Number 8

FAOMET

Agrometeorological Crop Forecasting Tools

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Food and Agriculture Organization of the United Nations

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INTRODUCTION

Pocket Computers in Agrometeorology (FAO, 1983) is a collection of techniques to solve some of the practical problems encountered in the regular activity of agrometeorologists and bioclimatologists. Each chapter is devoted to a different type of problem, and along with the solutions, the pocket computer "code" is given. This guide was published at a time when the cost of programmable calculators was well within the reach of most meteorological and agrometeorological services in developing countries.

Since then, the personal computer has become an affordable and powerful tool, and FAOMET (FAO agroMeteorological Tools) is the computer software version of the original pocket computers routines with some modifications. FAOMET is part of a family of FAO Early Warning Software and has developed and improved through continuous use by Regional and National Early Warning projects in Africa and the Agrometeorology Group at FAO. Several other early warning packages are available; for further information, write to the Senior Agrometeorologist, Agrometeorology Group, FAO, Viale delle Terme di Caracalla, 00153 Rome.

The use of this manual and the software assumes you have some degree of familiarity with the methods presented. The original Pocket Computers in Agrometeorology can be consulted as a valuable source of information on the techniques employed in the program. For general statistics and regression analysis, Steel and Torrie (1960) and Snedecor and Cochran (1967) can be consulted; for multivariate statistical analysis, Dagnelie (1975) is a formidable textbook, and for the gamma distribution and splines as well as the computer code for many other numerical analysis techniques, you are referred to Press *et al.*, (1986). The section on Penman-Monteith crop reference evapotranspiration was largely based on a report by Smith (1991) and the Length of the Growing Period was taken from the AgroEcological Zones study (FAO, 1978).

There is no provision in the program for file management, data entry or graphic display. For these operations, a spreadsheet or database management software can be used to format the data appropriately. The advantage of this approach is that you can use commercial packages with which you are already familiar.

The manual is written in a tutorial style, i.e., each option can be worked through with a sample data file provided on the diskette and the format of each input and output file is fully described and presented in the text accompanying the description of the option. In this way you will become familiar with the options when the time comes to use them on your own data files. Or more realistically, the manual can be picked up when it is needed and a particular option can be worked through with the sample file, each option taking no more than 5 minutes. It is advisable, however, that section 2 be thoroughly read as it outlines the entire program and the general formats of the files.

In the following text, menu options, filenames and commands which you should type as part of working through an option will appear in bold. Pointed brackets (< >) refer to a single keystroke, such as the escape key **<ESC>** and italics have been used to emphasize terminology or stress an important point.

1 GETTING STARTED

1.1 Hardware Requirements

The program will run on any PC of the 80x86 family or compatible with a hard disk, a high-density floppy drive, a graphics card (at least CGA) and 640 KB of random access memory. Although a math-coprocessor is not required, it is highly recommended for the more computationally intensive options in the program.

1.2 Installation and Configuration

A special installation utility is included on the distribution diskette. Depending on your diskette (labeled either "FAOMET" or "FAOINDEX, FAOMET and FAOUTIL"), the utility will install only FAOMET or all three programs, i.e., FAOINDEX, FAOMET and FAOUTIL. For only FAOMET, the installation utility is initiated by typing **FMINSTAL**, while the 3-program installation is executed by typing **AGROMET**. For the detailed step-by-step installation of FAOMET with **FMINSTAL**, the reader is referred to Appendix A.

To start the installation program, place the distribution diskette in drive A: or B:, change the default to that drive (i.e., type **A:** or **B:**) and, at the prompt, type either **FMINSTAL** or **AGROMET** as indicated on your diskette. The installation program will guide you through the installation procedure.

You will have to specify on which drive and directory you want to install the program; the default is C:\AGROMET.FAO. In addition you need to indicate where the sample input files, which come with the distribution diskette, should be copied; the default is C:\DATA.FAO (unless otherwise specified during the installation).

It is highly recommended that you install these files as they are needed to work through the options. At the very minimum, they can be used as a handy reference regarding the input file formats, a regular source of problems in the course of using FAOMET. The program and test files occupy approximately 1MB (full FAOMET, FAOINDEX and FAOUTIL installation) and installation takes approximately 8 minutes on an 80x86-based machine.

The paragraphs below provide some advanced information on the installation of FAOMET. You may wish to skip this section and move directly to 1.3, "Starting the program".

The installation adds the following two lines (fig. 1.2a) immediately after the PATH statement in your **AUTOEXEC.BAT** file. The original version of your **AUTOEXEC.BAT** file will be renamed to **AUTOEXEC.OLD**:

```
REM This and next line added by AGROMET: do not remove or modify them
path  %path%;C:\AGROMET.FAO
```

Figure 1.2a: Modification to your AUTOEXEC.BAT file

In addition, the installation procedure will create the file **FM.BAT** (fig. 1.2b) in the directory where the FAOMET files have been installed, i.e, C:\AGROMET.FAO, if the default was adopted.

Note that if your PATH statement is very long, the new path added by the installation program may not be taken into consideration, i.e., when you type **FM** in any directory, FAOMET will not start and you will get a "Bad command or file name" message instead. If this happens, you must either shorten your PATH statement or start the program from the FAOMET directory (C:\AGROMET.FAO).

The **FM.BAT** file has the following structure:

```
@echo off
SET FAODIR=C:\AGROMET.FAO
:DIRUTIL sets current directory as default data directory; may be suppressed
DIRUTIL
C:\AGROMET.FAO\FAOMET %1
: C:\AGROMET.FAO\FAOMET %1 /NOLOGO
SET FAODIR=
@echo on
```

Figure 1.2b: FM.BAT file

The environment variable, FAODIR, tells FAOMET where to look for the definition file, **FAOMET.DEF**, and for the **FAOMET.HLP** files. **DIRUTIL.EXE,** one of the programs on the distribution diskette, sets the current directory as the default directory by modifying the last line in **FAOMET.DEF**. If **DIRUTIL** is inactivated or removed from **FM.BAT**, the program will use the directory given in the last line of **FAOMET.DEF** as the default data directory, i.e., the directory shown when using options **<ALT> FF** in the **File** menu. Refer to section 3.2 for more information.

By using the switch /NOLOGO, the FAOMET screen and the copyright notice will not be displayed when the program is run.

Note that a file name can be given on the command line *without a path* when invoking FAOMET. For example, if you start FAOMET from the DOS command line with

FAOMET SC-MALI.DAT <ret>,

FAOMET will automatically read the file **SC-MALI.DAT** into memory upon startup.

FAOMET.DEF lists some of the defaults used by the program FAOMET: the default editor and the default code for missing data. Both can be changed temporarily in the FAOMET program itself by pressing **<ALT> D** or permanently by modifying the file **FAOMET.DEF** (fig. 1.2c).

```
* no path req'd if editor is in active path in FAOMET but under c:\DOS, an active path
EDITOR=C:\AGROMET.FAO\LISTS
*value below can be used to override default of -999
Missing=-999
* do not forget: no final \ in following line
Datadir=C:\DATA
```

Figure 1.2c: a portion of the FAOMET.DEF file

Note that you can use any editor, but for changes to take effect in FAOMET, a modified file must be saved and opened again (**<ALT> FF**). In addition, large editors may cause memory problems.

1.3 Starting the Program

To start the FAOMET program, type **FM <ret>** from C:\DATA.FAO or the directory you indicated should contain the sample files. This ensures that your output will be written to this directory.

2 BASIC CONCEPTS

In this chapter you will be introduced to FAOMET's menu system, the basic operations of the program and the file formats.

2.1 The Main Screen

After entering the program you will see 2 FAOMET introductory screens with the FAO logo and the copyright. To pass by these, press **<ret>** and the main screen will be displayed with a menu bar on top and a window listing the program defaults (fig. 2.1). From this screen you read in the data files, access any options and exit the program.

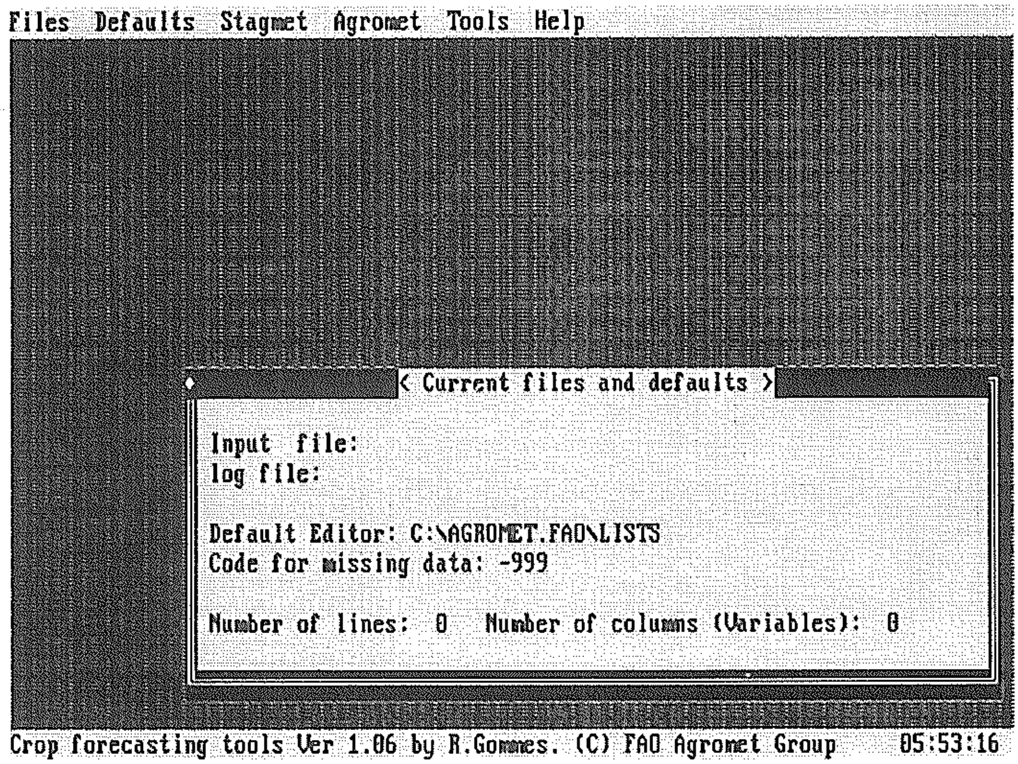

Figure 2.1 The main FAOMET menu and window screen

2.2 The Menu Options

The menu bar at the top of the main screen lists the 6 first level options available. Each option has a pull down menu with several second level options that can be accessed in one of 2 ways: either the menu is pulled down with a mouse and clicked on or the **<ALT>** key is pressed followed by the highlighted letter of the option. Note that in the text, you will normally be asked to access the options with the **<ALT>** key, but use of the mouse instead is possible in all cases. A breakdown of the program's first and second level structure is provided in fig. 2.2. Sections 3 to 6 explain each of the options in greater detail.

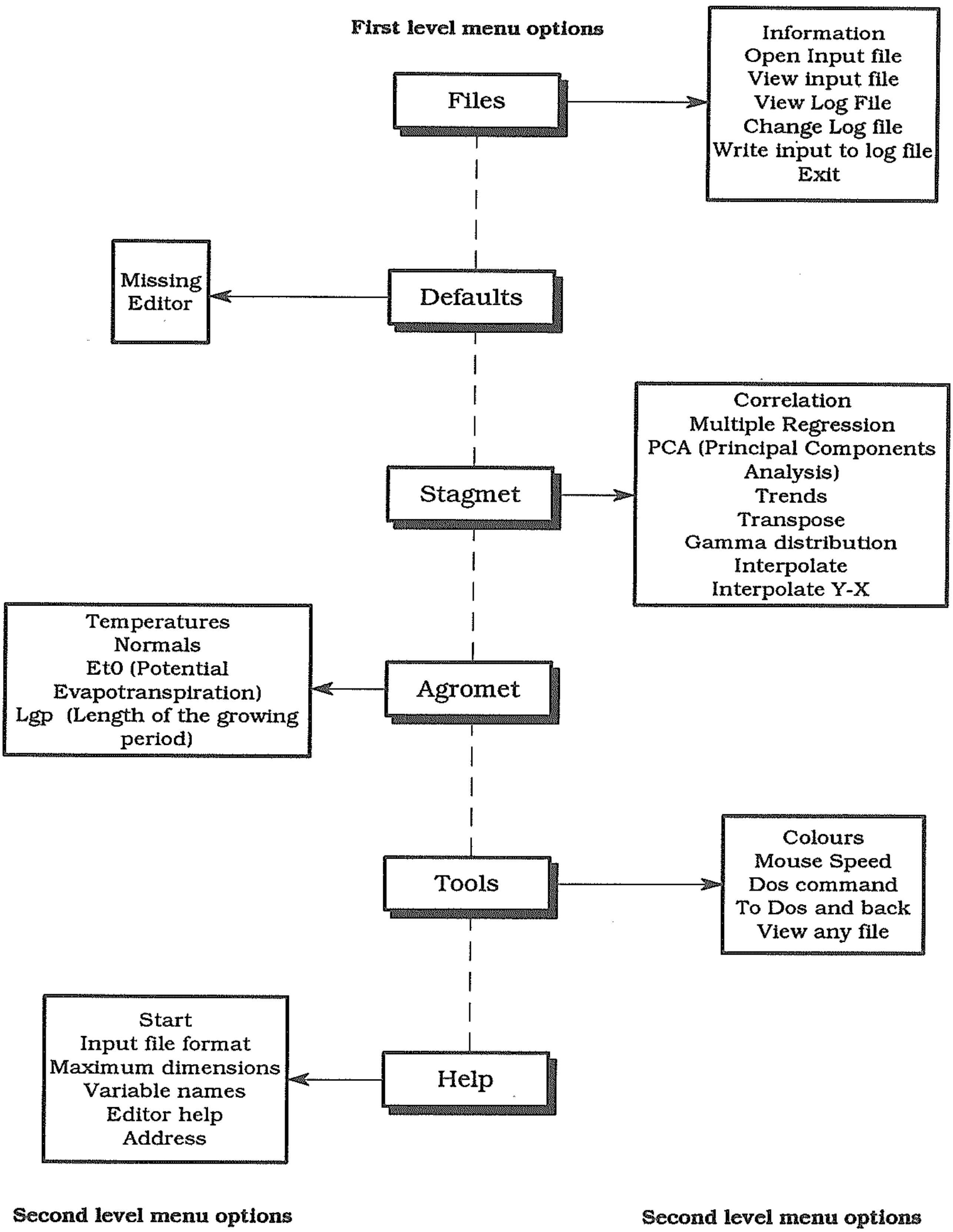

Figure 2.2: FAOMET menu structure

2.3 Defaults

The default code for missing data and the default editor that FAOMET uses are stated on the opening screen (fig. 2.1), both of which can be easily changed.

To change the default code of -999 for missing data, select **<ALT> D** to pull down the **Defaults** menu, press **M** for **Missing**, and enter your own code for missing data. To change the default editor, select **E** for **Editor** and you will be prompted to enter the path and name of your editing package. The editor supplied with FAOMET, **LIST.COM**, is a public domain software package that only allows you to view your files and is therefore not a true editor. The advantage of **LIST.COM** is that you can view files of any size without the 64K limit of many true editors and it is one of the smallest editors around.

2.4 File Formats

FAOMET requires that the input data are formatted in a certain manner which can be created easily with your spreadsheet or database package. The output from FAOMET is either in the same format or the information is written to a log file that also keeps track of all the operations that have occurred in a given session of FAOMET.

Take note of a very common source of error: if the "code for missing data" is set to -999, and the file actually contains -9999, which is your coding, the -9999 will not be interpreted as missing but will be used in the calculations as the negative number -9999, and will, quite obviously, lead to meaningless results in most instances.

2.4.1 Input files

The format of the input files is ASCII with the following basic structure:

one line with a title
one line with column headings
lines of data corresponding to the column headings

The first line is a string of text that identifies the contents of the file. The second line indicates the variables contained in the columns. The third line and onwards contains the data. Each line may optionally begin with a string of characters that represents the line identifier, typically a station name, which is then followed by the actual data values. The program assumes that the number of data items in lines 3 onwards is the same as on line 2. For instance, if line 2 lists 3 variables, all data items in excess of 3 will be ignored. If, on the other had, a data line contains insufficient data items, the program will issue a message.

Note that the line identifier need not enclosed in quotes. The quotes are only used to import the file into Lotus and other spreadsheets. In additon, valid variable names and line identifiers cannot contain spaces, for e.g., use "Normal_PET" or "PET(normal)" for a column heading as opposed to "Normal PET". Blank lines or lines containing only commas (a result of exporting from Microsoft Works) are ignored, as well as more than 1 space between data or variables. Spaces or commas must be used as separators between items.

The program can identify a number of variables by a the short forms listed in tab. 2.4.1. The table lists the column heading on the left that can be used in your files and the program will assume the meaning given on the right. Note that capitals are not required in your input file. Remember, if you use these predefined column headings and your units are wrong, the results will be wrong too!

Column Heading	Meaning	Units
LAT, X and LON, Y	latitude and longitude	Decimal degrees or degree minutes
ALT, ELE or Z	altitude, elevation	m
MO	month	1 to 12
DA or JO	day, date, jour	1 to 31
HO, SU, HE or DU	sunshine hours, heures, durée	0 to daylength
RA	incoming radiation, rayonnement	MJ/m^{-2}/day
FRA	sunshine fraction	0 to 1
WI or VE	wind, vent	m/s
TMA or TX	maximum temperature	°C
TMI or TN	minimum temperature	°C
TAV or TEM	average temperature	°C
RH, REL, HUM or HR	relative humidity, humidité relative	0 to 1
VAP or TEN	vapour pressure, tension de vapeur	kPa

Table 2.4.1 : Pre-defined column headings

To help you become accustomed with the format of the files, 5 different sample files are shown. All of these are acceptable to FAOMET. Choose the one that your spreadsheet or database program can easily copy (with the exception of number 5 which has been included to illustrate the flexibility of the input format!).

Examine the first sample input file, **SAMPLE1.DAT**, shown in fig. 2.4.1a. The title appears on the first line followed by a blank line which FAOMET ignores. The second line contains the column headings followed by 11 lines of space-separated data. Notice that neither the title nor the column headings are in quotations. FAOMET is able to identify what they are as a result of their position in the file and because they are separated by spaces.

```
      This is the title

 First    Second   Third    Last

  87.9     19.6      1.0    1661
  89.9     15.2     90.1     968
 153.0     19.7     56.6    1353
 132.1     17.0     91.0    1293
  88.8     18.3     93.7    1153
 220.9     17.8    106.9    1286
 117.7     17.8     65.5    1104
 109.0     18.3     41.8    1574
 156.1     17.8     57.4    1222
 181.5     16.8    140.6     902
 181.4     17.0     74.3    1150
```

Figure 2.4.1a : SAMPLE1.DAT

Now have a look at the second sample data file, **SAMPLE2.DAT**, appearing in fig. 2.4.1b. This time the title and the column headings are enclosed in quotes. Note the extra commas after the title which are ignored by FAOMET. Some spreadsheet programs will print extra commas because the title takes up only one cell and the spreadsheet is several cells wide. After the column headings are 10 lines of data; the first column contains the line identifier, which must be enclosed in quotes since line identifiers are not variables. Following the identifier are 4 columns of comma-separated data that matches the four column headings in the second line.

```
"This is the title",,,,,
,"First","Second","Third","Last",
"Line1",87.9,19.6,1,1661,
"Line2",89.9,15.2,90.1,968,
"Line3",153,19.7,56.6,1353,
"Line4",132.1,17,91,1293,
"Five",88.8,18.3,93.7,1153,
"Six",220.9,17.8,106.9,1286,
"Seven ",117.7,17.8,65.5,1104,
"Eight",109,18.3,41.8,1574,
"Nine",156.1,17.8,57.4,1222,
"Ten",181.5,16.8,140.6,902,
```

Figure 2.4.1b : SAMPLE2.DAT

The third sample file, **SAMPLE3.DAT** is similar to the previous file expect for the absence of the comma on the second line. As well, the data are space separated.

```
"This is the title"
"First" "Second" "Third" "Last"
"Line1" 87.9 19.6 1 1661
"Line2" 89.9 15.2 90.1 968
"Line3" 153 19.7 56.6 1353
"Line4" 132.1 17 91 1293
"Five" 88.8 18.3 93.7 1153
"Six" 220.9 17.8 106.9 1286
"Seven " 117.7 17.8 65.5 1104
"Eight" 109 18.3 41.8 1574
"Nine" 156.1 17.8 57.4 1222
"Ten" 181.5 16.8 140.6 902
```

Figure 2.4.1c : SAMPLE3.DAT

The fourth sample file, **SAMPLE4.DAT** (fig. 2.4.1d), is a slight variation on the other three. In this case, the column headings are enclosed in quotes, extra commas are on the title line, no line identifiers are included and the data are space-separated.

```
"This is the title",,,,,
"First" "Second" "Third" "Last"
87.9 19.6 1 1661
89.9 15.2 90.1 968
153 19.7 56.6 1353
132.1 17 91 1293
88.8 18.3 93.7 1153
220.9 17.8 106.9 1286
117.7 17.8 65.5 1104
109 18.3 41.8 1574
156.1 17.8 57.4 1222
181.5 16.8 140.6 902
```

Figure 2.4.1d: SAMPLE4.DAT

The final example input file, **SAMPLE5.DAT**, shown in fig. 2.4.1e, is a somewhat chaotic but quite acceptable file for FAOMET. The spaces in the title make no difference as FAOMET will remove the extra spaces when it prints out the title in the **FAOMET.LOG** file. All the blank lines are ignored. You can easily mix comma separated and space separated data within a file or within a single line as this example shows. Although you cannot put spaces in the middle of a column or line identifier, you can have spaces at the end of it, as in the example "Seven ". Line identifiers can be absent or present within the same file since FAOMET does not consider them to be variables. Finally, a line with data can start in the middle of the file as opposed to the beginning of the line if you wish.

Thus there is a great deal of flexibility regarding the input file format. Choose the one that is most easily created by your spreadsheet or database program.

```
"This      is       the       title"

,"First_of_four","Second_of_four "    "Third"       "Last"


"Line1",87.9,19.6,1,1661,

"Line2"    ,89.9       ,15.2,       90.1,       968
"Line3"    153     19.7     56.6    1353

132.1          17        ,91      1293

"Five",88.8,18.3,93.7,1153,
"Six",220.9,17.8,106.9,1286,
"Seven ",117.7,17.8,65.5,1104,

                     "Eight",109,18.3,41.8,1574,
                      "Nine",156.1,17.8,57.4,1222,
                            181.5,16.8,140.6,902,

                   181.4          17             74.3
 1150
```

Figure 2.4.1e: SAMPLE5.DAT

2.4.2 Formatting of Input Files with a Spreadsheet

To create a FAOMET input file with LOTUS123 v.3.1, the sequence of commands would be:

/ **Print File** filename
Options Other Unformatted Quit
Range highlight_range **Go Quit**

Bolded words are the actual LOTUS commands while unbold refers to user-defined input.

With Microsoft Works, you would print your worksheet to a text file. All character strings will automatically be placed in quotes and numbers will be comma separated.

2.4.3 Output Files

The output from FAOMET is either written to an ASCII file or the **FAOMET.LOG** file although several options write output to both these files. If the option writes output to an ASCII file, the filename will be based on the input filename. The first letter will be S or A for the Stagmet or Agromet function that was used and the second letter will be the particular option on that menu. This is followed by a single underline character, the first four letters of the input file name and a number. The first time you run the option with this input file, the number will be 1. Each successive time it will be incremented by 1, i.e., the output file will not be overwritten. For instance, if you use the geographic interpolation function on the Stagmet menu with the input file **SI-LGS.DAT**, the output file name will be **SI_SI-L1.DAT**.

The second form of output is the **FAOMET.LOG** file. In addition to being the only output file for several options, it is always created and records all the activities done in one session of using FAOMET. Each time FAOMET is exited and restarted, the log file is overwritten. The log file is an ASCII file and can therefore be edited within or outside of FAOMET with any editor.

An example **FAOMET.LOG** file is shown in fig. 2.4.2 after having read the file **SC-MALI.DAT** into memory and exiting the program. This file always displays the time and date, the input file name, the title (which is the first line of the input file), the list of variables with the minimum and maximum, the number of lines in your file and the date and time that you finished the session. If other options had then been chosen, this would also be listed in the file. See sections 4 and 5 for example **FAOMET.LOG** files that are created after running the different options on the Stagmet and Agromet menus.

```
————Beginning session (03 November 1993 at 23:04:55)————
————New input file OR code for 'missing' modified————
    Source file: C:\TESTDATA.FAO\SC-MALI.DAT
  Title: Mali 1990 Sorghum yield (LGS and normal rain are L10/1.2/3)
                    List of variables
    Nr  Name          Number missing  Minimum      Maximum
     1  NDVI26              0          128          202
     2  IND                 0          66.8         98.9
     3  YLD                 1          0            1040
     4  LON                 0          -11.1        -2.5
     5  LAT                 0          10.4         17
     6  LGS                 0          30           187
     7  NormRain            0          244          1317
     8  PTB28               0          3            135
  Complete data lines:  39  / Code for missing data: -999
————Closing file (03 November 1993 at 23:05:04)————
```

Figure 2.4.2 : An example FAOMET.LOG file

2.4.3 The Sample Files

The sample input files are located in the **\DATA.FAO** directory unless you have installed them in a directory of your choice. Although each file has the extension ***.DAT**, you are free to use your own extensions. The output files that correspond to each option are not included on the diskette but do appear in the text. You will need to run each option in order to create these yourself.

The sample files have names that indicate the option for which they should be used. The first letter is either **S** or **A** referring to the **S**tagmet or **A**gromet menu while the second letter denotes the individual option on each of these menus. For example, the file **SC-MALI.DAT** indicates that this file is used to illustrate the **C**orrelation function on the **S**tagmet menu. This file naming convention has been adopted only for the purpose of demonstrating the various FAOMET options and does **not** have to be respected when you create your own files!

3 DATA MANAGEMENT

From the **File** menu, files can be opened, read into memory, and viewed. In addition, from this screen you exit the program. To access these functions, pull down the **File** menu by pressing **<ALT> F** followed by the highlighted letter in the corresponding option.

3.1 Information

If you encounter an **UNEXPECTED ERROR** when opening a file, a message will appear listing the error number, you will be thrown out of the program and you will be instructed to check your input file. If you cannot find a solution to the problem, pull down this option on the **File** menu and you will be encouraged to send the file on a diskette to the address given in the **Help** information of the **U**tilities option.

UNEXPECTED ERROR 5 can occur if the number of data values in your file does not match the number of column headings. Use the editor to check your file carefully in the event of this error message.

UNEXPECTED ERRORS 1 to **4** have as yet not been encountered!

3.2 Opening an Input File

This option reads your input data file into memory and is necessary before you can perform any **S**tagmet or **A**gromet function. The file is read in line by line and a data check for certain errors is run. For example, FAOMET will not accept certain characters such as a space or a single quote in a line identifier. Make sure that your station names do not contain either of these. If they do, FAOMET will display a message stating that there are illegal alphabetic characters present in your input file. In addition, a character string will be listed containing the illegal character(s) and the number of the data line with the error. Press **<ret>** and a further message will appear declaring that your selected input file is not correctly formatted. Press **<ret>** to kick yourself out of FAOMET and use your editor to make the necessary changes.

As a consequence of the way in which data are read into memory in FAOMET, the program has some memory limitations. The maximum dimensions of your file will depend on the available RAM. With 640 KB of RAM, all the options can normally be run with 400 lines and 50 variables (or 40 lines and 500 variables). Errors will only appear when the value of the product between the number of lines and the number of variables is between 20 000 and 50 000. If an error message occurs indicating insufficient memory, reduce the dimensions of your input file. Note that the **A**gromet options can take much larger input data files than the **S**tagmet ones.

To read in your data file, press **<ALT> F** to pull down the **F**ile menu and select Open **i**nput file. You will see a file selection screen (fig. 3.2). If the path is correct, type in the data file or use the **<TAB>** key to move to the **F**iles box in the left bottom corner. Use the arrow keys to highlight the file and press **<ret>**. To change the path, use the **<TAB>** key to move to the **Paths** box in the righthand side. Highlight the drive, the directory and then select the file. Although FAOMET looks for ***.DAT** files, you can change this to read in a file with any extension. Alternatively you can use the mouse to find the correct file. Start FAOMET from the C:\DATA.FAO directory and you will automatically see the sample data files listed in the **Files** box.

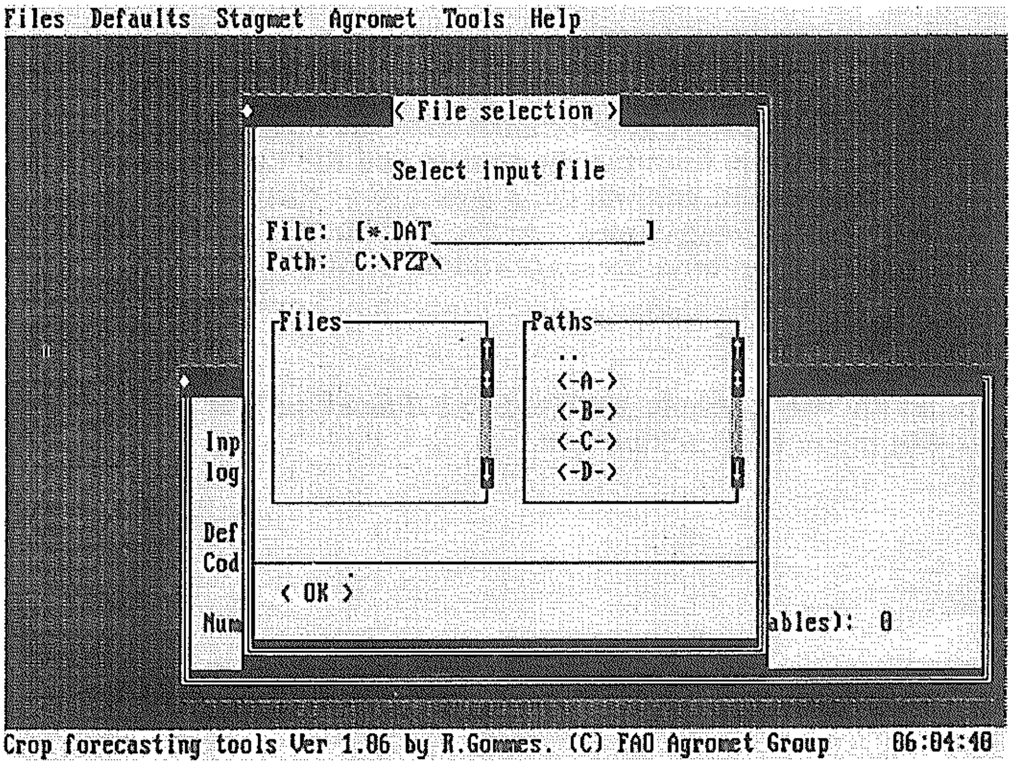

Figure 3.2: Opening a data input file

Note that it is also possible to start the program with a file name typed on the command line, for e.g., **FM SC-MALI.DAT <ret>**. This set of commands will start up the program and automatically read this file into memory.

3.3 Viewing an Input File

This option allows you to view but not edit your input file using the public domain software, **LIST.COM**. You will be temporarily transferred to this package, and after pushing **<ESC>**, control is returned to FAOMET and you can proceed.

3.4 Viewing a Log File

This option is the same as the one described in section 3.3; **LIST.COM** is invoked to view the **FAOMET.LOG** file, a special file created everytime that FAOMET is executed.

3.5 Changing a Log File

This options lets you change the default name of **FAOMET.LOG** to a name of your choice. This is a useful option if (a) you are running many options without exiting FAOMET, resulting in a log file larger than 64K, i.e., the limit of most DOS editors; (b) if you have your own file-naming system; or (c) if you do not want to overwrite the file each time you use FAOMET after exiting.

3.6 Writing Input to a Log File

This option will insert your original data file into the log file for situations where you might want to examine the results and the raw data at the same time. After running this option, you will get a message at the top of your screen saying that your input file is being copied into the **FAOMET.LOG** file. If no input file is currently in memory, an error message will be displayed.

3.7 Exiting the Program

To exit FAOMET, simply press **<ALT> FX** and type **Y** or use the mouse to pull down the **File** menu and click on **Exit**.

4 STAGMET OPTIONS

This chapter describes, in detail, the statistical functions available in FAOMET and illustrates each option with practical examples. You are encouraged to work through the step-by-step procedure using the sample files provided on the diskette to acquire hands-on experience with the input file formats and the information contained in the output.

Only a portion of the sample files are listed in the text and the output files have often been edited to show only the relevant information. Use an editor or the view input file option provided in FAOMET to see the complete files.

Under the Stagmet options, the lines in the input matrix are referred to as "observations", while columns correspond to the different "variables".

4.1 Computing a Correlation Matrix

This stagmet option allows you to describe your dataset with some simple statistics. Suppose that you are interested in modelling the yield of sorghum in Mali. You have yield data at the station level as well as several other geographical, agrometeorological and remote sensing variables. This option will calculate, for all variables in the data file:

- the **average**, which is the "central value" of a variable and is the sum of all the values of a variable divided by the total number of observations;

- the **standard deviation**, which is a measure of dispersion or variability and is the square root of the sum of the deviations of each observation from the mean squared, divided by the total number of observations;

- the **coefficient of variation**, which is a relative measure of variation and a useful statistic in comparing different variables. The standard deviation is expressed as a fraction or a percentage of the mean; and,

- a **matrix of correlation coefficients**, which is a table showing the association between each of the variables in the input file. A coefficient of correlation is a measure of the degree of closeness of a linear relationship between two variables and ranges from -1 to 1.

For more information on these statistical terms, you are referred to Snedecor and Cochran (1967) and Steel and Torrie (1960).

To work through this option, use the sample file, **SC-MALI.DAT**, shown in fig. 4.1a, which contains: sorghum yield data (YLD); the Normalized Difference Vegetation Index (**NDVI26**) during the 26th dekad (see Hielkiema and Snijders, 1993) for more information on this variable; the Water Requirement Satisfaction Index (**IND**), a variable computed by FAOINDEX (Gommes, 1993); the geographic coordinates (**LON** and **LAT**); the length of the growing period (**LGS**) (see section 5.4);

the normal annual rainfall at each station (**NormRain**), and an estimate of actual evaporation (in mm) for dekad 28 based on thermal inertia as estimated from METEOSAT images (**PTB28**).

```
"Mali 1990, Sorghum yield (LGS and normal rain are L10/1.2/3)"
" ","NDVI26","IND","YLD","LON","LAT","LGS","NormRain","PTB28"
"Bafoulabe",187,92.6,843,-10,14,115,1027,126
"Banamba",165,92.3,602,-7.3,13.7,121,914,119
"Bandiagara",144,86.1,431,-3.7,14.5,94,517,96
"Bankass",157,90.7,472,-3.6,13.5,116,749,103
"Baraoueli",175,95.4,755,-6.5,13,125,987,128
"Bla",170,97.1,838,-5.9,12.9,125,814,128
"Bougouni",183,97.6,395,-7.3,11.2,161,1297,124
"Diema",162,88.7,792,-9.5,14.5,104,737,116
"Dioila",181,97.1,496,-6.7,12.4,136,1103,135
"Dire",128,73.6,0,-3.2,16.3,44,364,40
```

Figure 4.1a : SC-MALI.DAT

After opening the file, press **<ALT> SC** to start the calculations. When they are complete, you will find yourself back at the main menu. Output will be written to the **FAOMET.LOG** file; view this file with the View Log File option on the File menu and you will see the same information as listed in fig. 4.1b.

In the log output file, you will see the list of variables with their corresponding ranges, the number of missing data points, the minimum and maximum value of each parameter, a table with the statistics for each variable and the correlation matrix.

```
            Title: Mali 1990 Sorghum yield (LGS and normal rain are L10/1.2/3)

                                  List of variables

                  Nr   Name          Number missing   Minimum        Maximum
                   1   NDVI26              0            128            202
                   2   IND                 0            66.8           98.9
                   3   YLD                 1            0              1040
                   4   LON                 0            -11.1          -2.5
                   5   LAT                 0            10.4           17
                   6   LGS                 0            30             187
                   7   NormRain            0            244            1317
                   8   PTB28               0            3              135

         Complete data lines:  39  / Code for missing data: -999

                                 VARIABLE STATISTICS

       Nr  (Name)           Average      St. Dev.     CV%       Min           Max
       ---------------------------------------------------------------------------------
        1  (NDVI26     )  | 0.1651D+03  0.1881E+02   11.4  0.1280D+03  0.2020D+03
        2  (IND        )  | 0.8947D+02  0.9059E+01   10.1  0.6680D+02  0.9890D+02
        3  (YLD        )  | 0.5794D+03  0.2507E+03   43.3  0.0000D+00  0.1040D+04
        4  (LON        )  | -.6289D+01  0.2385E+01   37.9  -.1110D+02  -.2500D+01
        5  (LAT        )  | 0.1365D+02  0.1573E+01   11.5  0.1040D+02  0.1700D+02
        6  (LGS        )  | 0.1144D+03  0.3412E+02   29.8  0.3000D+02  0.1870D+03
        7  (NormRain   )  | 0.8412D+03  0.2777E+03   33.0  0.2440D+03  0.1317D+04
        8  (PTB28      )  | 0.1050D+03  0.3152E+02   30.0  0.3000D+01  0.1350D+03


                                 CORRELATION MATRIX

                  1        2        3        4        5        6

     1            *                                                       1 (NDVI26)
     2      0.7925        *                                               2 (IND)
     3      0.5360   0.5474        *                                      3 (YLD)
     4     -0.7570  -0.4049  -0.4865        *                             4 (LON)
     5     -0.7298  -0.8128  -0.3389   0.2092        *                    5 (LAT)
     6      0.8183   0.8340   0.4162  -0.3842  -0.9728        *           6 (LGS)
     7      0.8496   0.8030   0.4061  -0.4795  -0.9001   0.9217           7 (NormRain)
     8      0.8075   0.8054   0.5818  -0.5235  -0.7900   0.8622           8 (PTB28)

                  1        2        3        4        5        6

                  7        8

     1                                1 (NDVI26)
     2                                2 (IND)
     3                                3 (YLD)
     4                                4 (LON)
     5                                5 (LAT)
     6                                6 (LGS)
     7            *                   7 (NormRain)
     8      0.8234        *           8 (PTB28)

                  7        8
```

Figure 4.1b : FAOMET.LOG file

4.2 Simple and Multiple Linear Regression

Although an association or correlation may exist between two variables, we may want a mathematical relationship linking the two. For example, we may want to model the sorghum yield (**YLD**) in Mali (from the previous example) as a function of the Water Requirement Satisfaction Index (**IND**) and express this mathematically by fitting an equation through the data. Since we assume that the yield changes as a result of a change in the index, the yield is the *dependent variable*, Y, and the index is the *independent variable*, X. The equation for the straight line of best fit would therefore be:

$$Y = a + bX_1$$

where a is the intercept, i.e., the value of the yield when the index, X_1, is 0, and b is the slope of the line. This is an example of simple linear regression and uses a method known as least squares. The resulting regression line is such that the sum of the squares of the departures of Y from the line will be as small as possible. This method takes all the observations into account, giving each of them an equal weight in determining the result.

Suppose we find that our simple linear model explains only a portion of the variation in yield so we will add 2 other independent variables to the relationship, **NDVI26**, X_2, and **LGS**, X_3. This is an example of multiple linear regression and the equation would become:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3$$

where b_1 to b_3 are the corresponding X coefficients.

To do this particular multiple regression, open the same example file as used in section 4.1, **SC-MALI.DAT**, and press **<ALT> SM**. The following screen will be displayed listing the variables in the input file (fig. 4.2a):

List of variables in input file...

ID#	Variable name	ID#	Variable name	ID#	Variable name
1	NDVI26	4	LON	7	NormRain
2	IND	5	LAT	8	PTB28
3	YLD	6	LGS		

```
ID# of number of dependent variable (<ret>=end) ? 3

Now input the ID# numbers of 'independent' variables
(0=exit, <ret> to end input)

            var  1  is ? 1
            var  2  is ? 2
            var  3  is ? 6
            var  4  is ?
```

Figure 4.2a : List of input variables

You will be prompted to enter the ID#s of the dependent and independent variables: enter 3 for **YLD** and 1, 2 and 6 for **NDVI**, **IND** and **LGS**, respectively.

Since there are only 3 independent variables in our model, press **<ret>** after the prompt for variable 4. The screen will clear and 2 questions will appear, one after the other:

```
Compute values of dependent variable (Y/N)  ?  Y

Compute Y from manually input X's (Y/N)  ?  N
```

Figure 4.2b : User Prompts

If you answer yes (Y) to computing the values of the dependent variable, the program will list a table of yield values computed with the regression equation. If you answer yes (Y) to the second question, you will be prompted to enter a value for each of the independent varaiables and the yield will be calculated and displayed on your screen. Try this option with an NDVI value of 0.3, an index of 90% and an LGS of 120 days.

Once these questions are answered, the regression equation is calculated and you will be brought back to the first screen listing the input variables. Press **<ret>** to go back to the main menu or try another regression with different independent variables.

The results of the regression analysis are listed in the **FAOMET.LOG** file (fig. 4.2c). The file contains a list of variables, the number of missing data, the minimum and maximum values and various statistics about the dependent and independent variables. This is followed by a correlation matrix of the variables, the number of observations and various other regression statistics including the:

- **Residual sum of squares**, which is the square of the individual deviations of the computed yield from the observed, and then summed.

- **Coefficient of determination**, which is the percentage of total variation accounted for by the regression. In this example, only 35.7% of the total variation has been accounted for by these three variables. The correlation coefficient given in the table is the square root of the coefficient of determination.

- **Snedecor's ratio of variance**, which is also known as the "F" statistic and can be used to test whether the variances are similar or not. Refer to Snedecor and Cochran (1967).

Following this list of statistics are the coefficients of regression for each variable, marked as **B(var#)**, and the regression equation would read as follows:

$$Y = 1307.30 + 5.65*NDVI26 + 13.97*IND - 2.58*LGS$$

Beside each coefficent is the standard error, **E(var#)**, and the ratio of **B(var#):E(var#)**, i.e., the "t" statistic, which can be used to test the significance of the individual coefficients. As a rule of thumb, only those variables with a B/E ratio of around 2 or greater should be retained. In practice, the straightforward multiple regression is run with a set variables and after eliminating those with a low B/E ratio, the regression is run again. In the last part of the output, a list of the actual or observed values and those computed from the regression equation are given. Under operational conditions, the average absolute error should be in the range of 10 to 15% or less.

```
Title: Mali 1990 Sorghum yield (LGS and normal rain are L10/1.2/3)

                         List of variables

 Nr    Name          Number missing   Minimum        Maximum
  1    NDVI26              0            128            202
  2    IND                 0            66.8           98.9
  3    YLD                 1            0              1040
  4    LON                 0            -11.1          -2.5
  5    LAT                 0            10.4           17
  6    LGS                 0            30             187
  7    NormRain            0            244            1317
  8    PTB28               0            3              135

              Dependent variable Y is nr  3 (YLD)

                       VARIABLE STATISTICS

Nr  (Name)          Average      St. Dev.      CV%       Min            Max
-------------------------------------------------------------------------------
 3  (YLD       )  | 0.5794D+03  0.2507D+03    43.3   0.0000D+00   0.1040D+04
 1  (NDVI26    )  | 0.1651D+03  0.1881D+02    11.4   0.1280D+03   0.2020D+03
 2  (IND       )  | 0.8947D+02  0.9059D+01    10.1   0.6680D+02   0.9890D+02
 6  (LGS       )  | 0.1144D+03  0.3412D+02    29.8   0.3000D+02   0.1870D+03

                       CORRELATION MATRIX

          3         1         2         6
3         *                                       3 (YLD)
1    0.5360         *                             1 (NDVI26)
2    0.5474    0.7925         *                   2 (IND)
6    0.4162    0.8183    0.8340         *         6 (LGS)
          3         1         2         6

                       REGRESSION STATISTICS

     Number of observations           N              38
     Residual sum of squares          RSS    0.1536D+07
     Correlation coefficient          r        0.597563
     Coefficient of determination     r²       0.357082
     Snedecor's ratio of variances    F      0.6295E+01


                      COEFFICIENTS OF REGRESSION

Variable        Coeff. of regression      Std. errors          B/E

                 B(0)=-1.3073044D+03

(NDVI26)         B(1)= 5.6454878D+00   E(1)=0.3401D+01  B/E(1)=  1.660
(IND)            B(2)= 1.3966770D+01   E(2)=0.7354D+01  B/E(2)=  1.899
(LGS)            B(6)=-2.5808350D+00   E(6)=0.2072D+01  B/E(6)=  1.246


                    Nr  observed computed  err%      abs. err.
                  ---------------------------------------------
   Bafoulabe         1    843.00   744.93   -12      -98.07141
   Banamba           2    602.00   601.05    -0       -0.94708
   Bandiagara        3    431.00   465.59    +8      +34.58615
   Bankass           4    472.00   546.45   +16      +74.44629
   Baraoueli         5    755.00   690.48    -9      -64.51862
   Bla               6    838.00   686.00   -18     -152.00256
   Bougouni          7    395.00   673.46   +70     +278.46216
   Diema             8    792.00   577.71   -27     -214.28986
   Dioila            9    496.00   719.71   +45     +223.70862
   Dire             10      0.00   329.72  -999     +223.70862
   Niafunke         27     has missing data
   Niono            28    429.00   518.06   +21      +89.05963
    etc.

      Average relative error (absolute values) :     26 %
                             Extreme errors:      -47% and    +87%
```

Figure 4.2c : FAOMET.LOG file

4.3 Principal Components Analysis (PCA)

Principal components analysis is a powerful tool used to examine the structure of the variables used to build your regression model. Since we are not certain as to whether the variables are independent of one another or whether they are important in explaining the variance in our yield, we can use principal components analysis to indicate variables with similar behaviours by redistributing the variance among a new set of uncorrelated axes (the principal components) and permitting the replacement of the initial, generally correlated, variables by non-correlated ones. The correlations between the components and the original variables gives some indications as to which variables are important, i.e., which variables are worth retaining in a multiple regression analysis.

Often one can also cancel the third or sometimes even the second principal component of the three. Moreover, the analysis also provides a complementary interpretation of the initial variables.

To illustrate how principal components analysis can be used, examine the input file **SP-MET.DAT** in fig. 4.3a (Dagnelie, 1975). The file contains annual yield from 1920 to 1930 and three climatological variables, the mean temperature, precipitation and radiation measured during the month of July. We imagine that the yield is a function of these three parameters but we suspect that the three variables are not entirely independent of one another.

```
"Meteorological and Yield Data Time Series"
" ","TemJul","RnJul","RdJul","Yield"
"Eg-1920",19.6,1,1661,28.8
"Eg-1921",15.2,90.1,968,29.8
"Eg-1922",19.7,56.6,1353,28.8
"Eg-1923",17.0,91.0,1293,31.0
"Eg-1924",18.3,93.7,1153,28.7
"Eg-1925",17.8,106.9,1286,23.5
"Eg-1926",17.8,65.5,1104,24.6
"Eg-1927",18.3,41.8,1574,27.8
"Eg-1928",17.8,57.4,1222,28.8
"Eg-1929",16.8,140.6,902,23.9
"Eg-1930",17.0,74.3,1150,26.5
```

Figure 4.3a : SP-MET.DAT

Pull down the Stagmet menu, **<ALT> S**, press **P** and a screen will be displayed listing the variables in each column of the data file above (fig. 4.3b). Below the list of variables, you will be prompted to indicate the number of variables and their ID#s: enter **3** for the total number and **1**, **2**, **3** for the ID#s. After the program has finished the calculations, you will find yourself back at screen#1. Press **<ret>** to exit this option unless you want to repeat the analysis.

List of variables in input file...

ID#	Variable name	ID#	Variable name	ID#	Variable name
1 2	TemJul RnJul	3 4	RdJul Yield		

```
How many variables (A=all, <ret>=end) ? 3

Now input the ID# of  3  variables <ret>=end

        var  1  is ? 1
        var  2  is ? 2
        var  3  is ? 3
```

Figure 4.3b : List of input variables

The output from this option is written to two files: **SP_SP-M.DAT**, which contains the actual values of the principal components (fig. 4.3c),

```
"Principal components matrix"
,"C-1","C-2","C-3"
"Eg-1920",3.0762,-.5088,-.0184
"Eg-1921",-2.2889,-1.3406,-.0741
"Eg-1922",1.3628,.717,-.2729
"Eg-1923",-.5932,-.3788,.6833
"Eg-1924",-.4316,.5911,-.0799
"Eg-1925",-.5101,.4145,.7205
"Eg-1926",-.3304,-.1875,-.5809
"Eg-1927",1.5769,-.5787,.614
"Eg-1928",.1267,-.4035,-.2853
"Eg-1929",-2.5724,.6037,.1075
```

Figure 4.3c : SP_SP-M.DAT

and the **FAOMET.LOG** file (shown in fig. 4.3d). This information allows you to interpret the results and determine what variables can be used in the regression model. The log file lists the variables, their extreme values, the percentage variance explained by each component, the accumulated variance and a correlation matrix. This information tells us that the first and second principal components together explain 94.4% of the total variance. Geometrically, this means that all the observed points find themselves on a plane; 94.4% of the variation is parallel to this plane while 5.6% is perpendicular to it. In addition, 81.6% of the variation corresponds to the first principal component and only 18.4% to the other two. Thus, both the second and third components can be discarded.

A correlation matrix is also provided in the output file which allows you to interpret the behaviour of the initial variables. Since the first principal component is positively correlated with temperature and radiation and negatively correlated with precipitation, the first principal component is an indicator of alternative good and bad weather. High values of the component correspond to high temperatures, high levels of solar radiation and low precipitation. The second component is poorly correlated with radiation and more weakly correlated with temperature and precipitation. The second component can therefore be considered as marking the annual distinction between the hot and humid years and the colder, drier ones.

```
            Title: Meteorological and Yield Data Time Series

                          List of variables

    Nr   Name          Number missing   Minimum        Maximum
     1   TemJul              0           15.2           19.7
     2   RnJul               0           1              140.6
     3   RdJul               0           902            1661
     4   Yield               0           23.5           31

Complete data lines:  11  / Code for missing data: -999

                 % VARIANCE /COMP.

   Component      %variance      %accum. variance

       1             81.6             81.6
       2             12.8             94.4
       3              5.6            100.0

   Correlations between Components and original variables below

                          TemJul
                          RnJul
                          RdJul

                        1          2          3
                      TemJul     RnJul      RdJul
                 ------------------------------------
               1 |     0.8671    -0.8990     0.9429 |  C-1
               2 |     0.4843     0.3760    -0.0868 |  C-2
               3 |    -0.1167     0.2246     0.3214 |  C-3
                 ------------------------------------
                         1          2          3
```

Figure 4.3d : FAOMET.LOG file

Now try principal components analysis on the file for Mali, **SC-MALI.DAT**. What does the analysis tell you about trying to build a yield regression model with these 8 variables?

4.4 Trend Analysis

Trend refers to the overall behaviour or tendency of one variable with respect to another and is generally expressed as being upward or downward. For example, during the past 100 years, yield has increased with time, i.e., an upward trend. The changes may be due to the adoption of new technologies (fertilizer, mechanization, irrigation), new varieties or the weather (e.g., the rainfall trend in the Sahel during the last 2 decades). The rate of the trend is the slope of a line of best fit and can be calculated by regressing one variable against time.

A situation of no trend or multiple trends is also possible. Two different types of trend changes are shown in fig. 4.4a: in the first curve, the slope (or rate of change) remains the same but the curve is shifted up or down due to a change in the Y-intercept; in the second curve, the slope changes and the two curves intersect at the point where the trend changes. With this function you can calculate when a trend change occurs and the types of trend changes that are present in your dataset.

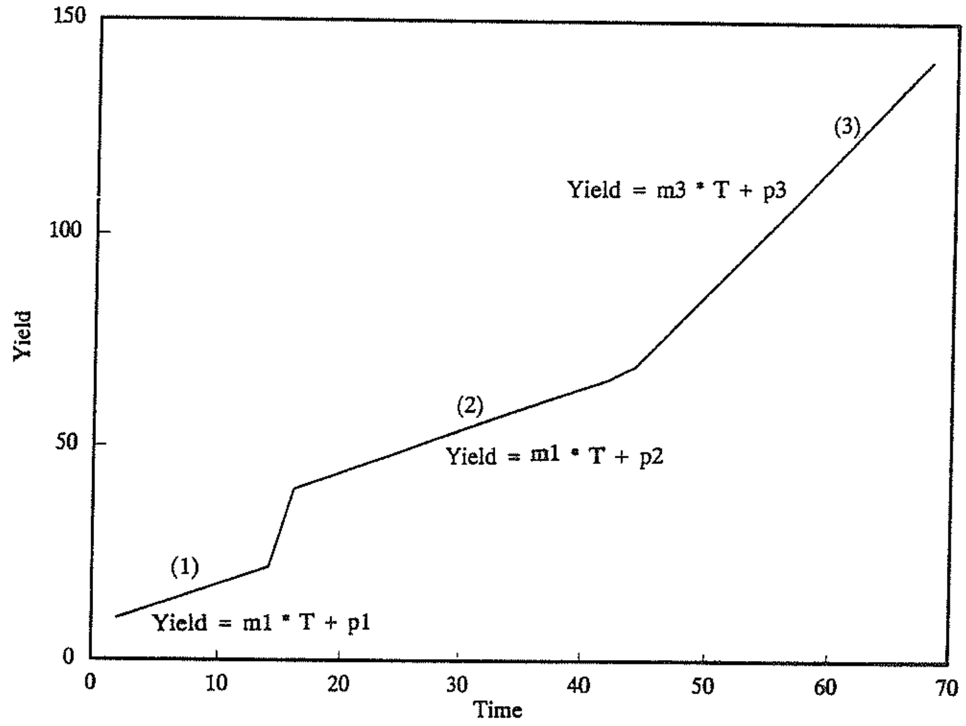

Figure 4.4a : Types of trend changes

Examine the sample file **ST-CHINA.DAT**, shown partially in fig 4.4b. The file contains yield, area and production time series data for potatoes in China from 1961 to 1990 taken from the AGRISTAT database (FAO, 1990). Let's use this data to determine if there is a trend change in yield over time.

```
"AGROSTAT/PC China Potatoes ('000 Ha, '000MT, MT/Ha)",,,
"Year","Area-Harvested","Production","Yield"
1961,1301,12907,9.92
1962,1501,13808,9.2
1963,1501,12010,8
1964,1602,14019,8.75
1965,1701,16016,9.42
1966,2001,18016,9
1967,2002,17923,8.95
1968,2002,17822,8.9
1969,1902,19328,10.16
1970,2002,21524,10.75
```

Figure 4.4b : ST-CHINA.DAT

Read this file into memory and press **<Alt> ST** to start the analysis. A screen will appear (fig. 4.4c) listing the variables in the input file, and you will be prompted to enter the ID#s of the variable with the suspected trend change, i.e., the yield, and the trend variable, i.e., the years. Although you can enter 1 for the ID# of the trend variable, the program assumes that the first column contains the time variable so for this example you can just type **<ret>**. After entering this information, FAOMET will do the calculations and write the output to the **FAOMET.LOG** file. View the file and you will see the same information as shown in fig. 4.4d.

List of variables in input file...

ID#	Variable name	ID#	Variable name	ID#	Variable name
1	Year	3	Production		
2	Area-Harvested	4	Yield		

```
Nr of variable with suspected trend change (<ret>=end) :      4
Nr of trend variable (<ret> for default 1,2,3...) :
```

Figure 4.4c: List of variables

This method involves the iterative calculation of 2 regression equations at a time: one from the first year in the time series, 1, to i and the second from i+1 until the last year in the time series, where m1 and m2 are the slopes of each equation, and p1 and p2 are the intercepts. Using the data in this example, in the first iteration, the program will calculate a regression equation from 1961 to 1962 and one from 1963 until 1990. The calculations will continue from i = 1963 until i = 1989.

For each iteration, the program will also calculate the year during which the two lines intersect (Itcp), the difference between the current year i and the intercept of that year, referred to as delta, and the difference between the slopes of the two regression equations, m1-m2. If the two lines intersect outside the range of the trend variable (for instance, before 1960 or after 1990 in this case), the intersect is given as "O.O.R", or out of range. Trend changes of the first type can be seen by examining the differences between the slope and the values of the intercepts of each equation, while trend changes of the second type occur when delta passes through a minimum.

At the top of the output file is a list of the variables found in the input file, the extreme values of the variables and the number of data points with missing data. This is followed by a large matrix containing 9 columns. The first six refer to the regression equations calculated iteratively by the program. The last three columns list the intersection point, the delta and the difference between the two slopes. Notice that delta reaches a minimum at 1976 and indicates a trend change of the second kind. No trend changes of the first kind occur in this example.

```
                    Source file: C:\TESTDATA.FAO\ST-CHINA.DAT

                 Title: AGROSTAT/PC China Potatoes ('000 Ha '000MT MT/Ha)

                                  List of variables

              Nr   Name              Number missing   Minimum        Maximum
               1   Year                    0           1961           1990
               2   Area-Harvested          0           1301           2852
               3   Production              0           12010          31663
               4   Yield                   0           8              13.5

      Complete data lines:  30  / Code for missing data: -999

 ----------------------Identify trend changes, option ST---------------------

                         Trend in variable  4  (Yield)

                         Trend-variable  is  1  (Year)

   1-i          m1          p1          i-end       m2          p2    Itcp.  Delta     m1-m2

1961-1962 -.716D+00 0.141E+04  1963-1990 0.689D-01  -.126E+03  1961  0.022  -7.852D-01
1961-1963 -.959D+00 0.189E+04  1964-1990 0.539D-01  -.957E+02  1961  0.067  -1.013D+00
1961-1964 -.471D+00 0.933E+03  1965-1990 0.414D-01  -.710E+02  O.O.R        -5.121D-01
1961-1965 -.145D+00 0.294E+03  1966-1990 0.321D-01  -.525E+02  O.O.R        -1.773D-01
1961-1966 -.912D-01 0.188E+03  1967-1990 0.153D-01  -.192E+02  O.O.R        -1.065D-01
1961-1967 -.676D-01 0.142E+03  1968-1990 -.714D-02  0.252E+02  O.O.R        -6.050D-02
1961-1968 -.562D-01 0.119E+03  1969-1990 -.368D-01  0.840E+02  O.O.R        -1.941D-02
1961-1969 0.367D-01 -.630E+02  1970-1990 -.572D-01  0.124E+03  O.O.R         9.390D-02
1961-1970 0.114D+00 -.215E+03  1971-1990 -.742D-01  0.158E+03  1982  0.409   1.884D-01
1961-1971 0.139D+00 -.264E+03  1972-1990 -.101D+00  0.210E+03  1980  0.319   2.397D-01
1961-1972 0.138D+00 -.262E+03  1973-1990 -.140D+00  0.288E+03  1981  0.306   2.780D-01
1961-1973 0.241D+00 -.464E+03  1974-1990 -.119D+00  0.248E+03  1976  0.105   3.604D-01
1961-1974 0.285D+00 -.550E+03  1975-1990 -.996D-01  0.209E+03  1974  0.011   3.842D-01
1961-1975 0.270D+00 -.521E+03  1976-1990 -.109D+00  0.227E+03  1975  0.002   3.788D-01
1961-1976 0.249D+00 -.479E+03  1977-1990 -.128D+00  0.264E+03  1976  0.000   3.763D-01
1961-1977 0.253D+00 -.488E+03  1978-1990 -.105D+00  0.219E+03  1975  0.060   3.577D-01
1961-1978 0.255D+00 -.493E+03  1979-1990 -.537D-01  0.117E+03  1973  0.161   3.091D-01
1961-1979 0.228D+00 -.438E+03  1980-1990 -.540D-01  0.118E+03  1974  0.172   2.817D-01
1961-1980 0.206D+00 -.395E+03  1981-1990 -.440D-01  0.982E+02  1974  0.203   2.497D-01
1961-1981 0.174D+00 -.333E+03  1982-1990 -.102D+00  0.214E+03  1978  0.115   2.767D-01
1961-1982 0.156D+00 -.298E+03  1983-1990 -.135D+00  0.279E+03  1979  0.089   2.917D-01
1961-1983 0.146D+00 -.277E+03  1984-1990 -.122D+00  0.254E+03  1979  0.123   2.683D-01
1961-1984 0.139D+00 -.264E+03  1985-1990 -.119D-01  0.343E+02  1973  0.364   1.512D-01
1961-1985 0.125D+00 -.236E+03  1986-1990 0.422D-01  -.733E+02  1964  0.713   8.263D-02
1961-1986 0.106D+00 -.198E+03  1987-1990 -.182D+00  0.372E+03  1983  0.095   2.874D-01
1961-1987 0.919D-01 -.171E+03  1988-1990 -.832D+00  0.167E+04  1988  0.025   9.243D-01
1961-1988 0.892D-01 -.166E+03  1989-1990 -.125D+01  0.249E+04  1988  0.013   1.334D+00
```

Figure 4.4d : FAOMET.LOG file

This output file can be read into any spreadsheet program to plot the behaviour of the interception point, delta and the difference between the slopes of the lines. This has been done and is shown in fig. 4.4e along with the original yield data. Use the **Write** input to log file option on the **File** menu to insert the original data into the **FAOMET.LOG** file. Notice that LOTUS 123 v.3.1 does not recognize the D for double precision. Use your editor's search and replace function to change the D's to E's (for exponential format).

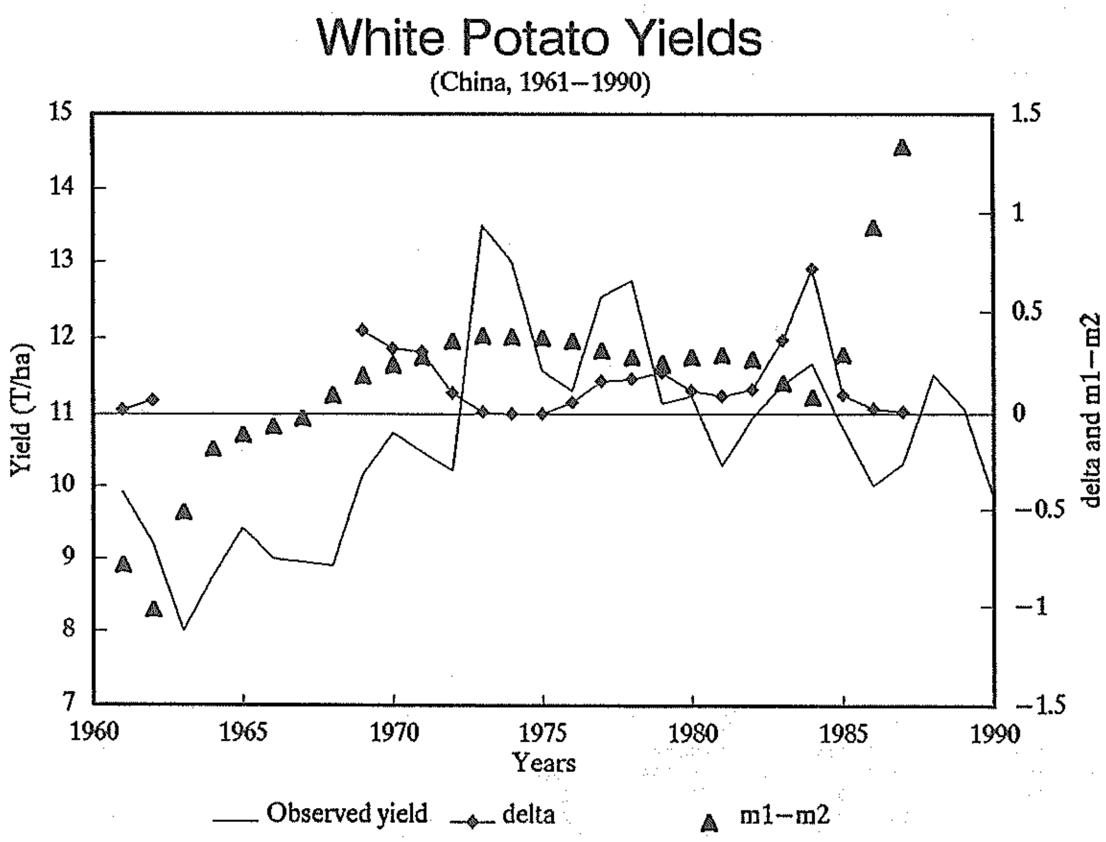

Figure 4.4e: Time series graph of yield, ltcp, delta and m1-m2

4.5 Matrix Transposition

In a world of unstandardized data formats, one is often faced with the problem of incompatible files. One simple but common example of incompatibility is the way in which the data of your matrix are arranged, i.e., what variables constitute your rows and which your columns. To solve this problem, you might simply need to transpose your matrix.

You might also want to transpose your matrix if you want to determine the correlations between stations using the **Stagmet Correlation** option. Suppose that the rows of your input matrix contain the station names and the variables (e.g. rainfall time series, yield data, etc.) make up the columns. To calculate a correlation matrix of the stations, which would show the degree of similarity between them, you would need to transpose your input matrix before running this option.

For example, take the file previously displayed in fig. 4.1a. The rows are composed of station names and the columns are 8 geographical, agrometeorological and remote sensing variables. Suppose that you had a program which requires that you list the stations by column. Read the file into FAOMET and run this option by pressing **<ALT> SA**. The matrix will be transposed and the output written to the file indicated on the screen, **SA_SA-M3.DAT**, shown in fig.4.5. The log file indicates only which option was used and the name of the output file.

```
"Transpose from C:\TESTDATA.FAO\SA-MALI.DAT"
"","Bafoulabe","Banamba","Bandiagara","Bankass","Baraoueli","Bla","Bougouni",
"NDVI26",187,165,144,157,175,170,183,
"IND",92.6,92.3,86.1,90.7,95.4,97.1,97.6,
"YLD",843,602,431,472,755,838,395,
"LON",-10,-7.3,-3.7,-3.6,-6.5,-5.9,-7.3,
"LAT",14,13.7,14.5,13.5,13,12.9,11.2,
"LGS",115,121,94,116,125,125,161,
"NormRain",1027,914,517,749,987,814,1297,
"PTB28",126,119,96,103,128,128,124,
```

Figure 4.5 : SA_SA-M3.DAT

4.6 Calculating Rainfall Probabilities according to the Incomplete Gamma Distribution

Rainfall is responsible for most of the year-to-year variability in crop yields in many developing and developed countries. If the varieties used are locally-adapted, the output will be *normal* whenever the rains are *normal*, given no other limiting factors such as pests or diseases.

When working operationally with rainfall data, one is often interested in knowing whether the rainfall recorded was unusually high or low. This can only be assessed by comparing the current rainfall with historical rainfall records covering a period of many years. Take the rainfall record for Rome which goes from 1782 to 1980 as an example. Suppose that the rainfall recorded in June 1981 was the lowest ever registered during that month. We can say that the rainfall received was *exceptionally* low and that rainfed crops in the field were likely to have suffered a severe water shortage, i.e., drought conditions. Or suppose we had poor rainfall this year and our crop badly needs an additional 100mm. What are the chances that we receive this rain?

A very high (or low) amount of rain that occurs, on average during a few years every century, is said to have a very low probability of occurrence. This is usually expressed as the probability of exceedence (P) of a given amount of rainfall. If P is below 5%, it means that rainfall was *exceptionally* high, since it will be exceeded (on average) only 5 years out of 100. Likewise, values above 95% correspond to exceptionally dry conditions. The probability range from 5 to 20 and from 80 to 95 is termed *unusual* and values from 21 to 79 are considered *normal*.

This option calculates rainfall probabilities based on the incomplete gamma distribution which best approximates the positively skewed rainfall distribution. Rainfall exhibits this type of distribution everywhere (i.e., many low or average values with some very high ones) but the skew is more marked in warm or cold semi-arid conditions. When rainfall increases, it tends towards a normal distribution. By integrating the area under the curve between 0 and the probability of exceedence desired, one can determine the rainfall threshold.

Open the sample file **SG-ROME.DAT** listed partially in fig. 4.6a. The file contains monthly rainfall time series data for Rome from 1782 to 1980. Years are listed along the rows and the columns are the months. Note that each year is enclosed in quotes and begins with "Y-". It is the Y- (or any non-numerical character) which is used to identify the item as a label rather than as a number. If we did not have the quotes or the Y-, the program would treat the years as regular numbers and include them in the probability calculations. The order of the columns is not important so the columns could cover July through June and data can belong to different stations.

Take note that this option can also be used with dekadal rainfall data rather than with monthly values as used in this example.

```
"Rome rainfall from 1782 to 1980"
"JAN" "FEB" "MAR" "APR" "MAY" "JUN" "JUL" "AUG" "SEP" "OCT" "NOV" "DEC" "YEAR"
"Y-1782" 33 107 22 126 27 42 8 0 41 176 133 52 767
"Y-1783" 94 96 64 56 69 65 8 6 71 122 16 140 807
"Y-1784" 162 134 71 51 40 45 6 3 17 308 103 181 1121
"Y-1785" 66 88 48 63 10 15 5 2 0 68 149 175 689
"Y-1786" 121 48 55 83 31 35 11 12 5 35 127 78 641
"Y-1787" 43 40 92 61 126 33 6 0 29 55 126 44 655
"Y-1788" 78 61 199 23 47 27 1 17 52 62 124 154 845
"Y-1789" 34 58 173 18 91 12 29 50 16 205 161 57 904
"Y-1790" 52 10 30 65 32 75 4 69 41 171 95 78 722
```

Figure 4.6a : SG-ROME.DAT

As the file is read into memory, FAOMET verifies that the matrix contains no negative data. If negative data are found, the program issues an error message and returns you to the opening screen. If all is well, you will be prompted to enter the lower and upper limits for the probability table as well as the step.

```
Input low value for probability table (none=END) ..... ? 0
Input high value.....................................? 200
And now type in step for table.......................? 20
```

Figure 4.6b : Opening prompt

Enter the values as given in fig. 4.6b; 0 to 200 refers to the amount of rainfall in mm and the probabilities will be calculated at intervals of 20 mm. A screen will then appear listing the variables in the input file (fig 4.6c).

List of variables in input file...

ID#	Variable name	ID#	Variable name	ID#	Variable name
1	JAN	6	JUN	11	NOV
2	FEB	7	JUL	12	DEC
3	MAR	8	AUG	13	YEAR
4	APR	9	SEP		
5	MAY	10	OCT		

Select variable for manual calculations (none=END) ? 1

Figure 4.6c : Second screen

Following the table you are prompted for manual calculations. As an example, enter 1 for January and 20 mm for the rainfall amount. The probability of exceedence is calculated and displayed as 94.81%, i.e., 20 mm of rainfall will be exceeded 94 out of 100 years. This reflects the fact that Rome is very wet in the month of January. After completion, press <ret> and the output will be written to the **FAOMET.LOG** file (fig. 4.6d).

The **FAOMET.LOG** file contains the list of variables followed by the statistics of the gamma distribution (Gamma and Beta) together with the number of years, the number of years with no rain (number of zeros), and the long-term average. This is followed by a probability of exceedence table listing the rainfall amounts ranging from 0 to 200 on the left-hand side followed by the probabilities.

Source file: C:\TESTDATA.FAO\SG-ROME.DAT

Title: Rome rainfall from 1782 to 1980

List of variables

Nr	Name	Number missing	Minimum	Maximum
1	JAN	1	4	227
2	FEB	1	0	218
3	MAR	1	0	199
4	APR	1	0	228
5	MAY	1	0	148
6	JUN	1	0	139
7	JUL	2	0	113
8	AUG	2	0	106
9	SEP	2	0	260
10	OCT	2	6	346
11	NOV	2	6	372
12	DEC	2	0	273
13	YEAR	2	316	1465

Complete data lines: 199 / Code for missing data: -999

——————Incomplete gamma law, option SG——————

Parameters of gamma Distribution

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
# years	198	198	198	198	198	198	197	197	197	197	197	197	197
# zeros	0	5	4	2	3	7	37	22	5	0	0	1	0
Beta	30.10	39.73	28.35	31.78	28.30	33.18	21.76	25.09	44.40	55.66	41.73	42.21	40.63
Gamma	2.67	1.72	2.52	1.99	1.92	1.11	0.94	1.15	1.47	2.11	2.65	2.31	19.74
Average	80.4	66.8	70.2	62.7	53.7	35.8	16.7	25.7	63.9	117.7	110.9	97.3	802.1

Gamma values between brackets are likely to yield meaningless probabilities!

Probability that given amount will be exceeded

AMOUNT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
0.0	1.000	0.975	0.979	0.989	0.984	0.964	0.812	0.888	0.974	1.000	1.000	0.994	1.000
20.0	0.948	0.836	0.907	0.858	0.812	0.582	0.305	0.463	0.798	0.959	0.974	0.948	1.000
40.0	0.790	0.633	0.718	0.633	0.555	0.334	0.118	0.222	0.590	0.861	0.885	0.825	1.000
60.0	0.597	0.453	0.512	0.430	0.347	0.188	0.046	0.105	0.420	0.738	0.756	0.673	1.000
80.0	0.421	0.314	0.341	0.279	0.207	0.105	0.018	0.048	0.293	0.614	0.615	0.525	1.000
100.0	0.283	0.212	0.216	0.175	0.119	0.059	0.007	0.022	0.201	0.498	0.483	0.397	1.000
120.0	0.184	0.142	0.133	0.107	0.067	0.032	0.002	0.010	0.136	0.397	0.368	0.293	1.000
140.0	0.116	0.093	0.079	0.064	0.037	0.018	0.001	0.004	0.092	0.312	0.275	0.212	1.000
160.0	0.071	0.061	0.046	0.038	0.020	0.010	0.000	0.002	0.061	0.243	0.201	0.151	1.000
180.0	0.043	0.039	0.026	0.022	0.011	0.005	0.000	0.001	0.041	0.187	0.145	0.106	1.000
200.0	0.026	0.025	0.015	0.013	0.005	0.003	0.000	0.000	0.027	0.143	0.103	0.074	1.000

Figure 4.6d : FAOMET.LOG file

Gamma values between brackets are likely to yield meaningless probabilities. This happens with extreme cases of data statistical distributions (i.e., distributions which cannot be approximated by a gamma distribution), for instance, when this option is run on the **ST-CHINA.DAT** file.

4.7 Geographic Interpolation for the Estimation of Missing Data

A common problem in dealing with meteorological data is missing values for a given time period, e.g., a missing dekad or missing data for a complete station. Suppose we are missing the normal annual rainfall for the station Aioun_El_Atrouss in Mauritania but the data are available from several neighbouring stations. The missing rainfall for this station is calculated using the inverse distance method, depicted graphically in fig. 4.7a.

Suppose that R is the station with missing data and R1, R2 and R3 are neighbouring stations for which data are available. Since the neighbouring stations are at different distances from R, labeled as d1, d2 and d3, respectively, we can weight the contribution of rainfall at each of the stations by the inverse of their distance to some power, p. For example, since d2 is less than d3, the corresponding weight for R2 and hence the contribution of the second station, will be less. Thus, the missing rainfall for station R is calculated by multiplying the rainfall at each of these stations by the calculated weights, divided by the sum of the weights.

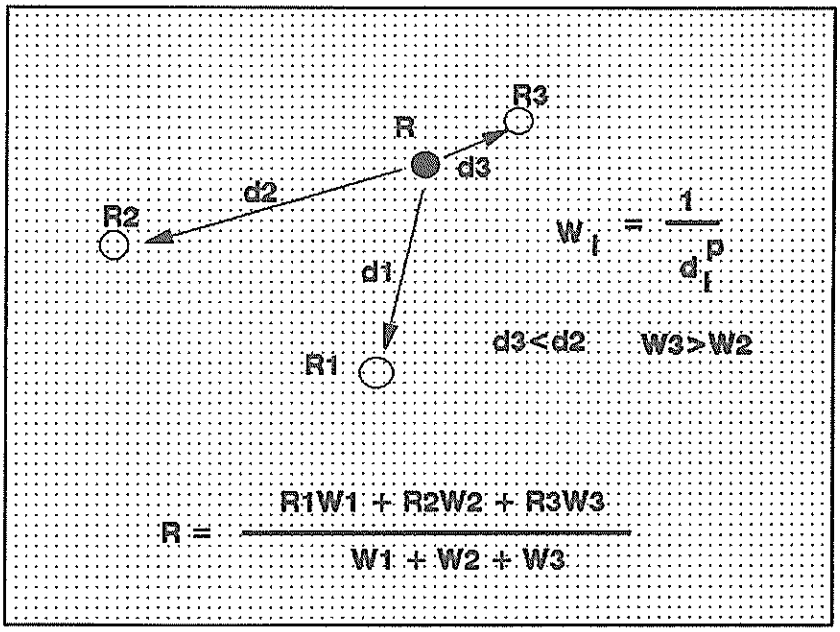

Figure 4.7a: The inverse distance method

To try this out, open the sample file **SI-LGS.DAT**. This file (shown in fig. 4.7b) consists of station information, length of the growing period and the normal annual rainfall for several stations in Mauritania and Mali.

LGS and Normal rain, Mali and surrounding areas. Adm=admin units.

	Lon.	Lat.	Alt.	LGS	NormRain
Same	-11.59	14.49	39	88	527
Kayes	-11.44	14.44	47	111	723
Tidjikja	-11.44	18.57	402	0	143
Kiffa	-11.4	16.64	115	70	352
Kenieba	-11.24	12.85	132	154	1408
Adm-Kenieba	-11.1	13	150	150	-999
Adm-Kayes	-11	14.5	90	-999	-999
Adm-Yelimane	-10.5	15.3	280	-999	-999
Adm-Bafoulabe	-10	14	200	-999	-999
Aioun_El_Atrouss	-9.6	16.7	223	53	316
Adm-Kita	-9.5	13.5	300	-999	-999
Adm-Diema	-9.5	14.5	280	-999	-999
Adm-Nioro	-9.5	15.4	250	-999	-999
Kita	-9.47	13.07	333	137	1142

Figure 4.7b : SI-LGS.DAT

Press **<Alt>SI** to activate this function and a screen with several options will appear (fig.4.7c):

```
Type in one of the choices below    (or ESC to end anytime) :

Max. nr of neighbours   (reject if >  10    ) ...................... X
Min. nr of neighbours   (reject if <  4     ) ...................... N
Radius of action Km     (reject if >  300   ) ...................... R
Power for weighting     (default   :  1.5   ) ...................... P
Format for coordinates  (default   : DD.dd  ) ...................... C
Result with ? decimals  (default   :  1     ) ...................... D
Zero negative results   (Default   : Yes    ) ...................... Z
Correct for elevation   (Default   : No     ) ...................... E

Accept current values and proceed ...................................... A




WARNING: replaces missing values ONLY in the destination file created when
leaving option SI (file name starting with SI_), but you can run successive
interpolations (e.g. with R=100, R=200). To use the new file with other
options, the SI_ file must be loaded as the input file with option FF
```

Figure 4.7c : First screen of choices

The options on this screen are accessed by pressing the letter on the right-hand side of the screen. Pressing the key either toggles between various possible options or prompts you to enter a value. The choices are as follows:

- **Option X** - allows you to change the maximum number of neighbouring stations to be used in the interpolation; the default value is set at 10, meaning that only the 10 nearest stations are used in the interpolation. This option should be used with care when interpolating PET and it is suggested that this number be reduced.

- **Option N** - lets you set the minimum requirement for the number of surrounding stations used in the interpolation. The default value is 1, meaning that at least one neighbouring station is required for the interpolation. If no stations are found within the "radius of action" **(option**

R), no value will be interpolated.

• **Option R** - allows you to choose the "radius of action", i.e., the greatest distance beyond which a station is assumed not to be relevant for the interpolation and is set to a default value of 300 km. The program computes distance in kilometers based on the geographic coordinates, and corrections are applied for the change in length of one degree.

• **Option P** - lets you apply a weighting factor; the greater the factor, the less influence points further out will have on the interpolation. If set to 0, the estimated value will be the arithmetic mean.

• **Option C** - allows you to specify the format of your station coordinates, either degree-minutes or decimal-degrees. Pressing C toggles between these two options.

• **Option D** - lets you decide on the number of decimal places in your interpolated result, ranging from 1 to 3.

• **Option Z** - lets you decide whether negative interpolated values should be set to zero. When working with rainfall data, for instance, negative numbers are meaningless and this option should be activated.

• **Option E** - allows you to include a correction for the systematic influence of altitude. For instance, there is a decrease in the temperature of 4 to 6 degrees for each 1000 m, so this effect is important to take into account when interpolating missing data for a mountainous country such as Ethiopia. The influence of temperature will be transferred to PET and other agrometeorological parameters when computed.

• **Option A** - Pressing **A** accepts all settings and proceeds to the second screen (fig.4.7d):

List of variables in input file...

ID#	Variable name	ID#	Variable name	ID#	Variable name
1 2	Lon. Lat.	3 4	Alt. LGS	5	NormRain

```
Default variable for longitude (or X) is  1  (Lon.)
Default variable for latitude  (or Y) is  2  (Lat.)
Accept defaults (Y/N) :Y
How many variables to estimate (A=all, <ret>=end) ?
```

Figure 4.7d : Second screen

If the default variables for longitude and latitude are correct, press **Y** to proceed. If they do not match, go back to the file and check your column headings. After this step you need to select the variables for which you want to interpolate missing data.

Press **A** for all and a message will appear telling you that the program is busy doing the interpolation. After finishing, you will be returned to screen 2 of fig. 4.7c and press **<ret>** to exit this option. The output is written to the file **SI_SI-L1.DAT** and is shown in fig 4.7e. Compare the stations in fig. 4.7b of the input file that had missing data with the interpolated answers in the output file.

```
"Estimates from 4 to 10 neighbours; Power= 1.5; Radius= 300;no Z-correction"
"","Lon.","Lat.","Alt.","LGS","NormRain"
"Same",-11.59,14.49,39,88,527
"Kayes",-11.44,14.44,47,111,723
"Tidjikja",-11.44,18.57,402,0,143
"Kiffa",-11.4,16.64,115,70,352
"Kenieba",-11.24,12.85,132,154,1408
"Adm-Kenieba",-11.1,13,150,150,1321.2
"Adm-Kayes",-11,14.5,90,107.9,749.7
"Adm-Yelimane",-10.5,15.3,280,100.3,703.5
"Adm-Bafoulabe",-10,14,200,120.2,925.2
"Aioun_El_Atrouss",-9.6,16.7,223,53,316
"Adm-Kita",-9.5,13.5,300,127.2,1016.6
"Adm-Diema",-9.5,14.5,280,110.1,822.9
"Adm-Nioro",-9.5,15.4,250,93.9,655.6
"Kita",-9.47,13.07,333,137,1142
```

Figure 4.7e : SI-SI-L1.DAT

You will notice that the station Aioun_El_Atrouss now has an interpolated normal rainfall value of 316mm.

4.8 Data Interpolation

Suppose we have a set of measured data, in this case data on the weight, leaf area and growth rate of Badischer Frueh maize measured on various days (expressed by the Julian day number). A portion of the sample data set, **SY-GRWTH.DAT**, is shown in fig 4.8a:

```
"'Badischer Frueh' maize, after Kreusler (1879) in Hunt, 1982"
"DayNr","gramDW/plant","sqmleaf/plant","growthg/(day.plant)"
140,0.3282, -999,0,
148,0.328, -999,0,
155,0.287, -999,-0.01,
162,0.255,0.00179,0,
169,0.308,0.00292,0.01,
176,0.637,0.01244,0.05,
183,2.319,0.04192,0.24,
190,4.654,0.07622,0.33,
197,9.019,0.1301,0.62,
204,20.001,0.2136,1.57,
```

Figure 4.8a : SY-GRWTH.DAT

We know the value of the weight on Julian day 140 and 148, since we took measurements on these days, but we are now really interested in the weight on day 144. Unfortunately we do not have an analytic expression that allows us to calculate the weight on any given day. To solve this, we employ the method referred to as quadratic spline interpolation, which essentially draws a curve through all the data points (after sorting them by increasing values of the X-variable) and then determines the values of the function at the points desired. The reader is referred to Press et al. (1986) for a detailed explanation of the method.

Open the sample input file and press **<Alt> SY** and the following screen (fig. 4.8b) will appear, listing the variables in the input file:

List of variables in input file...

ID#	Variable name	ID#	Variable name	ID#	Variable name
1 2	DayNr gramDW/plant	3 4	sqmleaf/plant growthg/(day.pl		

```
Default variable for X is  1  (DayNr)
Default variable for Y is  2  (gramDW/plant)
Accept defaults (Y/N/Esc) :
```

Figure 4.8b : First screen listing variables

The program automatically assumes that the X variable, i.e., the Julian day, is in column #1, and that the Y variable is in column #2. If this is not the case in your dataset, answer N and you be be prompted to enter the ID# of the X and Y variables. After accepting the variables, the minimum and maximum X values will be displayed and you will be required to choose the step of your X variable (fig. 4.8c). Notice that the default step is given as 1.13 in square brackets; this value is automatically calculated by the program. We will choose **1** since the Julian Day is an integer value. Press **S** to activate the option and upon completion, you will be returned to the first screen. Press **<ESC>** and you will exit.

```
          List of variables in input file...
```

ID#	Variable name	ID#	Variable name	ID#	Variable name
1 2	DayNr gramDW/plant	3 4	sqmleaf/plant growthg/(day.pl		

```
   Extreme X-values are  140  and  253
   Accept defaults (Y/N) :Y
   Step (for default [ 1.13 ] just type <ret>)  ? 1

   Select Spline, or Exit (S/E) :
```

Figure 4.8c

The output is written only to the **FAOMET.LOG** file; it contains the variables, their maximum and minimum values, followed by two columns: the Julian day with a time step of one day and the resulting splined values.

```
    Title: 'Badischer Frueh' maize after Kreusler (1879) in Hunt 1982
                           List of variables

        Nr   Name            Number missing   Minimum       Maximum
         1   DayNr                 0           140           253
         2   gramDW/plant          0           .255          124.76
         3   sqmleaf/plant         3           .00179        .3384
         4   growthg/(day.pla      0           -.4           3.78

   Complete data lines:  17  / Code for missing data: -999

Interpolated Y-values...

        Spline...

            X=DayNr              Y=gramDW/plant
            ----------------------------------------
             140                  .3282
             141                  .3296255
             142                  .3309128
             143                  .3319238
             144                  .3325205
             145                  .3325645
              "                     "
              "                     "
             247                  125.0707
             248                  125.0553
             249                  124.7683
             250                  124.2639
             251                  123.5965
             252                  122.8204
             253                  121.99
```

Figure 4.8d : FAOMET.LOG file

The **FAOMET.LOG** file was read into LOTUS 123 and graphed along with the original measured data points (fig. 4.8e).

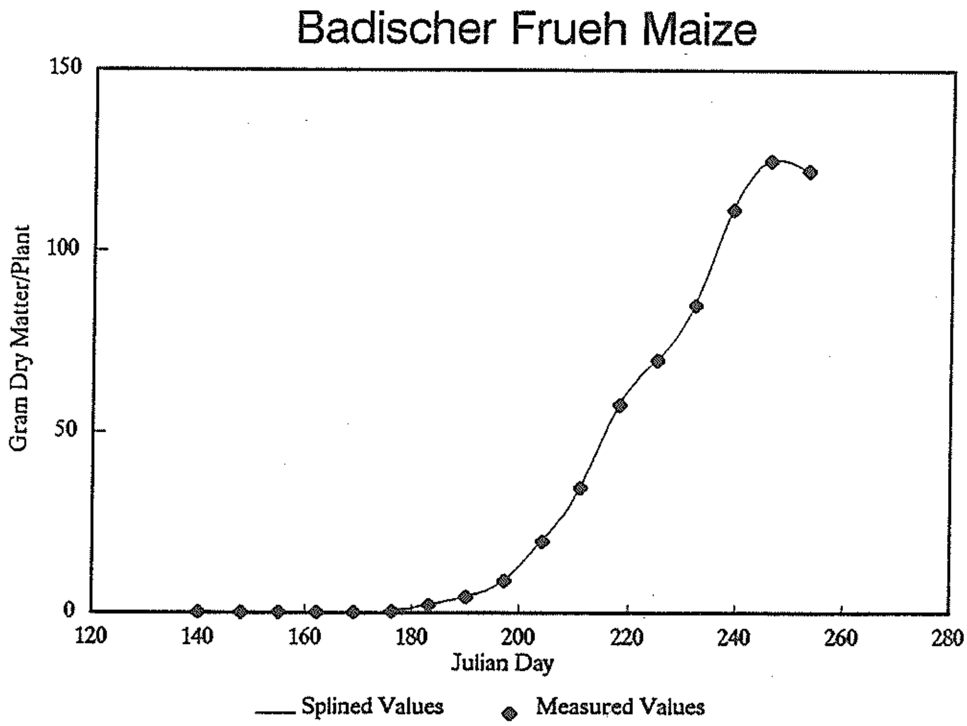

Figure 4.8e: Actual and splined values of maize dry weight

5 AGROMET OPTIONS

As well as statistical options, FAOMET also offers some agrometeorological functions that can be used in the monitoring of the growing season. The same format has been adopted as in the previous chapter and you are once again encouraged to work through the options with the sample files provided on the diskette.

5.1 Calculating Daytime and Nighttime Temperatures

In addition to minimum and maximum temperatures, daytime and nighttime temperatures are also important climate variables, for example, in the assessment of optimal growing conditions and for the calculation of maximum and reference yields.

These variables can be derived from a routine originally developed by Petricevic and explained in detail in FAO (1983). During a 24-hour day, temperature is assumed to vary smoothly according to 2 cosine curves which have their minimum and maximum points at the time of the minimum and maximum temperatures. Minimum temperature is assumed to occur at sunrise whereas the maximum temperature occurs one hour after local noon. Given the Julian day number and the latitude, the daylength (night length) can be evaluated. To calculate the daytime and nighttime temperatures for a particular location and time of year, the area under the portions of the 2 cosine curves corresponding to day and night, respectively, are calculated and divided by the calculated lengths.

Examine the input file **AT-ARGEN.DAT** shown in fig. 5.1a. The four variables needed to run this option are: maximum and minimum temperatures, latitude and the day number or month. For each station, there are 12 lines, one corresponding to each month of the year.

```
"Some Agentinian stations..."
" ","WMO-#","LON","LAT","ALT","Month","Rain","Tmax","Tmin","Vap","Wind","Frac",
"Rivadavia",87.065,-62.54,-24.1,205,1,121,35.9,21.4,0.89,2,0.67,
"Rivadavia",87.065,-62.54,-24.1,205,2,102,34.2,21,0.92,1.8,0.7,
"Rivadavia",87.065,-62.54,-24.1,205,3,87,33,19.5,0.82,1.8,0.66,
"Rivadavia",87.065,-62.54,-24.1,205,4,55,27.6,15.3,0.56,1.6,0.49,
"Rivadavia",87.065,-62.54,-24.1,205,5,17,25.1,12.3,0.35,1.8,0.5,
"Rivadavia",87.065,-62.54,-24.1,205,6,8,22.8,10.7,0.28,1.8,0.43,
"Rivadavia",87.065,-62.54,-24.1,205,7,6,24.6,9.5,0.29,2,0.64,
"Rivadavia",87.065,-62.54,-24.1,205,8,7,27.5,10.6,0.32,2,0.68,
"Rivadavia",87.065,-62.54,-24.1,205,9,13,30.5,14.2,0.44,2.2,0.63,
"Rivadavia",87.065,-62.54,-24.1,205,10,38,32.5,17.8,0.58,2.4,0.56,
"Rivadavia",87.065,-62.54,-24.1,205,11,81,33.9,19.4,0.73,2.2,0.6,
"Rivadavia",87.065,-62.54,-24.1,205,12,119,34.8,20.5,0.84,2,0.6,
```

Figure 5.1a : AT-ARGEN.DAT

Open this file into memory, press **<Alt>AT** and a screen listing the variables (fig. 5.1b) will appear. Beneath this table, FAOMET lists the ID#s of the four required input parameters; press **Y** to accept them. Should you encounter a situation where FAOMET has incorrectly identified the variables, enter **N**, after which you will be prompted to enter the ID#s of the missing variable(s) by hand. After accepting the variables you will be asked to select an ID# for the day of the month (1-31). Enter **N** and the program will automatically use a value of 15.

```
                List of variables in input file...
 ID# | Variable name    | ID# | Variable name   | ID# | Variable name
  1  | WMO-#            |  5  | Month           |  9  | Vap
  2  | LON              |  6  | Rain            | 10  | Wind
  3  | LAT              |  7  | Tmax            | 11  | Frac
  4  | ALT              |  8  | Tmin            |     |

                          DEFAULT VARIABLES...
Latitude .................. 3 (LAT)   Month (1-12)............... 5 (Mont)
Minimum temperature (°C).... 8 (Tmin)  Maximum temperature (°C).... 7 (Tmax)

Accept ALL variables above (Y/N/Esc) : Y

Select variable for Day number (1-31) (Y/N) ? N
```

Figure 5.1b : List of input variables

Another screen (fig. 5.1c) will appear asking you to indicate the number of decimal places you want in the results and the format of the geographic coordinates, i.e., in decimal degrees (DD.dd) or degree-minutes (DD.mm). Since the coordinates in the example file are in degree-minutes, press **C** to change to the correct format.

```
Type in your  choice     (or ESC to end anytime) :

Number of decimals of result        : 1     ........................ D
Format for coordinates              : DD.dd ........................ C

Accept current value and proceed ................................... A
```

Figure 5.1c : User options

Accept these options by pressing **A** and the calculations will proceed. The output will be written to the file **AT_AT-A1.DAT** (fig. 5.1d). Missing data, unrealistic low or high data, inconsistent minim and maxima, etc., are written to the **FAOMET.LOG** file along with the regular information usually written to this file.

```
"Day and nighttime temperatures "
" ","MaxTemp","MinTemp","Latitude","Month","Day","DL(hours)","DayTemp","NightTemp"
"Rivadavia",35.9,21.4,-24.1,1,15,13.4,31.1,25.5
"Rivadavia",34.2,21,-24.1,2,15,12.9,29.9,24.9
"Rivadavia",33,19.5,-24.1,3,15,12.2,28.7,23.7
"Rivadavia",27.6,15.3,-24.1,4,15,11.5,23.7,19.4
"Rivadavia",25.1,12.3,-24.1,5,15,10.9,21,16.7
"Rivadavia",22.8,10.7,-24.1,6,15,10.6,19,15
"Rivadavia",24.6,9.5,-24.1,7,15,10.7,19.8,14.8
"Rivadavia",27.5,10.6,-24.1,8,15,11.2,22.1,16.3
"Rivadavia",30.5,14.2,-24.1,9,15,11.9,25.3,19.5
"Rivadavia",32.5,17.8,-24.1,10,15,12.6,27.8,22.3
"Rivadavia",33.9,19.4,-24.1,11,15,13.2,29.2,23.6
"Rivadavia",34.8,20.5,-24.1,12,15,13.6,30.1,24.5
```

Figure 5.1d : AT_AT-A1.DAT

5.2 Interpolating Dekad Normals from Monthly Values

Operational agrometeterology often uses the dekad or 10-day total as the time period for monitoring and it usually involves comparing the current situation to the "normal" one, i.e., an average period of 30 years or longer. Since normals are usually published as monthly values, a function is needed to interpolate them to shorter periods.

This option works on the assumption that averaged over long periods, the weather elements typically assume the shape of smooth curves when plotted against time. The year-to-year variability is cancelled out, particularly when the time units are months or even dekads. For shorter periods than one dekad, very long periods are required and the concept of climatological normal no longer applies. The normals are particularly misleading for rainfall since they do not represent the expected or most likely value and this fact should be kept in mind when interpreting the data.

This option fits a parabolic curve through the monthly point data and calculates the area under the curve for a given dekad if the weather element is a sum (e.g., rainfall, PET and total sunshine hours), or the average (i.e., the sum under the curve divided by the time) for weather elements that are averages (e.g., temperatures and wind speed).

Examine the input file **AN-RAIN.DAT** shown in fig. 5.2a. The file contains monthly rainfall normals for several stations in Mongolia from January to December. The starting month is not important so long as they appear in sequential order.

Mongolia rainfall normal

	LON	LAT	alt	jan	feb	mar	apr	may	june	july	aug	sep	oct	nov	dec
ALTAI	96.15	46.24	2147	1.1	1.9	6	10.2	12.3	27.8	45	40.9	16.2	7.7	3.1	1.6
ARVAIKHEER	102.47	46.16	1813	0.9	1.4	4.5	7.8	14.7	34.7	85.1	64.7	20	6.8	3	1.6
BARUUN-URT	113.17	46.41	986	1.8	1.5	2.6	6.7	13.1	35.3	61.2	50.6	21.2	5.9	2.7	1.8
BARUUNKHARAA	106.04	48.55	807	4.1	3.4	4.4	8.8	18.6	56.5	82	73.9	34.8	11.3	6	5.1
BAYAN-UUL_DZAVHAN	96.24	49.42	1420	3.6	2.4	3.4	6.6	10	28.1	49.2	41.2	18.9	6.9	5.8	6.9
BAYANHONGOR	100.41	46.08	1860	2	2.8	4.1	8.6	14.4	33.3	56.2	48.2	18.3	7	2.7	1.8
BULGAN	103.33	48.48	1210	1.4	2	3.1	10.9	22.7	52.6	71.3	63.8	32.5	12.4	3.8	1.9
CHOIBALSAN	114.3	48.04	756	1.6	1.9	2.9	6.3	14.4	39	57.4	43.3	27.2	7.7	3.3	2.6
DALANZADGAD	104.25	43.35	1470	1.4	1.1	3.3	5.3	11.8	18.1	32.8	32.1	13.1	4.4	2	1
HOVD	91.39	48.01	1406	1.4	0.9	2.3	5.9	9.5	26.5	35	22.7	10.6	4.6	1.8	1.6
MANDALGOVI	106.17	45.46	1398	4	1.4	1.8	3.3	10.5	24.6	39.8	43	15.8	4.8	2.1	1.1
MUREN	100.1	49.38	1288	1.3	1	0.8	7	15.3	42.6	59.6	54.1	17.5	5.3	1.9	1.4
SAINSHAND	110.07	44.54	936	0.6	1.3	1.7	3.2	8.3	16.3	34.7	31	11.1	4.8	2.2	1.5
TOOROI	96.46	44.56	1182	1.2	1.3	0.9	1.9	2.2	7	13.5	12.1	4.3	2.1	0.6	0.9
TSETSERLEG	101.28	47.27	1697	1.9	2.7	5.8	16.3	32.6	63.1	75.4	66.9	26.7	13.4	5.8	2.6
UIGI	89.58	48.58	1714	0.6	0.5	1.3	4.5	10.6	25	34	20	12.5	3	0.7	1
ULAAN-BAATOR	106.59	47.56	1338	1.7	2	3.4	7.6	14	50	70.9	66.3	27.3	8.4	3.9	2.8
ULAAN-GOM	92.05	49.48	936	1.9	1.8	3.6	4.2	6.5	30	37.1	21.7	14.4	4.9	7.2	4.2
UNDURKHAAN	110.4	47.19	1027	1.2	2.6	2.5	7.9	15	42.2	65.4	49.4	23.4	8.2	3.3	2.4

Figure 5.2a : AN-RAIN.DAT

To run this option, read the file into memory and press **<Alt> AE**. A screen will appear (fig. 5.2b) listing the variables in the input file and press **Y** to proceed.

List of variables in input file...

ID#	Variable name	ID#	Variable name	ID#	Variable name
1	LON	6	mar	11	aug
2	LAT	7	apr	12	sep
3	alt	8	may	13	oct
4	jan	9	june	14	nov
5	feb	10	july	15	dec

Press Y to proceed (N or Esc to abort) :

Figure 5.2b : List of input variables

A second screen will appear requiring you to specify if the variable is a monthly total or sum (rainfall, PET, etc.) or an average (average daily PET, temperatures, etc.), if negative results should be assigned a value of zero in cases where negative values are meaningless and the number of decimals desired in the result; 1 is the default value. Change the second option to zero negative results by pressing **Z** since the data are rainfall and press **A** to continue.

```
Type in your  choice     (or ESC to end anytime) :

Are the monthly values sums or averages ? (Default: Sum     ) ........ T
Zero negative results                   ? (Default: No      ) ........ Z
Number of decimals of results           ? (Default:  1      ) ........ D

Accept current option and proceed ................................... A
```

Figure 5.2c : List of choices

The output is written to the file **AN_AN-R1.DAT** (fig. 5.2d) listing the station names followed by the 36 interpolated dekadal values.

```
"Dekad normals from monthly normals"
"","D1","D2","D3","D4","D5","D6",...etc...,"D32","D33","D34","D35","D36"
"ALTAI",27.9,31.7,34.1,-22.3,1.7,34.3,....,14.6,12.6,2.3,2.8,7
"ARVAIHEER",30.2,33.9,36.2,-20.1,2.5,33.1,....,23.3,19.1,4.4,3.8,7.8
"BARUUN-URT",33.6,37.7,39.8,-11,5.6,28.7,.....,18,15.4,3.4,4,8.9
"BARUUNKHARAA",32.1,35.1,36.9,-7.8,7.4,28.2,.....,26.1,22.9,9.2,8.6,12.8
"BAYAN-UUL_DZAVHAN",27.8,31.6,34.2,-17.1,4.4,33.3,....,14.6,12.6,3,3.7,7.9
```

Figure 5.2d : AN_AN-R1.DAT

Now try this option with the file, **AN-TEMP.DAT**, which contains monthly normals of maximum temperature for Mongolia. Remember to specify that the values are averages and not sums!

5.3 Calculating Potential Evapotranspiration (PET)

Potential evapotranspiration (PET) is defined as the maximum quantity of water which is transpired and evaporated by a uniform cover of short dense grass when the water supply is not limited. PET, together with rainfall data, constitute the main inputs to the soil water balance. The method used here is based on the modified Penman-Monteith equation, recommended by the Expert Consultation held in Rome in 1991 on this subject (Smith, 1991).

To calculate this variable, several measured weather station data and location specific information are required as a minimum:

- Temperature(s): (average temperature OR both maximum and minimum)
- Air moisture: vapour pressure OR relative humidity
- Sunshine: sunshine hours OR sunshine fraction
- Windspeed at any height
- Station elevation
- Station latitude
- Month

Optional data include the day of the month and the incoming shortwave radiation which, if missing, is estimated from the sunshine fraction and Ångstrom's formula:

$$R_s = R_t * (a + b\ n/N)$$

where R_s is the estimated shortwave radiation at station level; R_t is the extra-terrestrial radiation at the top of the atmosphere, n is the hours of bright sunshine as measured with a Campbell-Stokes sunshine recorder, and N is the daylength. The coefficients a and b have been given the default values of 0.25 and 0.50 corresponding to a tropical climate and can be changed depending on the location of the station.

Load the file **AT-ARGEN.DAT** used in the calculation of daytime and nighttime temperatures (fig. 5.1a) and press **<Alt> AE**.

The first screen (fig. 5.3a) displays the list of variables in the input file. If the program has identified the variables correctly, press **Y** to accept the defaults.

```
List of variables in input file...
```

ID#	Variable name	ID#	Variable name	ID#	Variable name
1	WMO-#	5	Month	9	Vap
2	LON	6	Rain	10	Wind
3	LAT	7	Tmax	11	Frac
4	ALT	8	Tmin		

```
DEFAULT VARIABLES...

Wind speed (m/s)........... 10 (Wind) Vapour pressure (kPa)....... 9 (Vap)
Maximum temperature (°C).... 7 (Tmax)  Minimum temperature (°C).... 8 (Tmin)
Latitude (DD.dd/DD.mm)...... 3 (LAT)   Month (1-12)................ 5 (Mont)
Elevation (m)............... 4 (ALT)   Sunshine fraction........... 11 (Frac)

Type Y if and only if ALL variables above have been identified correctly.
Otherwise type N; to quit (return to main menu), type Esc :
```

Figure 5.3a : List of input variables

You will then be prompted to indicate whether global radiation and day number are variables in the data file. For this example, answer N to both questions since neither of these variables are present in the input file. Thus, the global radiation will be calculated with Ångstrom's formula and sunshine hours, and a value of 15 will be adopted for the calculation of the solar declination.

```
Is there a variable for Radiation (Y/N) ? N

Is there a variable for Day number (1-31) (Y/N)
```

Figure 5.3b : User prompts

The next screen to appear (fig. 5.3c) will list the default parameters used in the calculation, with the option to change them (refer to Smith (1991) for details).

```
Type in one of the choices below    (or ESC to end anytime) :

    Incoming radiation, Coeff. A     :  .25   ........................ 1
    Incoming radiation, Coeff. B     :  .5    ........................ 2
    Outgoing radiation, Coeff. Ac    :  .9    ........................ 3
    Outgoing radiation, Coeff. Bc    :  .1    ........................ 4
    Vapour pressure Coeff A1         :  .34   ........................ 5
    Vapour pressure Coeff B1         : -.139  ........................ 6

    Format for coordinates           : DD.dd  ........................ C
    Height of anemometer(m)          :  2     ........................ W

    Albedo                           :  .23   ........................ L
    Crop Type                        : Grass       ................... T
    Crop height (m)                  :  .12   ........................ H

    Accept current values and proceed ................................ A
```

Figure 5.3c : Menu of choices for calculating PET

To change any of the settings, simply press the letter or number on the right-hand side. Parameters that may need changing are the a and b coefficients of Ångstrom's radiation formula depending on the geographic location of the station, the format of the geographic coordinates (i.e., decimal degrees or degree minutes) and the height of the anemometer in meters.

After accepting the default parameters, the calculations are carried out and the output is written to **AE_AE-A1.DAT**, shown in fig. 5.3d. This file consists of the station name, month number (from 1 to 12), daylength (in hours), net radiation (in MJ/m^2/day), aerodynamic resistance (in s/m), saturation deficit (kpa), the aerodynmic and radiation components of PET (both in mm/day), and three values of PET in mm/day, mm/month and mm/dekad.

```
"Penman-Monteith Ref. Crop ET with  Albedo= .23 for Grass"
"","Lat","M#","Day","DL(hours)","QN(MJ/sqm/day)","ra(s/m)","SD(kPa)",AT(mm/day)
"RadTerm(mm/day)","ETO(mm/day)","ETO(mm/month)","ETO(mm/dekad)"
"Rivadavia",-24.16667,1,15,13.43,19.17,95.63,3.34,3.95,3.71,7.65,237,77
"Rivadavia",-24.16667,2,15,12.87,18.43,106.25,3.01,3.37,3.46,6.83,191,68
"Rivadavia",-24.16667,3,15,12.23,15.88,106.25,2.83,3.33,2.73,6.06,187,61
"Rivadavia",-24.16667,4,15,11.51,11.28,119.54,2.16,2.72,1.66,4.38,131,44
"Rivadavia",-24.16667,5,15,10.93,9.42,106.25,1.96,3.02,1.02,4.04,125,40
"Rivadavia",-24.16667,6,15,10.61,7.81,106.25,1.75,2.88,.74,3.62,108,36
"Rivadavia",-24.16667,7,15,10.74,9.99,95.63,1.85,3.29,.82,4.12,127,41
"Rivadavia",-24.16667,8,15,11.24,12.23,95.63,2.15,3.59,1.29,4.87,151,49
"Rivadavia",-24.16667,9,15,11.92,14.2,86.94,2.55,4.11,1.97,6.08,182,61
"Rivadavia",-24.16667,10,15,12.61,15.44,79.69,2.88,4.53,2.56,7.09,219,71
"Rivadavia",-24.16667,11,15,13.25,17.58,86.94,3.04,4.21,3.21,7.41,222,74
"Rivadavia",-24.16667,12,15,13.58,18.21,95.63,3.15,3.86,3.52,7.38,228,74
```

Figure 5.3d : AE_AE-A1.DAT

5.4 Calculating the Length of the Growing Period

The length of the growing period (LGP or LGS), as defined by the Agro-Ecological Zones project (FAO, 1978), is the period (in days) during a year when precipitation exceeds half the potential evapotranspiration. A period required to evapotranspire an assumed 100 mm of water from excess precipitation stored in the soil profile is sometimes added. The present program makes no provision for stored soil moisture.

LGP is useful in calculating agricultural potential, can be used as a criterion for classifying areas and in roughly determining crop cycle lengths and calendars. The calculation of the growing period is based on a simple water balance model, comparing precipitation with PET, using monthly values.

A "normal" growing period, pictured in fig. 5.4a, has the following characteristics:

(1) A Beginning

The beginning of the growing period occurs when precipitation equals half PET and marks the start to the normal rainy season, shown as ***a*** in fig. 5.4a. A value of one half PET has been chosen as germinating crops do not evapotranspire at the full rate of PET and false starts to the rainy season are eliminated. The beginning marks the transition from the dry period to the "intermediate" period when PET/2 < R < PET.

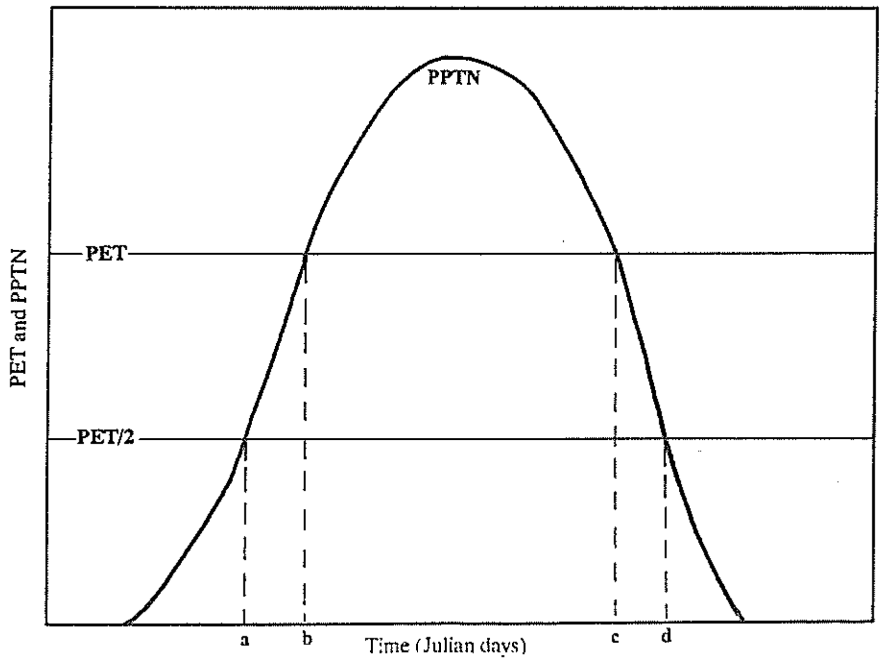

Figure 5.4a : A Normal Growing Period

(2) A Humid Period

This is the period during which precipitation exceeds PET. The beginning and ending dates (shown as ***b*** and ***c*** in fig. 5.4a, respectively) are the two points where the precipitation and PET curves cross.

(3) An End to the Growing Period

The end of the growing period occurs at the point where the precipitation curve crosses the one half PET curve (labeled as ***d*** in fig. 5.4a).

In addition to a normal growing period (marked as graph number 3 in fig. 5.4b), five other types can be defined. Beside each season type described below is the corresponding graph number in fig. 5.4b. The additional season types are as follows:

- **An All Year Round Dry Period (graph 1)**

  The average monthly precipitation for every month of the year is lower than half the average monthly PET. Areas with all year round dry periods have been inventoried separately as areas with a growing period of 0 days.

- **An Intermediate-Dry Growing Period (graph 2)**

  Throughout the year, the average monthly precipitation does not exceed the full rate of the average monthly PET, but it does exceed half the PET. The beginning and the end of such an intermediate growing period are defined as the points where the precipitation curve crosses the one half PET curve and no humid period exists.

- **An All Year Round Intermediate Growing Period (graph 4)**

  During the entire year, the rainfall stays permanently between PET and one half PET. This is a very rare type of season with no beginning or end.

- **An All Year Round Humid Growing Period (graph 5)**

  In this kind of season, the average monthly precipitation during every month of the year exceeds the full rate of the average monthly PET. Thus, there is no true start to the growing period or to the humid period. Areas with all year round humid growing periods are inventoried as areas with a normal growing period of 365 days.

- **An Intermediate-Humid Growing Period (graph 6)**

  This type of season has both an intermediate and a humid period but no dry period (i.e., a period in which the precipitation curve drops below one half PET).

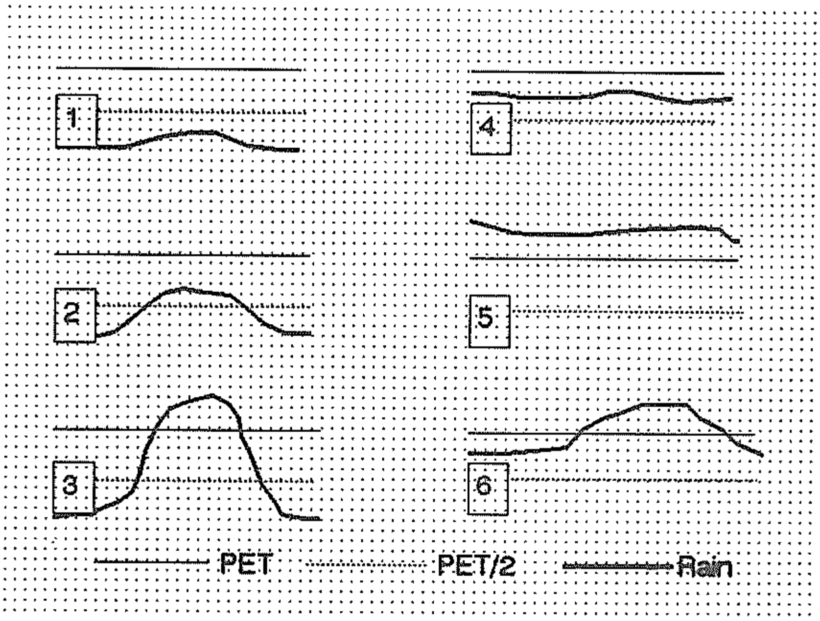

Figure 5.4b : Six Different Types of Growing Periods

Examine the sample data file, **AL-LGP.DAT**, shown in fig. 5.4c. The file lists stations in Africa with geographical coordinates between 2°N and S and 12 monthly values of rainfall and PET for each station. Notice that the rainfall and PET must appear on the same line although in fig. 5.4c, to be able to show the file here, they appear on two lines.

```
"Rainfall  and  PET  from  67  stations  between-2  and  2  degs.  latitude"
"Lon","Lat","Alt","R1","R2","R3","R4","R5","R6","R7","R8","R9","R10","R11","R12","E
1","E2","E3","E4","E5","E6","E7","E8","E9","E10","E11","E12"
"GOMA-ZAI",29.14,-1.41,1552,115,86,98,126,129,45,28,66,110,149,136,117,110,101,113,
102,105,111,116,115,120,117,113,103
"GABIRO-RWA",30.24,-1.32,1472,65,78,95,155,78,18,19,19,68,82,72,75,121,113,126,117,
118,122,130,133,139,124,120,116
"MACHAKOS-KEN",37.17,-1.31,1680,49,53,124,210,76,12,5,6,9,53,189,122,149,140,145,11
8,110,100,93,92,126,136,127,122
"GALOLE-KEN",40.02,-1.3,100,35,19,34,56,30,20,21,13,49,38,94,61,152,151,164,151,150
,132,136,145,166,152,146,137
"KITUI-KEN",38.01,-1.22,1090,41,24,118,244,56,5,3,5,6,82,304,143,151,154,165,127,12
4,117,114,130,150,161,134,126
"RUMANGAB-ZAI",29.22,-1.21,1620,114,115,170,216,156,112,83,140,193,203,200,154,104,
95,108,98,98,96,103,97,106,100,99,95
"NAIROBI-KEN",36.55,-1.19,1624,63,34,81,107,130,24,7,11,21,62,188,116,147,151,156,1
```

Figure 5.4c : AL-LGP.DAT

Open the sample file and press **<ALT> AL** to activate this option. You will be prompted to accept or change the fraction of PET used to define the beginning and the end of the growing season. Although we have been referring to one half PET as used in the AEZ project (1978), the program will accept values from 0.1 to 0.9. Accept the default value by pressing **<ret>** and the output will be written to the file **AL_AL-L1.DAT**, shown partially in fig.5.4d.

```
"Length of growing season with F= .5"
,"La","Lo","Alt","SeasTot","Nr","Type","LGS","BegSd.m","BegSJul","EndSd.m","BegHd.m","EndHd.m"
"GOMA-SAI", 29.14 ,-1.41 , 1552 , 1 , 1 , 3 , 231 , 9.08 , 221 , 27.03 , 23.09 , 23.01
"GABIRO-RWA", 30.24 ,-1.32 , 1472 , 1 , 1 , 3 , 250 , 18.09 , 261 , 25.05 , 29.03 , 1.05
"MACHAKOS-KEN", 37.17 ,-1.31 , 1680 , 2 , 1 , 3 , 93 , 23.02 , 54 , 26.05 , 21.03 , 7.05
"MACHAKOS-KEN", 37.17 ,-1.31 , 1680 , 2 , 2 , 3 , 81 , 19.1 , 292 , 7.01 , 3.11 , 16.12
"GALOLE-KEN", 40.02 ,-1.3 , 100 , 1 , 1 , 2 , 34 , 5.11 , 309 , 8.12 ,-999 ,-999
"KITUI-KEN", 38.01 ,-1.22 , 1090 , 2 , 1 , 3 , 84 , 15.1 , 288 , 6.01 , 25.1 , 20.12
"KITUI-KEN", 38.01 ,-1.22 , 1090 , 2 , 2 , 3 , 74 , 3.03 , 62 , 15.05 , 24.03 , 4.05
"RUHANGAB-ZAI", 29.22 ,-1.21 , 1620 , 1 , 1 , 6 , 340 ,-999 , 206 ,-999 , 25.07 , 29.06
"NAIROBI-KEN", 36.55 ,-1.19 , 1624 , 2 , 1 , 3 , 88 , 13.03 , 72 , 8.06 , 27.04 , 23.05
"NAIROBI-KEN", 36.55 ,-1.19 , 1624 , 2 , 2 , 3 , 88 , 16.1 , 289 , 11.01 , 1.11 , 13.12
"NAIROBI-KEN", 36.45 ,-1.18 , 1798 , 2 , 1 , 3 , 105 , 3.03 , 62 , 15.06 , 28.03 , 5.06
"NAIROBI-KEN", 36.45 ,-1.18 , 1798 , 2 , 2 , 3 , 78 , 21.1 , 294 , 6.01 , 9.11 , 27.11
"KABETE-KEN", 36.45 ,-1.16 , 1820 , 2 , 1 , 3 , 114 , 27.02 , 58 , 20.06 , 25.03 , 5.06
"KABETE-KEN", 36.45 ,-1.16 , 1820 , 2 , 2 , 3 , 78 , 17.1 , 290 , 2.01 , 13.11 , 21.11
"KABETE-KEN", 36.46 ,-1.15 , 1820 , 2 , 1 , 3 , 113 , 27.02 , 58 , 19.06 , 23.03 , 5.06
"KABETE-KEN", 36.46 ,-1.15 , 1820 , 2 , 2 , 2 , 72 , 19.1 , 292 , 29.12 ,-999 ,-999
```

Figure 5.4d : AL_AL-L1.DAT

The first line lists the fraction chosen for the determination of the beginning and end of the growing season. This is followed by several columns containing the station name, latitude, longitude, altitude and several growing season characteristics. Table 5.4 describes the parameters in the output file and the possible range of values.

Column Heading	Variable	Possible Values
Seastot	Total number of seasons	This variable is an integer from 1 to 5 for the total number of seasons at that station. Some "seasons" may be very short.
Nr	Season number	Each line in the output file is only one season. Multiple seasons are thus listed on multiple lines. This number is the increment of the total number of seasons (Seastot).
Type	Type of season	Season types are codes with a number: 1 - all year round dry 2 - intermediate-dry 3 - normal 4 - all year round intermediate 5 - all year round humid 6 - intermediate-humid
LGS	Length of the Growing Period	The length in 0 to 365 days
BegSJul	Beginning of the season	The start of the season in Julian days
BegSd.m	Beginning of the season	The dates are written in the format day.month where day can range from 1 to 31 and month from 1 to 12. A value of -999 indicates that no starting or ending date was found for this type of season.
EndSd.m	End of the season	
BegHd.m	Beginning of the humid period	
EndHd.m	End of the humid period	

Table 5.4 : Growing Season Characterisltics

The length of the growing season is taken as the period in days when rain exceeds half PET. For each of the types, the LGS is either 0, computed or 365 days, as shown below:

Season Type	LGS (days)
1	0
2	computed
3	computed
4	365
5	365
6	365

Note that a date given as, for example, 12.1 means 12 October (12.10), while the 12 January is coded as 12.01.

5.5 Calculating Potential Yield

This option is currently not available but is expected to appear in the next major version update (i.e, v.2.0!).

6 FAOMET UTILITIES

FAOMET includes a variety of utilities to change the colours, the mouse speed, exit to DOS, view files and retrieve help information. Pull down the **Utilities menu** to access any of these options.

6.1 Changing Colours

Select this option and a window will appear displaying 8 possible colours for the background text, the background screen, the window text and the cursor text. With the arrow keys, move the cursor, displayed as ###### to the feature that you wish to change and flip through the possible colour combinations. Note that these colours are not stored in memory and will automatically be reset to the default values after exiting the program.

6.2 Changing the Mouse Speed

With this option you can change the mouse speed. Simply select a number from 1 to 9 and press **<ret>**.

6.3 The DOS Command Line

This option allows single DOS commands to be issued without exiting the program. Choose this option and a command line will appear. After typing a command, press **<ret>** and you can continue working within FAOMET.

6.4 Exiting to DOS

FAOMET is equipped with a DOS shell for situations where the command line is not sufficient. Type **exit** at the DOS prompt to return to FAOMET after completing your tasks.

6.5 Viewing a File

With this option you can view any file on your hard disk regardless of the size but you cannot edit it. This option is particularly useful for viewing output files created by FAOMET without having to exit the program. The view utility used is **LIST.COM**. See section 2.3 for further information on using an external editor.

6.6 The Help Option

Upon activating the help screen, information is available on several selected topics. Beside each topic is the section number in the manual corresponding to the topic:

- starting the program (1.3)

- the input file format (2.4.1)

- the maximum dimensions of the program (3.2)
- information on use of an external editor (2.3)
- the contact address for general queries as well as any suggestions to improve to the program

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APPENDIX A: FMINSTAL

FMINSTAL is a small installation utility for the FAOMET program.

All programs of the FAO agrometeorology software family follow the general data file format described in section 2 of the FAOMET manual. They will run on an 8086 based machine and above, requiring at least a CGA screen.

The 1.44 MB diskette includes program files and a certain number of "sample files", which may be used to get acquainted with the program's operation (i.e., the "test data files").

The programs and test data files occupy approximately 575 kbytes and installation takes about 8 minutes. The programs cannot be installed from a hard disk, but the files may be copied from an already installed version on a hard disk to a floppy disk and installed again on the same or a different computer. Installation will work properly only if **all** the files are present. If you copy the files from a hard disk to a floppy disk, only the files with $$$ extensions of the install version (temporary files) can be omitted.

Installation Procedure

Follow the instructions below step by step...

A. Insert the distribution disk in a 1.44 MB floppy disk drive. The disk should not be write protected.

B. Change the default directory to the floppy disk drive (typing either **A:** or **B:**).

C. Type **FMINSTAL <ret>**. The program will display a screen with the FAO logo. Press any key to skip this screen. The program will then display a copyright notice. Again, press **<ret>** to skip this screen.

D. The program next displays a menu screen with three options: **S**tart, **D**OS and Exit. To select option **S**tart, press **<ALT> S**, i.e., hold both the **<ALT>** and **S** key down at the same time.

E. Press **c** to confirm start or **<ESC>** to return to point D above. The computer now displays a new screen and asks from which disk drive the FAOMET program is being installed.

F. Answer either **A** or **B** depending on your computer. The program now takes a minute to verify the files on the distribution disk and displays the names of the files as they are being verified.

G. After completing step F, you will be prompted to select one of the valid disk drives to which the FAOMET program files will be installed. The sample data files will be installed later to a different directory.

H. The name of the destination directory must now be given. If the default directory, **\AGROMET.FAO**, is acceptable, press **<ret>**. Otherwise, enter in a directory name of your choice.

I. If the selected directory already exists, a warning is issued. Answer **Y** or **N** and if required, retype the directory name.

J. The FAOMET program files will then be copied to your hard disk, displaying the file names as they are copied. The installation program also adds two lines to your **AUTOEXEC.BAT** file and saves the original as **AUTOEXEC.OLD**. The two lines, which are shown below, may be modified later if you wish.

REM This and next line added by AGROMET: do not remove or modify them
path %path%;J:\AGROMET.FAO

K. You are then prompted to type a default numeric code for missing data, followed by a screen asking for the default extension of data files (***.DAT** or ***.PRN**). The standard default for missing data is -999, but you may chose any value. However, avoid small positive numbers!

L. You must then indicate the destination of the DATA files. Follow the instructions as outlined in steps G and H above, i.e., first the drive...

M. and then the directory... (Remember, if the directory already exists, the same warning will be issued as described in step I).

N. The program now creates a batch file, **FM.BAT**, and a "definitions" file, **FAOMET.DEF**. You may decide to modify the **FAOMET.DEF** file at a later stage. Refer to section 1.2 of the manual for more details. You are then asked whether you want to copy the sample files to the data directory (it is highly suggested that you answer **Y** to this question!).

O. The sample files are copied to the hard disk. Again, their names are displayed as they are being copied.

P. You will then be informed for 20 seconds on how to start the program, i.e., by typing **FM** at the DOS prompt. Do not touch the keyboard while the message is being displayed.

Q. The installation is now complete. In order for the changes to your **AUTOEXEC.BAT** file to become active, your computer must be restarted. If you decide to reboot at this point, follow the instructions that are given (i.e., remove the floppy disk from the drive). Otherwise, be aware that you must turn the computer off and on again before the program can be started by typing **FM**. If you decide to leave the program, you will be taken to the main menu screen again; type **<Alt> E** followed by **x**.

Selected FAO agrometeorological publications

I. Agrometeorology Working Papers series

1. Bernard, E.A. 1992. **L'intensification de la production agricole par l'agrométéorologie.** 35 pages. (F)

2. Gommes, R. and Th. Nègre. 1992. **The role of agrometeorology in the alleviation of natural disasters.** 22 pages. (E)

3. See, L. and R. Gommes. 1993. **Gridded Datasets of Mean Monthly Minimum, Maximum and Daytime Temperatures in Africa.** 17 pages + 3 diskettes. (E)

4. Hoefsloot, P. 1993. **SUIVI: A program for input and analysis of agrometeorological data.** 129 pages + 1 diskette. (E)

5. Rojas, O. 1993. **Algunas Aplicaciones de la agrometeorología en la seguiridad alimentaria.** 37 pages. (S)

6. Le Houérou, H.N., Popov, G.F. and L. See. 1993. **Agro-bioclimatic Classification of Africa.** 227 pages. (E)

7. Lauciani, E. and A. Ponticiello. 1993. **Photosynthetically Active Radiation (PAR): Empirical determination and literature survey.** 85 pages. (E)

8. Gommes, R.A. and L. See. 1993. **FAOMET: Agrometeorological crop forecasting tools.** 57 pages. (E)

Frère, M. and G.F. Popov. 1986. **Early Agrometeorological crop yield forecasting.** FAO Plant Production and Protection Paper No 73. FAO, Rome. 150 pages. (E,S,F)

Henriques-Daza, M. 1991. **Efectos de las condiciones extremas del tiempo en la agricultura de Colombia entre 1938 y 1988.** Video tape (25 minutes). FAO, Rome. (S)

(*) E, S, F indicate that a publication is available in English, Spanish or French, respectively.

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