NATURAL RESOURCES SYSTEMS PROGRAMME

PROJECT REPORT[1]

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Report Title

Agricultural systems simulation I

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1. Agricultural Systems Simulation I

Objectives of the module

After completing this module, students will be able to:

- Define agricultural system simulation models.
- Name various models for simulation of agricultural systems.
- Name the benefits of using models for simulation of agricultural systems.
- Simulate maize growth and yield using PARCHED-THIRST software package.

Requirements for the module

- Knowledge of word and spreadsheet software such as Microsoft Word and Microsoft Excel
- Computer with Microsoft Windows 98/2000/XP
- PARCHED-THIRST software

1.1 Introduction

A Model is a description of some system intended to predict what happens if certain actions are taken. Simulation is the study of a model over time. A model is therefore an approximation of an existing or hypothetical system and we use the model in simulation in order to try to understand the real system better.
A computer model is a computer program which attempts to simulate an abstract model of a particular system. Computer simulations have become a useful part of modeling many natural systems to gain insight into the operation of those systems. Traditionally, the formal modeling of systems has been via a mathematical model, which attempts to find analytical solutions to problems which enable the prediction of the behaviour of the system from a set of parameters and initial conditions. Computer simulations build on, and are a useful adjunct to, purely mathematical models in science and technology.

1.2 Mathematical Models and Computer Simulation

A mathematical model is an equation or set of equations, which represents the behaviour of a system. For example, the relationship between dry matter accumulation and intercepted radiation is approximately linear for many crops during optimal vegetative growth (see Figure 1.1). Thus, the rate of dry matter production per day, GL (g m-2 d-1) can be expressed as

$$G_L = f_i \varepsilon S F_{temp} \qquad (1)$$

where: f_i is the fractional light interception of the canopy (see below)
ε_s is the conversion coefficient for intercepted light (g MJ-1)
S is daily solar radiation (MJ m-2 d-1) and
F_{temp} is a zero to unity temperature-based factor which simulates the effect of temperature on photosynthesis on the basis of mean daily air temperature (T) using the relationship shown in Figure 1.1.
Mathematical equations like the one above are used for producing computer models.

1.2.1 Why Computer Simulation Models?

Computer simulation models are used in the following instances;

- Where the real system is expensive or already in commercial use and we cannot risk damaging it.
- If the real system is mistreated, situations may occur that put human lives and safety in danger.
- Where we do not have the time and funding to build a real system. A model prototype could be built to prove our concept.
- Where the real system occurs in an environment that makes it impossible to observe.
- Where external reasons (e.g. political considerations, research ethics) limit our ability to carry out experiments on the real system.
- Where we want for some reason to keep our results secret.
- Where we do not have the technology to build the real system.
- Where we want to study a system on a time scale that is not suitable to humans, like the growth of plant.

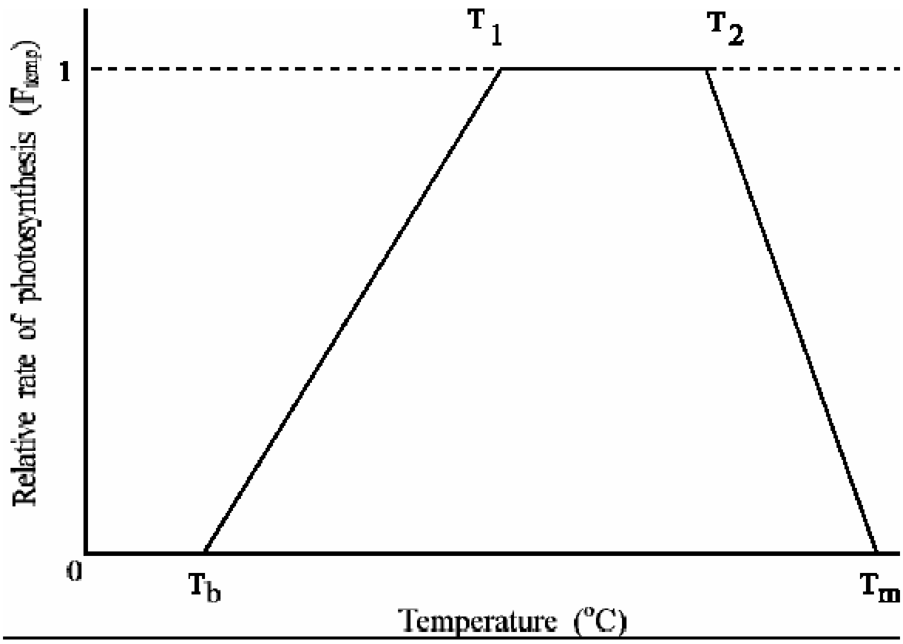


Figure 1.1: Graphical representation of mathematical model

1.2.2 Applications of Computer Simulation Models

Computer simulation models can be applied in various fields. These include among others:

- In training: Used to simulate some real system or object.
- In system design: Built in order to determine the final design of some system.
- In scientific research: Observation of some real life system, which we do not fully understand.
- As a presentation tool: An extremely complex system may be extremely hard to supervise by humans because of the large amount of incoming information

1.2.3 Practical Hints in Computer Modeling and Simulation

Some important practical hints in computer modelling and simulation include the following:

- Define the real world system to be modeled.
- Determine what the important properties of the system really are.
- Make the tough choices of simplification.
- Decide what properties you want to study and within what ranges of data.
- Decide what method to use, and be clear about why it is better than others.
- Give the model a good structure by dividing it into sets of sub-problems.
- Validate each part of the model functions as the corresponding part in the real system.
- Determine the models combined design parameters.
- Determine the margins of errors in the results, compared to the real world.
- Keep control over the model and its use, so that you can tell the difference between observed phenomena and that related to the real system.

1.2.4 Crop simulation models

Scientists have developed different computer models to help study various agricultural processes. Examples of crop simulation models are

- PARCHED-THIRST
- DSSAT

- APSIM

In this module we will use PARCHED-THIRST (PT) software as a tool for learning crop growth. The following section gives brief details of the PT software.

1.3 The PARCHED-THIRST Software

The PT software is a computer-based simulation model that is user-friendly and process-based. It combines the simulation of hydrology with growth and yield of a crop on any number of distinct or indistinct runoff producing areas (RPAs) and runoff receiving areas (RRAs). It is a distributed model, which simulates the rainfall-runoff process, soil moisture movement and the growth of sorghum, rice, maize and millet. The PT software is made up of various components as shown in Figure 1.2.

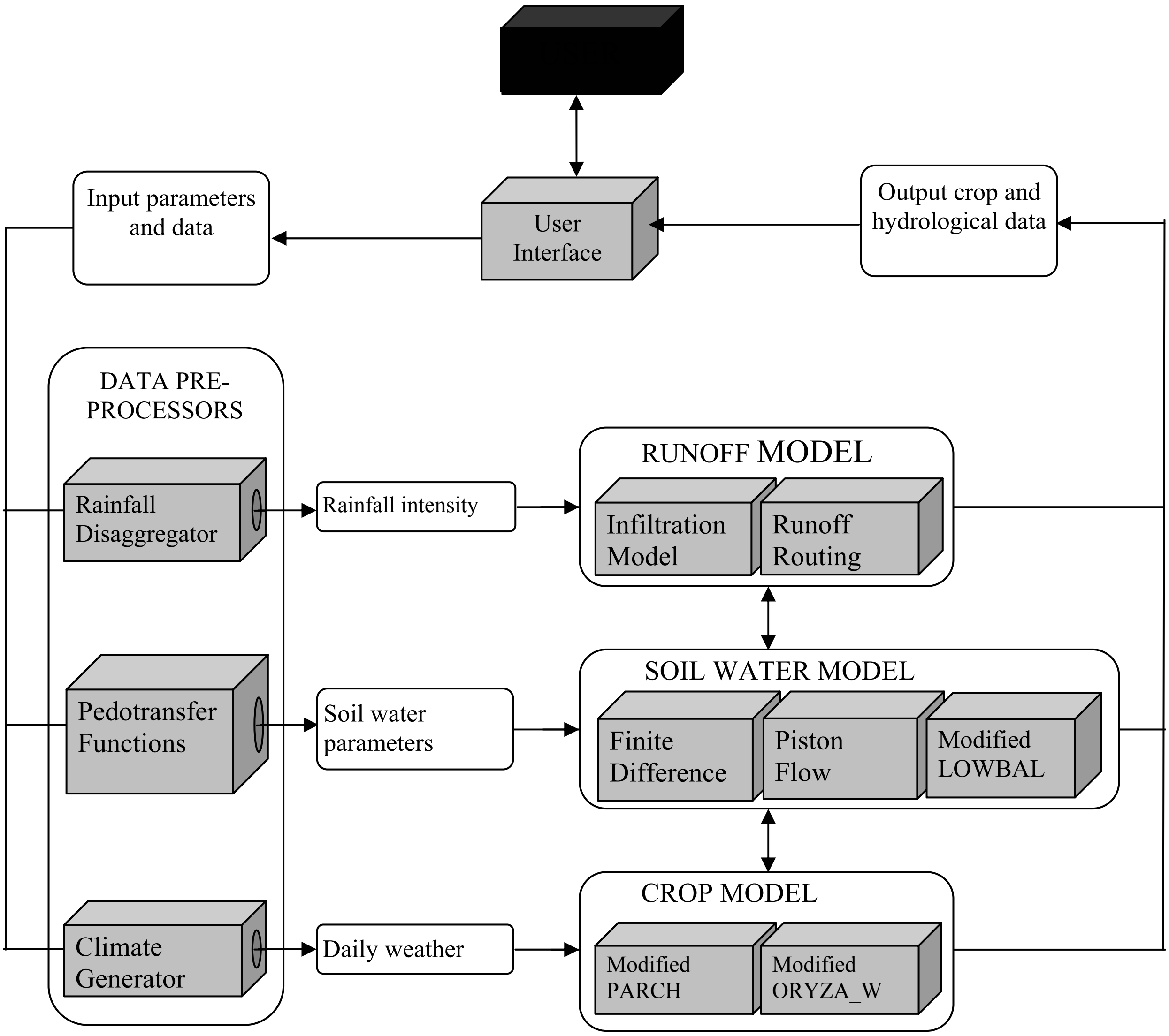


Figure 1.2. Components of the PT software

1.3.1 Components of the PARCHED-THIRST Software

The first component is the data preprocessors. These are used to prepare or convert input data into a form that it can be used by the various components of the model. The climate generator is used to generate missing weather data. Rainfall disaggregator is used to generate 5 minutes

rainfall intensity data from an assumed rainfall intensity distribution. Pedotransfer function is used to generate difficult-to-measure soil hydraulic parameters.
Soil moisture model is used to model the movement of water in the soil whereas the runoff model is based on runoff amount that is infiltration excess, which is modified by depression storage and surface sealing. Runoff routing is only considered in the case of larger catchments because in those cases runoff lag times can be significant.
The PT model incorporates two crop models which are PARCH and ORYZA_W models. The PARCH model simulates the growth of sorghum, millet and maize in response to the capture of light, water and nutrients on a daily basis. ORYZA_W Model is a model developed to simulate water-limited growth and development of rice.

1.3.2 Input Data

The PT model is driven by daily rainfall and other agro-meteorological data. In order to provide for simulation of long-term performance, the PARCHED-THIRST Climate Generator can be used to extend the available historical data. Daily rainfall values are then converted by the rainfall disaggregator into intensity data which are required by the infiltration model. The rainfall-runoff process is simulated as an infiltration excess with infiltration being determined by the Green-Ampt infiltration calculator. Because of the cost and difficulty of measuring soil hydraulic properties in the field, pedotransfer functions are included to allow for their prediction from readily-available soils data. The modified PARCH model adds soil-water redistribution and crop growth simulation routines which complete the system. RWH is simulated by having two profiles running simultaneously with runoff from the upper becoming an input for the lower of the two. Except for climate and soil texture, each profile can have different characteristics.

The crop growth model (PARCH), a sub-model of the PT model, uses a daily time step for the simulation of crop growth. On each day, the resources of light, water and nutrients are `intercepted' or `extracted' and converted into assimilated dry matter. Depending upon the availability of these resources and the crop's ability to sequester them, its growth is considered as light, water, or nutrient `limited'. An index of crop stress is calculated in terms of the ratio of light to water or nutrient limited growth. This stress index is then used to control a number of the crop's stress responses, such as leaf rolling or increased partitioning to roots. Partitioning of resources between crop organs is calculated by empirically derived fractions which are adjusted according to growth stage and level of stress. Resources partitioned to the leaf canopy and root system add to leaf area and root length thereby feeding back into subsequent calculations for light interception and water and nutrient uptake.

1.3.3 Output Data

The PT model has the ability to simulate the following:

- Crop growth
- Rainfall
- Crop yield
- Runoff
- Evaporation
- Evapotranspiration
- Drainage

1.4 Running the PT Software

Each simulation scenario is known as a system. A system has a number of properties which include start date, sowing dates, etc. It is also made up of a number of profiles. These are one dimensional 'blocks' of soil/plant/atmosphere which are assumed to represent an area with homogeneous soils, topography, vegetation, etc. Each profile is composed of crop, soil and weed objects which define the behaviour of the profile. A soil object is itself composed of a number of soil layer objects each with defined physical properties which are conceptually easy for users to understand and are object-orientation

1.4.1 Starting the PT software

Starting PT Model (PTv2.3)

Click on the Start button on the task bar to display a menu directly above.

- Move the mouse pointer up to Programs (don't click on a mouse button yet). A submenu appears.
- Move across to PTv2.3 keeping the pointer carefully over the word Programs until you get to the sub menu
- Move the pointer to PTv2.3 and click the left mouse button.
- The screen in Figure 1.3 appears.

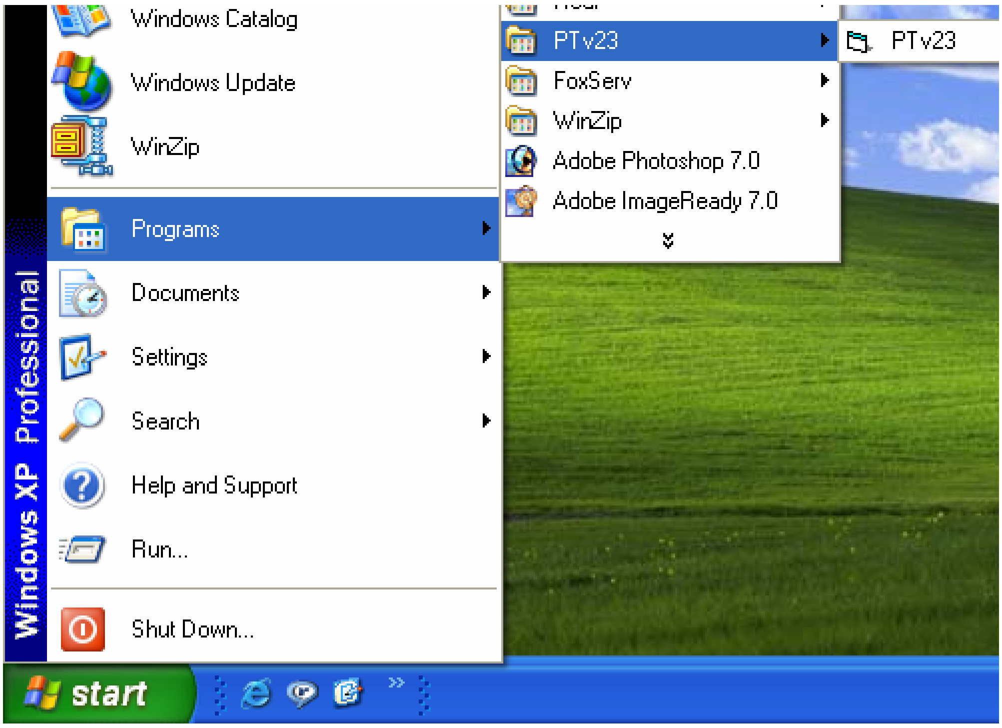


Figure 1.3. Starting PT v2.3 software

- To start PTv2.3 click the Experienced users button (Figure 1.4)
- To learn more about PTv2.3 click the Tutorials button
- If you are stack click the Help button
- Click the Exit button to close PTv2.3 program
- Click the Experienced Users button. The screen in Figure 1.5 appears.

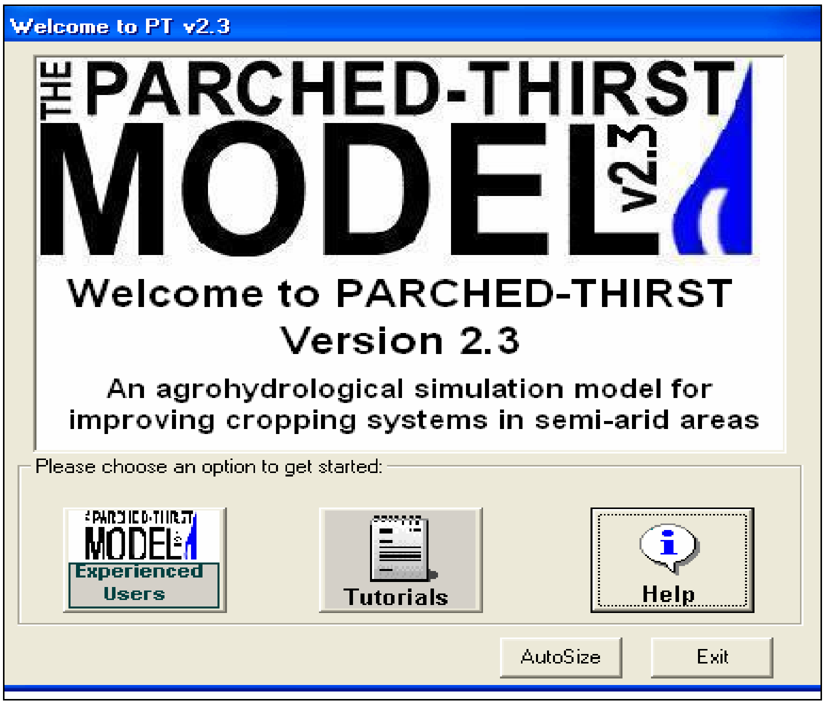


Figure 1.4. Starting PTv23

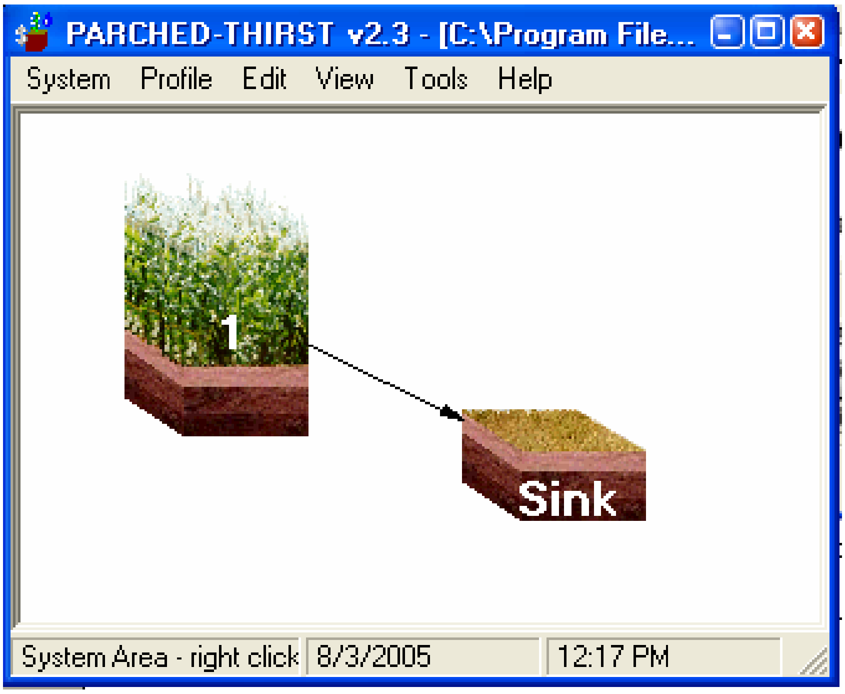


Figure 1.5. PTv23 front-end

Exploring PTv2.3 front-end

From Figure 1.5 answer the following questions.

- Mention the menus available in the PTv2.3 screen.
- For each menu, mention the menu items.

- Move the pointer over the icon labelled 1 and mention its name.

1.4.2 Exploring the System in the PT software

To open/load a System

- Click the System menu on the PTv2.3 menu bar
- Click the Open option
- Make sure the System folder appears at the Look in drop down menu
- Select the system you want to use from the list
- Click the Open button.
- A System properties screen shown in Figure 1.6 below is displayed
- Note the name of the system file

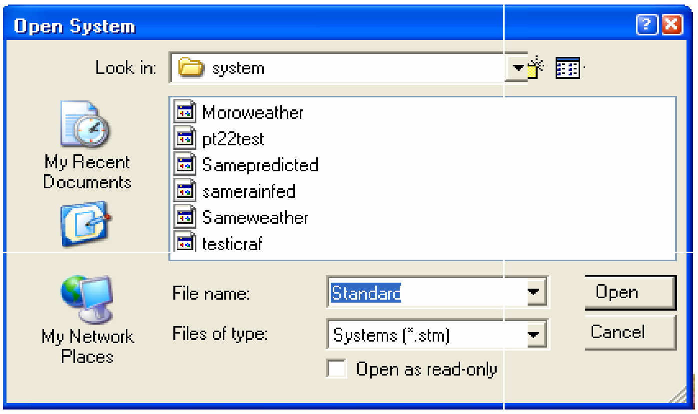


Figure 1.6. Opening the System file

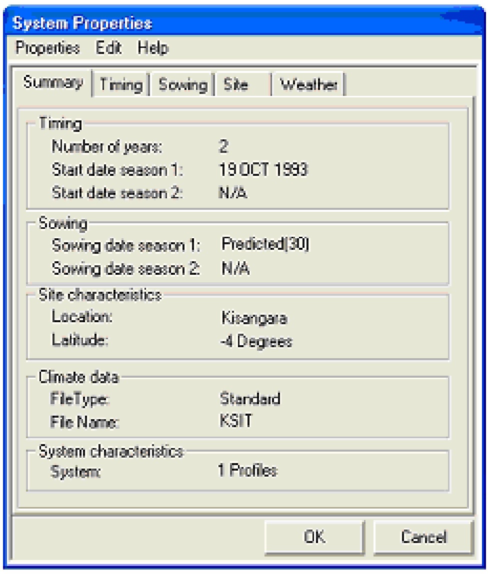


Figure 1.7. System properties dialogue box

Exploring the dialogue box for System properties

- Use the Weather tab to specify the name and location of the weather file of the system for which you want to simulate
- Use the Site tab to specify the location of the site for the system file
- Define the sowing date using the Sowing tab (Figure 1.7)

- Use the Timing tab to specify the number of years for which you want to run simulation, number of seasons/year, and season start date
- The Summary tab gives the summary of the system properties we have specified.
- Click OK button to save changes or click Cancel to discard any change.

1.4.3 Exploring the Profile Properties in PT

Opening and exploring the Profile Properties screen

- Click the Profile icon labelled 1
- Click the profile menu
- Click the Properties of option
- A screen of Figure 1.8 appears
- Summary tab - provides a summary of profile properties and their current settings
- Crop tab - allows the user to set the properties of any crop grown on the profile
- Weeds tab - allows the user to set the properties of any weeds growing in the profile
- Soil properties tab - allows the user to set the properties of the soil in the profile
- Soil surface tab - allows the user to set soil surface properties and define the area occupied by the profile

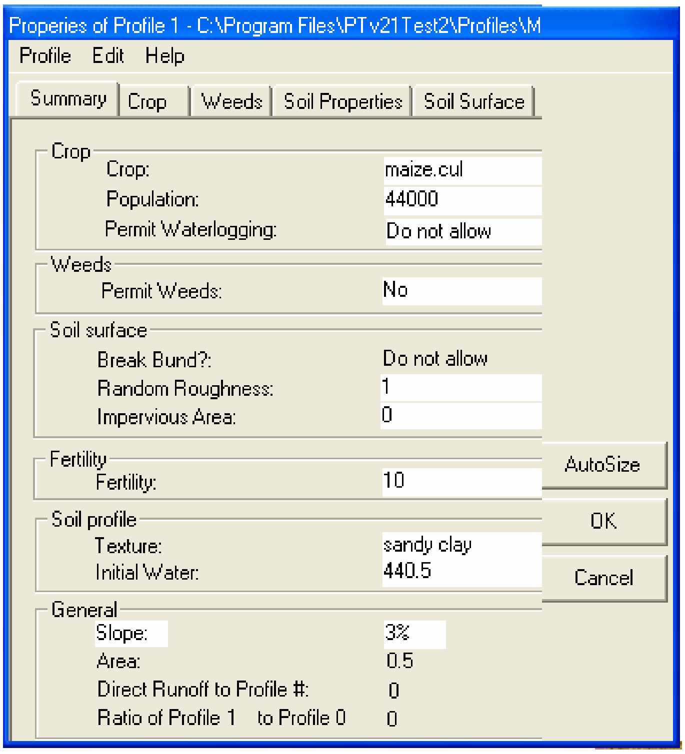


Figure 1.8. Profile properties

1.4.4 Running Simulations

After giving the model all necessary inputs, the model processes them and gives the output. During simulation you will specify two files. One for saving the simulation summary data and the other one for storing the daily output data.

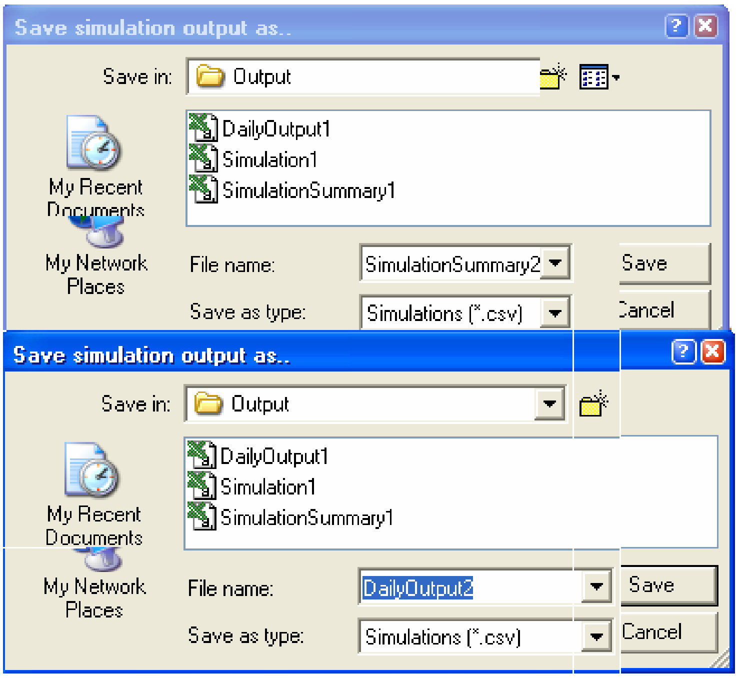


Figure 1.9. Saving simulation summaries

- Click the System menu on the menu bar then Click the Run option.
- In the Save Simulation Output as dialogue box specify the filename for the Simulation summary output (Figure 1.9). If possible replace the existing file. Then click save.
- In the Save Simulation Output as dialogue box specify the filename for the Daily Output data. If possible replace the existing file. Then click save.

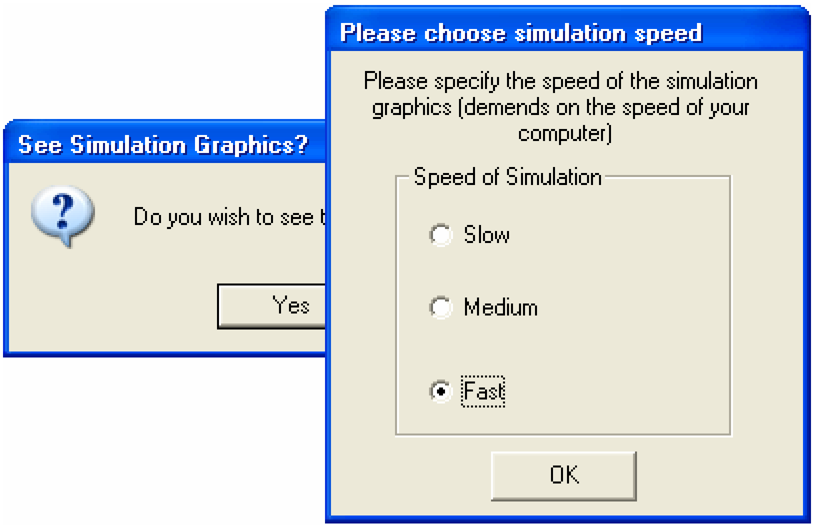


Figure 1.10. Option to see simulation summary and choose simulation speed

- In the See simulation graphics? Message box click yes to see how simulations are running
- In the Please choose simulation speed click fast and then click OK (Figure 1.10)

1.4.5 Exploring and understanding the Outputs from the simulation

There are three ways in which PTv2.3 provides the user with information about the simulations undertaken which are the run-time graphics, simulation summary and output files. The three types of outputs are described hereunder.

The run-time graphics

At any one time, Run-time graphics display the values of a number of key crop and soil water parameters with time for a single profile. The display is divided into a number of distinct areas as shown below: Crop growth pane, Soil water pane, Timing and development variables, Stress bar, Profile list and Pause button (Figure 1.11 and 1.12).

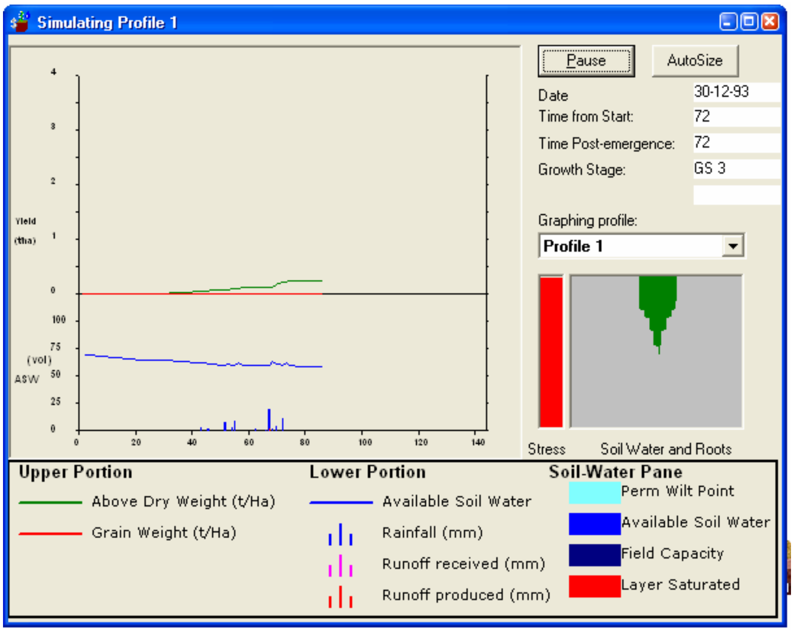


Figure 1.11: Running simulations

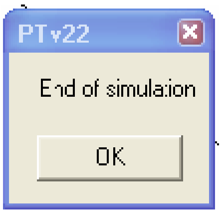


Figure 1.12: End of simulation

Simulation Output Summary

The Simulation summary is a graphical tool for analyzing simulation output. Summary of different variables such as rainfall, runoff, etc can be viewed by clicking appropriate tab. Comparisons can be done between seasons on different years.

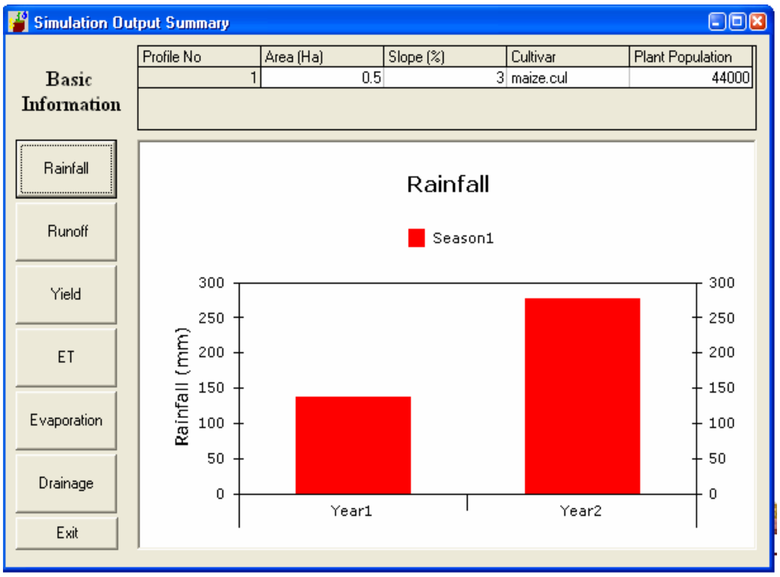
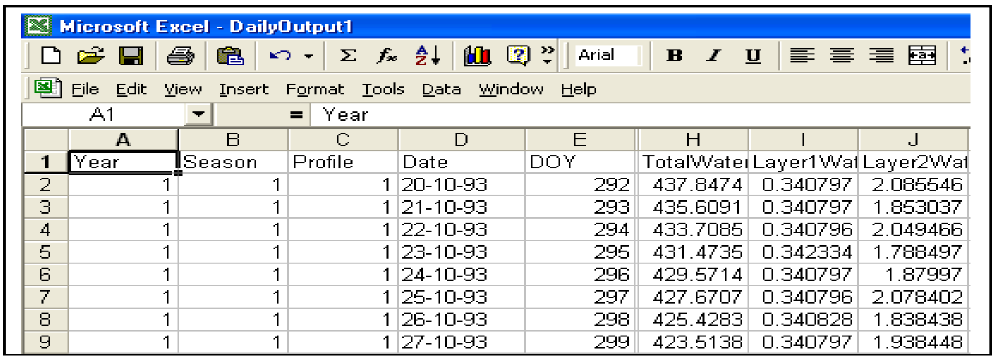


Figure 1.13: Simulation output summary obtained after running the simulation.

- The screen in Figure 1.13 will appear after the running simulation.
- Click the following tab to learn the output.
  - ✓ Rainfall
  - ✓ Runoff
  - ✓ Yield
  - ✓ ET
  - ✓ Evaporation
  - ✓ Drainage

Output Files

When PTv2.3 is run, it prompts the user to enter a filename under which to save simulation output. The type of output file produced by PTv2.3 is Text output file which will be created and the user is prompted to enter a text file filename (extension ".csv") for saving summary and daily simulation output respectively (Figure 1.14 and 1.15).



	A	B	C	D	E	H	I	J
1	Year	Season	Profile	Date	DOY	TotalWatei	Layer1Wat	Layer2Wat
2	1	1	1	20-10-93	292	437.8474	0.340797	2.085546
3	1	1	1	21-10-93	293	435.6091	0.340797	1.853037
4	1	1	1	22-10-93	294	433.7085	0.340796	2.049466
5	1	1	1	23-10-93	295	431.4735	0.342334	1.788497
6	1	1	1	24-10-93	296	429.5714	0.340797	1.87997
7	1	1	1	25-10-93	297	427.6707	0.340796	2.078402
8	1	1	1	26-10-93	298	425.4283	0.340828	1.838438
9	1	1	1	27-10-93	299	423.5138	0.340797	1.938448

Figure 1.14. Sample of the DailyOutput1 file

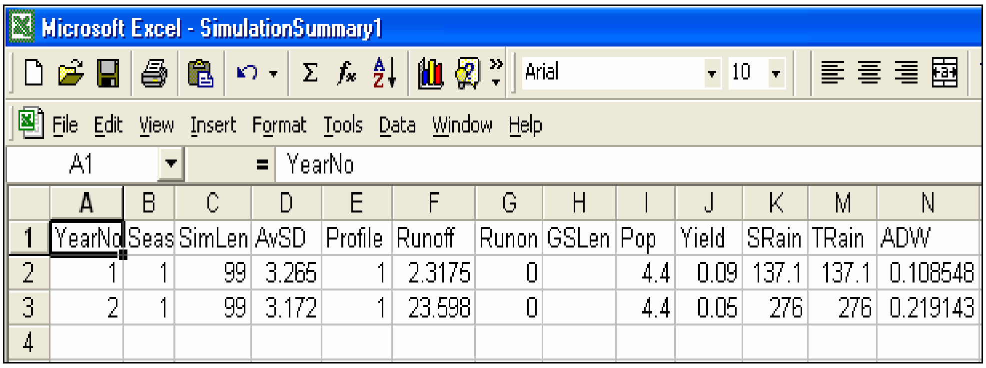


Figure 1.15. Sample of the SimulationSummary1 file

1.4.6 Working with output file

To open output files do the following:

- Open the Program files folder in your computer
- Open the PTv2.3 folder in the Program files folder
- Open the Output folder in the PTv2.3 folder
- In the right pane open the output files (Figure 1.16)

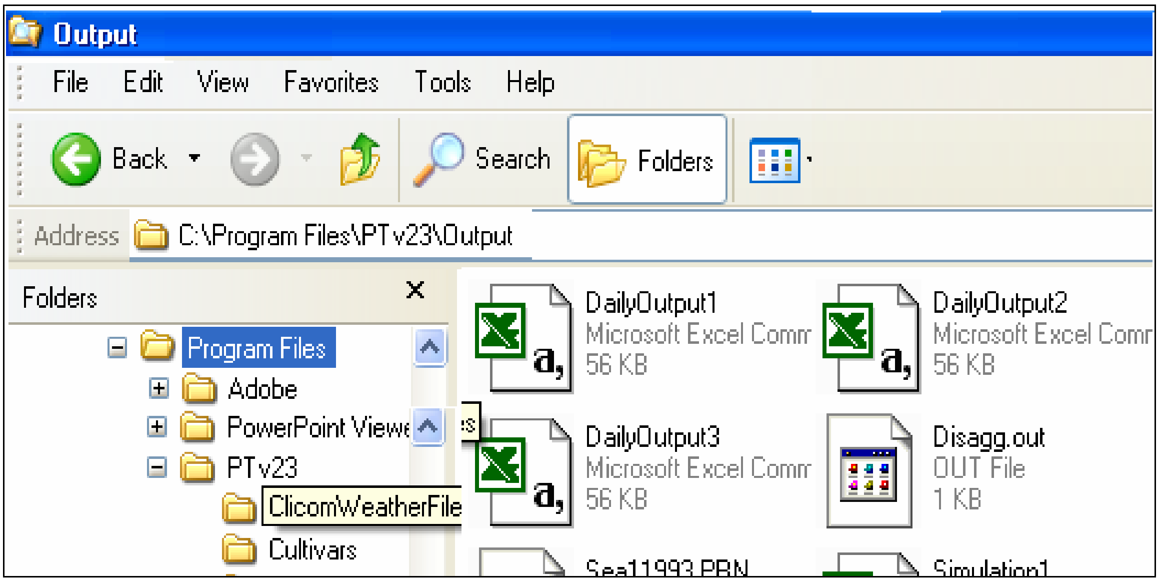


Figure 1.16. Opening the output files