Lab 12. Dynamics of Soil Systems

In this week's lab you will run a model that simulates the dynamic interactions of soil-plant-atmosphere systems. Your task will be to interpret the output of the model to assess the importance of soil/rooting depth on yield and the impact of land surface management on drainage.

Objectives

- Use a dynamic simulation model to understand the interactions of soil, plants and the atmosphere
- Review the four stages of the water budget and the influence of soil evaporation and transpiration on these stages
- Review the impact of soil depth and crop rooting depth on the water budget and crop yield.

There are two sections in this lab. The first section, RUNNING GAPS, is designed to introduce the user to the mechanics of running the GAPS software. The tutorial, USING GAPS, introduces the user to some of the different ways in which soil-plant-atmosphere simulation models can be used. This section includes a series of questions whose primary purpose is to suggest the manner and extent to which simulation models can be used to gain a better understanding of soil-plant-atmosphere systems. These questions are also meant to promote further interest in understanding soil-plant-atmosphere systems.

We assume the WinGAPS executable file as well as input files and scenarios are in one directory.

RUNNING GAPS

1. Once you are in the correct directory (C:\GAPS_260), open WinGAPSv1.1.exe and the Main Menu of GAPS will appear. Maximize the size of the main window.

   The Menu Bar at this level includes 6 choices: File, Scenario, Run, Window, and Help.
   Help is currently not implemented.

3. Select **Scenario**. Select **Load Scenario**. Select **TUTI.SET**.

   When you are selecting files for GAPS to use, a window will appear. At the top of this window is the type of file you are selecting (Scenario). In this case, we are selecting a "scenario" file, which can have any name and always has the extension *.SET. A SCENARIO file contains a set of specifications used to execute a specific simulation using GAPS.

4. Select **Run**.

   At the top of the screen, a message line appears. While GAPS is running, a "Running simulation" window will be open. The simulation can be suspended at any time by clicking on pause and reinstated by hitting any other key. When the simulation is done, the "Running simulation" window will disappear from the screen.

5. Select **Window/Close All .** Then select **Scenario/Runtime graphs/Select graphs… .** Deselect **Precipitation** by moving the cursor to it and clicking on it or pressing the space bar. Select **Air temperature**. Select **OK** and the select **Run**.

   Only 4 or fewer graphs may be selected to be seen simultaneously on the screen while running GAPS. If you select more, GAPS chooses 4 among those you've selected.

   When the simulation is done and you are finished viewing the graphs of the simulation results, select **Window \ Close All** to clear the main window of GAPS. Just select **Run** to generate the same results again.

6. There are several different types of output files that can be created and saved using GAPS. In this exercise, we will save a file that summarizes the results of a simulation. Select **Scenario \ Select Output Files \ Model summary**. All model summary files have the extension*.det but you do not have to include the extension in the file name. At the file name prompt, type TUT. Press **Enter**. Now run GAPS again.

    This time when you run GAPS, information about this particular simulation, including some summary simulation results, will be stored in the file TUT1.DET. This file is created at the end of the simulation.

7. Select **File \ Open \ Results file \ Model summary**. Open TUT1.DET.

    The TUT1A.DET file will now appear on the screen. As you can see, it contains a report of the input files you used, the procedures you ran. Some summary results of the simulation are contained in this file.

8. If you wish to print this file, select **File \ Print this file**.

USING GAPS

In this section you are going to use GAPS to quickly evaluate aspects of the atmosphere and soil environment important to crop growth.

In this simulation, we are using daily maximum and minimum temperature, precipitation and radiation from central Illinois from the year 1980. The growth of a relatively early maturing variety of maize is initially being simulated. The maize is being grown on a deep silt loam soil typical of the area.

This first simulation you are executing with GAPS includes components contained in most soil-plant-atmosphere simulation models.

Climate variables such as air temperature and precipitation are used to control or drive certain aspects of crop growth and consequently are called driving variables.

The crop is described at any time in the simulation by one or more equations of state. In this case, the crop is described both in terms of the weight of one of its components (grain dry matter) and the morphology of another of its components (leaf area index).

1. Run GAPS with **Air temperature, Precipitation, Leaf area index**, and **Yield** view graphs selected.

Q1.1 On approximately what day does the corn emerge and on what day do the leaves senesce (leaf area index goes to 0)? When does grain growth (yield information) begin and end? When is the crop harvested?

Q1.2 What is the highest and lowest temperature during the crop growing season? Could the growing season have been extended and still avoided temperatures of 0 °C or less?

Q1.3 How would you describe the distribution of precipitation over the year relative to precipitation during the growing season and the yield formation stage?

2. Close all graphs by selecting **Window / Close all** from the main menu. Select **Air temperature, Soil temperature by Layer, Accumulated Degree Days** and **Leaf area index** runtime graphs. Run GAPS.

    Notice the values for soil layer are not evenly distributed on the y-axis on the **Soil Temperature by Layer** graph. When the temperature of the top three soil surface layers is consistently above 10 degrees C, pause the simulation. (If you miss this, just stop the simulation, close all windows and Run GAPS again). Record the day of the year. Then resume the simulation.

Q1.4 On what day does the plant emerge? Is this later than the day you recorded above? Should the farmer have planted their crop sooner this year?

Q1.5 How many degree days have accumulated when the plant senesces. Could the farmer have extended the growing season this year by choosing a corn variety that took longer to mature?

3. Return to the **Runtime graphs** and select **Potential ETP / day, Net radiation, Potential transpiration / day** and **Leaf area index**. Run GAPS.

Q1.6 How does potential ETP (evapotranspiration) compare with net radiation?

Q1.7 How does potential transpiration compare with LAI?

4. Return to the **Runtime graphs** and select **Potential transpiration / day, Actual transpiration / day** and **Actual soil evaporation / day**. Run GAPS.

Q1.8 When is potential soil evaporation at its highest and lowest? Why?

Q1.9 How does actual soil evaporation compare to potential soil evaporation? How does actual transpiration compare to potential transpiration? (To get a better feel for this, select Transpiration Ratio and Evaporation Ratio from the view graph menus).

5. Return to the **Runtime graphs** and select **Precipitation, Soil water content by layer, Evaporation / day and Rooting depth**. Select **Run**.

Q1.10 What happens to the soil water content after it rains in the first few months of the simulation?

Q1.11 What happens to the soil water content as the crop begins to grow?

6. Return to the **Runtime graphs** and select **Soil water content by layer**, **Transpiration Ratio, Leaf Area Index** and **Yield**. Select **Run**.

Q1.12 When might the soil water content be limiting crop growth and how does this relate to the timing of yield formation?

Q1.13 Do you think that water stress might have limited grain yield in this case? Do you think that having a corn variety that grew for a longer time would experience the same degree of water stress?

Q1.14 Looking at this simulation, what might be some ideas as to how the crop might avoid water stress?

7. Test some of your ideas by running the same simulation with a late maturing maize variety, select **Scenario \ Select input file \ Plant**, and load TUT1B.PLT. Run the model and answer questions 1.12-1.14. Try running the same simulation with a late maturing variety with deeper roots by selecting **Scenario \ Select input file \ Plant,** and load TUT1C.PLT. Run the model again and answer questions 1.12-1.14.

In this section we will explore the effects of simulating ETP and plant water uptake on soil water status and fluxes, including drainage. You will be comparing the effects of climate and cropping on drainage in two very different environments: the Illinois / maize system from tutorial 1 and a Nepal/ rice system.

8. Select **Scenario \ Load scenario**. Select TUT2.SET. Run.

Q1.15 Describe briefly how the temperature and precipitation patterns in Nepal differ from those in Illinois.

9. Select the same graphs as in section 6 above, and address questions 1.12-1.14 for the Nepal cropping system.

10. Return to **Runtime graphs** and select **Precipitation, Drainage from bottom of profile, Actual Evap per Day and Actual Trans per Day**. Also, select **Scenario \ Select Output files \ Model summary** and save the results of this simulation as Nepal_with_crop.

Q1.16 Is drainage occurring, and if so, when?

Q1.17 Approximately when are the 4 stages of the water budget occurring? (You might want to run again selecting the **Soil Water content by Layer** graph).

11. Select **Scenario \ Load Scenario** and select TUT2_no_plant.SET. Also, select **Scenario \ Select Output files \ Model summary** and save the results of this simulation as Nepal_without_crop.

Q1.18 is drainage occurring, and if so, when?

Q1.19 Open the two output files and record the values for the water budget. Explain why they differ.

12. Repeat steps 10 and 11 for TUT1_no_plant.SET, and answer questions Q1.16-Q1.19.