These training exercises are accompanied by a collection of associated screenshots in the file *APSIMForPlantationForestryInstructionsExercisesScreenShots.docx.*
You might not exactly create the values and colours in graphs as shown, but the main aim is to build, run and graph simulations successfully, i.e. the simulations should run as planned and without error messages.
Contact Philip if something is unclear (+61 409 242 677, Philip.Smethurst@csiro.au) and if you have suggestions for improving these training instructions.

Files provided for saving in the same folder as your simulations:

- APSIMForPlantationForestryInstructionsExercises.docx (these instructions)
- APSIMForPlantationForestryInstructionsExercisesScreenShots.docx (open, and follow it with the following exercises)
- lincoln.met
- WarragulCO2.met
- ObservedDataForPlantationForestryTraining.xlsx

1. Tour the website	a. Go to the website www.apsim.info. Visit the various tabs to generally familiarise yourself with the type of content in each. Especially look at: b. Click on the Download tab, and further downloading instructions are provided in Exercise 3 below. c. APSIM Next Generation/Model documentation: https://apsimnextgeneration.netlify.app/modeldocumentation/ d. Demonstration videos: https://www.apsim.info/support/videos/
2. Understand licencing and development	a. Read development and licencing options at: https://www.apsim.info/download-apsim/downloads/
3. Download APSIM Next Generation	a. After clicking on the Download tab of the website, then click on REGISTER NOW, or use this link: https://apsimdev.apsim.info/APSIM.Registration.Portal/Register.aspx b. Here, make sure at 'Version:' you select the Next Generation version that suits your system (i.e. Windows, Debian or Mac), which for training requires a non-commercial (free) licence. c. You will be sent an email with a link to click on to commence the download. d. Even though you selected Next Generation, a new screen of options will be provided that is defaulted to APSIM Classic. If you use the email option, you can ignore this new screen of options. If you want to proceed with this new screen of options, again make sure you choose APSIM Next Generation (and we recommend you choose the latest version of it), then click on your type of platform, and continue. e. You will be asked to instal Windows Desktop Runtime, if it is not already available on your computer, and this might require administrator permission. If so, accept and proceed. f. Where you have the option to instal for all users or yourself, choose yourself, unless you have already invoked administrator rights on your computer. g. Other than that, choosing defaults is fine by clicking on 'Next'.

4. Tour the GUI	a. Click on each of the tabs to see what they offer, but you can ignore the tabs 'Importing old .apsim files' and 'View Cloud Jobs'. b. In the training toolbox, the tutorial simulations (Exercises 1-4) provide basic and general training in APSIM Next Generation, which approximately follow those for Exercises 1-5 in the training manual for APSIM Classic (https://www.apsim.info/support/apsim-training-manuals/). However, currently there is no similar training manual for APSIM Next Generation. Instead, video guides for APSIM Next Generation are available at https://www.apsim.info/support/videos/, and the following is training that is more relevant to plantation forestry.
5. File locations and types	a. Essential file types for one simulation: (1) .apsimx, which is the main simulation file, but it can contain several individual simulations. (2) .met, which is the daily weather file. Each simulation needs one met file, which must cover the duration of the whole simulation. b. Optional file: .xlsx, which contains observed data c. Generated file types: .db, .db-shm, and .db-wal are database files, .bak is a backup file. These generated files are not necessary to ruin a simulation, as they will be generated or overwritten during a run. d. Using SaveAs, you can direct the GUI to save your simulation (.apsimx) to a particular location. A local drive will work fastest, but cloud locations can also be used satisfactorily if you have good connectivity. e. .met and .xlsx files do not necessarily have to be in the same folder as .apsimx files, but doing so helps keep all the relevant files for a simulation in one place.
6. Run an example	a. Open the EucalyptusRotation example b. Save it to a location on your computer c. Run it by right-clicking over the Simulation or Simulations nodes. d. View it at various levels (nodes) of the structure of the simulation nodes, e.g. Memo, Weather, Clock, Summary etc. e. Note the progress bar at the bottom of your screen. This is also where error messages will appear. It's option to clear those messages by clicking on the Clear status tab of the GUI.
7. Tips for using the GUI	a. Right clicking provides context-sensitive options, e.g. Run, Rename, Copy, Paste, Enable/disable, Empty Datastore, Refresh, Export, and documentation options. b. Hovering your mouse over a node shows in a black box the type of node it is called in APSIM, but it might appear by a different name in the GUI if it has been renamed. c. Organise your simulation stack into a sequence that makes sense for you by moving nodes up or down, and rename them if it would be more meaningful. d. A Map can take longer than expected to display – patience required, sorry. This might have been improved lately. e. Use only numbers, letters and spaces to renaming a node. f. Nodes can be moved up or down in the stack by using Ctrl-<up/down arrow>

8. Error messages, unexpected behaviours, Summary node, Support	a. Building simulations usually involves iteratively adding or modifying components, realising it didn't run at all or completely as intended, and working towards resolving problems. b. Error messages are often produced in red at the bottom of the GUI. These can be difficult to understand, but can provide key words about where in your simulation the problem is occurring, e.g. in a Report, or in Soil Water. There you might also an find an indication of what was wrong, e.g. the model and report variable is not recognised if you are running a Eucalyptus model but the report refers to a Pinus model, or a <plant>Soil node is not included at Soil.Physical, where PinusSoil might exist, but you actually need EucalyptusSoil. c. In the error message shown in the screenshot, an attempt was made to report a Pinus variable, without a Pinus model being present in the simulation, as this simulation uses the Eucalyptus example. d. No error messages might have been produced, but the run might not produce any results. Perhaps by error your planting date is outside the date window of the Clock, or nitrogen or water stress levels are so high that the plant failed to grow at all. e. The Summary node can also provide insights into how your simulation ran and where a problem occurred. f. An option might be to abandon the changes you made, perhaps by going back to a previous version of the simulation. This can be facilitated by using a version control system, e.g. OneDrive, or your own periodic SaveAs and renaming system. g. Ask someone else for help. Working with similarly or more experienced users can provide a source of help, e.g. email them the files, explain the problem, and ask for help. h. Use the Training and Support options at https://www.apsim.info/support/
9. Modify an example	a. In the EucalyptusRotation example that you just ran, modify the following one at a time, rerunning the simulation in between changes: b. Weather to lincoln.met c. Change Clock start date to 30/3/1995 d. In TreeManagament, change within row spacing to 1 m e. Change Cultivar to nitens f. Change Planting date to 1-may g. Change Amount of fertilizer N to 200 kg/ha h. In Soil/Organic, change Soil Organic C (%, 0-10 cm) to 1.5 i. By trying a few different fertilizer rates and soil C concentrations, you should see sensitivity to N availability in the various graphs. j. Tip: Copy-pasting individual or blocks of values is possible, e.g. copy all Soil/Physical/AirDry to Eucalyptus LL k. What sensitivity would there be to a drier climate? How could you test that? l. One option: Copy, paste (or drag) the individual (child) simulation called '**EucalyptusRotation**' to the top (parent) Simulations level, which should provide an identical but renamed simulation. Rename it to '**EucalyptusRotationDry**'.

	m. Copy the ClimateController tool from the Management toolbox, and paste it into the individual simulation at the same level as the weather node. Change rainfall multiplier to 0.5. n. Run both simulations by choosing the run option while at the top Simulation level. It is also possible to run only the newly created or changed simulation, but then you would also have to refresh the Datastore after running to display updated results at the top graph level. o. Copy one or all of your existing graph nodes (not just the series level) to the top Simulation level. p. Within the graph options for the series, choose 'Colour by Simulation name' and click on 'Show in legend' q. This should show you both simulations plotted on one graph.
10. Download a soil	a. Copy, paste (or drag) the simulation to the top Simulation level and rename it, which should provide an identical but renamed simulation. b. Right-click on the plantation node c. Select Download Soil d. Click on Search for soils e. Choose Loam (Lincoln No 1404) f. This soil won't work yet, as it doesn't have a plant type at the Physical node g. Copy and paste EucalyptusSoil from the previous soil used onto the Physical node of the current simulation. h. Delete the previous soil in this simulation, as you only want one soil in each Plantation (stand) i. The copy and pasted EucalyptusSoil has an extra horizon - delete that layer in EucalyptusSoil j. Copy and paste the LL15 cells to Eucalyptus LL column. Otherwise, an error will be shown on running, because Eucalyptus LL will be less than air dry values. k. Rename this simulation '**LincolnDry**' l. Run all simulations again (or just the new one and refresh the Datastore) m. You just added a soil from a soil database for a location within 100 km of the weather file location. n. View the graphs to see the difference it made.
11. Download met	a. Copy, paste (or drag) the simulation to the top Simulation level, which should provide an identical but renamed simulation. Rename it '**LincolnMetWarragulSoilDry**' b. Right-click on the simulation node c. Select Download Weather d. Provide latitude and longitude OR place name (e.g. Warragul) and Get location for placename (which will update the latitude and longitude to the Warragul location), complete other requested information, and Ok e. Click on Save to update the appearance of the weather data. f. Run all simulations again (or just the new one and refresh the Datastore) and updated graphs

12. Modify soil and met	a. Change some soil values within a reasonable range, e.g. rooting depth (XF), EucalyptusLL, C:N ratio b. Change rainfall multiplier to 2, then back to 0.5 c. Did productivity change in a reasonable way? d. Note that we have been working with minimal met files. Other columns can be added, e.g. wind and CO2, but that is most easily achieved in Excel. A CO2 column is already provided in an alternative met file 'WarragulCO2.met'. If CO2 data are provided, APSIM takes them into account. Copy and rename the most recent simulation to '**LincolnSoilWarragulMetDryCO2**', and use this modified met file. What effect did that have on predicted growth? Answer: 2.7% increase in DBH over the period of our simulation.
13. Replacements and Map	a. From the Standard toolbox/Structural, add a Replacements node at the top Simulation level. b. This will enable us to change a report once here, which replaces it for all reports of exactly the same name in all individual simulations. c. From any of the individual simulations, copy the Report and paste it into the Replacements node. d. From the Standard Toolbox/Standard models, add a Map node at the top simulation level. e. It might be a little slow to display, but eventually it will display the locations of the latitudes and longitudes in all met files.
14. Modify a report or create a new one, graph results	a. Lines of a report can be commented out with // b. Tips for preparing reports are available at the bottom of the page at: https://apsimnextgeneration.netlify.app/modeldocumentation/. c. In the Report in Replacements, in Reporting variables, type at the bottom below existing variables reported [Eucalyptus]., with the dot. d. You should see some options pop up. Select Leaf. There are many variables to choose from to report. Type another dot for another level of options and select Fn. e. Do the same, but select Fw. f. This adds the two main stresses of interest: Fn nitrogen stress, Fw water stress. g. Run all simulations again h. Copy the LAI graph and relabel it Fw. In the options, select Eucalyptus.Fw as the Y-axis. i. Repeat for Fn j. These graphs now show relative N or water stress on a scale of 1 none to 0 total stress. k. Copy the ClimateController to Replacements. Substantially alter rainfall and look at how it changes the Fw and Fn graphs. l. Reporting so far has been daily, but we'll now change that to annual. m. Copy, paste and rename the Report in Replacements as 'ReportAnnual' n. Change its reporting frequency to EndOfYear and delete the less interesting variables o. Copy the new report into a simulation. p. Rerun that simulation and view the data in the new report.

15. Build an experiment	a.	Experiments in APSIM, which works like Replacements, can be very useful for efficiently building multiple simulations that have a similar base. This could be, for example, to emulate a real experiment in the field or glasshouse, or to investigate sensitivity to one or a combination of variables in a simulation.
	b.	Open the Factorial example simulation, and copy the **ManagerExpt** simulation at the bottom across to your simulation stack.
	c.	Replace the base simulation in that with the latest you developed above, i.e. LincolnSoilWarragulMetDryCO2. This will generate an error message, as something referred to as a factor that was in the original base of the experiment is not in the replacement base. Delete the current 33 and 66 Factor options that came over from the Factorial example. The error message should disappear below, and whatever is in this status location of the GUI can be cleared by clicking on Clear Status on the toolbar.
	d.	Rename that base simulation to e.g. '**LincolnSoilWarragulMetDryCO2NExp**t', and delete it's graphs as they will not display anyway at this level of an experiment.
	e.	Note at the NRate node that we have four options for specifying factors (treatments) in the experiment. We will practice the first 3 options in sequence 1-3. Option 4 has an example in the 'Compound' experiment of the Factorial example. Try option 4, if you wish.
	f.	If treatment combinations in an experiment are set up correctly, the combinations of treatments to be simulated will be visible at the top of the Experiment node.
	g.	*Option 1.* Fetch the 'Fertilise on fixed dates' tool from the Management Toolbox and place it the base simulation
	h.	At the NRate node, in the righthand area, in the blank line below 4, type '[Fertilise on fixed dates].Script.Amount = 10,210' or type only '[Fertilise on fixed dates].' and build the rest using the typing options provided plus your typing. Here you are telling APSIM which component of the base simulation that you are going to use as factor.
	i.	Reset TreeManagement within row spacing to 3 m
	j.	Run the experiment simulation and check results.
	k.	*Option 2.* Change '10,210' to '10 to 210 step 50'
	l.	Run the experiment simulation and check results.
	m.	It is difficult to understand the DBH graph, for example, as there it now contains too many. So copy that graph and place it at the Expt node, which will restrict it to only showing results from our experiment.
	n.	Options 3. Where in option 1 you had typed '[Fertilise on fixed dates].Script.Amount = ...', delete everything after ']'.
	o.	Copy the 'Fertilise on fixed dates' node form the base simulation twice into the NRate node of the experiment. Therein, change one of the rates to 0 and the other to 150.
	p.	Run the experiment simulation and check results.
	q.	If you want to try something a little more complex. I suggest to add stocking as a factor by adjusting within-row spacing, and using the 'Permutation' node from 'Experiment' in the Factorial example. For example, as a level of a Stocking factor, add TreeManagement twice and change within-row spacing to 4.1667 to achieve 800 tree/ha and to 2.083 to achieve 1600 trees/ha.

16. Add uniform or biased mortality and thinning as an Operation	a. At this stage of APSIM development for plantations, users specify exactly the population density (stocking) – from planting to the end of the simulation, as mortality is not induced by environmental stress or age in the model currently. This is an area for future model improvement. b. Open the Pinus example. Find and copy into the most recent of your simulations, the nodes called 'TreeThinning', 'TreeThinningFromAboveOrBelow' and 'Management'. c. From the 'C' and 'CThinFromBelow' factor specifications of the Pinus experiment, copy and paste some script into your 'Management' node to achieve the two types of thinning. You might have to change the dates to be within your specified rotation dates. The 'TreeThinning' script achieves a uniform thinning, e.g. every third row or mortality that is uniform across all tree sizes. In contrast 'TreeThinningFromAboveOrBelow' achieves a biased thinning or mortality to reflect thinning from above or below, i.e. proportionally more or less biomass is removed than the number of stems. Look in the script to find ThinBias = 0.7, which is where this thinning bias can currently be changed. d. The 'Management' node here is a renamed Operation node, which enables a model on a specified date to be called and told to do something by providing the inputs for that model. Here we used it for thinning, but any model in a simulation can be called, e.g. fertilization. e. Run the experiment simulation and check results. Add a graph of AboveGround.Wt. Note that at the main thinning average DBH and Ht don't change, but AboveGround.Wt shows an associated decrease. Adding a graph at different levels of the simulation will result in different levels of data that can be sourced for a graph – the higher the level the more data are available. Keeping a graph at a low level reduces clutter and complexity of graphing if you have more than one simulation or experiment, but the opposite is useful if you want to view all those one graph. f. By disabling and then enabling, and rerunning and viewing results in between, you can notice the effect of mortality and thinning on the results. Rather than toggling Enable like this, Management could have been added as a factor.
17. Add fertiliser and weeds	a. Various forms of N fertilizer can be added to a zone by using the fertilizer tools from the Management toolbox. Crop sowing and tree management tools also include options fertilizing at sowing or planting. Fertilizer can also be applied as an Operation – copy the specific syntax required from another Operation, and modify the date, and fertilizer amount, type and depth. b. More than one plant can be grown in a zone (plantation) of a simulation, e.g. pasture or an annual crop can be sown, managed, harvested or grazed. This provides one method of including weeds in plantation simulation, and such weeds can usually be forced to approximate expected weed behaviour in terms of light, water, N use. Apart from pastures or crop species already available in APSIM, SCRUM is a functional plant model that provides a simplified plant for the purpose of

		using resources in that zone. Caution: This option has not been fully evaluated for plantation forestry.
	c.	A 2-zone system is also available as the ‘Gliricidia Stripcrop Example’ in the Agroforestry folder of examples. Theoretically, Gliricidia can be substituted with Pinus or Eucalyptus as the tree species, and another plant species added to the ‘crop’ zone. Caution: This option has not been fully evaluated for plantation forestry.
	d.	As an example of b above, sow a crop of barley every year (but don’t harvest it) by copying nodes ‘Barley’ and ‘Sow on a fixed date’ from the Barley example.
	e.	Add a report line [Barley].AboveGround.Wt, disable all other simulations as they don’t have barley.
	f.	Run the simulation.
	g.	Add barley AboveGround.Wt to the AboveGroundWt graph that you already have, by duplicating the graph series, renaming them Trees and Weeds, and for Weeds, choose Barley aboveground wt to plot, and use a right axis and dotted line.
	h.	The graph should show that barley grows during the first few years but thereafter appears to be outcompeted by the trees.
18. Include observed data	a.	If available, observed data can be include for comparison to predicted values. This can assist in evaluating the level of confidence to be placed in predictions. Comparisons of temporal trends are possible. Model skill can also be formally evaluated using statistics that can be calculated in APSIM.
	b.	Data are imported into APSIM as a node under the Datastore. The node can be copied from ‘Standard toolbox/Data store and analysis models/ExcelInput’.
	c.	We need to provide a .xlsx file of observations. Use the one provided called ‘ObservedDataForPlantationForestryTraining.xlsx’, which contains entirely hypothetical height data. The top row provides column names, the first of which is essential and must be named ‘SimulationName’. Various columns provide the x or y values of graphs that you plan to plot. Provided in the example are Clock.Today and Eucalyptus.Stem.Ht, which must exactly match those reported for predictions.
	d.	At the observed node in the Datastore, direct it to the location of the observed file, and specify the name of the worksheet ‘Height’.
	e.	Refresh the Datastore and check that it has imported the observed data by viewing them in the ‘Height’ report.
	f.	Copy the previous experiment, rename it and the base simulation ‘ExptWithOvP’, and modify it to be only an N rate experiment with at least the N fertiliser rates of 0, 50 and 150 kg N ha^{-1}.
	g.	Extend the harvest age to 12 years
	h.	Run the simulation.
	i.	Refresh the Datastore
	j.	Add a graph of tree heights. Duplicate the Predicted node and rename it Observed
	k.	For the Observed node, use markers instead of lines.
19. Include OvP node and graph	a.	Copy to the Datastore ‘Standard toolbox/Data store and analysis models/ PredictedObserved’. Rename it OvP.

	b. Complete the requested information for reports to be used to construct an OvP report, with predicted values to come from the Report, observed values to come from Height, and SimulationID for first field name for matching, and Clock.Today for second field name for matching. Leave the third field name for matching blank. c. Refresh Datastore d. Copy and paste one of your x-y scatter graphs and rename it OvP Height e. Refine it: Use Data Source as OvP, x-axis as Predicted.Eucalyptus.Stem.Ht, y-axis as Observed.Eucalyptus.Stem.Ht f. Copy from the Standard toolbox/Graphs/Graph/Regression' and place at the Series level of the OvP graph. g. You should see an x-y plot of observed and predicted heights and statistics in the top left corner. h. The appearance of the graph probably needs changing, e.g. no lines, and marker and colours by SimulationName, and legend place at bottom right. i. Predicted heights are only reported if > 3 m. It therefore does not make sense to include comparisons below this height. So, filter this graph with '[Observed.Eucalyptus.Stem.Ht]>3.0'
20. Calibrate soil and use a graph filter	a. OvP graphs are rarely initially as good as you want them to be. Improvement might be provided by calibrating input values of soil, genotype or climate, if that is justified. Unmodified soils are usually under suspicion for not being completely correct. Here we work through a simple example of calibrating a soil. Plant parameters in the cultivar file might also need calibration for the production of a new cultivar, but that can be more complicated and is not be recommended until you have fully develop advanced skills in APSIM. Minor climate changes can be handled using the climate controller. b. The OvP graph above indicated that we over-predicted observed height. Perhaps water or N was more available in this simulation than in reality. c. First check on the extent of N and water stress (Fn and Fw, respectively) by copying those graphs from the previous experiment into this one. You should see that we have substantial N and water stress. In the system from most treatments. But we are actually over-predicting, which means we need more stress. So we need to decrease N and water uptake to achieve better OvP statistics. d. Iteratively change Soil.Physical.Eucalyptus LL and Eucalyptus KL for various depths, and also Soil.Organic.C and CNRatio, and check the resultant OvP fit – trying to achieve 1:1 agreement. There are many combinations of these parameters that would achieve a suitable result, and one way to check that we are changing the right parameters at the right depth would be to also have OvP graphs for soil water and soil N availability, but we don't have those available to us for this example. e. Change EucalyptusLL (plant lower limit of water extraction, mm/mm), EucalyptusKL (plant daily maximum proportion of available water that can be taken up, mm/mm), EucalyptusXF (plant vertical root growth factor; 0 = no root growth), Initial water (mm), and Soil.Organic C (%), C:N, FBiom (fraction of C and N in microbial biomass), and FInert (fraction of C and N inert; 1 = none active). A combination that works is shown in the screenshots.

	f. If you need a more detailed explanation of soil parameters, refer to (1) https://www.apsim.info/wp-content/uploads/2019/10/Soil-matters.pdf, (2) https://www.apsim.info/wp-content/uploads/2021/01/Methods-for-PAWWRC-estimation_DNRME.pdf, (3) https://www.apsim.info/wp-content/uploads/2019/09/Parameters-for-soil-water-Ver20-190815.docx g. Any of the other soil parameters, e.g. in SoilWater, Chemical and Initial conditions, might also have been justifiably changed. h. Note the improvement in model skill
21. Build your own case study and extending your skills	a. You now have the basic skills needed to design and build you own simulation using the above elements. Start simple then build complexity. b. There are many additional options and capabilities in APSIM that you have not been introduced to, but which you'll discover as your experience grows. Tips to expanding your capabilities is to view the video training exercises, examples and tutorials, read recent papers about APSIM use, and sharing APSIM experiences with collaborators. c. Another level of complexity is to join the APSIM community on GitHub, download and run validations, and track the linked code of models if you want to understand more of the detailed coding behind APSIM and become a developer. d. But you don't need to be working at that level to submit issues for problems that you are experiencing, or suggestions for improvement. e. Developers from several countries are continuously and simultaneously working on many different aspects of APSIM, and there is a small team that checks almost daily for issues solved and the need for a new version to be released.