DEVELOPMENT OF A CROP MONITORING AND FORECASTING SYSTEM
FOR MAJOR AGRICULTURAL COMMODITIES
IN HAMADAN PROVINCE, IRAN

a cooperation and contract agreement between

the Agricultural Statistics and Information Department, Ministry of Agriculture, Iran
and
the International Institute for Aerospace Survey and Earth Sciences, the Netherlands

Instructions
to use the HAM98 procedure for crop yield forecasting

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1. Introduction

ACTUAL97 is a version of the crop growth simulation model PS123, which served crop yield forecasting for the Razan Sharestan. On the basis of a manual, explanatory notes on the input / output structures, a list of acronyms and the source code, ASID successfully implemented the model for crop yield forecasting for whole of Hamadan province (eight Sharestans).

Consequently, the objective of these ‘instructions’ is yet achieved. An interactive approach instructing the user leading to crop yield forecasts for Razan was developed and to be found on diskette ASID981.

Figure 1. The symbol of the Hamadan project.

For ASID stressing the need in 1998 to forecast crop yield for the whole of Hamadan, HAM98 was developed on the basis of the provided input data files. This approach reduces the redundancy in input data typical for the earlier versions. These instructions emphasize upon running HAM98 and illustrate some results.
2. Procedure of regional crop yield forecasting

The main structure of the forecast procedure is illustrated on the next page. HAM98 has a comparable structure.

The procedure consists of two main steps. First you try to find variables explaining actual crop yield, secondly you generate values for these variables for the year of forecasting and estimate the actual yield.

The actual yield estimate functions, in step one elaborated by means of regression, have simulated crop parameters as explanatory variables. The crop growth simulation model is the core module in the whole procedure and it calculates potential production on the basis of the characteristics of Land Use Systems (LUS; crop, crop management, weather of the season and soil). Land Use Systems in Hamadan province can be characterized with data collected by ASID, including historic actual crop yield. The data bases have a geo-referencing component, allowing to associate village related data on historic actual yield and crop management with the location specific soil and weather conditions, giving rise to the creation of Land Mapping Units (LMU’s) being nothing more but geo-referenced and temporal unique LUS’s.

Each record in the LMU file contains a polygon identifier referring to the spatial component of the LUS, and identifiers referring to the different data bases:
- ASID data base; crop and crop management data, site specific
- SOIL data base; soil data, site specific
- WEATHER data base; weather data, site specific.

Traversing the LMU file, the relevant parameters for simulation purposes are queried from the spatial relational database, transformed to ASCII comma-delimited format and inputted in the simulation model according to the here after explained input file structures. (The simulation results can be geographically displayed and analyzed with the same LMU polygon identifier)

The simulation results are related to the historic actual yield data and by means of regression the most accurately explaining variable is identified. Forecasting yield for 1998 some data used in the first step are not available. Besides crop acreage, to be derived from satellite imagery, crop management is unknown and daily weather only till the day of forecasting. Establishing the actual yield estimate functions this has to be kept in mind. The hereafter illustrated functions relate actual crop yield with simulated parameters generated at the day of forecasting (Julian Day Number, JDN 196, or about the 15th of July). Another approach is relating actual yield with simulated parameters generated at the day of maturity. This relationship is expected to be more accurate. For forecasting however you’ll need to substitute the missing daily weather data with averaged weather data.

You simulate the explanatory variable, fill in its value in the yield estimate function and the actual yield of this LUS (LMU) is forecasted.

Aggregating all LUS specific forecasted yields to one per crop requires averaging them according to their relative weights as determined by their relative spatial occurrence.
MAIN PROGRAM

GOSUB INTERFACE
START PS123:
PRINT: "This model is still in development and not for practical application!!"

** PART (1): PROGRAMME INITIALISATION **

LUSNR = 0
RESTART:
LUSNR = LUSNR + 1

INPUT:
GOSUB SELECTPS
GOSUB SELECTGEOREFERENCE
GOSUB SELECTLUSCOMPLETE
GOSUB SELECTWEATHER
GOSUB SELECTSOIL
GOSUB SELECTCROP
GOSUB SELECTMANAGEMENT
GOSUB INITIALISE

** PART (2): INTERVAL CALCULATIONS **

CYCLENR = 0
NEXTCYCLE:
CYCLENR = CYCLENR +1

GOSUB TEMPERATURE
GOSUB ASSIMILATION
GOSUB WATERBALANCE
GOSUB NETASSIMILATION
GOSUB PARTITIONING
GOSUB PS3START
GOTO NEXTCYCLE

** PART (3): OUTPUT OF RESULTS AND RESETTING **

OUTPUT:
GOSUB OUTPUTINFILE

RESETTING: (clear the arrays which contain irrelevant calculation results):
IF LUSNR < NRLUS THEN GOTO RESTART

** PART (4): ANALYSIS, APPLICATION & PRESENTATION **

IF REGRESSED? = YES THEN GOTO FORECAST
REGRESSACTYLD: (create $Y = aX^2 + bX + c$)
REGRESSED? = YES
GOTO PS123 (simulate $X$’s for the considered year of forecasting)

FORECAST: (calculate $Y$’s and unify for the whole province (correct for soil frequency per crop stratum)

PRESENTMAP:
GOSUB GEOMAP

END
Figure 2. The nine-year variance (A & B) of the growth of LAI and grains of irrigated barley, simulated at PS-1 (Ekkatan) and the illustrative variance of the actual yield at maturity and the moment of maturity (C).

Figure 2 illustrates the relation between ‘mid season’ parameters and actual yields. ‘B’ corresponds with the day of forecasting JDN 196 and ‘C’ with maturity. ‘A’ is even earlier than ‘B’.

Actual yield at C = Y = a.X^2 + b.X + c \ (R^2 = 1)

with X = simulated parameter generated at moment ‘A’ or ‘B’
and R^2 = indicator for accuracy

\[ R^2 = 1 - \frac{\text{SSE}}{\text{SST}} \]
\[ \text{SSE} = \sum (y_i - \hat{y}_i)^2 \]
\[ \text{SST} = \sum y_i^2 - \left( \frac{\sum y_i^2}{n} \right) \]

Instead of generating a simulated parameter at moment ‘B’ you can start collecting and analyzing data on actual crop performance at moment ‘B’ and elaborate actual yield estimate functions, formalizing the current forecast approach. Such data also permit to calibrate the crop growth simulation model for mid-season performance, which certainly will ameliorate its accuracy with respect to final yield explanation.
3. Results for irrigated wheat

3.1 Model calibration for irrigated wheat

The simulation model Hamadan was calibrated and validated for irrigated wheat, cv. Navid with experiment data from Ekbatan and Ghareh Gol stations.

PS1. Bio-physical yield potential was assumed 10,000 kg /ha and simulated near 10,000 kg /ha for the years 1992/1993 and 1993/94. The with relative development stage associated assimilate partitioning was defined to correspond with observed phenologic events (germination, stem extension, anthesis, and maturity)

PS2. The maximum yields observed in the fertilizer experiments were 5600 kg /ha in 1992/93 and 5600-6200 kg /ha in 1993/94. Conform the experiment data germination day was set at JDN = 298 for 1992 and at JDN = 307 for 1993 and irrigation schedule was set. Soil characteristics were defined as PrefsoilID = 20 (in Iran\FAO.dat). Water limited yield potentials simulated were 6400 kg /ha in 1992/93 and 7500 kg /ha in 1993/94. Both well above the actual yields conform project requirements and both with a simulated maximum LAI of around 3.2 m²/ m²

PS3. Minimum yields observed in the fertilizer experiments were 3925 kg /ha in 1992/93 and 3575 kg /ha in 1993/94. The soil characteristics were set such that the nutrient and water limited yield potential simulated corresponded with these observed unfertilized yields (4000 kg /ha in 1992/93 and 3600 in 1993/94). The nutrient and water limited yield potentials simulated with fertilizer gifts of 200 kg urea /ha and 190 kg di-ammonium phosphate /ha, corresponding with the gifts applied in the fertilizer experiments and leading to maximum yields, were between the observed maximum yields and the simulated water limited yield potentials.

Concluding, the model appears well calibrated for irrigated wheat in three levels of increasing complexity: PS1, PS2 and PS3 and in two years. On purpose, the water limited yield potential was simulated near 1000 kg /ha higher than the observed actual yield data.

3.2 Actual yield estimate functions for irrigated wheat

For 1997 the actual yield for irrigated wheat was forecasted from the 16th of July onwards. Data query for Sharestan Razan (Tehran, July 1997) resulted in 43 LMU’s including historic actual yield data. Transformed to ASCII format, you’ll find them in C:\Ham98 \Actyl\RazNyld.dat. The referred to soil data (81 polygons) are stored in C:\Ham98 \Iran \Rz50soil.dat.

For the whole of Hamadan province (eight Sharestans), a data set with 620 LMU’s was provided in ASCII format (C:\Ham98 \Actyl \Yld1N.dat to Yld8N.dat). The referred to soil data (381 polygons) are stored in C:\Iran \Hm50soil.dat. Regrettably, the provided format appeared erroneous which led to inefficient time spending. Two parameters had to be added.
Irrigated wheat in Razan, actual yield explained by FCSSO3

\[ y = 0.0001x^2 - 0.6206x + 2793.8 \]
\[ R^2 = 0.3991 \]

Irrigated wheat in Razan, actual yield explained by FCSSO3, excluding FCSSO3 < 1500

\[ y = 9E-05x^2 - 0.0094x + 1738.8 \]
\[ R^2 = 0.712 \]

Figure 3a & 3b. Actual yield estimate function for irrigated wheat in Razan

Irrigated wheat in Hamadan, actual yield explained by FCSSO3

\[ y = 5E-05x^2 - 0.3554x + 2807.9 \]
\[ R^2 = 0.034 \]

Figure 4. Actual yield estimate function for irrigated wheat in Hamadan

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The actual yield estimate functions illustrated in figure 3 and 4 resulted from regression analysis. FCSSO3 is the simulated variable identified to explain actual yield. It stands for Seed Storage Organ (ear) generated at JDN 196 and simulated at production situation 3 (nutrient and water limited potential, PS3). Striking is the low accuracy achieved for Hamadan and the relatively high accuracy for Razan. Aggregation of the data reduces the number of regression points and may make the trend line visible, if any. It increases the accuracy of the regressed function though the standard deviation of the aggregated data must be reported. Here, no aggregation took place.

Simulation for Razan resulted in 0 kg/ha or ranging between 1500 - 7500 kg/ha. The accuracy of the trend line could be improved excluding obvious failures simulated 0 kg/ha. Below the threshold value of 1500 kg/ha, nothing is known about the actual yield and is assumed to tend to the intercept of 1750 kg/ha (instead of the intercept of 2800 kg/ha of figure 3a).

The actual yield of irrigated wheat is:

- in Hamadan: $0,00005 \times FCSSO3^2 - 0,3534 \times FCSSO3 + 2800 \quad (R^2 = 0,034)$

- in Razan: $0,00009 \times FCSSO3^2 - 0,0094 \times FCSSO3 + 1740 \quad (R^2 = 0,71)$

The extremely low accuracy for Hamadan is easily explained. The quality of the provided input data is of somewhat suspect quality. Firstly, the historic management data were apparently incorrectly queried from the ASID database (see \Actyl\Yld1N to Yld8N.dat). Reported nitrogen and phosphorus fertilizer doses go up to several tens of thousands of kg/ha. For the most LMU’s, the production potential simulated at PS3 thus corresponds with the production potential simulated at PS2. As a consequence, the crop growth was simulated with fertilizer doses similar for all LMU’s and defined according to the average of the historically applied doses reported for Razan. The results are shown in figure 4. For overruling the reported LMU specific actual doses by the average doses, the Hamadan model was substituted by the Hama model. It is highly recommended to redo the query from the database and divide the fertilizer gift (kg) with the area (ha) of the sample. The weakest point in the whole crop yield simulation is the accurateness of the description of actual management practices. Real life management practices in Hamadan province with respect to irrigation timing is virtually unknown while the model outcome reacts sensitive to this parameter.

A second reason for the low quality was the quality of the provided weather data. At first sight the data appeared correct but making the model run led to some difficulties. The data of weather station Soob are incorrect though appear easy to correct. The values for E0 and ETO should be divided by ten. Full quality screening is difficult because a number of nearly 140 files (14 stations with generally 10 weather years, all with 365 days). A value of 0 % for relative humidity (RHA) leads to calculation errors and is there for in the model replaced by 0,1%. Later it appeared that all weather data from DARG are erroneous (too high E0 and ETO), leading to odd water use efficiencies, as well as some years of KANG.
A third reason were the incorrect queried soil data. The model input parameters Groundwater and Depth were missing, giving rise to LMU’s simulated with totally wrong input parameters. (Earlier text: For sure, an error occurs somewhere in the provided soil data file Hm50soil.dat). What however is of very much more importance is the quality of the soil hydrologic characteristics defined relative to the soil hydrologic characteristics in the field. Emphasizing that the majority of the observed soils of Hamadan province have clay loamy texture and a minority loamy texture. Lighter and heavier textures hardly occur. Simulations at PS2 appeared highly sensitive to the change from loam to clay loam texture. It might be worthwhile to change the default settings such that the hydrology of the clay loam class becomes less favorable for crop growth.

Using other simulated parameters did not lead to a more accurate explanation of the actual yield data of Hamadan province. Regressed were the simulated maximum leaf area index, the water limited (PS2) and bio-physical (PS1) production potentials of rains and total dry matter at JDN 196 and at maturity and the ratio of PS1/PS2 and PS2/PS1, without better results. The water limited grain production potential, excluding simulated values below 2500 kg/ha, led to an accuracy of $R^2 = 0.06$, not worth mentioning.

3.3 Actual yield forecasts for irrigated wheat.

Crop yield forecasts for irrigated wheat were generated running the model again. This time, the different LMU’s differ only in soil type. Input weather data were similar everywhere and derived from Ekbatan station, the only station with data available for 1997. The lacking data from JDN 196 onwards were substituted with multi year averages, though zero’s would do as well.

Historic fertilizer management data were averaged and inputted similar for each LMU. (It is worthwhile to forecast fertilizer use on the basis of extrapolating trend lines of fertilizer use from 1986 to 1996 into 1997 and use these values).

For Hamadan the HM50soil.dat file was used to describe soil characteristics and for Razan the Rz50soil.dat input file.

Extra input files were Regraz.dat and Regrham.dat, describing the yet established actual yield estimate functions.

FCSOS3 was generated again at JDN 196, used to quantify X and to calculate Y (actual yield). An output file was generated each LMU, containing the forecasted actual yield for 1997. Running the batch file Sumfc, all these individual files were copied into one and stored in the \Fcast\Output\*.out. Ryldn for Razan, Yldn for Hamadan. The individual files are deleted. Besides forecasted actual yield for 1997, the output file indicates the soil type and its relative frequency of spatial occurrence (%) within the considered land use stratum (here irrigated agriculture as interpreted from satellite imagery).

The forecasted yields for each LMU (81 for Razan and 381 for Hamadan) were averaged into one yield figure for the region considered. The average is weighted according to the above mentioned relative frequencies. A difficulty here is that for example a frequent soil
type is poorly represented by a low number of LMU’s. As a consequence, the actual yield averaged for this spatially heavily weighted soil unit is relatively little reliable while it represents a high weight in the averaging for the whole region.

The actual yield forecast in 1997 for irrigated wheat in Hamadan was 2300 kg /ha. The not weighted average yield forecast was 2340 kg /ha with a standard deviation of 190 kg /ha.

The actual yield forecast in 1997 for irrigated wheat in Razan was 2680 kg /ha. The not weighted average yield forecast was 2710 kg /ha with a standard deviation of 130 kg /ha.

4. Instructions for the use of HAM98

These instructions allow you to repeat and verify the above results.

1. Copy the content of the diskette to your hard disk. Keep the directory structure intact (see next page).
2. Run the INSTRUCT model to check all input data structures. Screen and organize your input data (see Annex 1). Change settings were necessary. For the exact meaning of each parameter and how these are analyzed you refer to the source code of the model HAMADAN (in directory QB and Annex 2).
3. Prior to running you check the file programmed to be first input (Start981.dat). See Annex 1 to check its content! If you don’t, please don’t read further. The important parameter setting to check is Switch982$. If it is “C”, then the model simulates Land Use Systems with historic actual yield data. If it is “A” or “B” then Land Use Systems for the current year will be simulated prior to forecasting. Chose “C”.
PrefsoilID = 20 is the soil defined for calibration purposes for irrigated wheat, cv. Navid.
The last parameter of this file is the file referring to all other input files (\Iran\Inpfiles.dat). Check! The first file here referred to is HamLus.dat in the root directory defining the identifiers defining the Land Use Systems of one crop in one Sharestan. For simulating irrigated wheat (cv. Navid) in Razan copy Actyld\RazNyld.dat to Hamlus.dat. For the simulation of irrigated wheat in Hamadan, Sharestan one, copy \Actyld\Yld1N.dat to Hamlus.dat.
4. Run the model Hamadan for Navid in Razan and the model Hama for Navid in Sharestan one. The only difference between these two models is that the Hama model substitutes the LMU specific historic actual fertilizer doses with average fertilizer doses equal for all LMU’s. After running, run the batch file SumAct to organize your output files. In the directory \Actyld\output \you’ll find the output files containing the simulated parameters and corresponding actual yield
(RyldN.out for Navid in Razan and YldN.out for Navid in Hamadan, Sharestan one).

5. Stay in this directory, open the spreadsheet RGR1.xls and run the indicated macros (under ‘TOOLS’) to import the simulation output files and to create actual yield estimate functions for each crop (Y = aX² + bX + c). X is the simulated explanatory parameter. A spreadsheet version of each output file will be created and you open these to check the generated charts and to identify which function is most accurate. Write this formula together with the explanatory variable on paper.

6. Before running the simulation model Hamadan again, you change the settings of Switch982$ in Start981.dat from “C” to “A” prior to forecasting. For the simulation of Navid in Razan in 1997 copy \Fcast\RzFc97N.dat to Hamlus.dat. For Navid in Hamadan, Sharestan one, copy \Fcast\HmFc97N.dat to Hamlus.dat. Open \Fcast\Regres.dat and edit the values of the regression coefficients a, b and c and X conform what you wrote on paper in step 5. Run the model and run the batch file Sumfc to organize your output files, containing the actual yield forecasts for each LMU. Output for Navid in Razan you find in \Fcast\Output\Rfc97N.out and for Navid in Hamadan, Sharestan one in \Fcast\Output\Hfc97N.out.

7. In the same directory you open the spreadsheet FC1.XLS and run the indicated macro’s under ‘TOOLS’ to import the latest output files and to aggregate all LMU related actual yield forecasts into one actual yield forecast (kg / ha) for the considered region (Razan or Hamadan, Sharestan one), weighted according to the soil type frequency (%) for each land use stratum. The results are written to the latest output files in Xls format. Close the spreadsheet FC1.Xls and check the results in the spreadsheets Rfc97N.Xls or Hfc97N.Xls.

8. You have your forecasts.

Instead of the above, you can replace step 4 by running the batch files StartAct. StartAct copies \Actyld\Act.dat to Start981.dat, copies the \Actyld\*.dat files one by one to Hamlus.dat and output is generated for all five crops in Razan and for Navid in Hamadan (eight Sharestans). Run the batch file SumAct to organize your output data. In Wageningen, this step takes about 15 minutes.

The macro’s in step 5 are only available for Navid, irrigated wheat. (For the other four crops default actual yield estimate functions will be used in the next step).

Step 6 can be replaced by batch file StartFc. It copies \Fcast\Fcast.dat to Start981.dat, all \Fcast\*.dat files one by one to Hamlus.dat and generates output for all five crops in Razan and for Navid in Hamadan. Please note that you will not edit the above established regression functions in \Fcast\Regres.dat, but in \Fcast\RegrRaz.dat for Razan and in \Fcast\RegrHam.dat for Hamadan.
In Wageningen this step takes about 20 minutes. Please, be aware that regrettably, an error still occurs in the Hm50soil.dat file and for this reason you must stay and touch the keyboard after running Navid in Hamadan.

The macro's in step 7 are available for all five crops in Razan and for Navid in Hamadan.

You have your forecasts for all crops in Razan and for Navid in Hamadan.
5. Conclusions

The model runs properly for the whole of Hamadan. The comparison between Navid in Razan and Navid in Hamadan shows the importance of the quality of the input data. Regression between potential- and actual yields in Razan had an accuracy of $R^2 = 0.7$.

Simulation at PS1 does not lead to significant difficulties though the relation with actual yields will be poor because of the low level of production determining variables incorporated. The principles of simulation at PS3 are that simple that the relation with actual yield is rather good; the more fertilizer, the more yield. Simulation at PS2 however proved relatively difficult because of accuracy of the provided input data. Soil data were erroneous, many weather data were erroneous and management data are inaccurately described for simulation purposes and yield gap analysis. In other words, actual crop growth is difficult to describe as a function of water availability.

What was the sowing data and the irrigation schedule this year? What is the infiltration capacity of the soil and what are the hydrologic characteristics of the soil body? These questions deserve attention to be answered.

The whole procedure, the model and the input / output structures are carefully explained.
Annex 1. Input and output file parameter structures and acronyms.

STARTINPUT$ = "START981.DAT"

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DUMMY$</td>
<td>Parameter heading titles</td>
</tr>
<tr>
<td>HAMID</td>
<td>Identifies nothing</td>
</tr>
<tr>
<td>SWITCH982$</td>
<td>Selects whether for forecast (&quot;A&quot; or &quot;B&quot;) or to simulate historical actual yields (&quot;C&quot;)</td>
</tr>
<tr>
<td>PSSELECT$</td>
<td>Identifies at which Production Situation to simulate (PS1, PS2 or PS3). Set to &quot;1&quot; &quot;2&quot; or &quot;3&quot;.</td>
</tr>
<tr>
<td>OUTOPTION$</td>
<td>Defines how to output, daily results (&quot;A&quot;), relevant results only (&quot;B&quot;) or on screen (&quot;C&quot;)</td>
</tr>
<tr>
<td>PREFSOIL$</td>
<td>Identifies the FAO soil group preferred (1 to 20) to link with crop type instead of linking geographically (Prefsoil = 0) with village (irrespective of crop type and scale). For Navid calibration purposes you set to 20.</td>
</tr>
<tr>
<td>LABFIELD</td>
<td>Defines whether texture class is determined in the field (1) or in the laboratory (2). If in the laboratory, then the input texture class will be considered one class lighter.</td>
</tr>
<tr>
<td>CALIBR$</td>
<td>If &quot;N&quot; then the irrigation schedule conform the calibration experiment data for irrigated wheat, cv. Navid will be set. If &quot;0&quot; then the irrigation schedule will be determined dynamically within defined ranges.</td>
</tr>
</tbody>
</table>

INPUTFILE$ | Refers to the file in where all other files are referred to. |

"HAMID SWITCH982$ PSSELECT$ OUTOPTION$ PREFSOIL$ LABFIELD INPUTFILE$"

RUNNING THE BATCH FILE STARTACT, THE "ACTYLD YLD*.DAT" FILES WILL BE COPIED TO HAMLUS.DAT AND SWITCH982$ SHOULD BE "C"

RUNNING THE BATCH FILE STARTFC, THE "FCAST HMFC97*.DAT" FILES WILL BE COPIED TO HAMLUS.DAT AND SWITCH982$ SHOULD BE "A"
INPUTFILE$ = "IRAN\INPUTFILES.DAT"

INPUT #1, RUNINPUTFILE$
INPUT #1, CROPFILE$, MANAFILE$, PS3MANAFILE$, FCASTDAYFILE$, REGRESSIONFILE$
INPUT #1, FAOSOILFILE$, FAOFREQFILE$, TEXTUREFILE$, REGIONFILE$

RUNINPUTFILE$: Refers to the file defining the LUS’s by use of identifiers referring to the here below files
CROPFILE$: Refers to the file defining crop physiology
MANAFILE$: Refers to the file defining management parameter settings
PS3MANAFILE$: Refers to the file defining nutrient management parameter settings
FCASTDAYFILE$: Refers to the file defining the date of forecasting (before maturity)
REGRESSIONFILE$: Refers to the file defining actual yield estimate functions ($Y = aX^2 + bX + c$)
FAOSOILFILE$: Refers to the file defining the FAO soil characteristics
FAOFREQFILE$: Refers to the file defining the frequencies of occurrence of the FAO soil groups for each land use stratum, as derived from GIS overlying.
TEXTUREFILE$: Refers to the file defining soil hydrology as a function of texture class
REGIONFILE$: Refers to the file defining the region (Sharestan)

"HAMLUS.DAT"
"ir\hamcrop.dat", "ir\hammana.dat", "ir\ps3mana.dat", "ir\fcastday.dat", "fcast\regres.dat"
"ir\fao.dat", "ir\frequ.dat", "ir\texture.dat", "ir\region.dat"
RUNINPUTFILES = “HAMLUS.DAT” (for STARTACT, SWITCH982$ = “C”)

<table>
<thead>
<tr>
<th>MANA, PS3MANA, IRIE, ACTSOILFILE$, RUNOUTPUTS$</th>
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</thead>
<tbody>
<tr>
<td>NRLUS, DUMMY$</td>
</tr>
<tr>
<td>ACTID, FAOID, FAO888, SDB, ACTSOILID, POLYID,</td>
</tr>
<tr>
<td>CROPID, ACTNGIFT, ACTPGIFT, ...</td>
</tr>
<tr>
<td>... YIELD, YEAR, SAMPLE, SHAR, STATION$</td>
</tr>
<tr>
<td>ACTID, FAOID, FAO888, SDB, ACTSOILID, POLYID,</td>
</tr>
<tr>
<td>CROPID, ACTNGIFT, ACTPGIFT, ...</td>
</tr>
<tr>
<td>... YIELD, YEAR, SAMPLE, SHAR, STATION$</td>
</tr>
<tr>
<td>etc.</td>
</tr>
</tbody>
</table>

| MANA | Identifies which management package will be input |
| PS3MANA | Identifies which PS3 management package will be input |
| IRIE | Indicates whether irrigation was applied |
| ACTSOILFILE$ | Indicates the file with soil data and polygon-id's of the 1:50.000 map |
| RUNOUTPUTS$ | Output file |
| NRLUS | Indicates the number of LUS's to simulate |
| DUMMY$ | Heading parameter titles |
| ACTID | Identifies the Land Use System with historical actual yields included |
| FAOID | Identifies which soil of the 1:250.000 soil map will be input |
| FAO888$ | Name of the FAO soil group * |
| SDB | Defines whether the Land Use System is located on the 1:250.000 or 1:50.000 soil map |
| ACTSOILID | Identifies which soil of the 1:50.000 map will be input |
| POLYID | Identifies the soil map polygon |
| CROPID | Identifier from ASID data base which identifies crop |
| ACTNGIFT | Historical nitrogen fertilizer gift (kg/ha) |
| ACTPGIFT | Historical phosphorus fertilizer gift (kg/ha) |
| YIELD | Historical actual yield, aggregated to village level (kg/ha) |
| YEAR | Historical year |
| SAMPLE | Sample number |
| SHAR | Sharestan identifier |
| STATION$ | Name of the weather station file |

3.2.1,"Iran\HM/50soil.dat","YLDN”
82, “Actid,Faoi,FAO,SDB,Actsoilid,Hamsoil4
1,Product,urea/ha,phosp/ha,actyld/ha,year,shar,station$"
1,2,"cnc",0,0,652,102,7246,3,10590,74,3147,68,90,10,1,"Iran\weather\mala"
2,2,"cnc",0,0,652,102,250,250,237,5,94,3,1,"Iran\weather\mala"
3,2,"cnc",0,0,652,102,280,280,340,94,4,1,"Iran\weather\kang"
4,2,"cnc",0,0,652,102,2900,3866,67,1851,85,95,3,1,"Iran\weather\kang"
5,11,"RGC",0,0,780,102,500,500,3000,90,2,1,"Iran\weather\kang"
6,3,"cnc",0,0,646,102,2059,44,2541,89,2914,87,93,17,1,"Iran\weather\kang"
7,3,"cnc",0,0,646,102,2384,67,2336,1636,43,95,15,1,"Iran\weather\kang"
8,3,"cnc",0,0,646,102,2348,61,2743,1,78,4689,51,93,11,1,"Iran\weather\kang"
9,10,"rg",0,0,580,102,1475,4425,1853,13,90,4,1,"Iran\weather\kang"
10,2,"cnc",0,0,564,102,4614,23,6053,08,2128,09,95,11,1,"Iran\weather\kang"
continues to .....
71,2,"cnc",0,0,742,102,9288,53,1014,87,2182,23,92,12,1,"Iran\weather\mala"
72,11,"RGC",0,0,655,102,2759,8,25,2754,5,3890,35,91,12,1,"Iran\weather\kang"
73,11,"RGC",0,0,655,102,2424,0,36,2341,93,2454,18,92,15,1,"Iran\weather\kang"
74,10,"rg",0,0,532,102,1000,725,343,73,95,14,1,"Iran\weather\kang"
75,3,"cnc",0,0,646,102,50,100,1125,95,1,1,"Iran\weather\kang"
76,11,"RGC",0,0,656,102,38000,28500,3131,58,93,12,1,"Iran\weather\kang"
77,3,"cnc",0,0,646,102,9235,25,16922,75,1870,87,91,12,1,"Iran\weather\kang"
78,3,"cnc",0,0,646,102,3246,38,3118,69,4446,12,92,15,1,"Iran\weather\kang"
79,10,"rg",0,0,532,102,2460,71,1950,3150,81,93,8,1,"Iran\weather\kang"
80,10,"rg",0,0,532,102,4228,57,4228,57,561,45,95,3,1,"Iran\weather\kang"
81,2,"cnc",0,0,651,102,7200,7971,43,2119,8,90,7,1,"Iran\weather\kang"
82,2,"cnc",0,0,651,102,739,29,739,29,2892,15,93,5,1,"Iran\weather\kang"
RUNINPUTFILES = "HAMLUS.DAT" (for STARTFC, SWITCH982$ = "A")

NRLUS, DUMMY$, ACTSOIL$, STATION$, RUNOUTPUT$
LUSID, SHAR, MANA, PS3MANA, CROP, SOIL, HARVESTYEAR, SOIL
LUSID, SHAR, MANA, PS3MANA, CROP, SOIL, HARVESTYEAR, SOIL
LUSID, SHAR, MANA, PS3MANA, CROP, SOIL, HARVESTYEAR, SOIL
Etc.

NRLUS Number of LUS's to simulate
DUMMY$ Parameter heading titles
ACTSOIL$ Identifies soil input file
STATION$ Identifies serie of weather input files (no year)
RUNOUTPUT$ Output file
LUSID Identifies the Land Use Systems in file
SHAR Sharestan identifier
MANA Identifies which management package will be input
PS3MANA Identifies which PS3 management package will be input
CROP Identifies which crop will be input
HARVESTYEAR Defines the year of harvest
SOIL Identifies which soil will be input

381, "FCID SHAR MANA PS3MANA CROP HRVSTYEAR SOIL", "Iran\HM50soil.dat", "Iran\weather\ekba", "Hm97N"
1,1,3,2,1,97,1
2,1,3,2,1,97,2
3,1,3,2,1,97,3
4,1,3,2,1,97,4
5,1,3,2,1,97,5
6,1,3,2,1,97,6
7,1,3,2,1,97,7
8,1,3,2,1,97,8
9,1,3,2,1,97,9
10,1,3,2,1,97,10
continues to ...
371,1,3,2,1,97,371
372,1,3,2,1,97,372
373,1,3,2,1,97,373
374,1,3,2,1,97,374
375,1,3,2,1,97,375
376,1,3,2,1,97,376
377,1,3,2,1,97,377
378,1,3,2,1,97,378
379,1,3,2,1,97,379
380,1,3,2,1,97,380
381,1,3,2,1,97,381
MANAFILES = "IRAN \ HAMMANA. DAT"

<table>
<thead>
<tr>
<th>INPUT #1, DUMMY$</th>
<th>INPUT #1, MANANR, CV§, SOWMOMENTS$, SOWDAY, SOWPERIOD, SEED, MORT, PSISTART, PSISOW, ..........</th>
</tr>
</thead>
<tbody>
<tr>
<td>FURROW, SSINT, FXZTS$, FALLUP, FALLOW, FALLW, ECE, ECEW, IRRIGATIONS, IE, TIMEIRR, IRMAX, IRREFF</td>
<td></td>
</tr>
<tr>
<td>INPUT #1, MANANR, CV§, SOWMOMENTS$, SOWDAY, SOWPERIOD, SEED, MORT, PSISTART, PSISOW, ..........</td>
<td></td>
</tr>
<tr>
<td>FURROW, SSINT, FXZTS$, FALLUP, FALLOW, FALLW, ECE, ECEW, IRRIGATIONS, IE, TIMEIRR, IRMAX, IRREFF</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DUMMY$</th>
<th>Parameter heading titles</th>
</tr>
</thead>
<tbody>
<tr>
<td>MANANR</td>
<td>Identifies management package</td>
</tr>
<tr>
<td>CV§</td>
<td>Variety of crop</td>
</tr>
<tr>
<td>SOWMOMENTS$</td>
<td>Defines whether sowing takes place before (&quot;B&quot;) or after (&quot;A&quot;) the winter</td>
</tr>
<tr>
<td>SOWDAY</td>
<td>First day of sowing according to generalized cropping calendar</td>
</tr>
<tr>
<td>SOWPERIOD</td>
<td>Period after sowday that resowing is allowed (d)</td>
</tr>
<tr>
<td>SEED</td>
<td>Sowing density (kg/ha)</td>
</tr>
<tr>
<td>MORT</td>
<td>Mortality of the seed</td>
</tr>
<tr>
<td>PSISTART</td>
<td>Initial soil humidity (cm)</td>
</tr>
<tr>
<td>PSISOW</td>
<td>Soil humidity below what crop simulation restarts (within sowperiod) (cm)</td>
</tr>
<tr>
<td>FURROW</td>
<td>Soil surface roughness (cm)</td>
</tr>
<tr>
<td>SSINT</td>
<td>Initial soil surface water storage (cm)</td>
</tr>
<tr>
<td>FXZTS$</td>
<td>Defines whether the depth of the ground water is fixed or variable</td>
</tr>
<tr>
<td>FALLUP</td>
<td>Upper boundary of soil with fallow water (cm)</td>
</tr>
<tr>
<td>FALLOW</td>
<td>Lower boundary of soil with fallow water (cm)</td>
</tr>
<tr>
<td>FALLW</td>
<td>Amount of fallow water stored in soil (cm)</td>
</tr>
<tr>
<td>ECE</td>
<td>Initial electrical conductivity of the soil solution</td>
</tr>
<tr>
<td>ECEW</td>
<td>Electrical conductivity of irrigation water</td>
</tr>
<tr>
<td>IRRIGATIONS</td>
<td>Defines whether irrigation takes place</td>
</tr>
<tr>
<td>IE</td>
<td>Water dose for each irrigation gift (cm)</td>
</tr>
<tr>
<td>TIMEIRR</td>
<td>Irrigation timing factor, relative to PSILEAF, determining at what soil humidity will be irrigated.</td>
</tr>
<tr>
<td>IRMAX</td>
<td>Maximum number of irrigation water applications</td>
</tr>
<tr>
<td>IRREFF</td>
<td>Irrigation management efficiency factor</td>
</tr>
</tbody>
</table>

"Mananr CV§ Sowman$ sowday sower seed mort psisr$ psisow furrow ssint fxzt$ fallup fallow fallw ece ecew irrig ie timeirr irmax irreff"  
1. "Navíd", "B", 300, 1, 160, 0.1, 1.1, 1.1, 1.1, 1.1, 1.1  
2. "Navíd", "B", 300, 60, 160, 0.1, 5000, 2000, 4.0, "F", 50, 110, 1.1, 1.1, 1.1, 1.1, 7.0, 0.1, 4.0, 0.6  
3. "Navíd", "B", 300, 60, 160, 0.1, 10000, 5000, 4.1, "F", 50, 110, 1.1, 1.1, 1.1, 7.0, 0.1, 4.0, 0.6  
4. "Sardari", "B", 285, 60, 100, 0.1, 5000, 2000, 4.0, "F", 50, 110, 6.1, 1.1, 0.0, 0.0, 0.0  
5. "Sardari", "B", 294, 60, 100, 0.1, 5000, 2000, 4.0, "F", 50, 110, 6.1, 1.1, 0.0, 0.0, 0.0  
6. "Makouee", "B", 300, 60, 160, 0.1, 5000, 2000, 4.0, "F", 50, 110, 6.1, 1.1, 7.0, 1.5, 0.6  
7. "Makouee", "B", 300, 60, 160, 0.1, 5000, 2000, 4.0, "F", 50, 110, 6.1, 1.1, 7.0, 1.5, 0.6  
8. "Zarjo", "B", 300, 60, 100, 0.1, 5000, 2000, 4.0, "F", 50, 110, 6.1, 1.0, 0.0, 0.0, 0.0  
9. "Zarjo", "A", 50, 60, 100, 0.1, 5000, 2000, 4.0, "F", 50, 110, 6.1, 1.0, 0.0, 0.0, 0.0  
10. "Draga", "A", 140, 10, 500, 0.05, 1.1, 1.1, 1.1, 1.1, 1.1  
11. "Draga", "A", 140, 10, 2000, 0.05, 3000, 2000, 10.7, "F", 50, 110, 6.1, 1.1, 7.0, 1.7, 0.2, 14.0, 0.7  
12. "Draga", "A", 160, 10, 500, 0.05, 2000, 500, 10.3, "F", 40, 110, 6.1, 1.1, 7.0, 1.4, 0.3, 14.0, 0.7  
13. "Draga", "A", 140, 10, 2000, 0.05, 3000, 2000, 10.7, "F", 50, 110, 6.1, 1.1, 7.0, 1.3, 14.0, 0.7  

p.s. these values were not applied in the here reported simulations. Newly added parameter is IRREFF, indicating the ratio between net and gross irrigation doses. TIMEIRR replaces the earlier IRREFF.
PS3MANAFILES = "IRAN\PS3MANA.DAT" (Dose is not taken into account while running with SWITCH982$ = "C")

```
INPUT #1, DUMMY$
INPUT #1, PS3MANAID, CONYLD, RFN, NDEF$, PDEFS, NITFERS, NITMOD$, PHOSFERS, PHOSMOD$, NDOSE, PDOSE
INPUT #1, PS3MANAID, CONYLD, RFN, NDEF$, PDEFS, NITFERS, NITMOD$, PHOSFERS, PHOSMOD$, NDOSE, PDOSE

DUMMY$
PS3MANAID Titles
CONYLD Identifies the fertilizer management package
RFN Maximum unfertilized control yield (kg/ha)
NDEF$ Nitrogen recovery fraction (kg/kg)
PDEFS Defines whether nitrogen is deficient
NITFERS Defines whether phosphorus is deficient
NITMOD$ Nitrogen fertilizer type applied
PHOSFERS The mode of nitrogen fertilizer application
PHOSMOD$ Phosphorus fertilizer type applied
NDOSE The mode of phosphorus fertilizer application
PDOSE Amount of nitrogen fertilizer applied (kg/ha)

 histórico average gifts for Navid
 histórico average gifts for Sardari
 histórico average gifts for Makowe
 histórico average gifts for Zarjo
 histórico average gifts for Drag"`
CROPLABELS
C3C4S
TSUM
TLEAF
TLOW
RDROOT
RDM
RDINT
PSILEAF
SLAMAX
SLAMIN
KE
TCM
RLEAF
RRT
RSTEM
RSO
AERENCHYM
WTG
RESFR
RDISTR
ECLEAF
ECROOT
ECSTEM
ECGO
NSO
NSTRAW
PSO
PSTRAW
NRPTS
CRDS
FRLEAF
FRROOT
FRSTEM
FRSO

Labels the crop and variety
Threshold temperature for development (°C)
Heat requirement for full development of plant (°C.d)
Heat requirement for full leaf development (°C.d)
Threshold temperature below which plant dies (°C)
(Tabulated) RDS at which root growth ceases
Maximum depth of rooting system (cm)
Initial equivalent rooting depth (cm)
Critical leaf water head (cm)
Maximum specific leaf area (m²/kg)
Minimum specific leaf area (m²/kg)
Visible light extinction coefficient of the canopy
(Tabulated) maximum turbulence coefficient
Relative maintenance respiration rate for leaves (kg/kg/d)
,, for roots
,, for stems
,, for storage organs
Indicates whether aeration is required
Weight of thousand grains (g) *
Fraction of the straw at flowering partitioned to the assimilate reserve pool (kg/kg)
Root distribution factor
Efficiency of assimilate conversion for the leaves (kg/kg)
,, for the roots
,, for the stems
,, for the storage organs
Minimum nitrogen content of the storage organs (kg/kg)
Minimum nitrogen content of the straw (kg/kg)
Minimum phosphorus content of the storage organs (kg/kg)
Minimum phosphorus content of the straw (kg/kg)
Number of interpolation points
Relative development stage
Fraction of the assimilates partitioned to the leaves (kg/kg)
,, to the roots
,, to the stems
,, to the storage organs

"WHEAT, cv. Navid"
"C3*, 3.2000, 1275.35, 55, 125.7, 14000
24.15, 52.1, 0.022, 0.015, 0.01
0.40, .10, .4
.72, .72, .68, .79, 0.004, 0011, 0005
7
.0, .10, .20, .25, .50, 55.1
.5, .55, .75, .30, .15, 0.0
.5, .45, .15, .10, .05, 0.0
.0, 0.0, .10, .60, .80, 0.0
.0, 0.0, 0.0, 1.1

"WHEAT, cv. Sardari"
"C3*, 3.2000, 1225.35, 55, 125.7, 14000
22.13, 50.1, 0.022, 0.015, 0.01
0.40, .10, .85
.72, .72, .68, .79, 0.004, 0011, 0005
7
.0, .10, .20, .25, .50, 55.1
.45, .55, .65, .30, .15, 0.0
.5, .45, .20, .15, .10, 0.0
.0, 0.0, .15, .55, .75, 0.0
.0, 0.0, 0.0, 1.1
"BARLEY, cv. Makouee"
"C3",2,1650,975,-35,.56,150,7,16000
27,17,-.44,1,1,.022,.010,.015,.007
0,35,.01,.75
.72,.72,.69,.79,.01,.004,.0011,.0005
7
.00,.05,.20,.25,.50,.56,1
.35,.50,.65,.35,.15,.00,.00
.65,.50,.20,.15,.05,.00,.00
.00,.00,.15,.50,.80,.00,.00
.00,.00,.00,.00,.00,1,1
"BARLEY, cv. Zarja"
"C3",2,1250,700,.35,.56,150,7,16000
27,17,-.44,1,1,.022,.010,.015,.007
0,35,.01,.75
.72,.72,.69,.79,.01,.004,.0011,.0005
7
.00,.05,.20,.25,.50,.56,1
.30,.50,.65,.35,.15,.00,.00
.70,.50,.20,.15,.05,.00,.00
.00,.00,.15,.50,.80,.00,.00
.00,.00,.00,.00,.00,1,1
"POTATO (cv. Drarga Wageningen)"
"C3",5,1500,1050,-10,.56,60,10,7000
30,20,.5,.1,1,.01,.01,.015,.007
0,10000,.10,.9
.72,.72,.69,.85,.0085,.015,.0011,.0014
5
.00,.10,.25,.5,1
.65,.60,.15,.0,0
.25,.30,.25,.0,0
.10,.10,.60,.0,0
.00,.00,.00,1,1

ps. the settings for RESFR and RDSTR for Navid were respectively 0.2 and 0.85 during the here reported simulations.
```plaintext
IF ACTSOILID = 0 (SDB = 0) THEN SOILFILES$ = FAOSOILFILES$  (FAO.DAT)
IF ACTSOILID <> 0 (SDB = 1) THEN SOILFILES$ = ACTSOILFILES$  (HM50SOIL.DAT)

SOILFILES$ = "IRAN \ HM50SOIL.DAT"

INPUT #1, DUMMY$
INPUT #1, NRSOILS, SOILNRS$
INPUT #1, SOILD, AREA, POLYID, FAO88$, PERMEAB, STONE, TEXTURID, DEPTH, SALIN, OSLOPE, ......
GWTER, IRRATING, SHNR, LB1, EC1, OC1, PH1
INPUT #1, SOILD, AREA, POLYID, FAO88$, PERMEAB, STONE, TEXTURID, DEPTH, SALIN, OSLOPE, ......
GWTER, IRRATING, SHNR, LB1, EC1, OC1, PH1
Etc.

DUMMY$ Parameter heading titles
NRSOILS Number of soil polygons in file
SOILNRS Identifies the soil parent material (with respect to phosphate fixation)
SOILD Identifies the soils in file
AREA Area of the soil polygon (m$^2$) *
POLYID Identifier of the soil polygon *
FAO88$ Name of the FAO soil group
PERMEAB Permeability of the soil (classes of cm/h) *
STONE Stoniness of the soil (volume classes)
TEXTURID Identifies texture
DEPTH Rootable soil depth (cm classes)
SALIN Soil salinity (classes of mmho / cm)
OSLOPE Overall slope (classes of %)
GWTER Depth of ground water (classes of cm)
IRRATING Suitability rating for irrigated agriculture (classes)
SHNR Identifies Sharestan *
LB1 Lower boundary of the topsoil (cm)
EC1 Electrical conductivity of the topsoil (msiemens/cm) *
OC1 Organic carbon content of the topsoil (%) 
PH1 pH of the topsoil *

"Titles"
381,"8"
1,126079,10,"CMC",4,0,5,0,1,1,2,25,1,0,8
2,9171335,15,"CLH",4,0,5,0,1,2,2,15,1,1,8
3,228235,33,"CHL",4,0,5,0,2,3,2,15,1,1,8
4,9472205,43,"CLH",4,0,5,0,1,2,2,20,1,1,8
5,3985769,46,"CHL",4,0,5,0,2,3,2,15,1,1,8
6,38900640,68,"RCG",4,0,5,0,2,3,2,20,0,0,8
continues to ......
376,998754,936,"CMC",4,0,4,0,2,4,9,22,1,8
377,2132572,940,"CMB",4,0,5,0,2,2,2,9,22,1,8
378,87638,957,"FLC",3,0,3,0,3,3,9,25,1,0,8
379,1076316,958,"FLC",3,2,3,0,3,4,9,25,1,0,8
580,8261401,959,"FLC",5,0,5,0,3,5,9,25,1,0,8
381,495683,960,"FLC",3,1,3,0,3,3,9,25,1,0,8

ps. this file example is erroneous. It has only 15 parameters describing each soil polygon, instead of the required 17. The parameters DEPTH and GWATER are missing.
```
TEXTUREFILES = "IRAN\TEXTURE. DAT"

TEXTURELABELS
SM0, GAM
PSIMAX, K0, ALFA, AK
SO, KTR
DUMMY$

TEXTURELABELS
SM0, GAM
PSIMAX, K0, ALFA, AK
SO, KTR
DUMMY$

e etc.

TEXTURELABELS
SM0
GAM
PSIMAX
K0
ALFA
AK
SO
KTR

Labels the texture classes
Total pore volume (cm/cm)
Texture specific constant (1/cm²)
Texture specific suction boundary (cm)
Saturated hydraulic conductivity (cm/d)
Texture specific geometry constant (1/cm)
Texture specific empirical constant (1/cm²·s/d)
Reference sorptivity (cm²/d)
Hydraulic permeability of the transmission zone (cm/d)

"Coarse sands"
.4,.1
100,650,.15,.1
50,430
0
"Loamy sands"
.45,.03
130,150,.07,13
20,100
0
"Sandy loams"
.5,.02
155,60,.05,30
17,40
0
"Loams"
.47,.015
170,20,.04,30
17,14
0
"Clayloams"
.445,.007
260,4,.03,3
8,5
0
"Clays"
.5,.006
300,2,.025,1.7
5,2
0

26
REGIONFILES = “IRAN \ REGION.DAT”

INPUT #1, NRREGIONDIR
INPUT #1, REGIONNRDIR(X), PROVINCEDIR$(X), SHARESTANDIR$(X)
INPUT #1, REGIONNRDIR(X), PROVINCEDIR$(X), SHARESTANDIR$(X)
Etc.

NRREGIONDIR Number of regions
REGIONNRDIR Region identifier
PROVINCEDIR$ Province name
SHARESTANDIR$ Sharestan name

8
1. "HAMADAN", "ONE"
2. "HAMADAN", "TWO"
3. "HAMADAN", "THREE"
4. "HAMADAN", "FOUR"
5. "HAMADAN", "FIVE"
6. "HAMADAN", "SIX"
7. "HAMADAN", "SEVEN"
8. "HAMADAN", "EIGHT"
FAORQFILES = “IRAN \ FREQ.DAT”

<table>
<thead>
<tr>
<th>INPUT #1, NRFRQSOILS, FRQTITLE$</th>
<th>INPUT #1, FAOFRQID(X), FAO88FRQ$X, FAOFRQNAME$X, TEXTURENAME$X, IRRIAREA(X),</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RAINFEDAREA(X), PASTUREAREA(X), MIXEDAREA(X)</td>
</tr>
<tr>
<td></td>
<td>RAINFEDAREA(X), PASTUREAREA(X), MIXEDAREA(X)</td>
</tr>
<tr>
<td></td>
<td>Etc.</td>
</tr>
</tbody>
</table>

NRFRQSOILS | Number of FAO soil groups considered (max. = 10)
FRQTITLE$  | Comments
FAOFRQID(X) | Identifier
FAO88FRQ$X | FAO soil group abbreviation
FAOFRQNAME$X | Full name
TEXTURENAME$X | Texture class name
IRRIAREA(X) | Spatial proportion (%) of FAO soil group X in land use stratum ‘irrigated agriculture’
RAINFEDAREA(X) | Spatial proportion (%) of FAO soil group X in land use stratum ‘irrigated agriculture’
PASTUREAREA(X) | Spatial proportion (%) of FAO soil group X in land use stratum ‘irrigated agriculture’
MIXEDAREA(X) | Spatial proportion (%) of FAO soil group X in land use stratum ‘irrigated agriculture’

10, "The number of choices is limited to only 10 soils"
1, "CLH", "Haplic Calcisol", "clayloam",1,1,4,1,3
2, "CMC", "Calcic Cambisol", "clayloam",3,4,10,29
3, "CME", "Eutric Cambisol", "clayloam",3,2,6,2,6
4, "FLC", "Calcic Fluvisol", "loam",5,1,0,0
5, "LPE", "Eutric Leptosol", "clayloam",0,2,0,0
8, "LT", "Lithosol", "sandy loam",2,5,21,6
10, "RG", "Regosols", "sandy loam",5,12,41,31
11, "RGC", "Calcic Regosol", "clayloam",4,6,2,7
13, "SNG", "Gleyic & Orthic Solonetz", "clayloam",4,1,0,0
20, "Calibre", "No limitations", "loam",0,0,0,0
IF HARVESTYEAR = 96 AND SOWMOMENT = “A” THEN YEAR = 96
IF HARVESTYEAR = 96 AND SOWMOMENT = “B” THEN YEAR = 95

WEATHERFILES = “IRAN \ WEATHER \ DARG96. DAT”

<table>
<thead>
<tr>
<th>SITE LABELS</th>
<th>LATITUDE (° N - S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAT</td>
<td>Labels the name of the weather station</td>
</tr>
<tr>
<td>LON</td>
<td>Longitude (° W - E)</td>
</tr>
<tr>
<td>ELEVATION</td>
<td>Elevation (m)</td>
</tr>
<tr>
<td>JDN</td>
<td>Julian day Number (1-365)</td>
</tr>
<tr>
<td>TMAX</td>
<td>Daily maximum temperature (°C)</td>
</tr>
<tr>
<td>TMIN</td>
<td>Daily minimum temperature (°C)</td>
</tr>
<tr>
<td>PREC</td>
<td>Daily precipitation (cm)</td>
</tr>
<tr>
<td>RHA</td>
<td>Daily relative humidity (0-1)</td>
</tr>
<tr>
<td>E0</td>
<td>Daily potential evaporation (cm)</td>
</tr>
<tr>
<td>SUNH</td>
<td>Daily sunshine hours (h)</td>
</tr>
<tr>
<td>ETO</td>
<td>Daily potential evapotranspiration (cm)</td>
</tr>
</tbody>
</table>

"dargazin96", 35.21, 49.04, 1870

1, 10.00, -5.00, 0.00, 0.61, 0.16, 5.00, 0.11
2, 10.50, -4.50, 0.00, 0.62, 0.17, 2.00, 0.12
3, 8.00, 0.50, 0.00, 0.68, 0.17, 0.00, 0.12
4, 8.00, 1.00, 0.00, 0.91, 0.11, 1.80, 0.08
5, 5.30, 0.30, 1.00, 0.95, 0.07, 1.10, 0.05
6, 3.50, 1.00, 1.50, 0.80, 0.14, 2.80, 0.10
7, 7.50, -1.00, 0.00, 0.64, 0.16, 0.70, 0.11
8, 3.00, -1.00, 0.00, 0.85, 0.13, 3.30, 0.09
9, 4.50, -3.50, 0.00, 0.87, 0.07, 0.00, 0.05
10, -2.00, -4.00, 0.00, 0.93, 0.06, 0.00, 0.04
11, -1.50, -5.00, 0.20, 0.72, 0.16, 5.30, 0.11

continues to …..
152, 29.00, 8.00, 0.00, 0.35, 3.76, 12.40, 2.63
153, 30.00, 11.00, 0.00, 0.36, 3.30, 12.20, 2.31
154, 31.00, 8.50, 0.00, 0.46, 3.44, 12.70, 2.41
155, 32.00, 14.50, 0.00, 0.42, 3.97, 10.30, 2.78
156, 27.50, 12.00, 0.00, 0.38, 3.31, 9.80, 2.46
157, 26.00, 7.50, 0.00, 0.36, 4.13, 13.10, 2.89
158, 27.00, 6.00, 0.00, 0.47, 4.14, 13.30, 2.90
159, 28.00, 7.00, 0.00, 0.36, 3.86, 12.90, 2.70
160, 28.00, 10.50, 0.00, 0.39, 4.06, 12.20, 2.84
161, 28.00, 10.00, 0.00, 0.41, 3.91, 13.10, 2.74
162, 25.00, 10.00, 0.00, 0.39, 4.00, 13.10, 2.80
163, 26.00, 10.00, 0.00, 0.42, 4.24, 12.70, 2.97
164, 28.50, 10.00, 0.00, 0.36, 4.33, 13.30, 3.03
165, 29.50, 11.50, 0.00, 0.35, 4.37, 12.90, 3.06
166, 30.00, 11.50, 0.00, 0.41, 4.10, 12.80, 2.87
continues to …..
233, 33.50, 14.50, 0.00, 0.26, 3.33, 11.10, 2.47
234, 34.50, 17.00, 0.00, 0.27, 3.46, 7.00, 2.42
235, 34.00, 18.50, 0.00, 0.30, 3.44, 10.40, 2.41

(note the extremely high values for E0 and ETO)
236.33,00,11.50,0.00,0.34,3.41,11.80,2.39
237.31,50,12.00,0.00,0.22,3.39,12.00,2.37
238.32,50,12.50,0.00,0.28,3.23,12.10,2.26
239,32.00,13.00,0.00,0.23,2.87,11.90,2.01
240,31.50,12.50,0.00,0.25,3.04,11.90,2.13
241,32.00,13.50,0.00,0.26,2.97,11.20,2.08
242,28.00,13.00,0.00,0.28,2.87,11.50,2.01
243,29.50,12.50,0.60,0.23,3.01,11.50,2.11
244,29.50,13.50,0.00,0.29,3.04,10.00,2.13
245,29.00,12.50,0.00,0.31,2.84,10.80,1.99
246,30.00,12.00,0.00,0.29,2.70,10.30,1.89
continues to ..... 
355,10.30,-4.00,0.00,0.77,0.10,0.00,0.07
356,4.00,2.00,0.50,0.97,0.06,0.30,0.04
357,6.00,0.50,1.40,0.93,0.10,2.50,0.07
358,5.00,-3.00,0.00,0.88,0.14,6.10,0.10
359,7.00,-2.00,0.00,0.75,0.16,5.90,0.11
360,7.50,-1.00,0.00,0.80,0.10,1.00,0.07
361,8.00,0.50,0.00,0.82,0.20,8.60,0.14
362,13.00,-2.00,0.00,0.72,0.21,9.00,0.15
363,14.00,2.00,0.00,0.66,0.26,3.60,0.18
364,14.50,0.00,0.00,0.49,0.31,3.20,0.22
365,10.00,-2.00,0.00,0.09,0.14,8.50,0.10

IF RHA(L) = 0 THEN RHA(L) = 0.1

AVAILABLE WEATHER STATIONS ARE "IRAN \ WEATHER \\n
EKBA (daily multi year averages)
EKBA 86 – 97 (97 contains multi year averages from JDN 196 onwards)
NASE 86 – 96
NOJE 86 – 96
ARAK 86 – 95
KESH 86 – 96
BROU 89 – 95
GHOR 90 – 95
KHOR 86 – 96
KANG 87 – 96 (some are corrupt)
BIIA 88 – 96
DARG 97 – 96 (are all corrupt)
MALA 89 – 96
SOOB 86 – 91 (believed to be all corrupt)
HAMF 86 – 96
**FCASTDAYSFILEs = “IRAN \ FCASTDAYS.DAT”**

<table>
<thead>
<tr>
<th>INPUT #1, DUMMY$</th>
<th>INPUT #1, FCASTDAY</th>
</tr>
</thead>
</table>

*DUMMY*$ | Comments
FCASTDAY | Julian Day Number (JDN 1 - 365) at which forecasting takes place and for which day output will be generated. (JDN 1 = 1$^{st}$ of January).

*Forecastday*
196

**REGRESSIONFILES = “FCAST \ REGRES.DAT”**

<table>
<thead>
<tr>
<th>INPUT #1, DUMMY$</th>
<th>INPUT #1, DUMMY$, X$, COEFFA, COEFFB, COEFFC</th>
</tr>
</thead>
</table>

*DUMMY*$ | Parameter heading titles
DUMMY$ | Crop indicator
X$ | Explanatory variable X. Simulated output parameter incorporated into regression for explaining actual yield (actual yield = $Y = a.X^2 + b.X + c$)
COEFFA | Regression coefficient ‘a’
COEFFB | Regression coefficient ‘b’
COEFFC | Regression coefficient ‘c’

*CrapCV, X, aX^2 + bX + c”*
"Navid", "SSO3", -0.00003, 1.0962, 0
"Sardari", "TDM3", 0.2401, -183.23
"Makouee", "SSO3", -0.0002, 1.5411, 0
"Zarjo", "SSO3", -0.00005, 0.5085, 0
"Drage", "SSO3", 0.2119, 4323.4
RUNOUTPUTFILES = "RUNOUTPUT + YEAR.DAT"

LUSID, "": SOWYEAR, "": FAO88, SOILFREQ, GERDAY, ANTHESIS, LASTDAY, IRRSUM, FCSSO3, FCTDM3, SS03, TDM3, LAITOP, FCSSO, FCTDM, SSO(Z), TDM(Z), YIELD, FCYLD, STATION, POLYID

**LUSID**
Identifies simulated Land Use System

**SOWYEAR**
Year of sowing

**FAO88**
FAO soil group

**SOILFREQ**
Spatial frequency of occurrence (%) of soil group X within the considered land use stratum

**GERDAY**
JDN at which crop germinated

**ANTHESIS**
JDN at which crop reached anthesis

**LASTDAY**
JDN at which crop reached maturity and simulation stops

**IRRSUM**
The total amount of irrigation water applied (cm)

**FCSSO3**
Storage organ potential at PS3 at the forecast day (kg/ha)

**FCTDM3**
Total dry mass potential at PS3 at the forecast day (kg/ha)

**SS03**
Storage organs potential at PS3 at maturity (kg/ha)

**TDM3**
Total dry mass potential at PS3 at maturity (kg/ha)

**LAITOP**
Maximum leaf area index achieved (m²/m²)

**FCSSO**
Storage organ potential at PS2 or PS1 at the forecast day (kg/ha)

**FCTDM**
Total dry mass potential at PS2 or PS1 at the forecast day (kg/ha)

**SSO**
Storage organs potential at PS2 or PS1 at maturity (kg/ha)

**TDM**
Total dry mass potential at PS2 or PS1 at maturity (kg/ha)

**YIELD**
Historic actual yield (kg/ha)

**FCYLD**
Forecasted actual yield of this LUS, calculated using the regression coefficients and simulated explanatory variable

**STATION**
Weather station

**POLYID**
Identifies soil polygon, prior to geographic display

During running a simulation, each land use system generates its own output file.

Add them all together into one output file for each crop, delete the original output files, and bring the added files to \ACTYLD\OUTPUT\*.OUT or \FCAST\OUTPUT\*.OUT

By running the batch files SUMACT or SUMFC (depending whether SWITCH982S was "A" or "C"; actual yield simulation or forecasting)
Annex 2.1  Source code of the Hamadan model.

CLS
GOTO START
PRINT "********************************************************************"
PRINT "**                        HAMADAN                            **
PRINT "**       A SIMPLE MODEL SIMULATING INDICATORS FOR              **
PRINT "**       ACTUAL CROP YIELD FORECASTING                        **
PRINT "**                        WITH ATTENTION FOR                  **
PRINT "**                         - salt stress                       **
PRINT "**                         - response to fertilizer gifts                  **
PRINT "**                         - dynamic timing of germination and irrigation **
PRINT "**                         - residual fallow water                            **
PRINT "**                         - actual crop yield forecasting                         **
PRINT "**                        NOT FOR PRACTICAL APPLICATION: THIS MODEL IS STILL UNDER **
PRINT "**                        DEVELOPMENT !!                           **
PRINT "**                        Last modification                       **
PRINT "**                        F.M. Driessen; FS123; 17 July 1996             **
PRINT "**                        Johan Leenasr; HAMADAN; January 1998           **
PRINT "********************************************************************"
PRINT " Press any key"
WHILE INKEY$ = "": WEND
PRINT ""
PRINT ""
PRINT ""
PRINT ""
PRINT "************************************************************************
PRINT "**                        ITC / ASID research contract               **
PRINT "**                        Development of                              **
PRINT "**                        a crop monitoring and forecasting system **
PRINT "**                        for major agricultural commodities in Hamadan province **
PRINT "**                        WATER2.BA is an external module, describing the waterbalance **
PRINT "************************************************************************
PRINT " Press any key"
WHILE INKEY$ = "": WEND
'
This programme consists of three parts:
'(1) PROGRAMME INITI ALISATION,
'(2) INTERVAL CALCULATIONS, and
'(3) OUTPUT OF RESULTS.
'
************************************************************************
**                          PART (1): PROGRAMME INITI ALISATION           **
************************************************************************
'
START:
SWITCH$ = "F"
GOSUB STARTHAM
GOSUB REGIONANDCROP
GOSUB SWITCH982
GOSUB MANASCREEN
GOSUB OUTPUTOPTION
'

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' Fields are dimensioned for the storage of relevant parameters.
DIM TMAX(365), TMIN(365), PREC(365), RHA(365), EO(365), SUNH(365), ETO(365)
DIM TDAY(365), T24h(365), ECEW(365), ECET(365), ECE(365)
DIM SLEAF(365), SROOT(365), SSTEM(365), SSQ(365), LIVSLEAF(365), LAI(365)
DIM TDM(365), LFDRS(365), CFWATER(365), IE(365), RDS(365), RDTAP(365), RESVEG(365)
DIM FRLEAF(20), FRROOT(20), FRSTEM(20), FRSO(20), CRDS(20)
DIM SOILLABELS(20), CROPLABELS(30), SITELABELS(61), LUSLABELS(30)

' A Land Use System is composed of a Land Unit and a Land Utilisation Type.

DEF FNASN (X) = ATN(X / SQR(1 - X ^ 2))

RUNZERO:
YEARNR = 1
LUSNR = 1 'if > 1 year in 1 LUS then LUSNR <= RUNNR
RUNNR = 0
SOW = 0
'RESTART: same LUS
RUNNR = RUNNR + 1

GOSUB INPUTSTARTFILE
GOSUB FILEINPUTFILE
GOSUB LUSCOMPLETE
GOSUB MANAGEMENTINPUT
IF VAL(PSSELECTS) = 3 THEN
GOSUB P33MANINPUT

END IF
GOSUB SELECTCROP
GOSUB SELECTSOIL
GOSUB CONDUCTIVITY
GOSUB REGIONFILE
GOSUB SOILFREQCROP
GOSUB WEATHERFILE
GOSUB WEATHERDATA
GOSUB FCASTDAYINPUT

' Before the calculations can start, a number of parameter values must
' be set to zero; other parameters may have an initial value other than
' zero (e.g. S(org)). Functions and numerical constants must be declared.

RESOWING:
GOSUB INITIALISE

*********************************************************************************
*** PART (2): INTERVAL CALCULATIONS ***
*********************************************************************************

NEXTCYCLE:
'-- DETERMINE THE TEMPERATURES AND RDS AT MID-INTERVAL --

' In this step, daily and daytime temperatures (T24h and TDAY) are computed.
' The following order of the calculations: DEC, SSIN, CCOS, SSCC, DL. Next,
' the radiation components RDN, SC, PAR, EXTRA, TRANS, PARCAN and CANRAD are
' calculated. The then estimated temperatures TDAY and T24h are used to
' check for TOO LOW AIR temperatures.

GOSUB TEMPCALC

34
' Use these AIR temperatures to check for TOO LOW temperature:

IF TMIN(DAY) > TLOW THEN
   TCOUNT = 0
ELSE
   TCOUNT = TCOUNT + Dt
END IF

IF (TMIN(DAY) < 0 AND TLOW > TMIN(DAY)) OR TCOUNT > 10 THEN GOTO PS3AFTERLASTDAY

' Now, calculate the difference between air temperature and canopy temperature and correct TDAY and T24h of the CANOPY:

GOSUB TEMPDIFF

TDAY(DAY) = TDAY(DAY) + TEMPDIFF
T24h = (DL * TDAY(DAY) + (24 - DL) * Tnight) / 24
T24h(DAY) = T24h

' Calculate the mid-term RDS using the canopy temperature:

GOSUB MIDTERMARDS

' -- DETERMINE SLA AND LAI --

IF RDS = 0 THEN RDS = .01 ' To avoid LOG(0)
SLAMAXD = SLAMAX - .45 * (TREF - TREFmain) * (ELEVATION / 1000) * .5
SLAMIND = SLAMIN - .45 * (TREF - TREFmain) * (ELEVATION / 1000) * .5
'SLAMAXD = SLAMAX - (ELEVATION / 1000) * 3
'SLAMIND = SLAMIN - (ELEVATION / 1000) * 3
SLA = SLAMIND - .5 * (SLAMAXD - SLAMIND) * LOG(RDS) ' See Danalatos/Barros

IF SLA > SLAMAXD THEN SLA = SLAMAXD ' At very low RDS

LAI = LIVSLEAF * SLA * .0001
LAI(RUNDAY) = LAI ' LAI(365) array needed for printout only!
IF LAI(RUNDAY) > LAI(RUNDAY - 1) THEN
   LAITOP = LAI(RUNDAY)
ELSE
   LAITOP = LAITOP
END IF

' IF DAY = (ANTHESIS + 1) AND ANTHESIS > 0 THEN LAITOP = LAI

' -- DETERMINE THE MAXIMUM RATE OF CO2 ASSIMILATION (AMAX) --

GOSUB AMAX

CC = EFF * ke * PARCAN
Fgc = DL * (AMAX / ke) * LOG((AMAX + CC) / (AMAX + CC * EXP(-LAI * ke)))

' -- DETERMINE IRRIGATION SCHEDULE --

IF SWITCH$ = "F" THEN GOSUB IRRIGATIONINPUT

' -- DETERMINE CFWATER --

IF VAL(PSELECTION) > 1 THEN
   GOSUB WATERBALANCE
ELSE
   CFWATER = 1
   CFWATER(RUNDAY) = 1
END IF

IF DROUGHTLIMIT >= INT(PSILEAF / 750 + .5) AND SEED <= 0 THEN GOTO PS3AFTERLASTDAY
' After (PSileaf/1000) consecutive days of zero transpiration the crop perishes.

IF AERENCHYM <= 1 AND WETLIMIT >= 20 THEN GOTO PS3AFTERLASTDAY
' After 20 consecutive days of excessive wetness crops without aerenchym fail.

' -- CALCULATE FGASS AND ALLOCATE FRACTIONS OF FGASS TO PLANT ORGANS --

GOSUB GAORG

' -- DETERMINE THE MAINTENANCE RESPIRATION RATE --

' Following order: MREFORG -> CFTEMP -> (CFWATER) -> MRORG

GOSUB REFMaint
GOSUB TEMPCORRECT
GOSUB ACTMAINT

' -- DETERMINE NAA(org) AND DWI(org) OF ALL ORGANS --

' Following order: NAAORG --> DWIORG

GOSUB NETASSORG
GOSUB DRYWTINCREMEN T

' -- CALCULATE ORGAN WeIGHTS AND CORRECT FOR DEAD LEAVES --

' Following order: S(org) ==> RDS ==> livS(leaf)

GOSUB GROSSSOR G
GOSUB ENDRDS
GOSUB DEADLEAVES

' -- CALCULATE TDM AND TLDM AT END OF INTERVAL --

GOSUB TDMTLDM
GOSUB FORECAST

' -- ANOTHER INTERVAL ?? --

IF RDS < 1 THEN
  DAY = DAY + Dt
  IF DAY = 366 THEN
    YEAR = YEAR + 1
    YEARS = STR$(YEAR)
    LENGTH = LEN(YEARS)
    YEARS = RIGHT$(YEARS, LENGTH - 1)
    WEATHERFILES = STATIONS$ + YEARS$ + ".DAT"
    GOSUB NEWYEAR
    DAY = 1
  END IF
RUNDAY = RUNDAY + Dt
IF RUNDAY > 365 THEN GOTO TOOLONGONFIELD
GOTO NEXTCYCLE
END IF

PS3AFTERLASTDAY:
IF VAL(PSSSELECT$) = 3 THEN
    TARSO = SSO(RUNDAY)
    TARTDM = TDM(RUNDAY)
    GOSUB PSS3START
    SSO3 = SO3
    TDM3 = DM3
END IF
IF VAL(PSSSELECT$) = 3 THEN
    TARSO = FCSSO
    TARTDM = FCTDM
    GOSUB PSS3START
    FCSSO3 = SO3
    FCTDM3 = DM3
END IF

'AFTERFERTILIZATION:

ACTYLDFORECAST:
CLS
IF SWITCH982$ = "A" THEN
    OPEN REVERSIONFILE$ FOR INPUT AS #1
    INPUT #1, DUMMY$
    IF CROP > 1 THEN
        FOR X = 1 TO (CROP - 1)
            LINE INPUT #1, DUMMY$
        NEXT X
    END IF
END IF

INPUT #1, DUMMY$, X$, COEFFA, COEFFB, COEFFC
CLOSE #1
END IF

IF X$ = "FCSSO3" THEN EXPLX = FCSSO3
IF X$ = "FCTDM3" THEN EXPLX = FCTDM3
IF X$ = "SSO3" THEN EXPLX = SSO3
IF X$ = "TDM3" THEN EXPLX = TDM3
IF X$ = "LAITOP" THEN EXPLX = LAITOP
IF X$ = "FCSSO" THEN EXPLX = FCSSO
IF X$ = "FCTDM" THEN EXPLX = FCTDM
IF X$ = "SSO" THEN EXPLX = SSO
IF X$ = "TDM" THEN EXPLX = TDM
FCYLD = (COEFFA * EXPLX * EXPLX) + (COEFFB * EXPLX) + COEFFC

OUTPUTTING:

'******************************************************************************************
** PART (3): OUTPUT OF CALCULATION RESULTS                                           **
'******************************************************************************************
IF OUTOPTIONS$ = "C" OR OUTOPTIONS$ = "c" THEN GOSUB OUTPUTONSCREEN
GOSUB OUTPUTONFILE

'******************************************************************************************
** RESUMING OR EXITING THE PROGRAM                                                    **
'******************************************************************************************

' Now that the calculations for one scenario are finished, the user
' must decide whether to analyse another scenario or to END.
ANOTHER SCENARIO:
CLS
IF DAY <= SOWDAY + SOWPERIOD AND DAY > SOWDAY THEN GOTO SAMEONE

IF NRYEARS = 1 AND NRLUS = 1 THEN GOTO LOGGINGOUT
IF NRYEARS = 1 AND NRLUS <= 1 THEN
  LUSNR = LUSNR + 1
  IF LUSNR > NRLUS THEN
    GOTO LOGGINGOUT
  ELSE
    GOTO NEWONE
  END IF
END IF

IF NRYEARS <= 1 AND NRLUS = 1 THEN
  YEARNR = YEARNR + 1
  IF YEARNR > NRYEARS THEN
    GOTO LOGGINGOUT
  ELSE
    GOTO NEWONE
  END IF
END IF

IF NRYEARS <= 1 AND NRLUS <= 1 THEN
  YEARNR = YEARNR + 1
  IF YEARNR > NRYEARS THEN
    LUSNR = LUSNR + 1
    IF LUSNR > NRLUS THEN
      GOTO LOGGINGOUT
    ELSE
      YEARNR = 1
    GOTO NEWONE
  END IF
END IF

ELSE GOTO NEWONE
END IF

NEWONE: ' (SAME LUS/NEXT YEAR OR NEXT LUS/1ST YEAR)
CLS
SOW = 0: PSIINT = PSISTART: GERDAY = SOWDAY
IRRIGATIONS = 0
GOTO RESETTING

SAMEONE: ' (DAY <= SOWDAY + SOWPERIOD AND DAY > SOWDAY)
CLS
SOW = SOW + 1: GERDAY = DAY
ZTINT = ZT: SSINT = SS: PSIINT = PSI
GOTO RESETTING

RESETTING:
CLS
IRRSUM = 0: DROUGHTLIMIT = 0: WETLIMIT = 0
IRRIS = 0: LASTDAY = 0: CROPDAY = 0: L = 0
TREF = 0: TREFmain = 0: COUNT = 0
'SDRI = 0: SDST = 0: SVAPEST = 0: VPA = 0
' OP = 0: SOILSALT = 0: DELTSALT = 0: ECE = 0: ECET = 0: ECEW = 0: ECGRW = 0
' SALTDEEP = 0: SALTPERCED = 0: SALTRISEN = 0: SALTIRRIG = 0
FLOW = 0: dFLOW = 0: CR = 0
RDS = 0: RDTAP = 0: RESVEG = 0: RESSO = 0
ANTHESIS = 0: SEXTENSION = 0: GRAINFILL = 0
INTFRSO = 0: INTFRSTEM = 0: INTFRLEAF = 0: INTFRROOT = 0
'
' Clear the arrays which contain calculation RESULTS:

ERASE SLEAF, LIVSLEAF, SROOT, SSTEM, SSO, TDM, LAI, LFRDS, RDS
ERASE CFWATER, IE, ECW, ECET, ECE, RDTAP

IF SWITCH$ = "F" THEN
   IF SOW > 0 THEN
      GOTO RESOWING ' SOWING -> GOSUB INITIALISE
   ELSEIF SOW = 0 THEN
      IF YEARNR > 1 AND YEARNR <= NRYEARS THEN
         GOSUB WEATHERDATA
         GOTO RESOWING
      ELSE
         GOTO RESTART
      END IF
   END IF
END IF

CROPOUTCOLD:

' ' SUBROUTINE TO ACCOUNT FOR LOW TEMPERATURES --

CLS
IF SWITCH$ = "F" OR SWITCH$ = "C" THEN GOTO ANOTHERSCENARIO

TOOLONGONFIELD:

' ' SUBROUTINE TO SIGNAL TOO LONG GROWING PERIOD --

CLS
IF SWITCH$ = "F" OR SWITCH$ = "T" THEN GOTO ANOTHERSCENARIO

CROPOUTDRY:

' ' SUBROUTINE TO ACCOUNT FOR LETHAL DROUGHT --

CLS
IF SWITCH$ = "F" OR SWITCH$ = "T" THEN GOTO ANOTHERSCENARIO

CROPOUTWET:

' ' SUBROUTINE TO ACCOUNT FOR LETHAL WETNESS --

CLS
IF SWITCH$ = "F" OR SWITCH$ = "T" THEN GOTO ANOTHERSCENARIO

SHALLOWWATER:

' ' SUBROUTINE TO SIGNAL (SUDDEN) SHALLOW GROUNDWATER --

CLS
IF SWITCH$ = "F" OR SWITCH$ = "T" THEN GOTO ANOTHERSCENARIO

LOGGINGOUT:

' ' SUBROUTINE TO QUIT THE ANALYSIS ALTOGETHER --
CLS
LOCATE 8, 2: PRINT "DON'T FORGET TO RUN THE BATCH FILE *.BAT IN THIS DIRECTORY"
LOCATE 12, 2: PRINT "THANK YOU FOR KEEPING THE COMPUTER ROOM CLEAN."
LOCATE 14, 2: PRINT "REMARKS: (remove this message later)"
LOCATE 15, 2: PRINT "1.- Weather station 'SOOF' is corrupt (E0 & E10) and replaced by 'EKBA'"
LOCATE 16, 2: PRINT "2.- The historic management data are corrupt! Check fertilizer doses / ha."
LOCATE 17, 2: PRINT "3.- The Hamadan soil data seem corrupt!. Are salinity and depth exchanged?"
END

_______________________________
--- BLOCK WITH INPUT SUBROUTINES ---
_______________________________

STARTHAM:
CLS
STARTINPUTFILE$ = "START981.DAT"
OPEN STARTINPUTFILE$ FOR INPUT AS #1
INPUT #1, DUMMY$
INPUT #1, HAMID, SWITCH982$, PSSELECT$, OUTOPTION$, PREFSOILID, LABFIELD, CALIBR$, INPUTFILE$
CLOSE #1
RETURN

REGIONANDCROP:
CLS
NRACROPS = 1
NRSHARS = 1
RETURN

SWITCH982:
CLS
IF SWITCH982$ = "A" OR SWITCH982$ = "a" THEN SWITCH982$ = "A"
IF SWITCH982$ = "B" OR SWITCH982$ = "b" THEN SWITCH982$ = "B"
IF SWITCH982$ = "C" OR SWITCH982$ = "c" THEN SWITCH982$ = "C"
CLS
IF SWITCH982$ = "B" THEN
  LOCATE 8, 2: PRINT "INPUT THE REGRESSION FUNCTION BETWEEN EXPLANATORY PARAMETER (X) AND ACTUAL YIELD (Y)"
  LOCATE 10, 2: PRINT "ACTUAL YIELD = Y = a.X^2 + b.X + c "
  LOCATE 12, 6: INPUT "Type which explanatory parameter (X) to be used", X$
  LOCATE 13, 6: INPUT "Type the value of regression coefficient 'a', COEFFA"
  LOCATE 14, 6: INPUT "Type the value of regression coefficient 'b', COEFFB"
  LOCATE 15, 6: INPUT "Type the value of regression coefficient 'c', COEFFC"
  LOCATE 16, 2: INPUT "Type the Standard Deviation", REGRSTDEV
  LOCATE 18, 2: PRINT "The actual yield estimate function = Y = (", COEFFA; " * " , X$, " * " , X$, "); (+ ", COEFFB; " * ", X$, "); (+ ", COEFFC
  LOCATE 20, 2: PRINT "PRESS ANY KEY TO CONTINUE"; WHILE INKEY$ = ""; WEND
END IF
RETURN

MENASCREEN:
RETURN

OUTPUTOPTION:
RETURN

INPUTSTARTFILE:
' SELECTS APPROPRIATE LUS INDICATOR
RETURN

FILEINPUTFILE:
OPEN INPUTFILE$ FOR INPUT AS #1
INPUT #1, RUNINPUTFILE$
INPUT #1, CROPFILE$, MANAFILE$, PS3MANAFILE$, FCASTDAYFILE$, REGRESSIONFILE$
INPUT #1, FAOSOILFILE$, FAOFRQFILE$, TEXTUREFILE$, REGIONFILE$
CLOSE #1
RETURN

LUSCOMPLETE:
CLS
NRYEARS = 1
IF SWITCH982$ <> "C" THEN GOTO FORECASTLUS

ACTUALLUS:
CLS
OPEN RUNINPUTFILE$ FOR INPUT AS #1
INPUT #1, MANA, PS3MANA, IRIE, ACTSOILFILE$, RUNOUTPUT$
INPUT #1, NRLUS, DUMMY$
IF LUSNR <> 1 THEN
    FOR X = 1 TO (LUSNR - 1)
        LINE INPUT #1, DUMMY$
    NEXT X
END IF
INPUT #1, LUSID, FAOID, FAO88$, SDB, ACTSOILID, POLYID, CROPID, ACTNGIFT, ACTPGIFT, YIELD,
HARVESTYEAR, SAMPLE, SHAR, STATION$
CLOSE #1
IF ACTSOILID <> 0 THEN
    SOILFILE$ = ACTSOILFILE$
    SOIL = ACTSOILID
ELSE
    SOILFILE$ = FAOSOILFILE$
    SOIL = FAOID
END IF

IF CROPID = 102 AND IRIE = 1 THEN CROP = 1
IF CROPID = 102 AND IRIE = 0 THEN CROP = 2
IF CROPID = 104 AND IRIE = 1 THEN CROP = 3
IF CROPID = 104 AND IRIE = 0 THEN CROP = 4
IF CROPID = 170 AND IRIE = 1 THEN CROP = 5
IF STATION$ = "Iran\weather\SOOB" OR STATION$ = "Iran\weather\soob" THEN STATION$ =
    "IRAN\WEATHER\EKBA"
RETURN

FORECASTLUS:
' SELECTS APPROPRIATE LU & LUS INDICATORS
CLS
OPEN RUNINPUTFILE$ FOR INPUT AS #1
INPUT #1, NRLUS, DUMMY$, SOILFILE$, STATION$, RUNOUTPUT$
IF LUSNR <> 1 THEN
    FOR X = 1 TO (LUSNR - 1)
        LINE INPUT #1, DUMMY$
    NEXT X
END IF
INPUT #1, LUSID, SHAR, MANA, PS3MANA, CROP, HARVESTYEAR, SOIL
CLOSE #1
IF STATION$ = "Iran\weather\SOOB" OR STATION$ = "Iran\weather\soob" THEN STATION$ = "IRANWEATHER\EKBA"
RETURN

REGIONFILE:
OPEN REGIONFILE$ FOR INPUT AS #1
INPUT #1, NRREGIONDIR
FOR X = 1 TO NRREGIONDIR
INPUT #1, REGIONNRDIR(X), PROVINCDIR$(X), SHARESTANDIR$(X)
NEXT X
CLOSE #1
SHARESTANS$ = SHARESTANDIR$(SHAR)
RETURN

'
-- SUBROUTINE TO SELECT APPROPRIATE WEATHER DATA --
'
WEATHERFILE:
CLS
IF SOWMOMENT$ = "B" THEN STARTYEAR = HARVESTYEAR - 1
IF SOWMOMENT$ = "A" THEN STARTYEAR = HARVESTYEAR

IF YEARNR = 1 THEN
    YEAR = STARTYEAR
ELSE YEAR = STARTYEAR - 1 + YEARNR
END IF
HARVESTYEARS$ = STR$(HARVESTYEAR)
LENGTH = LEN(HARVESTYEARS$)
HARVESTYEARS$ =_rights$(HARVESTYEARS$, LENGTH - 1)

YEARS$ = STR$(YEAR)
LENGTH = LEN(YEARS$)
YEARS$ =_rights$(YEARS$, LENGTH - 1)
WEATHERFILES$ = STATIONS$ + YEARS$ + ".DAT"
RETURN

NEWYEAR:
WEATHERDATA:
CLS
OPEN WEATHERFILES$ FOR INPUT AS #1
INPUT #1, SITELABEL$, LAT, LON, ELEVATION
FOR L = 1 TO 365
    INPUT #1, DUMMY1, TMAX(L), TMIN(L), PREC(L), RHA(L), E0(L), SUNH(L), ET0(L)
    IF RHA(L) = 0 THEN RHA(L) = .1
NEXT L
'DUMMY1 is the day number in the year (DAY)
CLOSE #1
RETURN

SELECTSOIL:
'

-- SUBROUTINE TO SELECT APPROPRIATE SOIL DATA --
'
CLS
IF PREFSOILID > 0 THEN
    SOILFILE$ = FAOSOILFILE$
    SOIL = PREFSOILID
END IF

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STARTSOILINPUT:
OPEN SOILFILES FOR INPUT AS #1
LINE INPUT #1, DUMMY$
INPUT #1, NRSoIIs, SOIlnRS
IF SOI <- 1 THEN
FOR X = 1 TO (SOIL - 1)
   LINE INPUT #1, DUMMY$
NEXT X
END IF
INPUT #1, SOIIID, ARFA, POLYID, FAO88S, PERMEAB, STONE, TEXTURID, DEPTH, SALIN, OSLOPE,
GWTER, IRRATING, SHNR, LB1, EC1, OC1, PHI
CLOSE #1

IF STONE < .5 THEN STONEVOL = 0 (0-1)
IF STONE >= .5 AND STONE < 1.5 THEN STONEVOL = .225
IF STONE >= 1.5 AND STONE < 2.5 THEN STONEVOL = .525
IF STONE >= 2.5 THEN STONEVOL = .875
STONEFF = 1 - STONEVOL

IF TEXTURID < 2.5 THEN TEXTURE = 2
IF TEXTURID >= 2.5 AND TEXTURID < 3.5 THEN TEXTURE = 3
IF TEXTURID > 3.5 AND TEXTURID < 4.5 THEN TEXTURE = 4
IF TEXTURID >= 4.5 AND TEXTURID < 5.5 THEN TEXTURE = 5
IF TEXTURID >= 5.5 THEN TEXTURE = 6

IF DEPTH < .5 THEN SOILDEPTH = 160 (cm)
IF DEPTH >= .5 AND DEPTH < 1.5 THEN SOILDEPTH = 100
IF DEPTH >= 1.5 AND DEPTH < 2.5 THEN SOILDEPTH = 65
IF DEPTH >= 2.5 AND DEPTH < 3.5 THEN SOILDEPTH = 32.5
IF DEPTH >= 3.5 THEN SOILDEPTH = 17.5

IF SALIN < .5 THEN SALINITY = 2 (mumho/cm)
IF SALIN >= .5 AND SALIN < 1.5 THEN SALINITY = 6
IF SALIN >= 1.5 AND SALIN < 2.5 THEN SALINITY = 12
IF SALIN >= 2.5 AND SALIN < 3.5 THEN SALINITY = 24
IF SALIN >= 3.5 THEN SALINITY = 48
ECGRW = SALINITY

IF OSLOPE >= 0 AND OSLOPE < .5 THEN SLOPE = 1 (3)
IF OSLOPE >= .5 AND OSLOPE < 1.5 THEN SLOPE = 3.5
IF OSLOPE >= 1.5 AND OSLOPE < 2.5 THEN SLOPE = 6.5
IF OSLOPE >= 2.5 AND OSLOPE < 3.5 THEN SLOPE = 10
IF OSLOPE >= 3.5 AND OSLOPE < 4.5 THEN SLOPE = 18.5
IF OSLOPE >= 4.5 AND OSLOPE < 5.5 THEN SLOPE = 32.5
IF OSLOPE >= 5.5 THEN SLOPE = 55
IF OSLOPE = 0 THEN SLOPE = 80

IF GWTER = 0 THEN GWATER = 1234
IF GWTER > 0 AND GWTER < 5 THEN GWATER = 500
IF GWTER >= 5 AND GWTER < 1.5 THEN GWATER = 200
IF GWTER >= 1.5 AND GWTER < 2.5 THEN GWATER = 120
IF GWTER >= 2.5 AND GWTER < 3.5 THEN GWATER = 90
IF GWTER >= 3.5 THEN GWATER = 60
ZTINT = GWATER

TOPSOIL = LB1
OC = OC1

IF LABFIELD = 2 THEN TEXTURE = TEXTURE - 1
IF TEXTURE = 0 THEN TEXTURE = 1
OPEN TEXTUREFILES FOR INPUT AS #1
IF TEXTURE <> 1 THEN
   FOR X = 1 TO (TEXTURE - 1)
      FOR L = 1 TO 5
         LINE INPUT #1, DUMMY$
      NEXT L
   NEXT X
END IF
INPUT #1, TEXTURELABEL$
INPUT #1, SM0, GAM
INPUT #1, PSIlmax, K0, ALFA, AK
INPUT #1, S0, KTR
LINE INPUT #1, DUMMY$
CLOSE #1
RETURN
'
SOILFREQCROP:
CLS
OPEN FAOFREQFILES FOR INPUT AS #1
INPUT #1, NRFRQSOILOSOILS, FRQITITL$
FOR X = 1 TO NRFRQSOILOSOILS
   INPUT #1, FAOFROIQDX(X), FAO88FRQ$(X), FAOFRQNAME$(X), TEXTURENAME$(X), IRRIAREA(X),
   RAINFEDAREA(X), PASTUREAREA(X), MIXEDAREA(X)
NEXT X
CLOSE #1
'
FOR X = 1 TO NRFRQSOILOSOILS
   IF FAO88S = FAO88FRQ$(X) THEN
      IF IRRIGATIONS = 0 THEN SOILFREQ = RAINFEDAREA(X)
      IF IRRIGATIONS = 1 THEN SOILFREQ = IRRIAREA(X)
      GOTO AFTERFREQ
   ELSE
      SOILFREQ = 0
   END IF
NEXT X
AFTERFREQ:
RETURN
'
CONDUCTIVITY:
RETURN
SELECTCROP:
'
—— SUBROUTINE TO COLLECT CROP DATA FROM CROP FILE ——

CLS
OPEN CROPFILES FOR INPUT AS #1
IF CROP <> 1 THEN
   FOR X = 1 TO (CROP - 1)
      FOR L = 1 TO 11
         LINE INPUT #1, DUMMY$
      NEXT L
   NEXT X
END IF
'
INPUT #1, CROPLABEL$
INPUT #1, C3C4S, T0, TSUM, TLEAF, TLOW, RDSROOT, RDM, RDINT, PSILEAF
INPUT #1, SLAMAX, SLAMIN, ke, TCM, RLEAF, RRT, RSTEM, RSO
INPUT #1, AERENCHYM, WTG, RESER, RDBSTR
INPUT #1, ECLEAF, ECROOT, ECSTEM, ECSO, NSO, NSTRAW, P5O, PSTRAW
INPUT #1, NRRTS

FOR Y = 1 TO NRPTS
    INPUT #1, CRDS(Y)
NEXT Y
FOR Y = 1 TO NRPTS
    INPUT #1, FRLAF(Y)
NEXT Y
FOR Y = 1 TO NRPTS
    INPUT #1, FRRoot(Y)
NEXT Y
FOR Y = 1 TO NRPTS
    INPUT #1, FRstem(Y)
NEXT Y
FOR Y = 1 TO NRPTS
    INPUT #1, FRSO(Y)
NEXT Y
CLOSE #1
RETURN

MANAGEMENTINPUT:
CLS
MANANR = MANA
OPEN MANAFIL$ FOR INPUT AS #1
LINE INPUT #1, DUMMYS
IF MANANR <> 1 THEN
    FOR X = 1 TO (MANANR - 1)
        LINE INPUT #1, DUMMYS
    NEXT X
END IF
INPUT #1, MANANR, CV$, SOWMOMENTS$, SOWDAY, SOWPERIOD, SEED, MORT, PSISTART, PSISOW, FURROW, SSINT, FDZT$, FALLUP, FALLOW, FALLW, ECE, ECEW, IRRIGATIONS, GROSSIE, TIMEIRR, IRMAX, IRREFF
CLOSE #1
ENDOFMANAGEMENTDATA:
GERDAY = SOWDAY
PSINT = PSISTART
RETURN

PS3MANAINPUT:
CLS
PS3MANANR = PS3MANA
OPEN PS3MANAFIL$ FOR INPUT AS #1
LINE INPUT #1, DUMMYS
IF PS3MANANR <> 1 THEN
    FOR X = 1 TO (PS3MANANR - 1)
        LINE INPUT #1, DUMMYS
    NEXT X
END IF
INPUT #1, PS3MANAIND, CONYLD, RFN, NDFERS, PDEFS, NITFERS, NITMODS, PHOSFERS, PHOSMODS, NDose, PDose
CLOSE #1
IF SWITCH982$ = "C" THEN
    NDose = ACTNGLF1
    PDose = ACTPG2F1
END IF
RETURN

FCASTDAYINPUT:
CLS
OPEN FCASTDAY$ FOR INPUT AS #1
LINE INPUT #1, DUMMY$
INPUT #1, FCASTDAY
CLOSE #1
RETURN

INITIALISE:

'----------------------------------------
' -- SUBROUTINE TO INITIALISE THE CALCULATIONS --
'----------------------------------------

CLS

' General constants and functions:
Pi = 3.14159; RAD = Pi / 180; Q10 = 2; Dt = 1; MolWt = 58.4
LATHEAT = 2.45 * 10^-6
BOLTZ = .0047

' Soil constants and functions:
SS = SSINT; ZT = ZTINT; PSI = PSIINT; RD = RDINT

' Crop constants and functions:
RELCROP = .27
EFF = .5
TLDINT = .67 * SEED * (1 - MORT) ' Assuming 0.33*(SEED*(1-MORT)) respired.
HEATCAP = 3 * 10^-6 For living plant matter 2 to 3 * 10^-6 J/m3.K

' Initial values:
RUNDAY = 1: DAY = GERDAY
SLEAF = FRLEAF(1) * TLDINT
SRROOT = FRROOT(1) * TLDINT
SSTEM = FRSTEM(1) * TLDINT
SSO = FRSO(1) * TLDINT
LIVSLEAF = SLEAF
RDS = 0; DRDS = 0; RDSLEAF = 0; LFRDS = 0; DRYLEAF = 0
RETURN

TEMPCALC:

'----------------------------------------
' -- SUBROUTINE TO CALCULATE THE TEMPERATURE --
'----------------------------------------

LOCATE 10, 7: PRINT "PROCESSING:"

LOCATE 12, 7: PRINT "runday "; RUNDAY
LOCATE 14, 7: PRINT "Sharestan "; SHARESTANS$; " with "; NRLUS; " LUSs"
LOCATE 15, 7: PRINT "Land Use System "; LUSID
LOCATE 17, 7: PRINT "Crop "; CROPLABELS
LOCATE 18, 7: PRINT "Soil "; FAO88$
LOCATE 20, 7: PRINT "Weather year "; STATIONS$; YEAR

' First, calculate the daylength:

DEC = -23.45 * COS(2 * Pi * (DAY + 10) / 365)
SSIN, CCOS, SSCC are auxiliary variables.
SSIN = SIN(LAT * RAD) * SIN(DEC * RAD)
CCOS = COS(LAT * RAD) * COS(DEC * RAD)
SSCC = SSIN / CCOS
DL = 12 * (Pi + 2 * FNASN(SSCC)) / Pi

' Then, calculate the incoming radiation:
RDN = (SSIN + 24 * CCOS * SQR(1 - SSCC * SSCC) / (PI * DL))
SC = 1353 * (1 + .033 * COS(2 * PI * DAY / 365)) 'The Solar Constant
EXTRA = SC * RDN * 3600 * DL 'Extraterrestrial (global) radiation, J/m2.d
a = .29 * COS(LAT * RAD)
B = .52
TRANS0 = a + B * SUNH(DAY) / DL 'radiation not lost in atmosphere
CANDRO = EXTRA * TRANS0 'Global radiation at canopy level, J/m2.d
PARFRAC0 = .5 'at elevation = 0 m.
PARCANO = CANDRO * PARFRAC0 / (3600 * DL)
PARCAN = PARCAN0 'parcan is constant with height
PARFRAC = PARFRAC0 - (ELEVATION / 1000) * .07 'parfrac decreases with elevation
CANRAD = CANDRO / PARFRAC 'canrad (PAR + UV) increases with elevation
TRANS = CANDRO / EXTRA 'trans is still high at high elevation

'To calculate PARCAN (at canopy level) from PAR, mission losses of
'radiation travelling through the atmosphere must be accounted for.

'Next, calculate UNCORRECTED daytime, nighttime and T24h temperatures:

'If TMAX occurs at 14.00 hrs and diurnal fluctuation is skewed:
'Maurits v.d. Berg (personal communication)

SUNRISE = 12 - DL / 2
SUNSET = SUNRISE + DL
TAV = (TMAX(DAY) + TMIN(DAY)) / 2
AMPL = (TMAX(DAY) - TMIN(DAY)) / 2
AUX = PI * (SUNSET - 14) / (SUNRISE + 10)
TDAY = TAV + (SUNSET - 14) * AMPL * SIN(AUX) / (DL + AUX)
Tnight = TAV - AMPL * SIN(AUX) / (PI - AUX)
T24h = (DL * TDAY + (24 - DL) * Tnight) / 24
TDAY(DAY) = TDAY

RETURN

TEMPDIFF:

'First, calculate longwave radiation losses:

SVAPEST = 6.11 * EXP(17.4 * TDAY(DAY) / (TDAY(DAY) + 239))
VPA = SVAPEST * RHA(DAY) 'ESTimated actual vapour pressure
LWLOSS = BOLTZ * (TDAY(DAY) + 273) ^ 4 * (.56 - SQR(VPA) * .079) * (.1 + .9 * SUNH(DAY) / DL)

'Then, calculate net intercepted radiation (INTER, in J/m2):

INTER = (CANDRO * (1 - REFLCROP) - LWLOSS) * Dt 'At full plant cover
IF RUNDAY = 1 THEN
   LAI = LIVSLEAF * SLAMAX * .0001
   CFWATER = 1
END IF
CFLEAF = 1 - EXP(-ke * LAI) 'Groundcover fraction of the actual canopy
INTER = INTER * CFLEAF

'Then APPROXIMATE the actual transpiration rate (TREST) to quantify
'TRLOSS, i.e. the energy needed for vapourisation of water lost in actual
' transpiration:

TR0 = ETO(DAY) - .05 * E0(DAY)  ' Potential transpiration rate, in cm/d
TC = 1 + (TCM - 1) * CFLEAF  ' Turbulence coefficient
TRM = TR0 * CFLEAF * TC  ' Maximum transpiration rate, in cm/d
IF TRM <= 0 THEN TRM = .01  ' To avoid division by zero for rainy days

TREST = TRM * CFWATER

TRLOSS = 10 * TREST * Dt * LATHEAT  ' in J/m2

' Finally, calculate the difference between air and canopy temperatures:

TEMPDIFF = (INTER - TRLOSS) / (HEATCAP * 1) "1" meter to satisfy dimensions

RETURN

MDINTERMRS:

' SUBROUTINE TO CALCULATE RDS AT MID_INTERVAL --

DRDS = (T24h - T0) * Dt / TSUM
IF DRDS < 0 THEN DRDS = 0
RDS = RDS + .5 * DRDS

RETURN

AMAX:

' SUBROUTINE TO CALCULATE AMAX --

' Calculate reference temperature

SUMWEEG = 0; TACC = 0
REFPERIOD = RUNDAY
IF REFPERIOD > 10 THEN REFPERIOD = 10
FOR X = 1 TO REFPERIOD
  SUMWEEG = SUMWEEG + X / REFPERIOD
  HULP = DAY - REFPERIOD + X
  IF HULP < 1 THEN HULP = HULP + 365
  TACC = TACC + TDAY(HULP) * X / REFPERIOD
NEXT X
TREF = TACC / SUMWEEG

IF RUNDAY = 1 THEN TREF = TDAY(GERDAY)
IF TREF < 40 THEN TREF = 40  ' CHECK THESE BOUNDARY VALUES !!
IF TREF > 30 THEN TREF = 30

' With the calculated TDAY and TREF values, AMAX can be approximated.

IF C3C4$ = "C3" OR C3C4$ = "c3" THEN
  AMAXO = 1.8 * TREF - .15 * (TREF - TDAY) ^ 2
ELSEIF TDAY <= TREF THEN
  AMAXO = 110 - 10 * (TREF - TDAY)
ELSE
  AMAXO = 110 - 2 * (TDAY - TREF)
END IF
AMAX = AMAXO * EXP(-0.034 * ELEVATION) / (T24h + 273))

'AMAX = AMAXO
IF C3C4S = C3S AND AMAX > 70 THEN AMAX = 70
IF AMAX <= 1 THEN AMAX = 1

RETURN

GAAORG:

'-- SUBROUTINE TO CALCULATE THE GROSS ASSIMILATE AVAILABILITY --
'-- FOR GROWTH OF EACH PLANT ORGAN (LEAF, ROOT, STEM, S.O.) --

'The total gross assimilation rate (Fgass):'

FGASS = Fgc * (30 / 44) * CFWATER

'Calculation of fr(org); interpolate between inflection points'

AA = 0; BB = 0; CC = 0 'Indicator that RDS >= 1'
FOR PTS = 1 TO NRPTS
    IF RDS >= CRDS(PTS) AND RDS < CRDS(PTS + 1) THEN AA = PTS; BB = PTS + 1
    IF RDS = = 1 THEN CC = 1
NEXT PTS

IF CC = 1 THEN
    INTFRLEAF = FRLEAF(NRPTS)
    INTFRROOT = FRROOT(NRPTS)
    INTFRSTEM = FRSTEM(NRPTS)
    INTFRSO = FRSO(NRPTS)
ELSE
    INTFRLEAF = FRLEAF(AA) + (RDS - CRDS(AA)) * (FRLEAF(BB) - FRLEAF(AA)) / (CRDS(BB) - CRDS(AA))
    INTFRROOT = FRROOT(AA) + (RDS - CRDS(AA)) * (FRROOT(BB) - FRROOT(AA)) / (CRDS(BB) - CRDS(AA))
    INTFRSTEM = FRSTEM(AA) + (RDS - CRDS(AA)) * (FRSTEM(BB) - FRSTEM(AA)) / (CRDS(BB) - CRDS(AA))
    INTFRSO = FRSO(AA) + (RDS - CRDS(AA)) * (FRSO(BB) - FRSO(AA)) / (CRDS(BB) - CRDS(AA))
END IF

IF SEXTENSION > 0 THEN
    IF ANTHESIS = 0 THEN
        GOTO ANTH
    ELSEIF GRAINFILL = 0 THEN GOTO GRNFILL
    ELSE GOTO GAA
    END IF
ELSE
    IF INTFRSTEM > INTFRLEAF THEN SEXTENSION = DAY
END IF

ANTH:
IF ANTHESIS = 0 THEN GOTO GAA
IF INTRFSO = 0 THEN ANTHESIS = DAY
GRNFILL:
IF GRAINFILL = 0 THEN GOTO GAA
IF INTFRSO = 1 THEN GRAINFILL = DAY

'Gross Availability of Assimilates per organ GAA(org)

GAA:
GAALEAF = FGASS * INTFRLEAF

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GAAROOT = FGASS * INTRFRROOT
GAASTEM = FGASS * INTERSTEM
GAASSO = FGASS * INFRSO

RETURN

REFMAINT:

'-- SUBROUTINE TO CALCULATE THE MAINTENANCE RESPIRATION LOSSES --'
'-- INCURRED IN EACH ORGAN UNDER REFERENCE CONDITIONS --'

MREFLEAF = RLEAF * LIVSLEAF
MREFROOT = RRT * SROOT
MREFSTEM = RSTEM * SSTEM
MREFSO = RSO * SSO

RETURN

TEMCORRECT:

'-- SUBROUTINE TO CALCULATE cf(temp) --'

TACCRESP = 0

'Determine the value of TACCRESP by adding for each day in the
'REFFEPIOD the fraction of (canopy) T24h which is considered in the
'calculation of TREFMAIN (the reference temperature for MRRREF).

FOR X = 1 TO REFFEPIOD
    HULP = DAY - REFFEPIOD + X
    IF HULP < 1 THEN HULP = HULP + 365
    TACCRESP = TACCRESP + T24h(HULP) * X / REFFEPIOD
NEXT X

'Recall that SUMWEEG and REFFEPIOD were calculated before.

TREFmain = TACCRESP / SUMWEEG
IF RUNDAY = 1 THEN TREFmain = T24h(GERDAY)

CFTEMP = Q10 ^ ((T24h - TREFmain) / 10)
'PRINT CTEMP
'WHILE INKEY$ = "": WEND

RETURN

ACTMAINT:

'-- SUBROUTINE TO CALCULATE MRRORG --'

'MRRORG depends on CFTEMP as maintenance (respiration) requirements
'are co-determined by assimilatory processes which are temperature
'dependent.

MRRLEAF = MREFLEAF * CFTEMP * cfwater
MRRROOT = MREFROOT * CFTEMP * cfwater
MRRSTEM = MREFSTEM * CFTEMP * cfwater
MRRSO = MREFSO * CFTEMP * cfwater
RETURN

NETASSORG:

\- SUBROUTINE TO CALCULATE NAA\(\text{org}\) --

\- in the generative stage of crop development, maintenance requirements of the
\- generative organs are met first, followed by net generative assimilation.
\- The eventual rest is used for vegetative maintenance. When maintenance
\- requirements are higher than assimilation, then negative assimilation of the
\- vegetative parts is simulated.

IF INFRSO > .5 THEN

MRRT = MRRLEAF + MRRROOT + MRRSTEM + MRRSO
MRRVEG = MRRLEAF + MRRROOT + MRRSTEM
NAAT = FGASS - MRRT

NAASO = GAASO - MRRSO
NAATVEG = NAAT - NAASO - MRRSO
NAALEAF = NAATVEG * MRRLEAF / MRRVEG
NAAROOT = NAATVEG * MRRROOT / MRRVEG
NAASTEM = NAATVEG * MRRSTEM / MRRVEG

ELSE

NAALEAF = GAALEAF - MRRLEAF
NAAROOT = GAAROOT - MRRROOT
NAASTEM = GAASTEM - MRRSTEM
NAASO = GAASO - MRRSO

\- an assimilate reserve pool can be defined as a fraction of the weight of living
\- leaves and stems.

RESVEG = RESFR * (LIVSLEAF + SSTEM)
RESVEG(RUNDAY) = RESVEG

END IF
RETURN

DRYWRTINCREMEN:

\- SUBROUTINE TO CALCULATE DWI\(\text{org}\) --

\- DWILEAF = NAALEAF * ECLEAF * Dt
DWIROOT = NAAROOT * ECROOT * Dt
DWISTEM = NAASTEM * ECSTEM * Dt
DWISO = NAASO * ECSO * Dt

RETURN

GROSSSOR:

\- SUBROUTINE TO CALCULATE S-ORG AND CORRECT FOR DEAD LEAVES --

\- SLEAF = SLEAF + DWILEAF
SSROOT = SSROOT + DWIROOT
SSSTEM = SSSTEM + DWISTEM
SSO = SSO + DWISO
SLEAF(RUNDAY) = SLEAF
SROOT(RUNDAY) = SROOT
SSTEM(RUNDAY) = SSTEM
SSO(RUNDAY) = SSO

RETURN

ENDRDS:

'-- SUBROUTINE TO CALCULATE RDS AT INTERVAL END --

RDS = RDS + .5 * DRDS
RDS(RUNDAY) = RDS

RETURN

DEADLEAVES:

'-- SUBROUTINE TO CALCULATE THE DEAD LEAF MASS --

'Increased dying of leaves under drought stress is accounted for
automatically because canopy temperature goes up and leaves live shorter.
The relative leaf development stage (LFRDS) is adjusted first:

LFRDS = LFRDS + DRDS
LFRDS(RUNDAY) = LFRDS

'Determine whether there are any dead leaves. If there are no dead leaves,
'livS(leaf) = S(leaf) and the correction procedure is aborted.

IF LFRDS <= (MLEAF / TSUM) THEN
   LIVSLEAF = SLEAF
ELSE
   DIELEAFRDS = LFRDS - (MLEAF / TSUM)
   FOR X = 1 TO RUNDAY
      IF LFRDS(X) >= DIELEAFRDS AND LFRDS(X - DT) < DIELEAFRDS THEN
         LIVSLEAF = SLEAF(RUNDAY) - SLEAF(X)
      END IF
   NEXT X
ENDIF

MAXRLFDRATE = .03 (1/DT)
RLFDRATE = MAXRLFDRATE * (LAI - 4) / 4
IF RLFDRATE <= 0 THEN RLFDRATE = 0
IF RLFDRATE >= MAXRLFDRATE THEN RLFDRATE = MAXRLFDRATE

LIVSLEAF = LIVSLEAF - (LIVSLEAF * RLFDRATE)

IF LIVSLEAF < 0 THEN LIVSLEAF = 0
LIVSLEAF(RUNDAY) = LIVSLEAF

RETURN

TDMTLDM:

'-- SUBROUTINE TO CALCULATE TDM AND TLDM --

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TDM = SLEAF + SROOT + SSTEM + SSO
TLDM = LIVSLEAF + SROOT + SSTEM + SSO
TDM(RUNDAY) = TDM
RETURN
'
FORECAST:
IF DAY = FCASTDAY THEN
FCSSO = SSO
FCTDM = TDM
FCLAI = LAI
END IF
RETURN
'
OUTPUTONSCREEN:
'
-- SUBROUTINE TO PRINT CALCULATION RESULTS ON THE SCREEN --
'
CLS
Z = RUNDAY  'To remember the last value of DAY
'
PRINT
PRINT "", SHARESTANS; " PRODUCTION SITUATION "; PSSELECTS; ";
PRINT "; CROPLABELS; " is harvested at "; SITELABELS; " and germinated in 19"; SOWYEAR
IF PSSELECTS <> "1" THEN
    PRINT " Soil is "; FAO88S; " ("; TEXTURELABELS; ") with an initial humidity (PSI) of "; PSIINT; " cm)."
    PRINT " Irrigation implied "; IRRES; " gifts, with a NET total input of "; IRRESUM; " cm water."
    PRINT " Initial salinity (ECe) was "; ECe; " mS/cm."
END IF
PRINT ""
PRINT "DAY RDS LAI ECast SLEAF SROOT SSTEM SSO RDTAP CFWATER"
FOR X = 1 TO 79: PRINT ";": NEXT
PRINT
IF Z > 180 THEN
    W = 30
ELSE
    W = 14
END IF
'
L = GERDAY
LASTDAY = GERDAY + Z
WHILE L < LASTDAY
    CROPDAY = L  ' Running Julian day nr at any moment in crop cycle
    RUNDAY = L - GERDAY + 1

    WW = W  ' WW = length of reported interval in d
    IF RUNDAY = 1 THEN WW = 1
    IF (Z - RUNDAY) < W THEN WW = Z - RUNDAY

    IF WW <> 0 THEN
        IF CROPDAY > 365 THEN CROPDAY = CROPDAY - 365
        FOR TELLER = RUNDAY TO (RUNDAY + WW - 1)
            SUMCFWATER = SUMCFWATER + CFWATER(TELLER)
        NEXT TELLER
        PRINT USING "####"; CROPDAY;
        PRINT USING "####.##", RDS(RUNDAY); LAI(RUNDAY); ECET(RUNDAY);
        PRINT USING "####.##", SLEAF(RUNDAY); SROOT(RUNDAY); SSTEM(RUNDAY);
        SSO(RUNDAY); RDTAP(RUNDAY);
        PRINT USING "####.##", SUMCFWATER / WW
        L = L + WW
    END IF
END WHILE
SUMCFWATER = 0
END IF
L = L + W
WEND

IF LASTDAY > 365 THEN LASTDAY = LASTDAY - 365
PRINT USING "###"; LASTDAY;
PRINT USING "###.###"; RDS(Z); LAI(Z); ECET(Z);
PRINT USING "####.####"; SLEAF(Z); SROOT(Z); SSTEM(Z); SSO(Z); RDTAP(Z);
PRINT USING "####.####"; CFWATER(Z)
FOR X = 1 TO 79: PRINT ";"; : NEXT
IF VAL(PSESELECTS) = 3 THEN
PRINT "WITH GIFTS (KG/HA) OF "; NDose; NFERTILIZER$; " AND "; PDose; PFERTILIZER$
PRINT "THE YIELD AT PS3 IS "; SS03; " AND THE TOTAL DRY MATTER IS "; TD3
PRINT "" END IF
PRINT "THE RESULTS ARE WRITTEN TO FILE. PRESS ANY KEY TO CONTINUE"; WHILE INKEY$ = "":
END IF
CLS
RETURN

OUTPUTINFILE:

\ ' \_ SUBROUTINE TO PRINT CALCULATION RESULTS IN FILE \_'

CLS
LUSIND$ = STR$(LUSID)
LENGTH = LEN(LUSIND$)
LUSIND$ = RIGHT$(LUSIND$, LENGTH - 1)
OUTPUTFILE$ = RUNOUTPUT$ + LUSIND$ + "." + HARVESTYEAR$ 
RUNOUTPUTFILE$ = RUNOUTPUT$ + LUSIND$
Z = RUNDAY - 1
IF OUTOPTIONS = "B" OR OUTOPTIONS = "b" THEN GOTO RESUMEDOUTPUT

SKIPPRT:
OPEN OUTPUTFILE$ FOR OUTPUT AS #1
PRINT
PRINT #1, " PRODUCTION SITUATION "; PSSELECTS; ";
PRINT #1, " CROPLABEL$; " is grown at "; SITELABELS;
PRINT #1, " from DAY; GERDAY; "in year"; SOWYEAR; " onwards."
IF PSELECTS <= "1" THEN
PRINT #1, " The plot is on "; TEXTURELABELS; " (PSLimit ="; PSINT; " cm)"
PRINT #1, " and is; IRRS; "times irrigated";
PRINT #1, " with a NET total irrigation input of"; IRRSUM; " cm water. Initial ECe is "; ECE; " mS/cm."
IF FALLW > 0 THEN
PRINT #1, " Amount of residual fallow water in soil profile was "; FALLW; " cm."
END IF
END IF
FOR X = 1 TO 78: PRINT #1, ";"; : NEXT
PRINT: PRINT #1,

IF (TMIN(DAY) < 0 AND TLOW > TMIN(DAY)) OR TCOUNT > 10 THEN
PRINT #1, "THIS SCENARIO IS NOT VIABLE DUE TO TOO LOW TEMPERATURES"
GOTO DAILYOUTPUT
END IF
IF RUNDAY > 365 THEN
PRINT #1, "CROP > 365 DAYS ON THE FIELD. CALCULATIONS TERMINATED."
GOTO DAILYOUTPUT
END IF
IF DROUGHTLIMT >= INT(PSLEAF / 1000 + .5) AND SEED <= 0 THEN
  PRINT #1, "CROP DIED DUE TO LETHAL DROUGHTNESS"
  GOTO DAILYOUTPUT
END IF
IF AERENCHYM <= 1 AND WETLIMIT >= 20 THEN
  PRINT #1, "CROP DIED DUE TO PROLONGED WETNESS"
  GOTO DAILYOUTPUT
END IF
IF ZT <= RD AND SEED <= 0 AND AERENCHYM <= 1 AND VAL(PSSELECTS) <= 1 THEN
  PRINT #1, "PHREATIC LEVEL RISED WITHIN EQUIVALENT ROOTING DEPTH"
  PRINT #1, "CROP DROWNED AND DIED."
  GOTO DAILYOUTPUT
END IF
PRINT #1,
FOR X = 1 TO 78: PRINT #1, ";"; : NEXT

DAILYOUTPUT:
PRINT #1,
PRINT #1, "DAY RDS LAI ECET SLEAF SROOT SSTEM SSO RDTAP CFWATER"
FOR X = 1 TO 78: PRINT #1, ";"; : NEXT

PRINT #1,
  W = 1
L = GERDAY
LASTDAY = GERDAY + Z
WHILE L < LASTDAY
  CROPDAY = L 'Running Julian day nr at any moment in crop cycle
  RUNDAY = L - GERDAY + 1
  WW = W ' WW = length of reported interval in d
  IF RUNDAY = 1 THEN WW = 1
  IF (Z - RUNDAY) < W THEN WW = Z - RUNDAY
  IF WW <= 0 THEN
    IF CROPDAY > 365 THEN CROPDAY = CROPDAY - 365
    FOR TELLER = RUNDAY TO (RUNDAY + WW - 1)
      SUMCFWATER = SUMCFWATER + CFWATER(TELLER)
    NEXT TELLER
    PRINT #1, USING "#####"; CROPDAY;
    PRINT #1, USING "##.##"; RDS(RUNDAY); LAI(RUNDAY); ECET(RUNDAY);
    PRINT #1, USING "##.##"; SLEAF(RUNDAY); SROOT(RUNDAY); SSTEM(RUNDAY);
    SSO(RUNDAY); RDTAP(RUNDAY);
    PRINT #1, USING "#####.##"; SUMCFWATER / WW
    SUMCFWATER = 0
  END IF
  L = L + W
END WEND
IF LASTDAY > 365 THEN LASTDAY = LASTDAY - 365
PRINT #1, USING "#####"; LASTDAY;
PRINT #1, USING "##.##"; RDS(Z); LAI(Z); ECET(Z);
PRINT #1, USING "##.##"; SLEAF(Z); SROOT(Z); SSTEM(Z); SSO(Z); RDTAP(Z);
PRINT #1, USING "#####.##"; CFWATER(Z)
CLOSE #1
******************************************************************************
RESUMEDOUTPUT:
' PRINT ALL LASTDAY RESULTS OF A RUN IN ONE FILE
CLS
IF YEARNR > 1 THEN
  OPEN RUNOUTPUTFILE$ FOR INPUT AS #1

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LINE INPUT #1, PREVIOUSDUMMY$
FOR Q = 1 TO YEARNR - 1
LINE INPUT #1, PREVIOUS$(Q)
NEXT Q
END IF
CLOSE #1

OPEN RUNOUTPUTFILE$ FOR OUTPUT AS #1

IF YEARNR > 1 THEN
    PRINT #1, PREVIOUSDUMMY$
    FOR Q = 1 TO YEARNR - 1
    PRINT #1, PREVIOUS$(Q)
    NEXT Q
    PRINT #1, LUSID; " "; HARVESTYEAR$; " "; FAO88$;
    PRINT #1, USING "######"; SOILFREQ; GERDAY; ANTHESIS; LASTDAY; IRRSUM;
    PRINT #1, USING "######"; FCSSO3; FCTDM3; SS03; TDM3;
    PRINT #1, USING "###."; LAITOP;
    PRINT #1, USING "######"; FCSSO; FCTDM; SS0(Z); TDM(Z); YIELD; FCYLD;
    PRINT #1, " "; STATIONS$; POLYID
ELSE
    PRINT #1, "LUSID HRVSTYR FAO88 SFRQ GER ANTH LAST IRR FCSSO3 FCDM3 SS03 TDM3 LAI FCSSO FCTDM SS0 TDM YIELD SAMPLE"
    PRINT #1, LUSID; " "; HARVESTYEAR$; " "; FAO88$;
    PRINT #1, USING "######"; SOILFREQ; GERDAY; ANTHESIS; LASTDAY; IRRSUM;
    PRINT #1, USING "######"; FCSSO3; FCTDM3; SS03; TDM3;
    PRINT #1, USING "###."; LAITOP;
    PRINT #1, USING "######"; FCSSO; FCTDM; SS0(Z); TDM(Z); YIELD; FCYLD;
    PRINT #1, " "; STATIONS$; POLYID
END IF
CLOSE #1
RETURN


IRRIGATIONINPUT:

' --- TIMING OF IRRIGATION IS MADE FUNCTION OF DAILY CIRCUMSTANCES

CLS
IF IRRIGATIONS = 0 OR VAL(PSSELECT$) = 1 THEN RETURN
IF CALIBR$ = "N" OR CALIBR$ = "n" THEN GOTO IRRICALIBRN
GOTO IRRITIMING

' navid CALIBRATION EXPERIMENT SETTINGS

IRRICALIBRN:
IF YEAR = 93 THEN
    IF DAY = 109 THEN GOTO IRRIDOO
    IF DAY = 144 THEN GOTO IRRIDO
    IF DAY = 159 THEN GOTO IRRIDO
END IF
IF YEAR = 94 THEN
    IF DAY = 104 THEN GOTO IRRIDO
    IF DAY = 144 THEN GOTO IRRIDO
    IF DAY = 158 THEN GOTO IRRIDO
    IF DAY = 175 THEN GOTO IRRIDO
END IF
IF YEAR = 95 THEN
    IF DAY = 99 THEN GOTO IRRIDO

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IF DAY = 169 THEN GOTO IRRIDO
END IF
RETURN

IRRITIMING:
PSIFIELDCAP = 333
SMP$PSIFIELDCAP = SM0 * STONEFF * PSILEAF ^ (-GAM * LOG(PSIFIELDCAP))
SMP$PSILEAF = SM0 * STONEFF * PSILEAF ^ (-GAM * LOG(PSILEAF))
SMP$PSIRANGE = SMP$PSIFIELDCAP - SMP$PSILEAF
AVALIDWATERRATIO = (SMPSI - SMP$PSILEAF) / SMP$PSIRANGE

IF CROPLABEL$ = "POTATO" THEN GOTO IRRIPOTATO
IF DAY = (SEXTENSION + 1) AND SEXTENSION > 0 THEN GOTO IRRIDO
IF DAY = (ANTHESS + 1) AND ANTHESS > 0 THEN GOTO IRRIDO
IF DAY > (SEXTENSION + 1) AND SEXTENSION > 0 AND ANTHESS = 0 AND AVAILWATERRATIO < TIMEIRR AND IRRIS < (IRMAX - 1) THEN GOTO IRRIDO
IF DAY > (ANTHESS +1) AND ANTHESS > 0 AND AVAILWATERRATIO < TIMEIRR AND IRRIS < IRRMAX THEN GOTO IRRIDO
RETURN

IRRIPOTATO:
IF AVAILWATERRATIO < IRREFF AND IRRIS < IRRMAX THEN GOTO IRRIDO
RETURN

IRRIDO:
IF LAI <= 0 THEN RETURN
IE(EDAY) = RUNDAY
NETIRR = GROSSIE * IRREFF
ECEW(IE(EDAY)) = ECEW
IRRSUM = IRRSUM + IE(EDAY)
IRRIS = IRRIS + 1
RETURN

WATERBALANCE:
REM $INCLUDE: 'WATER2.BA'
AFTERWATERBALANCE:
RETURN

******************************************************************************
PS$START:
CLS
******************************************************************************

DEFINITIONS:
RECFP:
IF SOILNR$ = "1" THEN RFP = .3: SOILMAT$ = " Quartzitic sand"
IF SOILNR$ = "2" THEN RFP = .25: SOILMAT$ = " Peat or muck"
IF SOILNR$ = "3" THEN RFP = .2: SOILMAT$ = " Coarse recent alluvium"
IF SOILNR$ = "4" THEN RFP = .15: SOILMAT$ = " Neutral alluvial clay"
IF SOILNR$ = "5" THEN RFP = .13: SOILMAT$ = " Near-neutral hemic"
IF SOILNR$ = "6" THEN RFP = .12: SOILMAT$ = " Near-neutral structured clay"
IF SOILNR$ = "7" THEN RFP = .11: SOILMAT$ = " Vertic clay"
IF SOILNR$ = "8" THEN RFP = .1: SOILMAT$ = " Calcareous material"
IF SOILNR$ = "9" THEN RFP = .075: SOILMAT$ = " Red/yellow trop. weathering"
IF SOILNR$ = "10" THEN RFP = .06: SOILMAT$ = " Acid podsolized"
IF SOILNR$ = "11" THEN RFP = .04: SOILMAT$ = " Acid sulphate"
IF SOILNR$ = "12" THEN RFP = .02: SOILMAT$ = " Allophane-rich volcanic"
NRECC:

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IF NITMOD$ = "1" THEN NRECCO = .9: NAPPLICATIONS$ = "single broadcast"
IF NITMOD$ = "2" THEN NRECCO = 1: NAPPLICATIONS$ = "split broadcast"
IF NITMOD$ = "3" THEN NRECCO = 1.1: NAPPLICATIONS$ = "banded"
IF NITMOD$ = "4" THEN NRECCO = 1.2: NAPPLICATIONS$ = "placed"

PRECC:
IF PHOSMOD$ = "1" THEN PRECCO = .9: PAPPLICATIONS$ = "single broadcast"
IF PHOSMOD$ = "2" THEN PRECCO = 1: PAPPLICATIONS$ = "split broadcast"
IF PHOSMOD$ = "3" THEN PRECCO = 1.3: PAPPLICATIONS$ = "banded"
IF PHOSMOD$ = "4" THEN PRECCO = 1.5: PAPPLICATIONS$ = "placed"

FERTCONC:
' This opportunity is also taken to store the name of the
' selected fertilizers in a string variable.
IF NITFERS$ = "1" THEN NCONT = .21: NFERTILIZER$ = "ammonium sulphate"
IF NITFERS$ = "2" THEN NCONT = .155: NFERTILIZER$ = "calcium nitrate"
IF NITFERS$ = "3" THEN NCONT = .16: NFERTILIZER$ = "Chile sulphate"
IF NITFERS$ = "4" THEN NCONT = .24: NFERTILIZER$ = "muriate of ammonium"
IF NITFERS$ = "5" THEN NCONT = .13: NFERTILIZER$ = "potassium nitrate"
IF NITFERS$ = "6" THEN NCONT = .46: NFERTILIZER$ = "urea"
IF PHOSFERS$ = "1" THEN PCONT = .21: PFERTILIZER$ = "monoammonium phosphate"
IF PHOSFERS$ = "2" THEN PCONT = .17: PFERTILIZER$ = "diammonium phosphate"
IF PHOSFERS$ = "3" THEN PCONT = .19: PFERTILIZER$ = "triple superphosphate"
IF PHOSFERS$ = "4" THEN PCONT = .07: PFERTILIZER$ = "rock phosphate"
IF PHOSFERS$ = "5" THEN PCONT = .21: PFERTILIZER$ = "di-ammonium phosphate"
RETURN

' ***********************************************
' ———— CALCULATION OF NUTRIENT LIMITED PRODUCTION POTENTIAL (PS-3) ————
' SOIL:
CLS
HA = 100000
CN = 10
KRAT_E = 2.1
BD = 1.6

SOIL VOL = TOPSOIL * HA / 100 ' (m3)
SOILKG = SOIL VOL * BD * 1000 ' (kg)
CKG = SOILKG * OC / 100 ' (kg)
CMINPOT = CKG * KRAT_E / 100 ' (kg)
NMNPOT = CMINPOT / CN ' (kg)
BUNTAKE = NMNPOT * RFN ' (assumed is that rf from of mineralized N is adsorbed)

CP = 80 ' C/P (organic P)
PMINPOT = CMINPOT / CP ' (kg)
BUPSOIL = PMINPOT * RFPP
PKG = SOILKG * P / 1000000 ' (kg)
PKF = KG * (1 - RFPP)
BUPTAKE = PKG * PKF
BUPTAKE = BUPSOIL

TARSTRAW = TARTDM - TARSO
IF TARSO = 0 THEN TARSO = 1
IF TARTDM = 0 THEN TARTDM = 2

TARSSON = NSO * TARSO ' target SSO N uptake
TARSTRAWN = NSTRAW * TARSTRAW  
TARTDNMN = TARSSON + TARSTRAWN  
TARHIN = TARSSON + TARTDMN  
TARHI = TARSO / TARTDM  
CFN = BUNTAKE / TARTDMN  
'BUNTAKE = CFN * TARTDMN  
BSSON = BUNTAKE * TARHIN  
BTDMNYLD = CFN * TARTDM  
BSSONYLD = BTDMNYLD * TARHI  
'Target straw N uptake  
'Target N uptake  
'Target N harvest index  
'Target harvest index  
'N sufficiency coefficient  
'Base N UPTAKE (BUNTAKE)  
Base SSO yield as determined by N  
TARSSOP = PSO * TARSO  
TARSTRWP = PSTRAW * TARSTRAW  
TARTDMP = TARSSOP + TARSTRWP  
TARHIP = TARSSOP / TARTDMP  
TARHI = TARSO / TARTDMP  
CFP = BUNTAKE / TARTDMP  
'BUNTAKE = CFP * TARTDMP  
BSSOP = BUNTAKE * TARHIP  
BTDMPYLD = CFP * TARTDMP  
BSSOPYLD = BTDMPYLD * TARHI  
'To be verified and/or corrected  
IF BTDMNYLD < BTDMPYLD THEN  
  BTDM = BTDMNYLD  
  BUNTAKE = BUNTAKE * .16  
ELSE  
  BTDM = BTDMPYLD  
  BUNTAKE = BUNTAKE / .04  
END IF  
BSSO = BTDM * TARHI  
BSTRAW = BTDM - BSSO  
IF BSSO > CONYLD THEN BSSO = CONYLD  
BUNTAKE = BUNTAKE * (BSSO / CONYLD)  
BUNTAKE = BUNTAKE * (BSSO / CONYLD)  
BTDM = BSSO / TARHI  
BSTRAW = BTDM - BSSO  
IF BSSO > TARSO THEN BSSO = TARSO  
IF BTDM > TARTD THEN BTDM = TARTD  
IF BSSO = 0 THEN BSSO = .001  
IF BTDM = 0 THEN BTDM = .001  
'RFP & RFN = P & N recovery fractions  
'FRP & FRN = P & N fertilizer requirements  
IF PHOSFERS$ = "4" THEN RFP = .04  
RFP = (TARTDMP - BUNTAKE) / (PCONT * RFP * PRECCO)  
IF PHOSFERS$ = "1" THEN BUNTAKE = BUNTAKE + FRP * .11 * .5 * PRECCO  
IF PHOSFERS$ = "5" THEN BUNTAKE = BUNTAKE + FRP * .16 * .5 * PRECCO  
'RETURN  
PS3YLD:  
'--------- NUTRIENT LIMITED PRODUCTION POTENTIAL ---------  
CLS  
NGAP = TARTDMN - BUNTAKE  
IF NGAP <= 0 THEN  
  'CFN = 1  
  TDM3N = TARTDMM
`CFN = NDOSE / FRN
TDMGAP = TARTDMD - BTDM
CFNFERT = NDOSE * NCONT * RFN * NRECCO / NGAP
TDM3N = BTDM + (CFNFERT * TDMGAP)
END IF
PGAP = TARTDMP - BUPTAKE
IF PGAP <= 0 THEN
  'CFP = 1
  TDM3P = TARTDMD
ELSE
  'CFP = PDOSA / FRP
  TDMGAP = TARTDMD - BTDM
  CFNFERT = PDOSA * PCONT * RFN * PRECCO / PGAP
  TDM3P = BTDM + (CFNFERT * TDMGAP)
END IF

'NGIFT = NDOSA * NCONT * RFN * NRECCO
'NFUPTAKE = BUPTAKE + NGIFT
'NFSOA = NFUPTAKE / NSO
IF NFSOA >= TARSO THEN NFSOA = TARSO
'NFSSOA3UPTAKE = NFSOA3 * NSO
'NFSRAW3UPTAKE = NFUPTAKE - NFSOA3UPTAKE
'NFTDM3 = NFSOA3 + (NFSSRAW3UPTAKE * NFSRAW)

'PGI = PDOSA * PCONT * RFN * PRECCO
'FUPTAKE = BUPTAKE + PGI
'PFSA = PFUPTAKE / PSO
IF PFSA >= TARSO THEN PFSA = TARSO
'PFSSOA3UPTAKE = PFSA * PSO
'PFSSRAW3UPTAKE = FUPTAKE - PFSSOA3UPTAKE
'PFDM3 = PFSA + (PFSSRAW3UPTAKE * PSTRAW)

IF NFSOA <= PFSSOA THEN
  SO3 = NFSOA
  DM3 = NFTDM3
ELSE
  SO3 = PFSSOA
  DM3 = PFDM3
END IF

IF TDM3N <= TDM3P THEN
  DM3 = TDM3N
ELSE
  DM3 = TDM3P
END IF
SO3 = DM3 * TARN
IF SO3 > TARSO THEN SO3 = TARSO
IF DM3 > TARTDMD THEN DM3 = TARTDMD
RETURN
GOTO AFTERFERTILIZATION
Annex 2.2  The source code of the module WATER2.BA

```
--- WATER BALANCE ROUTINE ---

-- Water flow through the upper soil boundary, UPFLUX --

-- Uptake of water from root zone is conditioned by total stress (PSItot)
  (composed of matric potential (PSI) AND osmotic pressure (OP)) that a plant
  must compensated before it can take up water. To find the relation between
  OP and ECET, the relation between OP and shift in freezing point (DELFPRNT)
  as given by Thorne & Peterson (1954) is combined with ECE-DELFPRNT relations
  from the handbook of Chemistry and Physics (Weast, 1975).

IF RUNDAY = 1 THEN ECE(RUNDAY) = ECE
TF RUNDAY = 1 THEN PSI = PSIINT
ECET = ECE / PSI ^ (-GAM * LOG(PSI))

OP = -15.99 + 424.6 * ECET + 1.229 * ECET ^ 2
PSItot = PSI + OP
ECET(RUNDAY) = ECET

END IF

-- The reference evaporative demand in the absence of a crop (Ebare) and
-- in the presence of a crop (EM)

RHS = EXP(-2.1649 * 10 ^ -4 * PSItot / (273 + T24h)) ' relation (9.5.1)
IF RHA(DAY) = 1 THEN
  Ebare = 0
ELSE
  Ebare = E0(DAY) * (RHS - RHA(DAY)) / (1 - RHA(DAY)) ' relation (9.5)
END IF

EM = Ebare * EXP(-LAI * ke) ' relation (9.6)

-- Mulch layer specifications: PSImul, RHmul, DMmul, Kmuli

PSImulm = (273 + T24h) * 10 ^ 4 * LOG(RHA(DAY))) / -2.1649 ' relation (6.16.1)
PSImul = (PSI + PSImulm) / 2 ' relation (6.16)
PSImultot = (PSItot + PSImulm) / 2 ' To calculate RHmul

RHmul = EXP(-2.1649 * 10 ^ -4 * PSImultot / (273 + T24h)) ' relation (6.22.4)

IF PSImul < PSImax THEN
  Kmuli = K0 * EXP(-ALFA * PSImul) ' relation (6.19a)
ELSE
  Kmuli = AK * PSImul ^ -1.4 ' relation (6.19b)
END IF

DMmul = Kmuli * (PSImulm - PSI) / (EM + Kmuli) ' relation (6.18)

-- Next, the supply of water (vapour) to the evaporating surface is calculated;
-- One needs to know the depth (RD) and the hydraulic conductivity (KPSI) of
-- the (equivalent) root zone.
```
IF PSI < PSI_max THEN
    KPSI = K0 * EXP(-ALFA * PSI) ' relation (6.13a)
ELSE
    KPSI = AK * PSI ^ (-1.4) ' relation (6.13b)
END IF

IF RUNDAY = 1 THEN
    oldRD = RDINT
ELSE
    oldRD = RD
END IF

IF RDS <= RDSROOT THEN
    RD = RDINT + RDS * (RDISTR * RDM - RDINT) / RDSROOT ' relation (6.12a)
ELSE
    RD = RDINT + RDM ' relation (6.12b)
END IF

IF RD > SOILDEPTH THEN RD = SOILDEPTH
RDTAPYES = RDTAP
RDTAP = RDINT + RDS * (RDM - RDINT) / RDSROOT ' root front at mid-interval
IF RDTAP > RDM THEN RDTAP = RDM
IF RDTAP > SOILDEPTH THEN RDTAP = SOILDEPTH

WATSUPPLY = KPSI * ((PSImul - PSI) / (RD - DMMul) - 1) ' relation (6.23)

' Next, the moisture contents of the mulch layer (SMmul) and the underlying
' root zone (SMPSI) are calculated.

SMMUL = SM0 * STONEFF * PSImul ^ (-GAM * LOG(PSImul)) / relation (6.14a)
IF PSI <= 5 THEN
    SMPSI = (SM0 - .01) * STONEFF
ELSE
    SMPSI = SM0 * STONEFF * PSI ^ (-GAM * LOG(PSI)) / relation (6.14a)
END IF

' The possible water vapour flux through the mulch layer (VAPFLUX):

AIRDIFF = 2.38 + .0192 * T24h ' relation (6.22.1)
DMDA = .9 * ((SM0 * STONEFF) - SMMUL) - .1' relation (6.22.2)
SVAP = 6.11 * EXP(17.4 * T24h / (239 + T24h)) / relation (6.22.3)

VAPFLUX = AIRDIFF * DMDA * SVAP * (RHmul - RHA(DAY)) / DMMul ' relation (6.22)

' Check whether VAPFLUX is a bottleneck for water supply to the upper soil
' boundary:

IF WATSUPPLY > VAPFLUX THEN
    VAPSUPPLY = VAPFLUX ' relation (6.24a)
ELSE
    VAPSUPPLY = WATSUPPLY ' relation (6.24b)
END IF

' Match the vapour supply (VAPSUPPLY) with the evaporative demand (EM):

IF VAPSUPPLY >= EM THEN
    EA = EM ' relation (6.25a)
ELSE
    EA = VAPSUPPLY ' relation (6.25b)
END IF

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IF SS > 0 THEN EA = EM * relation (9.7)
IF EA < 0 THEN EA = 0 * Water absorption from the atmosphere is not considered.

GROSSUP = PREC(DAY) + IE(RUNDAY) - EA * relation (9.3)

If a mulch layer is present, this absorbs part of GROSSUP until SMmul has
become equal to SMPSI; the rest of GROSSUP trickles down into the root zone.
This is the net surface supply (NETSUP, in cm/d):

MULWAT = DMmul * SMMUL + GROSSUP * Dt * relation (9.8.1)
IF MULWAT >= DMmul * SMPSI THEN
NETSUP = (MULWAT - DMmul * SMPSI) / Dt * relation (9.8a)
SMmul = SMPSI
ELSE
NETSUP = 0 * relation (9.8b)
SMMUL = SMMUL + GROSSUP / DMmul
END IF

-- THE INFILTRATION CAPACITY (IM) --

SMMIN = S0 / 38 * cm/sqrt.day = 1cm/sqrt.1440min*sqrt.1min
DTMIN = 30
IMMIN = .5 * SMMIN * (1 - SMMUL / (SM0 * STONEFF) * DTMIN ^ -.5)
KTRVEG = KTR * CFLAEF
IM = IMMIN + KTRVEG

IM = .5 * S0 * (1 - SMMUL / (SM0*STONEFF)) * Dt ^ -.5 + KTRVEG * relation (9.15)

Match net supply at the surface with infiltration rate.

ASSC = ASSC * LABOR / 10
IF SLOPE < 1 THEN SLOPE = 1 %
ASSC = FURROW * (1 - (2 * SLOPE) / 100)
IF ASSC <= 0 THEN ASSC = 0
IF NETSUP = IM THEN
DS = 0
SR = 0 * relation (9.9a)
ELSEIF NETSUP < IM THEN
IF (IM - NETSUP) >= SS / Dt THEN
DS = SS / Dt
SR = 0 * relation (9.9b)
ELSE
DS = IM - NETSUP
SR = 0 * relation (9.9c)
END IF
ELSE
IF (NETSUP - IM) > (ASSC - SS) / Dt THEN
DS = -(ASSC - SS) / Dt
SR = NETSUP - IM + DS * relation (9.9d)
ELSE
DS = IM - NETSUP
SR = 0 * relation (9.9e)
END IF
END IF

UPFLUX = NETSUP + DS - SR * relation (9.10)
SRSUM = SRSUM + SR
" Water flow through the lower root zone boundary "

' If ZT < RD capillary rise and percolation have become irrelevant

IF ZT <= RD THEN
  CR = 0
  D = 0
  GOTO ENDSUBFLOW
END IF

' DEEP PERCOLATION ACCORDING TO DARCY'S LAW

IF PSI <= (ZT - RD) THEN
  IF PSI <= PSImax THEN
    KPSI = K0 * EXP(-ALFA * PSI)
    D = K0 * EXP(-ALFA * (ZT - RD)) - KPSI
    SALTPERCED = D * Dt * ECET(RUNDAY) * MolWt 'in kg SALT lost
    CR = 0
    GOTO ENDSUBFLOW
  ELSE
    ' Solve flow equation directly (small D-values anyway)
    KPSI = AK * PSI ^ -1.4
    D = KPSI * (PSI / (ZT - RD) - 1)
    SALTPERCED = D * Dt * ECET(RUNDAY) * MolWt 'in kg SALT lost
    CR = 0
    GOTO ENDSUBFLOW
  END IF
ELSE
  D = 0
END IF

' To bypass timeconsuming iteration, we resort to Rijtema old function:

GOTO SKIPITERAT

' CAPILLARY RISE RATE BY 3-POINT GAUSSIAN INTEGRATION

INTBOUNDARY(1) = PSImax: INTBOUNDARY(2) = 1000: INTBOUNDARY(3) = 3000

WEIGHT(1) = .2777778: WEIGHT(2) = .4444444: WEIGHT(3) = .2777778
DISTANCE(1) = .1127016: DISTANCE(2) = .5: DISTANCE(3) = .8872983

' Determine the DELTA values

FOR i = 1 TO 3
  IF INTBOUNDARY(i) >= PSI THEN
    DELTA(i) = PSI - INTBOUNDARY(i - 1)
  ELSE
    DELTA(i) = INTBOUNDARY(i) - INTBOUNDARY(i - 1)
  END IF

  ' Integrate (determine integ)

  FOR j = 1 TO 3
    ' Divide each delta in 3 parts; n = following number
    n = (i - 1) * 3 + j

    ' Ip(n) is PSI at the end of part 'n'

  NEXT j
hp(n) = DELTA(i) * DISTANCE(j) + INTBOUNDARY(i - 1)

IF hp(n) < PSImax THEN
  KPSI(n) = K0 * EXP(-ALFA * hp(n))
ELSE
  KPSI(n) = AK * hp(n) ^ -1.4
END IF

NEXT j

IF INTBOUNDARY(i) >= PSI THEN EXIT FOR

NEXT i

' GOTO NOLOG

IF PSI > INTBOUNDARY(3) THEN
  LOGINT = 3 + 1
  DELTA(LOGINT) = (LOG(PSI) - LOG(INTBOUNDARY(LOGINT - 1))) / LOG(10)

FOR j = 1 TO 3
  n = 2 * 3 + j
  hp(n) = DELTA(LOGINT) * DISTANCE(j) + LOG(INTBOUNDARY(LOGINT - 1)) / LOG(10)

  IF hp(n) < PSImax THEN
    KPSI(n) = K0 * EXP(-ALFA * hp(n))
  ELSE
    KPSI(n) = AK * hp(n) ^ -1.4
  END IF

  integ(n) = DELTA(i) * WEIGHT(j) * KPSI(n) * LOG(10) * hp(n)

  ' Action PMD: Check hp(n) with YU and Rappoldt !!!

NEXT j

END IF

NOLOG:

' Make a first guess of vertical FLOW using the analytical solution:

IF PSI < PSImax THEN
  KPSIx = K0 * EXP(-ALFA * PSI)
ELSE
  KPSIx = AK * PSI ^ -1.4
END IF

FLOW = KPSIx * (PSI / (ZT - RD) - 1)

' Iterate until less than .01 * (ZT - RD) cm difference remains between the computed vertical distance of FLOW (Z) and the real distance (ZT - RD):

ITERATIONS = 0
WHILE ABS(Z - (ZT - RD)) > .01 * (ZT - RD) AND ITERATIONS < 101
  ITERATIONS = ITERATIONS + 1

  ' Approximate value of Z:
  Z = 0
  FOR X = 1 TO n
    Z = Z + integ(X) / (KPSI(X) + FLOW)
  NEXT X

  ' Cut waiting time, take average if > 100 iterations:
  IF ITERATIONS = 100 THEN
\[ Z = \frac{(Z + (ZT - RD))}{2} \]

END IF

The rate of change of FLOW:

\[ d\text{FLOW} = \frac{Z}{(ZT - RD)} \]

\[ \text{FLOW} = \text{FLOW} \times d\text{FLOW} \]

WEND

\[ \text{CR} = \text{FLOW} \]

SKIPITERAT:

\[ \text{CR} = (\text{KPSI} \times \exp(\text{ALFA} \times (ZT - RD)) - K0) / (1 - \exp(\text{ALFA} \times (ZT - RD))) \]

Salt influx with CR, per day and in total.

\[ \text{SALTRISEN} = \text{CR} \times \text{DT} \times \text{ECGRW} \times \text{MolWt} \text{ in kg SALT added} \]

\[ \text{CUMSALT} = \text{CUMSALT} + \text{SALTRISEN} \]

\[ \text{CUMCR} = \text{CUMCR} + \text{CR} \]

PRINT SALTRISEN

' NOTE: WITH EITHER METHOD CR IS VERY LOW!!!

ENDSUBFLOW:

GERMINATION:

'----------------------

' CROP GROWTH AT LOW HUMIDITY IS FADED TILL PSISOW REACHED & REALSOW STARTS

IF YEAR = 1992 OR YEAR = 1993 OR YEAR = 1994 THEN GOTO WUPTAKE 'calibration settings
IF DAY > SOWDAY AND DAY <= SOWDAY + SOWPERIOD AND SOW = 0 AND PSI <= PSISOW THEN
    GOTO SAMEONE

END IF

WUPTAKE:

'----------------------

' Water uptake from interior root zone and CFWATER

' TRM was already calculated for TEMPDIFF!!
Rplant = 680 + .53 \times \text{PSILEAF} ' relation (6.9.1)
Root = 13 / (RD \times \text{KPSI}) ' relation (6.9.2)
MUR = (PSILEAF - PSItot) / (Rplant + Root) ' relation (6.9a)
IF MUR < 0 THEN MUR = 0 ' relation (6.9b)

'Matching the actual moisture content (SMPSI) with the wet critical contents
' (SM0 - 0.08), (SM0 - 0.04) and matching the moisture supply rate (MUR) with
'demand (TRM) produces an estimate of the actual transpiration rate (TR):

IF SMPSI >= (SM0 - .04) \times \text{STONEFF} THEN
    TR = 0 ' relation (9.13a)
    WETLIMIT = WETLIMIT + \text{DT}
ELSEIF (SM0 - .04) \times \text{STONEFF} > SMPSI > (SM0 - .08) \times \text{STONEFF} THEN
    TR = \text{TRM} \times (((SM0 - .04) \times \text{STONEFF}) - SMPSI) / .04 ' relation (9.13b)
    WETLIMIT = 0
ELSEIF MUR > TRM THEN
    TR = \text{TRM} ' relation (9.13c)
    WETLIMIT = 0
ELSE

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TR = MUR * relation (9.13d)
  WETLIMIT = 0
END IF
IF LAI = 0 THEN TR = 0
IF MUR = 0 THEN
  DROUGHTLIMIT = DROUGHTLIMIT + Dt
ELSE
  DROUGHTLIMIT = 0
END IF

'The correction factor cf(water) is now found:

CFWATER = TR / TRM * relation (9.2)
CFWATER(RUNDAY) = CFWATER

'__________________________________________________________
' ______________________________________________________
' - Adjustment of state variable values -
' ______________________________________________________
' ______________________________________________________

'First, the relative development stage (RDS) at the end of the interval is
'computed and the equivalent rooting depth (RD) is adjusted:

RDS = RDS + .5 * DRDS
IF RDS <= RDSROOT THEN
  RD = RDIINT + RDS * (RDIINT * RDM - RDINT) / RDSROOT * relation (6.12a)
ELSE
  RD = RDIINT * RDM * relation (6.12b)
END IF
IF RD > SOILDEPTH THEN RD = SOILDEPTH
RDTAP = RDIINT + RDS * (RDM - RDINT) / RDSROOT * root front at end interval
IF RDTAP > RDM THEN RDTAP = RDM
IF RDTAP > SOILDEPTH THEN RDTAP = SOILDEPTH
RDTAP(RUNDAY) = RDTAP
RDTAPGRWTH = RDTAP(RUNDAY) - RDTAP(RUNDAY - 1)

'Solve the water balance equation:

RSM = (UPFLUX + (CR + D) - TR) / RD * relation (9.1)

'Adjust the soil moisture content (SMPSI):

SMPSI = SMPSI + RSM * Dt * relation (9.16)

IF FALLOW = "y" OR FALLOW = "y" OR SWITCH1 = "f" OR SWITCH2 = "f" THEN
  SMFALLOW = FALLW / (FALLOW - FALLUP)
'PMD USES: SM1000 = SMO * 1000 ^ (-GAM * LOG(1000))
  IF RDTAP < FALLUP THEN
    SMPSI = SMPSI
  ELSEIF RDTAP >= FALLUP AND RDTAP < FALLUP THEN
    SMPSI = SMPSI + (RDTAPGRWTH * SMFALLOW * RDIINT) / RD
  ELSEIF RDTAP >= FALLUP THEN
    SMPSI = SMPSI + (RDTAPGRWTH * SMFALLOW * (1 - RDIINT)) / RD
END IF

'Rapid intake and slow discharge over the interval may cause SMPSI to be
'greater than the available pore space and is a consequence of the
'minimum interval length of one day

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SMGROSS = SMPSI
IF SMGROSS > (SM0 - .04) * STONEFF THEN
   SMPSI = (SM0 - .04) * STONEFF
   D = D - (SMGROSS - SMPSI) * RD / Dt
END IF

IF SMPSI < .01 THEN SMPSI = .01

'The quantity of salt present in the equivalent root zone at the beginning
'of a time interval is equal to yesterday's soil depth * yesterday's salt
'content, PLUS what is added by the increased depth of the root zone
'(SALTDEEP):

SALTDEEP = SMPSI * (RD - oldRD) * MolWt * ECET(RUNDAY - 1) in (RD-oldRD)/ha

'Salt added with IRRIGATION water (SALTIRRIG, in kg/ha) is considered as
'follows: NOT all irrigation water enters the soil; part is discharged as
'surface runoff. We do not consider direct evaporation because the salts
'remain behind.

IF (IE(RUNDAY) + SS / Dt) > IM THEN
   SALTIRRIG = (IM - SS / Dt) * Dt * ECEW(IEDAY) * MolWt
ELSE
   SALTIRRIG = IE(RUNDAY) * Dt * ECEW(IEDAY) * MolWt
END IF

IF RUNDAY = 1 THEN SOILSALT = SMPSI * RDINT * MolWt * ECET(RUNDAY)
'Initial SOILSALT is kg SALT in RDet/ha
DELTSALE = SALTDEEP + SALTIRRIG + SALTPERCED + SALTRISEN
SOILSALT = SOILSALT + DELTSALE

'If we know the total quantity of salts in the equivalent rooting zone,
'ECET for next RUNDAY can be calculated as SOILSALT / (RD * SMPSI * MolWt).

RUNDAY = RUNDAY + Dt
ECET(RUNDAY) = SOILSALT / (SMPSI * RD * MolWt)
ECET(RUNDAY) = INT(100 * ECET(RUNDAY) * SMPSI / (SM0 * STONEFF)) / 100

'Adjust the values of OP and PSlot:

OP = -15.99 + 424.6 * ECET(RUNDAY) + 1.229 * (ECET(RUNDAY)) ^ 2
PSI = EXP((1 / GAM * LOG((SM0 * STONEFF) / SMPSI)) ^ .5) relation (6.14b)
PSlot = PSI + OP
RUNDAY = RUNDAY - Dt

'Adjustment of the phreatic level (ZT):

'If groundwater is controlled by forced drainage or a nearby river,
'DELTZT cannot become negative.

DELTZT = 2 * (CR + D) * Dt / ((SM0 * STONEFF) - SMPSI) relation (9.17.1)

IF FIXZTS$ = "F" OR FIXZTS$ = "P" AND DELTZT < 0 THEN DELTZT = 0
ZT = ZT + DELTZT' relation (9.17)
IF ZT <= RD AND SEED <= 0 AND AERENCHYM <= 1 THEN
   GOSUB OUTPUTFILE
   GOTO SHALLOWWATER
END IF
Adjustment of the surface storage (SS):

\[ SS = SS - DS \cdot Dt \] relation (9.18)

IF SS < 0 THEN SS = 0
IF SS > ASSC THEN SS = ASSC

'END OF THE WATER BALANCE SUBROUTINE

\[ RDS = RDS - 5 \cdot DRDS \]

GOTO AFTERWATERBALANCE
Annex 3. Flow chart illustrating soil data base query and yield forecasting

1. SOILPAT1.DBF
2. SOILPAT2.DBF
3. SOILPAT3.DBF
4. SOILPAT3.XLS
5. RZ50SOIL.XLS
6. RZ50SOIL.DAT
7. TEXTURE.DAT
8. Yield estimate
9. HISTOUT.ASC
10. HISTOUT.XLS
11. Actyl = a Potyld + b (kg/ha)
12. Forecast
13. I997OUT.ASC
14. I997OUT.XLS
15. Actyl / soil
16. SDBANA1.DBF
17. LU-STRATAPAT.DBF
18. PAT4.DBF
19. Soil% / stratum
20. Weighted average of forecast of province

Open RZ50@YLD.DAT
for VILLAGE = 1 to V
if SDB > 0 then open RZ50SOIL.DAT
if SDB = 0 then open FAO.DAT
RUN
next V

Open 1997@.DAT
for LUS = 1 to RZ50
open RZ50SOIL.DAT
RUN
next LUS
SOILPAT1.DBF is a Polygon Attribute Table of the Arc-Info project. Polygon identifiers (HAMSOILID) allow to link with the geographical definition of the polygons and soil data base identifiers (SBDCODE) with soil data collected in the semi-detailed (1:50.000) soil inventory and stored in an ISRIC soil data base (SDB). SDBANA1.DBF contains soil chemical parameters.

In the case of Hamadan, the PAT file contained yet some SDB retrieved soil data as well as soil data collected in the reconnaissance (1:250.000) soil inventory. Even though the different scales of mapping and the different amounts of soil parameters inventoried and reported, were the two soil inventories combined into one map. The FAO soil group classification was the common parameter.

1. Verification and correction of the writing of SBDCODEs
2. Linking SOILPAT1.DBF with SBDANA1.DBF by common SBDCODE and selection of the model input soil parameters by data base query.
3. Creation of a common coding for the common FAO soil group classification of the reconnaissance and semi-detailed soil polygons; FAO88
4. Export to spreadsheet format (SOILPAT3.XLS)
5. Calculation of the average soil parameter class or value for each FAO soil group, based on the soil data attributed to the semi-detailed inventory. These averages, weighted according to area, substitute the soil data attributed to the reconnaissance soil polygons. Creation of two separate files (RZ50SOIL.XLS & FAO.XLS)
6. Transformation to comma-delimited ASCII files
7. Texture identifiers in the soil input files refer to texture identifiers in the texture file, which contains the definition of hydraulic soil properties default for each texture class.
8. Input of Land Use System defining parameters in the crop growth simulation model, including soil, prior to the simulation of historical actual yield data, retrieved from the ASID data base, and the elaboration of actual yield estimate functions for each crop. The historical data were aggregated to village level. For each village it is read from the Land Use System input file whether the location corresponds with a semi-detailed soil polygon or a reconnaissance soil polygon. If the first then the RZ50SOIL.DAT file is opened and the data inputted, I the second, the FAO.DAT file.
9. Run of the simulation for all identified Land Use Systems and output of the results into ASCII output files
10. Grouping of all ASCII output files into one file for each crop. Import into spreadsheet format.
11. Import in statistical analysis package (SPSS). Elaboration of the actual yield estimate functions by regression analysis according to the ‘step-wise’ method, which selects those simulated parameters which have highest explanatory value, evaluated by lowest deviation (**).
12. Input of land Use System defining parameters in the crop growth simulation model, including soil, prior to the simulation of crop growth and the generation of the forecast indicators. Only the Land Use Systems associated with the semi-detailed soil map polygons (RZ50SOIL.DAT) are analyzed.
13. Run of the simulation for all identified Land Use Systems and output of the results into ASCII output files.
14. Grouping of all ASCII output files into one file for each crop. Import into spreadsheet format.

15. Calculation of the actual yields for each Land Use System by substituting the explanatory parameters of the elaborated actual yield estimate functions by the simulated forecast indicators.

16. Prior to include the reconnaissance soil polygons into the forecasting analysis, the geo-referenced SOILPAT3 is overlaid with the geo-referenced LU-STRATAPAT.

17. The result of the overlying of the coverage’s is the geo-referenced RZPAT4 coverage.

18. Calculation of the FAO soil group frequency for each Land Use Stratum, based on area and expressed in percentages (relative weights).

19. Aggregation of the actual crop yield forecasts, weighted according to the calculated soil group frequency for each land use stratum (actual yield forecasts, aggregated per stratum)

20. Actual crop yield forecasts, expressed in kg/ha.

21. Calculation of the total crop production forecast of the considered region by multiplying the actual yield forecasts (kg/ha) by the area of each land use stratum (ha) and the area frequency of the different crops types within a land use stratum. Obviously, step 19, 20 and 21 can be omitted with one direct step.
### Annex 4. Soil database conversion table

<table>
<thead>
<tr>
<th>Typecode</th>
<th>Itemsymbol</th>
<th>Itemcode</th>
<th>Hamadan</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>p</td>
<td>1</td>
<td></td>
<td>Very rapid, above 25 cm/h.</td>
</tr>
<tr>
<td>01</td>
<td>p</td>
<td>2</td>
<td></td>
<td>Rapid, from 6 to 25 cm/h.</td>
</tr>
<tr>
<td>01</td>
<td>p</td>
<td>3</td>
<td></td>
<td>Moderate, from 2 to 6 cm/h.</td>
</tr>
<tr>
<td>01</td>
<td>p</td>
<td>4</td>
<td></td>
<td>Slow, from 0.1 to 2 cm/h.</td>
</tr>
<tr>
<td>01</td>
<td>p</td>
<td>5</td>
<td></td>
<td>Very slow, less than 0.1 cm/h.</td>
</tr>
<tr>
<td>02</td>
<td>i</td>
<td>0</td>
<td>0</td>
<td>&lt;15% of coarse fragments</td>
</tr>
<tr>
<td>02</td>
<td>i</td>
<td>1</td>
<td>g</td>
<td>Between 15 and 30% of coarse fragments.</td>
</tr>
<tr>
<td>02</td>
<td>i</td>
<td>2</td>
<td>G</td>
<td>Between 30 and 75% of coarse fragments.</td>
</tr>
<tr>
<td>02</td>
<td>i</td>
<td>3</td>
<td>Z</td>
<td>Above 75% of coarse fragments</td>
</tr>
<tr>
<td>03</td>
<td>x</td>
<td>1</td>
<td></td>
<td>Very coarse (sand, coarse sand)</td>
</tr>
<tr>
<td>03</td>
<td>x</td>
<td>2</td>
<td>C</td>
<td>Coarse (loamy coarse sand, fine sand)</td>
</tr>
<tr>
<td>03</td>
<td>x</td>
<td>3</td>
<td>L</td>
<td>Light (loamy fine sand, coarse sandy loam)</td>
</tr>
<tr>
<td>03</td>
<td>x</td>
<td>4</td>
<td>M</td>
<td>Medium (fine sandy loam, silt loam, silt, loam)</td>
</tr>
<tr>
<td>03</td>
<td>x</td>
<td>5</td>
<td>H</td>
<td>Heavy (silty clay loam, sandy clay loam, clay loam)</td>
</tr>
<tr>
<td>03</td>
<td>x</td>
<td>6</td>
<td>V</td>
<td>Very heavy (silty clay, clay, sandy clay)</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>f</td>
<td></td>
<td>Fine gravels 2-2.5 cm, volume: 15-35%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>g</td>
<td></td>
<td>Fine gravels 2-2.5 cm, volume: 3-15%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>z</td>
<td></td>
<td>Fine gravels 2-2.5 cm, volume: 75%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>(g)</td>
<td></td>
<td>Coarse gravels 2.5-7.5 cm, volume: 75%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>(z)</td>
<td></td>
<td>Coarse gravels 2.5-7.5 cm, volume: &gt;75%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>(s)</td>
<td></td>
<td>Stones 7.5-25 cm, volume: 15-35%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>S</td>
<td></td>
<td>Stones 7.5-25 cm, volume: 3-15%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>Z</td>
<td></td>
<td>Stones 7.5-25 cm, volume: &gt;75%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>[b]</td>
<td></td>
<td>Boulders &gt;25 cm, 2-5 m apart</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>(b)</td>
<td></td>
<td>Boulders &gt;25 cm, volume: &gt;75%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>b</td>
<td></td>
<td>Boulders &gt;25 cm, volume: 15-35%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>B</td>
<td></td>
<td>Boulders &gt;25 cm, volume: 15-35%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>[Z]</td>
<td></td>
<td>Boulders &gt;25 cm, volume: &gt;75%</td>
</tr>
<tr>
<td>04</td>
<td>j</td>
<td>0</td>
<td>0</td>
<td>No coarse fragments</td>
</tr>
<tr>
<td>05</td>
<td>h</td>
<td>1</td>
<td>1</td>
<td>Very deep, soil deeper than 120 cm</td>
</tr>
<tr>
<td>05</td>
<td>h</td>
<td>2</td>
<td>2</td>
<td>Deep, 120 cm, soil depth: 80 cm</td>
</tr>
<tr>
<td>05</td>
<td>h</td>
<td>3</td>
<td>3</td>
<td>Moderately deep, 80 &lt; soil depth: 50 cm</td>
</tr>
<tr>
<td>05</td>
<td>h</td>
<td>4</td>
<td>4</td>
<td>Shallow, 50 &lt; soil depth: 25 cm</td>
</tr>
<tr>
<td>05</td>
<td>h</td>
<td>4</td>
<td>4</td>
<td>Very shallow, 25 &lt; soil depth: 10 cm</td>
</tr>
<tr>
<td>06</td>
<td>y</td>
<td>Z</td>
<td></td>
<td>Gravel, &gt;75% stone &amp; gravels; thickness: 30 cm</td>
</tr>
<tr>
<td>06</td>
<td>y</td>
<td>P</td>
<td></td>
<td>Paralithic (lithic like), hardness by Mohs scale: 3</td>
</tr>
<tr>
<td>06</td>
<td>y</td>
<td>L</td>
<td></td>
<td>Lithic, hardness by Mohs scale: 3, Petrocalcic, Gypsum</td>
</tr>
<tr>
<td>06</td>
<td>y</td>
<td>0</td>
<td></td>
<td>No limiting layer</td>
</tr>
<tr>
<td>07</td>
<td>n</td>
<td>1</td>
<td>1</td>
<td>Rate between 1 and 2 cm/h</td>
</tr>
<tr>
<td>07</td>
<td>n</td>
<td>2</td>
<td>2</td>
<td>Rate between 0.5 and 1 cm/h</td>
</tr>
<tr>
<td>07</td>
<td>n</td>
<td>3</td>
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<td>Rate between 0.2 and 0.5 cm/h</td>
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<td>07</td>
<td>n</td>
<td>4</td>
<td>4</td>
<td>Rate lower than 0.2 cm/h</td>
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<td>Characteristic</td>
<td>Classification</td>
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<td>----------------</td>
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<tr>
<td>Rate</td>
<td>Higher than 2cm/hr.</td>
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<td>EC</td>
<td>Less than 4 mmhos/cm, no or very slight limitation</td>
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<tr>
<td>Salinity</td>
<td>4 to 8 mmhos/cm, slight salinity limitation</td>
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</tr>
<tr>
<td>Moderate</td>
<td>8 to 16 mmhos/cm, moderate salinity limitation</td>
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<tr>
<td>Severe</td>
<td>16 to 32 mmhos/cm, severe salinity limitation</td>
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<tr>
<td>Very Severe</td>
<td>More than 32 mmhos/cm, very severe salinity limitation</td>
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<tr>
<td>Alkalinity</td>
<td>Slight, ESP &lt;15% &amp; pH &gt;8.5, 8 &lt; SAR &lt; 13</td>
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<tr>
<td>Moderate</td>
<td>15 &lt; ESP &lt; 35%, 8.5 &lt; pH &lt; 9, 13 &lt; SAR &lt; 30</td>
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<tr>
<td>Severe</td>
<td>30 &lt; ESP &lt; 60% &amp; 9 &lt; pH &lt; 9.5, 30 &lt; SAR &lt; 70</td>
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<td>Very Severe</td>
<td>ESP &gt; 50% &amp; pH &gt; 9.5, SAR &gt; 70</td>
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<td>Alkalinity</td>
<td>No alkalinity problem, ESP &lt; 10% PH &lt; 8.5, SAR &lt; 8</td>
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<tr>
<td>Slope</td>
<td>Gently sloping: 0 to 2%</td>
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<tr>
<td>Steep</td>
<td>2.5% to 8%</td>
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</tr>
<tr>
<td>Very Steep</td>
<td>8% to 12%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very Very Steep</td>
<td>12% to 25%</td>
<td></td>
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</tr>
<tr>
<td>Terraces</td>
<td>25% to 40%</td>
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</tr>
<tr>
<td>Less than 1%</td>
<td>Empty or very slight, 0-15cm, Ave. Micro relief intensity, Earth moving &lt; 350 m3/ha</td>
<td></td>
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<tr>
<td>Moderate</td>
<td>15-30cm, Ave. Micro relief intensity, Earth moving 350-750 m3/ha</td>
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<tr>
<td>Strong</td>
<td>30-60cm, Ave. Micro relief intensity, Earth moving 750-1500 m3/ha</td>
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<tr>
<td>Stronger</td>
<td>&gt;60cm, Ave. Micro relief intensity, Earth moving &gt;1500 m3/ha</td>
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<td>Erosion</td>
<td>No apparent erosion</td>
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<td>Erosion by Water</td>
<td>Slight erosion by water</td>
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</tr>
<tr>
<td>Erosion by Water</td>
<td>Moderate erosion by water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion by Wind</td>
<td>Severe erosion by water</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Erosion by Wind</td>
<td>Land is destroyed by gully erosion</td>
<td></td>
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</tr>
<tr>
<td>Erosion by Wind</td>
<td>Slight erosion by wind</td>
<td></td>
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</tr>
<tr>
<td>Erosion by Wind</td>
<td>Moderate erosion by wind</td>
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<td>Erosion by Wind</td>
<td>Severe erosion by wind</td>
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<tr>
<td>Erosion Products</td>
<td>Slight deposition of water erosion products</td>
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<td>Moderate deposition of wind erosion products</td>
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<td>Sand dunes</td>
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<td>Erosion Products</td>
<td>No deposition of erosion products</td>
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<td>Freshwater</td>
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<td>---</td>
<td>---</td>
</tr>
<tr>
<td>15</td>
<td>w</td>
<td>S</td>
<td>Saline water, Ec of ground water &gt; 1500 micro mohs.</td>
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<td>Significant morphological characteristic: 1.2-2m</td>
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<td>P1</td>
<td>Slight limitations due to ponding</td>
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<tr>
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<td>z</td>
<td>P2</td>
<td>Moderate limitations due to ponding</td>
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<tr>
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<td>z</td>
<td>P3</td>
<td>Severe limitations due to ponding</td>
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<tr>
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<td>z</td>
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<td>No ponding hazard.</td>
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<td>Slight flooding hazard (every 6-10 year)</td>
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<td>f</td>
<td>F2</td>
<td>Moderate flooding hazard (every 3-5 year)</td>
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<td>19</td>
<td>f</td>
<td>F3</td>
<td>Severe flooding hazard (every 1-2 year)</td>
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<td>d</td>
<td>COM</td>
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Annex 5. Model performance verified

Crucial in the whole crop forecast procedure is the accuracy of the simulation model explaining actual crop yields. § 3.2 illustrates a reasonable performance explaining actual yields for the pilot area. However, the achieved accuracy explaining actual yields for the whole province is poor. Some important reasons are given in § 3.2. Of major importance appeared the difficulties describing and simulating the water-limited yield potential. The quality of a simulation depends on the quality of the model describing the actual situation and the quality of the data characterizing the actual situation. The quality of the basic data characterizing the selected land-use systems of Hamadan province was yet verified and concluded poor and incomplete for some important parameters. The consistency of the simulation model itself was verified as well and some results are illustrated in the following graphs. The point of focus was to verify the correctness of the relations between the simulated total amount of water transpired by the crop and simulated crop growth characteristics.

It was concluded that these relations are correct, concluding a consistent model accurately describing crop growth as a function of water availability.
The bio-physical yield potential is a function of temperature and radiation. Low availability of radiation leads to low total amounts of water transpired, indicating crop growth limited by radiation. A total amount of radiation of about 40,000 – 50,000 J/m² season does not constrain transpiration and hence production. Apparently, transpiration is limited by water availability in most situations.
Sufficiently available radiation leads to transpiration limited by water availability. Because production and transpiration are related, is the amount of radiation intercepted by the produced leaf area explained by transpiration. Again one sees that the amount of water transpired is short relative to the amount of radiation intercepted.
The water availability determines the opening of the stomata and hence transpiration and CO2 reduction and assimilation. The relationship is linear with a constant of about 1000 kg gross assimilates /cm water transpired.
Gross assimilation provides assimilates for crop maintenance respiration and crop growth. Transpiration explains the dry matter production. Here an approximate water use efficiency of 300 kg dry matter and 200 kg grain storage organs/cm water transpired is simulated. Some one quarter of the gross assimilation contributes to crop growth.
The total amount of dry matter simulated explains the total amount of grain storage organs simulated. Apparently, no striking water shortages occurred after anthesis, reducing the post-anthesis production relative to the vegetative production.
Though the crop yield appeared correctly simulated as a function of transpired water, no relation appears with actual yields. Apparently, the water availability is not well characterized or the actual yields are not water limited and are determined by other factors, like indicated for Razan pilot area.
The simulated total dry mass production is related with the harvest index, the relative development stage when the simulation stops, the water sufficiency factor and the water sufficiency factor after anthesis. All four parameters appear rather constant, independent of the total dry mass, except where low values are simulated. Striking is the relatively varying total dry mass with relatively constant water sufficiency factors, directly related with gross assimilation.