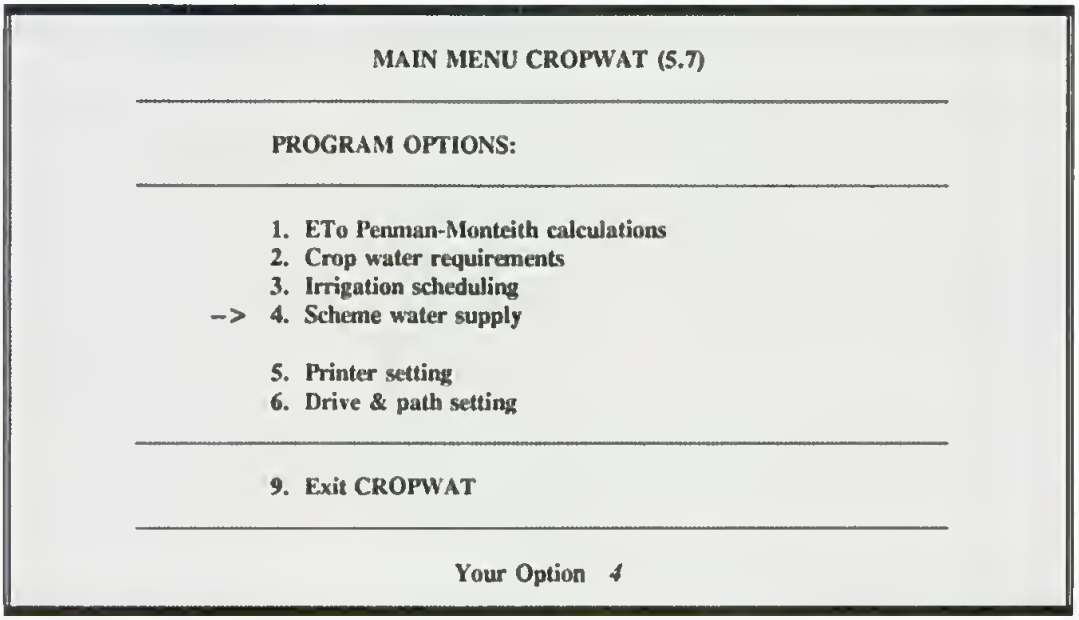
1. **Take another Soil**
2. **Revise Soil data**
3. **Revise Planting date**
4. **Revise Crop input**
5. **Take NEW set of CLIMATIC data**

6. **Return to Scheduling Options**
7. **Return to Main Menu**

Give your option (1-7) : *7*

8. SCHEME WATER SUPPLY

The calculation of scheme water supply can be made by choosing option 4 in the Main Menu:



The purpose of this program element is to determine the monthly irrigation water supply for an irrigation scheme where, on varying areas and for different planting dates, several irrigated crops are grown.

8.1 Data input

8.1.1 Crop Irrigation requirements

In proceeding program sessions the crop irrigation requirements have been determined and, if considered suitable for the scheme water supply, have been saved as field files with an adequate reference to crop, climate and planting date.

For the scheme irrigation requirements, a field file is successively called up, for each crop and planting date, from the list of displayed field files.

8.1.2 Cropped area

The area covered by each crop should be given as a percentage of the total scheme area.

An overview of the cropping pattern with the different cropped areas, planting dates and other information is shown in the screen overleaf.

Care should be taken that at any given moment the sum of individual crops does not exceed total scheme area. A check on this is provided by summarizing essential crop irrigation data.

Input Cropping Pattern

Compose from field files the desired cropping pattern

The following files are on the data disk:

RN-CT081 FLD	RN-GR011 FLD	RN-GR081 FLD	RN-GR082 FLD
RN-GR122 FLD	RN-PD072 FLD	RN-PD073 FLD	RN-PD081 FLD
RN-PD082 FLD	RN-PD122 FLD	RN-PD123 FLD	RN-SC011 FLD
RN-SG072 FLD	RN-SG081 FLD		

Enter NAME of Field file No. 1 : *rn-ct081*

Give area COTTON in % ? *20*

Do you want to continue with next field file (Y/N) ? *Y*

CROPPING PATTERN

Project : Climatic Station : KURNOOL

No.	CROP	Area %	Plant. date	Harvest date	ETCrop mm	EffRain mm	S.Eff. %	Yld. Red. %
1	COTTON	20	0 8	1 8	597.4	294.0	100	0
2	GROUNDNUT/K	30	15 8	15 8	361.7	248.0	100	0
3	PADDY	25	20 7	20 7	671.7	347.3	100	0
4	PADDY	25	10 8	10 8	626.5	298.2	100	0
5	GROUNDNUT/R	30	15 12	15 12	393.6	8.3	100	0
6	GROUNDNUT/R	30	0 1	1 1	428.9	11.6	100	0
7	PADDY	15	10 12	10 12	628.5	13.3	100	0
8	PADDY	15	20 12	20 12	660.7	13.6	100	0

8.2 Calculations

The 10-day values on crop irrigation requirements, derived from the different field files, are converted into monthly values. Multiplication of the individual crop irrigation requirements by the area percentage, give "relative" irrigation requirements, expressed in mm/day. Summation of these values for all crops gives the scheme water requirements and scheme water supply which can be converted into l/s/ha and l/s respectively.

By taking into account irrigation efficiencies and rotational criteria the gross scheme water supply requirements can be determined according to:

$$Q_{gross} = \frac{1}{e_p} * \frac{1}{t_i} * A_{scheme} + 0.116 * \sum (ET_{crop} - P_{eff}) * \frac{A_{crop}}{A_{scheme}}$$

where: Q_{gross} = gross scheme water supply (l/s)
e_p = scheme irrigation efficiency ($\leq$ 1)
t_i = operational time factor ($\leq$ 1)
A_{crop} = area covered by individual crop
A_{scheme} = total scheme area
$ET_{crop} - P_{eff}$ = net crop irrigation requirement

Summarizing (Σ) for all crops.

8.3 Output

1. A printout is given of selected cropping pattern with crop names, area coverage, planting date and summarized crop irrigation data as shown.

2. Results of net irrigation requirements are presented in table form on the screen as shown with monthly values on:

   - crop irrigation requirements
   - net scheme irrigation requirements in mm/day, l/s/ha and l/s
   - irrigated area as percentage of total scheme area
   - irrigation requirement in l/s for actually irrigated area

A printout in monthly values can be made if desired, an example of which is given.

NOTE: Future versions of CROPWAT will include a printout of decade values and calculation of gross irrigation supply taking into account irrigation efficiency and the operational time factor.

SCHEME IRRIGATION REQUIREMENTS

Project: Climatic Station : KURNOOL

No.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	3.3	3.5
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.6	2.6	0.7
3	0.0	0.0	0.0	0.0	0.0	0.9	9.9	6.0	4.8	4.7	2.5	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	4.2	8.3	4.9	4.9	5.3	1.2
5	1.9	4.6	5.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
6	0.9	3.9	5.7	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	7.2	8.0	8.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	8.9
8	7.2	8.0	8.8	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.8	10.2
SQ	3.6	5.0	5.8	2.4	0.0	0.2	3.5	3.6	2.5	3.2	4.1	4.2
SQ	107	149	174	72	0	7	106	107	75	96	124	126
SQ	0.41	0.57	0.67	0.28	0.00	0.03	0.41	0.41	0.29	0.37	0.48	0.49
Ar	110.0	90.0	90.0	45.0	0.0	8.3	41.7	50.0	66.7	100.0	106.7	88.3
AQ	0.38	0.64	0.75	0.62	0.00	0.30	0.99	0.83	0.44	0.37	0.45	0.55

SQ in mm/d
SQ in mm/m
SQ in ls/h
AR in %
AQ in ls/h

ANNEX 1

CROP CHARACTERISTICS

1. Length of crop development stages

2. Crop coefficients

3. Crop coefficients perennial crops:

Figure A.1	Alfalfa
Figure A.2	Citrus
Figure A.3	Deciduous fruit
Figure A.4	Banana

4. Soil water depletion fraction

   - for various soil groups
   - for various ETcrop ranges

5. Readily available soil moisture

6. Yield response factor

1. LENGTH OF CROP DEVELOPMENT STAGES OF SELECTED FIELD CROPS

Crop	Init.	Devel	Mid	Late	Total	Plant Date	Region
Artichoke	40	40	250	30	360	Apr (1 yr)	California
	20	40	220	30	310	May (2 yr)	(cut in May)
Beans	20	30	30	10	90	Feb/Mar	Calif., Mediterranean
(green)	15	25	25	10	75	Aug/Sep	Calif., Egypt, Lebanon
Beans (dry)	20	30	40	20	110	May/June	Continental Climates
	15	25	35/50	20	95	June	Pakistan, Calif.
Beets	15	25	20	10	70	Apr/May	Mediterranean
	25	30	25	10	90	Feb/Mar	Mediterranean & Arid
Carrots	20	30	50/30	20	100	Oct/Jan	Arid climate
	30	40	60	20	150	Feb/Mar	Mediterranean
Castor beans	25	40	65	50	180	March	(Semi)Arid Climates
Celery	25	40	95	20	180	Oct	(Semi)Arid
	25	40	45	15	125	April	Mediterranean
Cotton	30	50	60	55	195	Mar;Apr/May	Egypt; Pakistan
	30	50	60	55	195	Sept	Yemen
	30	50	55	45	180	April	Texas
Crucifers	20	30	20	10	80	April	Mediterranean
	25	35	25	10	95	February	Mediterranean
	30	35	90	40	195	Oct/Nov	Mediterranean
Cucumber	20	30	40	15	105	June/August	Arid Region
	25	35	50	20	130	Nov; Feb	Arid Region
Egg plant	30	40	40	20	130	October	Arid Region
	30	45	40	25	140	May/June	Mediterranean
Flax	25	35	50	40	150	April	Europe
	30	40	100	50	220	October	Arizona
Grains	20	30	60	40	150	April	Mediterranean
(small)	25	35	65	40	165	Oct/Nov	Pakistan; Arid Reg.
Groundnut	25	35	45	25	130	Dry season	West Africa
	35	45	35	25	140	May/June	Mediterranean
Lentil	20	30	60	40	150	April	Europe
	25	35	70	40	170	Oct/Nov	Arid Region
Lettuce	20	30	15	10	75	April	Mediterranean
	30	40	25	10	105	Nov/Jan	Mediterranean
	25	35	30	10	100	Oct/Nov	Arid Region
Maize	20	20	30	10	80	March	Philippines
(sweet)	20	25	25	10	80	May/June	Mediterranean
	20	30	50/30	10	90	Oct/Dec	Arid Climate
Maize	30	50	60	40	180	April	East Africa (alt.)
(grain)	25	40	45	30	140	Dec/Jan	Arid Climate
	20	35	40	30	125	June	Nigeria (humid)
	20	35	40	30	125	October	India (dry, cool)
	30	40	50	30	150	April	Spain (spring, aum.)
Melons	25	35	40	20	120	May	Mediterranean
	30	45	65	20	160	Dec/Jan	Arid Region
Millet	15	25	40	25	105	June	Pakistan
	20	30	55	35	140	April	Central USA

Crop	Init.	Devel	Mid	Late	Total	Plant Date	Region
Onion (dry)	15 20	25 35	70 110	40 45	150 210	April October	Mediterranean Arid Region
Onion (green)	25 20	30 45	10 20	5 10	70 95	April/May October	Mediterranean Arid Region
Peas	15 20	25 30	35 35	15 15	90 100	May March/April	Europe Mediterranean
Peppers	25/30 30	35 40	40 110	20 30	125 210	April/June October	Europe and Medit. Arid Region
Potato	25 25 30+15	30 30 35	30/45 45 50	30 30 30	115/130 130 145	Jan/Nov May April	(Semi)Arid Climate Continental Climate Europe
Radish	10 10	10 10	15 15	5 5	40 40	March/April Winter	Medit.; Europe Arid Region
Safflower	20 35	35 55	45 60	25 40	125 190	April Oct/Nov	California, USA Arid Region
Sorghum	20 20	35 35	40 45	30 30	130 140	May/June March/April	USA, Pakis., Med. Arid Region
Soybeans	20 20	30/35 25	60 75	25 30	140 150	May June	Central USA Japan
Spinach	20 20	20 30	25 40	5 10	70 100	Apr; Sep/Oct November	Mediterranean Arid Region
Squash (pumpkin)	20 25	30 35	30 35	20 25	100 120	March, Aug June	Mediterranean Europe
Squash (zucchini)	25 20	35 30	25 25	15 15	100 90	April May/June	Medit.; Arid Reg. Medit.; Europe
Sugarbeet	45 25 35	75 35 60	80 50 70	30 50 40	230 160 205	November May November	Mediterranean Mediterranean Arid Regiona
Sunflower	25	35	45	25	130	April/May	Medit.; California
Tomato	30 35 30	40 45 40	40 70 45	25 30 30	135 180 145	January Oct/Nov April/May	Arid Region Arid Region Mediterranean
Wheat/ Barley	15 20 15	25 25 30	50 60 65	30 30 40	120 135 150	November March/April July	Central India 35-45 °L East Africa
Winter Wheat	30	140	40	30	240	November	Mediterranean

From FAO Irrigation and Drainage Paper 24, Table 22.

2. CROP COEFFICIENTS (Kc)

CROP	Crop development stages					Total growing period
	Initial	Crop develop-ment	Mid-season	Late season	At harvest	
Banana						
tropical	0.4-0.5	0.7-0.85	1.0-1.1	0.9-1.0	0.75-0.85	0.7-0.8
subtropical	0.5-0.65	0.8-0.9	1.0-1.2	1.0-1.15	1.0-1.15	0.85-0.95
Bean						
green	0.3-0.4	0.65-0.75	0.95-1.05	0.9-0.95	0.85-0.95	0.85-0.9
dry	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75	0.25-0.3	0.7-0.8
Cabbage	0.4-0.5	0.7-0.8	0.95-1.1	0.9-1.0	0.8-0.95	0.7-0.8
Cotton	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.9	0.65-0.7	0.8-0.9
Grape	0.35-0.55	0.6-0.8	0.7-0.9	0.6-0.8	0.55-0.7	0.55-0.75
Groundnut	0.4-0.5	0.7-0.8	0.95-1.1	0.75-0.85	0.55-0.6	0.75-0.8
Maize						
sweet	0.3-0.5	0.7-0.9	1.05-1.2	1.0-1.15	0.95-1.1	0.8-0.95
grain	0.3-0.5*	0.7-0.85*	1.05-1.2*	0.8-0.95	0.55-0.6*	0.75-0.9*
Onion						
dry	0.4-0.6	0.7-0.8	0.95-1.1	0.85-0.9	0.75-0.85	0.8-0.9
green	0.4-0.6	0.6-0.75	0.95-1.05	0.95-1.05	0.95-1.05	0.65-0.8
Pea, fresh	0.4-0.5	0.7-0.85	1.05-1.2	1.0-1.15	0.95-1.1	0.8-0.95
Pepper, fresh	0.3-0.4	0.6-0.75	0.95-1.1	0.85-1.0	0.8-0.9	0.7-0.8
Potato	0.4-0.5	0.7-0.8	1.05-1.2	0.85-0.95	0.7-0.75	0.75-0.9
Rice	1.1-1.15	1.1-1.5	1.1-1.3	0.95-1.05	0.95-1.05	1.05-1.2
Safflower	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.7	0.2-0.25	0.65-0.7
Sorghum	0.3-0.4	0.7-0.75	1.0-1.15	0.75-0.8	0.5-0.55	0.75-0.85
Soybean	0.3-0.4	0.7-0.8	1.0-1.15	0.7-0.8	0.4-0.5	0.75-0.9
Sugarbeet	0.4-0.5	0.75-0.85	1.05-1.2	0.9-1.0	0.6-0.7	0.8-0.9
Sugarcane	0.4-0.5	0.7-1.0	1.0-1.3	0.75-0.8	0.5-0.6	0.85-1.05
Sunflower	0.3-0.4	0.7-0.8	1.05-1.2	0.7-0.8	0.35-0.45	0.75-0.85
Tobacco	0.3-0.4	0.7-0.8	1.0-1.2	0.9-1.0	0.75-0.85	0.85-0.95
Tomato	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.95	0.6-0.65	0.75-0.9
Watermelon	0.4-0.5	0.7-0.8	0.95-1.05	0.8-0.9	0.65-0.75	0.75-0.85
Wheat	0.3-0.4	0.7-0.8	.05-1.2	0.65-0.75	0.2-0.25	0.8-0.9
Alfalfa	0.3-0.4				1.05-1.2	0.85-1.05
Citrus						
clean weeding						0.65-0.75
no weed control						0.85-0.9
Olive						0.4-0.6

First figure : Under high humidity (RHmin > 70%) and low wind (U < 5 m/sec).
Second figure : Under low humidity (RHmin < 20%) and strong wind (> 5 m/sec).

From FAO Irrigation and Drainage Paper 33, Table 18.

3. CROP COEFFICIENTS PERENNIAL CROPS

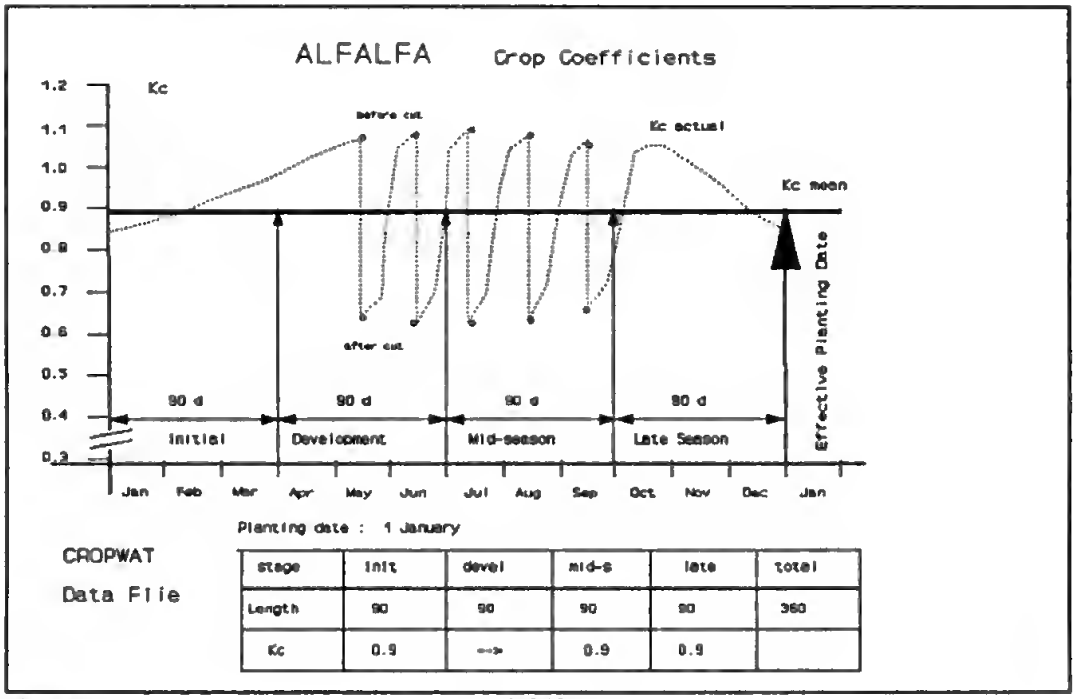


Figure A.1 **Alfalfa**

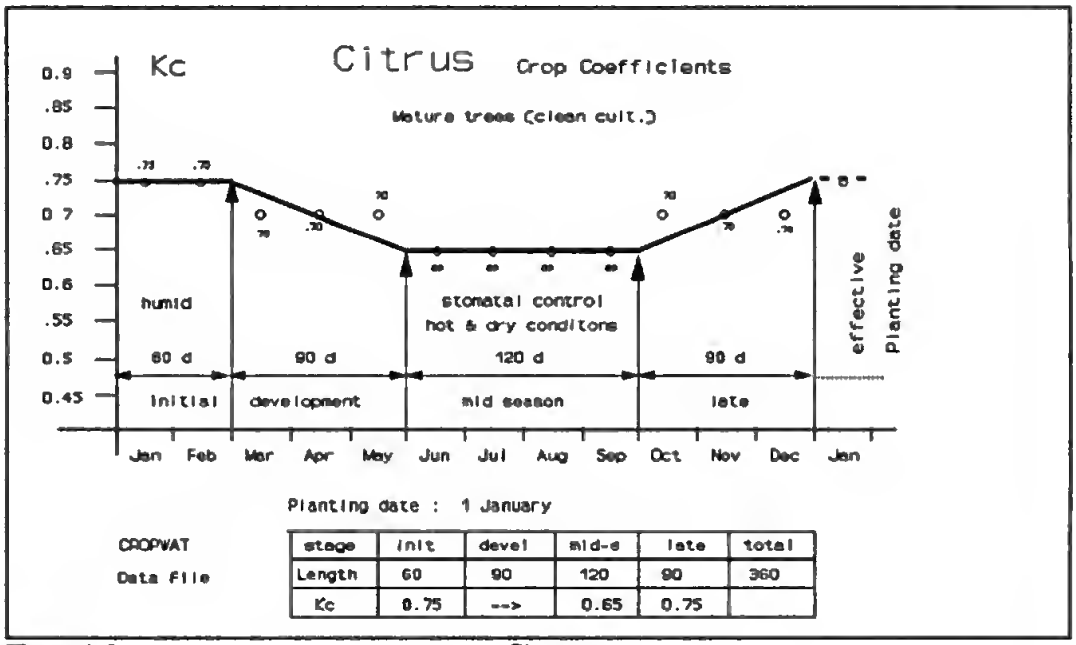


Figure A.2 **Citrus**

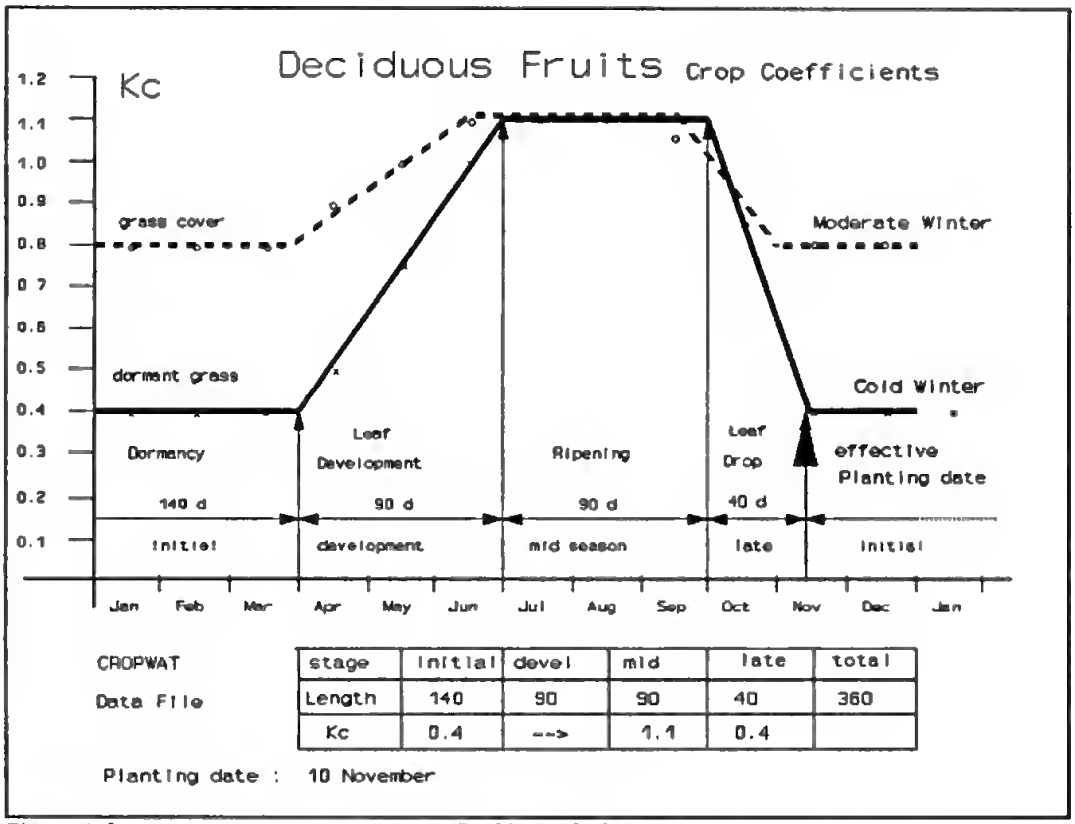


Figure A.3 **Deciduous fruit**

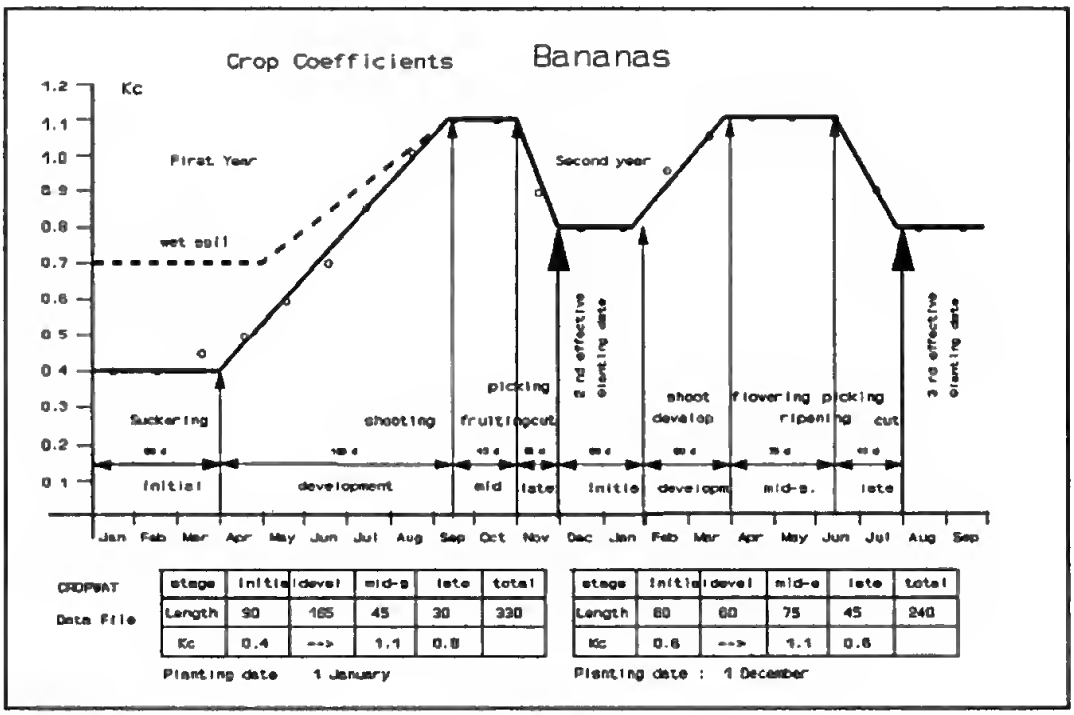


Figure A.4 **Banana**

4. SOIL WATER DEPLETION FRACTION

CROP GROUPS ACCORDING TO SOIL WATER DEPLETION

Group	Crops
1	onion, pepper, potato
2	banana, cabbage, grape, pea, tomato
3	alfalfa, bean, citrus, groundnut, pineapple, sunflower, water melon, wheat
4	cotton, maize. olive, safflower, sorghum, soybean, sugarbeet, sugarcane, tobacco

From FAO Irrigation and Drainage Paper 33, Table 19.

SOIL WATER DEPLETION FRACTION (p) FOR CROP CROPS AND MAXIMUM EVAPOTRANSPIRATION (ETm)

Crop Group	ETm mm/day								
	2	3	4	5	6	7	8	9	10
1	0.50	0.425	0.35	0.30	0.25	0.225	0.20	0.20	0.175
2	0.675	0.575	0.475	0.40	0.35	0.325	0.275	0.25	0.225
3	0.80	0.70	0.60	0.50	0.45	0.425	0.375	0.35	0.30
4	0.875	0.80	0.70	0.60	0.55	0.50	0.45	0.425	0.40

From FAO Irrigation and Drainage Paper 33, Table 20.

5. READILY AVAILABLE SOIL MOISTURE

GENERALIZED DATA ON ROOTING DEPTH OF FULL GROWN CROPS, FRACTION OF AVAILABLE SOIL WATER (p) AND READILY AVAILABLE SOIL WATER (p.Sa) FOR DIFFERENT SOIL TYPES (in mm/m soil depth) WHEN ETcrop is 5-6 mm/day

Crop	Rooting depth (d) m	Fraction (p) of available soil water[1]	Readily available soil water (p.Sa) mm/m[1]		
			fine	medium	coarse
Alfalfa	1.0-2.0	0.55	110	75	35
Banana	0.5-0.9	0.35	70	50	20
Barley[2]	1.0-1.5	0.55	110	75	35
Beans[2]	0.5-0.7	0.45	90	65	30
Beets	0.6-1.0	0.5	100	70	35
Cabbage	0.4-0.5	0.45	90	65	30
Carrots	0.5-1.0	0.35	70	50	20
Celery	0.3-0.5	0.2	40	25	10
Citrus	1.2-1.5	0.5	100	70	30
Clover	0.6-0.9	0.35	70	50	20
Cacao		0.2	40	30	15
Cotton	1.0-1.7	0.65	130	90	40
Cucumber	0.7-1.2	0.5	100	70	30
Dates	1.5-2.5	0.5	100	70	30
Dec. orchards	1.0-2.0	0.5	100	70	30
Flax[2]	1.0-1.5	0.5	100	70	30
Grains small[2]	0.9-1.5	0.6	120	80	40
winter[2]	1.5-2.0	0.6	120	80	40
Grapes	1.0-2.0	0.35	70	50	20
Grass	0.5-1.5	0.5	100	70	30
Groundnuts	0.5-1.0	0.4	80	55	25
Lettuce	0.3-0.5	0.3	60	40	20
Maize[2]	1.0-1.7	0.6	120	80	40
silage		0.5	100	70	30
Melons	1.0-1.5	0.35	70	50	25
Olives	1.2-1.7	0.65	130	95	45
Onions	0.3-0.5	0.25	50	35	15
Palm trees	0.7-1.1	0.65	130	90	40
Peas	0.6-1.0	0.35	70	50	25
Peppers	0.5-1.0	0.25	50	35	15
Pineapple	0.3-0.6	0.5	100	65	30
Potatoes	0.4-0.6	0.25	50	30	15
Safflower[2]	1.0-2.0	0.6	120	80	40
Sisal	0.5-1.0	0.8	155	110	50
Sorghum[2]	1.0-2.0	0.55	110	75	35
Soybeans	0.6-1.3	0.5	100	75	35
Spinach	0.3-0.5	0.2	40	30	15
Strawberries	0.2-0.3	0.15	30	20	10
Sugarbeet	0.7-1.2	0.5	100	70	30
Sugarcane[2]	1.2-2.0	0.65	130	90	40
Sunflower[2]	0.8-1.5	0.45	90	60	30
Sweet potatoes	1.0-1.5	0.65	130	90	40
Tobacco early	0.5-1.0	0.35	70	50	25
late		0.65	130	90	40
Tomatoes	0.7-1.5	0.4	180	60	25
Vegetables	0.3-0.6	0.2	40	30	15
Wheat	1.0-1.5	0.55	105	70	35
ripening		0.9	180	130	55
Total available soil water (Sa)			200	140	60

1 When ET_{crop} is 3 mm/day or smaller increase values by some 30%; when ET_{crop} is 8 mm/day or more reduce values by some 30%, assuming non-saline conditions (EC_e < 2 dS/m).

2 Higher values than those shown apply during ripening.

Sources: Taylor (1965), Stuart and Hagan (1972), Salter and Goode (1967), Rijtema (1965) and others.

From FAO Irrigation and Drainage Paper 24, Table 39.

6. YIELD RESPONSE FACTOR (ky)

YIELD RESPONSE FACTOR (ky)

Crop	Vegetative period (1)			Flowering period (2)	Yield formation (3)	Ripening (4)	Total growing period
	early (1a)	late (1b)	total				
Alfalfa			0.7-1.1				0.7-1.1
Banana							1.2-1.35
Bean			0.2	1.1	0.75	0.2	1.15
Cabbage	0.2				0.45	0.6	0.95
Citrus							0.8-1.1
Cotton			0.2	0.5		0.25	0.85
Grape							0.85
Groundnut			0.2	0.8	0.6	0.2	0.7
Maize			0.4	1.5	0.5	0.2	1.25
Onion			0.45		0.8	0.3	1.1
Pea	0.2			0.9	0.7	0.2	1.15
Pepper							1.1
Potato	0.45	0.8			0.7	0.2	1.1
Safflower		0.3		0.55	0.6		0.8
Sorghum			0.2	0.55	0.45	0.2	0.9
Soybean			0.2	0.8	1.0		0.85
Sugarbeet beet sugar							 0.6-1.0 0.7-1.1
Sugarcane			0.75		0.5	0.1	1.2
Sunflower	0.25	0.5		1.0	0.8		0.95
Tobacco	0.2	1.0			0.5		0.9
Tomato			0.4	1.1	0.8	0.4	1.05
Watermelon	0.45	0.7		0.8	0.8	0.3	1.1
Wheat winter spring			 0.2 0.2	 0.6 0.65	 0.5 0.55		 1.0 1.15

From FAO Irrigation and Drainage Paper 33, Table 24.

PART 2

GUIDELINES FOR CROPWAT

1. INTRODUCTION

The guidelines for using CROPWAT are meant as an example for design and management of irrigation schemes, taking the user, with the help of an actual data set, through the different steps required to calculate evapotranspiration and crop water requirements, starting with the collection and processing of input data to the application in scheme water supply and irrigation scheduling.

The guidelines are to be used in combination with the Manual of CROPWAT, which explains how to use the computer program and presents the underlying calculation procedures.

The example set used is taken from the Rajolibanda Diversion Scheme in Andhra Pradesh, India, one of the projects under the National Water Management Project proposed for rehabilitation and introduction of improved irrigation management practices.

2. CALCULATION OF REFERENCE EVAPOTRANSPIRATION

2.1 Introduction

The Reference Evapotranspiration, or ETo, represents the potential evaporation of a well-watered grass crop. The water needs of other crops are directly linked to this climatic parameter.

Several methods exist to determine the Reference Evapotranspiration, such as:

- Blaney-Criddle Method
- Penman Method
- Pan Evaporation Method.

The Penman-Monteith Method has been recommended as the appropriate combination method[t] to determine evapotranspiration from climatic data on:

- temperature
- humidity
- sunshine
- windspeed.

2.2 Data Collection

In order to calculate the reference evapotranspiration (ETo), the respective climatic data should be collected from the nearest and most representative meteorological station. Several institutes and agencies may keep climatic records such as the Irrigation Department, the Meteorological Service or nearby Agricultural Research Station and may provide information on climatic stations inside or in the vicinity of our irrigation scheme which should be considered for the crop water requirement calculations.

In some cases, when the scheme is large, more than one station may be available, but often no suitable stations with sufficient climatic data are located in the scheme. In such a case a careful selection should be made of the data. Figure 1 shows how an interpolation which may be carried out between stations outside and inside the irrigation scheme.

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t For further reference see Report of the Expert Consultation on Review of FAO Methodologies for Crop Water Requirement Calculations, held in May 1990 in Rome.

STATION : Rentachintala LAT. 16° 33' N LONG. 79° 33' E HEIGHT ABOVE M.S.L : 106 metres BASED ON OBSERVATIONS FROM 1931 TO 1960

Month		Station level pressure	Air Temperature										Humidity		Cloud Amount		Rainfall						Mean Wind Speed
			Mean						Extremes								Monthly Total	No. of rainy days	Total in wettest month with year	Total in driest month with year	Heaviest fall in 24 hours	Date and year	
			Dry bulb	Wet bulb	Dly max	Dly min	High in mth	Low in mth	High	Date /year	Low	Date /year	Relative humidity	Vapour pressure	All clouds	Low clouds							
		mb	°C	°C	°C	°C	°C	°C	°C		°C		%	mb	oktas	oktas	mm		mm	mm	mm		km/h
January	I	1003.6	21.7	18.5	31.2	17.3	23.7	14.1	35.0	30	10.6	9	71	18.7	2.5	0.9	0.4	0.1	3.8	9	3.0	1	5.0
	II	999.4	29.8	19.8						1958		1946	33	15.3	2.8	1.5			1948			1948	
February	I	1001.5	24.0	19.9	34.1	19.9	27.4	15.9	39.4	26	12.8	8	67	19.7	2.5	0.9	9.8	0.8	40.9	9	21.3	8	6.5
	II	992.1	33.0	21.0						1959		1949	31	14.5	2.7	1.3			1937			1956	
March	I	999.6	27.1	22.1	37.5	25.0	41.0	19.3	44.4	28	15.6	1	43	22.6	2.2	0.9	6.1	0.4	55.9	9	28.5	28	8.1
	II	994.9	36.2	22.7						1953		1952	28	16.1	2.3	1.1			1944			1950	
April	I	996.8	30.1	24.3	39.6	26.1	43.5	22.1	46.1	30	18.3	9	81	25.8	3.2	1.0	19.6	1.4	106.9	9	69.1	26	8.8
	II	992.0	37.8	25.7						1941		1937	28	17.9	3.6	1.8			1937			1948	
May	I	993.3	32.7	25.4	41.5	28.6	45.2	23.5	47.2	18	18.3	6	55	26.8	4.2	0.8	40.8	2.9	151.6	9	67.3	21	10.4
	II	988.3	39.1	25.3						1948		1955	31	20.6	4.8	2.3			1940			1940	
June	I	991.9	30.7	24.7	37.8	27.9	43.1	23.6	47.2	3	21.7	22	61	26.6	6.5	1.7	86.2	5.9	199.6	10.9	101.6	22	14.5
	II	987.1	36.0	25.4						1953		1947	43	24.0	6.3	3.2			1949	1952		1947	
July	I	992.0	28.5	24.2	34.1	23.3	38.0	22.9	40.6	9	21.7	28	70	27.0	7.0	2.4	115.0	8.9	191.5	50.5	87.6	31	13.3
	II	988.4	32.2	25.0						1952		1956	54	25.6	7.1	3.8			1938	1943		1953	
August	I	993.2	28.4	24.0	33.9	23.6	37.2	22.9	39.4	20	21.7	13	70	26.6	6.6	2.3	114.6	7.8	265.0	23.0	103.0	13	11.8
	II	989.3	32.1	24.9						1950		1958	55	25.3	6.9	3.4			1958	1900		1958	
September	I	994.8	28.0	24.2	33.4	24.8	36.6	22.8	38.3	21	21.3	23	74	27.3	5.9	2.9	146.1	8.1	375.2	40.4	154.9	28	7.9
	II	990.9	30.9	24.7						1946		1958	61	26.1	6.8	5.8			1960	1959		1954	
October	I	998.3	27.0	23.6	32.9	23.2	36.0	19.8	38.1	13	16.7	25	76	26.3	4.0	1.0	125.8	8.9	273.6	27.7	153.2	19	4.8
	II	994.6	30.4	25.7						1957		1950	57	23.6	5.8	2.9			1939	1951		1945	
November	I	1001.7	24.0	20.6	30.8	19.6	33.2	15.5	36.1	6	12.2	26	74	21.0	4.0	1.4	41.1	2.0	133.6	9	71.6	9	4.0
	II	998.0	28.9	21.4						1951		1950	50	19.4	4.4	2.0			1946			1956	
December	I	1003.8	21.4	18.1	29.9	16.8	32.1	13.6	34.4	14	10.0	31	73	18.2	2.9	9.9	13.3	0.7	71.6	9	53.3	11	3.8
	II	999.6	29.6	19.8						1951		1936	41	15.7	3.0	1.3			1952			1952	
Annual total or mean	I	997.5	27.8	22.5	34.7	23.2	45.4	13.0	47.2		10.0		68	24.0	4.4	1.4	717.6	46.7	1009.6	165.8	154.9		8.2
	II	993.3	32.9	23.1									43	20.3	4.7	2.3			1958	1960			
Number of years	I	23	25	23	25	23	25	25	23		23		25	25	23	20	23	25	25	23	23		25
	II	23	23	23									25	23	23	20							

Table 1 Example of climatological data record

In our example, the data for the Rajolibanda Scheme have been obtained from the following sources:

Temperature:	IMS Station, Kurnool (1930-1960)
Sunshine hours:	Airport, Hyderabad
Humidity:	IMS Station, Kurnool
Wind:	IMS Station, Kurnool

The data, together with the calculated ETo, are presented in Table 2.

2.3 Data Conversion

In general, climatic data by the National Meteorological Service are standardized. An example of such a record is given in Table 1 for the Indian Meteorological Service (IMS), which contains all the necessary data on temperature, humidity, sunshine and wind for Penman calculations. Normally some conversions are required in order to adjust the data into the format accepted by CROPWAT. In particular, attention should be given to the units in which the climatic records are given.

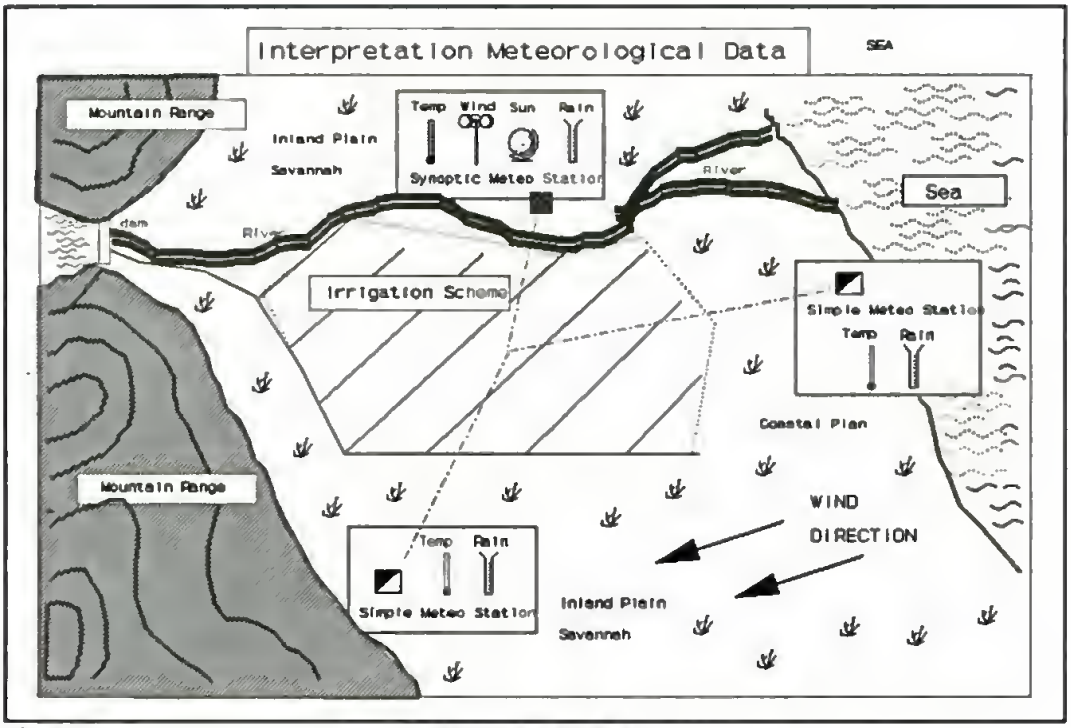

Figure 1 **Meteorological data**

As an example, the following notes for conversion of the climatic data provided by the Indian Meteorological Service (IMS) to the units required for CROPWAT are given.

Temperature data

IMS	:	Mean Daily Maximum and Minimum Temperature
CROPWAT	:	Maximum and Minimum Temperature
Conversion	:	No conversion needed

Humidity data

IMS	:	Relative Humidity (in percent) as well as the Vapour Pressure both for morning and afternoon
CROPWAT	:	Average daily Relative Humidity or Vapour Pressure
Conversion	:	Average of morning and afternoon values of vapour pressure
Comments	:	Vapour pressure rather than Relative Humidity values are taken, as the latter relate to temperature values at sunrise and noon

Sunshine data

IMS	:	Cloudiness in Oktas of sky of All and Low Clouds for morning and noon
CROPWAT	:	Sunshine hours (heliograph) or sunshine percentage
Conversion	:	According to the following relationship:

$$SSP = 0.95 - \frac{LC1 + LC2}{2} + \alpha * \frac{AC1 + AC2}{2}$$

where:
- SSP = sunshine rate (%)
- LC1 = low clouds at sunrise (oktas)
- LC2 = low clouds at noon (oktas)
- AC1 = high clouds at sunrise (oktas)
- AC2 = low clouds at noon (oktas)
- α = empirical parameter ($\approx$ 0.3)

Windspeed data

IMS	:	Average Daily Windrun in km/hour
CROPWAT	:	Average Daily Windspeed in km/day or m/sec
Conversion	:	WS km/day = 24 x WS km/hour

2.4 Climatic Data Input

Input of the climatic data including the information on altitude and latitude of the climatic station are described in the Manual of CROPWAT, para. 4.1. Table 2 shows the data of Kurnool, used for the further calculations in our examples.

2.5 Climatic Data and ETo Output

A printout of calculated ETo results can be made with the connected printer as shown in Table 2.

2.6 Climatic and ETo Data Saving

After checking the data for possible errors, the data set can be SAVED for future use in the crop water requirement calculations (see para. 4.3 in CROPWAT). It is important to give an appropriate name to the data set which can easily be recognized later. In our example, the name KURNOOL, referring to the climate station from which the data has been taken, was used.

Prior to exiting back to the CROPWAT input of rainfall data, you may wish to check the saved data by going back to the DATA INPUT MENU and retrieving the file, saved under the name KURNOOL.

Reference Evapotranspiration ETo according Penman-Monteith

Country : RAJOLIBANDA Meteo Station : KURNOOL
Altitude : 281 meter Coordinates : 16.00 N.L.

Month	AvgTemp °	Humidity %	Windspeed km/day	Sunshine hours	Radiation MJ/m²/day	ETo-PenMon mm/day
January	24.2	51	117	8.1	8.8	3.82
February	26.8	41	132	8.4	10.0	4.85
March	30.0	35	148	7.6	10.9	5.86
April	32.7	37	167	7.3	11.9	6.60
May	33.6	41	257	6.7	11.9	7.64
June	30.3	58	405	5.3	11.2	6.78
July	28.2	66	409	4.9	10.9	5.66
August	27.8	66	353	5.6	11.4	5.50
September	27.6	67	242	6.0	11.3	4.91
October	27.4	64	115	7.2	11.0	4.26
November	25.1	58	98	7.4	9.2	3.64
December	23.5	55	94	7.9	8.4	3.36
YEAR	28.1	53	211	6.9	10.6	1913

Table 2 **Printout - Climatic data and ETo Kurnool**

3. PROCESSING OF RAINFALL DATA

3.1 Introduction

The rainfall contributes to a greater or lesser extent in satisfying the crop water requirements. During the rainy season, a great part of the crop's water needs are covered by rainfall, while during the dry season, the major supply of water should come from irrigation. How much water is coming from rainfall and how much water should be covered by irrigation is, unfortunately, difficult to predict as yearly rainfall varies greatly.

In order to estimate the rainfall deficit for irrigation water requirements, a statistical analysis needs to be made from long-term rainfall records.

In addition to the variability of rainfall from year to year, not all rain which falls is also used by the crop. The intensity of rain may be such that part of the rainfall is lost due to surface runoff or due to deep percolation outside the rootzone.

In order to determine that part of the rainfall which effectively contributes to cover crop water requirements, a number of definitions are first given, while subsequently it is explained how the different rainfall values can be calculated and how they are incorporated in the crop water requirement calculations.

3.2 Rainfall Definitions

Average monthly rainfall:

Mathematically determined average for a series of rainfall records, most commonly available. To be used for CWR calculation to represent average climatic conditions.

Dependable rainfall:

The amount of rainfall which can be depended upon in 1 out of 4 or 5 years corresponding to a 75 or 80% probability of exceedance and representing a dry year. The dependable rainfall (80%) is used for the design of the irrigation system capacity.

Rainfall in wet, normal and dry years:

Defined as the rainfall with a respectively 20, 50 and 80% probability of exceedance, representing a wet, normal and dry year. The three values are useful for the programming of irrigation supply and simulation of irrigation management conditions. The rainfall in normal years (50% probability) is, in general, well approached by the average rainfall.

Historical or actual rainfall data:

The actual recorded rainfall used for evaluation purposes.

Effective rainfall:

Defined as that part of the rainfall which is effectively used by the crop after rainfall losses due to surface run off and deep percolation have been accounted for. The effective rainfall is the rainfall ultimately used to determine the irrigation requirement of the concerned crop.

3.3 Rain Data Collection

The precipitation data required for CROPWAT are monthly rainfall, commonly available from many climatic stations. In addition substations may be found with single rainfall records. For larger schemes, records of several rainfall stations may be available, allowing an analysis of the spatial variability.

To allow a calculation of rainfall probabilities, rainfall records from a range of years (15-30) are to be collected.

Rainfall records of the Rajalibanda Scheme are taken from Uppal Camp and are presented in Table 3.

	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	Ave
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	13	45	0	0	0	0	0	0	5
Mar	0	0	0	0	0	0	0	13	0	0	0	13	2
Apr	0	0	8	13	38	0	20	20	0	0	15	14	10
May	69	8	33	70	87	197	0	0	18	0	0	106	49
Jun	44	89	48	140	103	118	74	56	180	0	66	29	79
Jul	15	201	121	176	144	111	76	112	72	0	128	120	106
Aug	121	110	98	160	266	13	96	101	0	257	14	73	109
Sep	69	139	119	20	272	267	66	290	8	171	42	72	128
Oct	175	384	0	101	0	104	13	43	107	64	77	117	97
Nov	15	23	20	76	29	36	0	18	76	0	8	10	26
Dec	0	0	0	0	13	0	0	0	0	0	8	6	2
Tot	508	954	448	759	964	891	345	654	460	492	362	556	616

Table 3 Monthly rainfall data (1974-1985) Raingauge: Uppal Camp

3.4 Rain Data Processing

For programming of irrigation water supply and management, rainfall data of normal, wet and dry years are normally used.

An estimate of the respective rainfall data can be obtained by computing and plotting probabilities from the rainfall records. The different steps involved are:

i. Tabulate yearly rainfall totals for a given period.
ii. Arrange data in descending order of magnitude.
iii. Tabulate plotting position according to:

$$Fa = 100 * m / (N + 1)$$

where: N = number of records
m = rank number
Fa = plotting position

YEAR	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	
Rain	508	924	448	759	964	891	345	654	460	493	363	558	mm/year
Rank No	7	2	10	4	1	3	12	5	9	8	11	6	
Rank No	1	2	3	4	5	6	7	8	9	10	11	12	
Rain	964	924	891	759	654	559	508	493	460	448	363	345	mm/year
Fa	8	15	23	31	39	46	54	62	69	77	85	92	%

Table 4 Processing rainfall records (Uppal Camp)

iv. Plot values on log-normal probability paper, as shown in Figure 2.

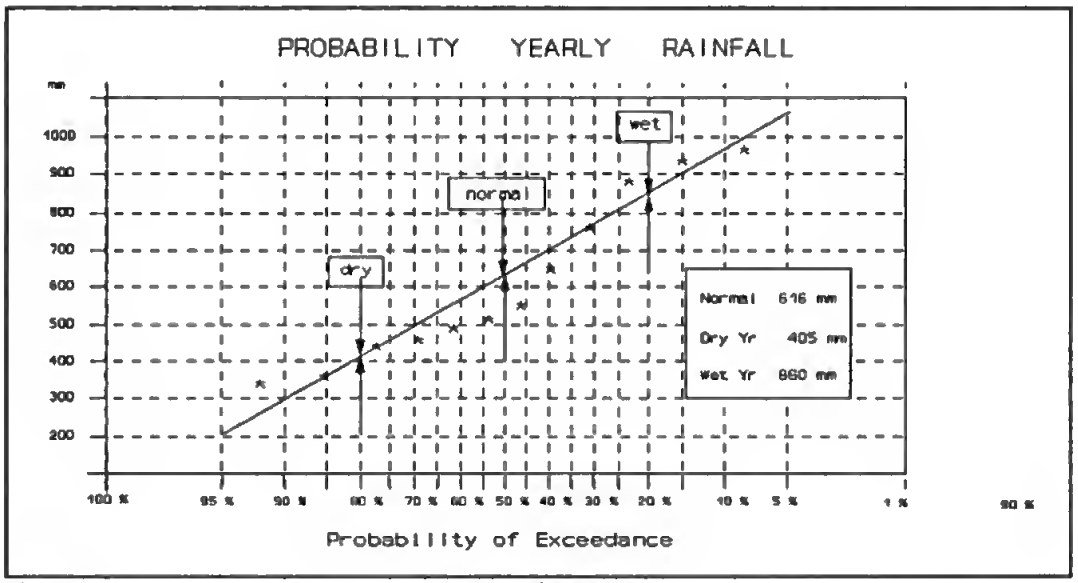

Figure 2 Dependable Rain

v. Select year values at 20, 50 and 80% probability: P80 = 405 mm
P50 = 620
P20 = 860

vi. Determine monthly values for the dry year according to the following relationship:

$$P_{i_{dry}} = P_{i_{av}} * \frac{P_{dry}}{P_{av}}$$

where: $P_{i\,av}$ = average monthly rainfall for month i
$P_{i\,dry}$ = monthly rainfall dry year for month i
P_{av} = average yearly rainfall
P_{dry} = yearly rainfall at 80% probability of exceedance

Similarly values for the wet year can be determined. Results are given in the following table.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
av	0	5	2	10	49	79	106	109	128	97	26	2	616
dry	0	3	1	7	32	52	70	72	84	65	17	2	405
wet	0	7	3	15	68	110	149	153	179	136	37	3	860

3.5 Effective Rainfall Method

To account for the losses due to runoff or percolation losses a choice can be made of one of the four methods given in CROPWAT.

In general, the efficiency of rainfall will decrease with increasing rainfall. For most rainfall values below 100 mm/month, the efficiency will be approximately 80%. It is therefore suggested to select Option 1 and give 80% as requested value.

In the water balance calculations included in the irrigation scheduling part of CROPWAT, a possibility exists to evaluate actual Efficiency values for different crops and soil conditions.

3.6 Rain Data Input

The input of rainfall data of the dry, normal and wet years for the CWR calculation with CROPWAT can be carried out as follows:

i. Choose option 2 in Main Menu CROPWAT "CWR Calculations".
ii. Choose option 3 in Input Menu "Climatic Data".
iii. Choose option 2 in Input Menu ETo data.
iv. Select ETo file of KURNOOL.
v. Proceed to Rainfall Input.
vi. Type rainfall data of concerned year and check input.
vii. Choose effective rainfall method (option 1).
viii. Check data and save data on diskette with appropriate name.

ix. Return to input menu climate data by responding:

- N(o) on CROPWAT question: "Revise Climatic Data"
- N(o) on CROPWAT question :"Revise Eff. Rainfall method"

x. Continue with step i for input climatic data of Dry and Wet year.

3.7 Saving Climatic Data

The rainfall data together with the ETo data should be saved after input of one set of data is completed.

The naming of the file should adequately reflect the type of rainfall and ETo data.

In our case, the following files are saved:

KURN-AV: for average ETo from Kurnool and average rainfall data
KURN-NOR: for average ETo data from Kurnool and rainfall data in a normal year (50%)
KURN-WET: for average ETo data and precipitation data of a year with rainfall of 20% probability of exceedance
KURN-DRY: for average ETo data and precipitation data of a year with rainfall of 80% probability of exceedance

3.8 Printout of Climatic Data

Table 5 shows a printout of the average climatic data file of KURNOOL (KURN-AV). The climatic files of KURN-NOR, KURN-WET and KURN-DRY are included in Appendix 1.

Climate file : kurn-av **Climate Station : KURNOOL**

	ETo (mm/day)	Rainfall (mm/month)	Eff. Rain (mm/month)
January	3.8	0.0	0.0
February	4.9	5.0	4.0
March	5.9	2.0	1.6
April	6.6	11.0	8.8
May	7.6	49.0	39.2
June	6.8	79.0	63.2
July	5.7	106.0	84.8
August	5.5	109.0	87.2
September	4.9	128.0	102.4
October	4.3	99.0	79.2
November	3.6	26.0	20.8
December	3.4	2.0	1.6
YEAR Total	1912.8	616.0	492.8 mm

Effective Rainfall: 80%

Table 5 Printout - Average climatic data Kurnool

4. CROPPING PATTERN AND CROP INFORMATION

4.1 Introduction

To determine the irrigation requirements of the Rajolibanda Diversion Scheme, an assessment should be made of the different crops grown under irrigation presently and possibly in the future. Furthermore, information on the various crop characteristics such as length of the growth cycle, crop factors, rooting depth, etc., should be collected.

4.2 Data Collection

A local survey should be carried out in the irrigation scheme to assess the crops grown rainfed as well as under irrigation. Through field observations, interviews with extension agents and farmers and additional information from other agencies, for instance a revenue department, an assessment can be made of the present cropping pattern.

Essential information collected from the field should include:

1. Crop and crop variety.
2. First and last planting date.
3. First and last harvesting date.

Additional information may include:

4. Indicative yield level.
5. Indicative irrigation practices:
   - field irrigation methods
   - irrigation frequencies and interval
   - irrigation application depths.

From the Agricultural Research Station, more accurate information may be collected on:

6. Crop characteristics:
   - length of individual growth stages
   - crop factors, relating crop evapotranspiration to grass evaporation
   - rooting depth
   - allowable depletion levels
   - yield response factors.

4.3 Cropping Pattern

The collected information on the planting and harvest dates should be systematically arranged in a cropping pattern.

The planting date of crops, in particular those which cover substantial areas or are high in water demands such as rice, may be spread over a period of 3-6 weeks. In such cases the crop may be subdivided into different crop units with planting date intervals of 10-15 days.

Table 6 provides an example of the different crop information to be collected for each crop and crop type necessary for the data input in CROPWAT. Figure 3 illustrates a possible distribution of crops over the year and over the irrigated area.

CROPPING PATTERN

Project : Rajolibanda Climatic Station : KURNOOL

No.	CROP	Area %	Planting dates	Harvest dates
1	PADDY	13	10 July	10 Nov
2	PADDY	12	20 July	20 Nov
3	PADDY	13	1 Aug	1 Dec
4	PADDY	12	10 Aug	10 Dec
5	PADDY	7	10 Dec	10 Apr
6	PADDY	6	20 Dec	20 Apr
7	PADDY	7	1 Jan	1 May
8	COTTON	15	1 Aug	1 Feb
9	GROUNDNUT	6	15 July	5 Nov
10	GROUNDNUT	7	1 Aug	20 Nov
11	GROUNDNUT	7	15 Aug	5 Dec
12	GROUNDNUT	20	15 Dec	5 Apr
13	GROUNDNUT	20	1 Jan	20 Apr
14	GROUNDNUT	20	15 Jan	5 May
15	SORGHUM	5	15 July	15 Nov
16	SORGHUM	5	1 Aug	1 Dec
17	SUGARCANE	5	1 Jan	1 Jan

Table 6 **Printout - Cropping pattern**

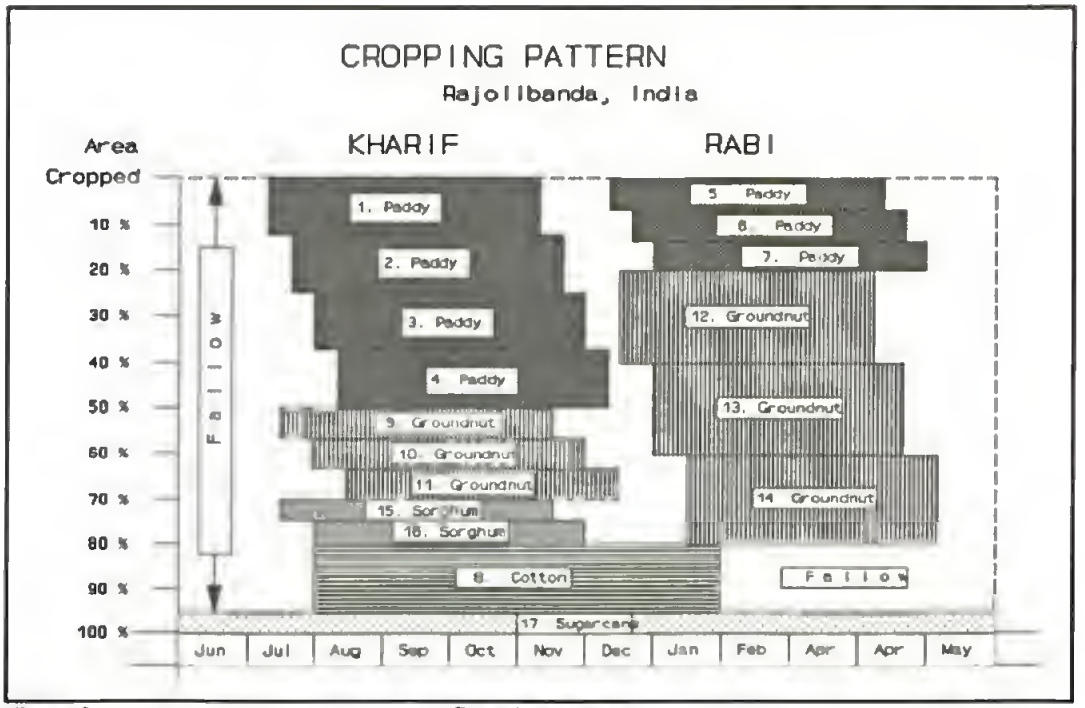

Figure 3 **Cropping pattern**

4.4 Crop Data Input

With the help of the data collected in the cropping pattern, the different crop files containing the necessary information for the CWR calculations can now be made. Insofar as the local data collected do not contain sufficient information on the different crop characteristics, the Tables in Annex 1 of the CROPWAT Manual may be consulted.

The sequence of steps for the Crop Data Input in CROPWAT (see chapter 5.2 of the Manual) is as follows:

i. In Crop Data Input Menu choose Option 1 New Data Input.

ii. Give crop name and crop type identification.

For instance Cropname: Paddy(Kharif), and type in the requested length of growth stage and crop factors for each development stage.

iii. Continue with data input for irrigation scheduling with inputs on rooting depth, allowable depletion and yield response factors.

iv. If connected to printer, a printout can be made of the summarized crop data as shown in Tables 7 and 8 for paddy and groundnut:

RICE DATA INPUT

Crop : PADDY

Growth period		Length	Stage	Crop coefficient
Nursery	(NUR)	30	days	1.20
Land preparation	(LP)	20	days	—
Initial Stage	(A)	20	days	1.10
Developm. Stage	(B)	30	days	—
Mid-season	(C)	40	days	1.05
Late Season	(D)	30	days	0.80
Total		150	days	
Nursery Area		10	%	
Land cultivation		180	mm	
Percolation rate		3.0	mm/day	

Table 7 Printout - Crop data Paddy

v. Make sure the data are adequately saved on the disk under an adequate and systematic file name convention, for instance:

for paddy in kharif season: **R-PADKH**

for groundnuts in rabi season: **R-GRNDNR**

NOTE: file name can only be eight characters long and cannot contain any spaces, points or commas.

CROP DATA

Crop : GROUNDNUT/RABI Crop file : grondnut

Growth Stage		Init	Devel	Mid	Late	Total
Crop Stage	[days]	20	30	35	25	110
Crop Coefficient	[coeff.]	0.20	-->	1.00	0.70	
Rooting Depth	[meter]	0.30	-->	0.80	0.80	
Depletion level	[fract.]	0.50	-->	0.50	0.50	
Yield-response F.	[coeff.]	0.40	0.60	1.00	0.80	0.80

Table 8 **Printout - Crop data Groundnut**

vi. Proceed to data input of next crop by responding Y(es) to:

< Input of another crop (Y/N) : N >

which returns the program to the Crop Data Input Menu.

5. CROP WATER REQUIREMENT CALCULATIONS

5.1 File Input

Calculation of the crop water requirements can be carried out by calling up successively the appropriate climate data set, the various crop files and the corresponding planting dates.

In our Rajolibanda project the following sequence is followed:

Climate files:
1. KURN-NOR - representing normal year
2. KURN-DRY - representing a dry year
3. KURN-WET - representing a wet year

Crop files:
1. R-PADDYK - Kharif Paddy
2. R-PADDYR - Rabi Paddy
3. R-COTTON - Kharif Cotton
4. R-GRNDNK - Kharif Groundnuts
5. R-GRNDNR - Rabi Groundnuts
6. R-SORGHK - Kharif Sorghum
7. R-SORGHR - Rabi Sorghum
8. R-SUGARC - Annual Sugarcane

(Trans)planting dates:

Paddy Kharif:	1.	10 July
	2.	20 July
	3.	1 August
	4.	10 August
Rabi:	5.	10 December
	6.	20 December
	7.	1 January
Cotton:	8.	1 August

Groundnut Kharif:	9.	15 July
	10.	1 August
	11.	15 August
	12.	15 December
	13.	1 January
	14.	15 January
Sorghum:	15.	15 July
	16.	1 August
Sugarcane:	17.	1 January (perennial)

For the input of the different files and the subsequent CWR calculations of each crop, the following steps are taken within the CROPWAT program:

i. From the CROPWAT Main Menu Option 2 the CWR Calculation is called up.

ii. From the Climate Data Input Option 2 is chosen for input of the files from disk. The climatic data records are presented on screen and data can be checked and possibly modified.

iii. From the Crop Data Input Menu Option 2 "Input from Disk" is chosen, also here data are presented on screen to be checked and possibly modified.

iv. For the input of the planting date the respective dates are given, the harvest date provides a check on the correct length of the growing season.

5.2 CWR Calculations

After input of the respective climate and crop files and planting dates, CROPWAT presents, in tabular form, the results of the calculations. A printout can be made of each of the CWR calculations as shown in Tables 9 and 10.

Irr. Req. of PADDY, transplanted 20 July for Climate : kurn-av

Month	Dec	Stage	Area %	Coeff	ETCrop mm/day	Perc mm/dy	LPrep mm/dy	RiceRq mm/dy	EffRain mm/dec	IRReq mm/dy	IRReq mm/dc
Jun	3	NUR	0.10	1.20	0.77	0.3	1.8	2.9	2.3	2.63	26.3
Jul	1	LP	0.33	1.18	2.28	1.0	8.1	11.4	8.4	10.51	105.1
Jul	2	LP	0.78	1.13	4.85	2.3	8.1	15.3	21.9	13.08	130.8
Jul	3	A	1.00	1.10	6.09	3.0	0.0	9.1	28.5	6.24	62.4
Aug	1	A	1.00	1.10	6.11	3.0	0.0	9.1	28.8	6.23	62.3
Aug	2	B	1.00	1.09	6.00	3.0	0.0	9.0	29.1	6.10	61.0
Aug	3	B	1.00	1.07	5.70	3.0	0.0	8.7	30.8	5.63	56.3
Sep	1	B	1.00	1.06	5.40	3.0	0.0	8.4	33.1	5.09	50.9
Sep	2	C	1.00	1.05	5.16	3.0	0.0	8.2	35.1	4.64	46.4
Sep	3	C	1.00	1.05	4.93	3.0	0.0	7.9	32.2	4.71	47.1
Oct	1	C	1.00	1.05	4.70	3.0	0.0	7.7	30.0	4.70	47.0
Oct	2	C	1.00	1.05	4.47	3.0	0.0	7.5	27.4	4.73	47.3
Oct	3	D	1.00	1.01	4.09	2.5	0.0	6.6	20.6	4.53	45.3
Nov	1	D	1.00	0.92	3.56	1.8	0.0	5.3	13.1	4.00	40.0
Nov	2	D	1.00	0.84	3.06	0.9	0.0	3.9	5.9	3.35	33.5
Totals					672	357	180	1209	347		862

Table 9 Printout - Crop water requirements paddy (20 July)

Crop Evapotranspiration and Irrigation Requirements

Climate File : kurn-av Climate Station : KURNOOL
Crop : GROUNDNUT/RAB1 Planting date : 15 December

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Dec	2	init	0.20	0.67	3.4	0.3	0.62	3.1
Dec	3	init	0.20	0.70	7.0	0.4	0.67	6.7
Jan	1	in/de	0.27	0.98	9.8	0.2	0.96	9.6
Jan	2	deve	0.47	1.78	17.8	0.0	1.78	17.8
Jan	3	deve	0.73	3.05	30.5	0.4	3.01	30.1
Feb	1	de/mi	0.93	4.21	42.1	0.9	4.12	41.2
Feb	2	mid	1.00	4.85	48.5	1.3	4.72	47.2
Feb	3	mid	1.00	5.19	51.9	1.1	5.08	50.8
Mar	1	mid	1.00	5.52	55.2	0.8	5.44	54.4
Mar	2	late	0.94	5.51	55.1	0.5	5.46	54.6
Mar	3	late	0.82	5.01	50.1	1.3	4.87	48.7
Apr	1	late	0.70	4.45	22.2	1.1	4.23	21.2
TOTAL					393.6	8.3		385.3

Table 10 Printout - Crop water requirements Groundnut (15 December)

5.3 CWR Field Files

To allow the calculation of scheme irrigation requirements and to evaluate the effect of changes in the cropping pattern, each CWR calculation should be saved on a so-called "field file".

Each field file should receive an appropriate file name, chosen such that it is easily identified. As the CWR calculation is different for each climate, crop and planting date, naming of the files is somewhat complex and the following codification is therefore proposed: (Reference: CROPWAT 5.3.3.)

1. Scheme Identification: 1st letter code:
   R identifies the Rajolibanda scheme.

2. Climate Type Ident: 2nd letter code:
   N, D, W identifies the climate type (normal, dry, wet, average).

3. Crop Identification: a 2-letter code
   PD = Paddy
   GN = Groundnut
   CT = Cotton
   SO = Sorghum
   SC = Sugarcane

4. Planting Date: 3-letter code
   01-12: January - December
   1-3: 1st - 3rd decade

The automatic sorting of the data files which is invoked every time CROPWAT is exited will group the different field files according to Scheme, Climate and Crop together, which will facilitate the selection of the files, for scheme water requirements. A typical CWR field file is thus:

RN-PD072 for the CWR of a paddy crop (PD), planted in a normal year (N) in the Rajolibanda Scheme (R), planted in July (07), tenth (2nd decade).

Below a printout of the different field files generated for our cropping pattern and alphabetically sorted is given:

```
                    Input Cropping Pattern

  Compose from field files the desired cropping pattern

  The following files are on the data disk:
 ==========================================

  RN-CT081 FLD     RN-GR011 FLD     RN-GR081 FLD     RN-GR082 FLD
  RN-GR122 FLD     RN-PD072 FLD     RN-PD073 FLD     RN-PD081 FLD
  RN-PD082 FLD     RN-PD122 FLD     RN-PD123 FLD     RN-SC011 FLD
  RN-SG072 FLD     RN-SG081 FLD
 ==========================================

  Enter NAME of Field file No. 1 : rn-ct081

  Give area COTTON in % ? 20

       Do you want to continue with next field file (Y/N) ? Y
```

Table 11 Input field files Rajolibanda for cropping pattern

5.4 Summary of CWR Calculations

A summary of the results of the different CWR calculation for our cropping pattern is given in the following table. Results of the individual calculations are given in Appendix 3.

CROPPING PATTERN

Project : Rajolibanda Climatic Station : KURNOOL

No.	CROP	Area %	Plant. date	Harvest date	ETCrop mm	EfRain mm	S.Eff. %	Yld.Red. %
1	PADDY	13	10 7	10 11	696.9	366.7	100	0
2	PADDY	12	20 7	20 11	671.7	347.3	100	0
3	PADDY	13	1 8	1 12	648.9	324.1	100	0
4	PADDY	12	10 8	10 12	626.5	298.2	100	0
5	PADDY	7	10 12	10 4	628.5	13.3	100	0
6	PADDY	6	20 12	20 4	660.7	13.6	100	0
7	PADDY	7	1 1	1 5	863.4	17.5	100	0
8	COTTON	15	1 8	1 2	597.4	294.0	100	0
9	GROUNDNUT	6	15 7	5 11	530.1	288.8	100	0
10	GROUNDNUT/	7	1 8	20 11	385.8	286.1	100	0
11	GROUNDNUT/	7	15 8	5 12	361.7	248.0	100	0
12	GROUNDNUT/	20	15 12	5 4	393.6	8.3	100	0
13	GROUNDNUT/	20	1 1	20 4	428.9	11.6	100	0
14	GROUNDNUT	20	15 1	5 5	609.6	24.5	100	0
15	SORGHUM	5	15 7	15 11	461.5	325.8	100	0
16	SORGHUM	5	1 8	1 12	436.2	290.2	100	0
17	SUGARCANE	5	1 1	1 1	1794.3	495.5	100	0

Table 12 Printout of crop water requirements

6. SCHEME AND CANAL WATER REQUIREMENTS

6.1 Calculation Procedures

The irrigation supply to any irrigation scheme or canal command area can be calculated by adding up the requirements of each crop area, as calculated and saved in our field files.

Any changes in cropping pattern can be conveniently calculated by modifying area size of the different field files.

Similarly, the irrigation supply for each canal unit can be determined.

SCHEME IRRIGATION REQUIREMENTS

Project : Climatic Station : KURNOOL

No	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
1	-	-	-	-	-	4.5	8.7	5.9	4.8	4.t	0.9	-	
2	-	-	-	-	-	0.9	9.9	6.0	4.8	4.7	2.5	-	
3	-	-	-	-	-	-	8.6	6.0	4.9	4.9	4.3	-	
4	-	-	-	-	-	-	4.2	8.3	4.9	4.9	5.3	1.2	
5	7.2	8.0	8.1	2.0	-	-	-	-	-	-	4.3	8.9	
6	7.2	8.0	8.8	4.5	-	-	-	-	-	-	0.8	10.2	
7	8.0	9.3	10.6	8.7	2.8	-	-	-	-	-	-	9.1	
8	2.8	-	-	-	-	-	-	-	0.1	1.7	3.3	3.5	
9	-	-	-	-	-	-	0.7	1.7	3.0	2.5	0.7	-	
10	-	-	-	-	-	-	-	-	0.9	1.6	1.4	-	
11	-	-	-	-	-	-	-	-	0.2	1.6	2.6	0.7	
12	1.9	4.6	5.3	1.4	-	-	-	-	-	-	-	0.4	
13	0.9	3.9	5.7	3.4	-	-	-	-	-	-	-	-	
14	1.0	3.0	7.1	7.1	1.8	-	-	-	-	-	-	1.5	
15	-	-	-	-	-	-	-	0.4	1.9	1.9	0.9	-	
16	-	-	-	-	-	-	-	-	0.9	2.3	2.3	-	
17	3.7	4.5	5.5	5.9	5.9	4.3	2.6	2.2	1.3	1.5	2.7	3.2	
SQ	2.9	4.2	5.7	3.7	0.8	0.9	4.1	3.5	2.9	3.2	3.1	3.2	mm/d
SQ	86	127	172	111	25	27	123	105	87	97	93	95	mm/m
SQ	0.33	0.49	0.66	0.43	0.10	0.10	0.48	0.41	0.34	0.37	0.36	0.37	l/s/h
Ar	100.3	85.3	85.3	58.5	13.9	17.5	54.8	64.3	85.3	100.0	86.3	80.1	%
AQ	0.33	0.58	0.78	0.73	0.70	0.59	0.87	0.63	0.39	0.37	0.41	0.46	l/s/h

Table 13 Printout - Scheme water requirements Rajolibanda

SQ1 : Net irrigation supply (mm/day)
SQ2 : Net irrigation supply (mm/month)
SQ3 : Net irrigation supply (l/s/ha)

AR : Irrigated area (%)
AQ : Net irrigation supply for irrigated area (l/s/ha)

The scheme requirement calculations in CROPWAT are initiated from the main menu by selecting option 4 "Scheme Supply".

6.2 Field File Input

The input of the different field files should be made on the basis of the earlier determined cropping pattern and planting dates.

Each crop planted will be allocated an area size according to the present or a proposed cropping pattern.

An overview of the cropping pattern with crops, area, planting and harvest dates and water requirements is provided in Table 12.

6.3 Scheme Water Requirements (SWR) Results

A printout of the scheme water requirements is shown in Table 13.

6.4 Evaluation of SWR Results

The results of the scheme water requirements for the given cropping pattern can now be compared with the available supply from the diversion at the anicut or reservoir.

Average monthly discharge of the Rajolibanda main canal (average over 1975-1985 period) is shown in the following table and compared with the calculated scheme requirements based on our schematic cropping pattern, and taking into account a 50% efficiency.

	KHARIF						
	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Actual Supply	5.8	26.3	35.4	36.2	39.6	38.5	181.8 MCM
Net SWR	27.0	123.0	105.0	87.0	97.0	93.0	532.0 mm
Irr. Eff.	50%	50%	50%	50%	50%	50%	%
Gross SWR	54.0	246.0	210.0	174.0	194.0	186.0	1064.0 mm
Irr. Area	10000	10000	10000	10000	10000	10000	HA
Supply Req.	5.4	24.6	21.0	17.4	19.4	18.6	106.4 MCM
Requir./Supply	93%	94%	59%	48%	49%	48%	59%

Table 14 Evaluation scheme water supply Kharif season

The ratio estimated scheme requirements and actual supply (average of 10 years) gives some interesting information on efficiency of supply and may provide indications for further adjustments in the cropping pattern and scheme water supply.

	RABI						
	DEC	JAN	FEB	MAR	APR	MAY	TOTAL
Actual Supply	35.4	34.9	31.2	35.8	30.0	1.1	168.4 MCM
Net SWR	95.0	86.0	127.0	172.0	111.0	25.0	616.0 mm
Irr. Eff.	50%	50%	50%	50%	50%	50%	%
Gross SWR	190.0	172.0	254.0	344.0	222.0	50.0	1232.0 mm
Irr. Area	10000	10000	10000	10000	10000	10000	HA
Supply Req.	19.0	17.2	25.4	34.4	22.2	5.0	123.2 MCM
Requir./Supply	54%	49%	81%	96%	74%	455%	73%

Table 15 Evaluation scheme water supply Rabi season

7. IRRIGATION SCHEDULING

7.1 Introduction

An important element of CROPWAT is the irrigation scheduling program, which has several application possibilities:

i. to develop indicative irrigation schedules:
   - for the agricultural extension service to promote better irrigation practices
   - for the irrigation service to establish improved rotational delivery schedules;

ii. to evaluate existing irrigation practices on water use efficiency and water stress conditions;

iii. to evaluate crop production under rainfed conditions, to assess feasibility of supplementary irrigation and to develop appropriate irrigation schedules;

iv. to develop alternative water delivery schedules under restricted water supply conditions.

The calculations of the scheduling program are based on a soil water budget, where, on a daily basis, the soil moisture status is determined, accounting for all ingoing and outgoing water in the root zone.

We will see using our example from the Rajolibanda scheme how the different applications are worked out.

7.2 Data Input

The data required for the water balance equation are:

i. Crop water requirements, as calculated from climatic data (ETo) and crop data (Kc, length of growth stages) representing uptake of water from the root zone by the crop;

ii. Rainfall, provided with the input of climatic data;

iii. Crop data, rooting depth, allowable depletion and yield response factors as provided earlier with the input of crop data;

iv. Soil data, information on the total available soil moisture content is required for the water balance calculations.

7.2.1 Soil data collection

Information from the soil surveys carried out in the Rajolibanda area show two distinct soil categories:

i. sandy loams, red loams and silty loams covering 21% of the command area, relatively shallow and free-draining, particularly suitable for upland crops;

ii. black clay soils, covering 77%, deep but poorly drained, suitable mainly for paddy and deep rooting crops like cotton.

No exact information on available soil moisture content of either of the two soils is available. A reasonable estimate seems:

- 140 mm/m for Red Sandy Loams
- 200 mm/m for Black Clay Soils

7.2.2 Soil data input

The soil information on available soil moisture content can accordingly be provided to the CROPWAT scheduling program and saved for later reference.

7.3 Irrigation Scheduling Applications

To illustrate the different applications of the scheduling program, we will subsequently work out four examples:

7.3.1 Development of indicative irrigation schedule

Objective:

To determine the irrigation water supply for a given crop in terms of frequency and irrigation depth, assuring optimal crop growth and efficient water use.

Conditions:

The irrigation schedule should meet the requirements of the field irrigation method practised and the operational criteria of the irrigation system (Warabandi). Furthermore, the validity of the schedule for different soil types and for variable rainfall conditions should be assessed.

Required data and information:

The essential information required for the development of an indicative schedule is given below for two crops:

1.	Crop:	Groundnut
	Planting date:	1 November
	Climate:	Kurnool Normal, Wet and Dry Years
	Soil:	Red Sandy Loam (140 mm/m)
	Irrigation method:	Furrow irrigation
	Net application:	40-50 mm
	Irrigation supply:	Warabandi system with fixed rotational interval period
2.	Crop:	Cotton
	Planting date:	1 August
	Climate:	Kurnool Normal, Wet and Dry Years (ET_o and Rain)
	Soil:	Black Clay Soil (200 mm/m)
	Irrigation method:	Basin irrigation
	Net application:	70-80 mm
	Irrigation supply:	Warabandi system with fixed rotational interval period

Scheduling procedures:

In order to develop the irrigation schedule which would fit our requirements, an interactive procedure is followed in which several runs are made with different timing and application options. Reference is made to chapter 7 of Part 1 which describes the input procedures.

The results of each run will be evaluated providing the information for the next option. A printout of each run is given in Appendix 4.1 with summarized results given in Table 17. An example of the printout of an irrigation schedule developed for groundnut is given in Table 16. The different runs provide an indication of the criteria which are evaluated and used for the next run.

IRRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Sandy Loam	Available Soilmoist	: 140 mm/m
		Initial Soilmoist	: 140 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/ 40 / 50 / 60 / 70 / 80 / 90 /100
Application : Fixed Irrigation depth of 45 mm

Field Application Efficiency 70%

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	40	25 Jan	B	53	100	100	45.0	7.0	0.0	64.3	0.19
2	10	5 Feb	B	38	100	100	45.0	0.0	2.6	64.3	0.74
3	10	15 Feb	C	39	100	100	45.0	0.0	1.1	64.3	0.74
4	10	25 Feb	C	43	100	100	45.0	3.7	0.0	64.3	0.74
5	10	5 Mar	C	50	100	100	45.0	11.1	0.0	64.3	0.74
6	10	15 Mar	D	58	93	99	45.0	20.0	0.0	64.3	0.74
7	10	25 Mar	D	62	82	97	45.0	25.0	0.0	64.3	0.74
END	11	6 Apr	D	62	83	97					

Total Gross Irrigation	450.0 mm	Total Rainfall	10.0 mm
Total Net Irrigation	315.0 mm	Effective Rain	10.0 mm
Total Irrigation Losses	3.7 mm	Total Rain Loss	0.0 mm
Moist Deficit at harvest	69.1 mm		
Net Supply + Soil retention	384.1 mm		
Actual Water use by crop	390.4 mm	Actual Irr.Req	380.4 mm
Potential Water use by crop	393.6 mm		
Efficiency Irr. Schedule	98.8 %	Efficiency Rain	100.0%
Deficiency Irr. Schedule	0.8 %		

YIELD REDUCTIONS Stage	A	B	C	D	Season	
Reductions in ETC	0.0	0.0	0.0	2.5	0.8	%
Yield Response factor	0.40	0.60	1.00	0.80	0.80	
Reductions in Yield	0.0	0.0	0.0	2.0	0.6	%
Cumulative Yield reduct.	0.0	0.0	0.0	2.0		%

Table 16 **Printout - Selected irrigation schedule for groundnut**

For groundnut, the following sequence of runs is made:

Run 1

Timing Option: (2) Irrigation at critical soil moisture content
Application Option: (2) Refill to field capacity
Evaluation Criteria: - Interval variance (16-11 days)
- Application variance (49-60 mm)

Run 2

Timing Option: (5) Irrigation after after fixed depletion soil moisture (40 mm)
Application Option: (4) Refill of fixed application depth (40 mm)
Evaluation Criteria: - Interval variance (13-7 days)

Run 3-5

Timing Option:	(4) Irrigation at various fixed intervals (7 days - 10 days)
Application Option:	(4) Refill of fixed application depth (40-45 mm)
Evaluation Criteria:	- Irrigation efficiency (61-72%) - Eventual yield reduction (0 - 10 - 2%)

Run 6

Timing Option:	(1) Each irrigation determined by user (40, 50, 60, 70, 80, 90, 100 days)
Application Option:	(4) Refill at fixed application depth (45 mm)
Evaluation Criteria:	- Irrigation efficiency (99%) - Yield reduction (2%)

Run 7-8

The effect of the selected irrigation schedule on irrigation and rain efficiency and yield reduction is evaluated for varying soil type and rainfall (dry and wet years):

Timing Option:	(1) Each irrigation defined by user (40, 50, 70, 80, 90, 100 days)
Application Option:	(4) Fixed irrigation depth (45 mm)
Evaluation Criteria:	- Irrigation efficiency (98-99%) - Yield reduction (13-0%)

GROUNDNUT		Planting date 15 December							
Run	Timing Option	Applic. Option	Interval days	Applic. depth (mm)	Irrig. Turns	Irrig. Supply (mm)	Sched. Effic.	Yield Reduc.	Rain Effic.
Average Year (10 mm) Red Sandy Loam (140 mm/m)									
1	2	2	39-16-11	49-60	6	339	100%	-	95%
2	5	4	36-13-7	40	9	360	100%	-	100%
3	4	4	7	40	15	600	61%	-	89%
4	4	4	10	40	11	440	75%	10%	100%
5	4	4	10	45	11	495	72%	2%	100%
6	1	4	40-10	45	7	315	99%	2%	100%
Average Year (10 mm) Red Sandy (100 mm/m)									
7	1	4	40-10	45	7	315	98%	13%	100%
Average Year (10 mm) Red Loamy (180 mm/m)									
8	1	4	40-10	45	7	315	99%	0%	100%

Table 17 **Summarized results scheduling runs for groundnut**

A similar procedure can be followed for cotton, of which the results are shown in Table 18.

As rainfall is more substantial (average 367), the effect of precipitation for wet and dry years is evaluated in separate runs, as well as the effect of medium and light soils.

COTTON	Planting date 1 August								
Run	Timing Option	Applic. Option	Interval days	Applic. depth (mm)	Irrig. Turns	Irrig. Supply (mm)	Sched. Effic.	Yield Reduc.	Rain Effic.
Average Year (367 mm) Black Clay Soil (200 mm/m)									
1	2	2	130-51	171	1	171	100%	-	74%
2	5	4	103-23-28	90	4	320	100%	-	73%
3	4	4	100-20	80	5	400	70%	-	73%
4	4	4	100-20	70	5	350	80%	-	73%
5	1	4	100-20	70	4	280	97%	-	74%
Average Year (367 mm) Red Sandy Loam (140 mm/m)									
6	1	4	100-20	70	4	280	97%	-	95%
Average Year (367 mm) Red Sandy (100 mm/m)									
7	1	4	100-20	70	4	280	97%	-	73%
Dry Year (240 mm) Black Clay Soil (200 mm/m)									
8	1	4	100-20	70	4	280	100%	-	91%
Wet Year (513 mm) Black Clay Soil (200 mm/m)									
9	1	4	100-20	70	4	280	86%	-	62%
10	1	4	120-20	70	3	210	100%	-	62%

Table 18 Summarized results scheduling runs for cotton

7.3.2 Evaluation of irrigation practices

Objective:

To assess adequacy of existing irrigation practices in terms of efficient water use and production level as a base to develop and promote better irrigation practices.

Required data and information:

In order to evaluate existing practices, actual data should be collected through field surveys and interviews with farmers. Although a detailed survey would provide more accurate information, a rapid survey on certain parameters would provide already useful indications, as shown in our example.

The minimum data information should include, apart from general information on climate, crops and soils:

Crop information:	Variety, planting date, harvest date
Climate:	Data on actual rainfall over concerned growing season, as far as available
Irrigation freq:	Actual dates of irrigation, or Average irrigation interval practised, or Number of irrigations over the growing season.
Irrigation appl:	Estimate of average irrigation depth per irrigation according to irrigation method practised
Soil:	Estimate texture class of soil

Example: Sorghum

During a field visit to Rajolibanda (1986), the following information was obtained from discussions with farmers and from field observations:

Crop:	HYV sorghum, grown for certified seed production
Planting date:	13 September
Harvest date:	20 January (estimated)
1st irrigation:	25 November
Interval period:	20-25 days
Irrigation method:	Basin irrigation, size 10 x 25 m
Application depth:	70-80 mm (estimated)
Soil type:	Red Clay (180 mm/m) (estimated)
Rainfall data:	Sept. 8 mm Oct. 107 mm Nov. 67 mm Dec. 0 Jan-April 0 mm
ET_o	Average climate data Kurnool

Data Processing

- Climate file generated with updated rainfall information, (see Appendix 4.2)
- Crop file for HYV sorghum updated (127 days).
- Soil file updated for Red Clay (180 mm).

CWR Calculation

The crop water requirements calculated for the concerned crop show:

Total ETcrop	= 412 mm
Eff. Rain	= 135 mm
Irr. Requirement	= 227 mm

Scheduling Procedures

After processing of CWR calculations and soil data input the following options are selected:

-	Timing Option:	(1) Each irrigation defined by user
-	Application Option:	(4) Fixed irrigation application according to field irrigation method (70 mm)

A printout of the results is given in Table 19.

The example shows a reasonably good adaption of farmers' practice to calculated irrigation requirements.

A further check may be made how valid the practice is, for instance, in normal, dry and wet years. Also a further assessment in the field of the application depth may confirm the results.

7.3.3 Rainfed production and supplementary irrigation

Objective:

- To assess the adequacy of rainfall for crop growth.
- To determine yield reductions due to rainfall deficits.

IRRIGATION SCHEDULING HYV Sorghum 13 September

Climate Station	: KURNOOL	Climate File	: kurn-86
Crop	: HYV Sorghum	Planting date	: 13 September
Soil	: Red Clay	Available Soil moisture	: 180 mm/m
		Initial Soil moisture	: 180 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/ 72 / 93 /114
Application : Fixed Irrigation depth of 70 mm

Field Application Efficiency 70%

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	72	25 Nov	C	27	100	100	70.0	0.0	21.4	100.0	0.16
2	21	16 Dec	C	39	100	100	70.0	0.0	0.3	100.0	0.55
3	21	7 Jan	D	42	100	100	70.0	5.1	0.0	100.0	0.55
END	14	21 Jan	D	23	100	100					

Total Gross Irrigation	300.0 mm	Total Rainfall	184.4 mm
Total Net Irrigation	210.0 mm	Effective Rain	182.5 mm
Total Irrigation Losses	21.7 mm	Total Rain Loss	2.0 mm
Moist Deficit at harvest	41.1 mm		
Net Supply + Soil retention	251.1 mm		
Actual Water use by crop	411.9 mm	Actual Irr.Req	229.4 mm
Potential Water use by crop	411.9 mm		
Efficiency Irr. Schedule	89.7 %	Efficiency Rain	98.9 %
Deficiency Irr. Schedule	0.0 %		

No yield reductions due to water shortage

Table 19 Printout - Evaluation irrigation practices sorghum

- To determine feasibility of supplementary irrigation.
- To develop supplementary irrigation schedules.

Required data:

Climate: The rainfall data used will concern in general statistically processed values with assigned probability values (80, 50 or 20), but also historical rainfall data may be used. In our example, climatic data of a normal year (50%) are used.

Crop: Crops and crop varieties normally grown under rainfall should be taken. An adjustment of the crop file may be necessary as rainfed crops will in general be better adapted to stress conditions than higher yielding irrigated crops; consequently length of growing stages, rooting depth, allowable depletion levels and yield response factor will need to be adjusted. In our example, cotton has been used as a crop to show the procedures.

Soil: Predominant soils for rainfed crops should be taken. In our example, the deep Black Clay Soils have been used to assess suitability of rainfed cotton.

CWR Calculations

The crop water requirements of cotton calculated earlier show for cotton planted 1 August the following summarized results:

Total ET cotton = 750 mm
Effective rain = 250 mm
Irr. Requirements = 501 mm

Scheduling Procedures

To assess the effect of rainfall deficits on crop growth, the following options should be selected in CROPWAT:

- Timing Option: (8) Rainfed, no irrigation applied
- Application Option: Not required

A printout of the results is shown in Table 20.

IRRIGATION SCHEDULING COTTON 1 August

Climate Station : KURNOOL
Crop : COTTON
Soil : Black Clay Soil
Climate File : kurn-wet
Planting date : 1 August
Available Soil moisture : 200 mm/m

Irrigation Options selected :
Timing : No Irrigations, only Rainfall
Field Application Efficiency 70%

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	11	11 Aug	A	10	100	100	15.5	8.9	35.3	50.9	0.54
2	10	21 Aug	A	7	100	100	22.1	8.7	28.9	51.0	0.59
3	10	1 Sep	B	6	100	100	21.4	8.8	32.4	53.9	0.62
4	10	11 Sep	B	6	100	100	23.2	10.2	34.9	58.1	0.67
5	10	21 Sep	B	6	100	100	28.2	12.5	33.5	61.7	0.71
6	10	1 Oct	B	6	100	100	33.6	14.5	22.8	56.4	0.65
7	10	11 Oct	B	6	100	100	44.7	16.3	7.8	52.6	0.61
8	10	21 Oct	C	7	100	100	48.0	20.3	0.0	48.0	0.56
9	10	1 Nov	C	10	100	100	36.1	28.5	0.0	36.1	0.42
10	10	11 Nov	C	17	100	100	22.2	48.4	0.0	22.2	0.26
11	10	21 Nov	C	28	100	100	9.3	79.0	0.0	9.3	0.11
12	10	1 Dec	C	40	100	100	6.6	111.4	0.0	6.6	0.08
13	10	11 Dec	C	52	100	100	3.8	145.4	0.0	3.8	0.04
14	10	21 Dec	D	64	92	99	1.0	179.7	0.0	1.0	0.01
15	10	1 Jan	D	73	68	79	0.7	205.8	0.0	0.7	0.01
16	10	11 Jan	D	80	52	59	0.3	223.7	0.0	0.3	0.00
17	10	21 Jan	D	84	40	45	0.0	236.2	0.0	0.0	0.00
END	10	1 Feb	D	87	33	36					

Total Gross Irrigation	0.0 mm	Total Rainfall	513.3 mm
Total Net Irrigation	0.0 mm	Effective Rain	317.5 mm
Total Irrigation Losses	0.0 mm	Total Rain Loss	195.8 mm
Efficiency Irr. Schedule	100.0 %	Efficiency Rain	61.9 %
Deficiency Irr. Schedule	8.4 %		

YIELD REDUCTIONS Stage	A	B	C	D	Season	
Reductions in ETC	0.0	0.0	0.0	36.8	8.4	%
Yield Response factor	0.40	0.60	0.80	0.40	0.80	
Reductions in Yield	0.0	0.0	0.0	14.7	6.8	%
Cumulative Yield reduct.	0.0	0.0	0.0	14.7		%

Table 20 Printout - Rainfed production level of cotton

Results show clearly that the yield of cotton is substantially affected by stress in the latter part of its growing stage, which will no doubt cause a premature senescence of the crop.

Supplementary irrigation will probably increase crop yields.

A supplementary supply of three irrigations every three weeks from 1 November would guarantee an optimal cotton production, as determined earlier under para. 7.2.1.

For further details, reference is made to Appendix 4.1.

7.3.4 Deficit irrigation

Objective

- To assess the effect of limited water supply on crop growth for conditions of restricted water availability.
- To develop an alternative irrigation schedule optimizing crop production under limited water supply conditions.

Required Data

A similar data set as used under option 7.2.1 can be used.

We have taken groundnuts planted in Rabi on 1 November with a normal climatic data set, grown on a red clay soil as an example to show the calculation procedures.

CWR Calculations

Crop water requirements of groundnuts have been calculated earlier:

Total ET crop	: 387 mm
Effective rain	: 27 mm
Irr. Requirements	: 350 mm

Scheduling Procedures

The following options should be selected in the CROPWAT scheduling program:

- Timing Option: Deficit Irrigation:
  (7) Fixed yield reduction or
  (6) Fixed ETo reduction;

NOTE: as our aim is to optimize crop production under restricted water supply, we will choose option 7.
An initial value: 10% may be given, in later runs possibly increased or decreased.

- Application Option: (4) Fixed irrigation depth
  40 mm typical for groundnut irrigated on furrows.

Scheduling Results

In Table 21 the results of the schedule are shown, with an approximate 10% reduction in yield. The irrigation supply is 240 mm, compared to a previous irrigation supply requirement of 440 mm (see para. 7.4.1).

IRRIGATION SCHEDULING GROUNDNUT/RAB1 15 December

Climate Station : KURNOOL
Crop : GROUNDNUT/RAB1
Soil : Red Sandy Loam

Climate File : kurn-av
Planting date : 15 December
Available Soil moisture : 140 mm/m
Initial Soil moisture : 140 mm/m

Irrigation Options selected :
Timing : Fixed yield deficit af: 10 %
Application : Fixed Irrigation depth of 45 mm

Field Application Efficiency 70%

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	51	6 Feb	C	73	58	89	45.0	36.7	0.0	64.3	0.15
2	11	17 Feb	C	71	63	88	45.0	35.0	0.0	64.3	0.68
3	10	27 Feb	C	71	65	89	45.0	34.0	0.0	64.3	0.74
4	10	7 Mar	C	72	62	88	45.0	35.7	0.0	64.3	0.74
5	10	17 Mar	D	74	59	86	45.0	37.4	0.0	64.3	0.74
6	10	27 Mar	D	72	61	87	45.0	36.0	0.0	64.3	0.74
END	9	6 Apr	D	62	82	96					

Total Gross Irrigation	385.7 mm	Total Rainfall	10.0 mm
Total Net Irrigation	270.0 mm	Effective Rain	10.0 mm
Total Irrigation Losses	0.0 mm	Total Rain Loss	0.0 mm
Moist Deficit at harvest	69.8 mm		
Net Supply + Soil retention	339.8 mm		
Actual Water use by crop	349.8 mm	Actual Irr.Req	339.8 mm
Potential Water use by crop	393.6 mm		
Efficiency Irr. Schedule	100.0 %	Efficiency Rain	100.0%
Deficiency Irr. Schedule	11.1 %		

YIELD REDUCTIONS Stage	A	B	C	D	Season	
Reductions in ETC	0.0	11.0	11.1	12.5	11.1	%
Yield Response factor	0.40	0.60	1.00	0.80	0.80	
Reductions in Yield	0.0	6.6	11.1	10.0	8.9	%
Cumulative Yield reduct.	0.0	6.6	17.0	25.3		%

Table 21 Printout - Deficit irrigation of groundnut

APPENDIX 1

PRINTOUT CLIMATIC DATA FILES

1. Reference Evapotranspiration Kurnool
2. Average Climatic Data Kurnool
3. Dry Year Climatic Data Kurnool
4. Normal Year Climatic Data Kurnool
5. Wet Year Climatic Data Kurnool
6. 1986 Climatic Data Kurnool

1.

Reference Evapotranspiration ETo according Penman-Monteith

Country	: RAJOLIBANDA	Meteo Station	: KURNOOL
Altitude	: 281 meter	Coordinates	: 16.00 N.L.

Month	AvgTemp °	Humidity %	Windspeed km/day	Sunshine hours	Radiation $MJ/m^2/day$	ETo-PenMon mm/day
January	24.2	51	117	8.1	8.8	3.82
February	26.8	41	132	8.4	10.0	4.85
March	30.0	35	148	7.6	10.9	5.86
April	32.7	37	167	7.3	11.9	6.60
May	33.6	41	257	6.7	11.9	7.64
June	30.3	58	405	5.3	11.2	6.78
July	28.2	66	409	4.9	10.9	5.66
August	27.8	66	353	5.6	11.4	5.50
September	27.6	67	242	6.0	11.3	4.91
October	27.4	64	115	7.2	11.0	4.26
November	25.1	58	98	7.4	9.2	3.64
December	23.5	55	94	7.9	8.4	3.36
YEAR	28.1	53	211	6.9	10.6	1913

2.

Climate file : kurn-av		Climate Station	: KURNOOL
	ETo (mm/day)	Rainfall (mm/month)	Eff. Rain (mm/month)
January	3.8	0.0	0.0
February	4.9	5.0	4.0
March	5.9	2.0	1.6
April	6.6	11.0	8.8
May	7.6	49.0	39.2
June	6.8	79.0	63.2
July	5.7	106.0	84.8
August	5.5	109.0	87.2
September	4.9	128.0	102.4
October	4.3	99.0	79.2
November	3.6	26.0	20.8
December	3.4	2.0	1.6
YEAR Total	1912.8	616.0	492.8 mm

Effective Rainfall: 80%

APPENDIX 2

CROP DATA FILES

1. Paddy
2. Sorghum
3. Sugarcane
4. Cotton
5. Groundnut - Kharif
6. Groundnut - Rabi

RICE DATA INPUT

Crop : PADDY

Growth period		Length	Stage	Crop coefficient
Nursery		30	days	1.20
Land preparation		20	days	—
Initial Stage	(A)	20	days	1.10
Developm. Stage	(B)	30	days	—
Mid-season	(C)	40	days	1.05
Late Season	(D)	30	days	0.80
Total		150	days	
Nursery Area		10	%	
Land cultivation		180	mm	
Percolation rate		3.0	mm/day	

Crop data : SORGHUM Crop file : SORGHUM

Growth Stage		Init	Devel	Mid	Late	Total
Length Stage	[days]	20	40	30	30	120
Crop Coefficient	[coeff.]	0.40	->	1.15	0.50	
Rooting Depth	[meter]	0.30	->	1.40	1.40	
Depletion level	[fract.]	0.60	->	0.50	0.80	
Yield-response F.	[coeff.]	0.20	0.40	0.55	0.20	0.90

Crop data : SUGARCANE-AVE Crop file : SUGARCAN

Growth Stage		Init	Devel	Mid	Late	Total
Length Stage	[days]	90	90	90	90	360
Crop Coefficient	[coeff.]	0.95	->	0.95	0.95	
Rooting Depth	[meter]	1.50	->	1.50	1.50	
Depletion level	[fract.]	0.60	->	0.60	0.60	
Yield-response F.	[coeff.]	1.20	1.20	1.20	1.20	1.20

Crop data : COTTON				Crop file : cotton		
Growth Stage		**Init**	**Devel**	**Mid**	**Late**	**Total**
Length Stage	[days]	30	50	55	45	180
Crop Coefficient	[coeff.]	0.40	->	1.10	0.55	
Rooting Depth	[meter]	0.30	->	1.40	1.40	
Depletion level	[fract.]	0.60	->	0.60	0.60	
Yield-response F.	[coeff.]	0.40	0.60	0.80	0.40	0.80

Crop data : GROUNDNUT/KHARIF				Crop file : grondnut		
Growth Stage		**Init**	**Devel**	**Mid**	**Late**	**Total**
Length Stage	[days]	20	30	35	25	110
Crop Coefficient	[coeff.]	0.40	->	1.00	0.70	
Rooting Depth	[meter]	0.30	->	0.80	0.80	
Depletion level	[fract.]	0.50	->	0.50	0.50	
Yield-response F.	[coeff.]	0.40	0.60	1.00	0.80	0.80

Crop data : GROUNDNUT/RABI				Crop file : grondnut		
Growth Stage		**Init**	**Devel**	**Mid**	**Late**	**Total**
Length Stage	[days]	20	30	35	25	110
Crop Coefficient	[coeff.]	0.20	->	1.00	0.70	
Rooting Depth	[meter]	0.30	->	0.80	0.80	
Depletion level	[fract.]	0.50	->	0.50	0.50	
Yield-response F.	[coeff.]	0.40	0.60	1.00	0.80	0.80

APPENDIX 3

CROP WATER REQUIRMENTS CALCULATIONS

No.	Crop	(T) Plant Date	Harvest Date
1	Paddy	10 July	10 Nov
2	Paddy	20 July	20 Nov
3	Paddy	1 Aug	1 Dec
4	Paddy	10 Aug	10 Dec
5	Paddy	10 Dec	10 Apr
6	Paddy	20 Dec	20 Apr
7	Paddy	1 Jan	1 May
8	Cotton	15 July	1 Feb
9	Groundnut	15 July	5 Nov
10	Groundnut	1 Aug	20 Nov
11	Groundnut	15 Aug	5 Dec
12	Groundnut	15 Dec	5 Apr
13	Groundnut	1 Jan	20 Apr
14	Groundnut	15 Jan	5 May
15	Sorghum	15 July	15 Nov
16	Sorghum	1 Aug	1 Dec
17	Sugarcane	perennial	

Crop 1

Rice Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Station : KURNOOL
Crop : PADDY
Date of Transplant : 10 July
Effective Rainfall : 80%

Month	Dec	Stage	Area %	Coeff	ETCrop mm/day	Perc mm/dy	LPrep mm/dy	RiceRq mm/dy	EffRain mm/dec	IRReq mm/dy	IRReq mm/dc
Jun	2	NUR	0.10	1.20	0.81	0.3	1.8	2.9	2.1	2.70	27.0
Jun	3	LP	0.33	1.18	2.45	1.0	8.1	11.5	7.6	10.76	107.6
Jul	1	LP	0.78	1.13	5.20	2.3	8.1	15.6	20.0	13.62	136.2
Jul	2	A	1.00	1.10	6.12	3.0	0.0	9.1	28.3	6.29	62.9
Jul	3	A	1.00	1.10	6.09	3.0	0.0	9.1	28.5	6.24	62.4
Aug	1	B	1.00	1.09	6.06	3.0	0.0	9.1	28.8	6.18	61.8
Aug	2	B	1.00	1.07	5.91	3.0	0.0	8.9	29.1	6.01	60.1
Aug	3	B	1.00	1.06	5.61	3.0	0.0	8.6	30.8	5.54	55.4
Sep	1	C	1.00	1.05	5.36	3.0	0.0	8.4	33.1	5.05	50.5
Sep	2	C	1.00	1.05	5.16	3.0	0.0	8.2	35.1	4.64	46.4
Sep	3	C	1.00	1.05	4.93	3.0	0.0	7.9	32.2	4.71	47.1
Oct	1	C	1.00	1.05	4.70	3.0	0.0	7.7	30.0	4.70	47.0
Oct	2	D	1.00	1.01	4.30	2.5	0.0	6.8	27.4	4.06	40.6
Oct	3	D	1.00	0.92	3.75	1.8	0.0	5.5	20.6	3.44	34.4
Nov	1	D	1.00	0.84	3.24	0.9	0.0	4.1	13.1	2.80	28.0
Totals					697	357	180	1234	367		867

Crop 2

Rice Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Station : KURNOOL
Crop : PADDY
Date of Transplant : 20 July
Effective Rainfall : 80%

Month	Dec	Stage	Area %	Coeff	ETCrop mm/day	Perc mm/dy	LPrep mm/dy	RiceRq mm/dy	EffRain mm/dec	IRReq mm/dy	IRReq mm/dc
Jun	3	NUR	0.10	1.20	0.77	0.3	1.8	2.9	2.3	2.63	26.3
Jul	1	LP	0.33	1.18	2.28	1.0	8.1	11.4	8.4	10.51	105.1
Jul	2	LP	0.78	1.13	4.85	2.3	8.1	15.3	21.9	13.08	130.8
Jul	3	A	1.00	1.10	6.09	3.0	0.0	9.1	28.5	6.24	62.4
Aug	1	A	1.00	1.10	6.11	3.0	0.0	9.1	28.8	6.23	62.3
Aug	2	B	1.00	1.09	6.00	3.0	0.0	9.0	29.1	6.10	61.0
Aug	3	B	1.00	1.07	5.70	3.0	0.0	8.7	30.8	5.63	56.3
Sep	1	B	1.00	1.06	5.40	3.0	0.0	8.4	33.1	5.09	50.9
Sep	2	C	1.00	1.05	5.16	3.0	0.0	8.2	35.1	4.64	46.4
Sep	3	C	1.00	1.05	4.93	3.0	0.0	7.9	32.2	4.71	47.1
Oct	1	C	1.00	1.05	4.70	3.0	0.0	7.7	30.0	4.70	47.0
Oct	2	C	1.00	1.05	4.47	3.0	0.0	7.5	27.4	4.73	47.3
Oct	3	D	1.00	1.01	4.09	2.5	0.0	6.6	20.6	4.53	45.3
Nov	1	D	1.00	0.92	3.56	1.8	0.0	5.3	13.1	4.00	40.0
Nov	2	D	1.00	0.84	3.06	0.9	0.0	3.9	5.9	3.35	33.5
Totals					672	357	180	1209	347		862

Crop 3

Rice Evapotranspiration and Irrigation Requirements

Climate File : kurn-av Station : KURNOOL
Crop : PADDY Date of Transplant : 1 Aug
Effective Rainfall : 80%

Month	Dec	Stage	Area %	Coeff	ETCrop mm/day	Perc mm/dy	LPrep mm/dy	RiceRq mm/dy	EffRain mm/dec	IRReq mm/dy	IRReq mm/dc
Jul	1	NUR	0.10	1.20	0.72	0.3	1.8	2.8	2.6	2.56	25.6
Jul	2	LP	0.33	1.18	2.12	1.0	8.1	11.2	9.2	10.28	102.8
Jul	3	LP	0.78	1.13	4.83	2.3	8.1	15.3	22.1	13.04	130.4
Aug	1	A	1.00	1.10	6.11	3.0	0.0	9.1	28.8	6.23	62.3
Aug	2	A	1.00	1.10	6.05	3.0	0.0	9.1	29.1	6.14	61.4
Aug	3	B	1.00	1.09	5.79	3.0	0.0	8.8	30.8	5.71	57.1
Sep	1	B	1.00	1.07	5.49	3.0	0.0	8.5	33.1	5.18	51.8
Sep	2	B	1.00	1.06	5.20	3.0	0.0	8.2	35.1	4.68	46.8
Sep	3	C	1.00	1.05	4.93	3.0	0.0	7.9	32.2	4.71	47.1
Oct	1	C	1.00	1.05	4.70	3.0	0.0	7.7	30.0	4.70	47.0
Oct	2	C	1.00	1.05	4.47	3.0	0.0	7.5	27.4	4.73	47.3
Oct	3	C	1.00	1.05	4.26	3.0	0.0	7.3	20.6	5.20	52.0
Nov	1	D	1.00	1.01	3.88	2.5	0.0	6.4	13.1	5.07	50.7
Nov	2	D	1.00	0.92	3.37	1.8	0.0	5.1	5.9	4.52	45.2
Nov	3	D	1.00	0.84	2.99	0.9	0.0	3.9	4.1	3.45	34.5
Totals					649	357	180	1186	324		862

Crop 4

Rice Evapotranspiration and Irrigation Requirements

Climate File : kurn-av Station : KURNOOL
Crop : PADDY Date of Transplant : 10 Aug
Effective Rainfall : 80%

Month	Dec	Stage	Area %	Coeff	ETCrop mm/day	Perc mm/dy	LPrep mm/dy	RiceRq mm/dy	EffRain mm/dec	IRReq mm/dy	IRReq mm/dc
Jul	2	NUR	0.10	1.20	0.67	0.3	1.8	2.8	2.8	2.48	24.8
Jul	3	LP	0.33	1.18	2.12	1.0	8.1	11.2	9.3	10.26	102.6
Aug	1	LP	0.78	1.13	4.84	2.3	8.1	15.3	22.3	13.03	130.3
Aug	2	A	1.00	1.10	6.05	3.0	0.0	9.1	29.1	6.14	61.4
Aug	3	A	1.00	1.10	5.83	3.0	0.0	8.8	30.8	5.76	57.6
Sep	1	B	1.00	1.09	5.57	3.0	0.0	8.6	33.1	5.26	52.6
Sep	2	B	1.00	1.07	5.28	3.0	0.0	8.3	35.1	4.76	47.6
Sep	3	B	1.00	1.06	4.97	3.0	0.0	8.0	32.2	4.74	47.4
Oct	1	C	1.00	1.05	4.70	3.0	0.0	7.7	30.0	4.70	47.0
Oct	2	C	1.00	1.05	4.47	3.0	0.0	7.5	27.4	4.73	47.3
Oct	3	C	1.00	1.05	4.26	3.0	0.0	7.3	20.6	5.20	52.0
Nov	1	C	1.00	1.05	4.04	3.0	0.0	7.0	13.1	5.73	57.3
Nov	2	D	1.00	1.01	3.67	2.5	0.0	6.2	5.9	5.58	55.8
Nov	3	D	1.00	0.92	3.28	1.8	0.0	5.0	4.1	4.62	46.2
Dec	1	D	1.00	0.84	2.91	0.9	0.0	3.8	2.3	3.55	35.5
Totals					627	357	180	1164	298		866

Crop 5

Rice Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Station : KURNOOL
Crop : PADDY
Date of Transplant : 10 December
Effective Rainfall : 80%

Month	Dec	Stage	Area %	Coeff	ETCrop mm/day	Perc mm/dy	LPrep mm/dy	RiceRq mm/dy	EffRain mm/dec	IRReq mm/dy	IRReq mm/dc
Nov	2	NUR	0.10	1.20	0.44	0.3	1.8	2.5	0.6	2.48	24.8
Nov	3	LP	0.33	1.18	1.35	1.0	8.1	10.4	1.3	10.30	103.0
Dec	1	LP	0.78	1.13	3.01	2.3	8.1	13.4	1.8	13.26	132.6
Dec	2	A	1.00	1.10	3.70	3.0	0.0	6.7	0.5	6.64	66.4
Dec	3	A	1.00	1.10	3.86	3.0	0.0	6.9	0.4	6.83	68.3
Jan	1	B	1.00	1.09	4.00	3.0	0.0	7.0	0.2	6.98	69.9
Jan	2	B	1.00	1.07	4.11	3.0	0.0	7.1	0.0	7.11	71.1
Jan	3	B	1.00	1.06	4.41	3.0	0.0	7.4	0.4	7.36	73.6
Feb	1	C	1.00	1.05	4.73	3.0	0.0	7.7	0.9	7.64	76.4
Feb	2	C	1.00	1.05	5.09	3.0	0.0	8.1	1.3	7.96	79.6
Feb	3	C	1.00	1.05	5.45	3.0	0.0	8.4	1.1	8.34	83.4
Mar	1	C	1.00	1.05	5.80	3.0	0.0	8.8	0.8	8.72	87.2
Mar	2	D	1.00	1.01	5.91	2.5	0.0	8.4	0.5	8.36	83.6
Mar	3	D	1.00	0.92	5.65	1.8	0.0	7.4	1.3	7.27	72.7
Apr	1	D	1.00	0.84	5.35	0.9	0.0	6.2	2.1	6.01	60.1
Totals					629	357	180	1166	13		1152

Crop 6

Rice Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Station : KURNOOL
Crop : PADDY
Date of Transplant : 20 December
Effective Rainfall : 80%

Month	Dec	Stage	Area %	Coeff	ETCrop mm/day	Perc mm/dy	LPrep mm/dy	RiceRq mm/dy	EffRain mm/dec	IRReq mm/dy	IRReq mm/dc
Nov	3	NUR	0.10	1.20	0.43	0.3	1.8	2.5	0.4	2.48	24.8
Dec	1	LP	0.33	1.18	1.32	1.0	8.1	10.4	0.8	10.32	103.2
Dec	2	LP	0.78	1.13	2.93	2.3	8.1	13.4	0.4	13.31	133.1
Dec	3	A	1.00	1.10	3.86	3.0	0.0	6.9	0.4	6.83	68.3
Jan	1	A	1.00	1.10	4.03	3.0	0.0	7.0	0.2	7.02	70.2
Jan	2	B	1.00	1.09	4.17	3.0	0.0	7.2	0.0	7.17	71.7
Jan	3	B	1.00	1.07	4.48	3.0	0.0	7.5	0.4	7.43	74.3
Feb	1	B	1.00	1.06	4.77	3.0	0.0	7.8	0.9	7.68	76.8
Feb	2	C	1.00	1.05	5.09	3.0	0.0	8.1	1.3	7.96	79.6
Feb	3	C	1.00	1.05	5.45	3.0	0.0	8.4	1.1	8.34	83.4
Mar	1	C	1.00	1.05	5.80	3.0	0.0	8.8	0.8	8.72	87.2
Mar	2	C	1.00	1.05	6.15	3.0	0.0	9.2	0.5	9.10	91.0
Mar	3	D	1.00	1.01	6.16	2.5	0.0	8.7	1.3	8.52	85.2
Apr	1	D	1.00	0.92	5.88	1.8	0.0	7.6	2.1	7.41	74.1
Apr	2	D	1.00	0.84	5.56	0.9	0.0	6.4	2.9	6.14	61.4
Totals					661	357	180	1198	14		1184

Crop 7

Rice Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Station : KURNOOL
Crop : PADDY
Date of Transplant : 1 January
Effective Rainfall : 80%

Month	Dec	Stage	Area %	Coeff	ETCrop mm/day	Perc mm/dy	LPrep mm/dy	RiceRq mm/dy	EffRain mm/dec	1RReq mm/dy	1RReq mm/dc
Dec	1	NUR	0.10	1.20	0.41	0.3	1.8	2.5	0.2	2.49	24.9
Dec	2	LP	0.33	1.18	1.28	1.0	8.1	10.4	0.2	10.34	103.4
Dec	3	LP	0.78	1.13	3.06	2.3	8.1	13.5	0.3	13.46	134.6
Jan	1	A	1.00	1.10	4.03	3.0	0.0	7.0	0.2	7.02	70.2
Jan	2	A	1.00	1.10	4.20	3.0	0.0	7.2	0.0	7.20	72.0
Jan	3	B	1.00	1.09	4.54	3.0	0.0	7.5	0.4	7.50	75.0
Feb	1	B	1.00	1.07	4.84	3.0	0.0	7.8	0.9	7.76	77.6
Feb	2	B	1.00	1.06	5.13	3.0	0.0	8.1	1.3	8.00	80.0
Feb	3	C	1.00	1.05	5.45	3.0	0.0	8.4	1.1	8.34	83.4
Mar	1	C	1.00	1.05	5.80	3.0	0.0	8.8	0.8	8.72	87.2
Mar	2	C	1.00	1.05	6.15	3.0	0.0	9.2	0.5	9.10	91.0
Mar	3	C	1.00	1.05	6.41	3.0	0.0	9.4	1.3	9.28	92.8
Apr	1	D	1.00	1.01	6.41	2.5	0.0	8.9	2.1	8.69	86.9
Apr	2	D	1.00	0.92	6.10	1.8	0.0	7.9	2.9	7.56	75.6
Apr	3	D	1.00	0.84	5.85	0.9	0.0	6.7	6.3	6.09	60.9
Totals					697	357	180	1234	19		1215

Crop 8

Crop Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Climate Station : KURNOOL
Crop : COTTON
Planting date : 1 August

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Aug	1	init	0.40	2.22	22.2	28.8	0.00	0.0
Aug	2	init	0.40	2.20	22.0	29.1	0.00	0.0
Aug	3	init	0.40	2.12	21.2	30.8	0.00	0.0
Sep	1	deve	0.47	2.40	24.0	33.1	0.00	0.0
Sep	2	deve	0.61	3.00	30.0	35.1	0.00	0.0
Sep	3	deve	0.75	3.52	35.2	32.2	0.30	3.0
Oct	1	deve	0.89	3.98	39.8	30.0	0.99	9.9
Oct	2	deve	1.03	4.39	43.9	27.4	1.65	16.5
Oct	3	mid	1.10	4.46	44.6	20.6	2.40	24.0
Nov	1	mid	1.10	4.23	42.3	13.1	2.92	29.2
Nov	2	mid	1.10	4.00	40.0	5.9	3.41	34.1
Nov	3	mid	1.10	3.90	39.1	4.1	3.49	34.9
Dec	1	mid	1.10	3.80	38.0	2.3	3.57	35.7
Dec	2	mi/lt	1.07	3.59	35.9	0.5	3.54	35.4
Dec	3	late	0.98	3.44	34.4	0.4	3.40	34.0
Jan	1	late	0.86	3.14	31.4	0.2	3.12	31.2
Jan	2	late	0.73	2.80	28.0	0.0	2.80	28.0
Jan	3	late	0.61	2.54	25.4	0.4	2.50	25.0
TOTAL					597.4	294.0		340.8

Crop 9

Crop Evapotranspiration and Irrigation Requirements

Climate File: kurn-av — Climate Station : KURNOOL
Crop : GROUNDNUT/KHARIF — Planting date : 15 July

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Jul	2	init	0.40	2.22	11.1	14.1	0.00	0.0
Jul	3	init	0.40	2.22	22.2	28.5	0.00	0.0
Aug	1	in/de	0.45	2.50	25.0	28.8	0.00	0.0
Aug	2	deve	0.60	3.30	33.0	29.1	0.39	3.9
Aug	3	deve	0.80	4.24	42.4	30.8	1.17	11.7
Sep	1	de/mi	0.95	4.85	48.5	33.1	1.54	15.4
Sep	2	mid	1.00	4.91	49.1	35.1	1.40	14.0
Sep	3	mid	1.00	4.69	46.9	32.2	1.47	14.7
Oct	1	mid	1.00	4.48	44.8	30.0	1.48	14.8
Oct	2	late	0.94	4.00	40.0	27.4	1.26	12.6
Oct	3	late	0.82	3.32	33.2	20.6	12.7	12.7
Nov	1	late	0.70	2.69	13.5	6.5	1.38	6.9
TOTAL					409.8	316.3		106.7

Crop 10

Crop Evapotranspiration and Irrigation Requirements

Climate File : kurn-av — Climate Station : KURNOOL
Crop : GROUNDNUT/KHARIF — Planting date : 1 August

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Aug	1	init	0.40	2.22	22.2	28.8	0.00	0.0
Aug	2	init	0.40	2.20	22.0	29.1	0.00	0.0
Aug	3	deve	0.50	2.65	26.5	30.8	0.00	0.0
Sep	1	deve	0.70	3.57	35.7	33.1	0.26	2.6
Sep	2	deve	0.90	4.42	44.2	35.1	0.91	9.1
Sep	3	mid	1.00	4.69	46.9	32.2	1.47	14.7
Oct	1	mid	1.00	4.48	44.8	30.0	1.48	14.8
Oct	2	mid	1.00	4.26	42.6	27.4	1.52	15.2
Oct	3	mi/lt	0.97	3.93	39.3	20.6	1.87	18.7
Nov	1	late	0.88	3.39	33.9	13.1	2.08	20.8
Nov	2	late	0.76	2.77	27.7	5.9	2.17	21.7
TOTAL					385.8	286.1		117.6

Crop 11

Crop Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Crop : GROUNDNUT/KHARIF
Climate Station : KURNOOL
Planting date : 15 August

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Aug	2	init	0.40	2.20	11.0	14.5	0.00	0.0
Aug	3	init	0.40	2.12	21.2	30.8	0.00	0.0
Sep	1	in/de	0.45	2.30	23.0	33.1	0.00	0.0
Sep	2	deve	0.60	2.95	29.5	35.1	0.00	0.0
Sep	3	deve	0.80	3.75	37.5	32.2	0.53	5.3
Oct	1	de/mi	0.95	4.25	42.5	30.0	1.26	12.6
Oct	2	mid	1.00	4.26	42.6	27.4	1.52	15.2
Oct	3	mid	1.00	4.05	40.5	20.6	2.00	20.0
Nov	1	mid	1.00	3.85	38.5	13.1	2.54	25.5
Nov	2	late	0.94	3.42	34.2	5.9	2.83	28.3
Nov	3	late	0.82	2.91	29.1	4.1	2.49	24.9
Dec	1	late	0.70	2.42	12.1	1.2	2.18	10.9
TOTAL					361.7	248.0		142.6

Crop 12

Crop Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Crop : GROUNDNUT/RABI
Climate Station : KURNOOL
Planting date : 15 December

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Dec	2	init	0.20	0.67	3.4	0.3	0.62	3.1
Dec	3	init	0.20	0.70	7.0	0.4	0.67	6.7
Jan	1	in/de	0.27	0.98	9.8	0.2	0.96	9.6
Jan	2	deve	0.47	1.78	17.8	0.0	1.78	17.8
Jan	3	deve	0.73	3.05	30.5	0.4	3.01	30.1
Feb	1	de/mi	0.93	4.21	42.1	0.9	4.12	41.2
Feb	2	mid	1.00	4.85	48.5	1.3	4.72	47.2
Feb	3	mid	1.00	5.19	51.9	1.1	5.08	50.8
Mar	1	mid	1.00	5.52	55.2	0.8	5.44	54.4
Mar	2	late	0.94	5.51	55.1	0.5	5.46	54.6
Mar	3	late	0.82	5.01	50.1	1.3	4.87	48.7
Apr	1	late	0.70	4.45	22.2	1.1	4.23	21.2
TOTAL					393.6	8.3		385.3

Crop 13

Crop Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Climate Station : KURNOOL
Crop : GROUNDNUT/RABI
Planting date : 1 January

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Jan	1	init	0.20	0.73	7.3	0.2	0.72	7.2
Jan	2	init	0.20	0.76	7.6	0.0	0.76	7.6
Jan	3	deve	0.33	1.39	13.9	0.4	1.34	13.4
Feb	1	deve	0.60	2.70	27.0	0.9	2.62	26.2
Feb	2	deve	0.87	4.20	42.0	1.3	4.07	40.7
Feb	3	mid	1.00	5.19	51.9	1.1	5.08	50.8
Mar	1	mid	1.00	5.52	55.2	0.8	5.44	54.4
Mar	2	mid	1.00	5.86	58.6	0.5	5.81	58.1
Mar	3	mi/lt	0.97	5.92	59.2	1.3	5.79	57.9
Apr	1	late	0.88	5.59	55.9	2.1	5.38	53.8
Apr	2	late	0.76	5.02	50.2	2.9	4.72	47.2
TOTAL					428.9	11.6		417.3

Crop 14

Crop Evapotranspiration and Irrigation Requirements

Climate File : kurn-av
Climate Station : KURNOOL
Crop : GROUNDNUT/RABI
Planting date : 15 January

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Jan	2	init	0.20	0.76	3.8	0.0	0.76	3.8
Jan	3	init	0.20	0.83	8.3	0.4	0.79	7.9
Feb	1	in/de	0.27	1.20	12.0	0.9	1.11	11.1
Feb	2	deve	0.47	2.26	22.6	1.3	2.13	21.3
Feb	3	deve	0.73	3.80	38.0	1.1	3.70	37.0
Mar	1	de/mi	0.93	5.16	51.6	0.8	5.08	50.8
Mar	2	mid	1.00	5.86	58.6	0.5	5.81	58.1
Mar	3	mid	1.00	6.11	61.1	1.3	5.97	59.7
Apr	1	mid	1.00	6.35	63.5	2.1	6.14	61.4
Apr	2	late	0.94	6.20	62.0	2.9	5.91	59.1
Apr	3	late	0.82	5.70	57.0	6.3	5.07	50.7
May	1	late	0.70	5.20	26.0	4.8	4.23	21.1
TOTAL					464.4	22.6		442.0

Crop 15

Crop Evapotranspiration and Irrigation Requirements

Climate File : KURN-AV Climate Station : KURNOOL
Crop : SORGHUM Planting date : 15 July

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Jul	2	init	0.40	2.22	11.1	14.1	0.00	0.0
Jul	3	init	0.40	2.22	22.2	28.5	0.00	0.0
Aug	1	in/de	0.45	2.48	24.8	28.8	0.00	0.0
Aug	2	deve	0.59	3.23	32.3	29.1	0.32	3.2
Aug	3	deve	0.78	4.11	31.1	30.8	1.03	10.3
Sep	1	deve	0.96	4.92	49.2	33.1	1.60	16.0
Sep	2	de/mi	1.10	5.42	54.2	35.1	1.90	19.0
Sep	3	mid	1.15	5.40	54.0	32.2	2.18	21.8
Oct	1	mid	1.15	5.15	51.5	30.0	2.15	21.5
Oct	2	mi/lt	1.10	4.67	46.7	27.4	1.93	19.3
Oct	3	late	0.93	3.78	37.8	20.6	1.73	17.3
Nov	1	late	0.72	2.76	27.6	13.1	1.45	14.5
Nov	2	late	0.50	1.82	9.1	3.0	1.23	6.1
TOTAL					461.5	325.8		149.1

Crop 16

Crop Evapotranspiration and Irrigation Requirements

Climate File : KURN-AV Climate Station : KURNOOL
Crop : SORGHUM Planting date : 1 August

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Aug	1	init	0.40	2.22	22.2	28.8	0.00	0.0
Aug	2	init	0.40	2.22	22.0	29.1	0.00	0.0
Aug	3	deve	0.49	2.62	26.2	30.8	0.00	0.0
Sep	1	deve	0.68	3.48	34.8	33.1	0.17	1.7
Sep	2	deve	0.87	4.27	42.7	35.1	0.75	7.5
Sep	3	deve	1.06	4.96	49.6	32.2	1.74	17.4
Oct	1	mid	1.15	5.15	51.5	30.0	2.15	21.5
Oct	2	mid	1.15	4.90	49.0	27.4	2.16	21.6
Oct	3	mid	1.15	4.66	46.6	20.6	2.60	26.0
Nov	1	late	1.04	4.01	40.1	13.1	2.70	27.0
Nov	2	late	0.83	3.00	30.0	5.9	2.41	24.1
Nov	3	late	0.61	2.1	21.6	4.1	1.74	17.4
TOTAL					436.2	290.2		164.2

Crop 17

Crop Evapotranspiration and Irrigation Requirements

Climate File : KURN-AV
Crop : SUGARCANE-AVE
Climate Station : KURNOOL
Planting date : 1 January

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Jan	1	init	0.95	3.48	34.8	0.2	3.47	34.7
Jan	2	init	0.95	3.63	36.3	0.0	3.63	36.3
Jan	3	init	0.95	3.96	39.6	0.4	3.91	39.1
Feb	1	init	0.95	4.28	42.8	0.9	4.19	41.9
Feb	2	init	0.95	4.61	46.1	1.3	4.47	44.7
Feb	3	init	0.95	4.93	49.3	1.1	4.82	48.2
Mar	1	init	0.95	5.25	52.5	0.8	5.17	51.7
Mar	2	init	0.95	5.57	55.7	0.5	5.51	55.1
Mar	3	init	0.95	5.80	58.0	1.3	5.67	56.7
Apr	1	deve	0.95	6.04	60.4	2.1	5.82	58.2
Apr	2	deve	0.95	6.27	62.7	2.9	5.98	59.8
Apr	3	deve	0.95	6.60	66.0	6.3	5.97	59.7
May	1	deve	0.95	7.06	70.6	9.7	6.09	60.9
May	2	deve	0.95	7.45	74.5	13.1	6.14	61.4
May	3	deve	0.95	7.11	71.1	15.7	5.54	55.4
Jun	1	deve	0.95	6.71	67.1	18.4	4.87	48.7
Jun	2	deve	0.95	6.44	64.4	21.1	4.33	43.3
Jun	3	deve	0.95	6.09	60.9	23.5	3.74	37.4
Jul	1	mid	0.95	5.67	56.7	25.9	3.08	30.8
Jul	2	mid	0.95	5.28	52.8	28.3	2.46	24.6
Jul	3	mid	0.95	5.26	52.6	28.5	2.41	24.1
Aug	1	mid	0.95	5.28	52.8	28.8	2.40	24.0
Aug	2	mid	0.95	5.23	52.3	29.1	2.32	23.2
Aug	3	mid	0.95	5.04	50.4	30.8	1.96	19.6
Sep	1	mid	0.95	4.85	48.5	33.1	1.54	15.4
Sep	2	mid	0.95	4.66	46.6	35.1	1.15	11.5
Sep	3	mid	0.95	4.46	44.6	32.2	1.24	12.4
Oct	1	late	0.95	4.25	42.5	30.0	1.26	12.6
Oct	2	late	0.95	4.05	40.5	27.4	1.31	13.1
Oct	3	late	0.95	3.85	38.5	20.6	1.79	17.9
Nov	1	late	0.95	3.65	36.5	13.1	2.35	23.5
Nov	2	late	0.95	3.46	34.6	5.9	2.86	28.6
Nov	3	late	0.95	3.37	33.7	4.1	2.96	29.6
Dec	1	late	0.95	3.28	32.8	2.3	3.05	30.5
Dec	2	late	0.95	3.19	31.9	0.5	3.14	31.4
Dec	3	late	0.95	3.34	33.4	0.4	3.30	33.0
TOTAL					1794.3	495.5		1298.8

APPENDIX 4.1

IRRIGATION SCHEDULING RUNS

Indicative Irrigation Schedules:

Groundnut

Run 1	:	Optimal Irrigation
Run 2	:	Application of 40 mm after 40 mm depletion
Run 3	:	Application of 40 mm every 7 days
Run 4	:	Application of 40 mm every 10 days
Run 5	:	Application of 45 mm every 10 days
Run 6	:	Application of 45 mm every 10 days starting 40th day
Run 7	:	Same as Run 6 for Light Soil
Run 8	:	Same as Run 6 for Heavy Soil

Cotton

Run 1	:	Optimal Irrigation
Run 2	:	Application of 80 mm after 80 mm depletion
Run 3	:	Application of 80 mm every 20 days after 81st day
Run 4	:	Application of 70 mm every 20 days after 81st day
Run 5	:	Four applications of 70 mm after day 100
Run 6	:	Same as Run 5 for Medium Soil
Run 7	:	Same as Run 5 for Light Soil
Run 8	:	Same as Run 5 for Dry Year
Run 9	:	Same as Run 5 for Wet Year
Run 10	:	Three applications (70) after day 120 for Wet Year

Groundnut : Run 1

IRRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Sandy Loam	Available Soilmoist	: 140 mm/m

Irrigation Options selected :
Timing : Irrigation applied at 100 % Readily Available Moist.
Application : Irrigation up to Field Capacity

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	39	24 Jan	B	51	100	100	48.9	0.0	0.0	69.9	0.21
2	16	10 Feb	C	53	100	100	59.0	0.0	0.0	84.3	0.61
3	12	22 Feb	C	51	100	100	57.2	0.0	0.0	81.7	0.79
4	11	3 Mar	C	51	100	100	56.7	0.0	0.0	81.0	0.85
5	11	14 Mar	D	53	100	100	59.9	0.0	0.0	85.5	0.90
6	11	25 Mar	D	51	100	100	56.9	0.0	0.0	81.3	0.86
END	11	6 Apr	D	41	100	100					

Total Gross Irrigation	483.8 mm	Total Rainfall	10.0 mm
Total Net Irrigation	338.6 mm	Effective Rain	9.5 mm
Total Irrigation Losses	0.0 mm	Total Rain Loss	0.5 mm
Efficiency Irr. Schedule	100.0 %	Efficiency Rain	95 %
Deficiency Irr. Schedule	0.0 %		

Groundnut : Run 2

IRRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Sandy Loam	Available Soilmoist	: 140 mm/m

Irrigation Options selected :
Timing : Fixed depletion of 40 mm
Application : Fixed Irrigation depth of 40 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	36	21 Jan	B	43	100	100	40.0	0.0	0.0	57.1	0.18
2	13	4 Feb	B	39	100	100	40.0	3.2	0.0	57.1	0.51
3	9	13 Feb	C	38	100	100	40.0	2.5	0.0	57.1	0.73
4	9	22 Feb	C	40	100	100	40.0	5.1	0.0	57.1	0.73
5	7	29 Feb	C	36	100	100	40.0	0.1	0.0	57.1	0.94
6	8	7 Mar	C	39	100	100	40.0	3.4	0.0	57.1	0.83
7	7	14 Mar	D	37	100	100	40.0	1.2	0.0	57.1	0.94
8	8	22 Mar	D	39	100	100	40.0	4.0	0.0	57.1	0.83
9	8	1 Apr	D	38	100	100	40.0	2.3	0.0	57.1	0.83
END	6	6 Apr	D	21	100	100					

Total Gross Irrigation	514.3 mm	Total Rainfall	10.0 mm
Total Net Irrigation	360.0 mm	Effective Rain	10.0 mm
Total Irrigation Losses	0.0 mm	Total Rain Loss	0.0 mm
Efficiency Irr. Schedule	100.0 %	Efficiency Rain	100 %
Deficiency Irr. Schedule	0.0 %		

Groundnut : Run 3

IRRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Sandy Loam	Available Soilmoist	: 140 mm/m

Irrigation Options selected :
Timing : Fixed Interval of 7 (A)/ 7 (B)/ 7 (C)/ 7 (D) days.
Application : Fixed Irrigation depth of 40 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	7	22 Dec	A	9	100	100	40.0	0.0	35.6	57.1	0.94
2	7	29 Dec	A	7	100	100	40.0	0.0	35.5	57.1	0.94
3	7	6 Jan	B	9	100	100	40.0	0.0	33.5	57.1	0.94
4	7	13 Jan	B	11	100	100	40.0	0.0	30.9	57.1	0.94
5	7	20 Jan	B	14	100	100	40.0	0.0	27.5	57.1	0.94
6	7	27 Jan	B	21	100	100	40.0	0.0	18.9	57.1	0.94
7	7	4 Feb	B	23	100	100	40.0	0.0	14.6	57.1	0.94
8	7	11 Feb	C	26	100	100	40.0	0.0	10.5	57.1	0.94
9	7	18 Feb	C	29	100	100	40.0	0.0	7.7	57.1	0.94
10	7	25 Feb	C	31	100	100	40.0	0.0	5.0	57.1	0.94
11	7	2 Mar	C	32	100	100	40.0	0.0	3.7	57.1	0.94
12	7	9 Mar	C	34	100	100	40.0	0.0	2.3	57.1	0.94
13	7	16 Mar	D	34	100	100	40.0	0.0	1.8	57.1	0.94
14	7	23 Mar	D	33	100	100	40.0	0.0	3.3	57.1	0.94
15	7	1 Apr	D	31	100	100	40.0	0.0	5.8	57.1	0.94
END	6	6 Apr	D	19	100	100					

Total Gross Irrigation	857.1 mm	Total Rainfall	10.0 mm
Total Net Irrigation	600.0 mm	Effective Rain	8.9 mm
Total Irrigation Losses	236.5 mm	Total Rain Loss	1.1 mm
Efficiency Irr. Schedule	60.6 %	Efficiency Rain	88.9 %
Deficiency Irr. Schedule	0.0 %		

Groundnut : Run 4

IRRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Sandy Loam	Available Soilmoist	: 140 mm/m

Irrigation Options selected :
Timing : Fixed Interval of 10 (A)/ 10 (B)/ 10 (C)/ 10 (D) days.
Application : Fixed Irrigation depth of 40 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	10	25 Dec	A	11	100	100	40.0	0.0	33.7	57.1	0.66
2	10	5 Jan	A	12	100	100	40.0	0.0	31.9	57.1	0.66
3	10	15 Jan	B	16	100	100	40.0	0.0	26.3	57.1	0.66
4	10	25 Jan	B	24	100	100	40.0	0.0	16.1	57.1	0.66
5	10	5 Feb	B	32	100	100	40.0	0.0	4.5	57.1	0.66
6	10	15 Feb	C	39	100	100	40.0	3.9	0.0	57.1	0.66
7	10	25 Feb	C	47	100	100	40.0	12.6	0.0	57.1	0.66
8	10	5 Mar	C	58	94	99	40.0	24.6	0.0	57.1	0.66
9	10	15 Mar	D	67	72	94	40.0	35.5	0.0	57.1	0.66
10	10	25 Mar	D	72	62	88	40.0	40.4	0.0	57.1	0.66
11	10	5 Apr	D	71	63	87	40.0	39.6	0.0	57.1	0.66
END	1	6 Apr	D	35	63	0					

Total Gross Irrigation	628.6 mm	Total Rainfall	10.0 mm
Total Net Irrigation	440.0 mm	Effective Rain	10.0 mm
Total Irrigation Losses	112.6 mm	Total Rain Loss	0.0 mm
Efficiency Irr. Schedule	74.4 %	Efficiency Rain	100 %
Deficiency Irr. Schedule	4.2 %		

YIELD REDUCTIONS	Stage A	B	C	D	Season	
Reductions in ETC	0.0	0.0	0.2	12.7	4.2	%
Yield Response factor	0.40	0.60	1.00	0.80	0.80	
Reductions in Yield	0.0	0.0	0.2	10.2	3.4	%
Cumulative Yield reduct.	0.0	0.0	0.2	10.3		%

Groundnut : Run 5

IRRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Sandy Loam	Available Soilmoist	: 140 mm/m

Irrigation Options selected :
Timing : Fixed Interval of 10 (A)/ 10 (B)/ 10 (C)/ 10 (D) days.
Application : Fixed Irrigation depth of 45 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	10	25 Dec	A	11	100	100	45.0	0.0	38.7	64.3	0.74
2	10	5 Jan	A	12	100	100	45.0	0.0	36.9	64.3	0.74
3	10	15 Jan	B	16	100	100	45.0	0.0	31.3	64.3	0.74
4	10	25 Jan	B	24	100	100	45.0	0.0	21.1	64.3	0.74
5	10	5 Feb	B	32	100	100	45.0	0.0	9.5	64.3	0.74
6	10	15 Feb	C	39	100	100	45.0	0.0	1.1	64.3	0.74
7	10	25 Feb	C	43	100	100	45.0	3.7	0.0	64.3	0.74
8	10	5 Mar	C	50	100	100	45.0	11.1	0.0	64.3	0.74
9	10	15 Mar	D	58	93	99	45.0	20.0	0.0	64.3	0.74
10	10	25 Mar	D	62	82	97	45.0	35.0	0.0	64.3	0.74
11	10	5 Apr	D	62	83	97	45.0	24.1	0.0	64.3	0.74
END	1	6 Apr	D	21	83	0					

Total Gross Irrigation	707.1 mm	Total Rainfall	10.0 mm
Total Net Irrigation	495.0 mm	Effective Rain	10.0 mm
Total Irrigation Losses	138.7 mm	Total Rain Loss	0.0 mm
Efficiency Irr. Schedule	72.0 %	Efficiency Rain	100 %
Deficiency Irr. Schedule	0.8 %		

YIELD REDUCTIONS	Stage A	B	C	D	Season	
Reductions in ETC	0.0	0.0	0.0	2.5	0.8	%
Yield Response factor	0.40	0.60	1.00	0.80	0.80	
Reductions in Yield	0.0	0.0	0.0	2.0	0.6	%
Cumulative Yield reduct.	0.0	0.0	0.0	2.0		%

Groundnut : Run 6

IRRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Sandy Loam	Available Soilmoist	: 140 mm/m

Irrigation Options selected :
Timing : Dates defined by user:/ 40 / 50/ 60 / 70 / 80 / 90 /100
Application : Fixed Irrigation depth of 45 mm

No. Irr.	Int days	Date	Stage	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	40	25 Jan	B	53	100	100	45.0	7.0	0.0	64.3	0.19
2	10	5 Feb	B	38	100	100	45.0	0.0	2.6	64.3	0.74
3	10	15 Feb	C	39	100	100	45.0	0.0	1.1	64.3	0.74
4	10	25 Feb	C	43	100	100	45.0	3.7	0.0	64.3	0.74
5	10	5 Mar	C	50	100	100	45.0	11.1	0.0	64.3	0.74
6	10	15 Mar	D	58	93	99	45.0	20.0	0.0	64.3	0.74
7	10	25 Mar	D	62	82	97	45.0	25.0	0.0	64.3	0.74
END	11	6 Apr	D	62	83	97					

Total Gross Irrigation	450.0 mm	Total Rainfall	10.0 mm
Total Net Irrigation	315.0 mm	Effective Rain	10.0 mm
Total Irrigation Losses	3.7 mm	Total Rain Loss	0.0 mm
Efficiency Irr. Schedule	98.8 %	Efficiency Rain	100 %
Deficiency Irr. Schedule	0.8 %		

YIELD REDUCTIONS	Stage A	B	C	D	Season	
Reductions in ETC	0.0	0.0	0.0	2.5	0.8	%
Yield Response factor	0.40	0.60	1.00	0.80	0.80	
Reductions in Yield	0.0	0.0	0.0	2.0	0.6	%
Cumulative Yield reduct.	0.0	0.0	0.0	2.0		%

Groundnut : Run 7

1RRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Sand	Available Soilmoist	: 100 mm/m

Irrigation Options selected :
Timing : Dates defined by user:/ 40 / 50/ 60 / 70 / 80 / 90 /100
Applicatioo : Fixed Irrigation depth of 45 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	40	25 Jan	B	69	68	93	45.0	3.3	0.0	64.3	0.19
2	10	5 Feb	B	48	100	100	45.0	0.0	6.2	64.3	0.74
3	10	15 Feb	C	55	100	100	45.0	0.0	1.1	64.3	0.74
4	10	25 Feb	C	60	91	99	45.0	3.2	0.0	64.3	0.74
5	10	5 Mar	C	67	76	96	45.0	8.7	0.0	64.3	0.74
6	10	15 Mar	D	73	63	92	45.0	13.4	0.0	64.3	0.74
7	10	25 Mar	D	74	60	89	45.0	14.2	0.0	64.3	0.74
END	11	6 Apr	D	70	68	92					

Total Gross Irrigation	450.0 mm	Total Rainfall	10.0 mm
Total Net Irrigation	315.0 mm	Effective Rain	10.0 mm
Total Irrigation Losses	7.3 mm	Total Rain Loss	0.0 mm
Efficiency Irr. Schedule	97.7 %	Efficiency Rain	100 %
Deficiency Irr. Schedule	5.1 %		

YIELD REDUCTIONS	Stage	A	B	C	D	Season	
Reductions in ETC		0.0	4.0	1.4	10.9	5.1	%
Yield Response factor		0.40	0.60	1.00	0.80	0.80	
Reductions in Yield		0.0	3.0	1.4	8.7	4.0	%
Cumulative Yield reduct.		0.0	3.0	4.3	12.6		%

Groundnut : Run 8

1RRIGATION SCHEDULING GROUNDNUT/RABI 15 December

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: GROUNDNUT/RABI	Planting date	: 15 December
Soil	: Red Loam	Available Soilmoist	: 180 mm/m

Irrigation Options selected :
Timing : Dates defined by user:/ 40 / 50 / 60 / 70 / 80 / 90 /100
Application : Fixed Irrigatioo depth of 45 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	40	25 Jan	B	41	100	100	45.0	7.0	0.0	64.3	0.19
2	10	5 Feb	B	29	100	100	45.0	0.0	2.6	64.3	\0.74
3	10	15 Feb	C	30	100	100	45.0	0.0	1.1	64.3	0.74
4	10	25 Feb	C	34	100	100	45.0	3.7	0.0	64.3	0.74
5	10	5 Mar	C	39	100	100	45.0	11.1	0.0	64.3	0.74
6	10	15 Mar	D	45	100	100	45.0	20.4	0.0	64.3	0.74
7	10	25 Mar	D	50	100	100	45.0	26.8	0.0	64.3	0.74
END	11	6 Apr	D	50	100	100					

Total Gross Irrigation	450.0 mm	Total Rainfall	10.0 mm
Total Net Irrigation	315.0 mm	Effective Rain	10.0 mm
Total Irrigation Losses	3.7 mm	Total Rain Loss	0.0 mm
Efficiency Irr. Schedule	98.8 %	Efficiency Rain	100 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 1

IRRIGATION SCHEDULING COTTON 1 August

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: COTTON	Planting date	: 1 August
Soil	: Black Clay Soil	Available Soilmoist	: 200 mm/m

Irrigation Options selected :
Timing : Irrigation applied at 100 % Readily Available Moist.
Application : Fixed Irrigation depth of 45 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	130	10 Dec	C	61	100	100	171.3	0.0	0.0	244.8	0.22
END	51	1 Feb	D	55	100	100					

Total Gross Irrigation	244.8 mm	Total Rainfall	366.9 mm
Total Net Irrigation	171.3 mm	Effective Rain	270.5 mm
Total Irrigation Losses	0.0 mm	Total Rain Loss	96.4 mm
Efficiency Irr. Schedule	100.0 %	Efficiency Rain	73.7 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 2

IRRIGATION SCHEDULING COTTON 1 August

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: COTTON	Planting date	: 1 August
Soil	: Black Clay Soil	Available Soilmoist	: 200 mm/m

Irrigation Options selected :
Timing : Fixed depletion of 80 mm
Application : Fixed Irrigation depth of 80 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	103	13 Nov	C	29	100	100	80.0	0.3	0.0	114.3	0.13
2	23	6 Dec	C	29	100	100	80.0	0.5	0.0	114.3	0.58
3	23	29 Dec	D	29	100	100	80.0	0.1	0.0	114.3	0.58
4	28	27 Jan	D	29	100	100	80.0	0.2	0.0	114.3	0.47
END	4	1 Feb	D	3	100	100					

Total Gross Irrigation	457.1 mm	Total Rainfall	366.9 mm
Total Net Irrigation	320.0 mm	Effective Rain	266.6 mm
Total Irrigation Losses	0.0 mm	Total Rain Loss	100.3 mm
Efficiency Irr. Schedule	100.0 %	Efficiency Rain	72.7 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 3

IRRIGATION SCHEDULING COTTON 1 August

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: COTTON	Planting date	: 1 August
Soil	: Black Clay Soil	Available Soilmoist	: 200 mm/m

Irrigation Options selected :
Timing : Fixed Interval of 100 (A)/100 (B)/ 20 (C)/ 20 (D) days.
Application : Fixed Irrigation depth of 80 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	81	21 OCt	C	10	100	100	80.0	0.0	52.8	114.3	0.16
2	20	11 Nov	C	17	100	100	80.0	0.0	31.0	114.3	0.66
3	20	1 Dec	C	24	100	100	80.0	0.0	12.5	114.3	0.66
4	20	21 Dec	D	25	100	100	80.0	0.0	9.8	114.3	0.66
5	20	11 Jan	D	23	100	100	80.0	0.0	15.6	114.3	0.66
END	20	1 Feb	D	18	100	100					

Total Gross Irrigation	571.4 mm	Total Rainfall	366.9 mm
Total Net Irrigation	400.0 mm	Effective Rain	266.2 mm
Total Irrigation Losses	121.7 mm	Total Rain Loss	100.7 mm
Efficiency Irr. Schedule	69.6 %	Efficiency Rain	72.6 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 4

IRRIGATION SCHEDULING COTTON 1 August

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: COTTON	Planting date	: 1 August
Soil	: Black Clay Soil	Available Soilmoist	: 200 mm/m

Irrigation Options selected :
Timing : Fixed Interval of 100 (A)/100 (B)/ 20 (C)/ 20 (D) days.
Application : Fixed Irrigation depth of 70 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	81	21 OCt	C	10	100	100	70.0	0.0	42.8	100.0	0.14
2	20	11 Nov	C	17	100	100	70.0	0.0	21.0	100.0	0.58
3	20	1 Dec	C	24	100	100	70.0	0.0	2.5	100.0	0.58
4	20	21 Dec	D	25	100	100	70.0	0.2	0.0	100.0	0.58
5	20	11 Jan	D	23	100	100	70.0	0.0	5.4	100.0	0.58
END	20	1 Feb	D	18	100	100					

Total Gross Irrigation	500.0 mm	Total Rainfall	366.9 mm
Total Net Irrigation	350.0 mm	Effective Rain	266.2 mm
Total Irrigation Losses	71.7 mm	Total Rain Loss	100.7 mm
Efficiency Irr. Schedule	679.5 %	Efficiency Rain	72.6 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 5

IRRIGATION SCHEDULING COTTON 1 August

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: COTTON	Planting date	: 1 August
Soil	: Black Clay Soil	Available Soilmoist	: 200 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/100 /120 /140 /160
Application : Fixed Irrigation depth of 70 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	100	10 Nov	C	24	100	100	70.0	0.0	1.7	100.0	0.12
2	20	1 Dec	C	24	100	100	70.0	0.0	2.3	100.0	0.58
3	20	20 Dec	D	25	100	100	70.0	0.6	0.0	100.0	0.58
4	20	10 Jan	D	23	100	100	70.0	0.0	4.4	100.0	0.58
END	21	1 Feb	D	19	100	100					

Total Gross Irrigation	400.0 mm	Total Rainfall	366.9 mm
Total Net Irrigation	280.0 mm	Effective Rain	270.5 mm
Total Irrigation Losses	8.3 mm	Total Rain Loss	96.4 mm
Efficiency Irr. Schedule	97.0 %	Efficiency Rain	73.7 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 6

IRRIGATION SCHEDULING COTTON 1 August

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: COTTON	Planting date	: 1 August
Soil	: Sandy loam	Available Soilmoist	: 140 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/100 /120 /140 /160
Application : Fixed Irrigation depth of 70 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	100	10 Nov	C	35	100	100	70.0	0.0	1.7	100.0	0.12
2	20	1 Dec	C	35	100	100	70.0	0.0	2.3	100.0	0.58
3	20	20 Dec	D	36	100	100	70.0	0.6	0.0	100.0	0.58
4	20	10 Jan	D	33	100	100	70.0	0.0	4.4	100.0	0.58
END	21	1 Feb	D	27	100	100					

Total Gross Irrigation	400.0 mm	Total Rainfall	366.9 mm
Total Net Irrigation	280.0 mm	Effective Rain	350.0 mm
Total Irrigation Losses	8.3 mm	Total Rain Loss	16.9 mm
Efficiency Irr. Schedule	97.0 %	Efficiency Rain	95.4 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 7

IRRIGATION SCHEDULING COTTON 1 August

Climate Station	: KURNOOL	Climate File	: kurn-av
Crop	: COTTON	Planting date	: 1 August
Soil	: Red Sand	Available Soilmoist	: 100 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/100 /120 /140 /160
Application : Fixed Irrigation depth of 70 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	100	10 Nov	C	49	100	100	70.0	0.0	1.7	100.0	0.12
2	20	1 Dec	C	48	100	100	70.0	0.0	2.3	100.0	0.58
3	20	20 Dec	D	50	100	100	70.0	0.6	0.0	100.0	0.58
4	20	10 Jan	D	47	100	100	70.0	0.0	4.4	100.0	0.58
END	21	1 Feb	D	38	100	100					

Total Gross Irrigation	400.0 mm	Total Rainfall	366.9 mm
Total Net Irrigation	280.0 mm	Effective Rain	268.1 mm
Total Irrigation Losses	8.3 mm	Total Rain Loss	98.8 mm
Efficiency Irr. Schedule	97.0 %	Efficiency Rain	73.1 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 8

IRRIGATION SCHEDULING COTTON 1 August

Climate Station	: KURNOOL	Climate File	: kurn-dry
Crop	: COTTON	Planting date	: 1 August
Soil	: Black Clay Soil	Available Soilmoist	: 200 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/100 /120 /140 /160
Application : Fixed Irrigation depth of 70 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	100	10 Nov	C	41	100	100	70.0	45.8	0.0	100.0	0.12
2	20	1 Dec	C	42	100	100	70.0	46.9	0.0	100.0	0.58
3	20	20 Dec	D	42	100	100	70.0	48.1	0.0	100.0	0.58
4	20	10 Jan	D	40	100	100	70.0	43.2	0.0	100.0	0.58
END	21	1 Feb	D	34	100	100					

Total Gross Irrigation	400.0 mm	Total Rainfall	240.1 mm
Total Net Irrigation	280.0 mm	Effective Rain	218.3 mm
Total Irrigation Losses	0.0 mm	Total Rain Loss	21.8 mm
Efficiency Irr. Schedule	100.0 %	Efficiency Rain	90.9 %
Deficiency Irr. Schedule	0.0 %		

Cotton : Run 9

IRRIGATION SCHEDULING COTTON 1 August

Climate Station : KURNOOL
Crop : COTTON
Soil : Black Clay Soil
Climate File : kurn-wet
Planting date : 1 August
Available Soilmoist : 200 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/100 /120 /140 /160
Application : Fixed Irrigation depth of 70 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	100	10 Nov	C	16	100	100	70.0	0.0	25.6	100.0	0.12
2	20	1 Dec	C	23	100	100	70.0	0.0	6.8	100.0	0.58
3	20	20 Dec	D	25	100	100	70.0	0.0	0.9	100.0	0.58
4	20	10 Jan	D	23	100	100	70.0	0.0	5.3	100.0	0.58
END	21	1 Feb	D	19	100	100					

Total Gross Irrigation 400.0 mm
Total Net Irrigation 280.0 mm
Total Irrigation Losses 38.6 mm
Total Rainfall 513.3 mm
Effective Rain 317.5 mm
Total Rain Loss 195.8 mm

Efficiency Irr. Schedule 86.2 %
Deficiency Irr. Schedule 0.0 %
Efficiency Rain 61.9 %

Cotton : Run 10

IRRIGATION SCHEDULING COTTON 1 August

Climate Station : KURNOOL
Crop : COTTON
Soil : Black Clay Soil
Climate File : kurn-wet
Planting date : 1 August
Available Soilmoist : 200 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/120 /140 /160
Application : Fixed Irrigation depth of 70 mm

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	120	1 Dec	C	38	100	100	70.0	37.6	0.0	100.0	0.10
2	20	20 Dec	D	38	100	100	70.0	36.7	0.0	100.0	0.58
3	20	10 Jan	D	36	100	100	70.0	31.4	0.0	100.0	0.58
END	21	1 Feb	D	30	100	100					

Total Gross Irrigation 300.0 mm
Total Net Irrigation 210.0 mm
Total Irrigation Losses 0.0 mm
Total Rainfall 513.3 mm
Effective Rain 317.5 mm
Total Rain Loss 195.8 mm

Efficiency Irr. Schedule 100.0 %
Deficiency Irr. Schedule 0.0 %
Efficiency Rain 61.9 %

APPENDIX 4.2

EVALUATION OF IRRIGATION PRACTICES

1. Climate File 1986
2. Adjusted Sorghum File
3. Crop Water Requirements HYV Sorghum
4. Irrigation Schedule as practised by farmer
5. Adjusted Irrigation Schedule
6. Farmer's practice for average year

1. Climate File 1986

Climate file : kurn-86 Climate Station : KURNOOL

	ETo (mm/day)	Rainfall (mm/month)	Eff. Rain (mm/month)
January	3.8	0.0	0.0
February	4.9	0.0	0.0
March	5.9	0.0	0.0
April	6.6	0.0	0.0
May	7.6	25.0	23.8
June	6.8	50.0	45.0
July	5.7	75.0	63.8
August	5.5	100.0	80.0
September	4.9	8.0	7.9
October	4.3	107.0	84.1
November	3.6	67.0	58.0
December	3.4	0.0	0.0
YEAR Total	1912.8	432.0	362.5 mm

Effective Rainfall with USBR method

2. Adjusted Sorghum File

Crop data : HYV SORGHUM Crop file : hyv-sorg

Growth Stage		Init	Devel	Mid	Late	Total
Length Stage	[days]	27	35	35	30	127
Crop Coefficient	[coeff.]	0.50	->	1.15	0.60	
Rooting Depth	[meter]	0.30	->	1.00	1.00	
Depletion level	[fract.]	0.50	->	0.50	0.80	
Yield-response F.	[coeff.]	0.60	0.60	1.20	0.80	1.00

3. Crop Water Requirements Sorghum

Crop Evapotranspiration and Irrigation Requirements

Climate File : KURN-AV Climate Station : KURNOOL
Crop : HYV Sorghum Planting date : 13 September

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq. mm/day	IRReq. mm/dec
Sep	2	init	0.50	2.46	17.2	24.6	0.00	0.0
Sep	3	init	0.50	2.35	23.5	32.2	0.00	0.0
Oct	1	init	0.50	2.24	22.4	30.0	0.00	0.0
Oct	2	deve	0.59	2.53	25.3	27.4	0.00	0.0
Oct	3	deve	0.78	3.16	31.6	20.6	1.10	11.0
Nov	1	deve	0.96	3.71	37.1	13.1	2.40	24.0
Nov	2	de/mi	1.10	4.02	40.2	5.9	3.42	34.2
Nov	3	mid	1.15	4.08	40.8	4.1	3.67	36.7
Dec	1	mid	1.15	3.97	39.7	2.3	3.74	37.4
Dec	2	mid	1.15	3.86	38.6	0.5	3.81	38.1
Dec	3	late	1.06	3.72	37.2	0.4	3.68	36.8
Jan	1	late	0.88	3.21	32.1	0.2	3.19	31.9
Jan	2	late	0.69	2.64	26.4	0.0	2.64	26.4
TOTAL					411.9	161.3		276.5

4. Irrigation Schedule as Practised by Farmer

IRRIGATION SCHEDULING 11YV Sorghum 13 September

Climate Station	: KURNOOL	Climate File	: kurn-86
Crop	: 11YV Sorghum	Planting date	: 13 September
Soil	: Red Clay	Available Soilmoist	: 180 mm/m
		Initial Soilmoist	: 180 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/ 72 / 93 /114
Application : Fixed Irrigation depth of 70 mm

Field Application Efficiency 70%

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
I	72	25 Nov	C	27	100	100	70.0	0.0	21.4	100.0	0.16
2	21	16 Dec	C	39	100	100	70.0	0.0	0.3	100.0	0.55
3	21	7 Jan	D	42	100	100	70.0	5.1	0.0	100.0	0.55
END	14	21 Jan	D	23	100	100					

Total Gross Irrigation	300.0 mm	Total Rainfall	184.4 mm
Total Net Irrigation	210.0 mm	Effective Rain	182.5 mm
Total Irrigation Losses	21.7 mm	Total Rain Loss	2.0 mm
Moist Deficit at harvest	41.1 mm		
Net Supply + Soil retention	251.1 mm		
Actual Water use by crop	411.9 mm	Actual Irr.Req	229.4 mm
Potential Water use by crop	411.9 mm		
Efficiency Irr. Schedule	89.7 %	Efficiency Rain	98.9 %
Deficiency Irr. Schedule	0.0 %		

No yield reductions due to water shortage.

5. Adjusted Schedule

IRRIGATION SCHEDULING 11YV Sorghum 13 September

Climate Station	: KURNOOL	Climate File	: kurn-86
Crop	: HYV Sorghum	Planting date	: 13 September
Soil	: Red Clay	Available Soilmoist	: 180 mm/m
		Initial Soilmoist	: 180 mm/m

Irrigation Options selected :
Timing : Dates defined by user :/ 80 /101
Application : Fixed Irrigation depth of 70 mm

Field Application Efficiency 70%

No. Irr.	Int days	Date	Stage -	Deplet %	TX %	ETA %	NetDep. mm	Deficit mm	Loss mm	GrDep. mm	Flow L/s/ha
1	80	3 Dec	C	41	100	100	70.0	3.4	0.0	100.0	0.14
2	21	24 Dec	D	44	100	100	70.0	8.6	0.0	100.0	0.55
END	27	21 Jan	D	50	100	100					

Total Gross Irrigation	200.0 mm	Total Rainfall	184.4 mm
Total Net Irrigation	140.0 mm	Effective Rain	182.5 mm
Total Irrigation Losses	0.0 mm	Total Rain Loss	2.0 mm
Moist Deficit at harvest	89.4 mm		
Net Supply + Soil retention	229.4 mm		
Actual Water use by crop	411.9 mm	Actual Irr.Req	229.4 mm
Potential Water use by crop	411.9 mm		
Efficiency Irr. Schedule	100.0 %	Efficiency Rain	98.9 %
Deficiency Irr. Schedule	0.0 %		

No yield reductions due to water shortage.

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