

APSIM Training Manual for West Africa

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APSIM 7.4

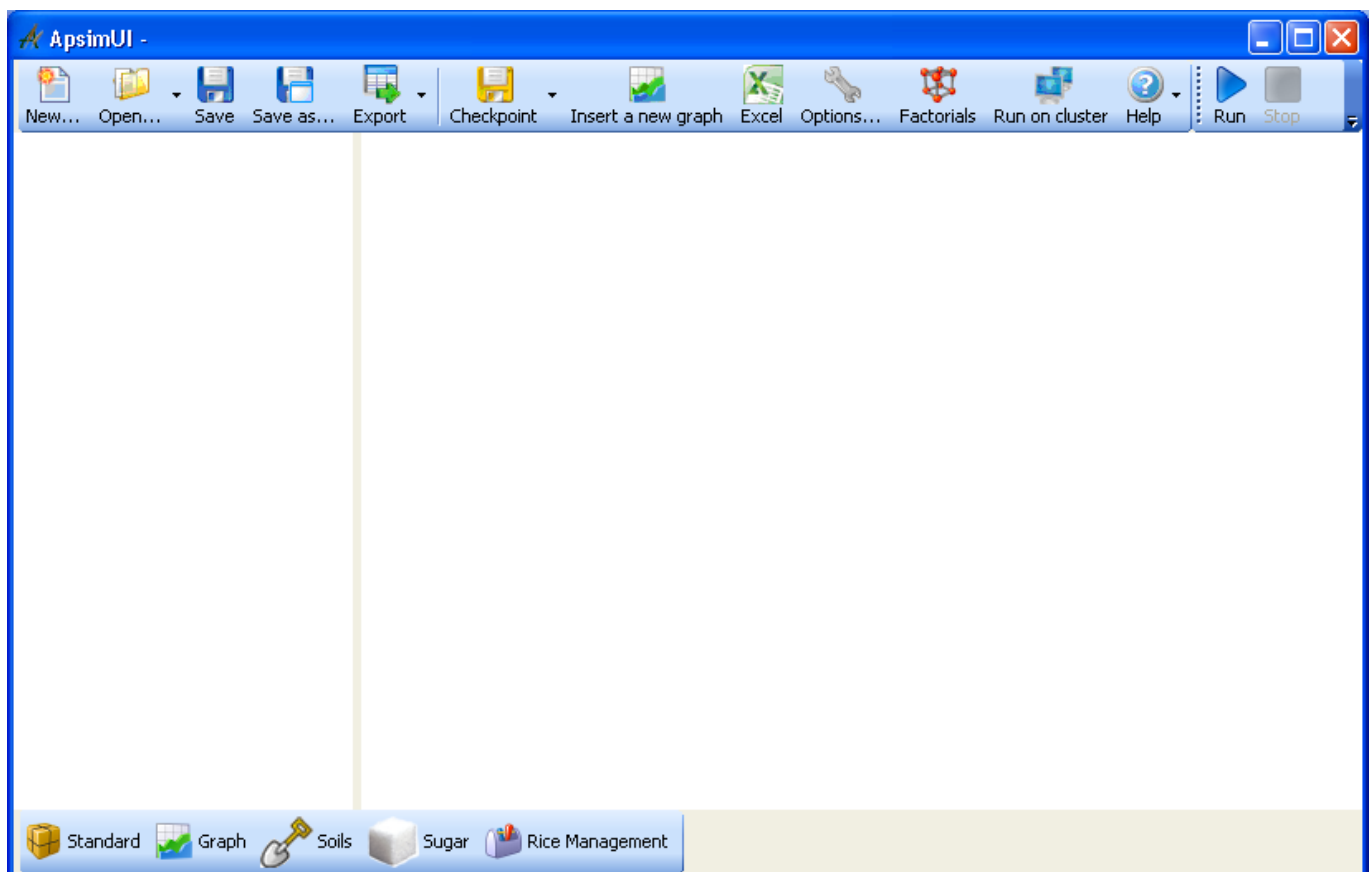
Overview of User Interface

Introduction

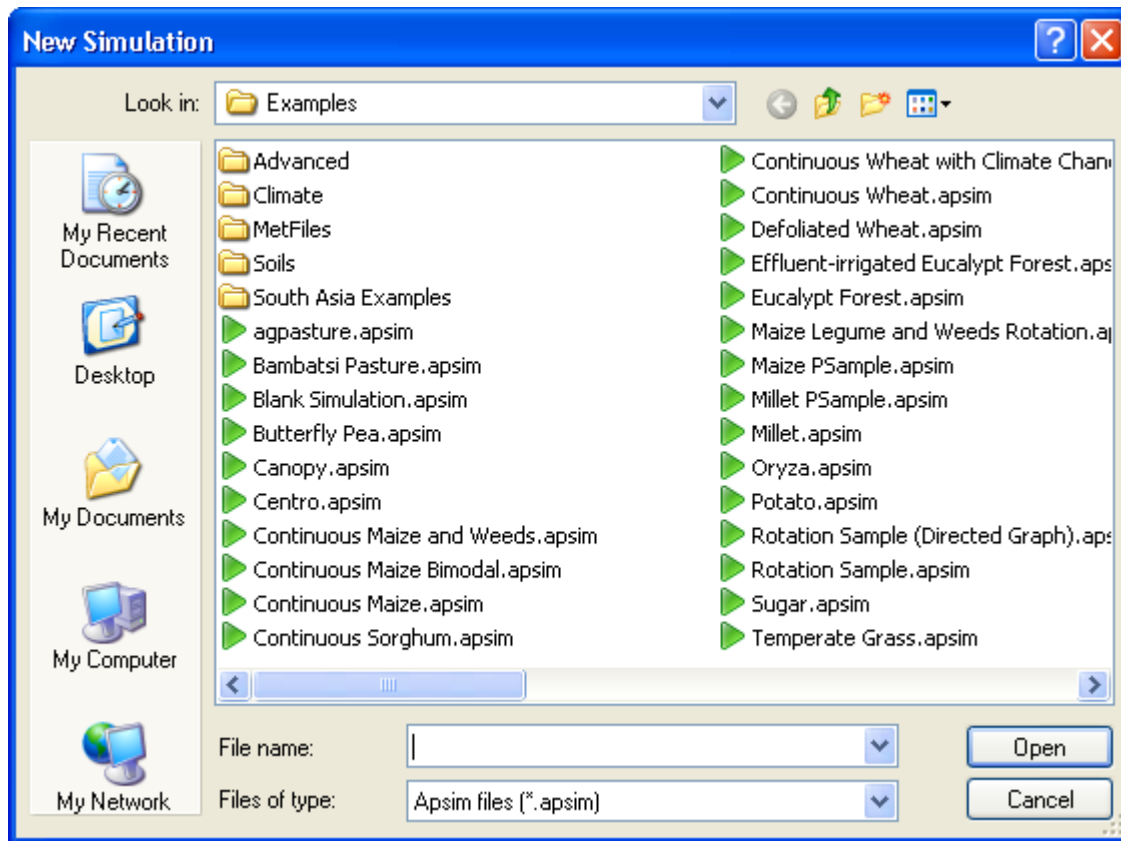
Starting with version 4, APSIM comes with a user interface that lets users configure simulations using a drag and drop paradigm. This interface provides complete access to all APSIM parameters and supports multiple point simulations.

Getting started

When first started (by clicking Windows Start Menu -> All Programs -> APSIM 7.4 r2286 -> APSIM User Interface), the interface shows a toolbar at the top, a toolbar at the bottom and two empty panes in between.

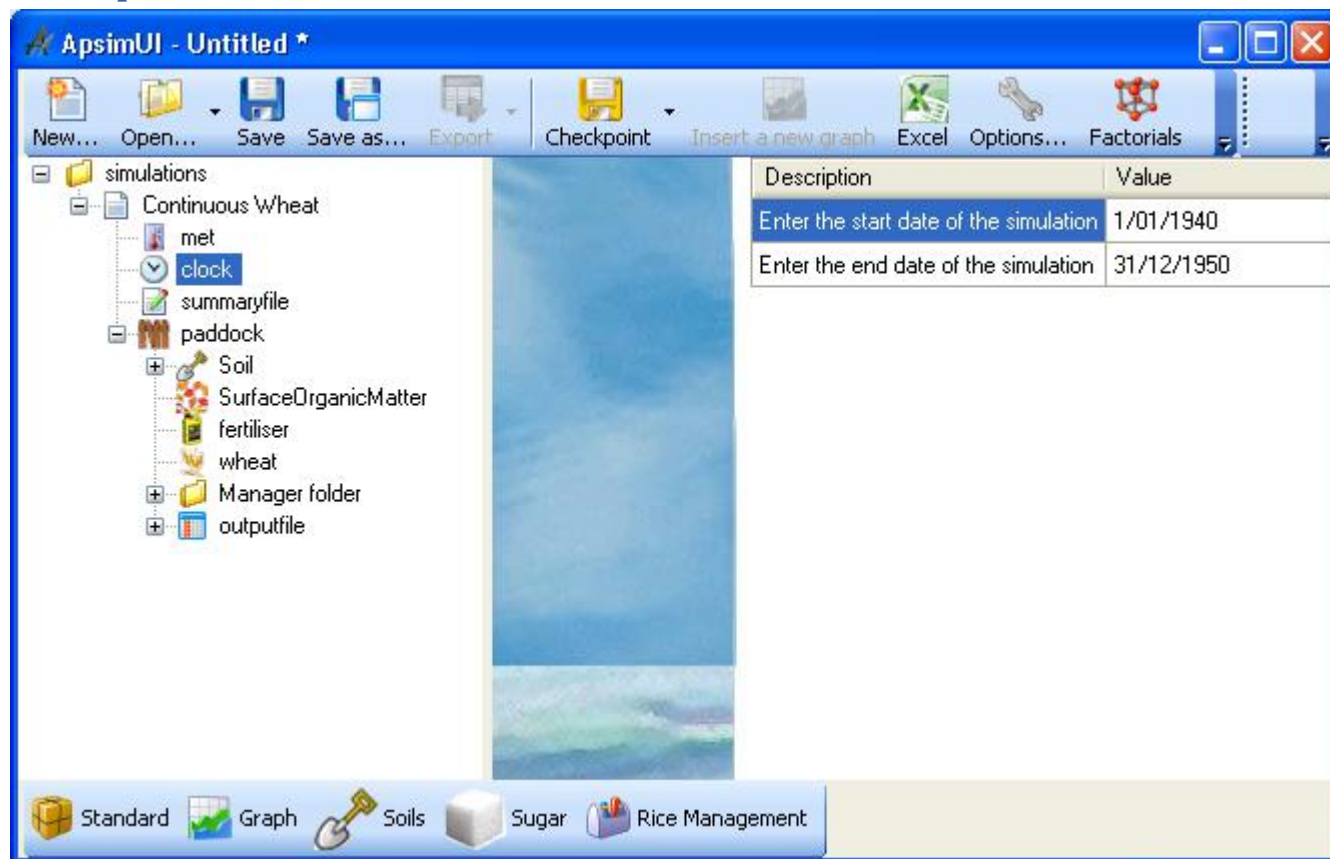


To create a simulation, click **New** on the toolbar at the top of the screen and select a simulation that is closest to the type of simulation you want to build.



This list of default simulations will be expanded over time. In fact, you can add your own default simulations to this list allowing you to reuse common simulations.

Description of a simulation



Simulation Configuration Tree

Properties for selected component (clock)

The tree control on the left shows the components that make up the APSIM simulation (Simulation Tree). Clicking on a component will show the properties for that component on the right. The picture above shows the clock component selected with its properties on the right.

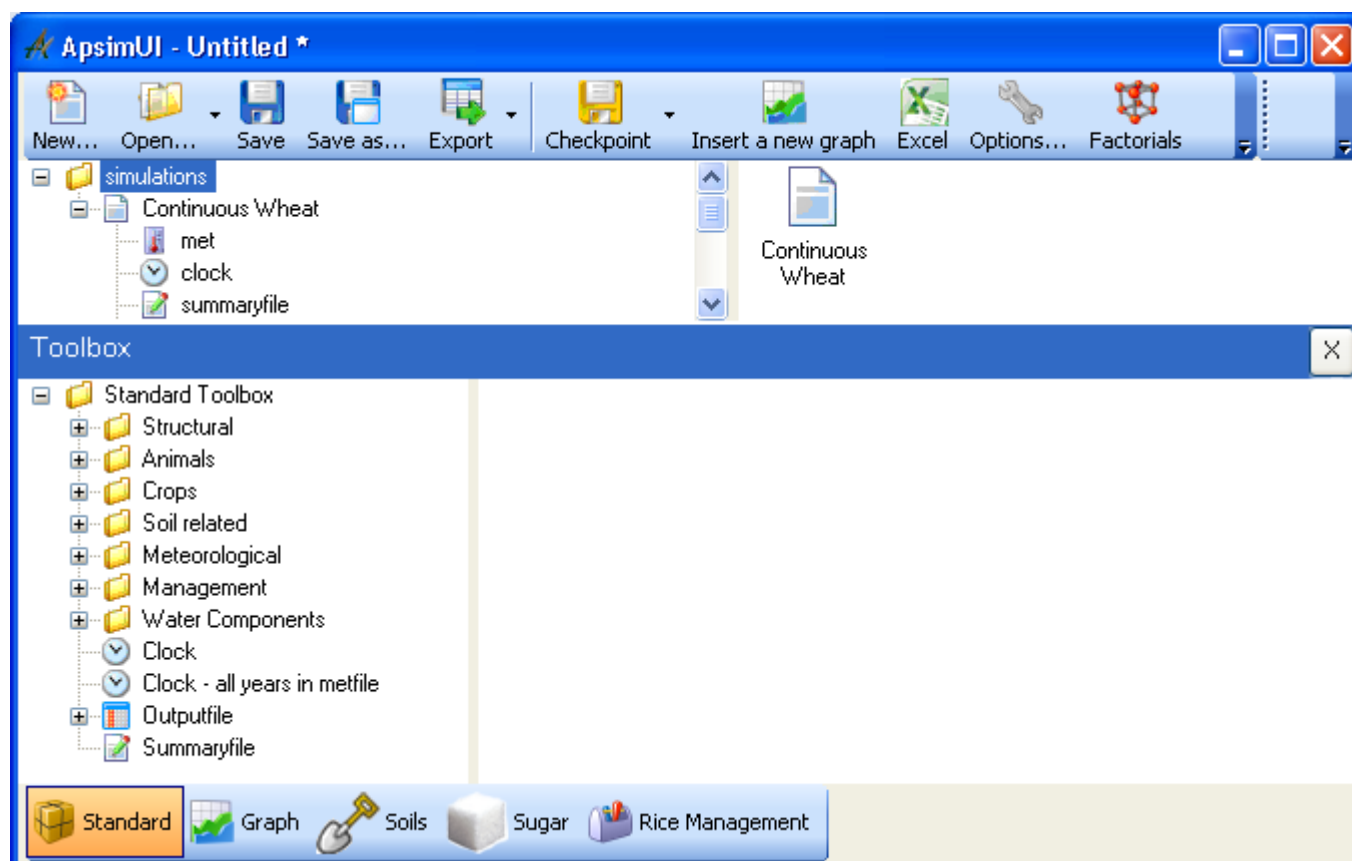
It is recommended that users work their way from top to bottom in the simulation tree, checking each component's properties. Components can be renamed by selecting them, pausing for a second and then clicking again. Components may be deleted from the simulation tree by selecting the component and pressing delete. They can also be renamed or deleted by right mouse clicking on them and selecting "Rename" or "Delete".

Remember though that deleting or renaming components usually has implications for other components. For example, deleting a crop usually means the management of that crop (e.g. sow, harvest etc), under the Manager component, needs to be changed as well.

Note that you can change the order of components in the tree. You do this by right mouse clicking on the component and clicking **Move Up** or **Move Down** or you can hold down the Ctrl key and use the up and down arrow. The order of the components is not usually important it is merely cosmetic. The only exception is the order under the Manager folder component.

Adding components to a simulation via Toolboxes

To add components to a simulation tree, click the **Standard** button on the toolbar at the bottom of the window. This will show the standard toolbox containing many components and simulation entities that can be dragged onto the simulation tree.



A toolbox is a collection of reusable simulation components. By default there are many in the standard toolbox that cover a lot of the standard functionality required. The onus, though, is very much on the user to know which combinations of components work together. It is not expected that first time users will know which components work together. The recommendation is to start with a pre-built simulation and modify it, rather than starting from scratch. If in doubt, contact the APSIM Forum (<https://groups.google.com/forum/#!forum/apsim>).

How to Build, Run and Graph a Simulation

Building, running and graphing simulations

Click on the **New** button and select a simulation that closest matches the simulation you're trying to create.

For this example, choose **Continuous Wheat Simulation**.

Weather

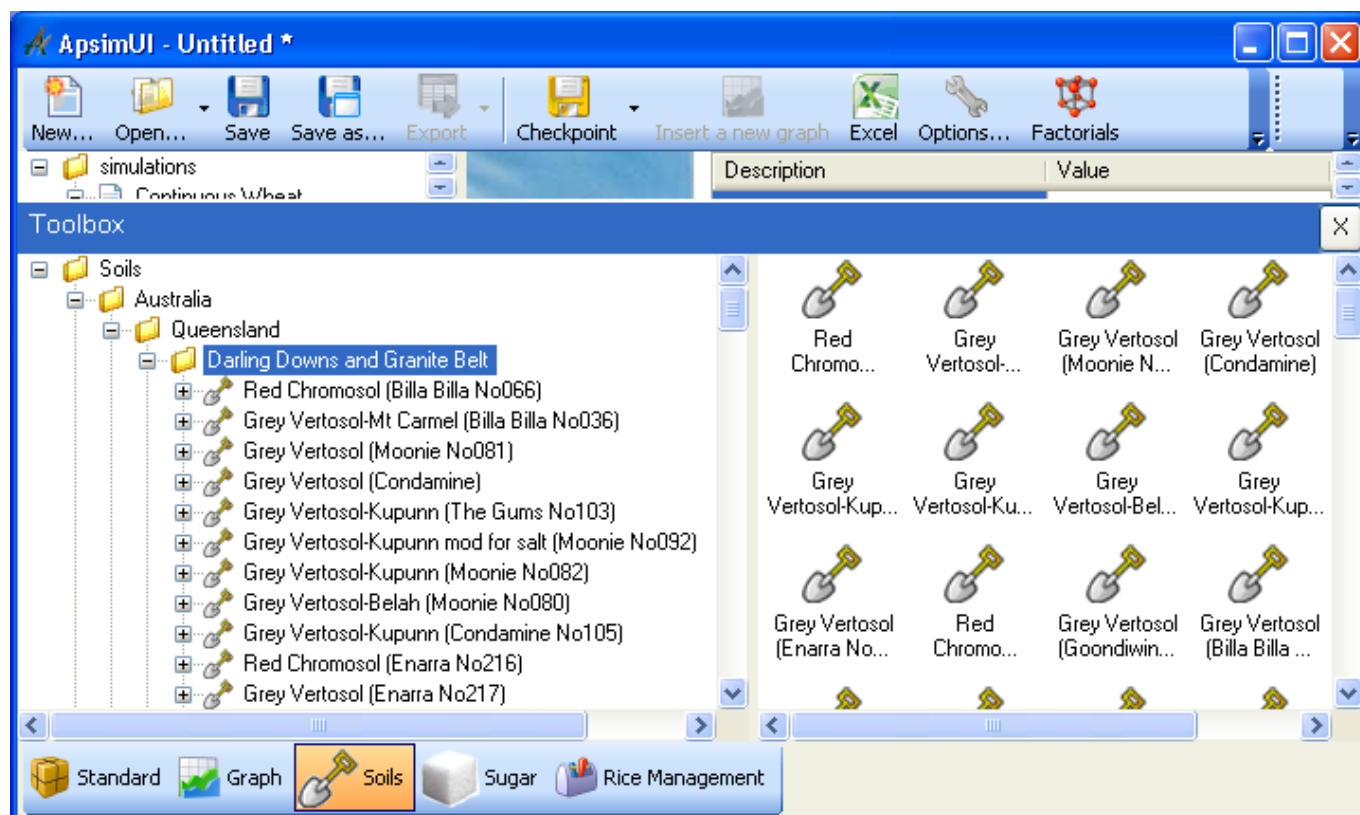
The weather properties are located under the Met component in the simulation tree. There you will have the ability to browse to a weather file. Weather files need to be in APSIM format and should have a .met extension. Some sample weather files (e.g. Dalby) can be found in the **Examples\MetFiles** directory under your APSIM installation.

e.g. **C:\Program Files\Apsim74 r2286\Examples\MetFiles**

Closely related to the weather file are the start and end date of simulation. These two properties can be found under the Clock component. They need to be within the range of the weather file. At this stage, to set the clock properties to include the entire climate record involves looking at the met file, taking note of the first and last date and entering those dates in the clock properties screen.

Soil

Picking a soil file involves finding a suitable soil from the **Soils** toolbox. To open the toolbox just click on the **Soils** button on the toolbar at the bottom of the window. The **Soils** toolbox has many soils to choose from.

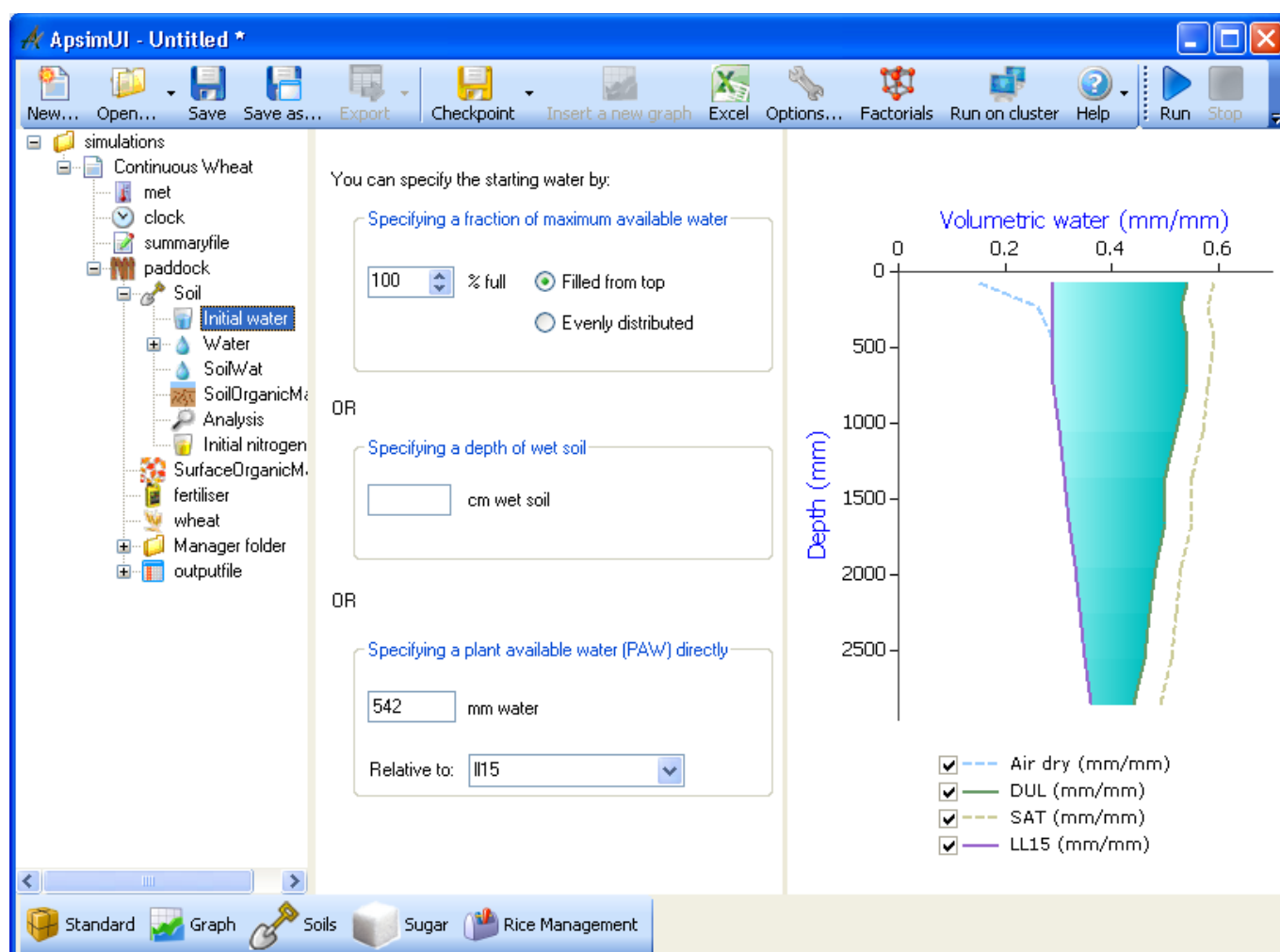


Drag your chosen soil from the toolbox and drop into the paddock on the simulation tree. You can then delete the existing soil in the paddock as it is no longer needed. Once the soil has been dropped it can be modified by clicking on it and then modifying the parameters to the right.

Important:

- Once you have dragged your soil onto your simulation tree, you should rename it to something with a shorter name.
 - Some soil names in the toolbox are too long and will cause your run to crash if it is not renamed to something shorter.
- It is important to remember that the soil must be parameterised for the crops that you're going to sow.
 - If your simulation is going to sow wheat, then the soil must have LL, KL and XF values for wheat.
 - These soil/crop values can be added to the soil but it is probably better to choose a soil that is already parameterised for the crops that you want.

The starting water that a simulation initialises with can be found by expanding the soil component in the simulation tree and then clicking Initial water.



The initial water can be specified in multiple ways by selecting one of the radio buttons and then entering a percent water or mm water. All changes made are automatically reflected in the graph on the right.

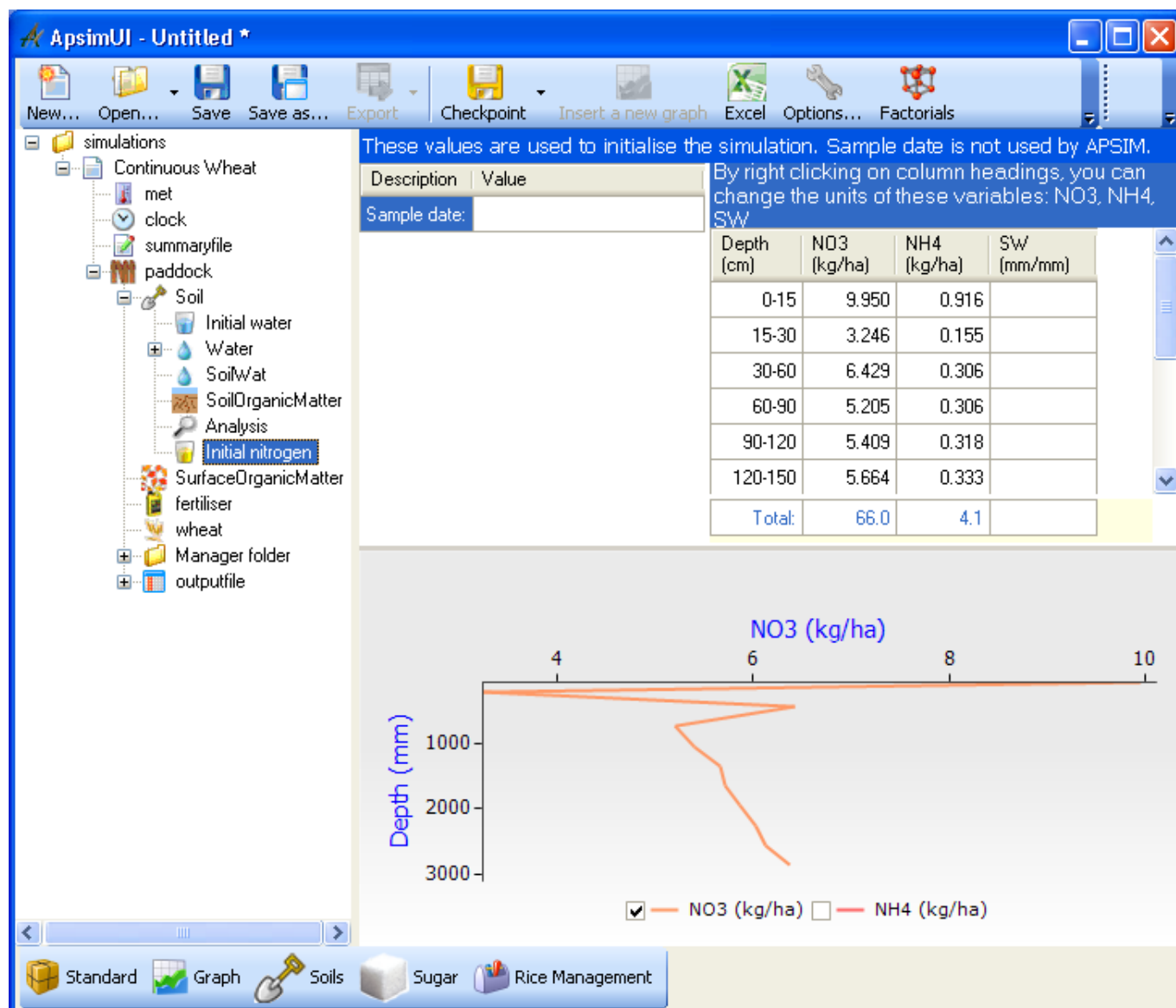
Initial water can also be specified directly on a layer by layer basis. See the SW column in the Initial Nitrogen node.

nb. by entering a date in the Initial Nitrogen component you are able to specify a measured soil water and/or nitrogen at any date during the simulation.

APSIM will reset the soilwater and/or nitrogen to these values on that date and keep going with its simulation.

If you leave the date blank, APSIM will assign it the initial start date of the simulation.

The starting nitrogen that a simulation initialises with can be found under the Initial Nitrogen node under the soil in the Simulation tree.



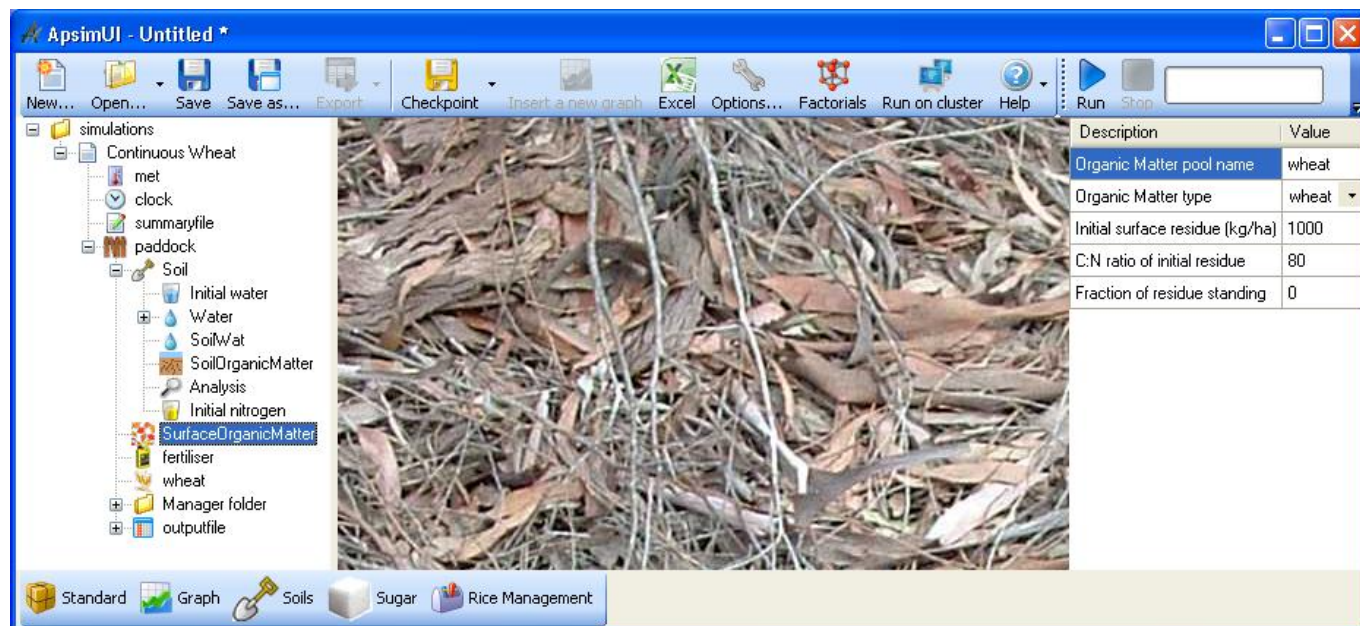
A single value for amount of nitrate or ammonia can be entered for the whole profile (in kg/ha)(by clicking in the respective "Total:" cells in the grid)

OR

amounts for individual layers can be entered in the grid.

Surface Residues / Organic Matter

The parameters for the initial surface residues can be found under the surface organic matter component in the simulation tree.



The "Organic Matter pool name" is simply an alphabetic description of the residue pool.

The more important parameters are the "Organic matter type" and "Initial surface residue", "C:N ratio of initial residue" and the "Fraction of residue standing".

Fertiliser

This component does not have any editable parameters. This component only needs to be present if you are going to be doing fertiliser applications in your simulation.

Crops

Crops can be dragged from the **Standard** Toolbox and dropped onto a paddock.

A crop can be deleted by selecting it and pressing Delete.

Crops typically don't have any editable parameters.

It is important to remember that the crop parameters LL (Lower Limit/Wilting Point), KL and XF (Both KL and XF are root growth parameters) come under the soil.

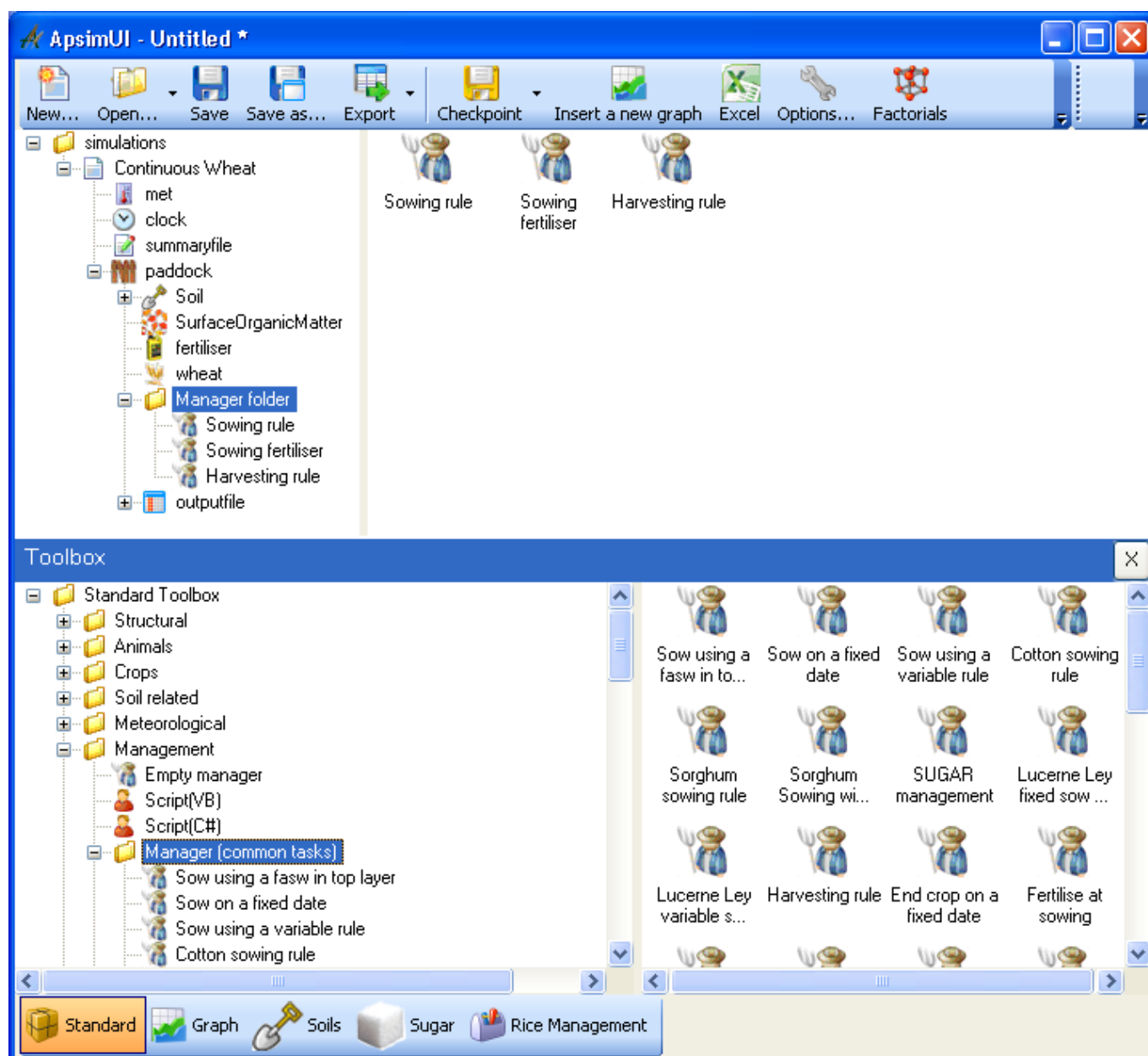
This is because they are soil properties even though they depend upon the specific crop.

Simulation management

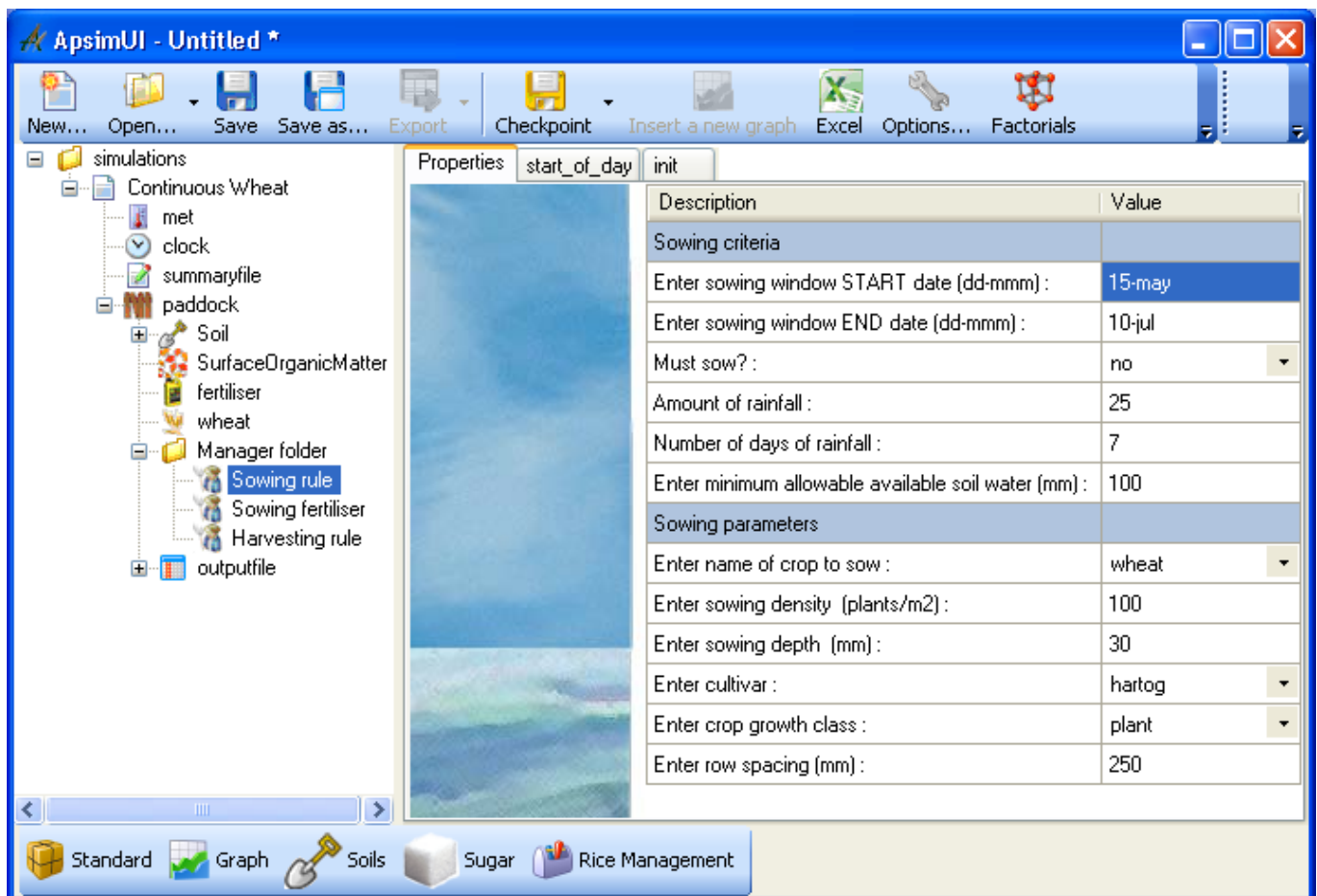
The Manager folder component contains all the management rules for the simulation.

e.g.

- sowing
- fertilising
- irrigation
- tillage
- resetting of water and nitrogen
- rotations



These rules can be dragged from the **Standard** toolbox (under Management folder in the **Standard** toolbox) and dropped under a Manager folder within a paddock.



The properties of the management rule can then be edited on the right.

The management rule in the toolbox cover the same sort of functionality as the older APSFront software.

It is also possible to drag an Operations Schedule component from the **Standard** toolbox and drop it on a paddock.

This component lets you exactly specify your own manager operations for sowing, harvesting, etc.

This will be familiar to you if you have used control / parameter files in the past.

Reporting

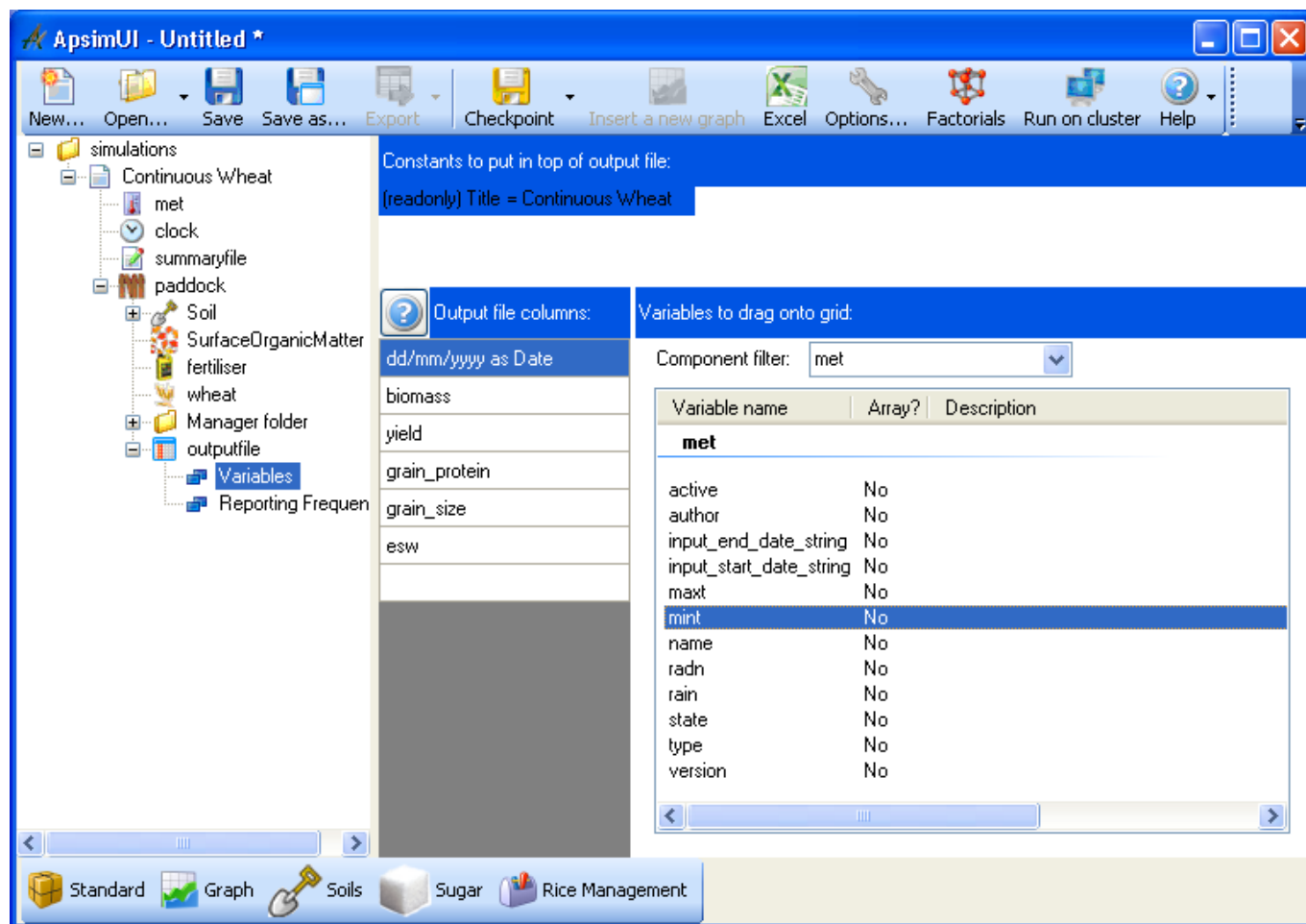
APSIM is capable of producing an ASCII space separated output file containing whatever APSIM variables you want.

In fact you need to exactly specify which variables you want output to the file.

This is all configured from the Outputfile component.

Variables

Expand the outputfile component and click Variables.



The top pane allows you to enter some text to put at the top of the output file. This is usually used to put some constant values that you have used in your simulation.

The bottom left pane lists which variables are to go into the output file (date, biomass yield etc) as columns.

These variables can be deleted and reordered up and down in the same way as the components in the simulation.

The bottom right pane gives you the variables that can be dragged onto the variable list in the left pane (adding them to the list; you can also double click them).

The variables are grouped according to the components currently plugged into the simulation.

To see the variables belonging to each component, simply choose the component from the "Component filter" drop down list.

Some variables are layer variables or profile variables

e.g.extractable soil water. Look for "Yes" or "No" in the **Array?** column to see if a variable is or not.

These variables that are, when dropped onto the variable list will produce a number for each layer in the output file.

If you want the sum of all layers, put a () in alongside the variable name in the **Variable name** column of the left pane.

Other options include a (1-3) for the first 3 layers, or a (5) for the fifth layer.

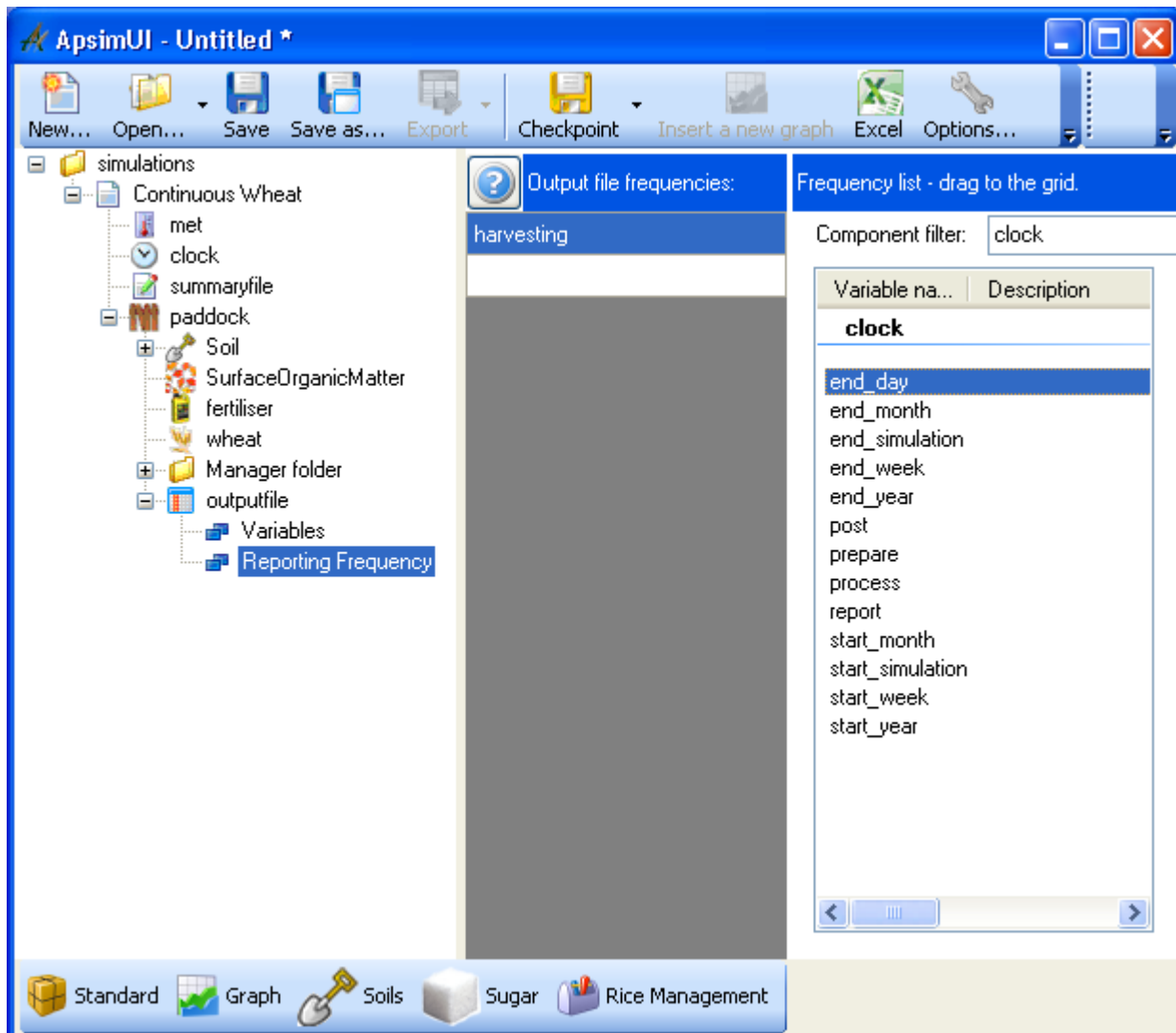
(click the ? button in the left pane for more information).

Reporting Frequency

The frequency of output is controlled by the Reporting Frequency sub component.

The left pane contains a list of events.

Whenever these specified events occur in the simulation, a line with the current values of the variables will be written to the output file.



In the example above, a line of output will be produced every time the simulation harvests a crop.

Just like with variables, use the "Component filter" drop down list on the right hand pane to see the events for each component that can be dragged to the left hand pane.

If you want Daily output this can be achieved by dragging **end_day** event to the left hand pane.

The end_day event can be found by selecting the clock component from the drop down list in the right pane.

APSIM is also capable of producing multiple output files.

The user simply needs to drag and drop multiple outputfile components onto the simulation tree from the **Standard** toolbox (Or duplicate an existing outputfile). Each can then be configured independently.

Precisely specifying outputs can quickly become tedious.

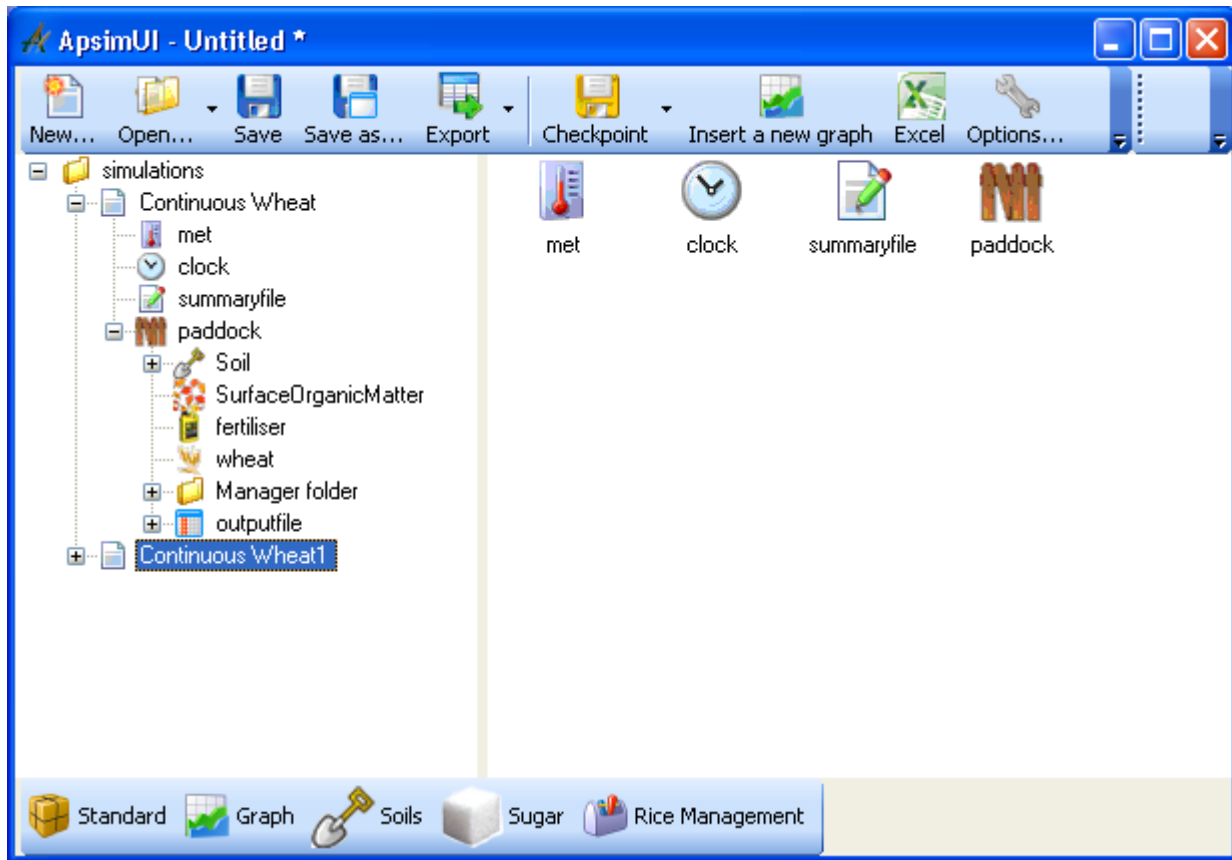
If you frequently use common outputs, why not create a toolbox and drag your configured outputfile component and drop it onto your toolbox. You can then easily reuse this configured outputfile in your next simulation. To see how to do this, read the overview on toolboxes.

Multiple Simulations

The user interface is capable of hosting multiple simulations within the single simulation tree.

The example we've been working through here has a single simulation called **Continuous Wheat**.

You can add another simulation by simply dragging this simulation and dropping it onto the top level node Simulations - a copy will be made and there will be two simulations in the simulation tree.



Notice the second simulation called Continuous Wheat1 at the bottom.

This simulation will be identical to the first simulation.

Usually you would change a parameter in the second simulation to see what effect this parameter has on the result compared with the first simulation.

Before you run the simulations the second simulation should be renamed to a more suitable name.

Running the Simulation(s)

Simulations can be saved to any folder by clicking the **Save** button.

Likewise, running a simulation is as simple as clicking **Run** on the button bar.

Click the **Run** button on the toolbar at the top of your screen to run the simulation.

Note:

If you have multiple simulations, and you only wish to run one of them, just click on the simulation that you wish to run so that it is highlighted like Continuous Wheat1 is in the image above.

Then click the **Run** button. This will cause only the Continuous Wheat1 simulation to run.

If you wish to run both simulations, just click on the very top simulations component to highlight it and then click the run button.

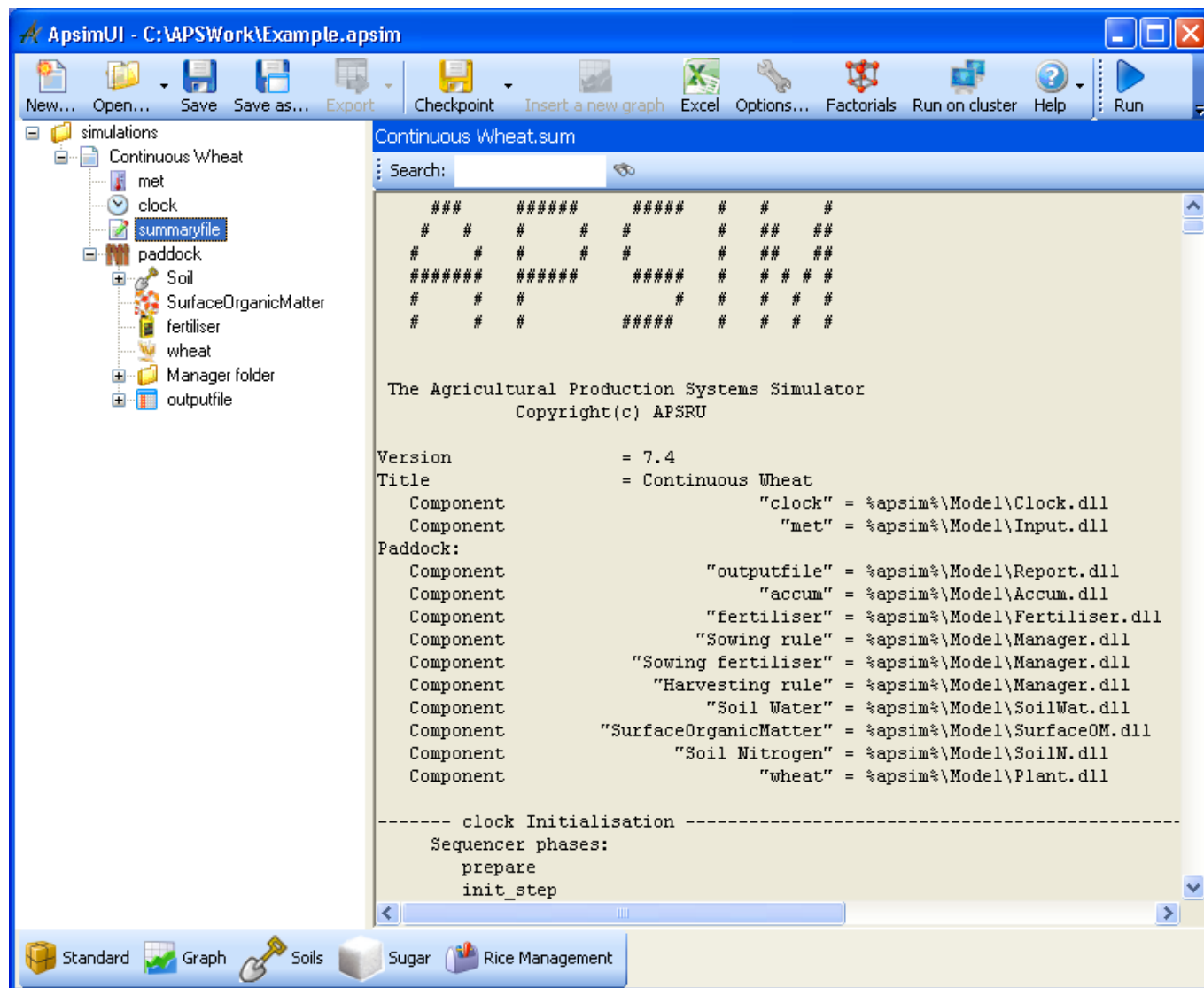
This will cause all the simulations in your tree to be run.

Often APSIM will produce a fatal error as a result of an invalid configuration or parameterisation.

In this instance, it is important to consult the summary file that APSIM produces.

Clicking on the summaryfile component will give quick access to the contents of this file.

When looking for errors, always scroll down to the first error and fix that first.



Once the simulation has successfully run just click on the outputfile component to see your output file.

Note: The output file and summary files are just plain text files.

As such the output files can be used as input for statistics software packages such as R, SYSTAT, MATLAB, GENSTAT etc.

Also they can be opened in any text editor.

After a run you will find the output files and summary files in the same folder that you have saved the simulation to.

The user interface automatically names the output and summary file.

It uses the simulation name in the tree (eg. Continuous Wheat Simulation) then adds the name of the output file (eg. outputfile)

(nb. you are allowed to rename outputfile).

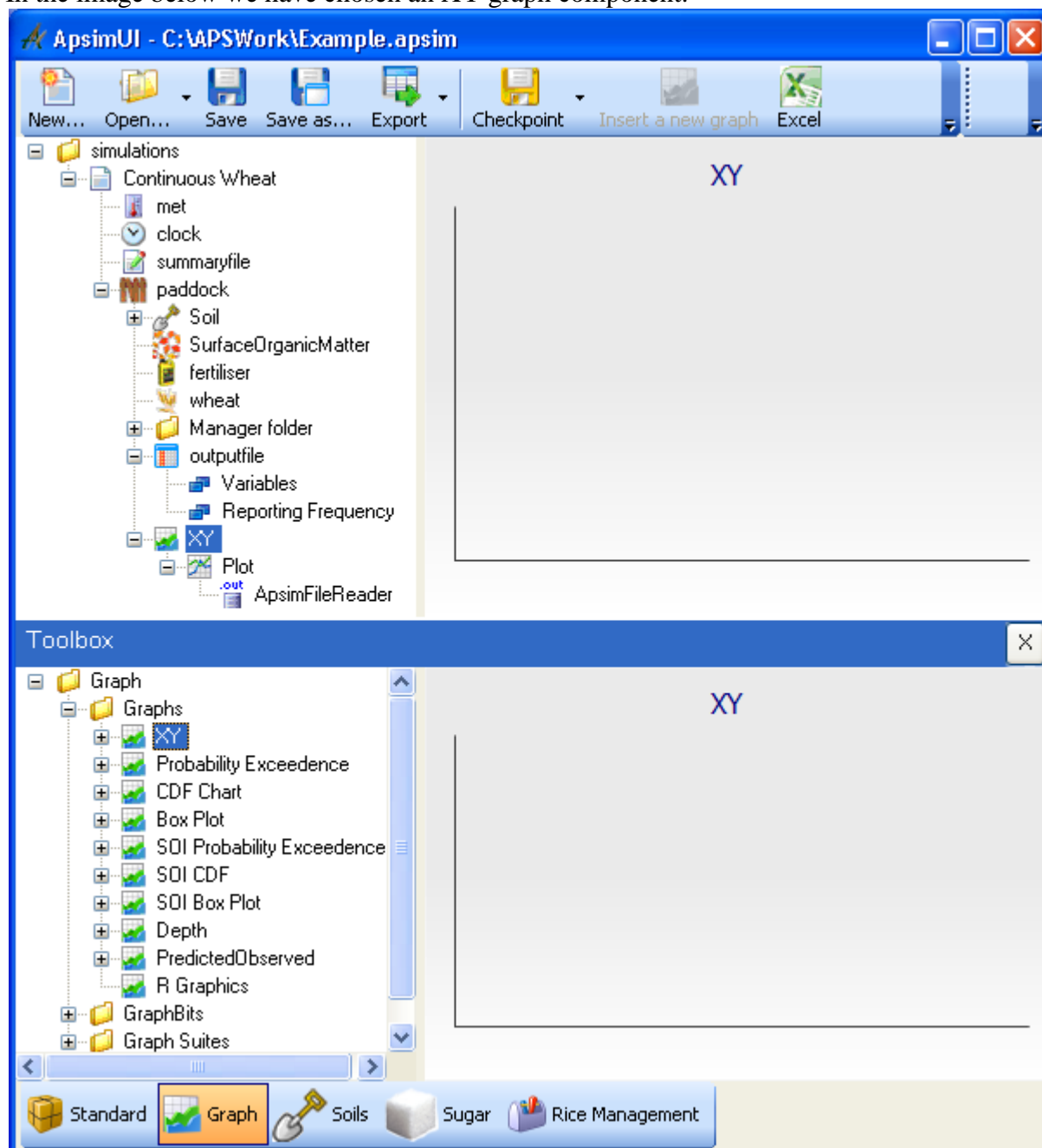
The suffixes .out and .sum are used for the output and summary files respectively. This automatic naming ensures you can easily identify which output and summary files belong to which simulations.

Graphing the output and Exporting to Excel

If you do not already have a graph component in your simulation tree, then you can drag one there from the **Graph** toolbox.

There are different types of graph components available allowing you to choose the type of graph you wish to use.

In the image below we have chosen an XY graph component.



The graph component is able to find any output file on the same level or lower in the simulation tree. So dropping a graph component on the top Simulations node will allow it to find all the output files in all the simulations.

Dropping on a specific simulation will allow it to find all the output files in the simulation and dropping it

on a paddock will allow it to find all of them in that paddock.
If you just drop it on a specific output file it will only be able to find that outputfile.

To graph the output file,
first fully expand the graph component by clicking the + symbol next to the graph component then work your way up from the bottom configuring each sub component.
You can usually ignore the very bottom component ApsimFileReader .
Then to view the graph all you have to do is, after working your way up from the bottom configuring sub components just click the graph component itself at the top level.
Depending up the type of graph component it was, you will see that type of graph in the properties pane.

APSIM has a button on the main application toolbar to send the output file to Microsoft Excel.



To send an output file or multiple output files to Excel, just select them in the simulation tree and click the **Excel** button

The help system

The Help button at the end of the main toolbar (at the top of the screen) gives quick access to the APSIM Documentation.

A lot of documentation, including the science documentation and how some of the modules perform at different locations (i.e. sensibility tests), can be found under **Module documentation**.

NOTE: The documentation you get when you click on this button is a copy saved to your hard drive that came when you installed APSIM.

It is provided for when you do not have an internet connection.

For a more up to date copy of the documentation please see the Documentation on our website (<http://www.apsim.info/Wiki/APSIM-Documentation.ashx>).

How to get started with African data

On the workshop CD you'll see a folder called "Apsim_Workshop". Copy this to your computer. The exercises below assume this will be "C:\Apsim_Workshop", though you can copy it to anywhere on your computer.

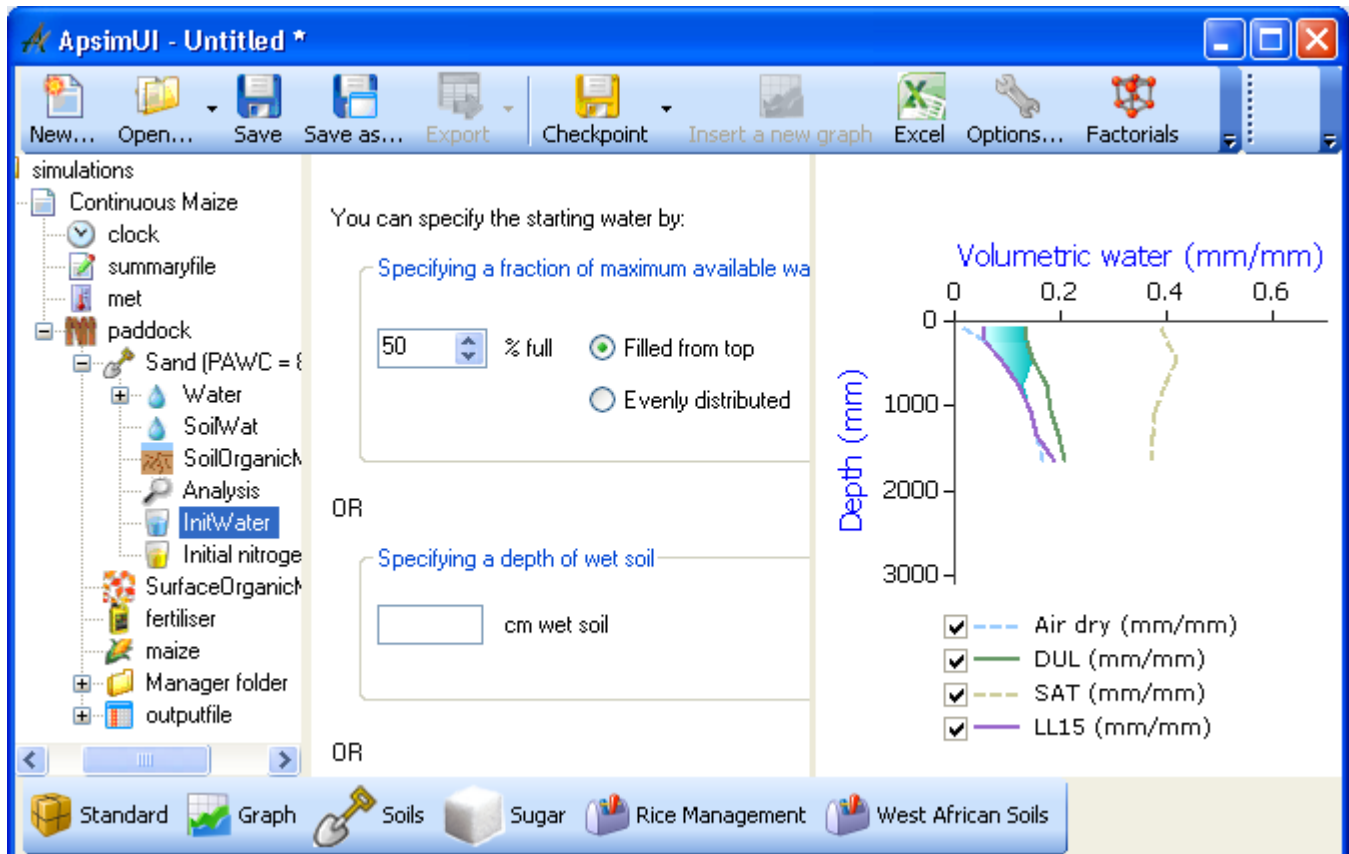
Follow the instructions in Create your own or Add someone else's toolbox to add the toolbox "West African Soils.soils" (located in C:\Apsim_Workshop\Toolboxes above) to your APSIM User Interface. Don't point APSIM to the toolbox on the CD - use the copy stored on your local computer.

Exercises

1. Fallow Water Balance

In this exercise you will explore the major elements of interest in soil water balance during a fallow - soil water storage, drainage, runoff, and evaporation. Changes will be examined over a one year period in the Segou region of Mali. The examples assume you have read and walked through the previous document: How to Build, Run and Graph a Simulation.

1. Create a new simulation using a Continuous Maize Simulation as a starting point.
2. Choose "Segou - Mali 1972-2001.met" weather (**c:\apsim_workshop\met**)
3. Enter the start date of the simulation: 1/07/1999
Enter the end date of the simulation: 30/11/1999
4. Delete the soil from within the paddock node ("Soil" - a generic Australian Black Earth).
5. In the West African Soils toolbox, look under Example Soils to find the soil "**Sand (PAWC = 87mm, 1.8m)**". Drag this soil onto the paddock node of the simulation tree. If you like you can also reorder the soil component so it comes straight under the paddock.
6. Set the starting water to 50% full - filled from the top. (Expand the soil branch to see InitWater – i.e. click the "+" next to "**Sand (PAWC = 87mm, 1.8m)**").



7. At the Initial nitrogen node, you will need to type in the soil Depth layers and set the starting NO₃ and NH₄. Set starting NO₃ to 11 kg/ha (i.e. 3 in top 2 layers and 1 in remaining layers) and starting NH₄ to 5 kg/ha (i.e. 2 in top 2 layers and 0.2 in remaining layers).

The screenshot shows the ApsimUI - Untitled window. The left sidebar displays a tree view of simulation components. The 'Initial nitrogen' node is selected. The main panel shows a table for initial nitrogen values across different soil depths. A tooltip explains that these values are used to initialise the simulation and that units can be changed by right-clicking on column headings.

Depth (cm)	NO ₃ (kg/ha)	NH ₄ (kg/ha)	SW (mm/mm)
0-15	3.000	2.000	0.000
15-30	3.000	2.000	
30-60	1.000	0.200	
60-90	1.000	0.200	
90-120	1.000	0.200	
120-150	1.000	0.200	
150-180	1.000	0.200	
Total:	11.0	5.0	

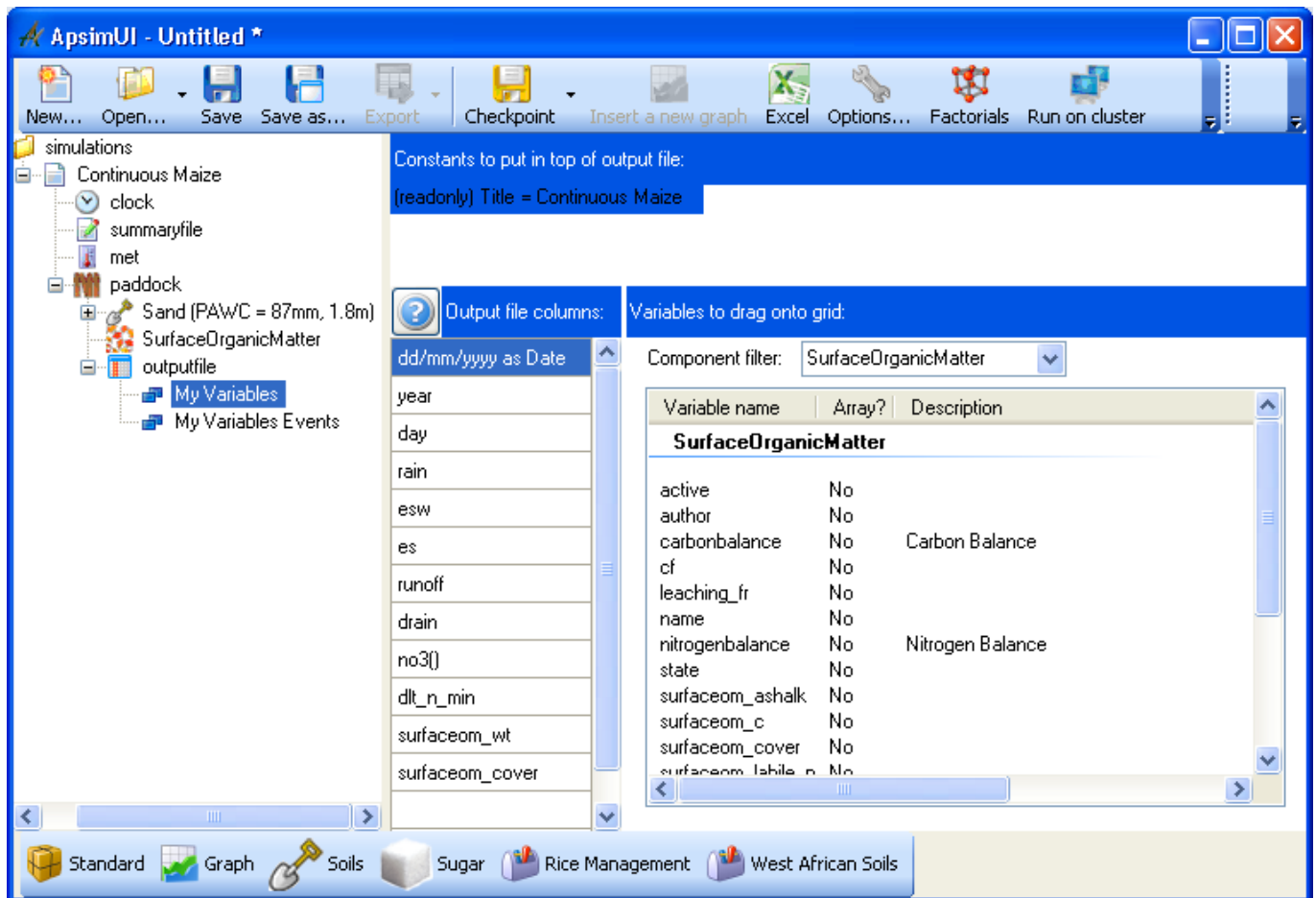
8. At the SurfaceOrganicMatter node, check that the default initial residue type in Organic matter pool and Organic matter type is 'maize' and the Initial surface residue is 0 kg/ha.

The screenshot shows the ApsimUI - Untitled window with the 'SurfaceOrganicMatter' node selected. The main panel displays a photograph of maize residue on the ground. To the right of the image is a table showing the configuration for the organic matter pool.

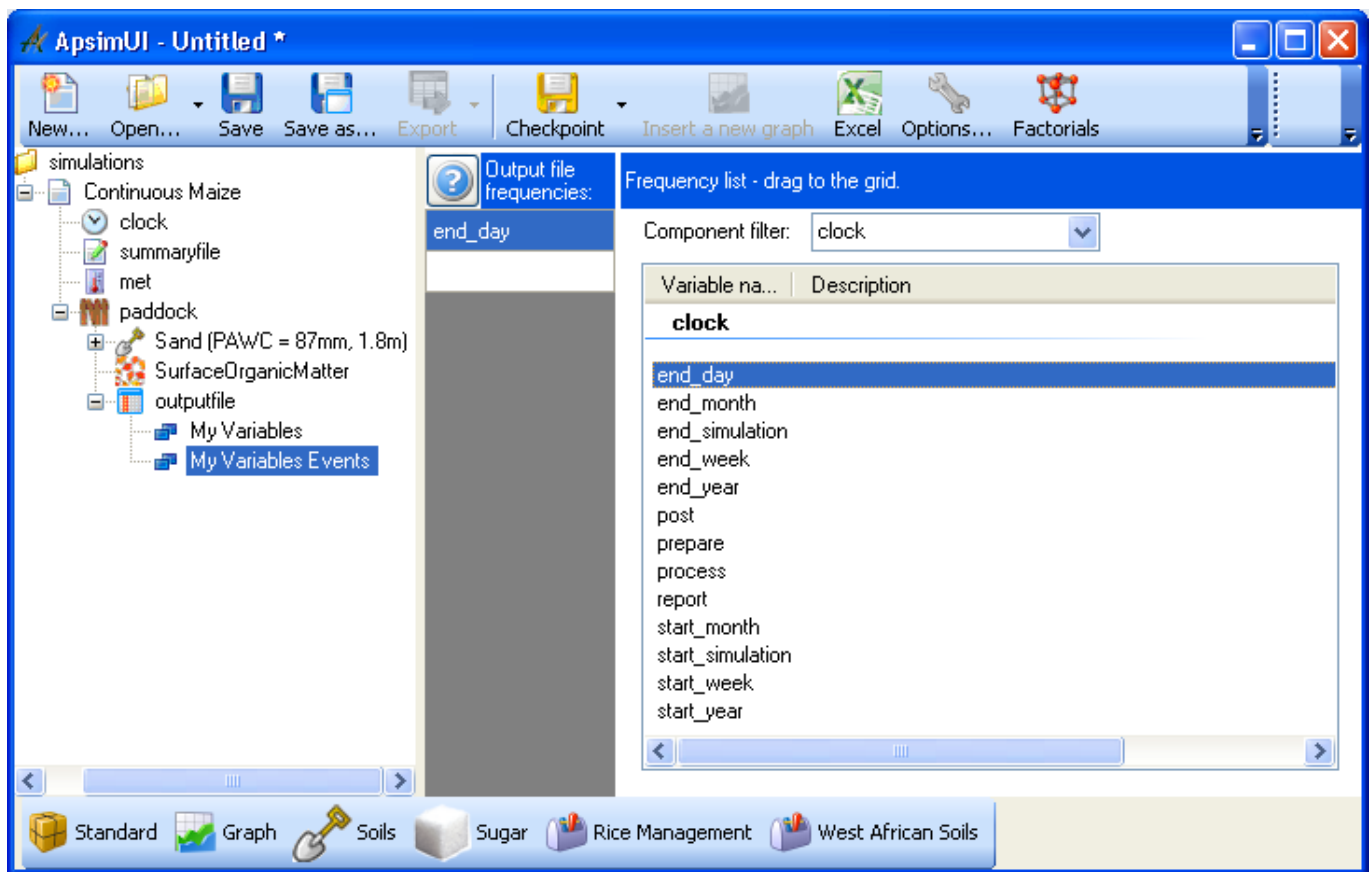
Description	Value
Organic Matter pool name	maize
Organic Matter type	maize
Initial surface residue (kg/ha)	0
C:N ratio of initial residue	80.0
Fraction of residue standing	0.0

9. Delete the Fertiliser, Maize and Manager components out of the simulation. They are not needed for a fallow run.
10. Select the outputfile's "My Variables" subcomponent. Choose these variables to report (after removing the old ones):

Component	Variable name	Description
Clock	dd/mm/yyyy as Date	
	Year	
	Day	
Met	Rain	
Sand	ESW	Extractable soil water (mm)
	ES -	Evaporation
	Runoff	
	DRAIN	Drainage
	NO3	- summed over profile Do this by putting () next to the name in the "Variable name" column.
	DLT_N_MIN()	N mineralised - summed over profile
Surface organic matter	SURFACEOM_WT	Weight of all surface organic materials.
	SURFACEOM_COVER	Fraction of ground covered by all surface organic materials.



11. Select the "My Variables Events" subcomponent. Choose "end_day" reporting frequency for the output file. This can be found under the "Clock" component filter.



12. Rename the simulation from 'Continuous Maize' to something more meaningful: Sand fallow.
13. Save the simulation file as *Exercise 1 - Fallow water balance.apsim*
14. Run the simulation.
15. Create a graph of Date vs ESW. To do this, click on the Graph Toolbox at the bottom of the window to open the toolbox. Then drag in an XY component onto the outputfile in your simulation. Click on the "+" symbol next to XY component to expand the node. Click on the Plot component. In the Plot window click on the X variables square to make sure the background of the square is pink. Now click on the "Date" column heading. It should appear in the list in the square. Now click on the Y variables square to make its background pink. Click on the esw column heading. It will be added to the Y variables square. To have a clean line plotted with no points, under "Point type", choose "None". Now click on the XY component to view the graph.

ApsimUI - C:\APSIM_Workshop\Examples\Exercise 1 - Fallow water balance.apsim

Simulations:

- Sand fallow
 - clock
 - summaryfile
 - met
 - paddock
 - Sand (PAWC = 87mm, 1.8m)
 - SurfaceOrganicMatter
 - outputfile
 - My Variables
 - My Variables Events
 - XY
 - Plot

Toolbox:

- Graphs
 - Probability Exceedence
 - CDF Chart
 - Box Plot
 - SOI Probability Exceedence
 - SOI CDF
 - SOI Box Plot
 - Depth
 - PredictedObserved
 - R Graphics
- GraphBits
- Graph Suites

XY variables:

X variables: Date

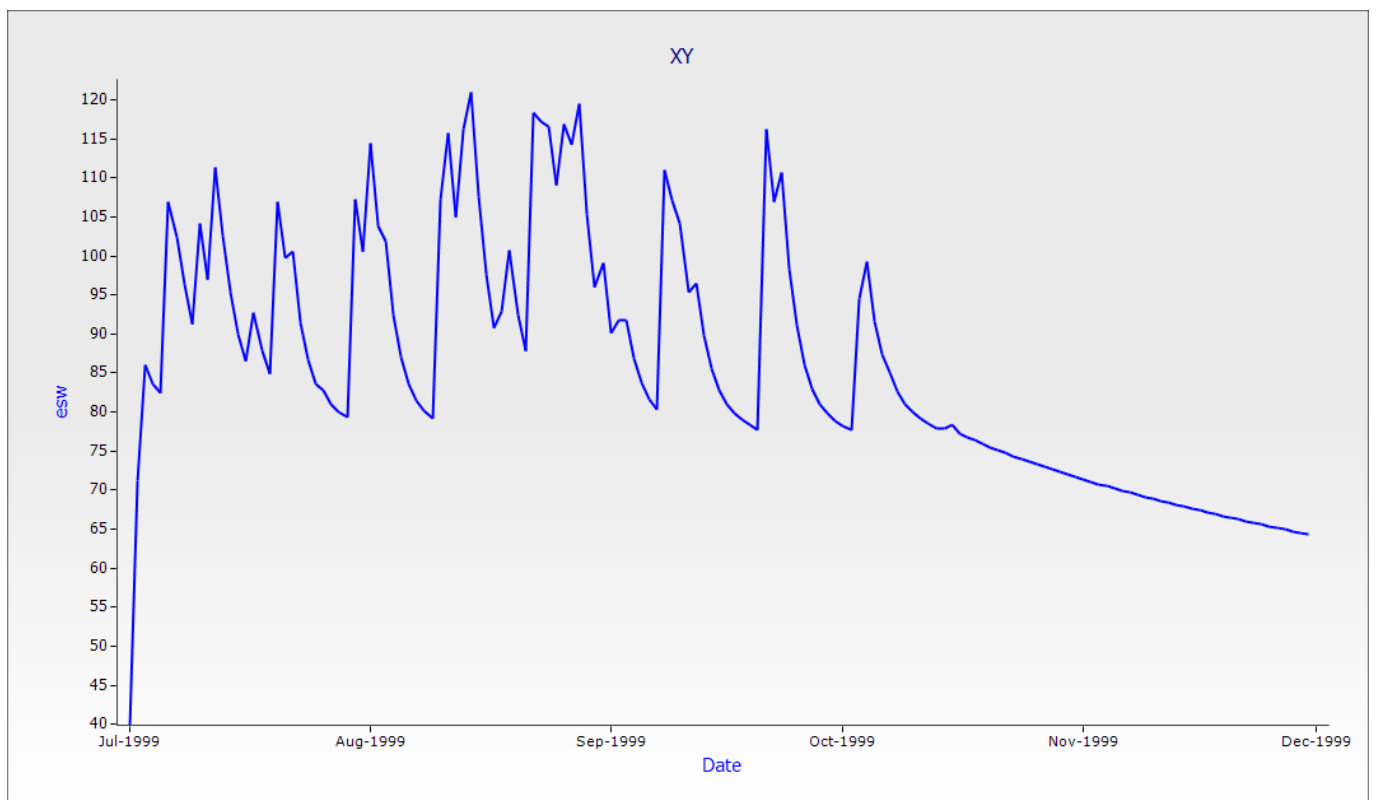
Y variables: esw

Type: Solid line

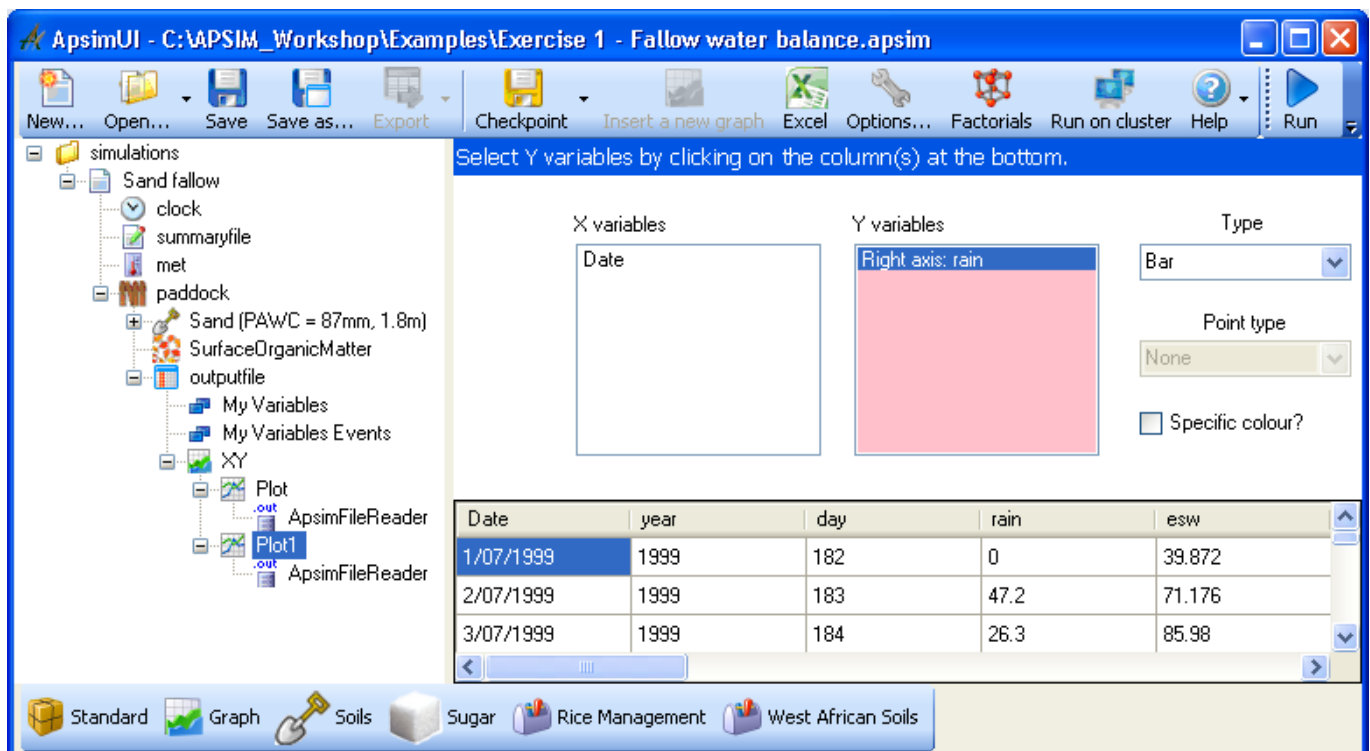
Point type: None

Specific colour? ☐

Standard Graph Soils Sugar Rice Management West African Soils

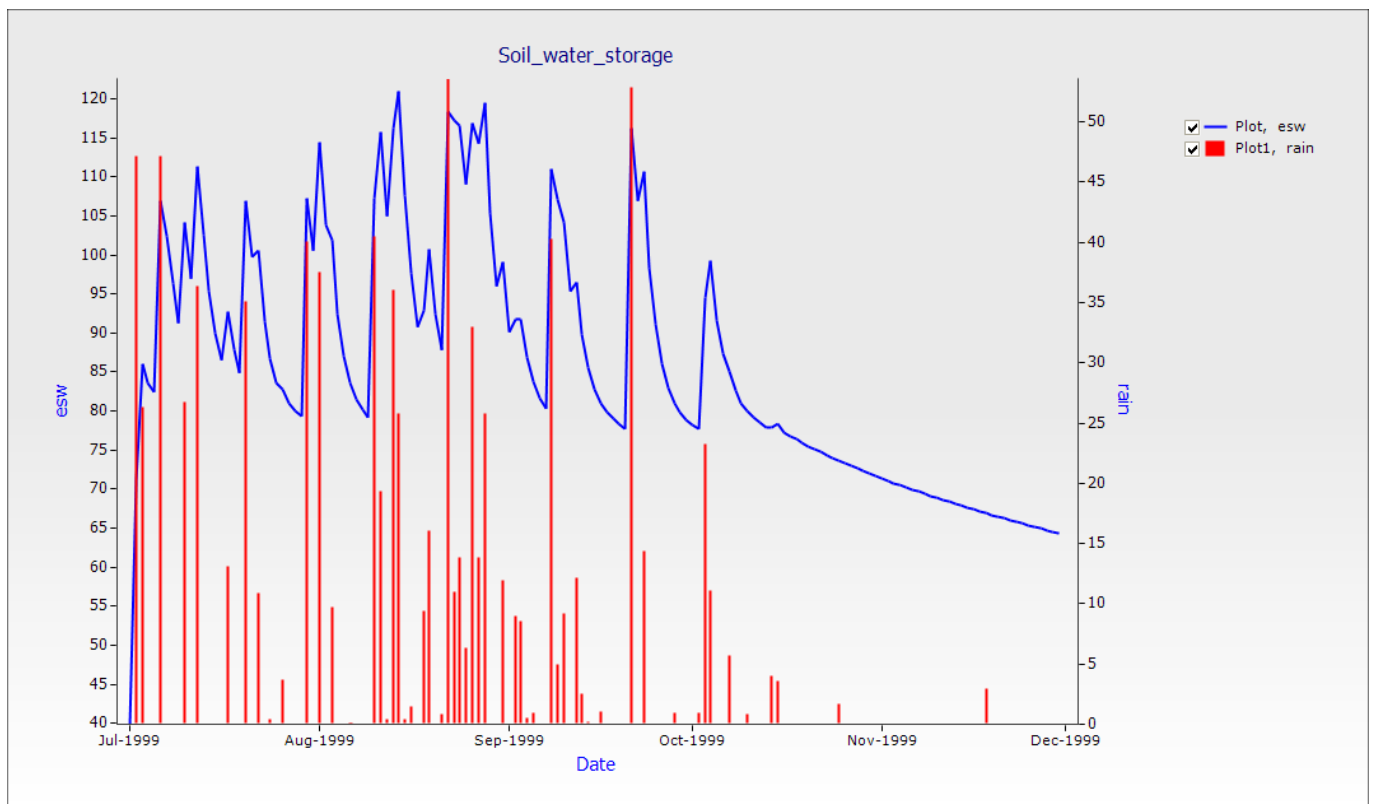


16. Once you have created a chart it is possible to make modifications by adding new variables. It is also possible to mix the type of plots used on a graph. As an example, we will add rain as a bar chart on the Y2 axis. To do this, drag “plot” onto the XY node to create a duplicate, ‘plot1’. At ‘plot1’, remove esw and add rain as the y variable. To make the "rain" appear on the right hand axis, click rain in the square to highlight it, then "right" mouse click on it again. In the popup menu click on "Right Hand Axis". Select “bar” chart from “type” drop_down menu. Select XY node to see the line and bar chart combination.



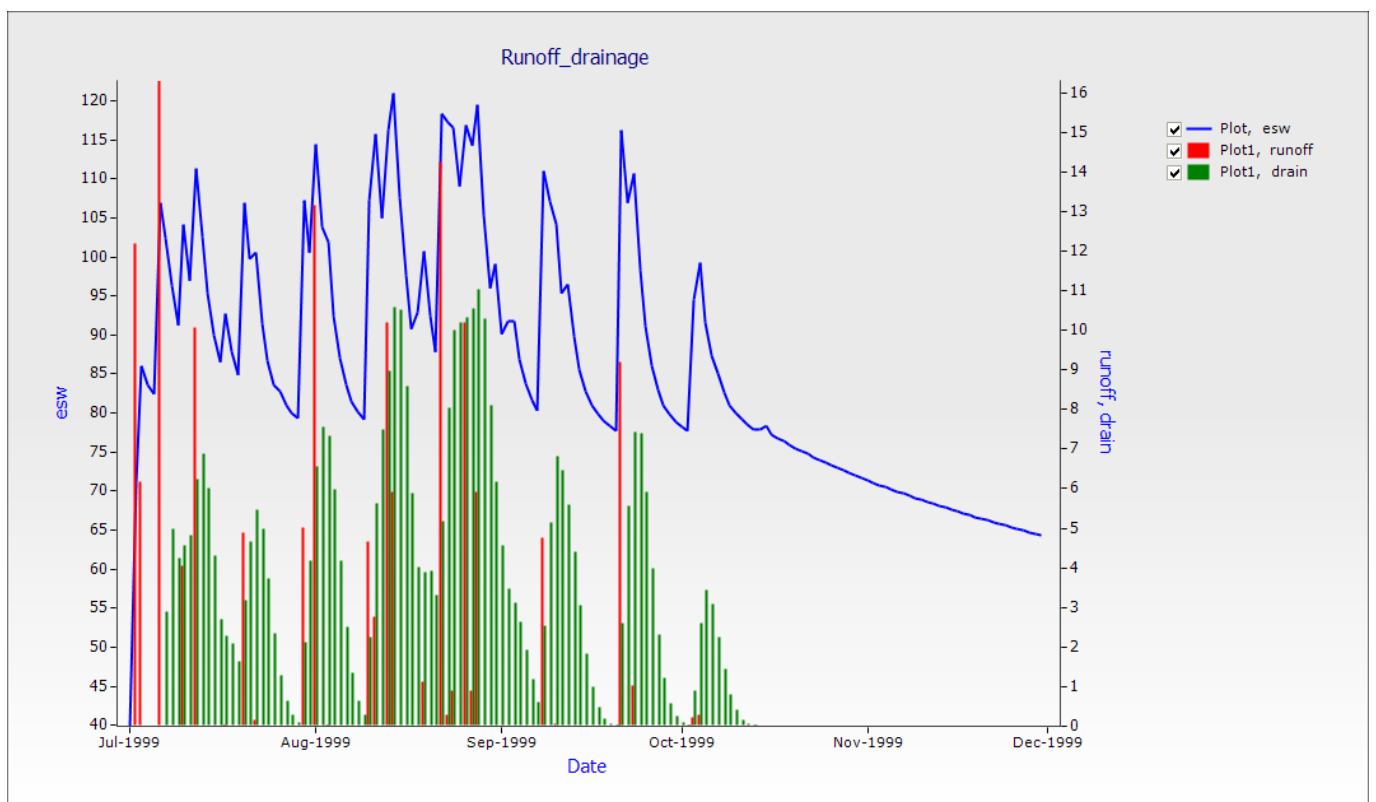
17. Rename the XY graph node to ‘Soil_water_storage’

The graph should show the ESW (in mm). The sudden increases are due to rainfall events and the declines to evaporation and drainage loss. The distribution of daily rainfall amounts helps see this more clearly.

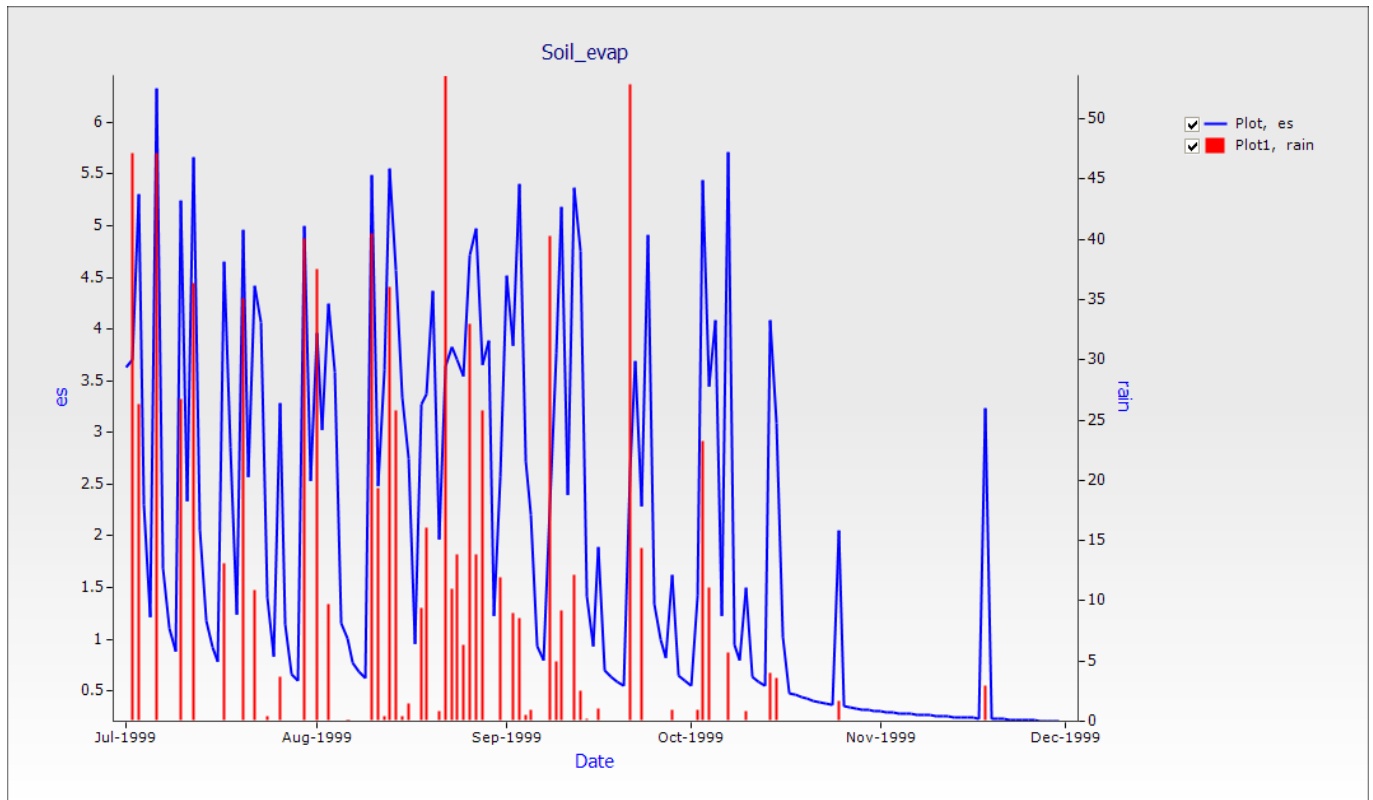


We can also examine other components of the simulated soil water balance.

18. Drag 'Soil_water_storage' to the outputfile node to make a copy of this graphics node. Rename the copy to 'Runoff_Drainage'
19. At the Plot1 node underneath the 'Runoff_Drainage' graph, remove rain from the Y variables box. Add runoff and drain to the Y variable box. Change 'type' to 'bar' Put both on the right hand axis (right click on the variable) to create a plot similar to the below figure.



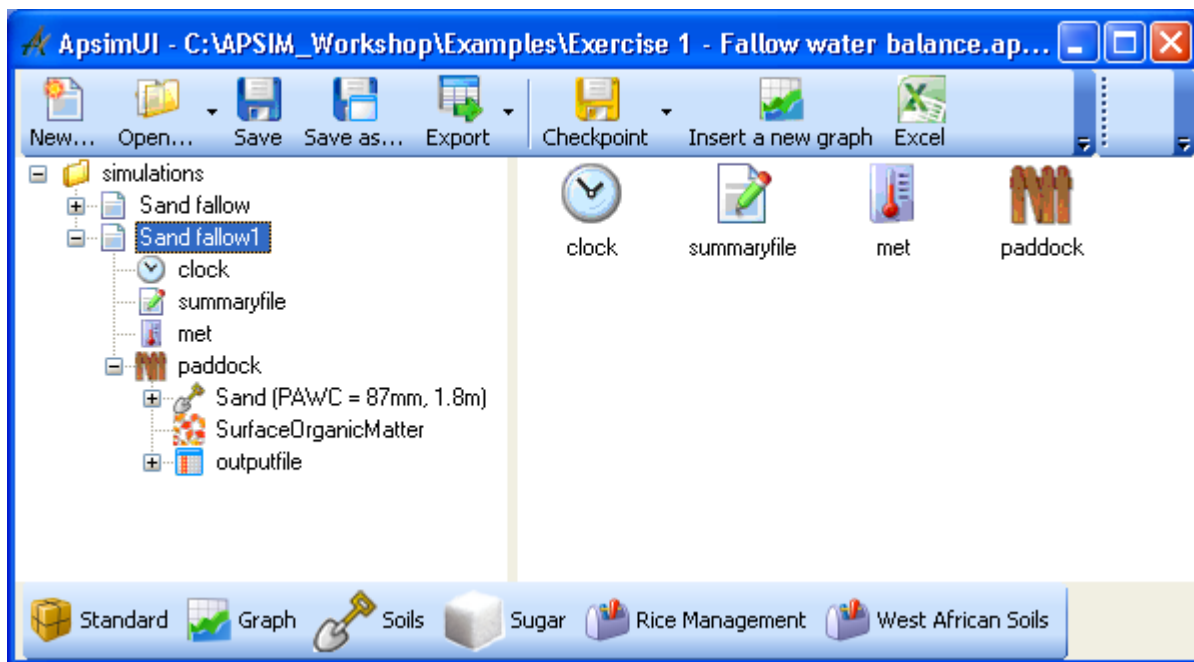
You could also make a plot of soil evaporation. See if you can do this for yourself.



The effect of soil type on the water balance

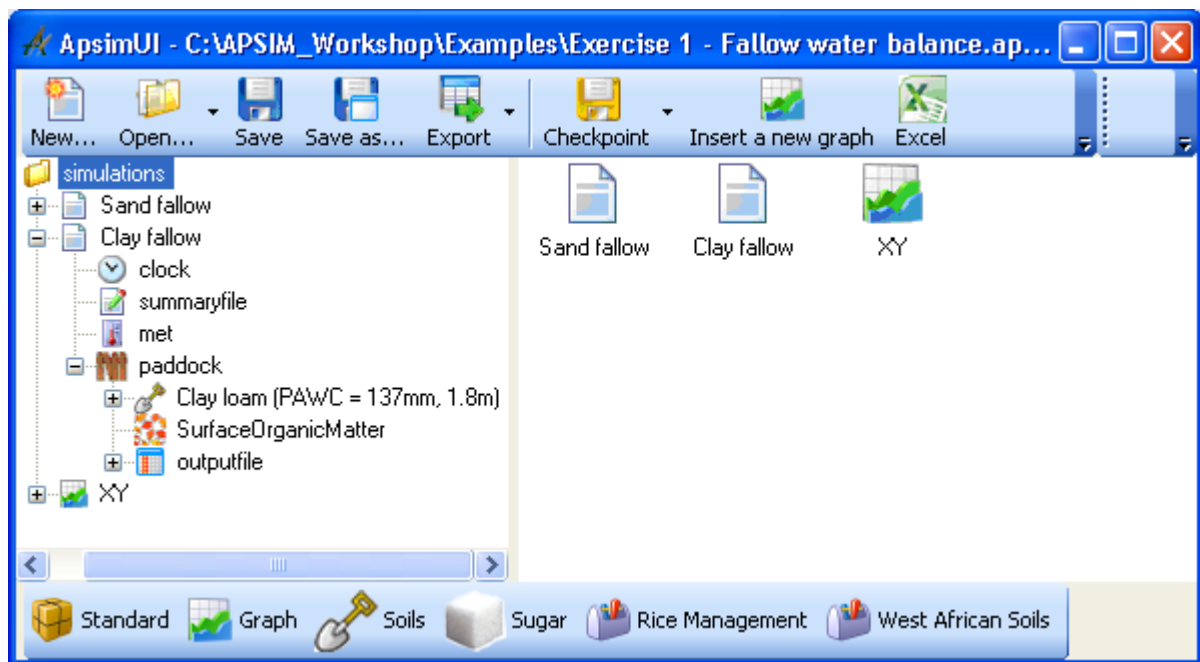
Runoff, es (evaporation) and drainage are affected by weather and soil water storage capacity. This run will take an additional soil into account, and compare runoff from both soil types. The user interface still contains all the specifications provided for the previous simulation.

If you drag the Sand fallow node in the Simulation Tree to the top node simulations, a copy of it will be made and your file will then have two simulations in it. e.g.

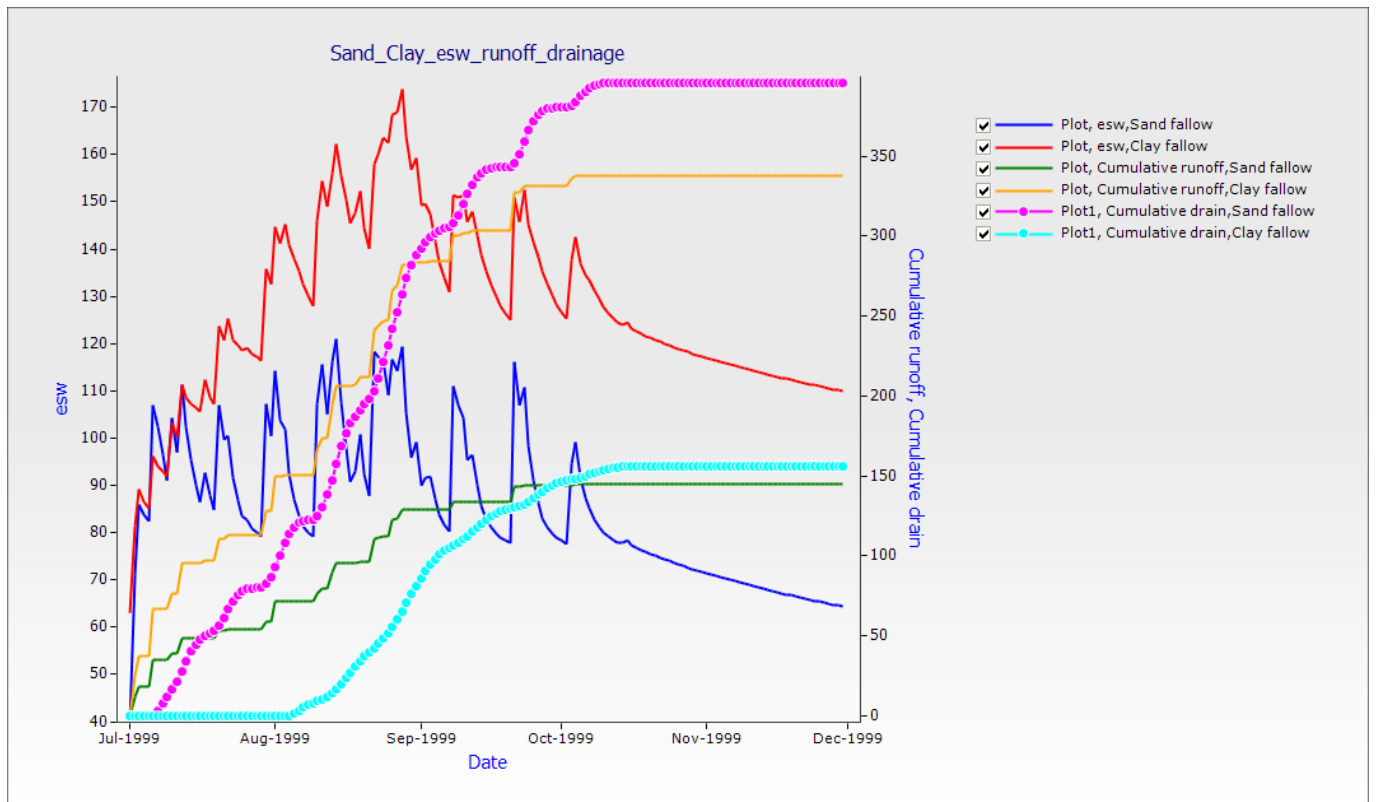


This second simulation can then be modified to add the characteristics of a Clay loam soil.

1. In the West African Soils toolbox, look under Example Soils to find the soil “Clay loam (PAWC = 137mm, 1.8m)”. Drag this soil onto the paddock node of the simulation tree and then remove the old soil. It is important you drag in a new soil BEFORE you delete the old one, otherwise the simulation will lose all your soil reporting variables.
2. Since now we have a new soil we will need to go and set the initial soil water (InitWater) to 50% filled from top and initial soil nitrogen (Initial nitrogen) to NO3 to 11 kg/ha and NH4 to 5 kg/ha, as before. When you delete soils you also delete the initial soil water conditions and initial soil nitrogen conditions so these will need to be set similar to the conditions of the "Sand" soil.
3. Rename the simulation to Clay Fallow.
4. Save the simulations.
5. Run APSIM for the Clay soil simulation.
6. Graph both the output files by dragging an XY graph onto the top node simulations in the simulation tree. By placing the XY graph under the simulations node, all output files in the simulation area will be available for plotting – in this case, the Sand and Clay outputs.



7. Create a graph of date vs esw and runoff(cumulative, right hand axis). To make the runoff cumulative, it is the same procedure as to make the rain appear on the right hand axis. Only select "Cumulative" from the popup menu instead of "Right Hand Axis". Set "Point Type" to "None".



The above figure includes a plot of drainage for the 2 soils. See if you can also add 'drain' as shown above to your esw-runoff plot. (Hint: create a plot1, do cumulative and right hand axis and choose 'circles' under Point Type).

The clay soil has higher runoff than the sandy soil for all simulated events. Cumulative runoff for the sand is approx 145mm. For the clay it is 340mm. Is this what you might expect, given the same rainfall and 50% full profiles as starting conditions?

At the beginning of the simulation, the clay soil has higher ESW because of its higher water holding capacity and the fact that both soils were initialised at 50% of capacity. In a few days, the ESW in the sand is the same as in the clay, meaning it has captured more of the rainfall. How could this happen?

The sandy soil attains field capacity (87mm) in early July and drainage from the bottom soil layer begins around this time. In the absence of a growing crop, the seasonal drainage is over 400mm. The clay soil attains field capacity (134mm) almost 1 month after the sand, and retains a higher esw than the sand for the remainder of the season. This is due to a combination of higher PAWC and less drainage beyond the root zone compared to the sand (cumulative clay soil drainage is about 155mm.)

Additional investigation: explore what effect curve number has on the water balance. eg. for the sandy soil, change curve number from 73 to 85 in the Soilwat node.

2. The Effect of Residue Cover on Soil Water Storage During Fallow

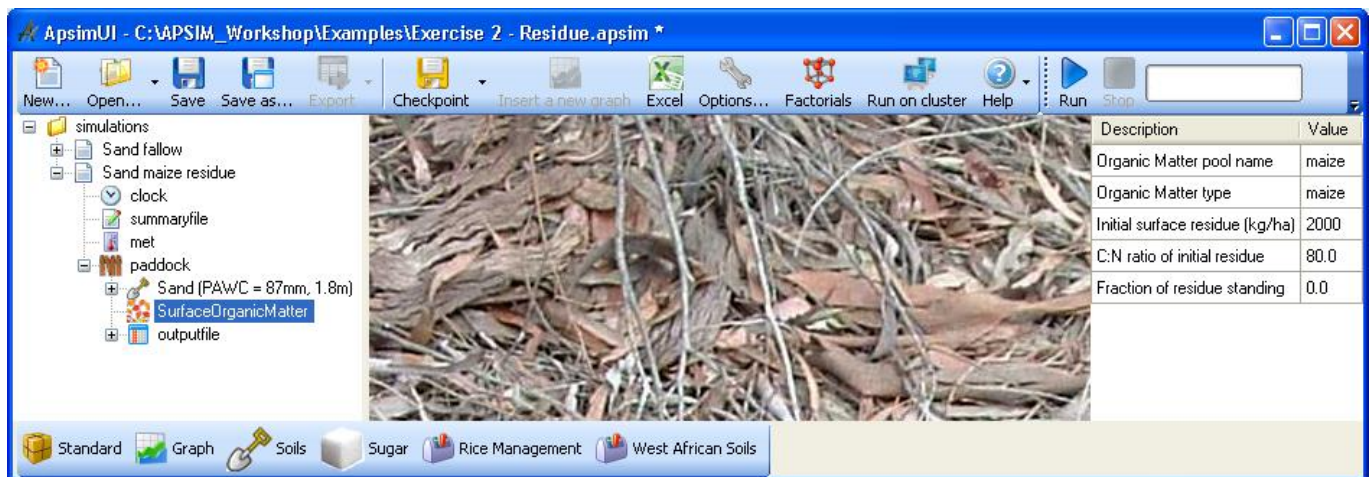
Tracking the decline of cover as residues decompose

APSIM simulates the influence of crop residues on the efficiency with which water is captured and retained during fallows. But residue cover declines as residues decompose. Residue decomposition is simulated in APSIM in response to weather, as well as the chemical composition of the residues. By doing this simulation you will reinforce skills learned in previous exercises and learn to do some basic editing of default values to 'customise' your simulations.

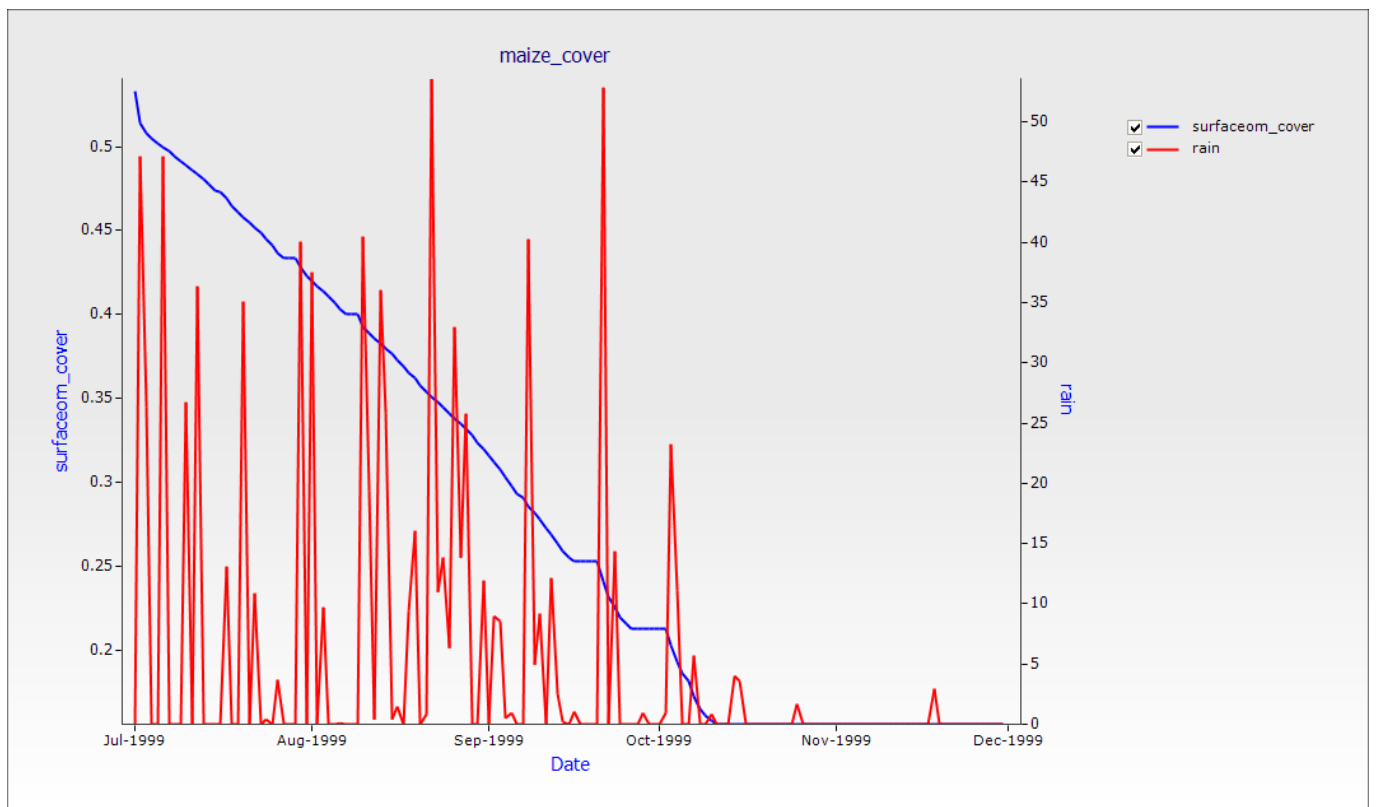
The examples assume you have read and walked through the previous document: How to Build, Run and Graph a Simulation.

This simulation will demonstrate how surface residue decomposes over time. You should use the previous simulation as a starting point for this simulation. You need to add an initial amount of surface residues.

1. Reopen the previous file (*Exercise 1 - Fallow water balance.apsim*)
2. Save the file as *Exercise 2 - Residue.apsim* (**Reminder:** don't forget to use the *Save as* button, **NOT** the *Save*, or you will save these changes to *Exercise 1 - Fallow water balance.apsim*)
3. Delete the Clay fallow simulation. We're going to use Sand fallow as our starting point for this exercise. Also delete the graph components.
4. Make a copy of the Sand fallow simulation by dragging to the top node in tree (*simulations*).
5. Rename second simulation to Sand maize residue
6. At the 'surface organic matter' node, set the starting surface organic matter mass to 2000 kg/ha and the Pool and Type of residues to maize.



7. Run the simulation
8. Create a graph of date vs surfaceom_cover and rain (right hand axis) for the *Sand maize Residue* simulation. Drag an XY graph from the "Graphs" folder in the Graph toolbox onto the outputfile, and rename it to *maize_cover*. Remember to set "Point type" to "None". To find out how to modify a graph see How To Modify a Graph Component.

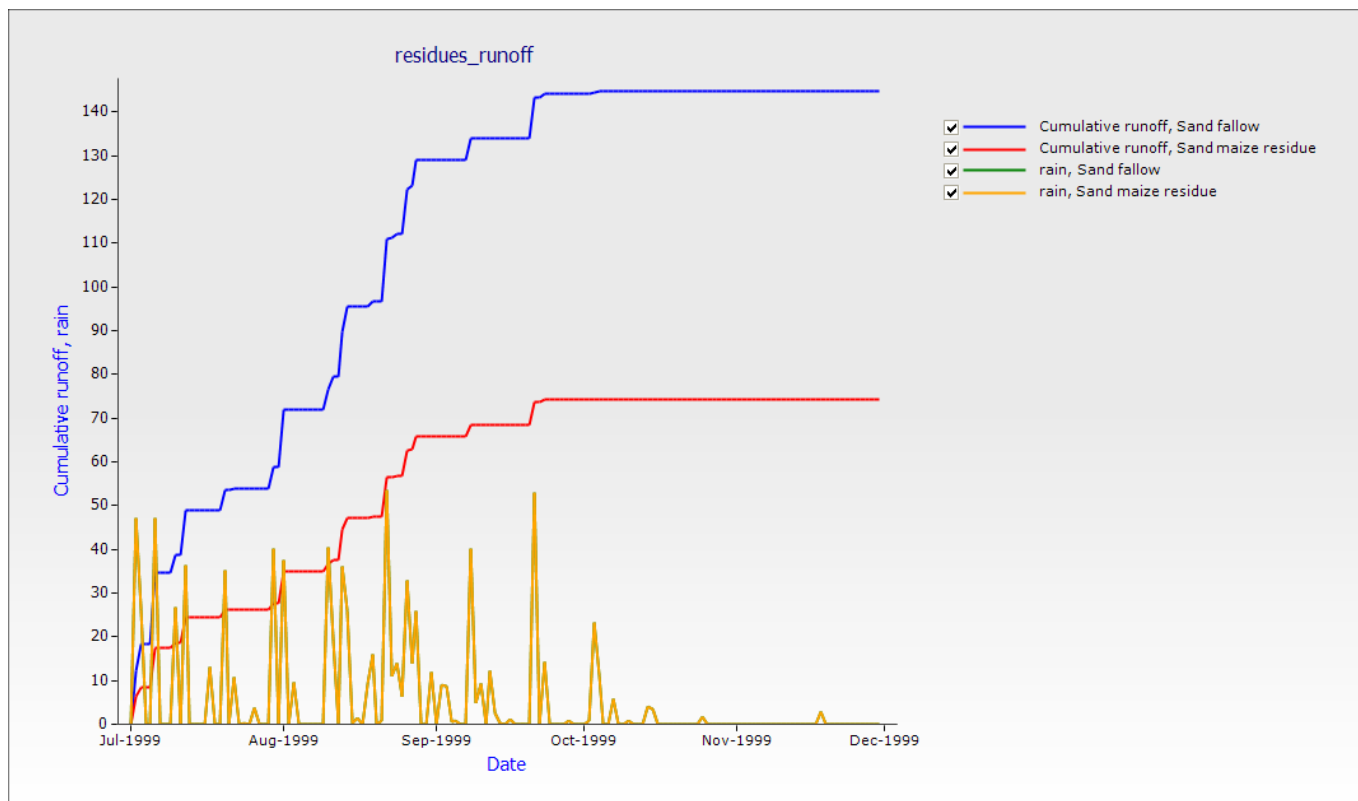


It can be seen that periods of high decomposition rate match with higher rainfall and low decomposition with dry periods.

The effect of cover decline on runoff and evaporation

In this activity, a comparison will be made of two simulations: 'Sand Fallow' and 'Sand Maize Residue'.

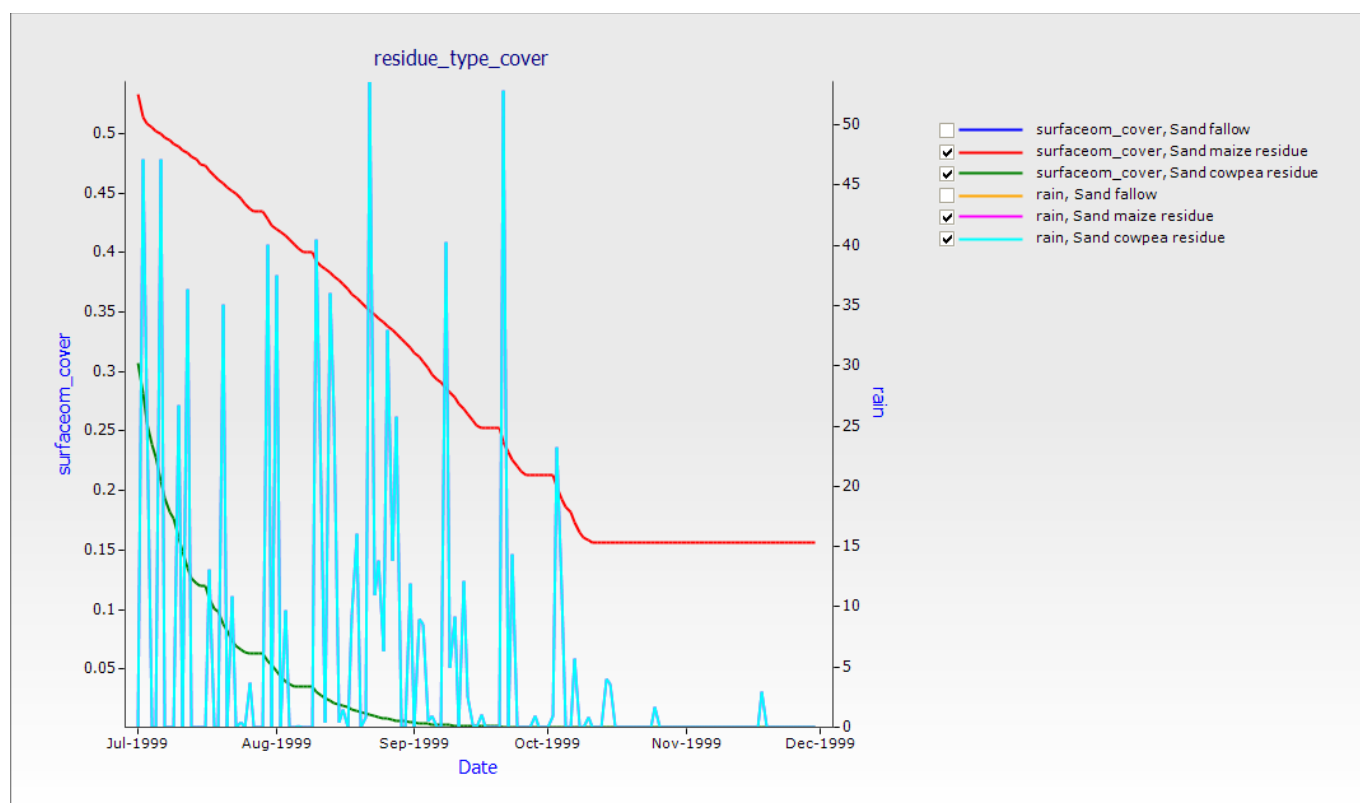
1. Copy the *maize_cover* graph that we've just created to the clipboard, and paste it onto the simulations node at the top of the tree.
2. Graph Date vs runoff(cumulative) and rain (this time on the same axis as the runoff, **NOT** right hand axis)
3. Rename this graph *residues_runoff*. Notice that data from both simulations (*Sand Fallow* and *Sand maize residue*) appears.



The effect of residue type on speed of decomposition

The APSIM residue model will decompose residues at differing rates according to the C:N ratio of the material. To demonstrate this we will reproduce the previous simulation but apply legume residues in the place of the maize residues.

1. Create another copy of the Sand maize residue simulation and call it Sand cowpea residue.
2. Change the residue parameters to 2000 kg/ha of cowpea (type) residue. Set the C:N ratio to 20. (Remember you may want to change the Organic Matter pool name to something like cowpea as well)
3. Run this new simulation. (If you just select this simulation in the tree and click the run button it will only run this simulation instead of all of them)
4. Graph the Sand maize and Sand cowpea residue simulations with residue cover as a function of time (eg date). Add rain to the right hand axis if you like.
5. Rename the graph to "residue_type_cover".



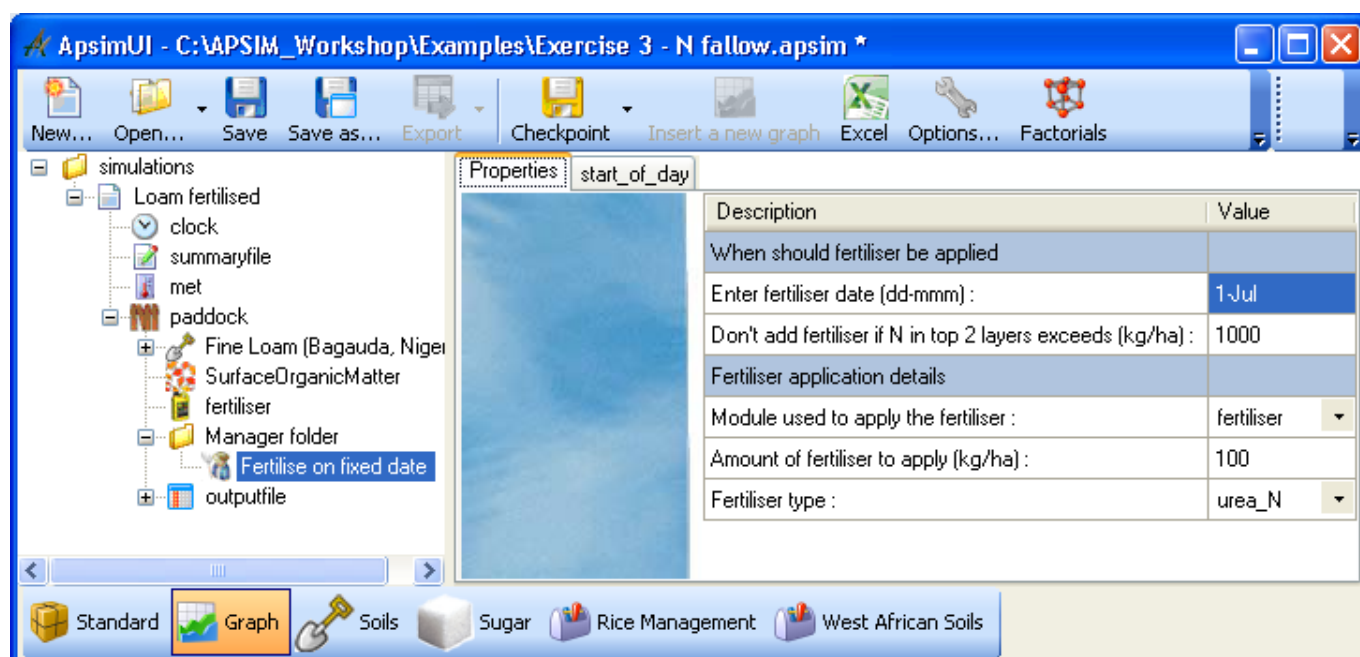
3. Nitrogen Cycling

In this exercise you will observe the fate of fertiliser nitrogen in a fallow situation: Urea to ammonium to nitrate and the loss of soil nitrate via denitrification.

This simulation will introduce us to editing a simple Manager rule and to more advanced features of graphing simulation results. Firstly we need to set up our weather and soil data. The simulation is on a fine loam soil in the Segou region in Mali.

The examples assume you have read and walked through the previous document: How to Build, Run and Graph a Simulation.

1. Start with a new simulation based on *Continuous maize*
2. Change simulation name to *Loam fertilised*
3. Save the file as *Exercise 3 - N Fallow.apsim*
4. Choose "Segou - Mali 1972-2001.met" weather (c:\apsim_workshop\met)
5. Enter the start date of the simulation: 1/07/1999
Enter the end date of the simulation: 30/11/1999
6. In the West African Soils toolbox, look under Nigeria\Kano to find the soil "Fine Loam (Bagauda, Nigeria)". Drag this soil onto the paddock node of the simulation tree. Remove the old soil.
7. Set the Starting water to 50% full, evenly distributed.
8. Set the Starting nitrogen to 11 kg/ha NO₃ and 5 kg/ha NH₄.
9. Set the initial surface organic matter to 2000 kg/ha maize residues.
10. Remove the maize component from the paddock, and all manager rules from the manager folder.
11. Drag a *Fertilise on fixed date* to your Manager component. ("Standard toolbox" -> "Management" -> "Manager (common tasks)")
12. Change the fertiliser management parameters to apply 100 kg/ha of urea_N on 1-Jul. (leave the "Don't add fertiliser if N in top 2 layers exceeds (kg/ha)" property, and set the "Module used to apply the fertiliser" to "fertiliser")



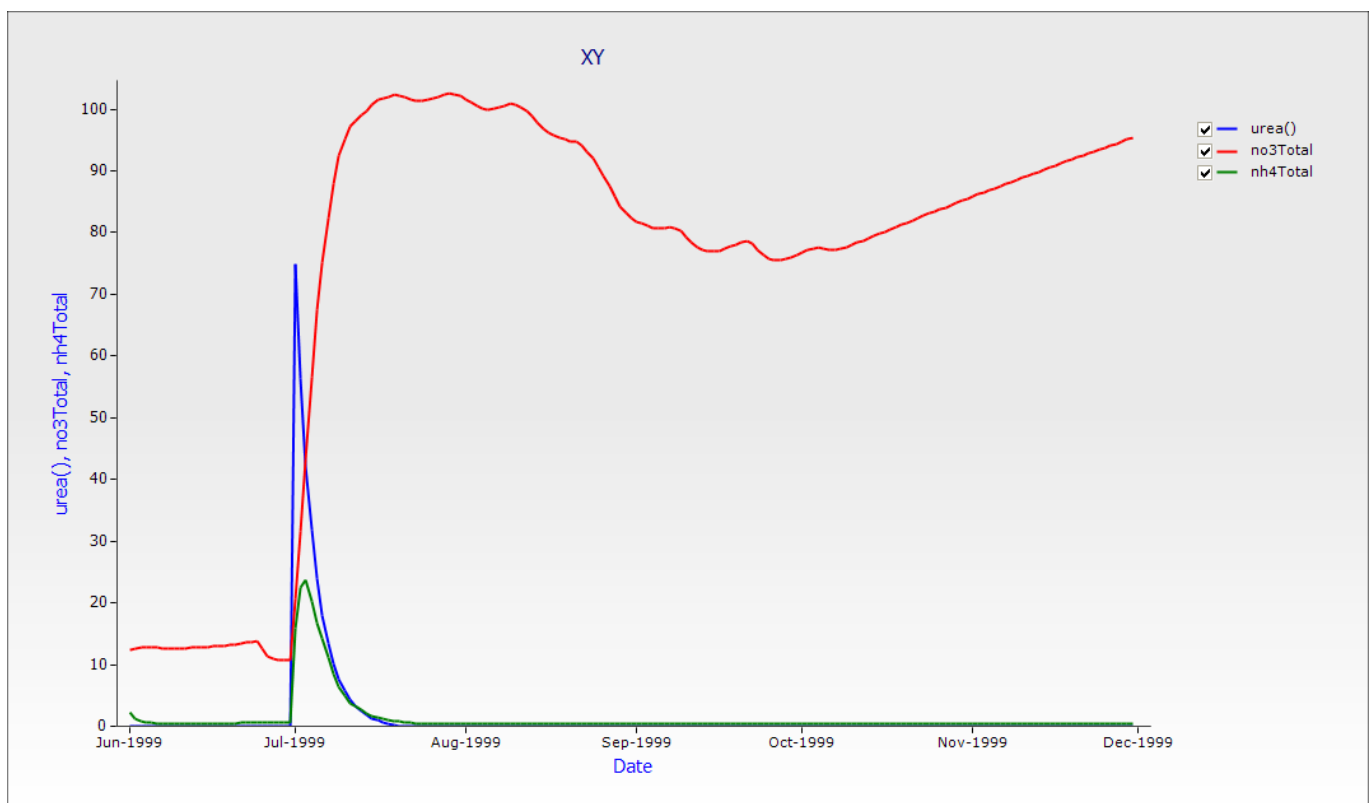
13. Make sure your simulation contains a *Fertiliser* component in your paddock. Even though it doesn't have any changeable properties it is still necessary when fertiliser is to be applied.
14. Choose these variables to report:

Component	Variable name	
Clock	dd/mm/yyyy as Date	
	Year	
	Day	
Met	Rain	
Soil (Fine Loam)	dlayer	The thickness (in mm) of each soil layer.
	esw	Extractable Soil Water (mm)
	drain	Drainage (mm)
	NO3() as NO3Total	Nitrate Nitrogen - summed over profile, aliased to NO3Total. (the as keyword creates an alias)
	NH4() as NH4Total	Ammonium Nitrogen, summed over profile, aliased to NH4Total.
	urea()	
	dnit()	
	NO3	Nitrate Nitrogen, layered
	NH4	Ammonium Nitrogen, layered

15. Change reporting frequency (in *My Variables Events*) to end_day.

16. Run the simulation.

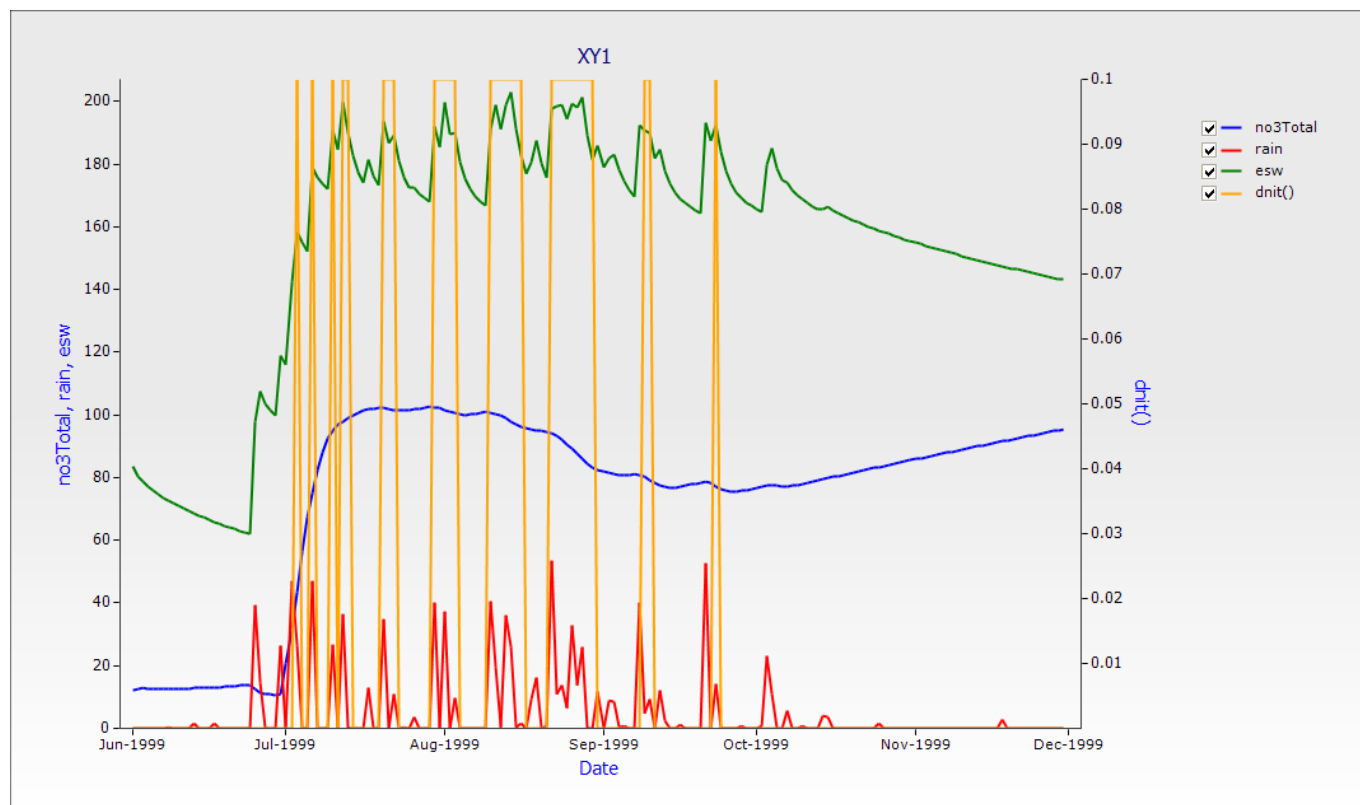
17. Create a graph of date vs urea, total ammonium and total nitrate. Drag an XY graph component onto the simulation. On the Plot node set "Point type" to "None" and leave "Type" as "Solid line".



Question: Why does the above graph look the way it does?

Illustrating the extent and conditions required for denitrification losses

Create a new chart of Date vs Rain, DNIT (on Right Hand Axis), ESW and NO3Total.



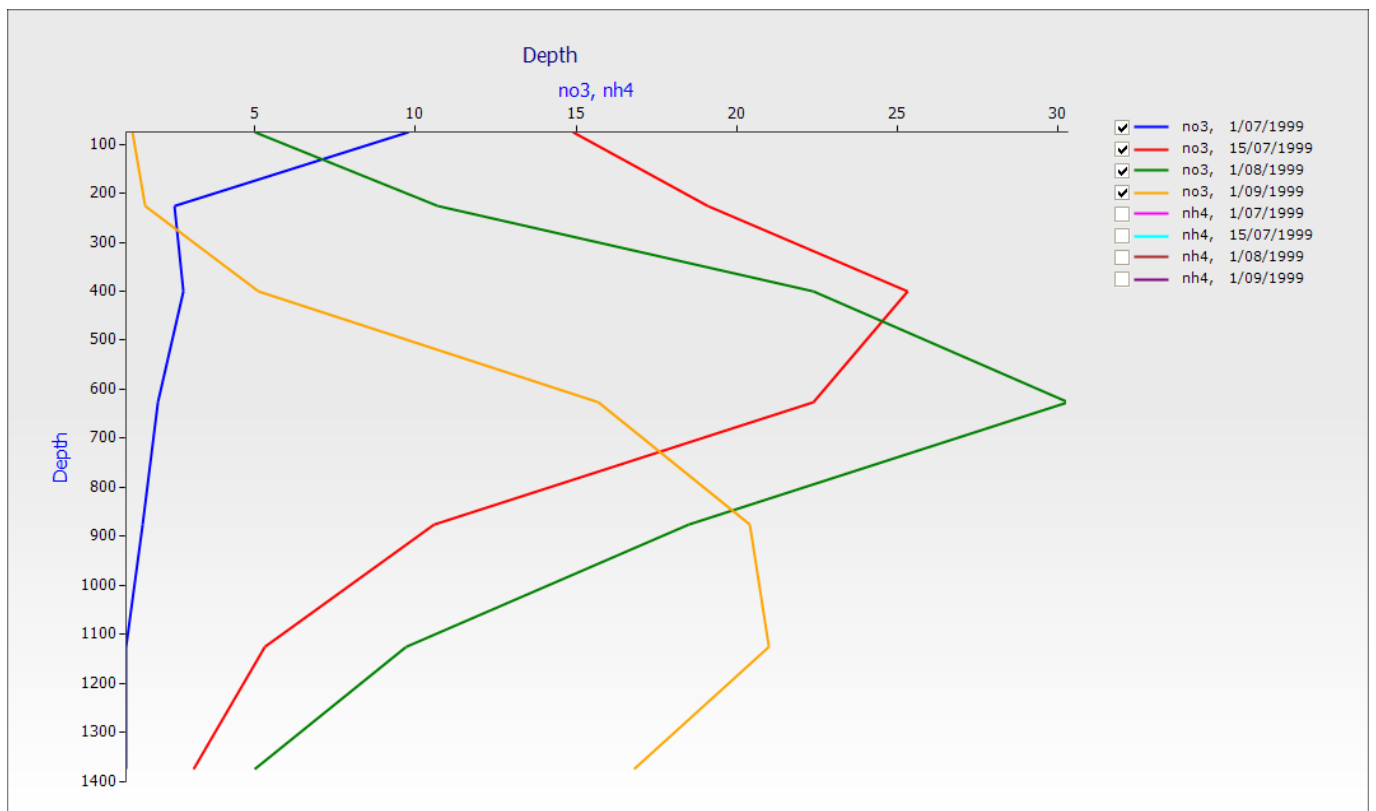
From this chart you can see that some nitrogen is lost via denitrification when large amounts of nitrate is available in saturated soil conditions. But why do you think the level of denitrification is so low (0.1 kgN/ha/day) in this case?

Exploring vertical movement of nitrate, after fertilisation, through the soil profile

Let's look at the distribution of nitrate through the soil profile at 15 and 31 days after fertilisation, and again at 2 months.

1. Create a depth graph (from the graph toolbox), and expand all the children. Go to the lowest depth node, and select (so that they show a tick mark) the dates 1/07/1999, 15/7/1999, 1/8/1999 and 1/9/1999. Go to the Plot node and select NO3 and NH4 as the X variables. Leave the Y variable as "Depth". Select the top graph node ("Depth") and untick the checkboxes for the "nh4" lines.

Depth plots can only be done when the simulation has dlayer in the output file along with at least one other layered variable. This is why we included no3 and nh4 as layered variables in the output file and not just the summed variables NO3Total and NO4Total.



From this chart you can see the distribution of nitrate in the soil profile on day 1, 15 and 31 days after the addition of urea fertiliser and at 2 months.

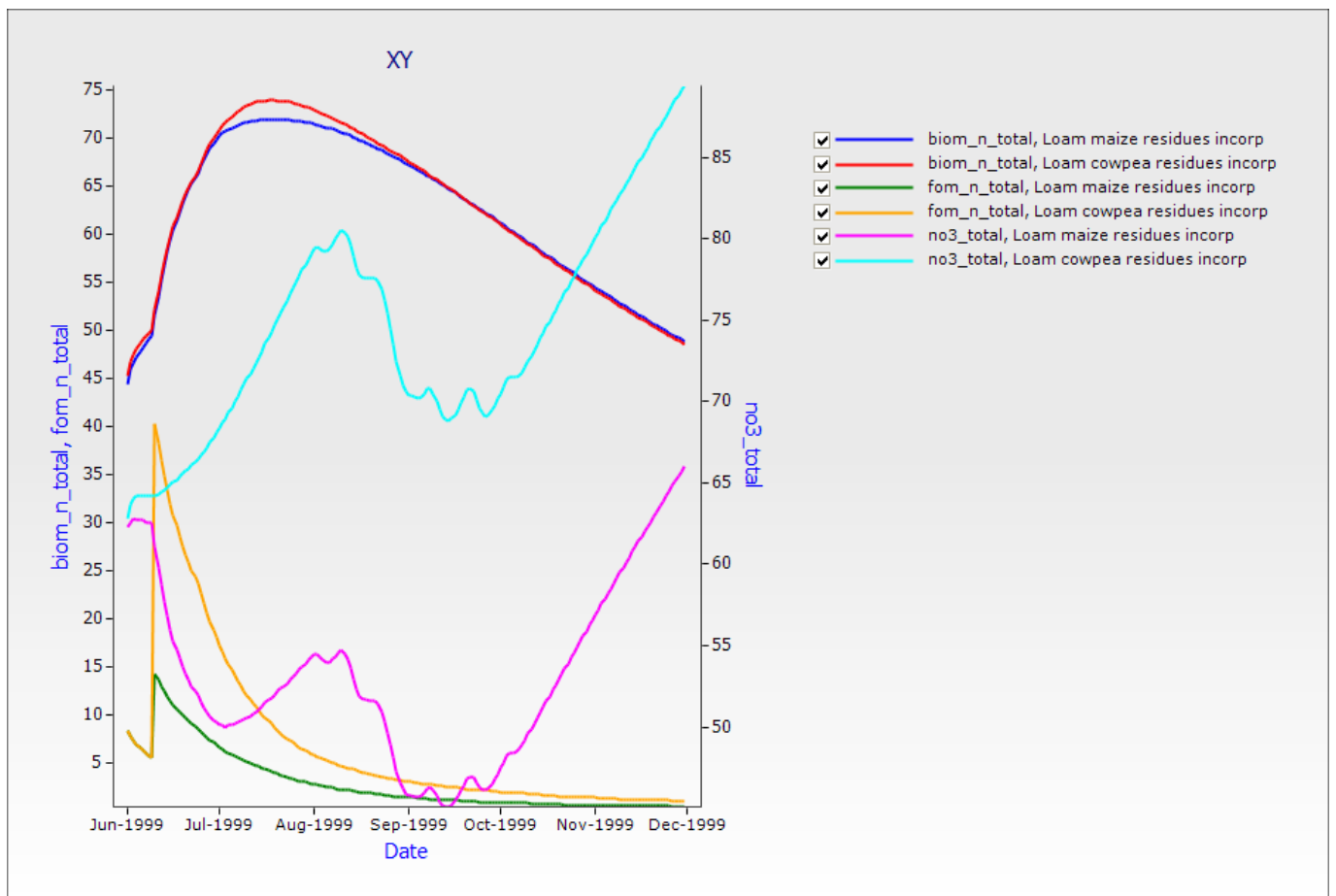
Movement of Nitrogen between Organic Matter Pools

In this exercise we track the movement of nitrogen in fresh organic matter into soil microbial biomass and further into mineral nitrogen. We shall compare the flows in these processes for incorporation of two types of residues – maize and cowpea.

1. Make a copy of the Loam fertilised simulation by dragging to the top node in the tree (*simulations*) This setup already includes maize residues on the surface at 2000 kg/ha
2. Change starting NO₃-N to 61 kg/ha (18 in top 2 layers, 5 in remaining layers), leaving NH₄-N at 5 kg/ha
3. Remove *Fertilise on fixed date* from your paddock component
4. Drag *Tillage on fixed date* to your 'paddock' component for this new simulation. (open "Standard toolbox" -> "Management" -> "Manager (common tasks)")
5. Change the Tillage management parameters to:
date = 10-Jun
Module used to apply the tillage = Surface Organic Matter
Tillage Type = user_defined
User defined depth of seedbed preparation = 100 (mm)
User defined fraction of surface residues to incorporate = 1.0
6. Change simulation name to *Loam maize residues incorp.*
7. Choose these variables to report:

Component	Variable name
Clock	dd/mm/yyyy as Date
Soil	Biom_n() as biom_n_Tot
	Fom_n() as fom_n_Tot
	NO ₃ () as no3_Tot

8. Create a copy of the *Loam maize residue incorp* simulation and call it *Loam cowpea residue incorp*
9. Change the initial surface residue parameters to 2000 kg/ha of cowpea (type) residue. Set the C:N ratio to **20**. (Remember you may want to change the **Organic Matter pool name** to cowpea as well)
10. Run the two simulations for residue incorporation.
11. Graph both residue incorporation simulations with no3_tot (right hand axis), biom_n_tot and fom_n_tot. (Drag an XY graph onto the top node (*simulations*), open the ApsimReader node and point to the 2 output files)



Inspect the change in fresh organic N in residues (fom_n) with time.

Note that there is a steep increase in the first few days when tillage incorporates the surface residues and this material is passed onto the soilN modules as FOM. Soil fom_n for legume is higher than for maize residues reflecting the differences in N content of the 2 materials as determined by the C:N ratios input to the model.

Differences between maize and legume dynamics in decomposition of FOM and its N content can be seen in the transfer of N into the microbial N pool (biom_n_tot), and the effects of this transfer on the net immobilisation/mineralisation of organic N from/to the soil nitrate pool.

What explains the large decreases in NO₃-N in August?

4. Crop simulation – single season

In this exercise we will simulate the growth and yield of maize and cowpea in the same season with identical starting conditions and compare their growth and water use.

You will learn a bit more about specifying a Manager template, execute more than one run in batch mode and use the simulator to do a “what-if” experiment with fertiliser rates and type. These skills can also be used to “experiment” with time of planting, rate of sowing, crop comparisons and different starting soil moisture conditions.

The examples assume you have read and walked through the previous document: How to Build, Run and Graph a Simulation.

1. Start a new simulation using Continuous Sorghum as a template
2. Choose “Segou - Mali 1972-2001.met” weather (c:\apsim_workshop\met)
3. Enter the start date of the simulation: 1/06/1997
Enter the end date of the simulation: 30/09/1997
4. In the West African Soils toolbox, look under Nigeria\Kano to find the soil “Fine Loam (Bagauda, Nigeria)”. Drag this soil onto the paddock node of the simulation tree.
5. Delete the existing soil.
6. Set the Starting water to 75% full - filled from top.
7. Set the Starting nitrogen to 11 kg/ha of NO₃ (i.e. 3 in top 2 layers and 1 in remaining layers) and starting NH₄ to 5 kg/ha (i.e. 2 in top 2 layers and 0.2 in remaining layers).
8. Drag Maize module onto the simulation paddock (from Standard Toolbox-> Crops) and **delete the sorghum module**
9. In the Surface Organic Matter component, change surface organic matter type and pool to maize, and set initial surface residue to 0 kg/ha.
10. In the *Manager* component, delete the *Sorghum Sowing rule*.
11. Drag “Sow on a fixed date” into the Manager component (from Standard Toolbox -> Management -> “Manager (common tasks)”)
12. Change the sowing rule to:
set sowing date to 5-Jul.
set name of crop to maize.
set sowing density to 4.4
set sowing depth (mm) to 30
set cultivar to katumani
set crop growth class to plant
set row spacing to 0.9 (**NB.** The maize module interprets the units here as metres, not millimetres, which can be confusing)
13. Check that the ‘*harvest rule*’ node indicates that *maize* should be harvested.

14. Choose these variables to report:

Component	Variable name
Clock	dd/mm/yyyy as Date
	Year
	Day
Soil	ESW
	NO3() as no3_tot
Maize	daysaftersowing as Mz_das
	lai as Mz_lai
	yield as Mz_grn
	biomass as Mz_tbm
	biomass_n as Mz_Nuptk

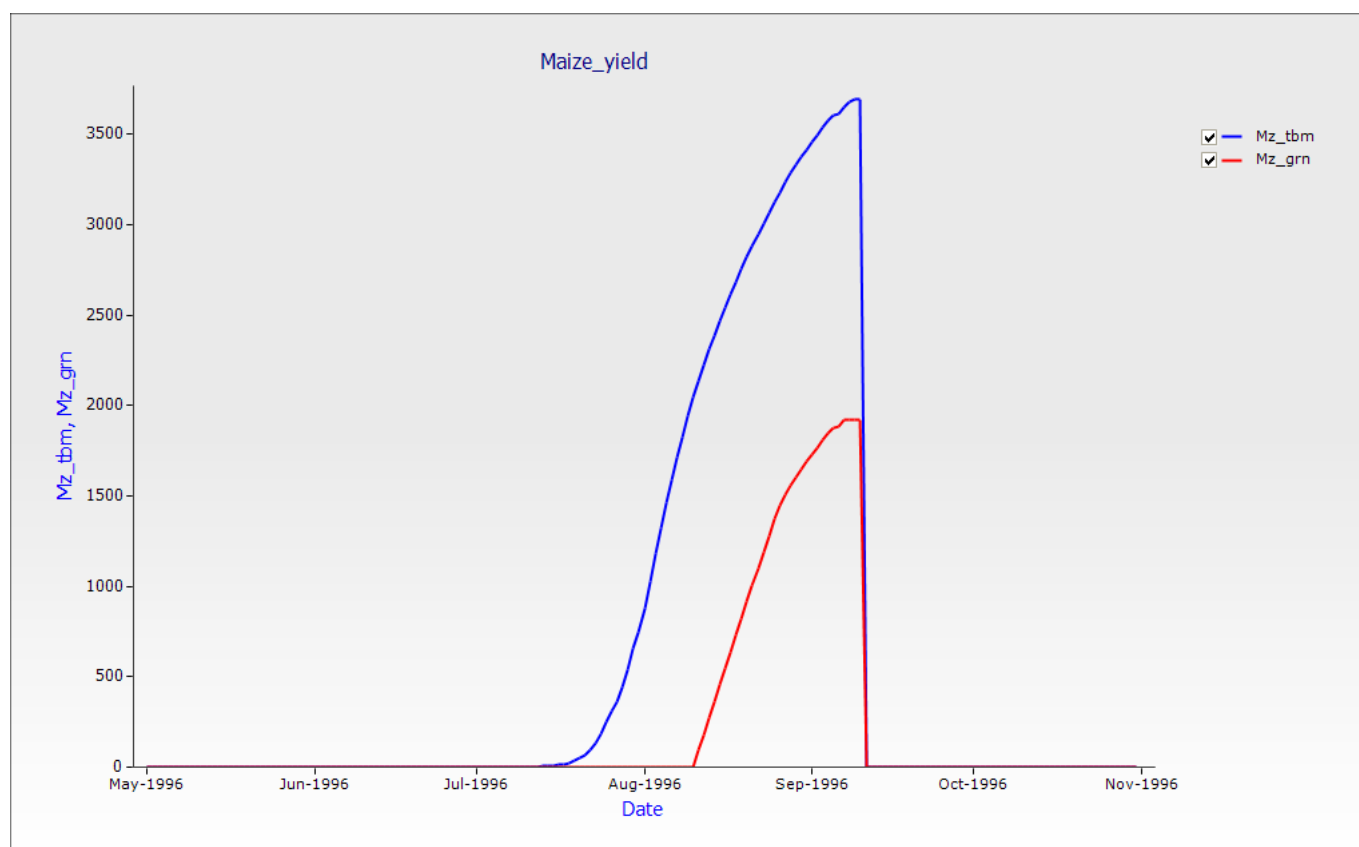
15. Choose an end_day reporting frequency.

16. Rename the simulation to *Maize_0N_1997*.

17. Save the simulation file as *Exercise 4 - Crops_single_season.apsim*

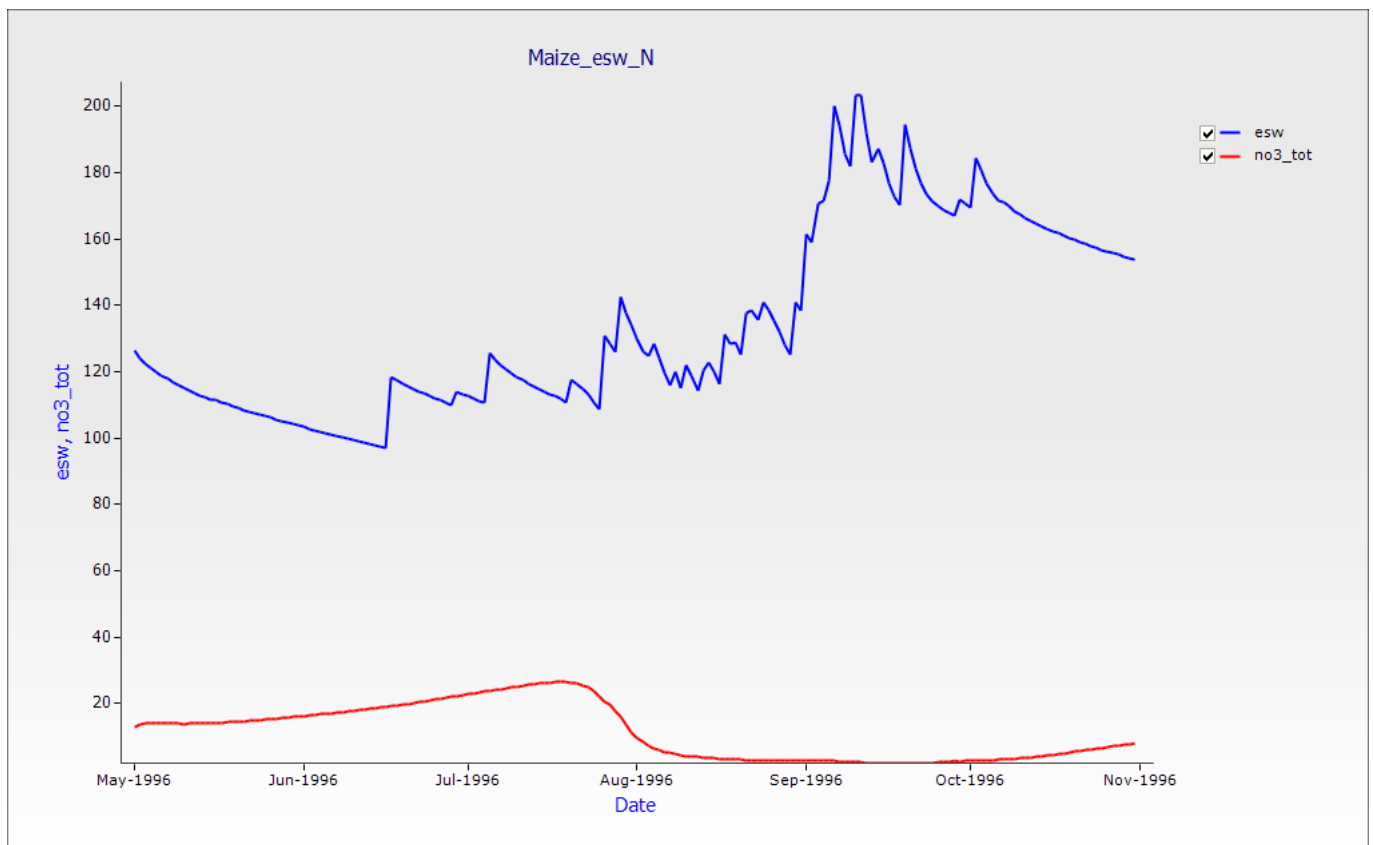
18. Run the maize simulation for the 1997 season.

19. Plot Mz_tbm and Mz_grn with an XY graph with Date on the X axis.



Let's examine the effects of the crop growth on soil resources.

Plot esw and no3_tot on an XY graph.

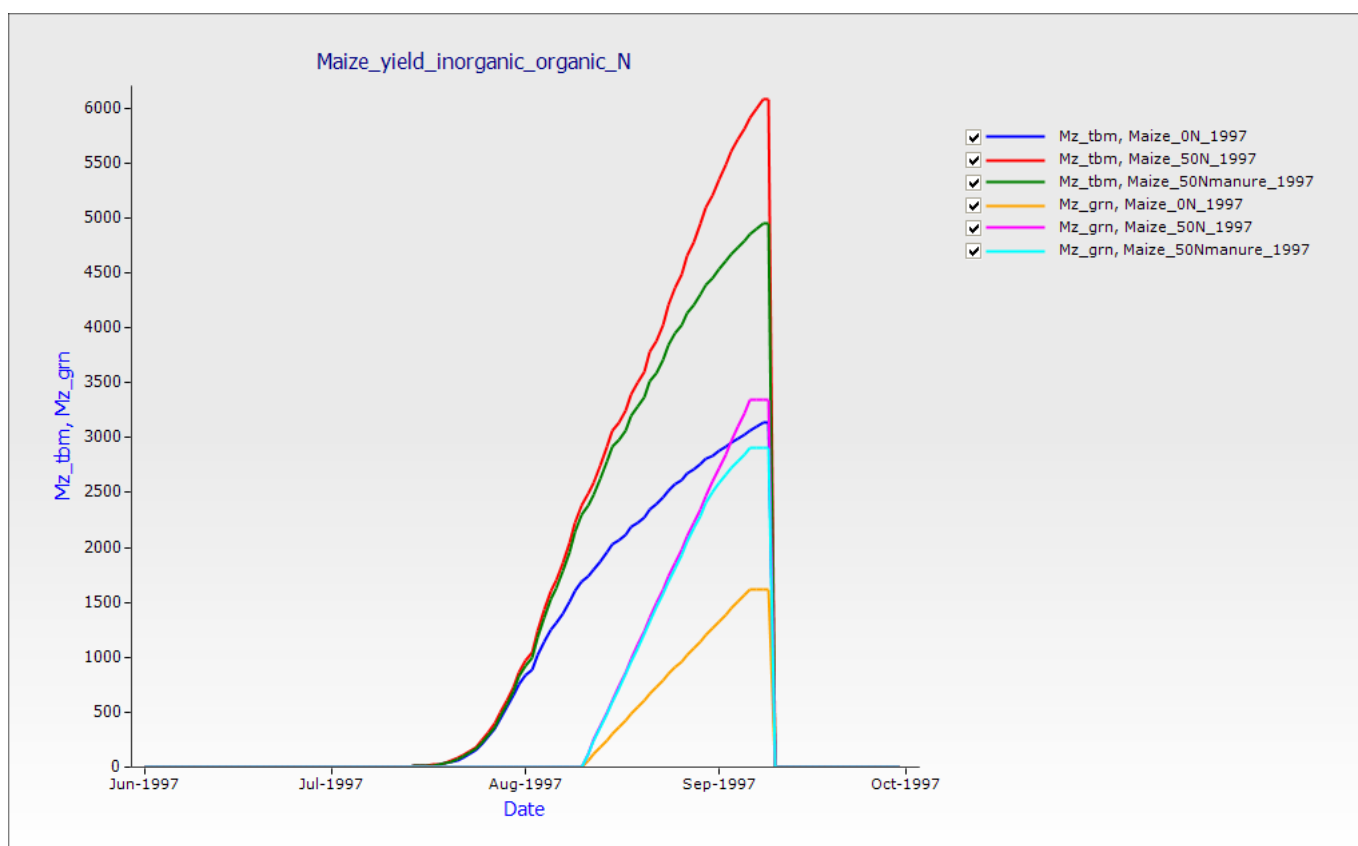


Response of maize to organic and inorganic N inputs

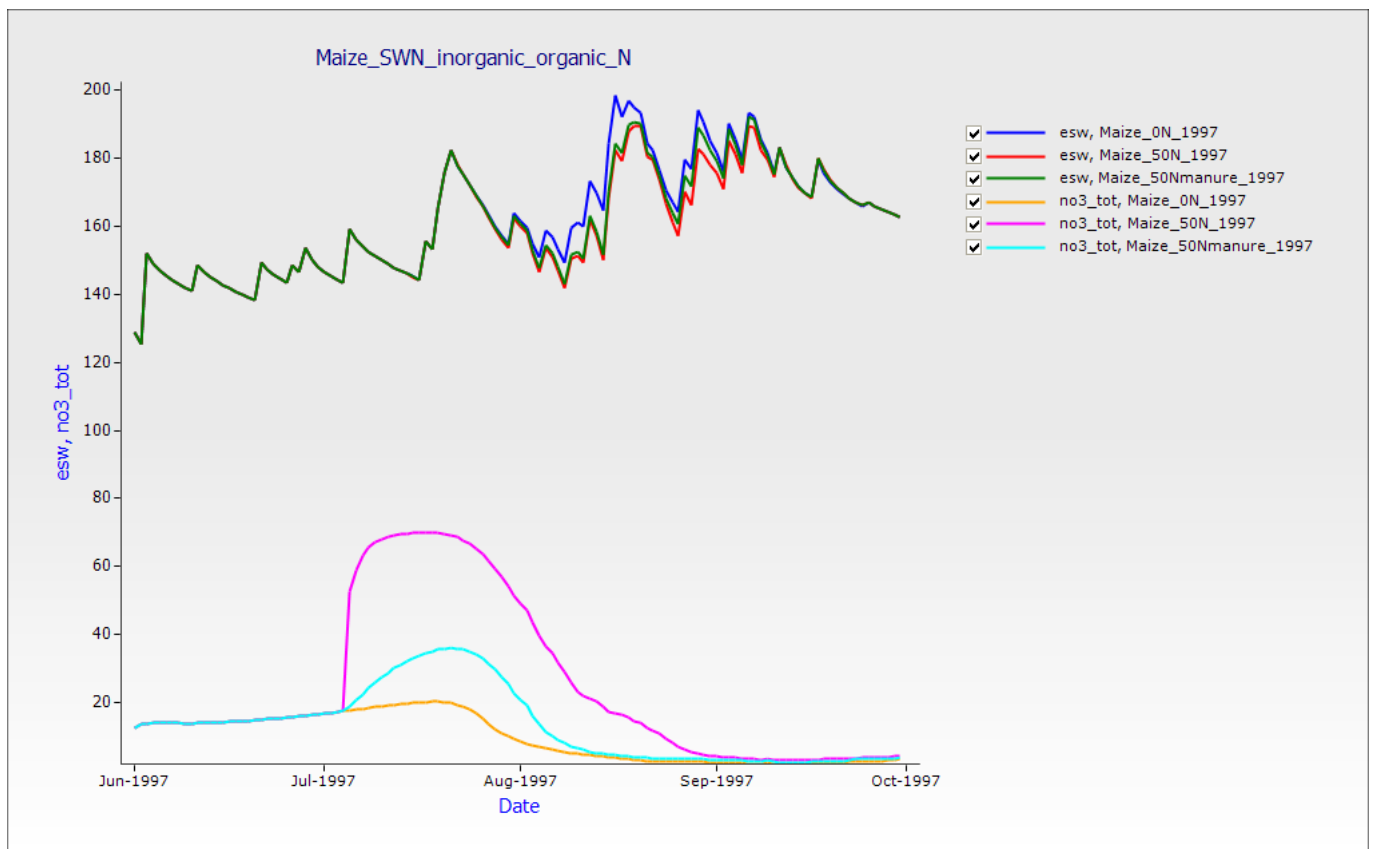
In this exercise we will simulate the growth and yield response of maize to nitrogen inputs as fertiliser and manure for a single season (1997).

1. Make a copy of the simulation *Maize_0N_1997* by dragging it to the simulations node at the top of the simulation tree.
2. Rename this copy to *Maize_50N_1997*.
3. Drag *Fertilise at sowing* on to the Manager Folder (from "Standard Toolbox" -> Management-> "Manager (common tasks)")
4. Change properties to:
 set module event to come from *maize*
 set module event to *sowing*
 set module to apply to *fertiliser*
 set amount to 50 (kg/ha)
 set type to *NH4NO3*
5. Save the file.
6. Make a copy of the simulation *Maize_50N_1997* by dragging to the simulations node at the top of the simulation tree.
7. Rename this copy to *Maize_50Nmanure_1997*.
8. Drag *Manure on fixed date* AND *Manure at sowing* onto Manager (These templates are found in "Standard toolbox" -> Management-> "African and Indian specialisations" -> "Phosphorus and Manure")
9. Drag *Tillage on a fixed date* onto Manager
10. Remove *Fertilise at sowing* from Manager

11. For *Manure on fixed date*, set date to 1-Jul, amount = 2500 kg/ha, type = manure, CNR = 8 and CPR = 50.
12. For *Manure at sowing*, set 'event from' to maize, amount = 2500 kg/ha, type = manure, CNR = 8 and CPR = 50. (Note: By default, SurfaceOM type = manure is 8%C in the standard apsim release. At CNR = 8, %N is 1%. This has been chosen so as to apply 25 kgN/ha at each application. This makes the total N applied equal to the fertilised treatment)
13. For *Tillage on fixed date*, set date = 5-sep, Module used = surface organic matter, Tillage Type = user_defined, depth = 100mm, fraction incorporation = 1.0
14. Save the file
15. Run both simulations
16. Create a XY chart of Mz_grn and Mz_tbm for the three simulations; *Maize_ON_1997*, *Maize_50N_1997*, and *Maize_50Nmanure_1997*.



The plot shows that the simulated maize biomass and grain yield is highest for N applied as fertiliser. Examine the effects of the different N inputs on soil resources. Plot no3_tot and esw vs date.



There is a rapid increase in soil no3 levels after application of the NH_4NO_3 and with nitrification taking place. Even so, the amount of $\text{NO}_3\text{-N}$ in the profile is depleted by crop uptake with time and approaches zero during the early stage of grain filling.

The manure input does not increase the NO_3 level much beyond the zero treatment during the whole cropping period.

5. Multiple season maize simulations

Maize response to N fertiliser - 10 year runs

In this exercise you will examine the response of maize crops to N fertiliser and observe yield probabilities for a 10 year period.

By doing this simulation you will learn about rule based sowing, long term simulations, resetting soil moisture and nitrogen at sowing and graphing probability data.

The examples assume you have read and walked through the previous document: How to Build, Run and Graph a Simulation

1. Start a new simulation using *Continuous Maize* as a template
2. Rename simulation to *Maize_0N_10years*
3. Choose the Segou weather, and set the clock to start on 1/01/1991, and end on 31/12/2000.
4. Choose the “Fine Loam (Bagauda, Nigeria)” soil. Starting conditions at 1/01/1991 are 25% for soil water, filled from the top; 7 kg/ha NO₃-N (as 3.8, 1.7, 0.3, 0.3, 0.3, 0.3 and 0.3 in each layer) and 5 kg/ha NH₄-N (as 3.0, 1.0, 0.2, 0.2, 0.2, 0.2, 0.2). Residue mass is set to zero (see surface organic matter node). We need to set up management for sowing and fertilisation of crops.
5. Open the Manager Folder under paddock. You will see four different manager rules. Click on “Sow using a variable rule with intercropping”. This is a highly generalised manager template. It deals with issues of sowing windows, soil and rainfall sowing criteria, cultivar selection and density, pre-, post- and at sowing N fertilisation, manure applications and tillage operations. This template also includes ‘intercropping’ in case you wish to sow weeds for instance. For now, we will sow maize only and mostly use the default settings with the following changes:

Crop properties

Enter cultivar : mwi_local

Sowing Criteria

Enter sowing window START date (dd-mmm): 1-May

Enter sowing window END date (dd-mmm): 31-Jul

Must Sow: yes

Enter amount of soil water (mm): 0

TopDress fertiliser application

Amount of TopDress fertiliser (kg/ha): 0

Pre-sowing fertiliser application

Amount of pre-crop fertiliser (kg/ha): 0

Tillage components

Name of your soil module : Fine Loam (Bagauda, Nigeria)

6. Leave the “Output at harvesting for intercropping” and “Harvesting rule for intercropping” rules with default settings.
7. Open “Remove all residues on a fixed date” and set remove date to 1-Dec.
8. To gauge the effect of rainfall variability alone on crop N response, we need to eliminate variations in starting conditions (soil water & N) and crop management (sowing date, density, cultivar) for the simulation. We need to re-set soil water and N at sowing each season so that carry-over effects of water and N or rundown in soil OC are not influencing the results. Drag *Reset Water, Nitrogen and SurfaceOM on Sowing* onto Manager (from "Standard Toolbox" -> Management -> "Manager (common tasks)")

Set event module = maize,

soil module = Fine Loam (Bagauda, Nigeria)

surface OM module = SurfaceOrganicMatter,

Reset soil water = yes,

Reset soil nitrogen = yes,

Reset surface organic matter = yes

9. Move the rule up to be the first rule under Manager component (The order is important in the Manager Component. It is the order the rules are checked in) Right click on the rule and select "Move up"

10. Choose these variables to report (deleting any default variables not required):

Component	Variable name
Clock	dd/mm/yyyy as Date
	Year
	Day
Met	Rain
Soil water	ESW
Soil nitrogen	NO3()
Maize	DaysAfterSowing
	Biomass
	Yield

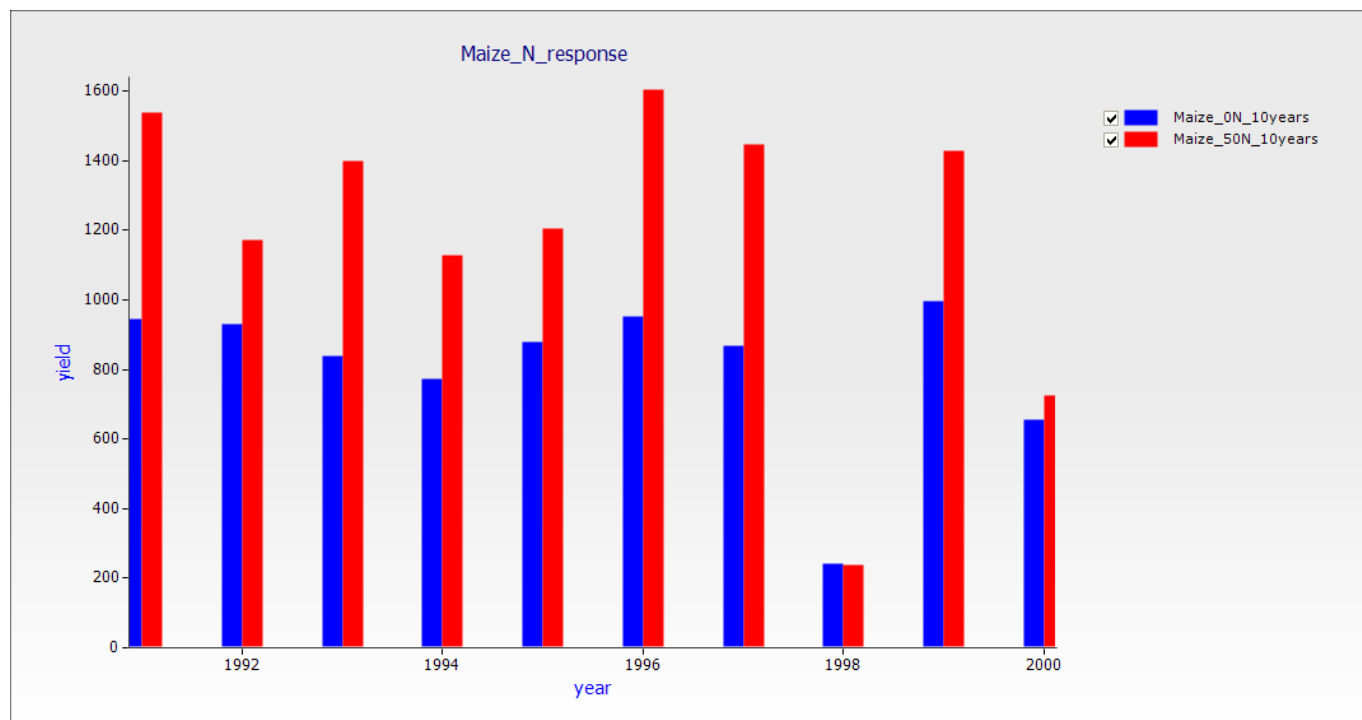
11. Save the simulation file as *Exercise 5 - Maize Simulations Multiple Seasons*

12. Make a copy of the simulation *Maize_0N_10years* by dragging to the simulations node at the top of the simulation tree.

13. Rename this copy to *Maize_50N_10years*. Open the "Sow using a variable rule with intercropping" and set Topdress fertiliser = 50 kg/ha at 35 days after sowing.

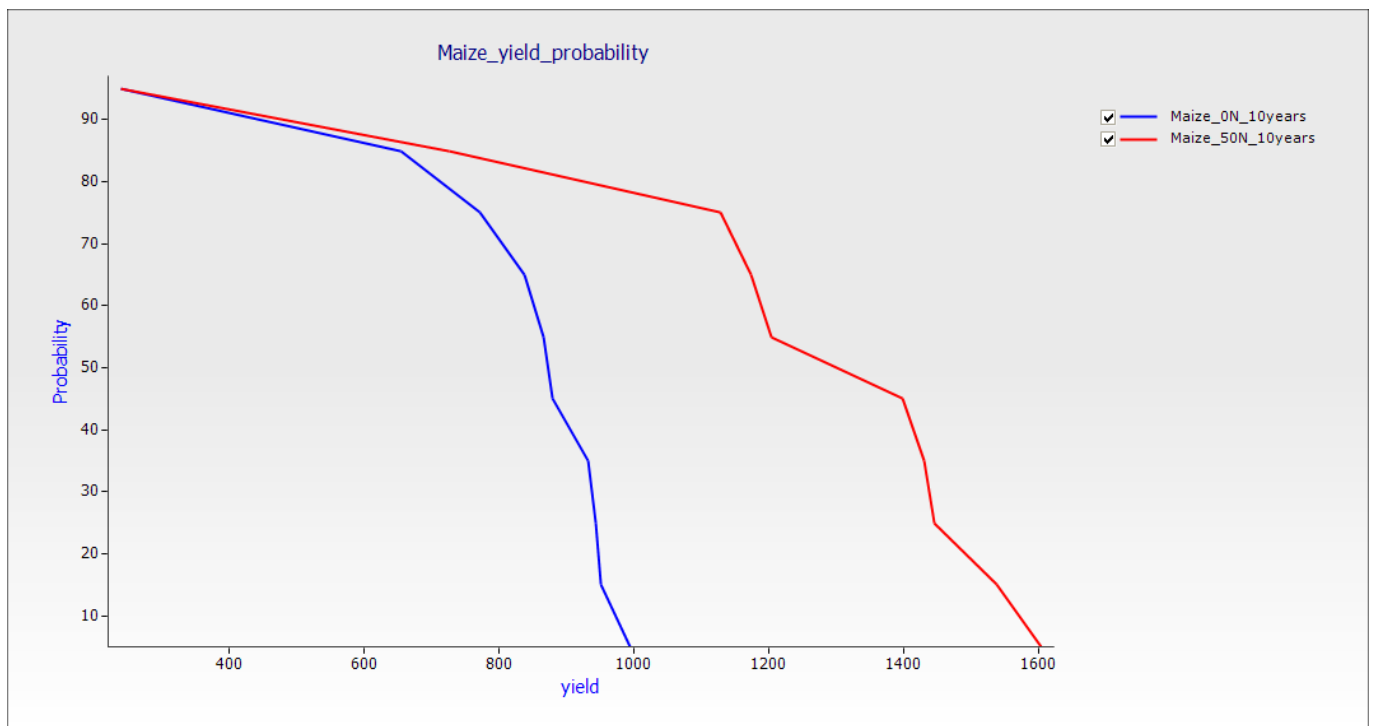
14. Run both long term simulations.

15. Plot yield vs year as a new bar chart.



N response is evident in all seasons except 1998. Clearly this is a low risk site for N inputs.

16. Create a probability of exceedance plot of Yield by using a Graph component. Drag a "Probability of Exceedence" component onto the simulations node from the Graph toolbox.



This graph shows the probability of exceeding a given yield for the soil and management conditions of the simulations.

6. Climate Change projections in APSIM

This exercise aims to explore the effects of climate change on maize cropping systems. Firstly, the response of maize to elevated CO₂ is examined.

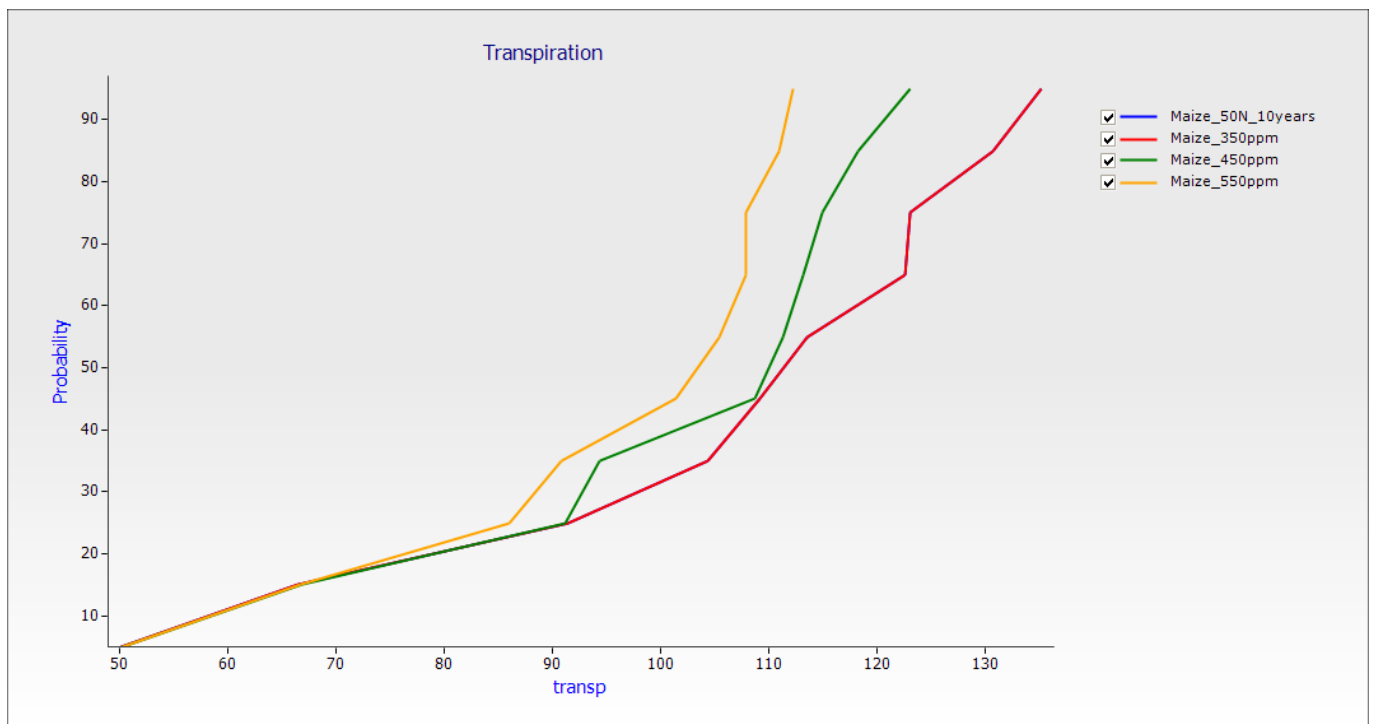
1. Construct a long term maize simulation at Segou - use the Multiple season maize simulations as a guide (the examples below use the *Maize_50N_10years* simulation). Save the simulation file as *Exercise 6 – Climate Change – CO₂ response*. For the analysis, we want to look at seasonal changes in rainfall, evaporation, transpiration and crop yields.
2. Add a “tracker” component from "Standard Toolbox" -> Management -> to the paddock and set up with the following:

Tracker variables	
sum of rain on start_of_day from sowing to now as	RainSinceSowing
sum of ep on end_of_day from sowing to now as	Transp
sum of es on end_of_day from sowing to now as	SoilEvap

3. In the outputfile, we need to report the following variables:

Component	Variable name
Clock	dd/mm/yyyy as Date
	Year
Maize	DaysAfterSowing
	Biomass
	Yield
Manager	DaysSinceSowing
tracker	RainSinceSowing
	SoilEvap
	Transp

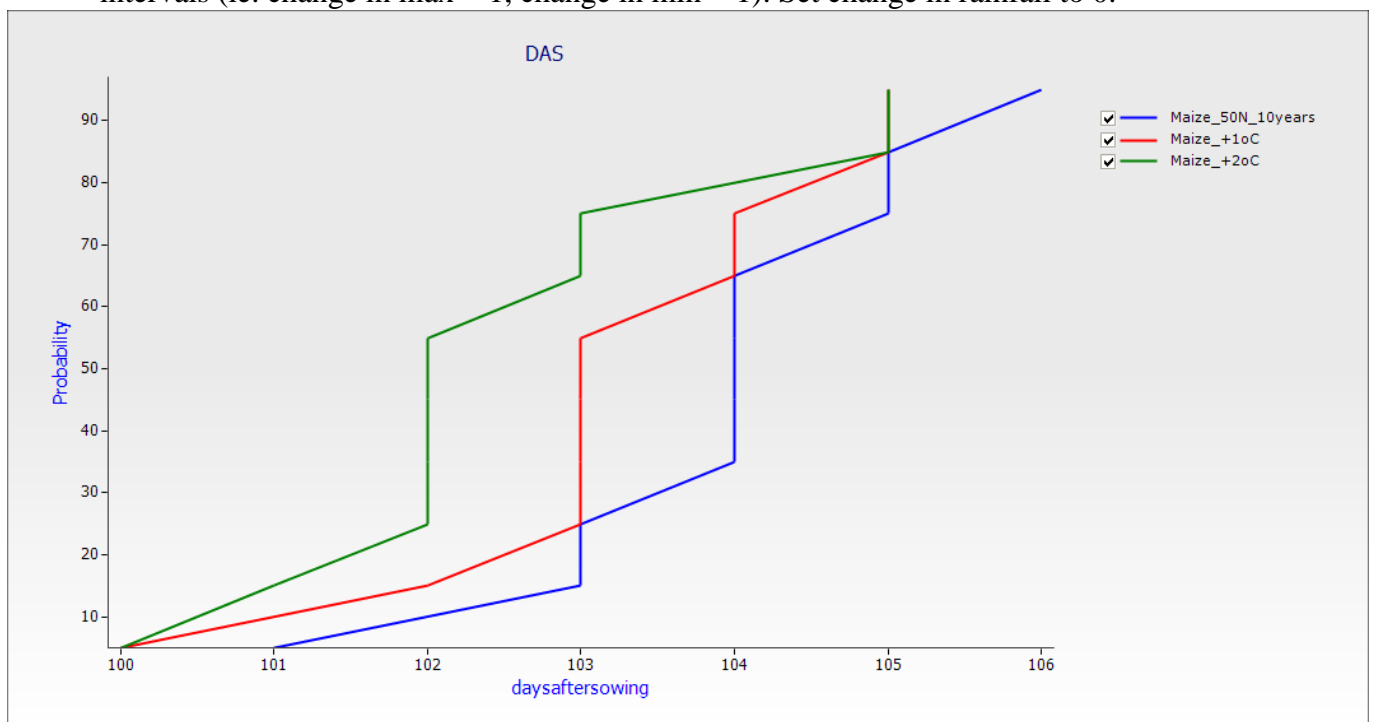
4. Make a linked simulation and rename it to "Maize 350ppm". There are several ways to make linked simulations:
 - a) **right click** and hold down on the source simulation and drag it to the top level (simulations) node. A popup menu appears when you let go, select the "Create Link Here" option.
 - b) Select the source simulation with the left mouse button, hold the keyboards **<alt>** key down, and drag it to the top level (simulations) node.The advantage of linked simulations is that changes made to any component are made to all linked components. More details are in the section Using linkage to reduce simulation duplication.
5. Select the *Maize 350ppm* simulation (in blue).
6. From the standard toolbox, drag an "ini" object from the "Structural" folder onto the maize component in the paddock. This will allow us to override the default "no CO₂ response" maize parameterisation with one that has TE and N responses. Click the "Browse" button on the ini file component and point it at the file "C:\Apsim_Workshop\CO₂_parameter_files\Maize-7.4-CO₂.xml" in the workshop files folder.
7. Drag an "Empty Manager" component onto the manager folder of the simulation, and on its "init" tab, write the equation "CO₂ = 350.0". This will set the value of CO₂ during the simulation to 350ppm.
8. Run the simulation and verify that the results are identical to the first via a CDF plot.
9. Make two more linked simulations, change the ambient CO₂ level to 450 and 550ppm respectively. Note changes in water use and crop yield. (**NB.** If you are using the Maize 350ppm simulation as the source, remember to unlink the manager node that sets ambient CO₂.)



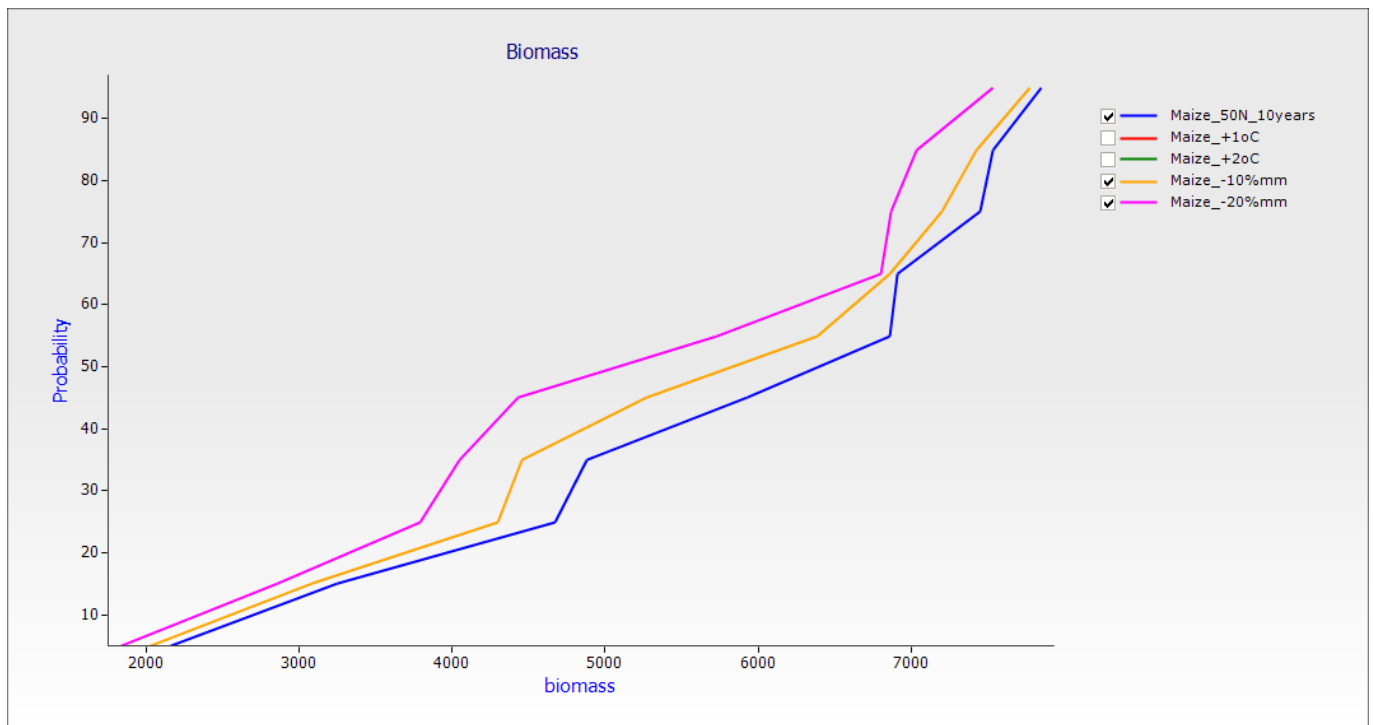
In crop rainfall and crop maturity times are identical in these simulations.

- Next we examine time to maturity (a function of temperature) - we begin by saving under a new name (Save As – *Exercise 6 – Climate Change – Temperature and rainfall.apsim*). Remove all the linked simulations, ie. ones containing the "CO2" management tabs created above. Make new linked simulations for 2 temperature scenarios: +1, +2 degrees rise. Drag a "Climate Control" object from the Meteorological folder in the standard toolbox onto each of the linked simulations manager folders.

The "Climate control" component allows us to change temperature by a constant amount, and rainfall by a percentage value. Once again, conduct a sensitivity experiment by increasing mean temperature by 1 degree intervals (ie. change in max = 0.5, change in min = 0.5) and 2 degree intervals (ie. change in max = 1, change in min = 1). Set change in rainfall to 0.



11. Next look at the effect of reduced rainfall on biomass. Make new linked simulations for -10% and -20% rainfall (set temperature changes to 0).



7. Rotations

In this exercise, you will create a maize cowpea rotation.

1. Create a new simulation based on "*Rotation Sample.apsim*"
2. Change the name of the simulation to "*maize cowpea rotation*" and save to the filename "*Exercise 7 – maize cowpea rotation*".
3. Choose the Segou weather, and set the clock to start on 1/01/1981, and end on 31/12/2000.
4. Choose the "Fine Loam (Bagauda, Nigeria)" soil. Starting conditions at 1/01/1981 are 0% for soil water; 13 kg/ha NO₃-N (as 4, 2, 2, 2, 1, 1 and 1 in each layer) and 7 kg/ha NH₄-N (as 1, 1, 1, 1, 1, 1, 1). Residue mass is set to 500 kg/ha maize (see surface organic matter node).
5. Delete the cotton, chickpea and wheat crops from the simulation and add maize and cowpea (standard toolbox\crops).
6. In the Manager folder, delete the cotton and chickpea sowing and harvesting rules and also the fertilise at sowing rule. There should be three rules left: Rotations, WheatSowing and WheatHarvesting.
7. Rename the WheatSowing rule to MaizeSowing and set up as follows:

Sowing Criteria

Enter sowing window START date (dd-mmm): 1-May

Enter sowing window END date (dd-mmm): 31-Jul

Must Sow: yes

Amount of rainfall : 20

Number of days of rainfall : 5

Enter minimum allowable available soil water (mm) : 0

Sowing parameters

Enter name of crop to sow : maize

Enter sowing density (plants/m²) : 2.2

Enter sowing depth (mm) : 100

Enter cultivar : mwi_local

Enter crop growth class : plant

Enter row spacing (mm) : 0.9

8. Copy the MaizeSowing rule to the manager folder and rename CowpeaSowing. Set up as follows:

Sowing Criteria

Enter sowing window START date (dd-mmm): 15-May

Enter sowing window END date (dd-mmm): 15-Jul

Must Sow: yes

Amount of rainfall : 20

Number of days of rainfall : 5

Enter minimum allowable available soil water (mm) : 0

Sowing parameters

Enter name of crop to sow : cowpea

Enter sowing density (plants/m²) : 6

Enter sowing depth (mm) : 100

Enter cultivar : spreading

Enter crop growth class : plant

Enter row spacing (mm) : 900

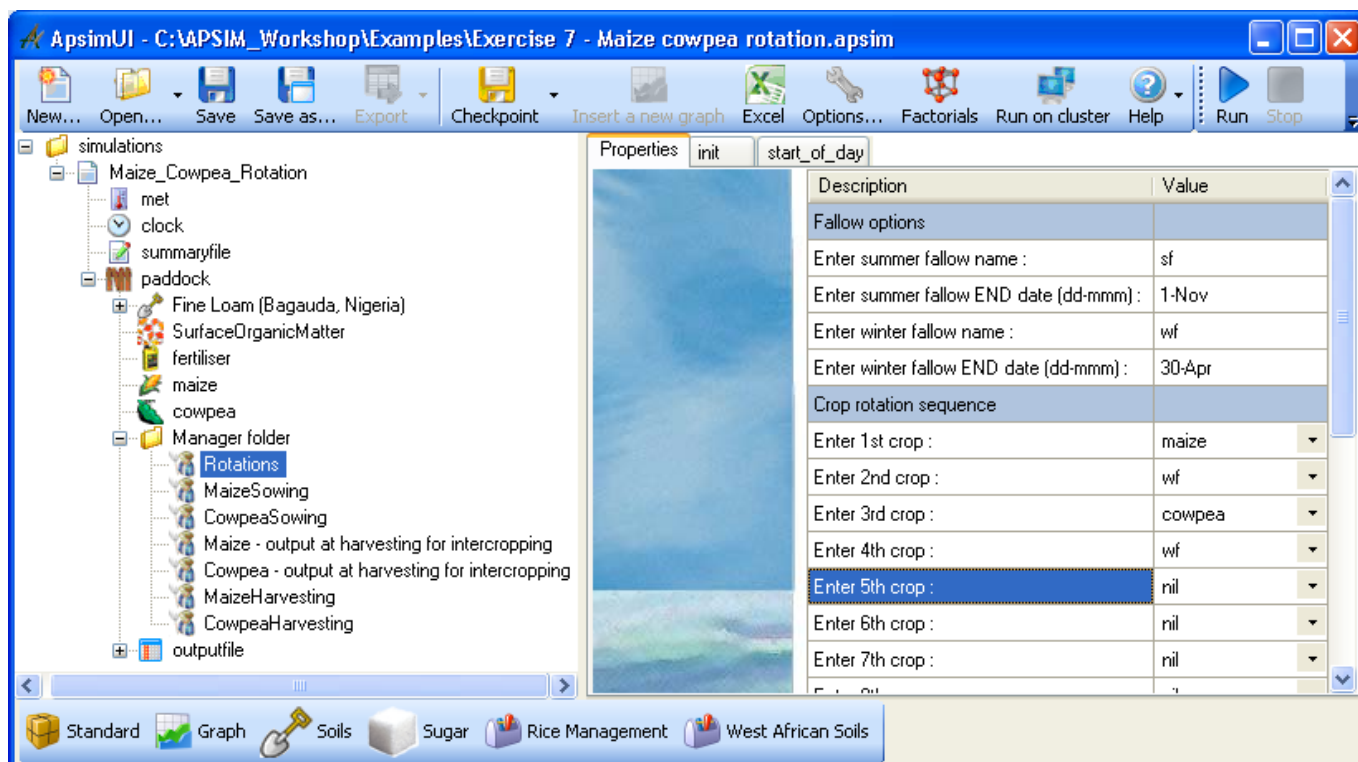
9. Rename the WheatHarvesting rule to MaizeHarvesting and change the crop to harvest to maize. Copy this rule and set up for cowpea.

10. As we are going to output results at harvest (not daily), an additional manager component is required to report the variables at harvest. Drag the “Output at harvesting for intercropping” to the Manager Folder (from Standard toolbox\Management\African and Indian Specialisations\Intercropping, Rotations and Weeds). Even though we are not using intercropping, this rule will still allow us to output variables each time a crop is harvested. Rename this rule to “Maize - output at harvesting for intercropping” and set the crop to harvest when ripe to maize.
11. Copy “Maize - output at harvesting for intercropping” to the manager folder and rename to “Cowpea - output at harvesting for intercropping”. Set the crop to harvest when ripe to cowpea.
12. Now we need to set up the crop *Rotations* rule. Firstly we need to set the END dates for the summer and winter fallow. Set summer fallow end date to “1-Nov” and winter fallow end date to “30-Apr”. Then set the rotation crop order to the following:

1st crop	maize
2nd crop	wf
3rd crop	cowpea
4th crop	wf
5th crop	nil

sf, *wf* and *nil* are standard abbreviations. *sf* for summer fallow, *wf* for winter fallow and *nil* for the point where the rotation will return to the beginning and repeat. APSIM will not recognise anything else.

When finished it should like this:



13. Before we move on to the output, we need to check the order of the manager rules. Make sure the Rotations rule comes first followed by the sowing rules, then the output rules and then the harvest rules (as in picture above).

In the outputfile, we need to report the following variables:

Component	Variable name
Clock	dd/mm/yyyy as Date
	Year
	Biomass
	Yield

14. Set the Reporting Frequency to “Harvesting” (you will need to type this in manually).

15. Run the simulations.

16. Create a bar graph of the yields of the two crops.

