NATURAL RESOURCES SYSTEMS PROGRAMME

***PROJECT REPORT*[1]**

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R8088A

Report Title

Soil and water conservation.

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4. Soil and Water Conservation

Objectives of the module

Having completed this module, students will be able to:

- Understand the effect of ridging (soil & water conservation) on depression storage and generation of surface runoff.
- Understand the effect of bund height (e.g. size of ridges) on profile moisture and consequently maize crop yield.
- Understand the effect of ground cover (including mulching) on soil evaporation/evapotranspiration.
- Understand the effect of soil bulk density (proxy for extent of soil compaction) on surface runoff.
- Understand the effect of texture of surface soil layer(s)/horizon(s) (e.g. sand vs. clay) on surface runoff and infiltration.

Requirements for the module

Module 4: Weather data

- Soil profile description details
- Location of the area, size of the area under cultivation, slope, surface characteristics and surface cover percentage.

4.1 Tillage

Tillage is all the work a farmer does to prepare his land for planting; i.e. all the operations undertaken to prepare a seed bed so the seeds can germinate properly. The word cultivation is usually used to describe all the work that is done after planting to keep the crop free of weeds, and aerate the soil.

4.1.1 Minimum Tillage

In recent decades, the possible adverse effects of conventional tillage have become increasingly apparent and attention has been devoted to alternative management methods. Many of these alternatives have been based upon the principle of reducing the number and intensity of tillage operations, that is, minimum tillage or reduced cultivation (Briggs and Courtney, 1989).

Minimum tillage is defined in many ways. It refers to soil management practices, which seek to minimize inputs and soil erosion, to maintain soil moisture and reduce soil disturbance and exposure. The terms “minimum tillage”, “zero tillage” and “direct drilling” are normally used to mean that there is no preparatory cultivation and that the seed is placed in the soil by a special drill which opens a slit only sufficiently wide and deep to receive the seed and to provide for its satisfactory coverage while the term “reduced tillage” is used to cover a wide range of practices, including the cultivating of relatively narrow strips for the establishment of row crops (Webster and Wilson, 1980).

Minimum tillage may also be defined as the least amount of tillage needed for quick seed germination and a good crop stand. It is associated with intensive use of pesticides. It is essential that farmers understand the objectives and limitations of tillage because tillage is a major cause of soil erosion and unnecessary tillage is a great expense (Knuti, et al , 1980). The objectives of tillage are temporary soil conditioning, seedbed preparation, water conservation, aeration, weed control and utilization and disposal of crop residues.

4.1.2 Effects of minimum tillage on soil properties

After direct drilling, initially the soil is more compact and has both lower total porosity and fewer large pores than after 2 or 3 years without cultivation (this is the case for perennial crops mainly dealt with by large scale farmers) then, later, there are more continuous pores and channels. The soil moisture content near the surface tends to be higher in the absence of cultivation, probably partly due to the increase in organic matter content that occurs.

The lack of tillage provides a more stable habitat for the soil organisms, while increased organic matter inputs from crop cover and crop residues supply a more constant food source for the fauna. As a result, population of soil organisms increases markedly. In some places, combining mulching with reduced tillage has been found to be advantageous, especially in conserving soil moisture and preventing the rain from breaking down aggregates.

Earthworm’s channels also facilitate rooting so that root expansion is rarely inhibited to any great extent in direct drilled soils. Finally, the increased biological activity helps to stabilize the soil structure, making it less prone to erosion.

4.2 Conservation Tillage

Conservation Tillage is about using a number of practices in combination which conserve soil, moisture, fertilizer, seeds, energy, time, and money. With Conservation Tillage, Minimum Tillage is used to plant the crop but other simple techniques are also applied which:

- Protect the soil from the damaging effects of rain splash;
- Reduce run off and keep more of the rain on the fields, this is called rain harvesting;

- Make the best use of costly fertiliser and seeds;
- Allow farmers to finish land preparation well before the rains come so they are ready in good time.

This umbrella term can include reduced tillage, minimum tillage, no-till, direct drill, mulch tillage, stubble-mulch farming, trash farming, strip tillage, plough-plant. The application is mainly in mechanized high production farming with good rainfall, or for the control of wind erosion where there is large-scale mechanized cereal production. It is less applicable to low input level crop production, or subsistence agriculture.

Identification of soil compaction and its limitations to root growth is usually done under three criteria

- Through soil observation in which dark soil streak and water ponding and runoff indicate soil compaction on surface layers. Increased power requirement especially in deep cultivation and low rate of water infiltration indicate below ground soil compaction.
- Through plant observation where crop emergence and growth is uneven. Reduced plant heights started growth is indication of both below ground and surface soil compaction.
- Through soil investigation in which a soil probes penetrometer on small diameter sampling tube may be used to detect compacted soil zones.

4.2.1 Soil and Water Conservation in Mountainous Areas

There are various techniques of conserving soil and water in the mountainous areas. Some of the techniques include alley cropping, grass strips, level bunds, thrown uphill level terrace (Fanya juu), graded bunds, bench terrace, cut and carry, grassland improvement, tree planting, micro basin and normal tillage.

The advantages of the mentioned soil and water conservation techniques include improved soil aeration, control of weeds, increased water infiltration, control of evaporation, minimizes soil erosion and runoff, assist in incorporation of crop residues.

4.2.2 Effects of reducing soil evaporation on evapotranspiration

Evaporation

Evaporation is the process whereby liquid water is converted to water vapour (vaporization) and removed from the evaporating surface (vapour removal). Where the evaporating surface is the soil surface, the degree of shading of the crop canopy and the amount of water available at the evaporating surface are other factors that affect the evaporation process. Frequent rains, irrigation and water transported upwards in a soil from a shallow water table wet the soil surface. Where the soil is able to supply water fast enough to satisfy the evaporation demand, the evaporation from the soil is determined only by the meteorological conditions. However, where the interval between rains and irrigation becomes large and the ability of the soil to conduct moisture to pear the surface is small, the water content in the topsoil drops and the soil surface dries out. Under these circumstances the limited availability of water exerts a controlling influence on soil evaporation. In the absence of any supply of water to the soil surface, evaporation decreases rapidly and may cease almost completely within a few days.

Evapotranspiration

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Transpiration consists of the vaporization of liquid water contained in plant tissues and the vapour removal to the atmosphere. Transpiration, like direct evaporation, depends on the energy supply, vapour pressure gradient and wind. Therefore, apart from the water availability in the topsoil, the evapotranspiration, a combination of evaporation and transpiration, from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops as the crop canopy shades more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process. In Figure 4.1 the partitioning of evapotranspiration into evaporation and transpiration is plotted in correspondence to leaf area per unit surface of soil below it. At sowing nearly 100% of ET comes from evaporation, while at full crop cover more than 90% of ET comes from transpiration.

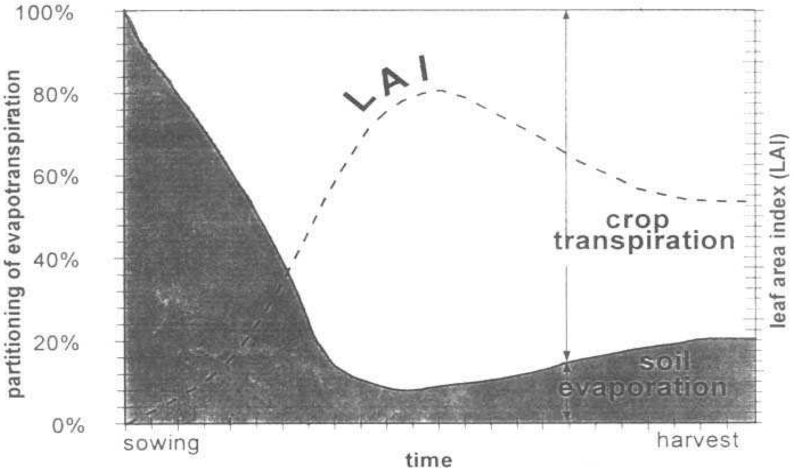

Figure 4.1: Change in partitioning of evapotranspiration with crop growth

Where field conditions differ from the standard conditions, correction factors are required to adjust ETc. The adjustment reflects the effect on crop evapotranspiration of the environmental and management conditions in the field.

4.2.3 Surface roughness

After cultivation the soil surface is rough, and clayey soils have a rough surface, especially just after ploughing (Figure 4.2). The amount of water which can be stored on the soil before runoff takes place is large at this time. It is difficult to estimate surface storage as the lowest point between depressions controls the depth at which flow starts, and this is not known. However, from Figure 4.2 and 4.3 an idea of difference in amount of storage can be obtained by calculating the area under the horizontal line which touches the highest clods.

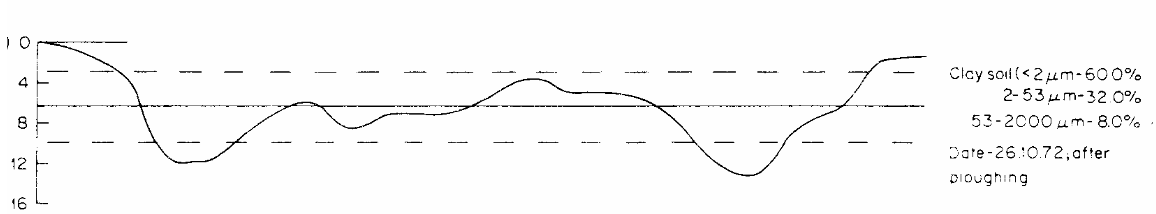

Figure 4.2. Surface depression storage for a clay soil

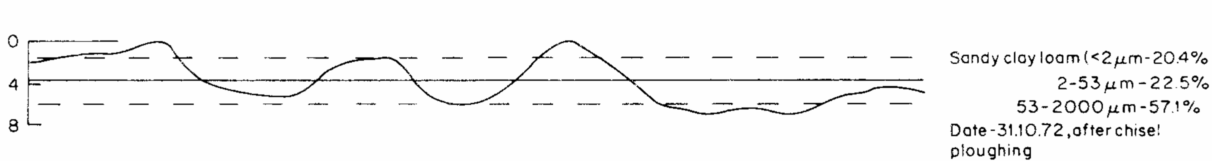

Figure 4.3. Surface depression storage for a sandy clay loam

After ploughing the clay soils have 1.6 – 2.3 times more storage volume than does the sandy clay loam, and the mean depth from the horizontal is much greater. The surface is generally not worked for sometime after ploughing to allow clods to weather and break down and the field is then harrowed to produce a fine tilth and the seed is drilled. Surface roughness is least after drilling and rolling of the seed bed and differences between soil types are then smallest, the clay having only 1.1 times more storage.

4.3 Exercises

4.3.1 Exercise 1: Soil Evaporation and Evapotranspiration

Step one: Open PTv23

- Double-click on the PTv2.3 model icon, or from the Start task bar go to Programs and from the program list click PTv2.3. The PTv2.3 main window and Welcome screen will appear as shown in Figure 4.4.

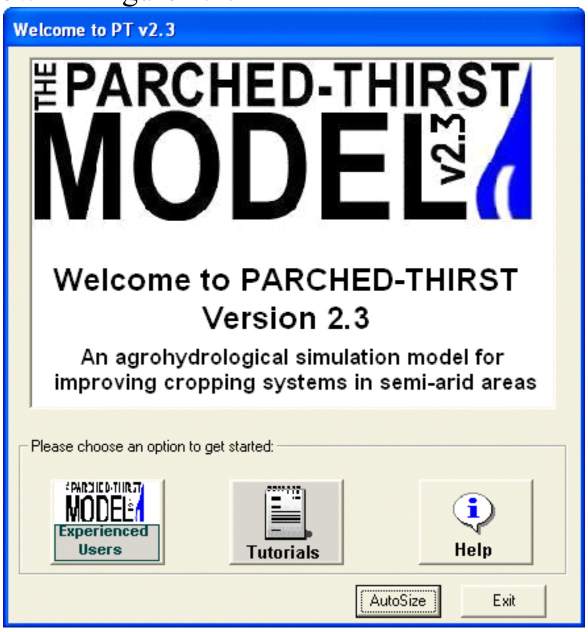

Figure 4.4. PT v2.3 Welcome screen

- On the Welcome screen, click on the Experienced Users button to be taken straight to the main system window of PTv2.3.
- On the main windowpane select System menu and click on Open as shown in Figure 4.5. Select the file named Soil Evaporation (a RWH system) and click on the Open button to open the RWH system of figure 4.6.

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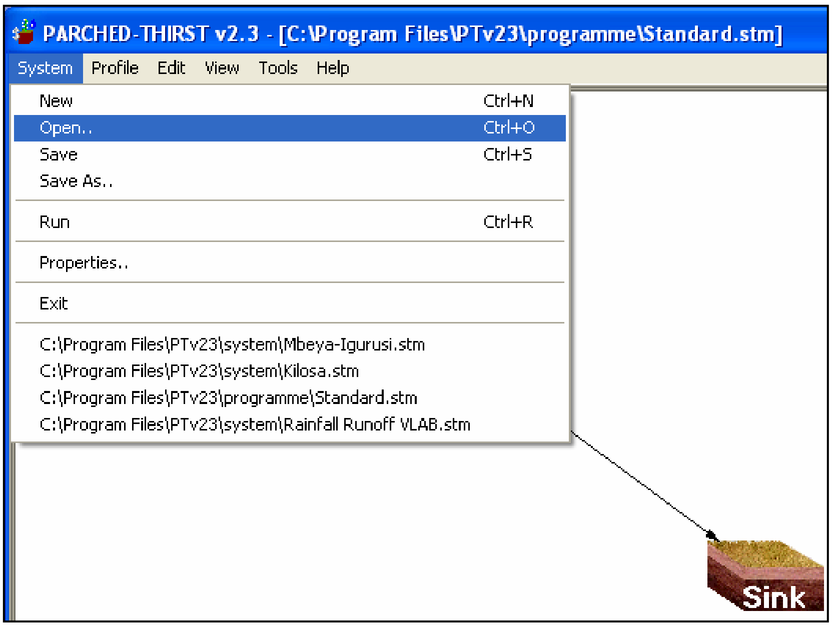

Figure 4.5. Opening systems from the system menu

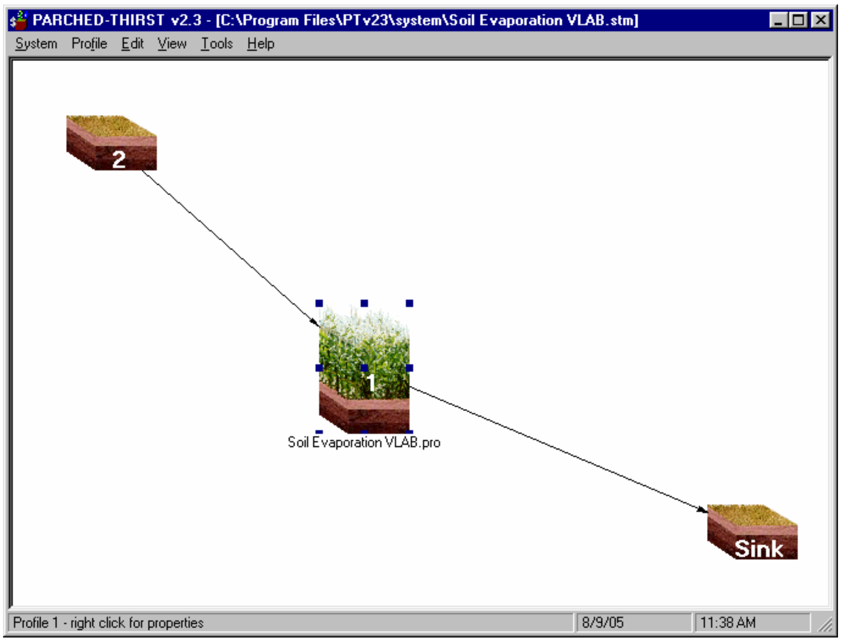

Figure 4.6: A simple RWH system in which runoff is harvested from Profile 2 (the catchment area/runoff generating area) and directed to Profile 1 (the cropped area).

Step two: Check soil properties settings

- Double click on the Soil Evaporation VLAB profile icon (Box with 1) to open the profile properties window. You can also open the properties window by Right clicking on the profile and then clicking on properties of profile 1 as shown in figure 4.7.
- Click on the Soil Surface tab to view the window figure 4.8.

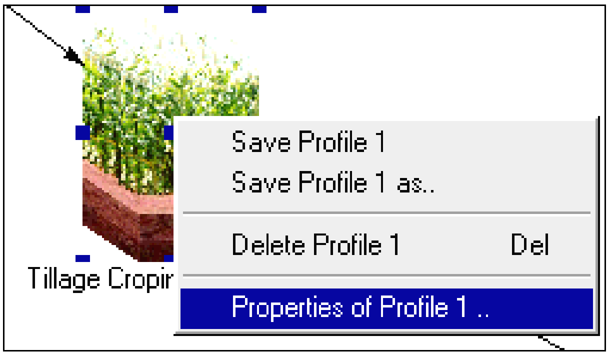

Figure 4.7: Opening the profile properties window

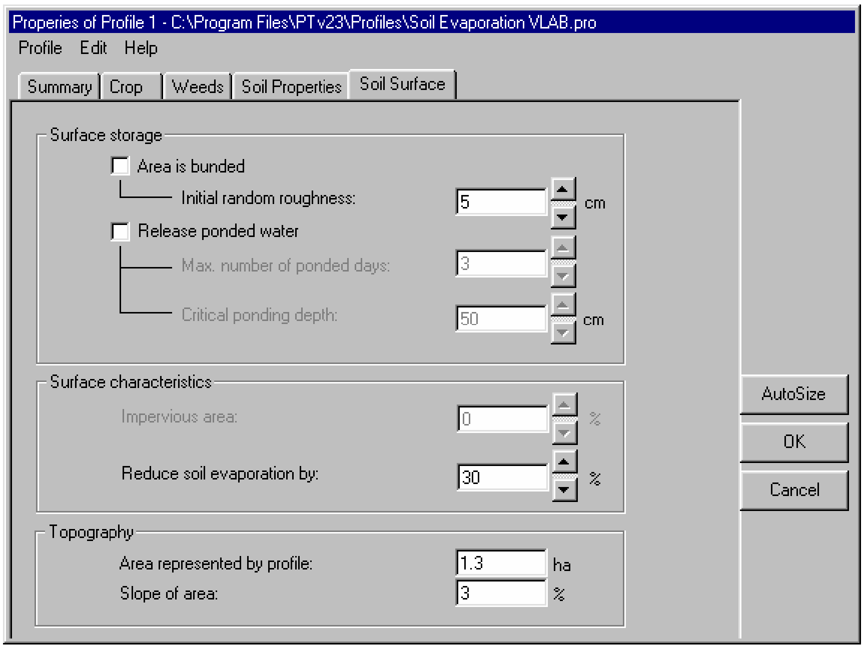

Figure 4.8: Profile properties window

- Under Surface storage and Topography, leave the settings as they are (Figure 4.9).
- Under Surface Characteristics, change the value in the Reduce soil evaporation by text box from 30 to 0 (Use the navigation button on the right of the textbox). Click OK to return to the main window pane.

Step Three: Run Simulation

- Go to the system menu and click on Run. You will be prompted to save your output files twice, as shown in the Figure 4.10 below.

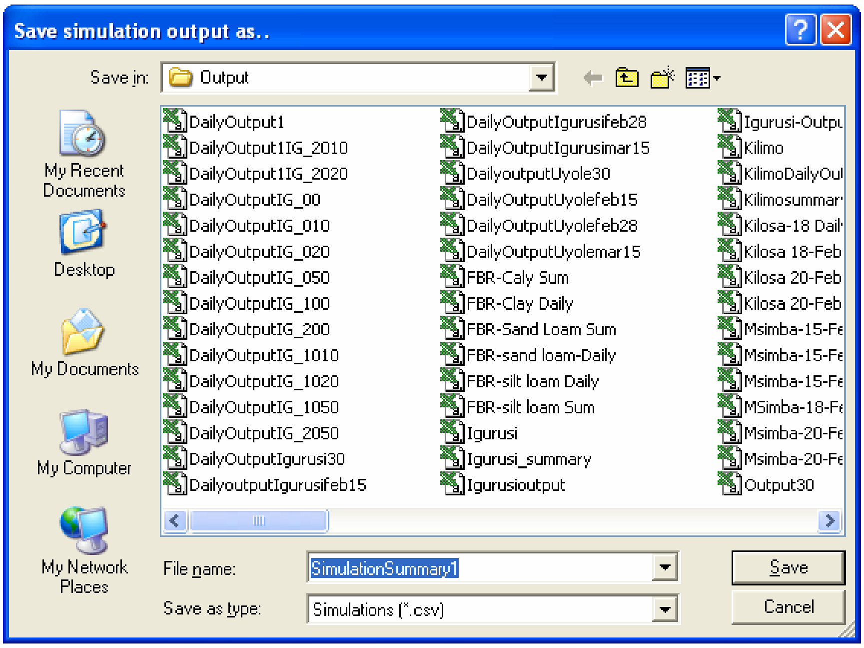

Figure 4.9. Saving output simulation summary

- Name the output summary (first window) as Soil Evaporation Summary 0pc and the daily output files (second window) as Soil Evaporation Daily 0pc.
- On the see simulation graphics? Dialogue box click on Yes (Figure 4.10) to view simulation graphics.
- Under Speed of simulation (figure 4.11) select Fast.

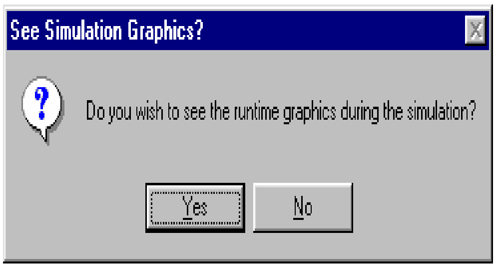

Figure 4.10 Simulation graphics dialogue

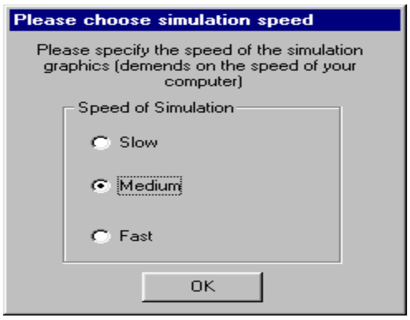

Figure 4.11 Simulation Speed dialogue

- Click OK to continue. You will see simulation graphics of figure 51 below.

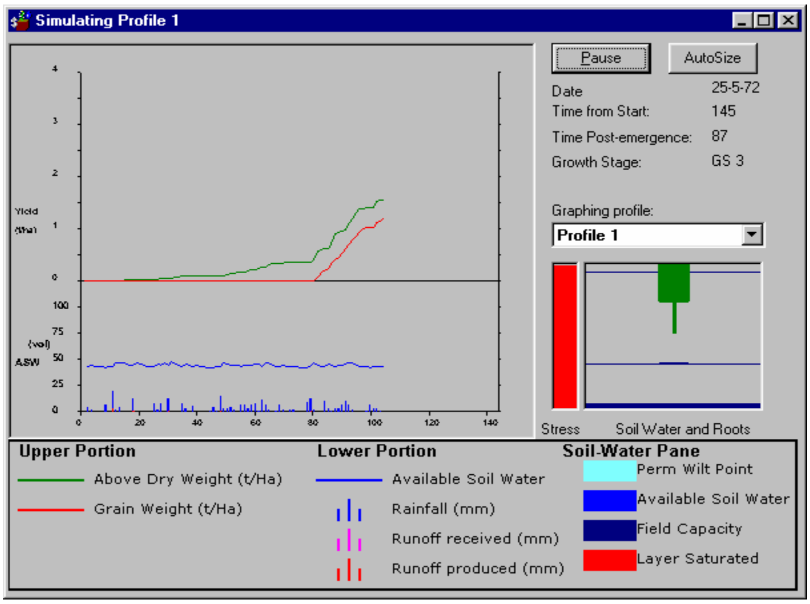

Figure 4.12. Simulation graphics

- Wait until you see the message "End of Simulation." Click OK to view the simulation output summary graphs of Figure 4.13 below.
- Click on the ET button and record in a table the ET for season 1 (Red) for all the four years of simulation. Click Exit to return to the main window pane.

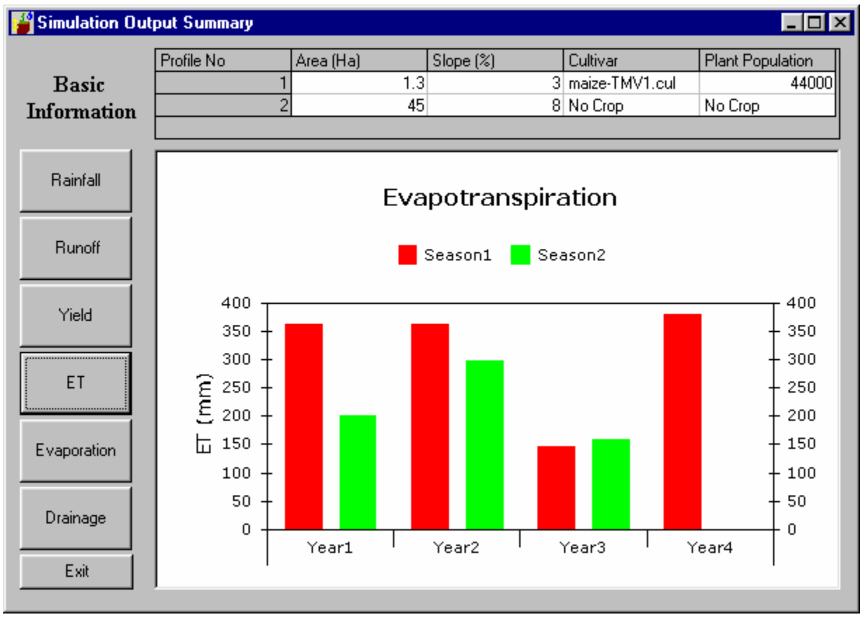

Figure 4.13. Output summary window

- Open again the profile 1 Properties window and set the soil surface properties to 15% (Follow the same procedure). Run the simulation and record ET in the same table as in above.
- Repeat this procedure by reducing soil evaporation by 30%, 45%, 60%, 80% and 100% , then Summarise the results in a single table as shown in Table 4.

Assignment

Plot the Percentage reduction in soil evaporation against Average evapotranspiration to obtain a chart similar to that of Figure 4.14 and comment on your results.

Table 4:1. Summary table – Soil Evaporation

% Reduction	Evapotranspiration (mm)				
	Year 1	Year 2	Year 3	Year 4	Average
0	361	362	146.8	379	312.2
15					
30					
45					
60					
80					
100					

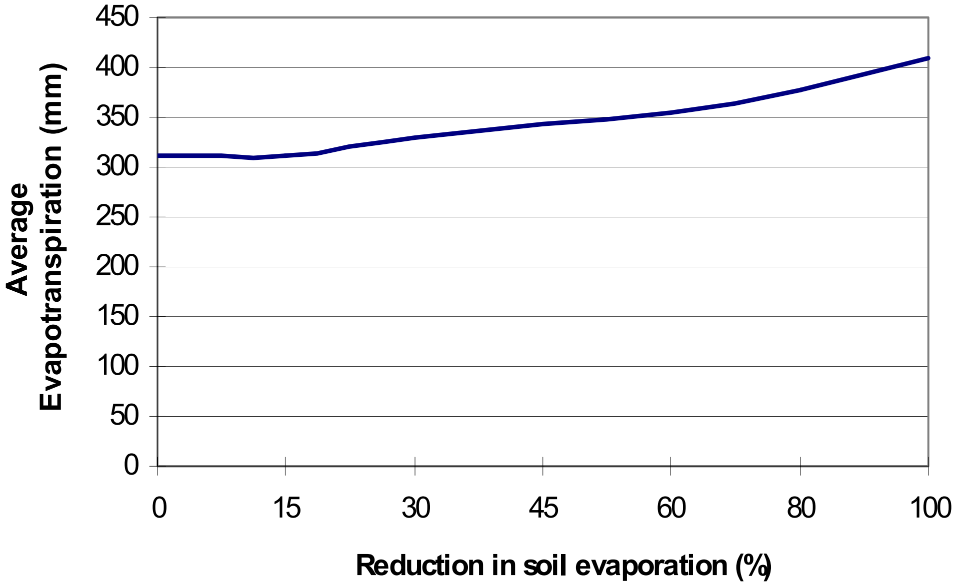

Figure 4.14. Effect of reducing Soil evaporation on evapotranspiration.

4.3.2 Exercise 2: Effect of tillage and ridging on runoff generation

Step One: Start PTv2.3

- Start PTv2.3 and open the file Tillage system of Figure 4.15 (Procedures are similar to those in exercise1).
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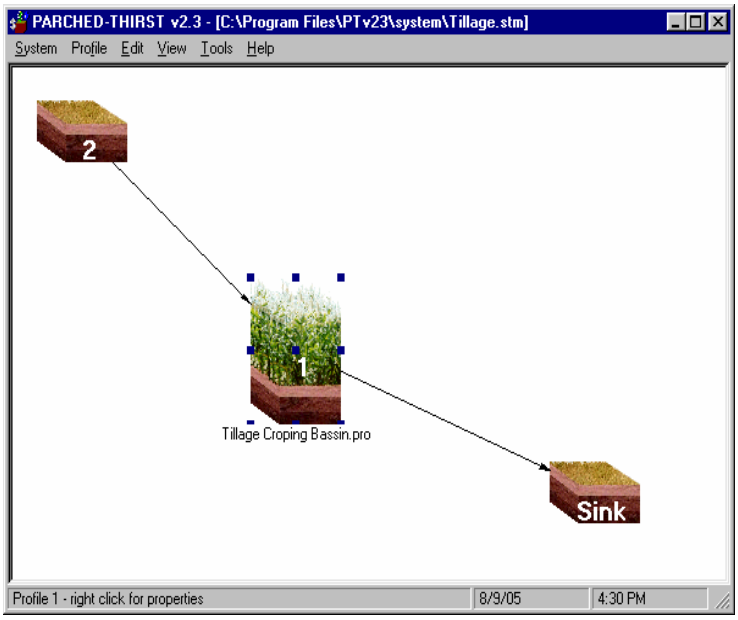

Figure 4.15. Tillage system main window

- Open profile 1 properties window (Same procedure as in exercise 1) and click the soil surface tab. This time, we will be dealing with the surface storage properties; i.e. all other properties will remain unchanged.

Step Two: Setting tillage and runoff parameters

- Under Surface Storage uncheck the Area is bunded checkbox (see Figure 4.16), to allow the model to deal with initial surface roughness. Set Initial random roughness to 1 cm, leave the Release ponded water check box unchecked. Click OK to return to main window.

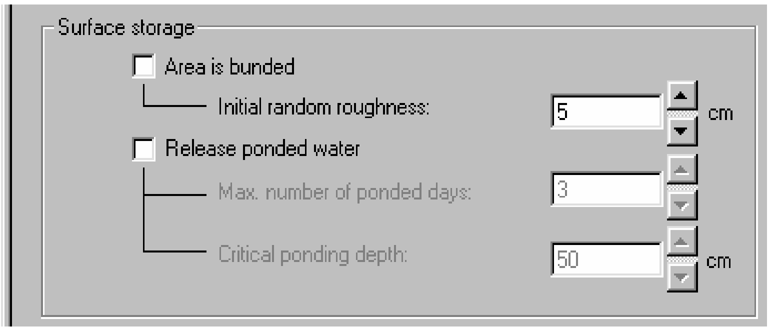

Figure 4.16. Surface storage panel

- Run the system simulation (name the output summary and the daily output files as Tillage summary 1 cm and Tillage daily 1 cm respectively). Record the runoff from the output summary (Figure 4.17) for every year as shown in Table 4.2.

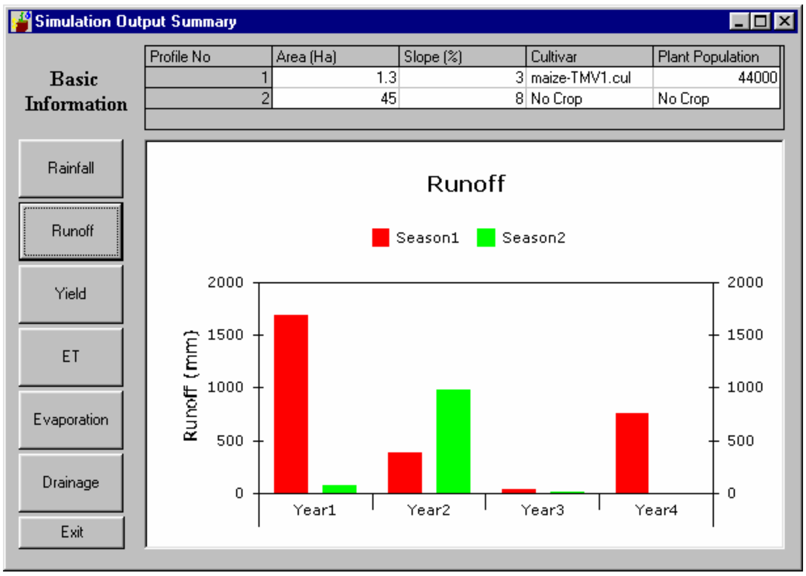

Figure 4.17. A screen-shot of Output Summary in PT

- Re-run the system for different surface roughness and record all the runoff data in Table 4.2.

Table 4:2. for filling runoff amounts based on different tillage (surface roughness) settings.

Roughness (cm)	Runoff (mm)				
	Year 1	Year 2	Year 3	Year 4	Average
1	1650	350	-	750	
5					
10					
15					

Step Three: Study the effects of ridging on runoff generation
Under Surface Storage, check now the Area is bunded checkbox (Figure 4.18), and increase the bund height to 10 cm. Leave all others settings unchanged

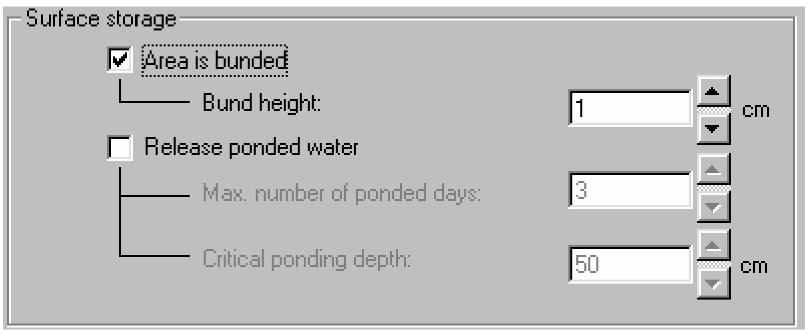

Figure 4.18. Area is bunded check box checked

- Run the simulation and record the output runoff and the yield from the output summary into Table 4.3 and Table 4.4 respectively.
- Repeat the same procedure for bund height = 20, 30, 40,…100cm

Table 4:3. Effect of bunding on Runoff generation

Bund Height (cm)	Runoff (mm)			
	Year 1	Year 2	Year 3	Year 4
10	1500	170		650
20				
30				
40				
50				
60				
70				
80				
90				
100				

Table 4:4. Table of results – Effect of bunding on yield

Bund Height (cm)	Yield (t/ha)			
	Year 1	Year 2	Year 3	Year 4
10	0.55	0.78	0.06	0.27
20				
30				
40				
50				
60				
70				
80				
90				
100				

Assignment

- Plot roughness vs. runoff .The patterns of the graphs should look like that of Figure 4.19.
- Plot bund height versus runoff to obtain graphs with patterns similar to those shown in Figure 4.20 and Figure 4.21.
- Analyse your results in Figures 4.19, 4.20 and 4.21; and draw up conclusions.

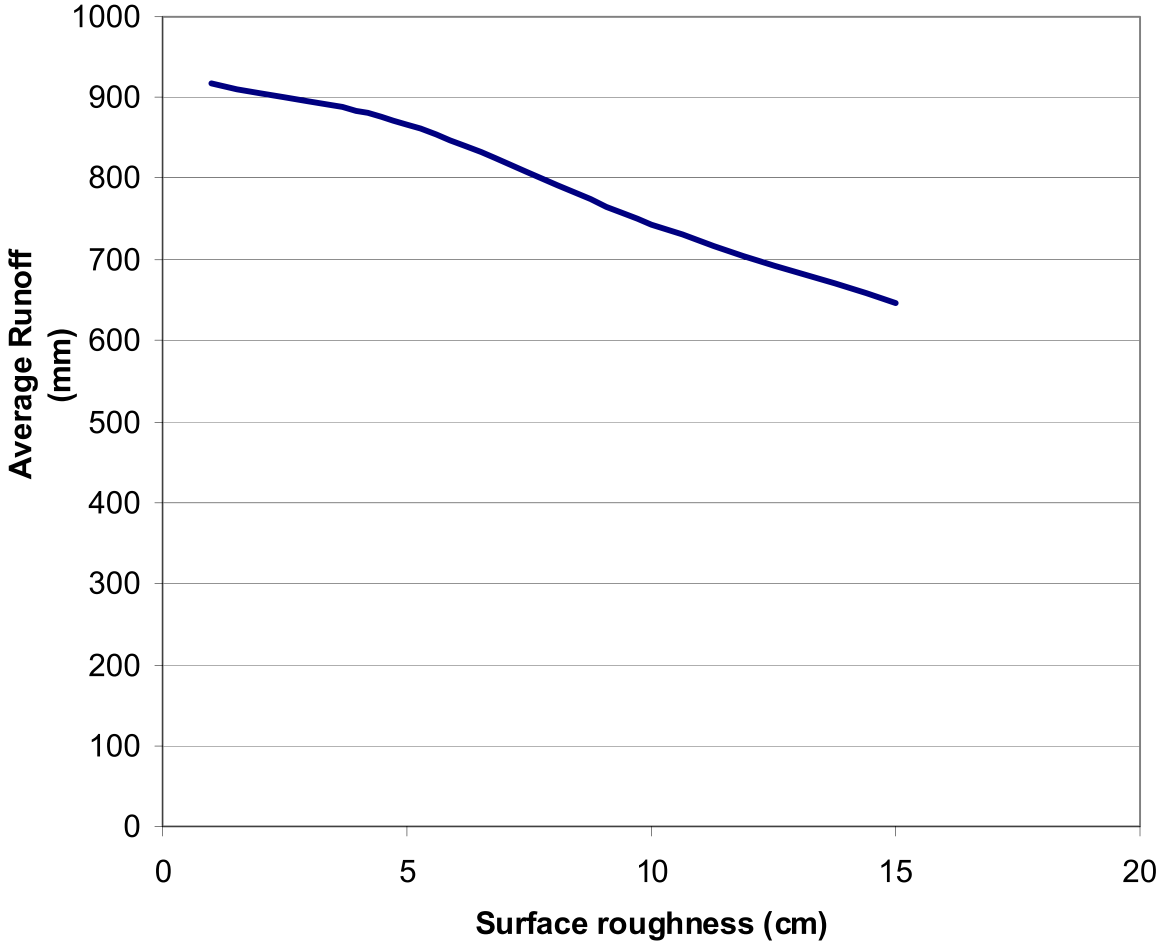

Figure 4.19. Expected relationship between surface roughness (depressions) and runoff

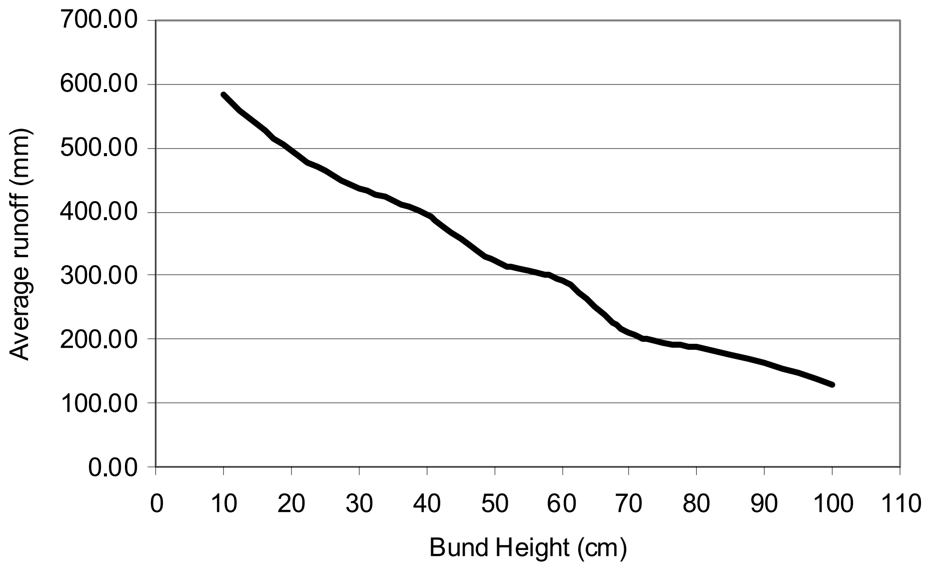

Figure 4.20. Bund height (depressions) versus runoff amount

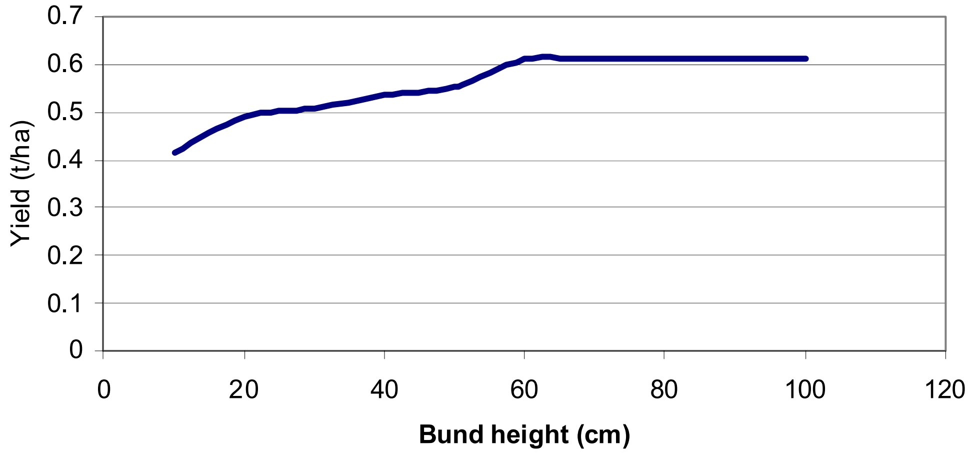

Figure 4.21. Effects of bund heights (depressions) on maize yield

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4.4 References

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