State-and-Transition Simulation Modeling of Landscape Dynamics using ST-Sim

Self-Directed Training Course
Part 2

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Table of Contents

Preparing for Part 2 of the course

The suite of exercises provided in this document represent Part 2 (i.e. Exercises 3-8) of the self-directed training course; as such they assume you have already completed Part 1.

1. Follow the instructions for Part 1 of the course

If you have not already done so, please review the instructions at the beginning of Part 1 at: https://apexrms.com/training

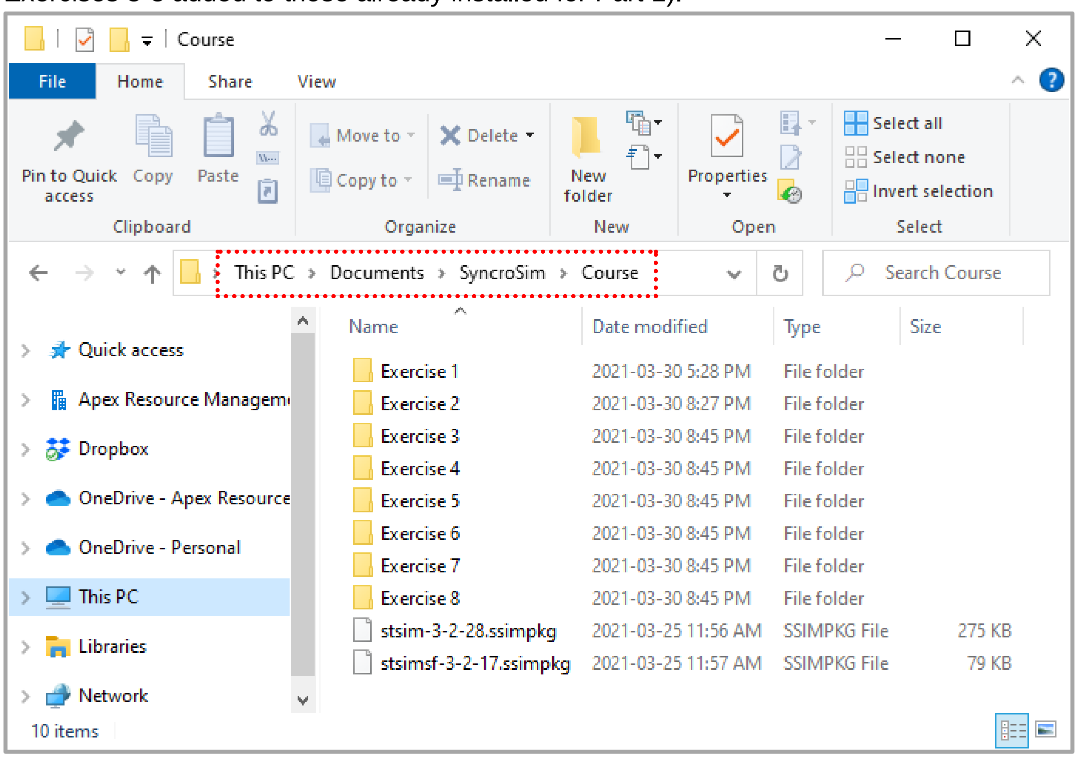
2. Download and install the course files for Part 2

1. Download the zip file https://apexrms.com/download/stsim-course-files-part-2-2-3-5/

2. Find the folder you used for your exercise files in Part 1 (which we recommended as **Documents\SyncroSim\Course**).

3. Unzip the contents of the downloaded file to the same folder you used for the Part 1 exercises. (i.e., right-click on the zip file, select **Extract All**, set **Documents\SyncroSim\Course** as the destination for extracted files, then click on **Extract**). ***Note that you will need the password provided to you by email to unzip the course files for Part 2***.

4. A series of subfolders should now appear in your **Course** folder as shown below (with the files for Exercises 3-8 added to those already installed for Part 1).



3. Follow the online course material and exercises

As in Part 1, you will continue listening to a recording of a live 2-day course (delivered in Australia in January 2021), pausing the recording periodically to do exercises at your own pace.

- The video playlist for the original live course has been divided into the following 11 segments; Part 2 starts with Exercise 3:

Course Overview	*Exercise 5: Spatial variability*
Introduction	*Exercise 6: Attributes*
Exercise 1: Getting started	*Exercise 7: Stocks and flows*
Exercise 2: Spatial model	*Exercise 8: Command line & R*
Exercise 3: Landscape stratification	*Other Advanced Features*
Exercise 4: Temporal variability	

- A video recording of the entire course can be viewed as a YouTube playlist at: https://youtube.com/playlist?list=PL57N-QiM8Rikg1ih5ieogJDv9Wa9TMA67
- To avoid a blurry presentation, ***make sure your YouTube Quality is set to 1080p*** (under the Settings icon at the bottom right of the YouTube window)
- Specific instructions for each of the exercises can be found in the remainder of this document.

4. Ask questions and provide feedback

We encourage you to ask questions and provide feedback both during and after the course through the ST-Sim Self-Directed Forum; alternatively you can purchase additional hourly support from us at any time.

Exercise 3: Stratifying your landscape

Objectives

- Understanding how to use model strata to configure model inputs
- Using primary strata to vary transition probabilities
- Using secondary strata to vary transition targets
- Displaying maps of primary strata

In this exercise, you will model transition pathways (Fire, Harvest, and Succession) similar to those seen in Exercise 2 on a much larger landscape. You will also learn how to assign ecological strata to your models, using wet and dry ecozones as an example. Management strata shall also be included within your models by separating your landscape into harvest blocks.

Task 1 – Loading Exercise 3 Library

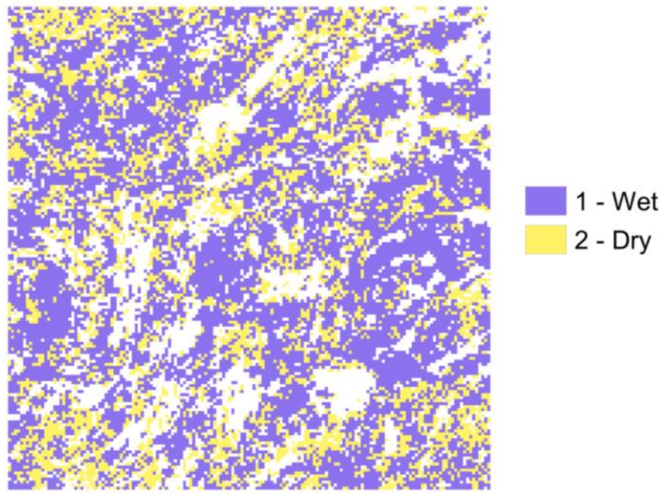
1. Open SyncroSim. Close any libraries that you may currently have displayed in the **Scenario Manager** (**File | Close All**).

2. Select **File | Open Library** and navigate to the file **Exercise 3.ssim.** If you installed your course materials to the recommended folder location, this file can be found in the folder **Documents\SyncroSim\Course\Exercise 3.** Click **Open**.

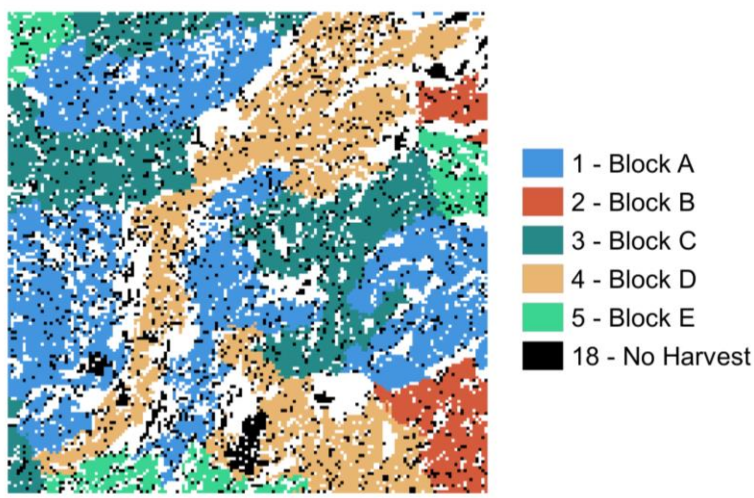
Task 2 – Review strata, state, and age definitions

1. Open the **Definitions** for Exercise 3 and click on the **Terminology** tab. You will see that there are three different types of stratification that can be used in ST-Sim: **Primary** (Ecozone for this exercise)**, Secondary** (Harvest Block for this exercise)**,** and **Tertiary** (not used for this exercise).

2. Now click on the **Strata** tab. By default, this screen displays the Primary Stratum, however we have renamed the Primary Stratum as Ecozone (see the **Terminology** tab). In the previous exercise you did not include ecozone classifications within the model, and as a result, transition pathways were applied across the landscape without taking climatic conditions into consideration. In this exercise, two ecozone strata (Wet and Dry) have been defined for your models (see map below). Later on, you will assign unique transition probabilities to forest types and grassland (referred to collectively as Cover Type) within each ecozone to represent ecological variation across the landscape. Note that each Ecozone has been assigned an ID value. The ID value is important as it is used to identify the stratum of each cell in a raster map (e.g., a raster value of 1 corresponds to a cell in the Wet stratum). In this exercise, you will be using the Primary Stratum (i.e., Ecozone) to change transition pathways in the model.

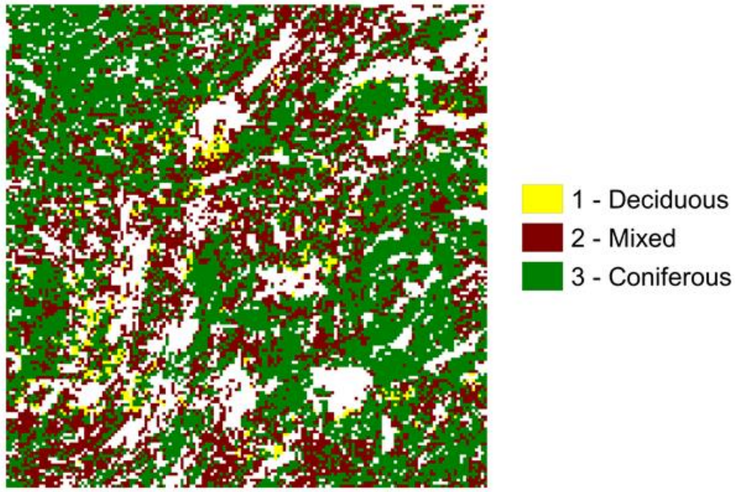


3. On the left sidebar of the window, click on Harvest Block (i.e., Secondary Stratum). Note that there are six different Secondary Strata or Harvest Blocks (see map below). Similar to what was done for the Ecozones, each Harvest Block has an ID value which is used to identify the stratum of each cell in a raster. In this exercise, we will be using Secondary Strata (i.e., Harvest Blocks) to set varying area targets for timber harvest.

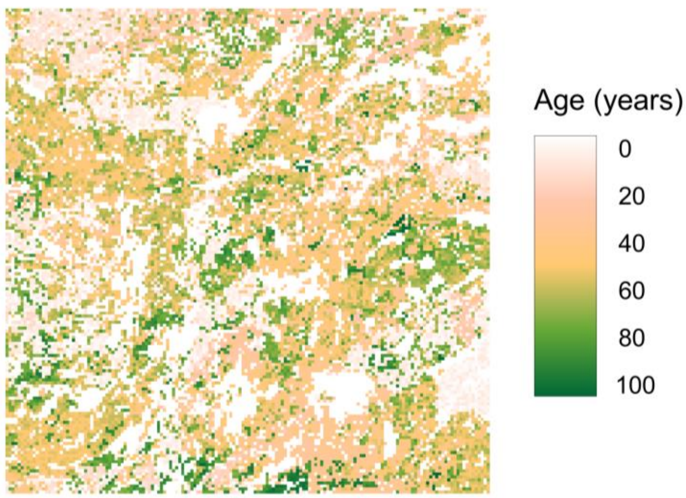


4. We will not be using Tertiary Stratum in this exercise.

5. Switch to the **States** tab. You will notice that along with our three forest types from the previous exercise, there is a new Cover Type called Grassland. Instead of using a State Class: All naming system such as in the previous exercise, your models now contain three Seral Stage values – Young, Mid, and Mature. For State Class, Grassland:Young has been added with an ID value of 4. The initial conditions for your landscape will begin with only three Cover Types (Deciduous, Mixed, and Coniferous), as shown in the map below. Later in this exercise, you will create a model where some Coniferous forest transitions to Grassland via Harvest.



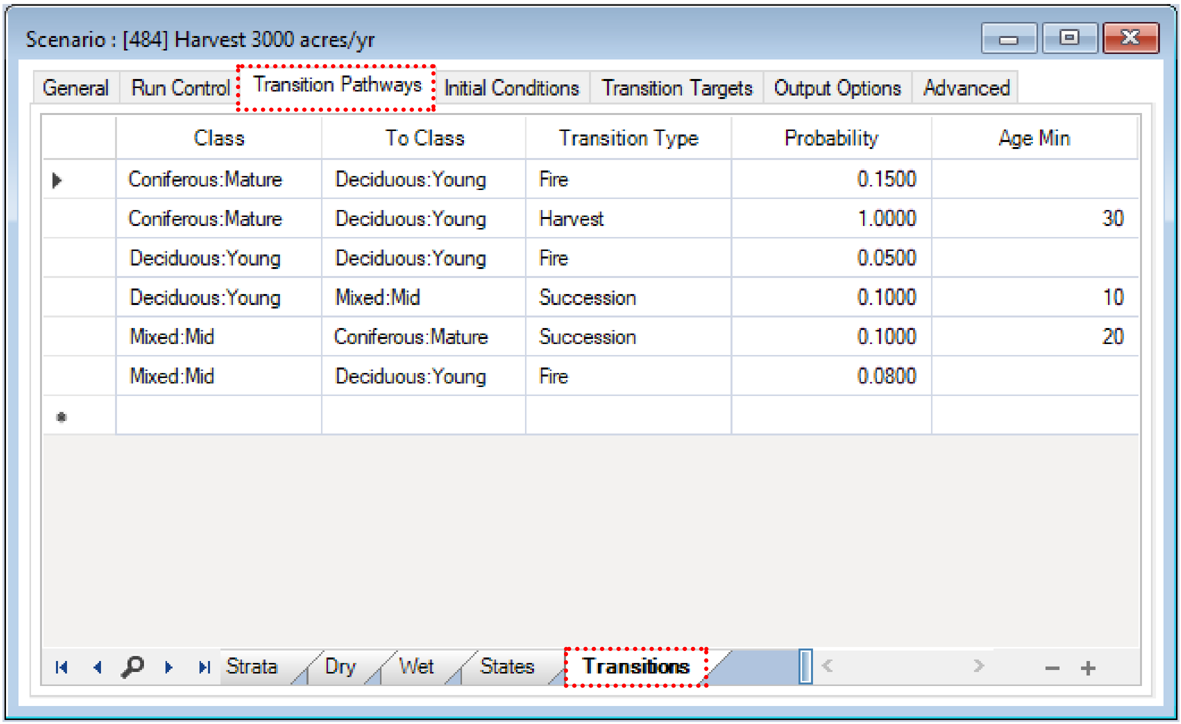
6. Now switch to the **Ages** tab. For Age Groups, you will notice that Cover Types within your landscape have been categorized into four groupings of Maximum Age (20, 40, 60, and 80 years old). The initial age distribution across your landscape is shown in the map below.



7. Close the **Definitions** window.

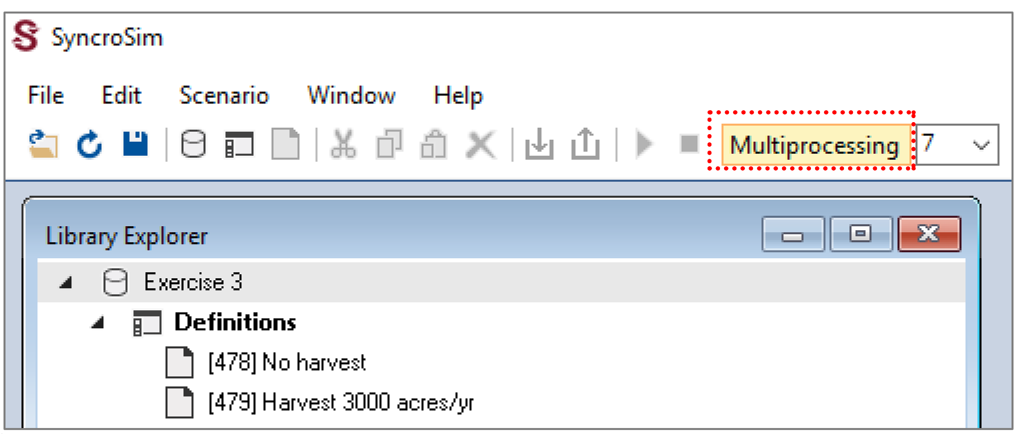
Task 3 – Review scenario properties and run existing scenarios

1. There should be two scenarios within the Exercise 3 library – a **No harvest** scenario, and a scenario in which 3000 acres of timber are harvested per year, named **Harvest 3000 acres/yr**. Right-click on the scenario **Harvest 3000 acres/yr** and select *Properties*. Switch to the **Transition Pathways** tab and click on the **Transitions** sheet (tab at the bottom) to review the transition dynamics depicted in this model. Note that the transition pathways and probabilities are identical to those used in the previous exercise. The other scenario in your library, **No harvest**, has similar transition dynamics. Close the **Scenario** window.



2. In these pre-made scenarios, the raster files for your models' spatial initial conditions have already been entered for your convenience. If you are curious, open the Properties of either scenario to check the names of the imported raster files on the **Initial Conditions** tab under the **Spatial** node.

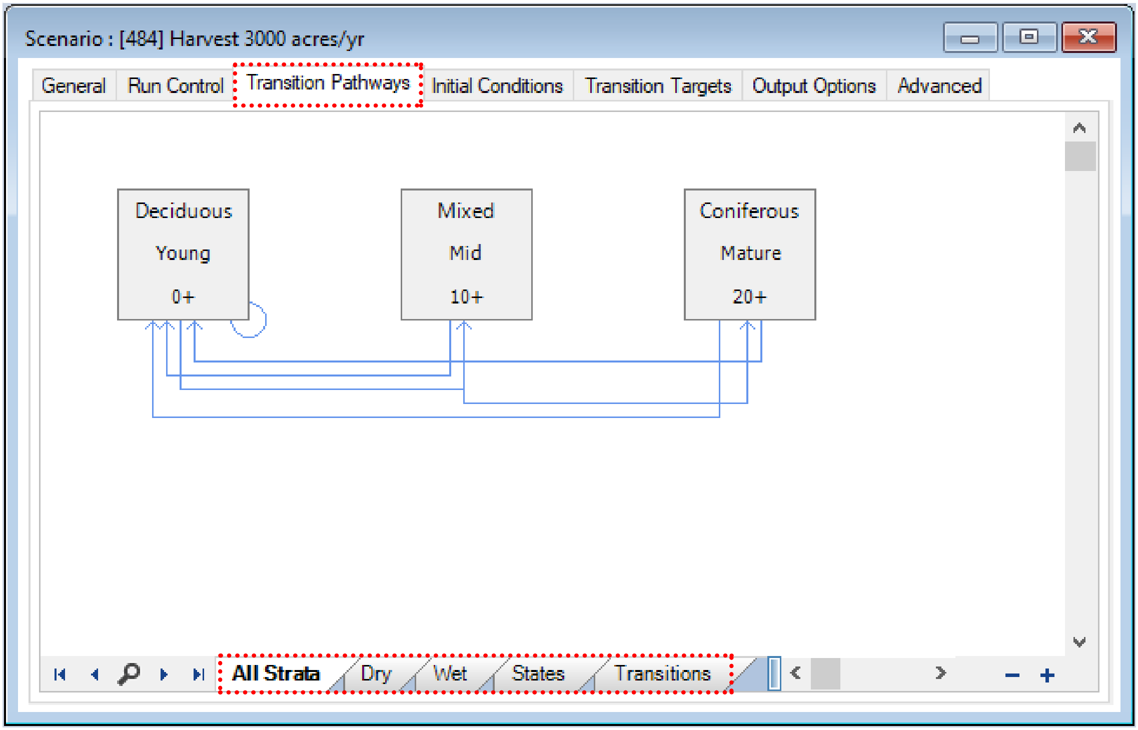
3. Make sure that **Multiprocessing** is turned on (click on this word in the main toolbar to highlight it) and run the two scenarios simultaneously by selecting both scenarios and then clicking the **Run Scenario** button.



Task 4 – Define transition pathways by ecozone

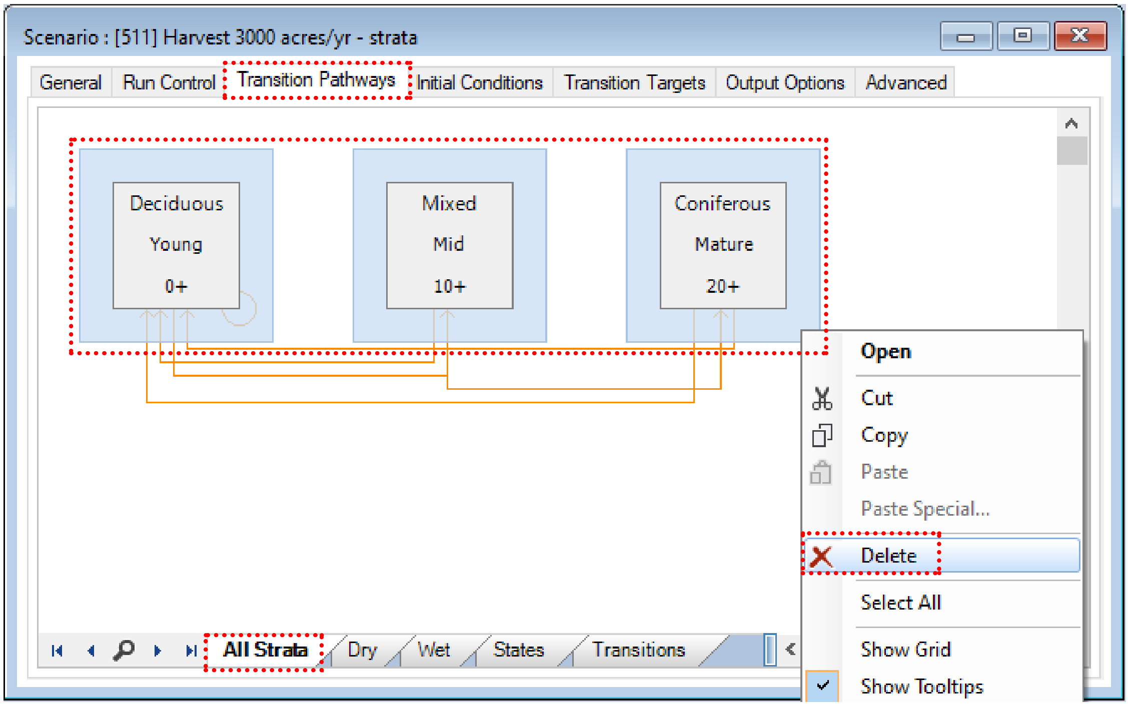
1. Right-click on the **Harvest 3000 acres/yr** scenario and select *Properties*. Switch to the **Transition Pathways** tab.

2. Note that along the bottom of this screen there are now five worksheets:

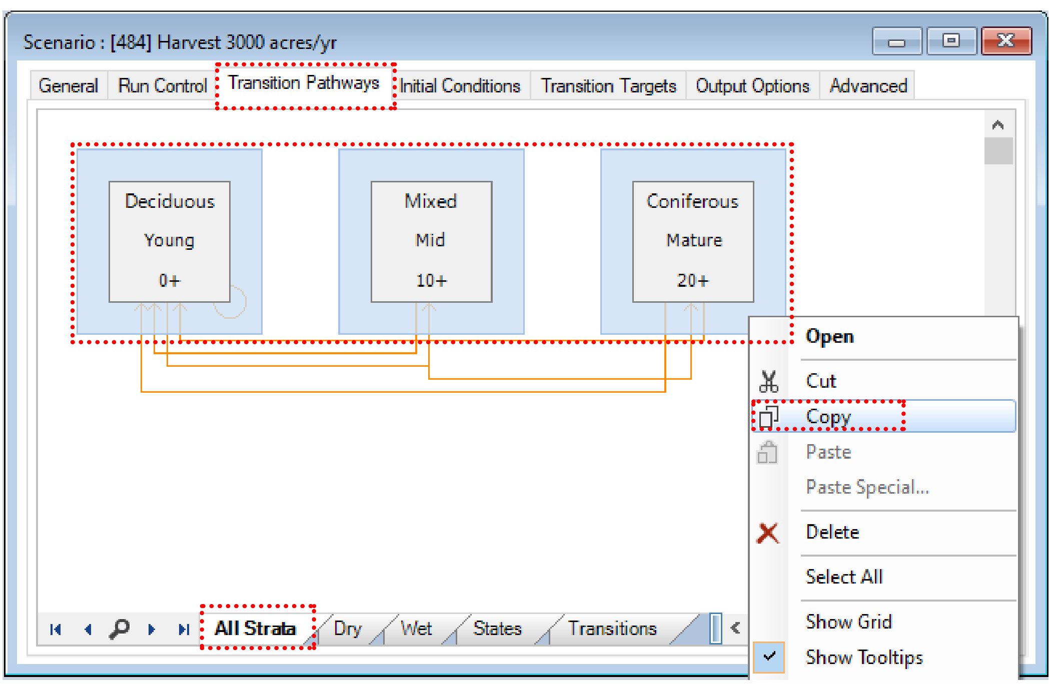


Have a look at each worksheet. Note that for this scenario, transition pathways have been defined in the **All Strata** worksheet and are visible as read-only for the **Dry** and **Wet** worksheets. Look at the **States** sheet to see that it lists each state class, along with minimum age and position in the diagram. Close the **Harvest 3000 acres/yr** scenario.

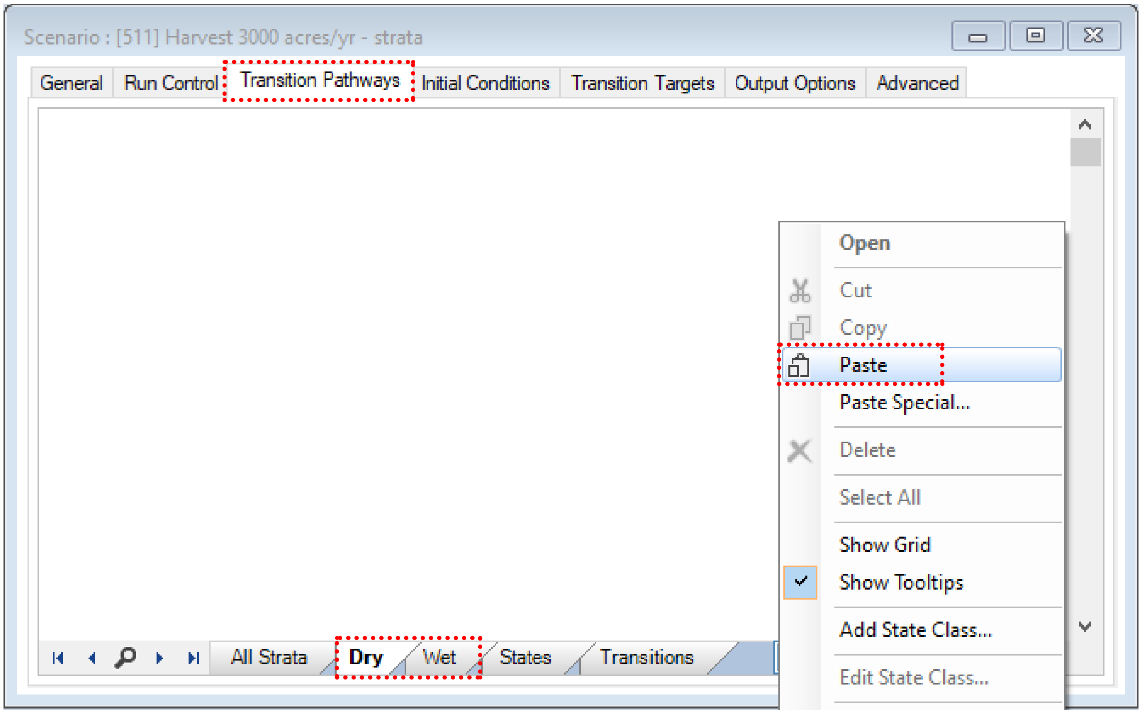
3. Returning to the **Library Explorer** window, make a copy of the **Harvest 3000 acres/yr** scenario – i.e., right-click on the scenario and select *Copy*, then right click in the blank space underneath the previous scenario and select *Paste*. Rename this scenario "Harvest 3000 acres/yr – strata", and navigate to the **Transition Pathways| All Strata** tab. Highlight all the boxes by drawing a square around them with your mouse while holding down the left button, then click **Delete** on your keyboard. Confirm that it is OK to delete these state classes from the pathways by clicking on **Yes**. You have now deleted all the Transition Pathways in this scenario.

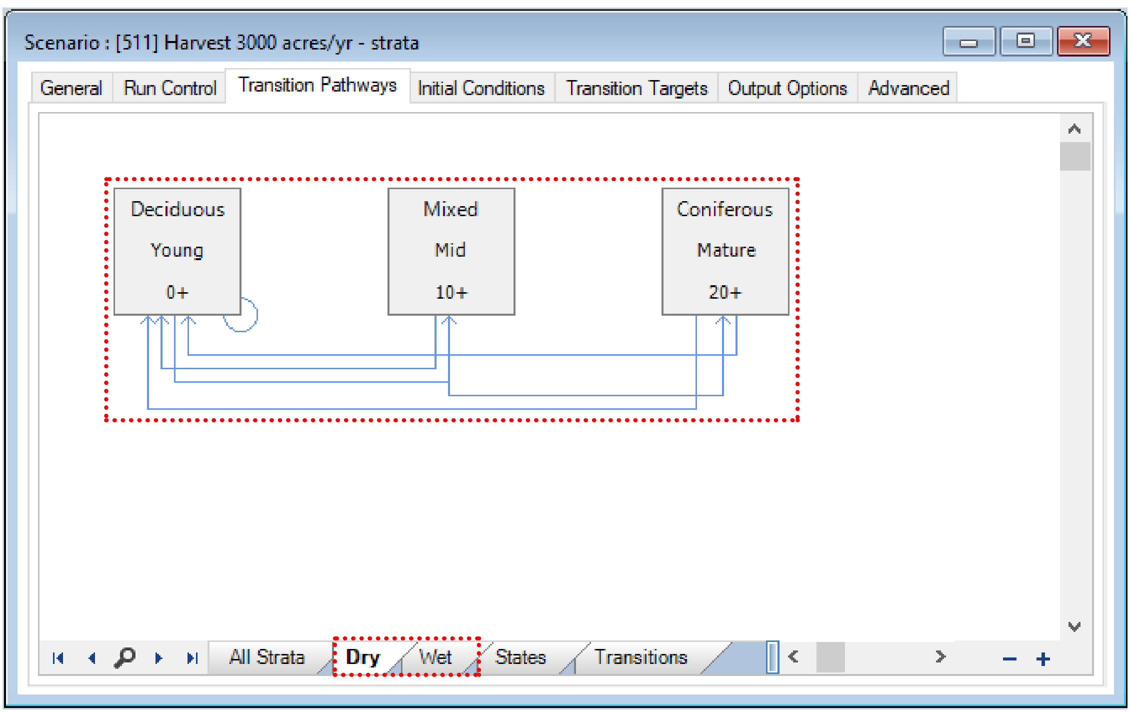


4. Return to the original **Harvest 3000 acres/yr** scenario, navigate to the **All Strata** worksheet and use your mouse (click, hold and drag) to draw a square around all the boxes and arrows in the diagram. Right-click on this diagram and select *Copy*.

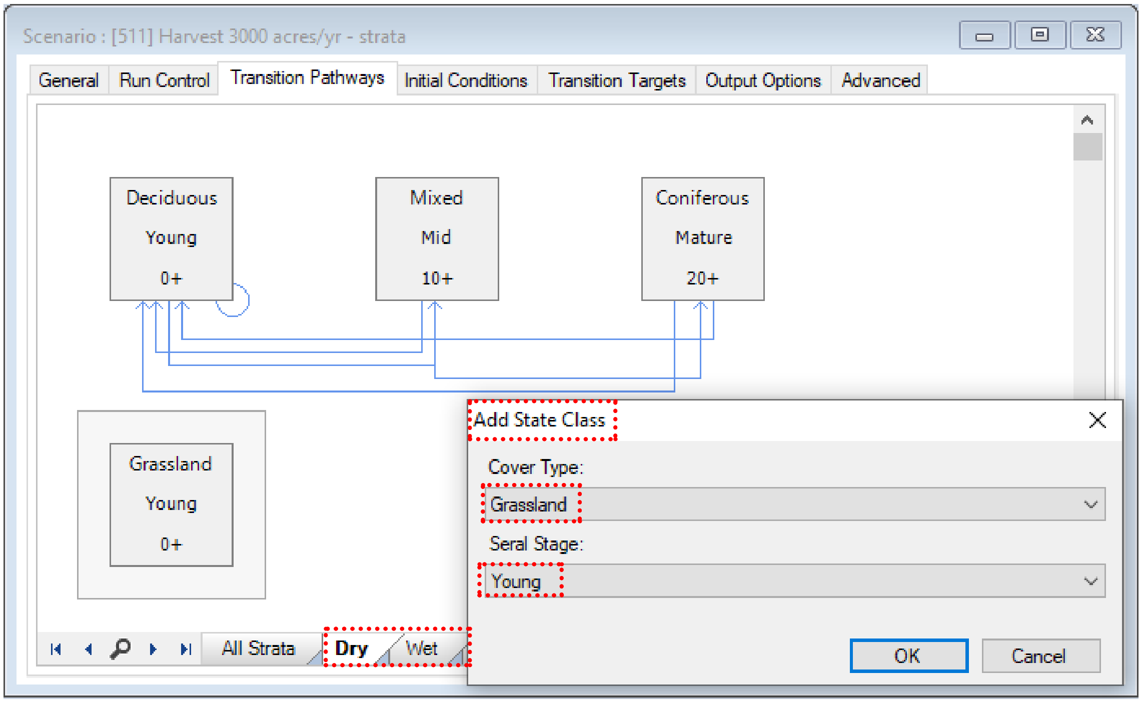


5. Returning back to the **Harvest 3000 acres/yr– strata** scenario, navigate to the **Dry** worksheet, right click and select *Paste***.** Repeat the paste on the **Wet** worksheet. Now in the **Harvest 3000 acres/yr– strata** scenario, pathways are defined separately for each stratum (i.e., Ecozone), and thus can be modified to vary between strata.

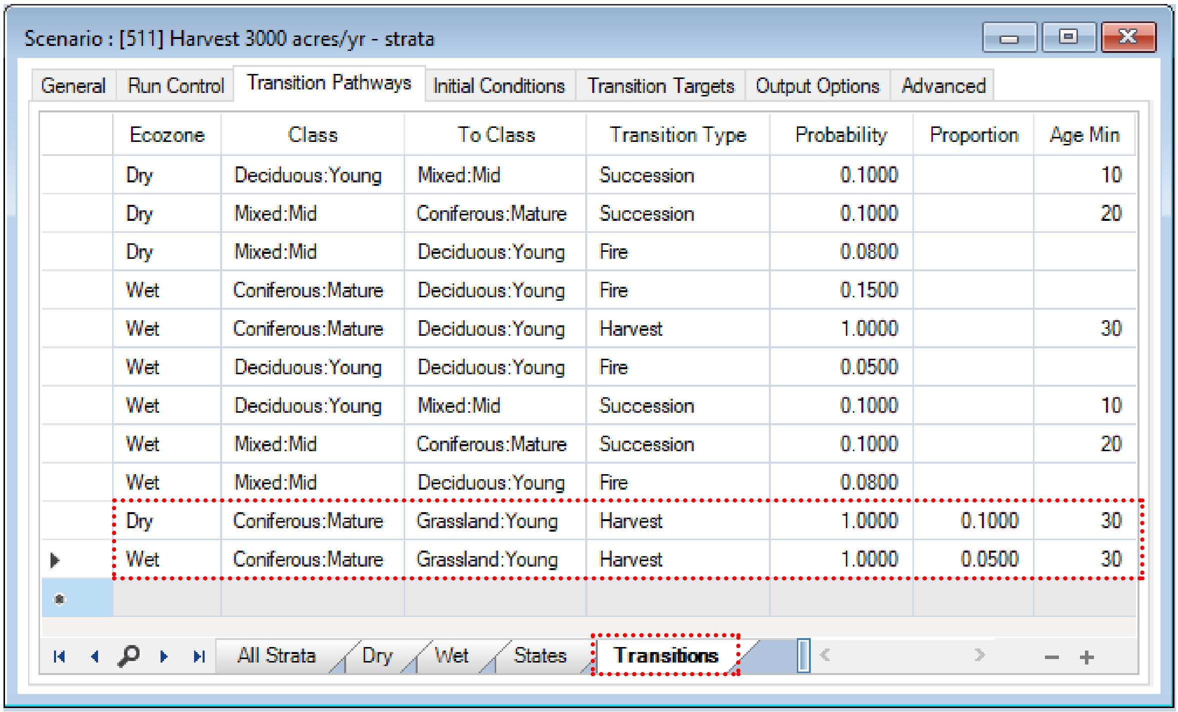




6. You can now add the Grassland state class to your Wet and Dry pathway diagrams. On the **Dry** worksheet, right-click anywhere on the blank space of the **Transition Pathways** window and select *Add State Class*. For **Cover Type**, select *Grassland*, and for **Seral Stage**, select *Young*. Click **OK**. Repeat these steps in the **Wet** worksheet.

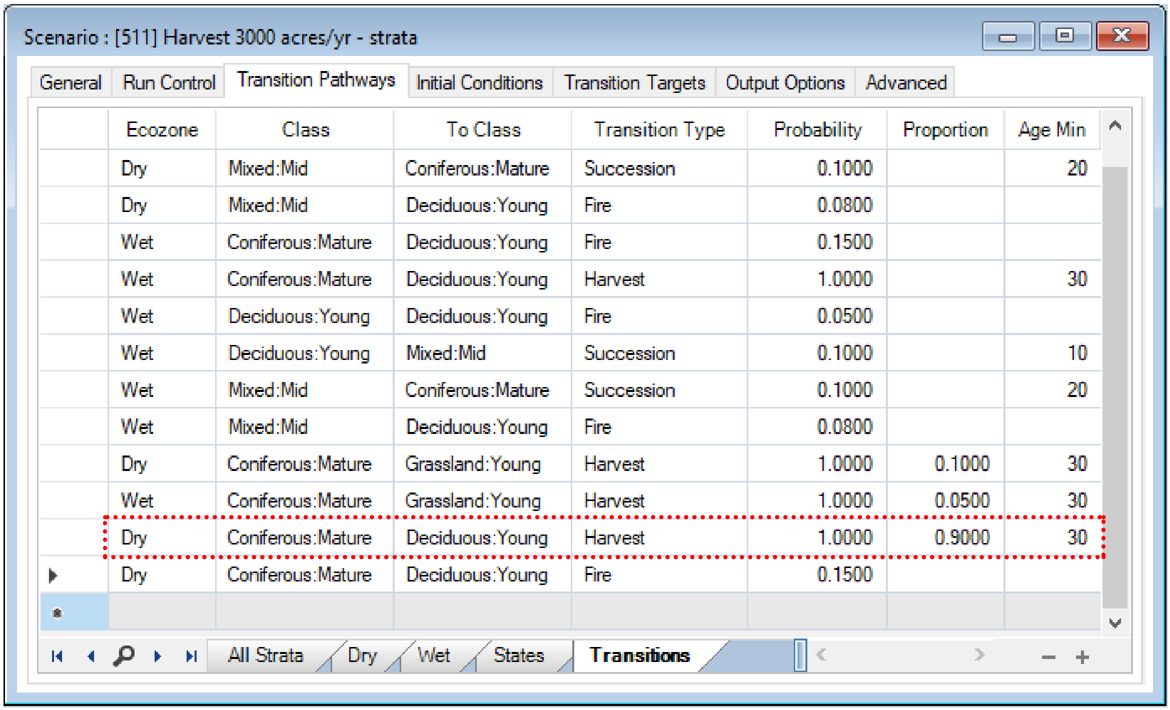


7. Now you will model the effect of timber harvest permanently changing the productivity of the landscape over time, with greater damage occurring on Dry sites. We will assume that in the Dry Ecozone, 10% of any area which has been harvested transitions to the new Grassland cover type, while in the Wet Ecozone, 5% of any harvested area transitions to the Grassland cover type. To enter these assumptions into our model, switch to the **Transitions** sheet, right-click on the table and add **Proportion.** Within the table:
   a) Enter a new row with the following values: **Ecozone** as *Dry*, **Class** as *Coniferous:Mature*, **To Class** as *Grassland:Young*, **Transition Type** as *Harvest*, **Probability** as *1.0*, **Proportion** as *0.10*, and **Age Min** as *30*.
   b) Enter another row with the following values: **Ecozone** as *Wet*, **Class** as *Coniferous:Mature*, **To Class** as *Grassland:Young*, **Transition Type** as *Harvest*, **Probability** as *1.0*, **Proportion** as *0.05*, and **Age Min** as *30*.

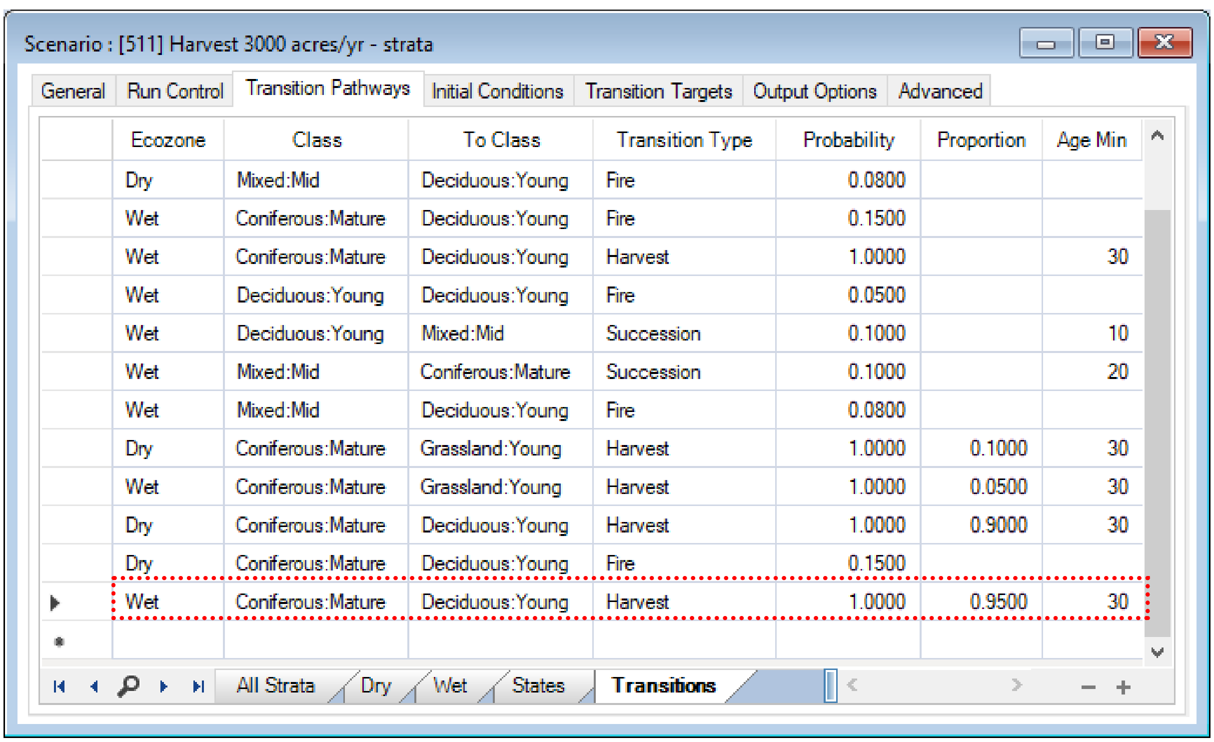


Ecozone	Class	To Class	Transition Type	Probability	Proportion	Age Min
Dry	Deciduous:Young	Mixed:Mid	Succession	0.1000		10
Dry	Mixed:Mid	Coniferous:Mature	Succession	0.1000		20
Dry	Mixed:Mid	Deciduous:Young	Fire	0.0800		
Wet	Coniferous:Mature	Deciduous:Young	Fire	0.1500		
Wet	Coniferous:Mature	Deciduous:Young	Harvest	1.0000		30
Wet	Deciduous:Young	Deciduous:Young	Fire	0.0500		
Wet	Deciduous:Young	Mixed:Mid	Succession	0.1000		10
Wet	Mixed:Mid	Coniferous:Mature	Succession	0.1000		20
Wet	Mixed:Mid	Deciduous:Young	Fire	0.0800		
Dry	Coniferous:Mature	Grassland:Young	Harvest	1.0000	0.1000	30
Wet	Coniferous:Mature	Grassland:Young	Harvest	1.0000	0.0500	30

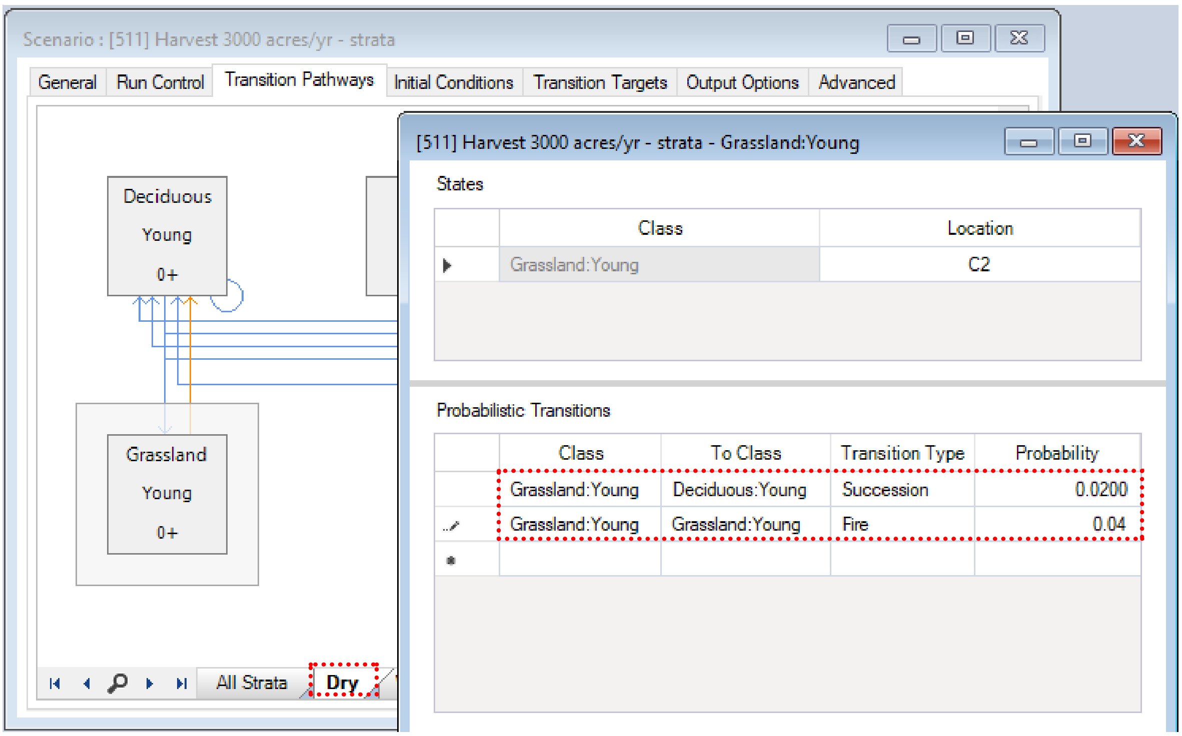
8. You will notice that in the previous step, we entered the Probability of Coniferous:Mature transitioning to Grassland:Young by Harvest as 1 for both the Dry and Wet ecozones. However, we entered unique values for the Proportion transitioned in the Dry and Wet ecozones. This is because we now have two paths that our coniferous forest can take when it is harvested for timber; it can either transition to deciduous forest, or transition to grassland. As such, the Proportion column acts as a subset of our transition Probability**.** For example, in the Dry Ecozone, we entered 10% of coniferous forest area becoming grassland after a harvest event. As such, 90% of the remaining harvested area will become deciduous forest. These values are each a Proportion of a total Probability of 1. The Probability of coniferous forest transitioning to either grassland or deciduous forest via harvest is 1 for each Cover Type, as both cover types ultimately will occur on the landscape after harvest, but in different proportions. Still within the **Transitions** table, enter a **Proportion** of *0.90* for the existing entry that specifies *Coniferous:Mature* transitioning to *Deciduous:Young* via *Harvest* in the *Dry* **Ecozone**.



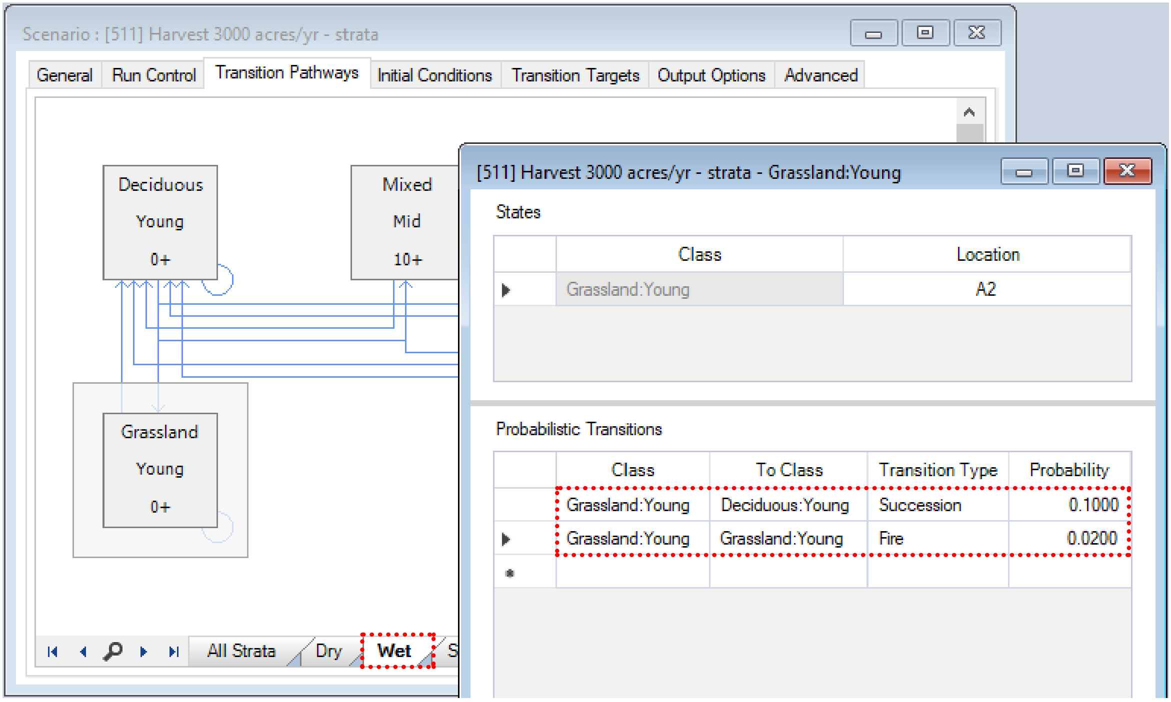
9. Similarly to what was done in the previous step, enter a **Proportion** of *0.95* for *Coniferous:Mature* transitioning to *Deciduous:Young* via *Harvest* in the *Wet* **Ecozone**.



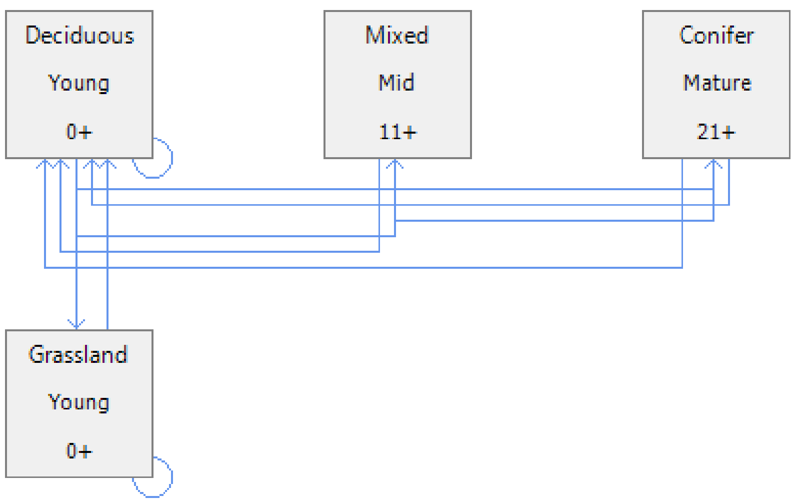
10. Transition dynamics for your model can be added within the **Transitions** table as shown in the previous steps. Alternatively, you can double-click (or right-click, Open) on State Class boxes within your **Dry** and **Wet** worksheets and enter transition dynamics within the **Probabilistic Transitions** tables. Following this method, navigate to the **Dry** worksheet and open the Grassland state class box on the pathway diagram. Add a *Succession* pathway from *Grassland:Young* to *Deciduous:Young* with a **Probability** of *0.02*. Next, add a *Fire* pathway from *Grassland:Young* back to itself with a **Probability** of *0.04*.



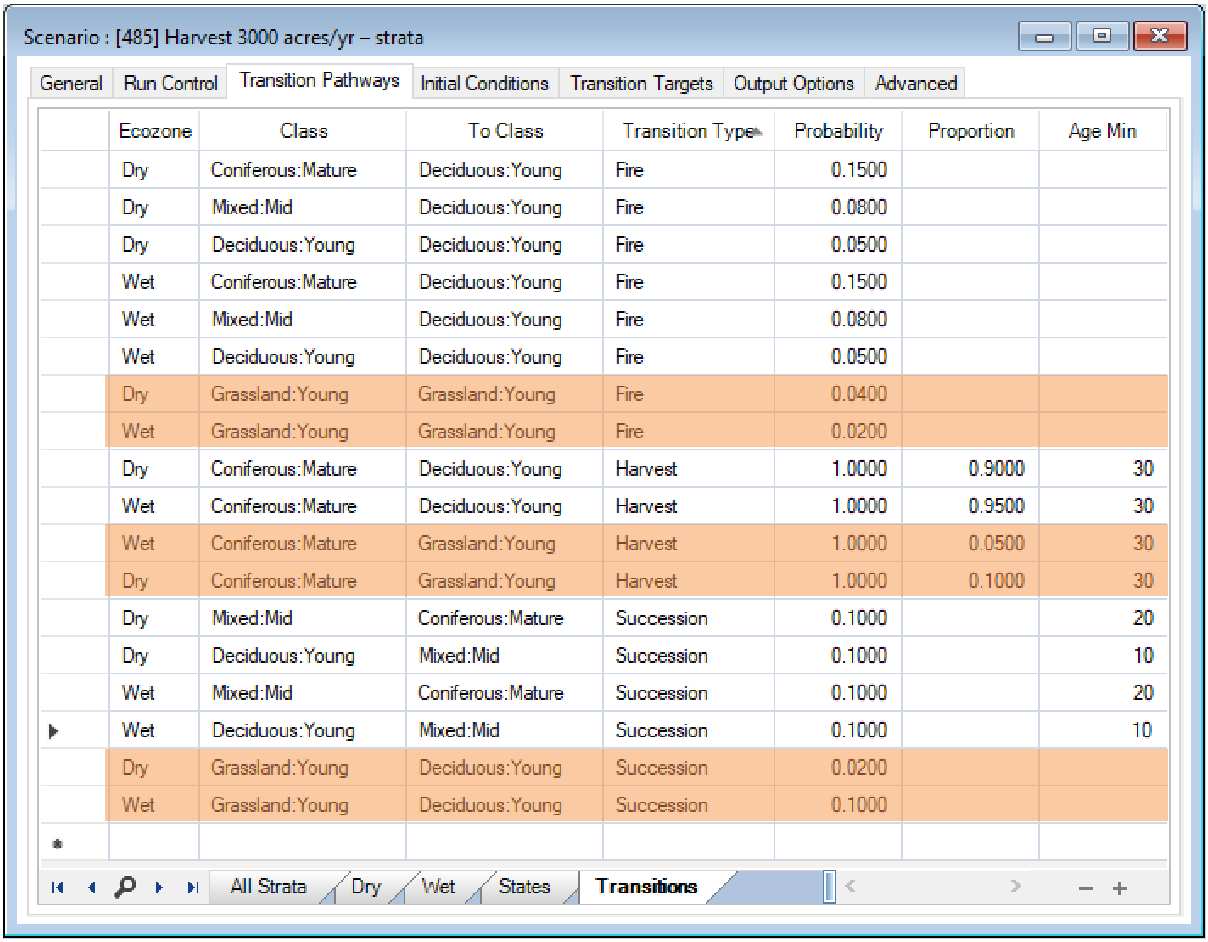
Repeat the same steps in the pathway diagram on the **Wet** worksheet but enter a **Probability** of *0.1* for *Succession* and a **Probability** of *0.02* for *Fire* instead. **Save** your work.



11. When done, your pathway diagram should look like this for each of the Dry and Wet strata:



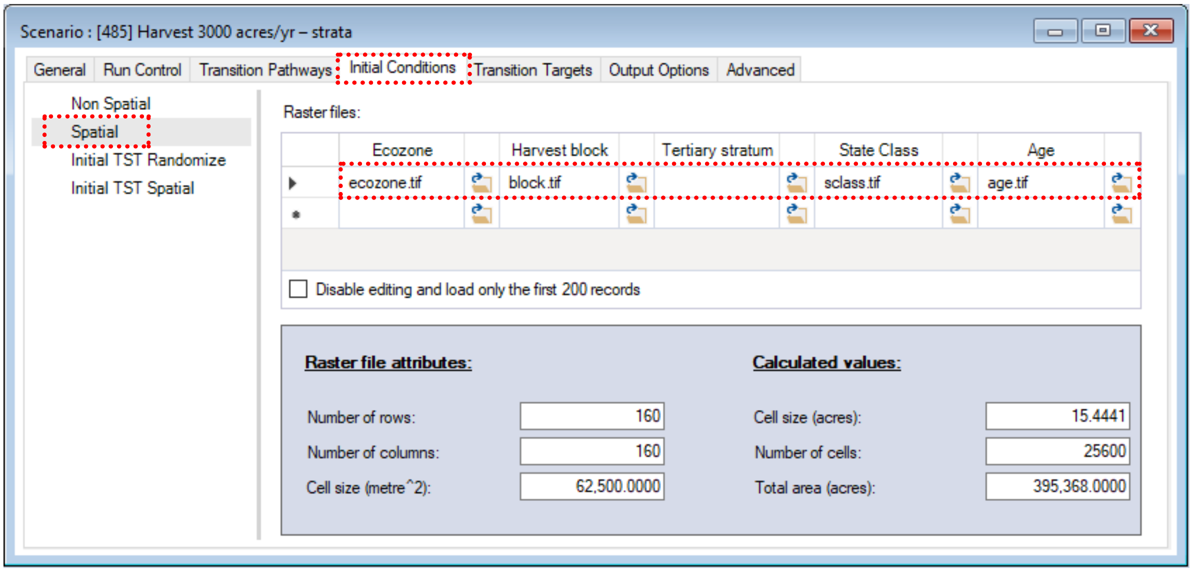
Your list of all Transitions (as displayed on the **Transitions** sheet) should include the following new highlighted rows:



Ecozone	Class	To Class	Transition Type	Probability	Proportion	Age Min
Dry	Coniferous:Mature	Deciduous:Young	Fire	0.1500		
Dry	Mixed:Mid	Deciduous:Young	Fire	0.0800		
Dry	Deciduous:Young	Deciduous:Young	Fire	0.0500		
Wet	Coniferous:Mature	Deciduous:Young	Fire	0.1500		
Wet	Mixed:Mid	Deciduous:Young	Fire	0.0800		
Wet	Deciduous:Young	Deciduous:Young	Fire	0.0500		
Dry	Grassland:Young	Grassland:Young	Fire	0.0400		
Wet	Grassland:Young	Grassland:Young	Fire	0.0200		
Dry	Coniferous:Mature	Deciduous:Young	Harvest	1.0000	0.9000	30
Wet	Coniferous:Mature	Deciduous:Young	Harvest	1.0000	0.9500	30
Wet	Coniferous:Mature	Grassland:Young	Harvest	1.0000	0.0500	30
Dry	Coniferous:Mature	Grassland:Young	Harvest	1.0000	0.1000	30
Dry	Mixed:Mid	Coniferous:Mature	Succession	0.1000		20
Dry	Deciduous:Young	Mixed:Mid	Succession	0.1000		10
Wet	Mixed:Mid	Coniferous:Mature	Succession	0.1000		20
Wet	Deciduous:Young	Mixed:Mid	Succession	0.1000		10
Dry	Grassland:Young	Deciduous:Young	Succession	0.0200		
Wet	Grassland:Young	Deciduous:Young	Succession	0.1000		

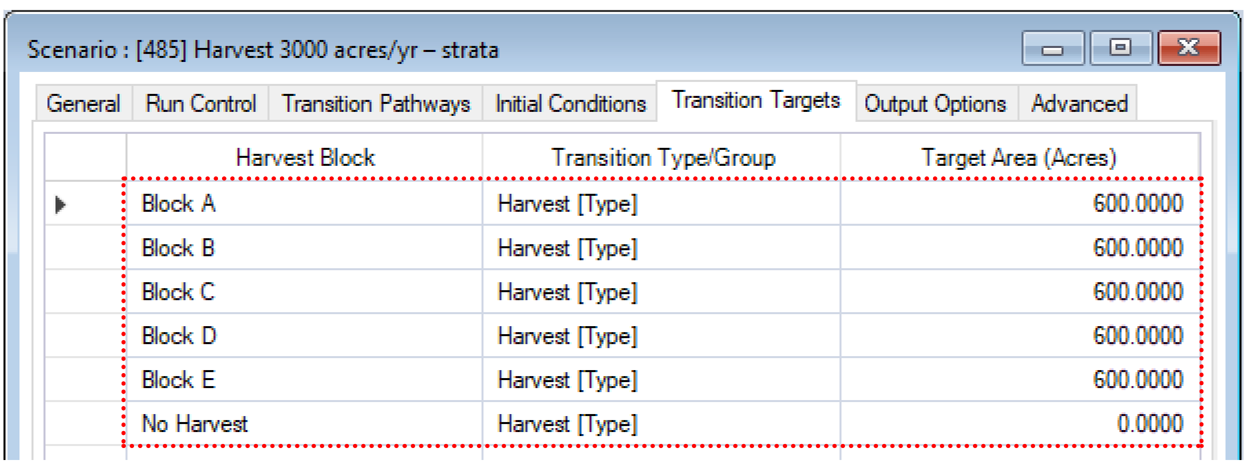
Task 5 – View the spatial initial conditions

1. Still in the **Scenario** window for the **Harvest 3000 acres/yr– strata** scenario, navigate to the **Initial Conditions** tab, and select the **Spatial** node on the left of the screen. Note the names of the raster files being loaded along the first row of the grid on display and their properties in the lower portion of the screen. These raster files are those which you saw at the beginning of the exercise in Task 2.



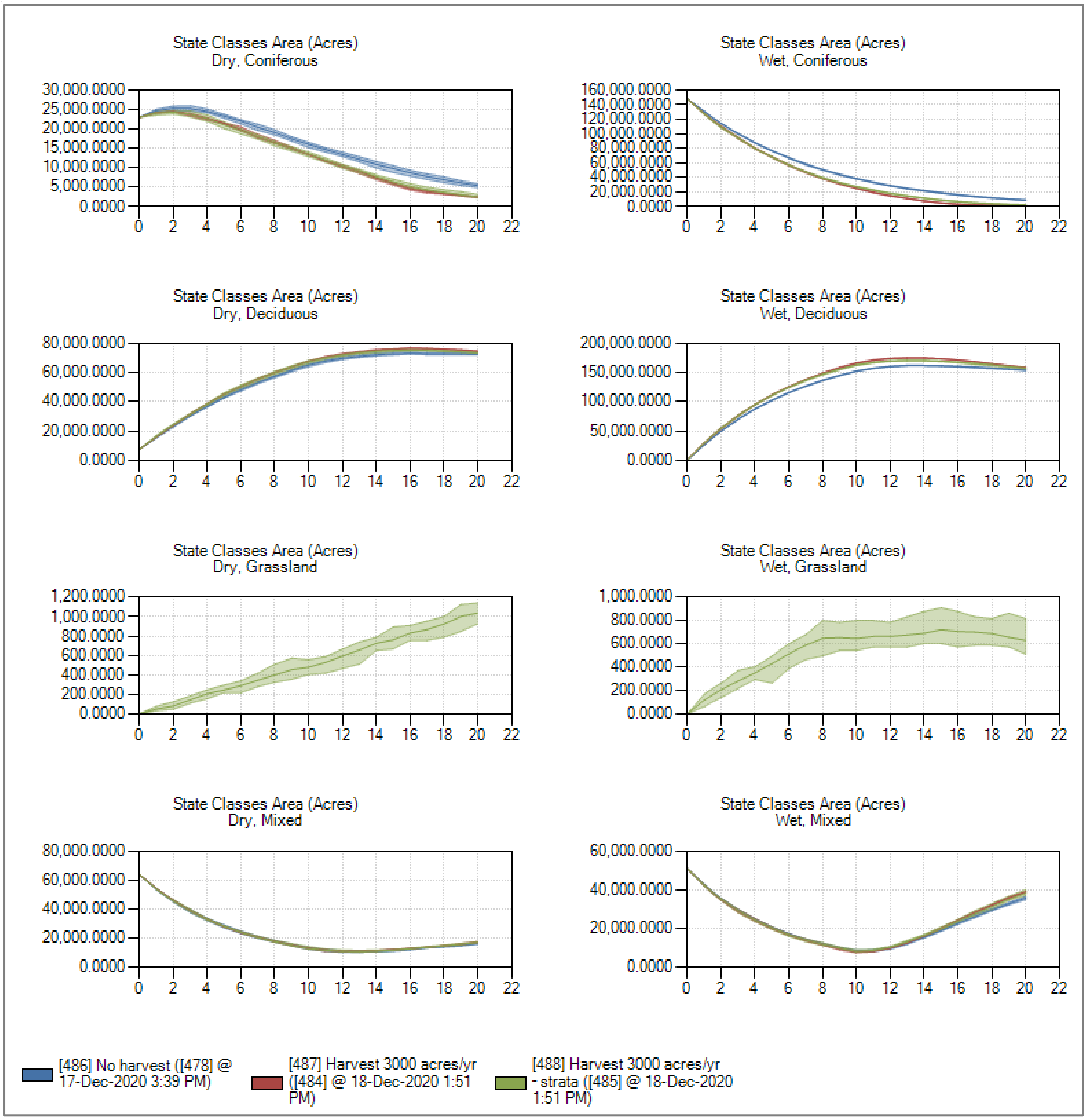
Task 6 – Define transition targets by harvest block, create a full scenario and run the model

1. Still in the **Scenario** window for the **Harvest 3000 acres/yr – strata** scenario, navigate to the **Transition Targets** tab. Right-click on the table and select **Harvest Block** to add this column to your table. Enter five Harvest Blocks, labelled *A* through *E*, each with a transition **Target Area** of *600* acres. Add a **Harvest Block** called *No Harvest* with a transition target of *0*. Close the **Scenario** window and **Save** your work.

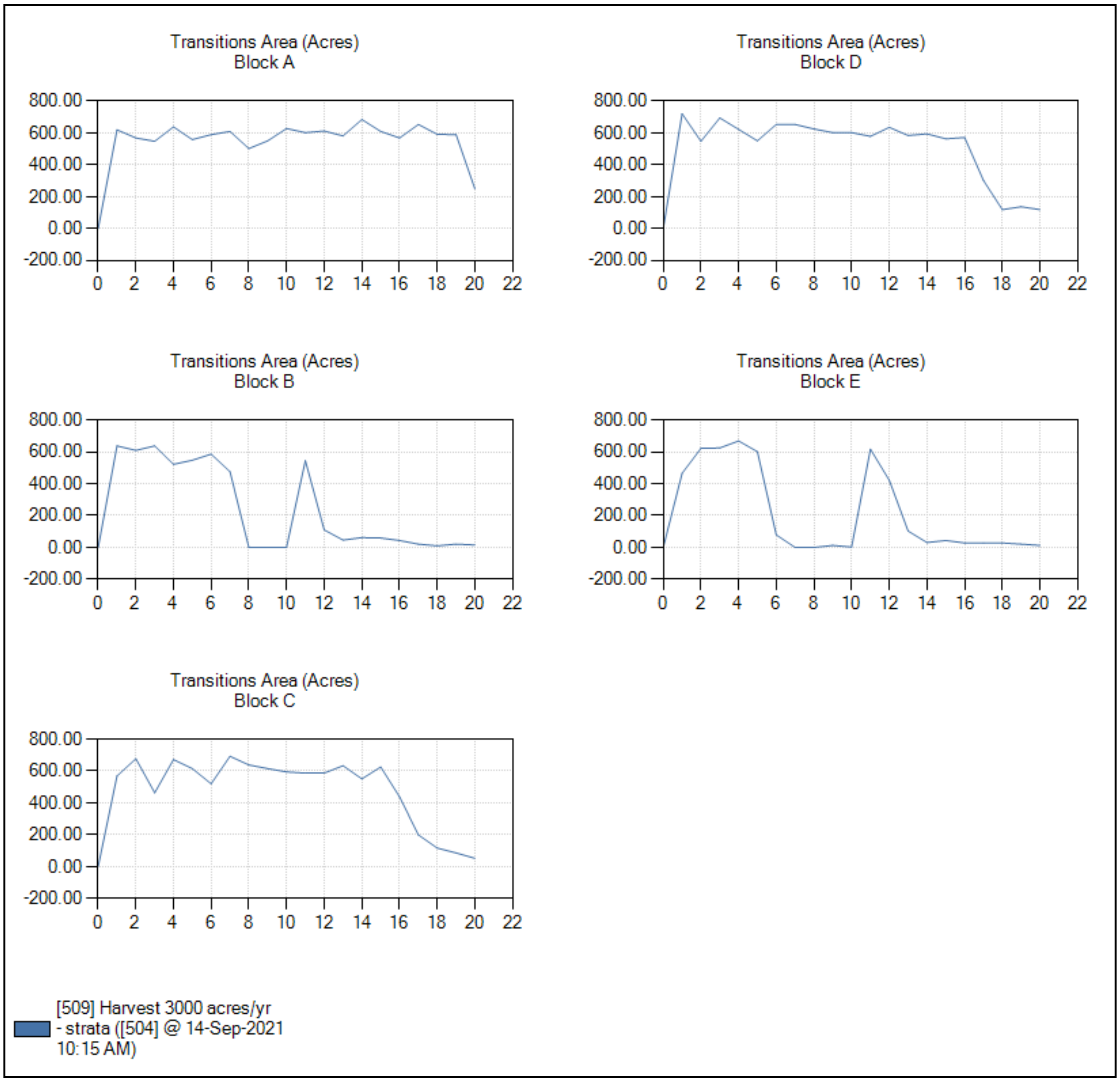


2. **Run** this new scenario.

3. Create a new chart of State Class Area by Ecozone showing Min/Max ranges. To do this, open the *States* chart, expand the node for **State Classes** and check the box for *Area (Acres)*. Expand the node for **Disaggregate By** and check the box for *Ecozone* and *State Class*. Select *Min/Max* from the **Error Bar Type** drop-down list. Click **Apply**.



4. Create a chart that displays Harvest Area by Harvest Block. First, remove the run results for all but the **Harvest 3000 acres/yr – strata** scenario. Create a new chart named “Harvest”. Within the chart, expand the node for **Transitions** and check the box for *Area (Acres)*. Expand the node for **Disaggregate By** and check the box for *Harvest Block*. Expand the **Include Data For** node, then the **Harvest Block** node, and check the boxes for **Block A**, **Block B**, **Block C**, **Block D**, **Block E**, and **No Harvest**. Finally, expand the node for **Transition Type/Group** and check the box for *Harvest (Type)*. Click **Apply**.



Do some Harvest Blocks appear to harvest more timber over the 20-year timeframe than other Harvest Blocks? Why might this be? Could this have anything to do with the relative amount of Wet and Dry Ecozones within each Harvest Block?

Bonus Question: *Often timber harvest is aggregated in a portion of a landscape for several years before moving on to a new area. Can you create a new scenario that models harvest over time in such a way that the entire 3000-acre harvest target occurs in a single block for four consecutive years before moving on to the next harvest block? Is this pattern of harvest sustainable? Explain why.*

Exercise 4: *Adding temporal variability to transitions*

Objectives

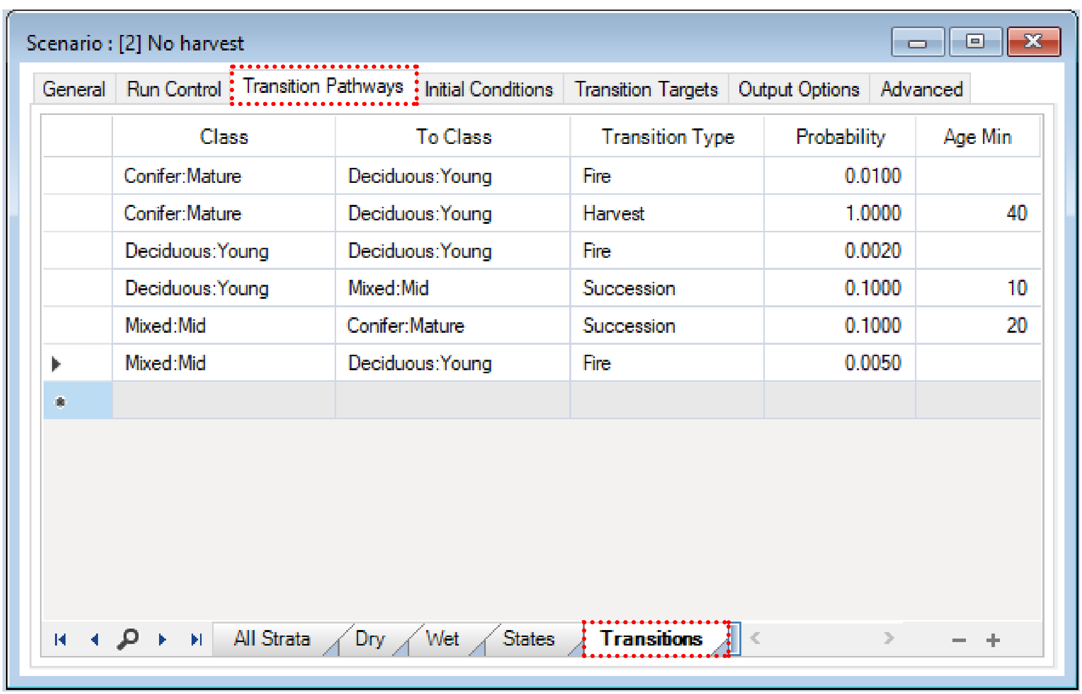
- Understanding how to add variability and uncertainty to transitions over time
- Using transition multipliers
- Sampling from built-in and user-generated probability distributions

Task 1 – Retrospective simulation using actual area burned

We begin this exercise by setting up an historical simulation in order to better understand what the consequences may have been of past variability in fire across our landscape.

1. Open SyncroSim. Select **File | Open Library** and navigate to the file **Exercise 4.ssim.** If you installed your course materials to the recommended folder location, this file can be found in the folder **Documents\SyncroSim\Course\Exercise 4.** Click **Open**.

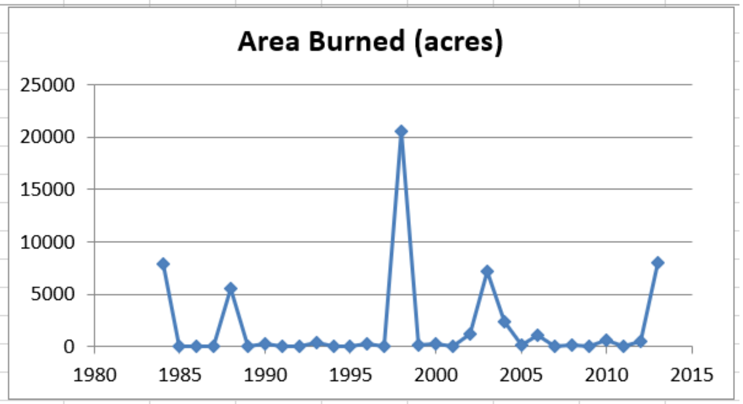
2. In this exercise we will work with the same landscape as in Exercise 3.The model we will be using is slightly different, however. To see the differences, open the **No harvest** scenario and navigate to the **Transitions** sheet of the **Transition Pathways** tab. While this model is very similar to that used to start Exercise 3, the base fire probabilities have been reduced (by roughly an order of magnitude) and the minimum age for conifer harvest has been increased slightly (from 30 to 40).

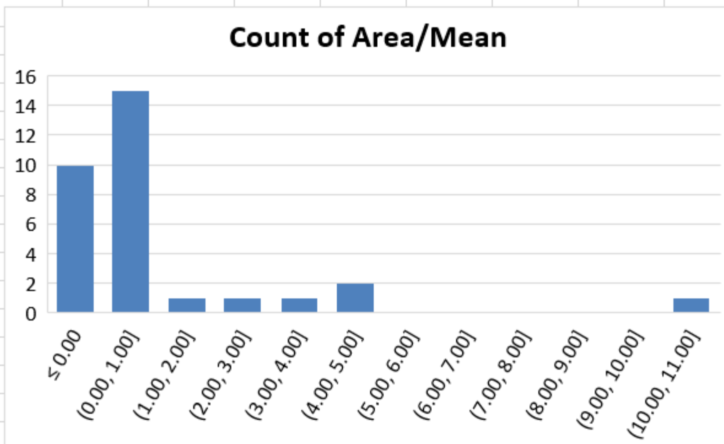


3. We will begin this exercise by adding variability over time to our fire transitions. If you have Microsoft Excel installed on your computer, you can open the file **Documents\SyncroSim\Course\Exercise 4\Files\Historical Fire Data.xlsx**; alternatively, the spreadsheet data and charts are shown below. This file shows an historical time series of area

burned for our study area, including the area burned each year (both in area and as a "normalized" proportion of the mean area burned).

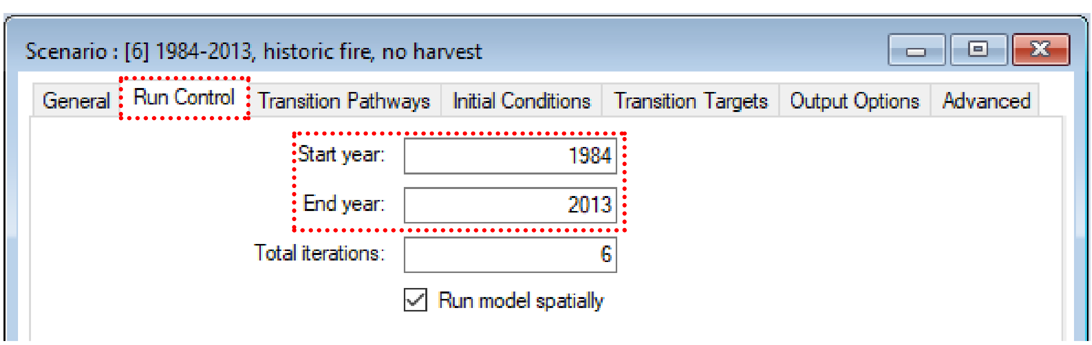
Year	Area Burned	Area/ Mean
1984	7938	4.18
1985	0	0.00
1986	0	0.00
1987	62	0.03
1988	5498	2.89
1989	0	0.00
1990	340	0.18
1991	31	0.02
1992	0	0.00
1993	386	0.20
1994	0	0.00
1995	0	0.00
1996	232	0.12
1997	0	0.00
1998	20587	10.84
1999	216	0.11
2000	232	0.12
2001	93	0.05
2002	1236	0.65
2003	7243	3.81
2004	2332	1.23
2005	154	0.08
2006	1143	0.60
2007	0	0.00
2008	170	0.09
2009	0	0.00
2010	649	0.34
2011	0	0.00
2012	463	0.24
2013	7985	4.20
Mean	**1900**	**1**





4. We will first setup a scenario in which we model the <u>historical period</u> (i.e., 1984-2013) for which we have fire data. Start by creating a copy of the existing **No harvest** scenario and renaming this copy "1984-2013, historic fire, no harvest".

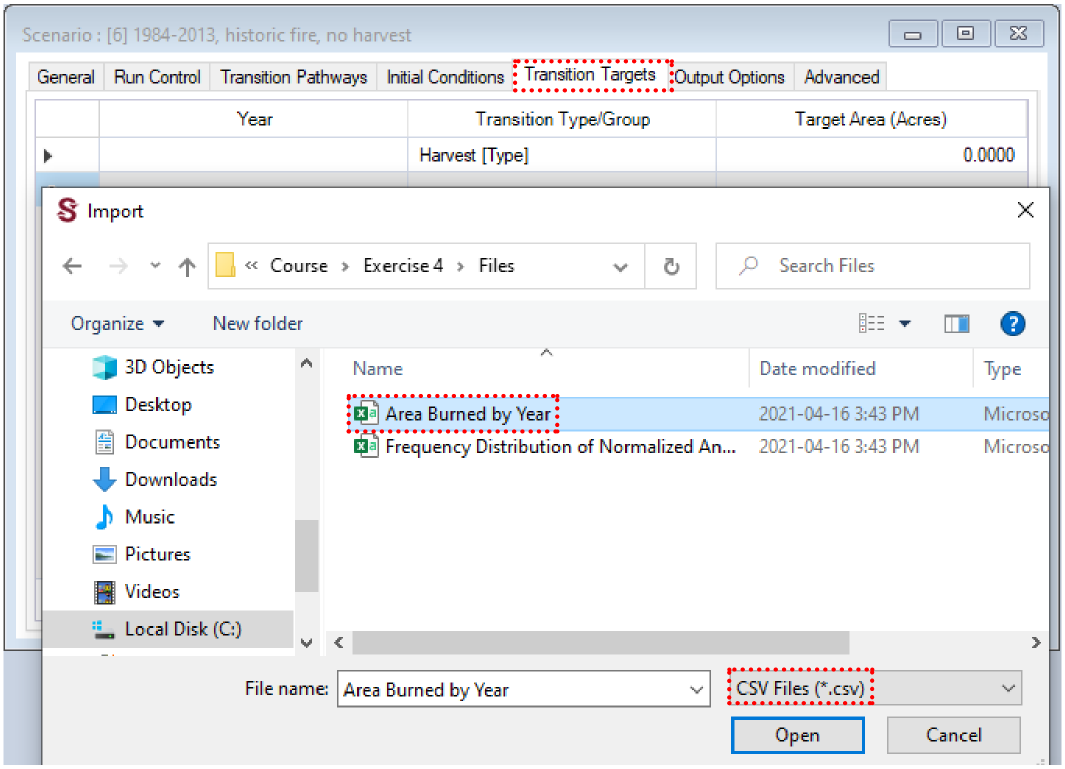
5. We will now configure this new scenario to represent the period 1984-2013, modelled following the temporal pattern of actual area burned and assuming no harvest. First edit the **Run Control** Datafeed in which you set the start and end years to be *1984* and *2013*.

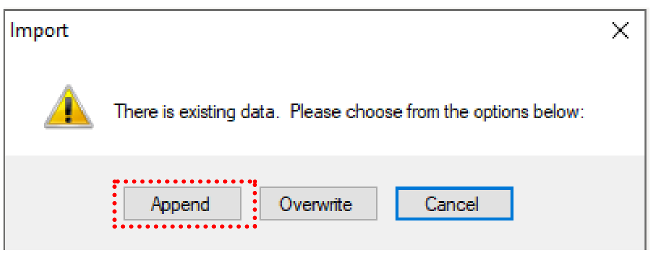


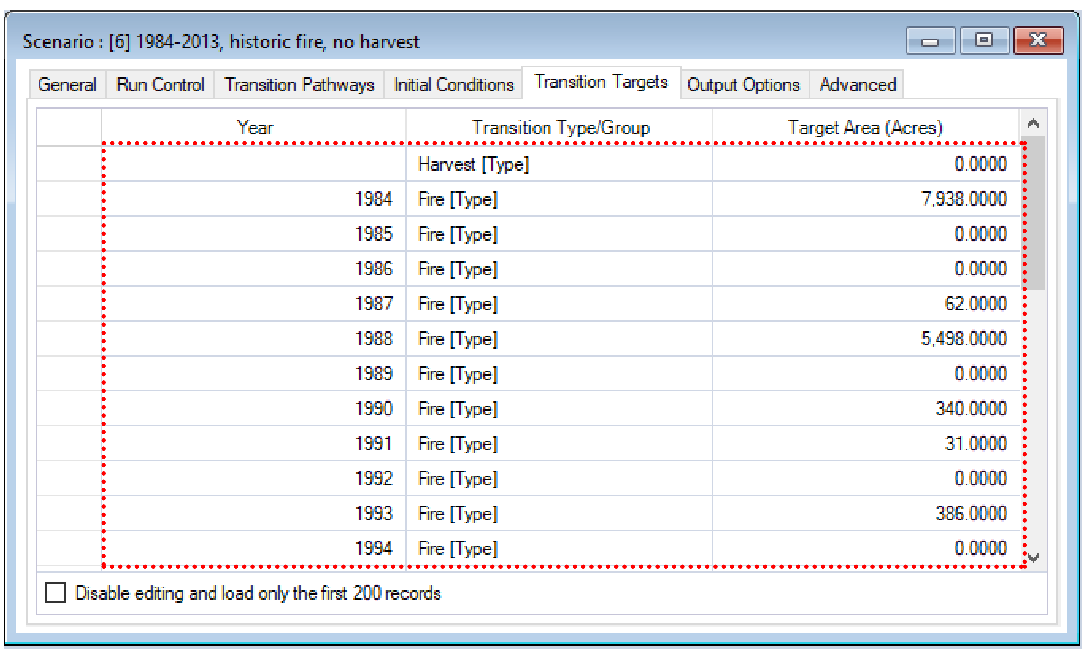
6. Next you will need to modify the way in which Fire is represented. Because we know the actual area burned for each year of our simulation, we will represent Fire using **Transition Targets** (rather than using probabilities).To do this, you will modify **Transition Targets** by entering the actual area burned using data stored in a CSV text file. Using Windows Explorer, navigate to the folder containing the additional course files for Exercise 4 (in **Documents\SyncroSim\Course\Exercise 4\Files**), and then open the file called **Area Burned by Year.csv** (you can open this in either Excel or Notepad).You will see that this contains a time series of the area burned (in acres) by year. Close the file before proceeding to the next step.

Timestep	TransitionGroupID	Amount
1984	Fire [Type]	7938
1985	Fire [Type]	0
1986	Fire [Type]	0
1987	Fire [Type]	62
1988	Fire [Type]	5498
1989	Fire [Type]	0
1990	Fire [Type]	340
1991	Fire [Type]	31
1992	Fire [Type]	0
1993	Fire [Type]	386
1994	Fire [Type]	0
1995	Fire [Type]	0
1996	Fire [Type]	232
1997	Fire [Type]	0
1998	Fire [Type]	20587
1999	Fire [Type]	216
2000	Fire [Type]	232
2001	Fire [Type]	93
2002	Fire [Type]	1236
2003	Fire [Type]	7243
2004	Fire [Type]	2332
2005	Fire [Type]	154
2006	Fire [Type]	1143
2007	Fire [Type]	0
2008	Fire [Type]	170
2009	Fire [Type]	0
2010	Fire [Type]	649
2011	Fire [Type]	0
2012	Fire [Type]	463
2013	Fire [Type]	7985

7. To import these values as targets, navigate to the **Transition Targets** for your scenario, then right-click anywhere on the grid and select *Import***.** Change the file type to *CSV* at the bottom right of the **Import** screen, and then navigate to and select the file **Area Burned by Year.csv** (from the folder **Documents\SyncroSim\Course\Exercise 4\Files**). Be sure to choose **Append** when asked, as you will want to retain the existing target that already sets your Harvest to zero. The values from the **Area Burned by Year.csv** file should now appear in your table.


Scenario : [6] 1984-2013, historic fire, no harvest
General
Run Control
Transition Pathways
Initial Conditions
Transition Targets
Output Options
Advanced
Year
Transition Type/Group
Target Area (Acres)
Harvest [Type]
0.0000
Import
Course
Exercise 4
Files
Search Files
Organize
New folder
3D Objects
Desktop
Documents
Downloads
Music
Pictures
Videos
Local Disk (C:)
Name
Date modified
Type
Area Burned by Year
2021-04-16 3:43 PM
Frequency Distribution of Normalized An...
2021-04-16 3:43 PM
File name:
Area Burned by Year
CSV Files (*.csv)
Open
Cancel


Import
There is existing data. Please choose from the options below:
Append
Overwrite
Cancel

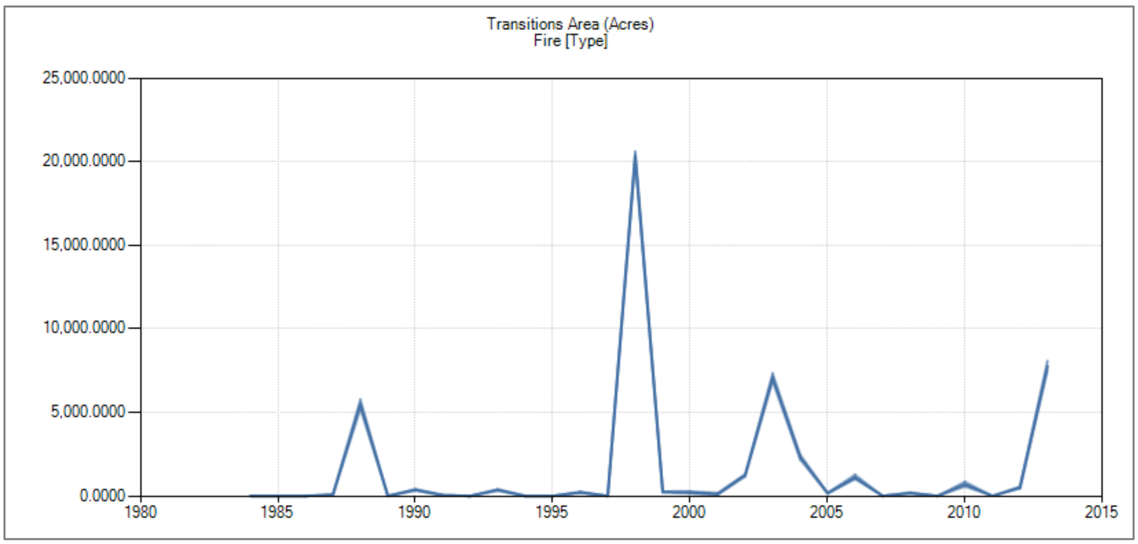

Scenario : [6] 1984-2013, historic fire, no harvest
General
Run Control
Transition Pathways
Initial Conditions
Transition Targets
Output Options
Advanced
Year
Transition Type/Group
Target Area (Acres)
Harvest [Type]
0.0000
1984
Fire [Type]
7,938.0000
1985
Fire [Type]
0.0000
1986
Fire [Type]
0.0000
1987
Fire [Type]
62.0000
1988
Fire [Type]
5,498.0000
1989
Fire [Type]
0.0000
1990
Fire [Type]
340.0000
1991
Fire [Type]
31.0000
1992
Fire [Type]
0.0000
1993
Fire [Type]
386.0000
1994
Fire [Type]
0.0000
Disable editing and load only the first 200 records

8. **Close** the **Scenario** window and **Save** your work.

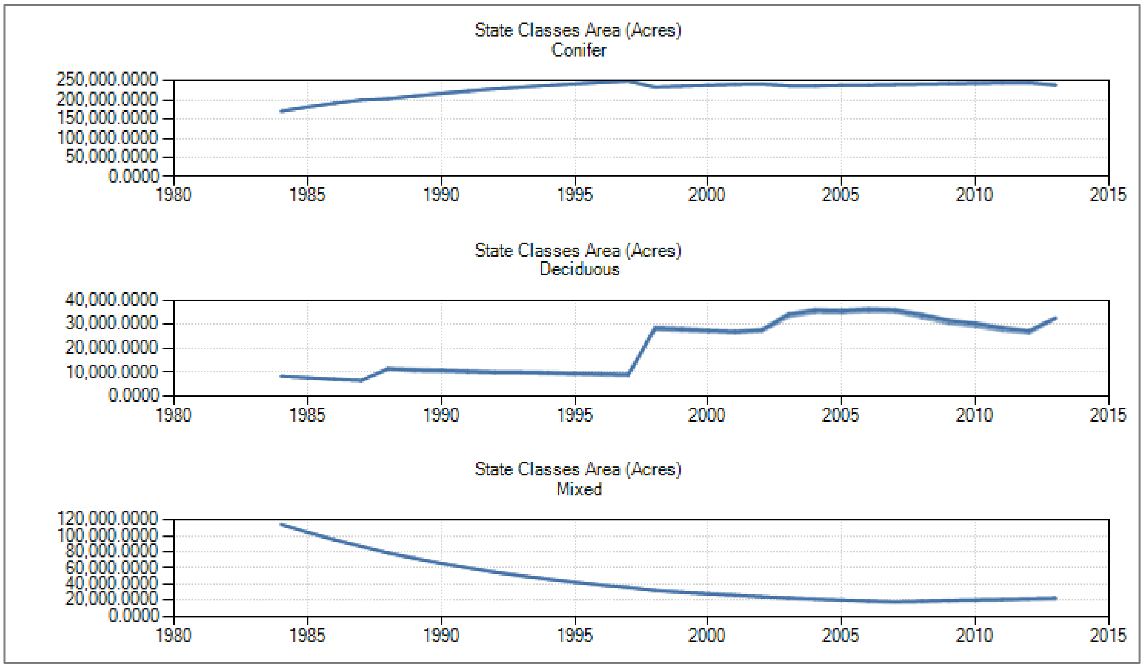
Why is it necessary in this model to explicitly set the Harvest target to zero?

9. You should now **Run** your scenario **1984-2013, historic fire, no harvest**.

10. Create a Chart of your Fire Transitions over time. To do this, open the **Transitions** Chart. Expand the node for **Transitions** and check the box for *Area (Acres)*. Expand the node for **Disaggregate By** and check the box for *Transition Type/Group*. Expand the node for **Include Data for**, then the node **Transition Type/Group** and check the box for *Fire (Type)*.Click **Apply** and adjust the time step (*1980*, *2013*).



11. Next, create a Chart of the Area in each Forest Type over time. To do this, open the **States** Chart. Expand the node for **State Classes** and check the box for *Area (Acres)*. Expand the node for **Disaggregate By** and check the box for *Cover Type*. Click **Apply** and adjust the time step (*1980*, *2013*).



What do you notice about the variability across iterations for your area burned?

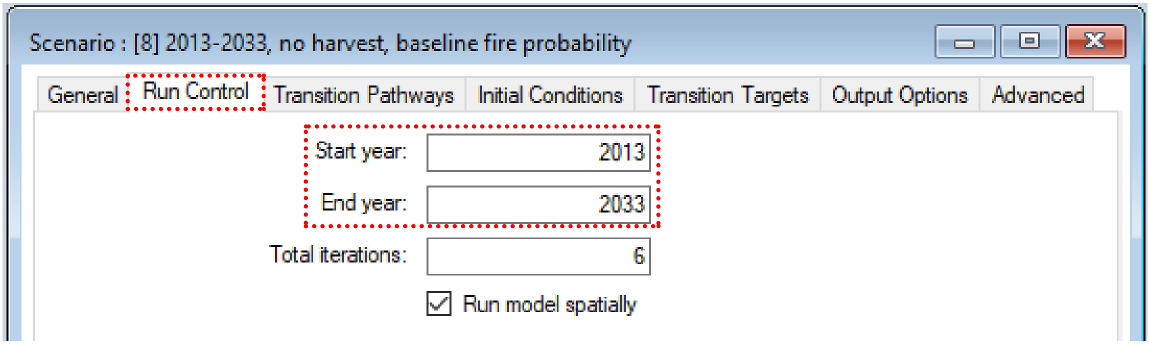
What is the effect of the large area burned in 1998 on the composition of the landscape?

Task 2 – Doubling baseline fire probabilities

Our next challenge is to make projections into the future using different assumptions about the probability of fire. To do this, we will setup transition multipliers that scale the amount of fire up or down, and use these to project our landscape forward in time. For this task we will look at doubling the fire probability defined in our transition pathways.

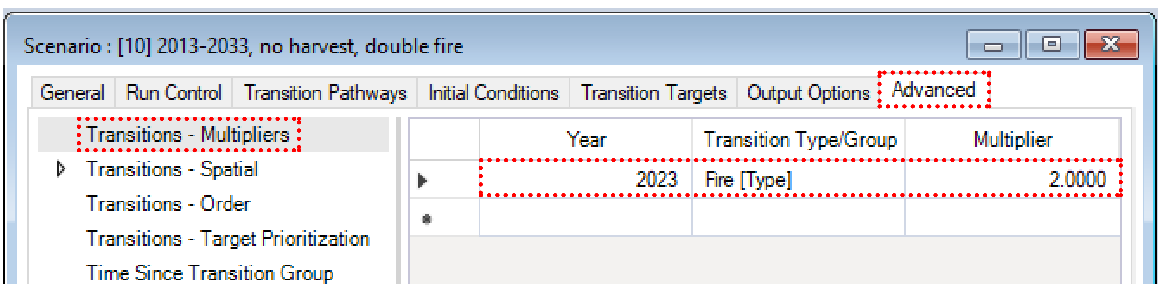
1. Begin by removing your Task 1 scenario's results from your charts (right-click and select **Remove from Results**).

2. Create another copy of the **No Harvest** scenario. Rename this copy "2013-2033, no harvest, baseline fire probability". For this scenario, modify your **Run Control** to start your model in 2013 (the last year of your retrospective simulation) and run it forward for 20 years. **Run** this scenario. Check that the output makes sense.

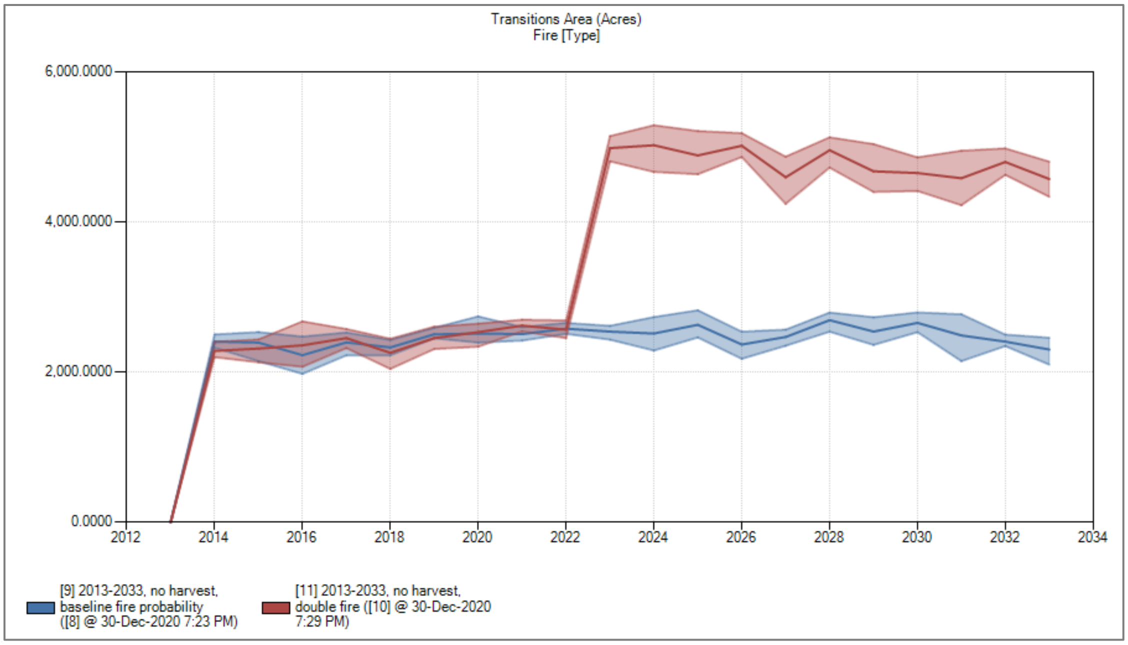


3. To ease your way into using Transition Multipliers, next you will setup a scenario that simply doubles the amount of the baseline fire, starting in year 2023. To do this you will need to copy the **2013-2033, no harvest, baseline fire** scenario, rename it “2013-2033, no harvest, double fire” and edit the **Transition Multiplier** Datafeed.

4. On this new scenario, navigate to the **Transition Multipliers** Datafeed (under the **Advanced** tab), turn on the optional **Year** column, and enter a single line in the grid that sets a **Multiplier** of *2* in the **Year** *2023* for *Fire*.



5. **Run** this scenario. Compare the results (for Fire transition) to the previous scenario with only the baseline fire. If you set things up correctly, you should see that the amount of fire doubles in 2023, and continues to be doubled to the end of the simulation.



Task 3 – Adding uncertainty to the doubling effect

Now we will apply some additional uncertainty regarding this doubling effect. Instead of simply assuming fire probabilities double, we will instead now assume that after 2023 the fire probabilities will be somewhere between 1.5 and 2.5 times the baseline levels.

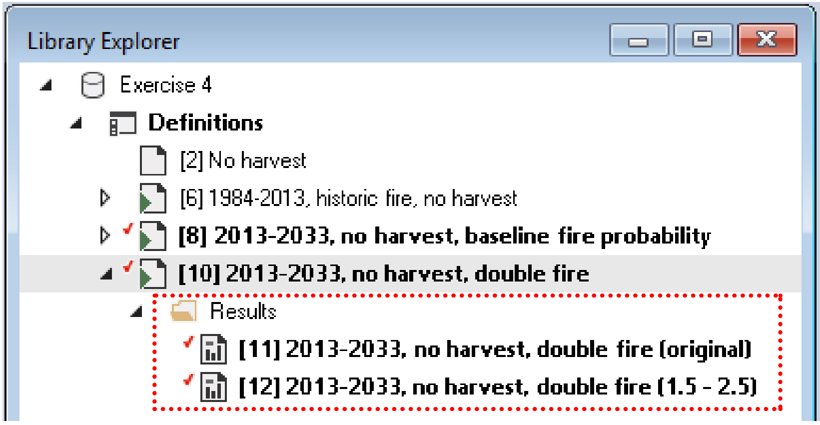
1. To do this, modify the **Transition Multipliers** for the scenario you just ran such that the multiplier is no longer fixed at a value of 2, but rather it is sampled from a uniform distribution that varies between *1.5* and *2.5 (Hint: display the optional columns for **Multiplier Distribution**, **Multiplier Sampling Frequency, Multiplier Min** and **Multiplier Max**).*

2. Decide also the frequency with which you will sample from this distribution (we suggest *Iteration and Timestep*).

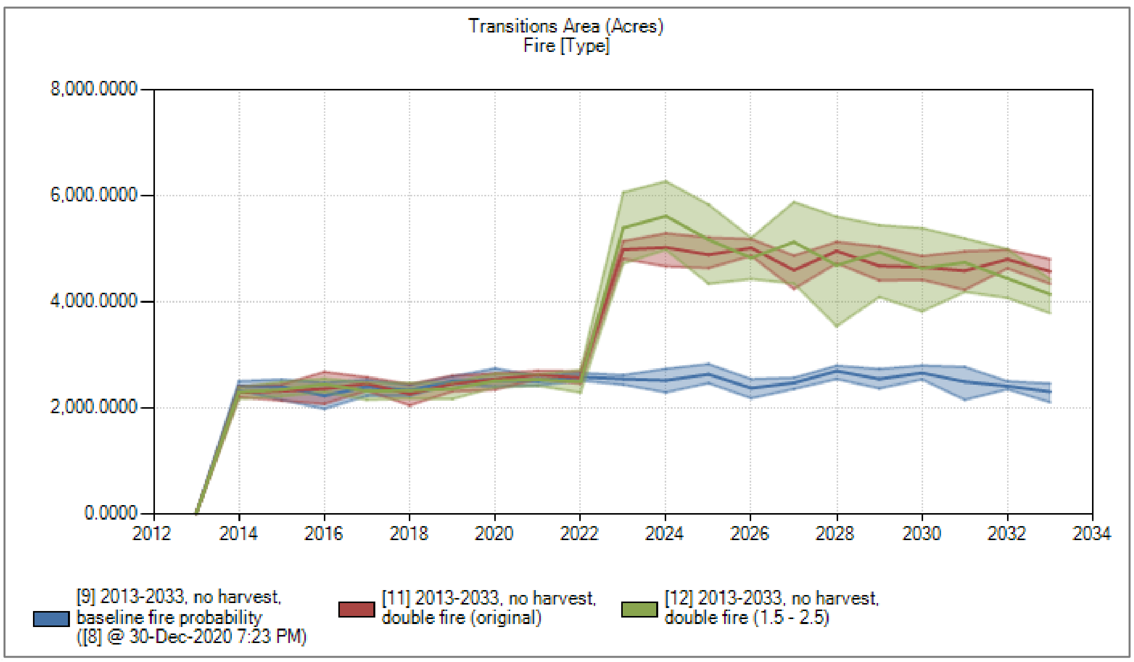
Year	Transition Type/...	Multiplier	Multiplier Distribution	Multiplier Sampling Frequency	Multiplier Min	Multiplier Max
2023	Fire [Type]	2.0000	Uniform	Iteration and Timestep	1.5000	2.5000

3. Re-run your scenario with the added uncertainty in the multiplier. Open the scenario's **Results** folder to see both sets of run results.

4. Change the names of the two Results Scenarios to highlight the difference between them. To do this, open the first Results Scenario for **2013-2033, no harvest, double fire** and modify the default name to "2013-2033, no harvest, double fire (original)". For the second Results Scenario, modify the default name to "2013-2033, no harvest, double fire (1.5 – 2.5)".



5. Compare the two runs in a single chart *(Hint: because you are comparing two runs of the same scenario, you will need to make sure both Results Scenarios for this same full scenario are added to your results before charting).* Your **Transitions** Chart should look something like this:



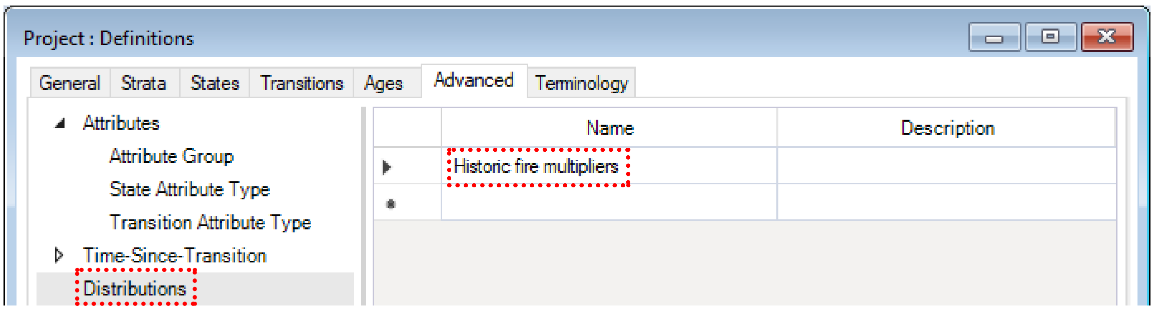
What is the effect of sampling from this uniform distribution on your projections for fire after 2023?

Task 4 – Adding historic inter-annual variability to the fire probabilities

Let's now make projections into the future that are consistent with the historical inter-annual variability in fire. To do this we will: (1) create our own custom probability distribution that matches the historical frequency distribution of normalized annual area burned; and (2) sample our multipliers from this custom distribution when simulating forward in time. We use normalized values for the distribution so that the multipliers do not change our mean baseline fire probabilities, but rather only modify the distribution of those probabilities around the baseline means. In this way, we will generate future simulations that have the same variability in fire as was observed in the past, yet respect the original baseline mean fire probabilities.

1. Create a new scenario (copied from **2013-2033, no harvest, baseline fire probability** scenario) and rename it “2013-2033, no harvest, historic fire variability”.

2. Our first step is to create a custom probability distribution in ST-Sim. To do this, right click on the **Definitions** within the **Exercise 4** Library and select *Properties*. Navigate to the **Advanced** tab and click **Distributions** on the left sidebar. Here you will simply provide a name for your distribution. We suggest “Historic fire multipliers”. Make sure to **Save** your work before closing the **Definitions** window.

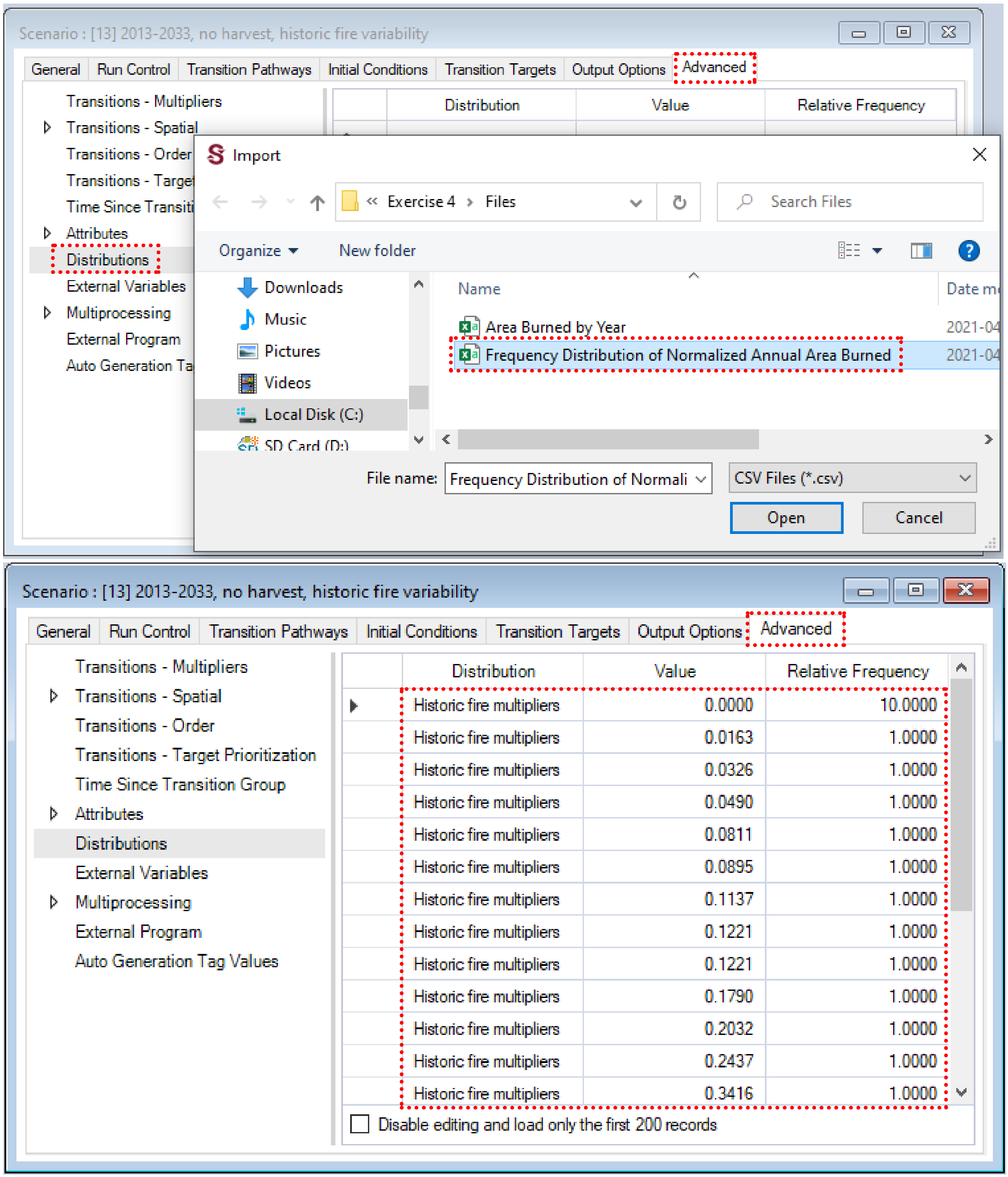


3. Next you will import a frequency distribution (from a CSV file) that matches the distribution of historical area/mean values. Using Windows Explorer, navigate to the folder containing the additional course files for Exercise 4 (in **Documents\SyncroSim\Course\Exercise 4\Files**), and then open the file called **Frequency Distribution of Normalized Annual Area Burned.csv** (you can open this in either Excel or Notepad). You will see that this contains a frequency distribution of the normalized area burned values for the 30-year time series shown in Task 1 (note that 10 of 30 years had no area burned).

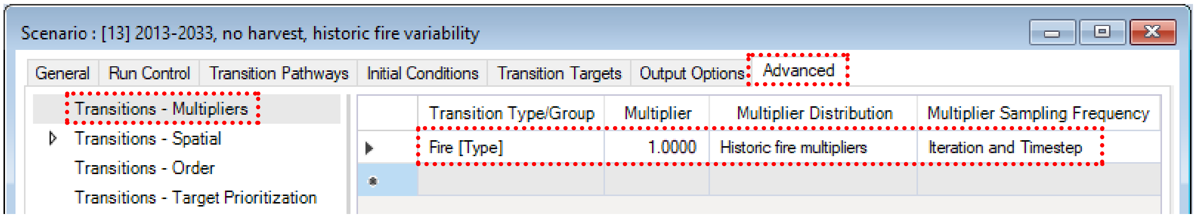
DistributionTypeID	Value	ValueDistribution RelativeFrequency
Historic fire multipliers	0	10
Historic fire multipliers	0.016319	1
Historic fire multipliers	0.032637	1
Historic fire multipliers	0.048956	1
Historic fire multipliers	0.081067	1
Historic fire multipliers	0.089489	1
Historic fire multipliers	0.113704	1
Historic fire multipliers	0.122127	1
Historic fire multipliers	0.122127	1
Historic fire multipliers	0.178979	1
Historic fire multipliers	0.203194	1
Historic fire multipliers	0.243727	1
Historic fire multipliers	0.341639	1
Historic fire multipliers	0.601685	1
Historic fire multipliers	0.65064	1
Historic fire multipliers	1.227584	1
Historic fire multipliers	2.894192	1
Historic fire multipliers	3.812774	1
Historic fire multipliers	4.178628	1
Historic fire multipliers	4.203369	1
Historic fire multipliers	10.83716	1

4. Close the Excel file before proceeding. To add this distribution to ST-Sim, open the scenario you just created (**2013-2033, no harvest, historic fire variability**) and navigate to the **Distributions** Datafeed (under **Advanced**). Add the optional **Relative Frequency** column.

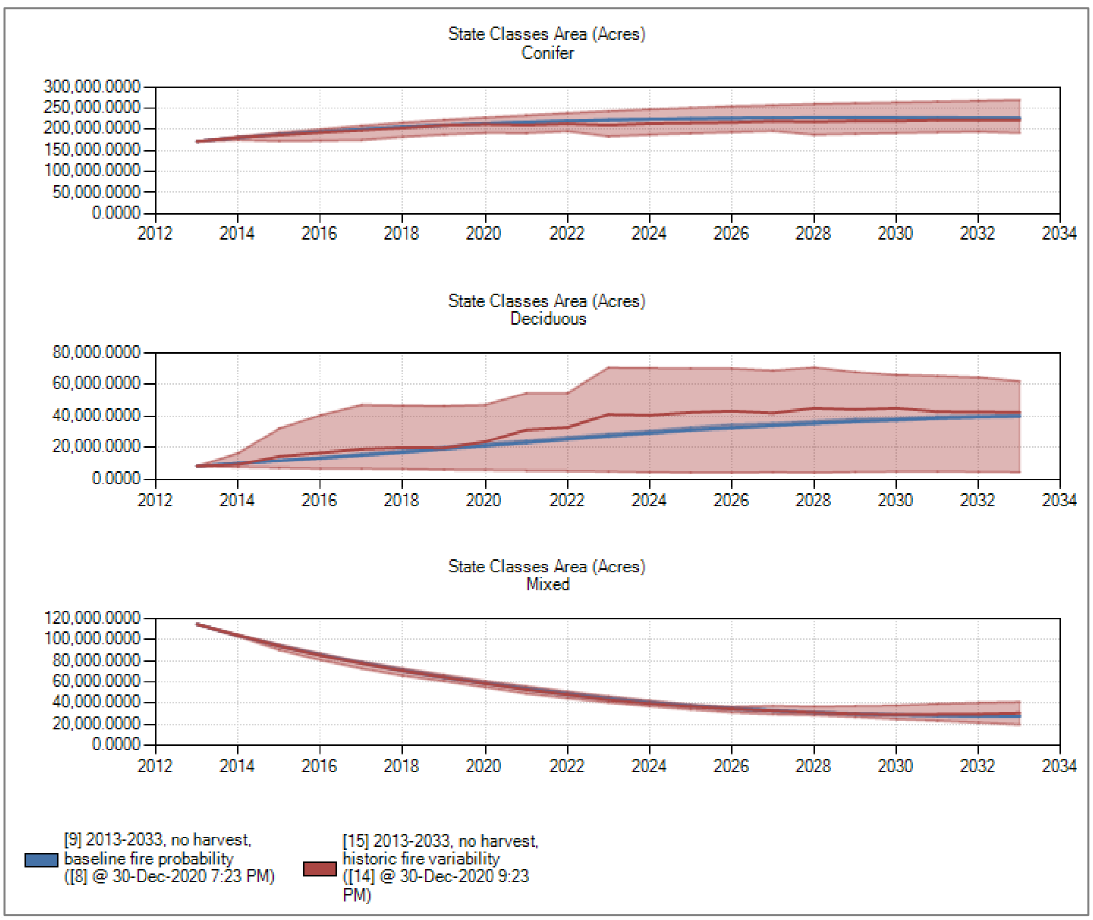
5. To import the frequency distribution data, right-click anywhere on the grid and select *Import*. Make sure the file type is set to *CSV* at the bottom right of the *Import* screen, and then select the file **Frequency Distribution of Normalized Annual Area Burned.csv** (from the folder **Documents\SyncroSim\Course\Exercise 4\Files**).

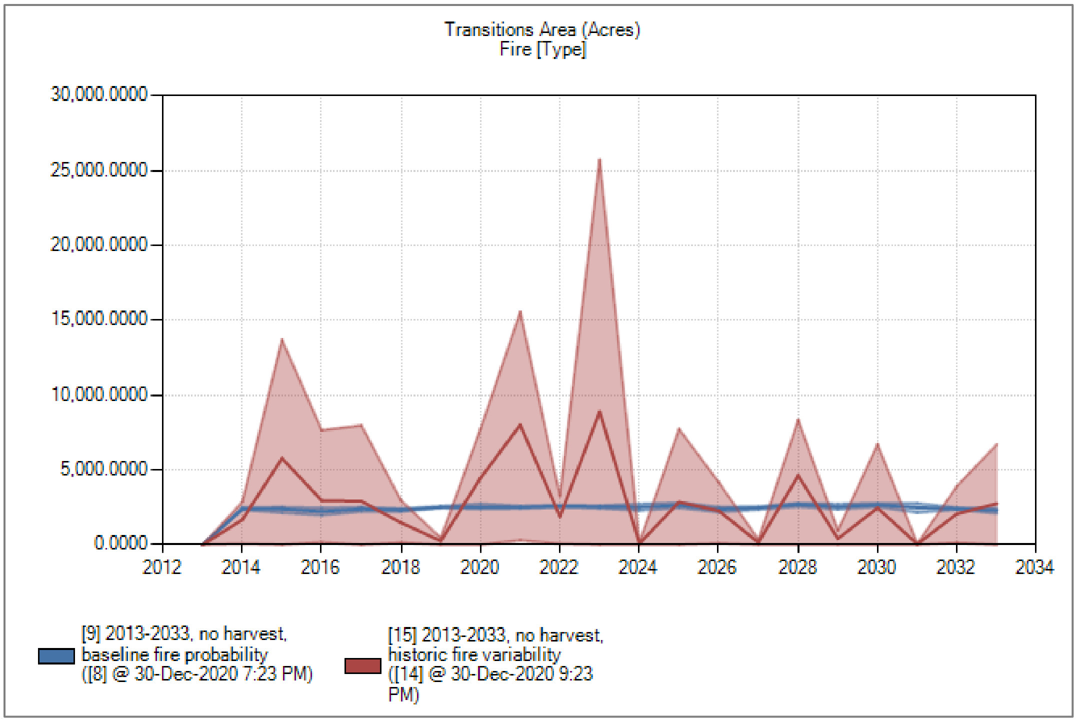


6. You will now tell ST-Sim to sample from this distribution in order to generate multipliers that will scale the base fire probability up and down for each timestep of each Monte Carlo realization of your future simulations. In the **Transition Multipliers** Datafeed, set this scenario to sample every *Iteration and Timestep* from the new *Historic fire multipliers* distribution you just created.

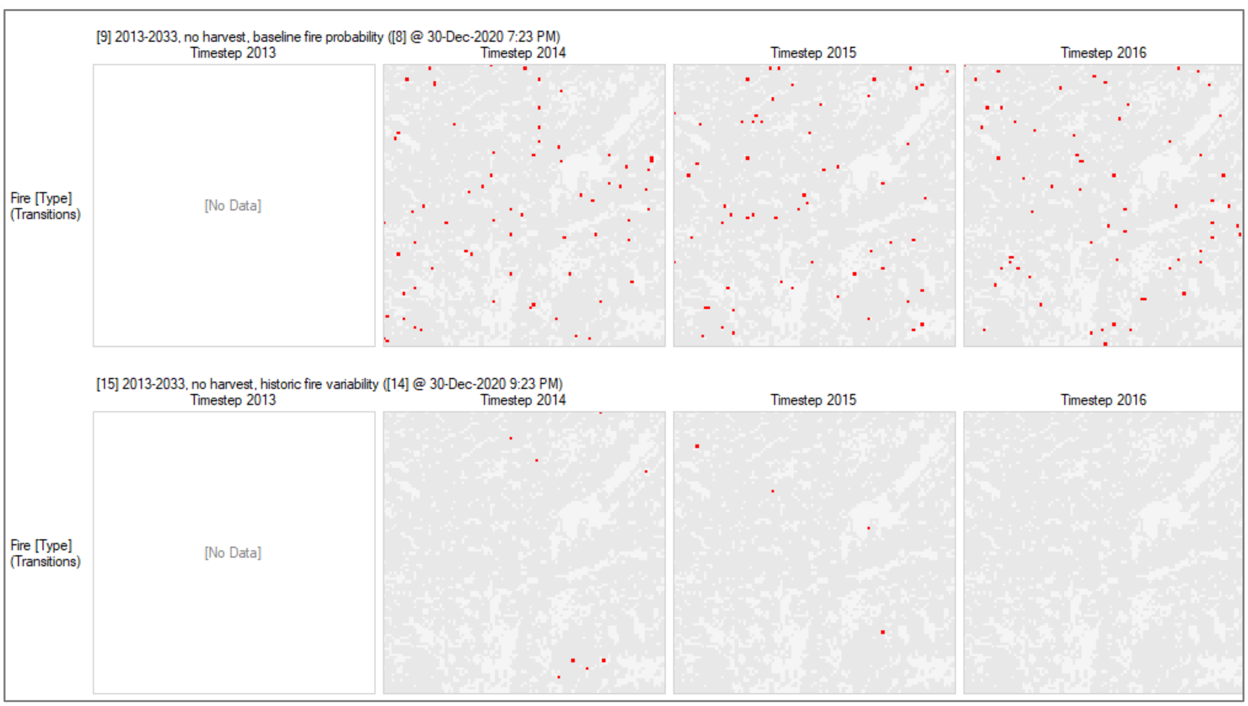


7. **Run**your**2013-2033, no harvest, historic fire variability** scenario and compare the projections to the similar scenario with no variability (the **2013-2033, no harvest, baseline fire probability** scenario).Compare both the state classes and the transitions using the **States** and **Transitions** Charts.





8. Next, display a time series of Maps for all years (i.e., 2013-2033) of projected fire.



How does the mean annual proportion area burned (over all 20 simulated years) compare between the scenario with only baseline fire and the scenario that adds to this historic variability?

What is the effect of adding temporal variability in fire to our predictions regarding uncertainty as to the future amount of conifer old growth (i.e., age 80+)?

What do you think of the spatial pattern of projected fire?

Bonus Question: *Take the future scenario with historic fire variability that you just created and add to it a harvest of 2000 acres/yr. Use Transition Multipliers to model the rotation of this harvest through the five harvest blocks (A to E) over time, where all the harvest occurs in block A for 4 years, then all in block B for the next four years, etc.*

Exercise 5: Adding spatial variability to transitions

Objectives

- Understanding how to add spatial multipliers to force transitions for specific locations over time
- Using transition size distributions so that rather than transitioning one cell at a time, transition events are simulated

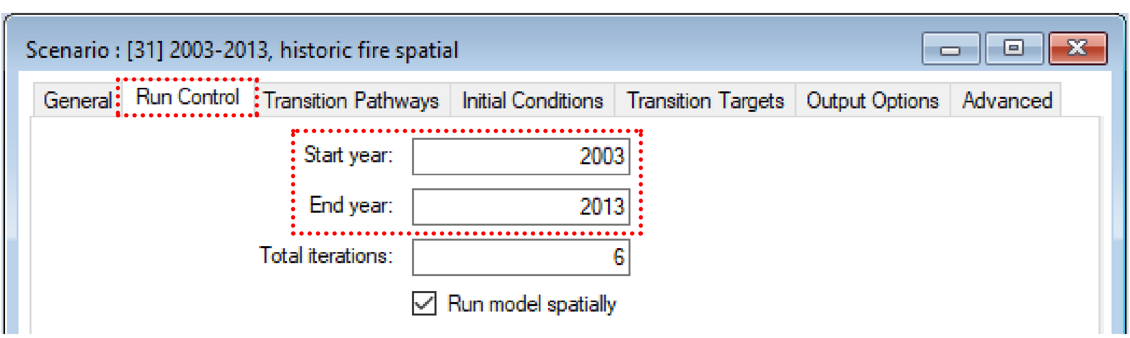
Task 1 – Retrospective simulation using actual fire maps

We begin this exercise by setting up an historical simulation in order to better understand the consequences of past variability in fire across our landscape. Unlike the previous exercise, however, this time we will use each year's actual past fire maps (rather than only the total area burned).

1. Open SyncroSim. Select **File | Open Library** and navigate to the file **Exercise 5.ssim.** If you installed your course materials to the recommended folder location, this file can be found in the folder **Documents\SyncroSim\Course\Exercise 5.** Click **Open**.

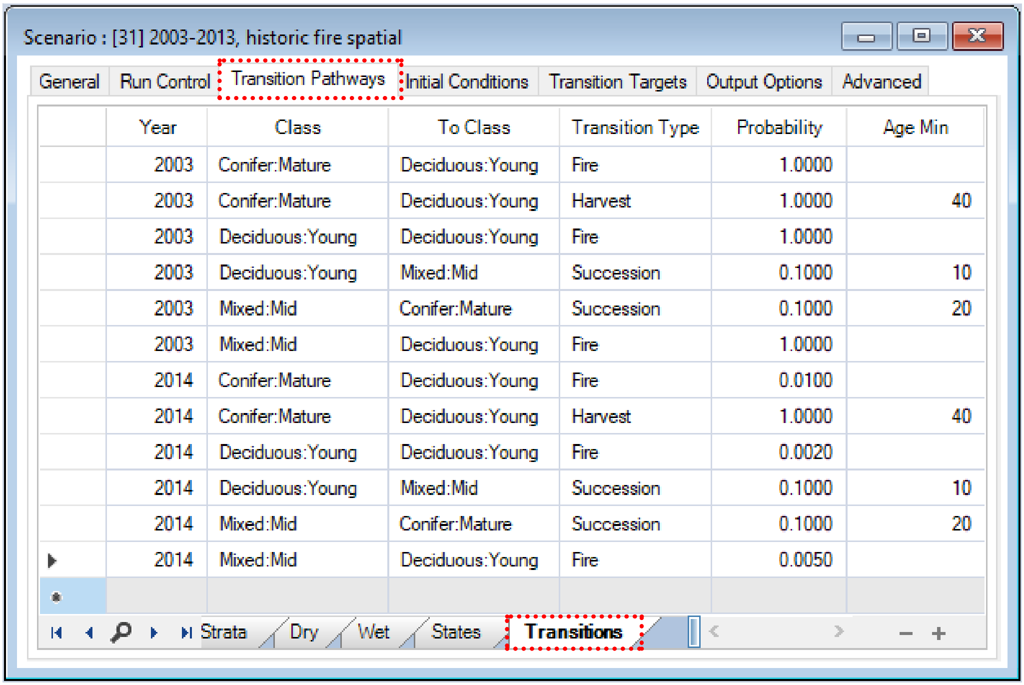
2. In the library for this exercise, you will see a scenario called **1984-2013, historic fire (non-spatial), no harvest**. This scenario is identical to the retrospective scenario you created in Exercise 4, except that the Transition Pathways have been modified slightly to reflect differences in fire probabilities for historical and future periods of our simulations (more on this later). Make a copy of this scenario and call it "2003-2013, historic fire spatial".

3. As the scenario name suggests, our retrospective simulation for this exercise will cover the period 2003-2013 (rather than the period 1984-2013 used with the non-spatial fire data previously). In this exercise we will be running the model initialized in 2003 for an historic 10-year retrospective simulation corresponding to the time period for which we have maps of fire perimeters (i.e., 2004-2014). In the **Run Control** Datafeed, set the simulation to start in *2003* and end in *2013*, with *6* iterations.

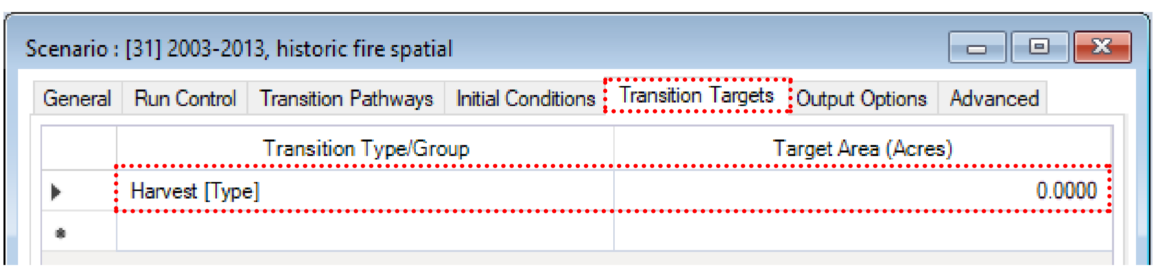


4. Next, we will look at the changes made to our Transition Pathways for this exercise. Navigate to the **Transitions** sheet on the **Transition Pathways** tab. You will see that there are now twice the rows that existed in the previous exercise. The pathways with Year set to 2014 are identical to those in the previous exercise – these represent the pathways that will be used later in the exercise for simulation years 2014 and beyond. A copy of the pathways (with Year set to 2003) represents those that will now be used for simulation years from 2003 to 2013 (i.e., the new

historical period). The only difference between the two sets of pathways is that, for the historical period (i.e., with Year=2003), the probability for each of the three Fire transition pathways has been changed to 1. This prepares us to specify deterministically which cells to transition due to fire each year over our historical period using the Spatial Multipliers Datafeed.

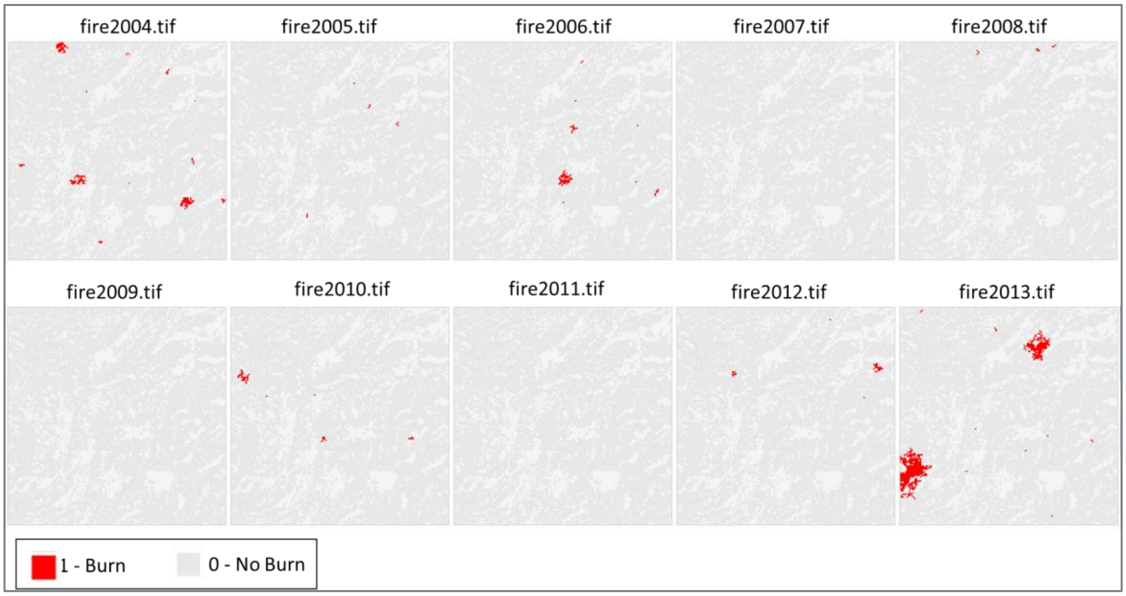


5. We will also remove the existing Transition Targets for Fire in this scenario, as these represent the old non-spatial targets for fire over the historical period (and we will be using maps instead to define the area burned spatially in this exercise). Navigate to the **Transition Targets** Datafeed and delete all the targets associated with the Fire Transition Type, so only the Harvest target (set to 0) remains.

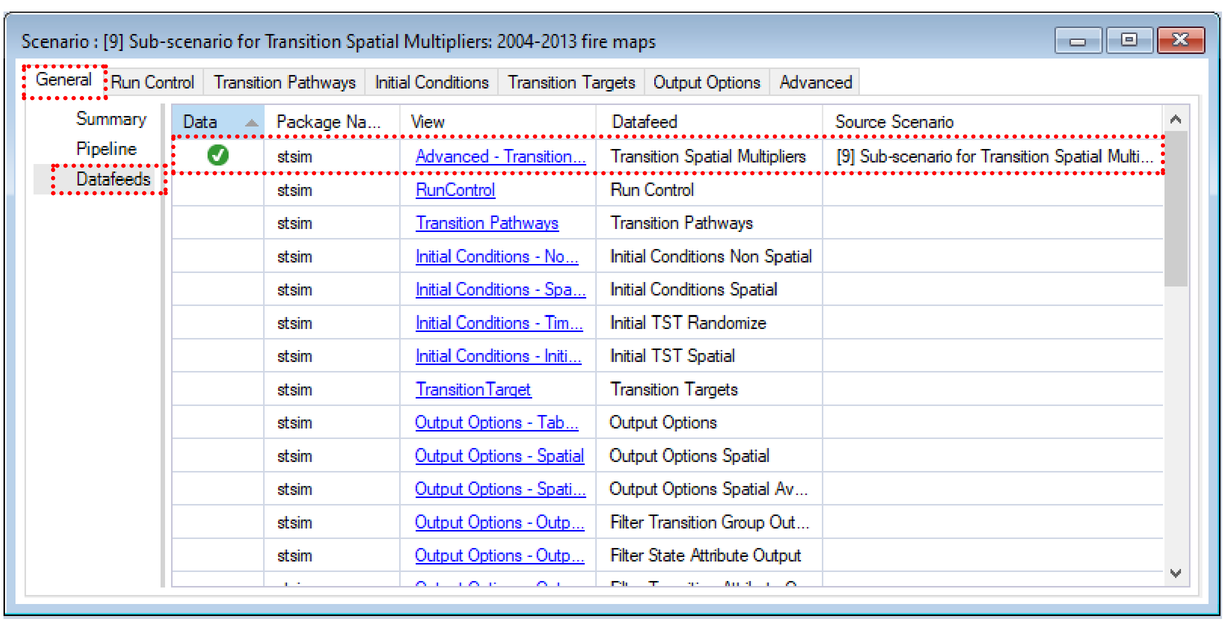


6. Close the **Scenario** window of your newly created **2003-2013, historic fire spatial** scenario.

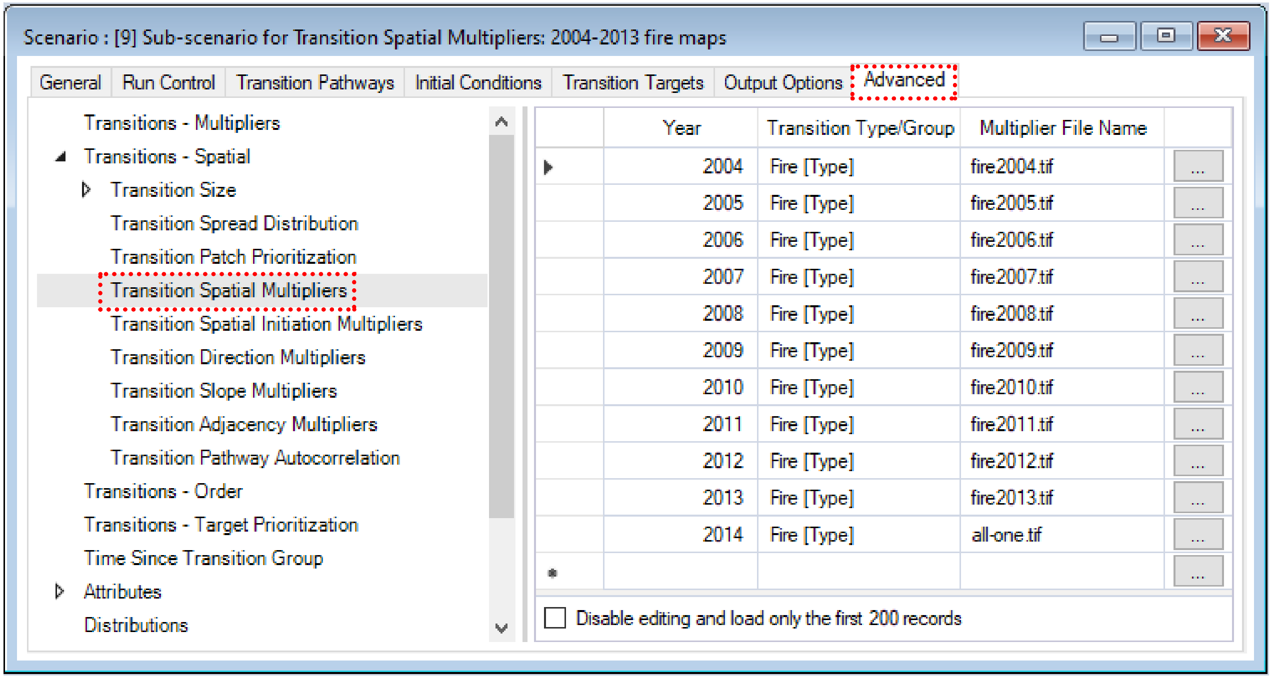
7. We will now setup the Spatial Multipliers Datafeed. This model input allows one to provide a “multiplier” on the base fire probabilities for each cell and timestep of the simulation, where the multipliers are specified as a time series of raster maps. As a result of setting our base fire probabilities to 1and removing all fire transition targets (in the previous two steps), any cell and year that has a multiplier value of 1 will now be forced to burn in our simulation (as the product of the multiplier and the base probability will always be 1); conversely, a cell and year with a multiplier of 0 will not burn. In this way, we can use the actual fire raster files (as shown below with values of 1 for burn and 0 for no-burn) directly as our spatial multipliers.



8. To save you time, we have already imported the time series of fire raster files shown above into ST-Sim for use as Spatial Multipliers. To do so, we created a *sub-scenario* containing only the Spatial Multipliers (and nothing else). Sub-scenarios are used as building blocks for creating full (i.e., runnable) scenarios. To view this sub-scenario, expand the folder called **Sub-scenarios** in the SyncroSim **Library Explorer**, and then open the scenario called **Sub-scenario for Transition Spatial Multipliers: 2004-2013 fire maps**. Within this scenario, click on the **General** tab followed by the **Datafeeds** node. Here you will see a list of all the possible input Datafeeds for ST-Sim. Green checks (to the left) tell you which of these Datafeeds contain data in this scenario. In this sub-scenario there is only a single green check beside the Datafeed **Transition Spatial Multipliers**, telling us that the scenario contains data for only this one Datafeed.

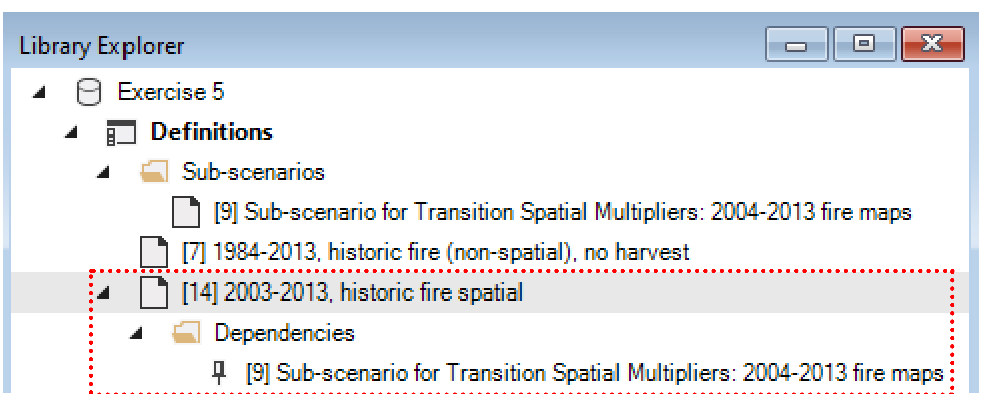


9. To view the contents of this sub-scenario, click on the Transition Spatial Multipliers hyperlink (under the **View** column of the **Datafeeds** node). You will see that our set of Spatial Multipliers consists of an actual fire raster file (as named and shown below) assigned to the Transition Type Fire for every Year from 2004-2013.



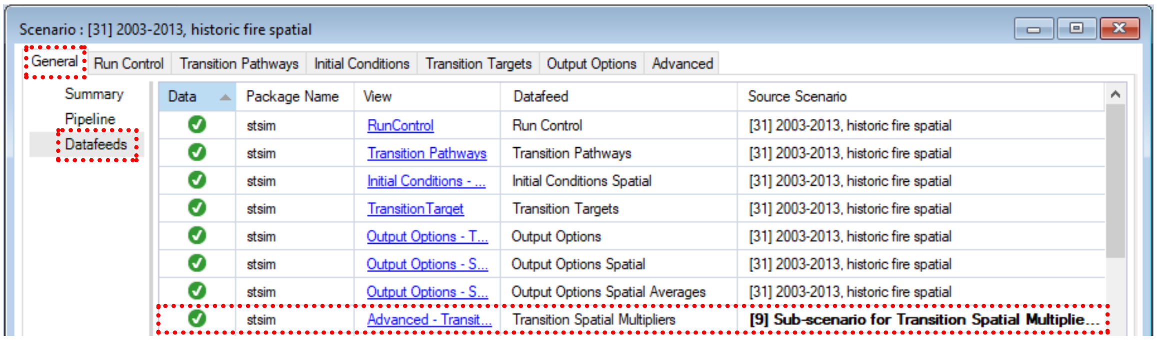
10. Close the window for the sub-scenario called **Sub-scenario for Transition Spatial Multipliers: 2004-2013 fire maps**.

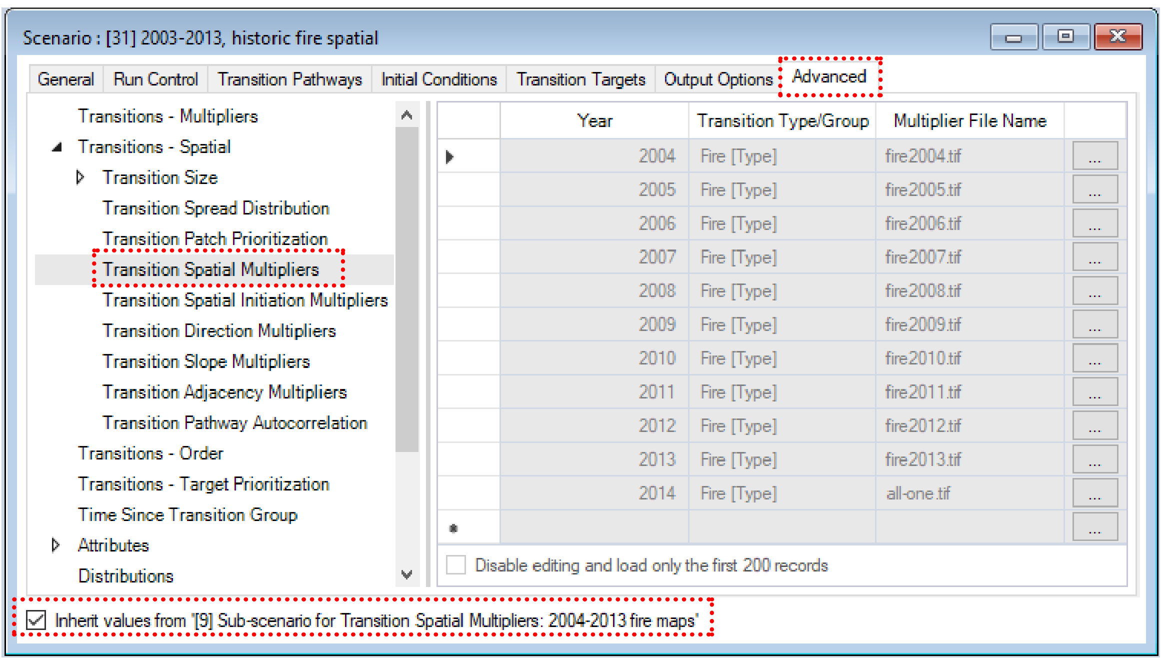
11. You will now add the Spatial Multipliers (as defined in the sub-scenario) to our original full scenario. Using the SyncroSim **Library Explorer**, drag and drop the sub-scenario (called **Sub-scenario for Transition Spatial Multipliers: 2004-2013 fire maps**) on top of the full scenario (called **2003-2013, historic fire spatial**). This creates a *dependency* in SyncroSim between the full scenario and the sub-scenario, which you can see if you expand the full scenario's view in the **Library Explorer**.



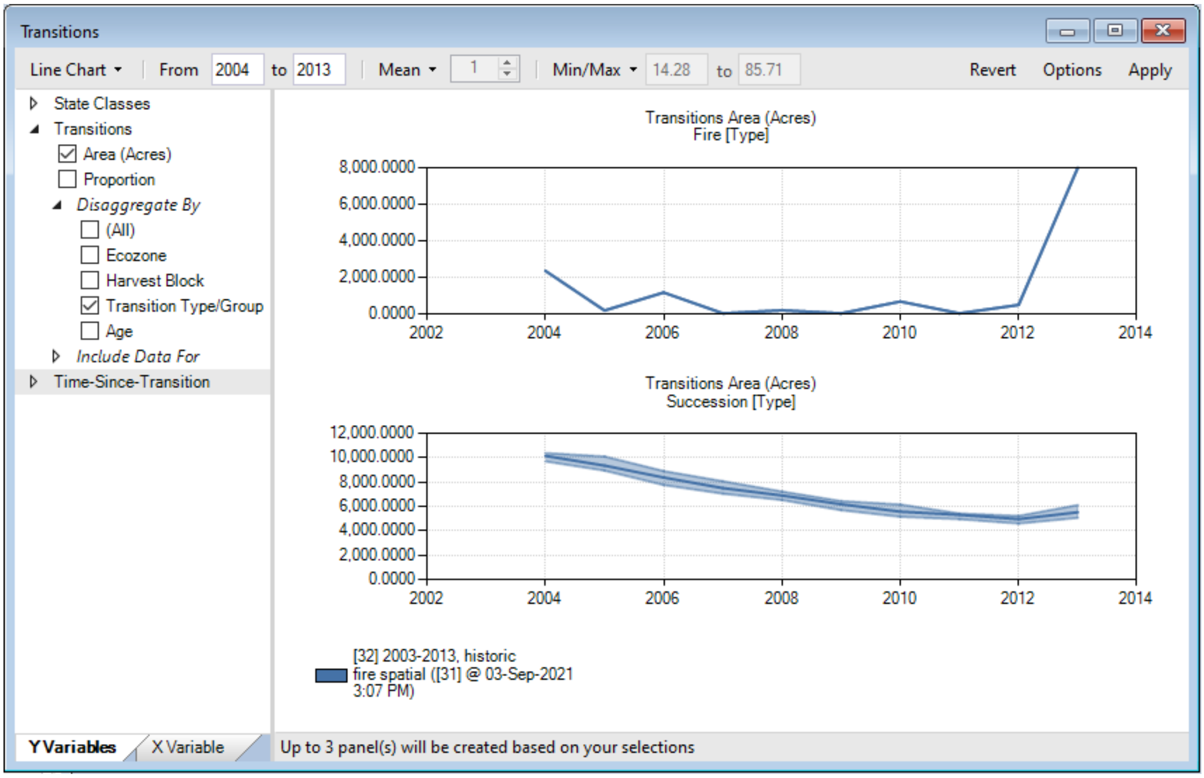
12. Now re-open the full scenario (i.e., the one called **2003-2013, historic fire spatial**). Navigate to the **Datafeeds** node under the **General** tab for this scenario to see a list of all the Datafeeds for

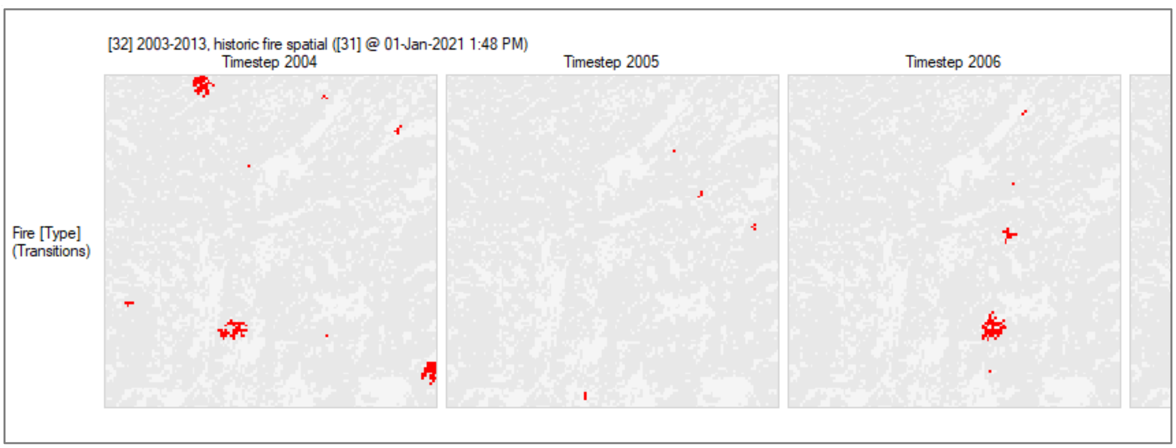
which inputs have been entered. Near the bottom of the list of checked entries, you will see a row for **Transition Spatial Multipliers** showing the dependency you just created. Click on the Transition Spatial Multipliers hyperlink again to see the values (in read-only format) that have been inherited from the corresponding sub-scenario.





13. You can now **Run** the full scenario (called **2003-2013, historic fire spatial**). When the run is complete, open both the **Transitions** Chart and **Fire** Map to see the time series of fire generated in this simulation. For both the Charts and Maps, set the **Timesteps** to *2004-2013* in order to view the entire projected historical time series of fire.



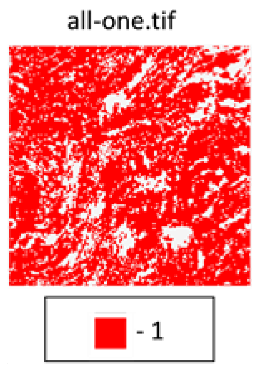


How does the variability between years compare for the projected amount of Fire vs Succession? Can you explain why?

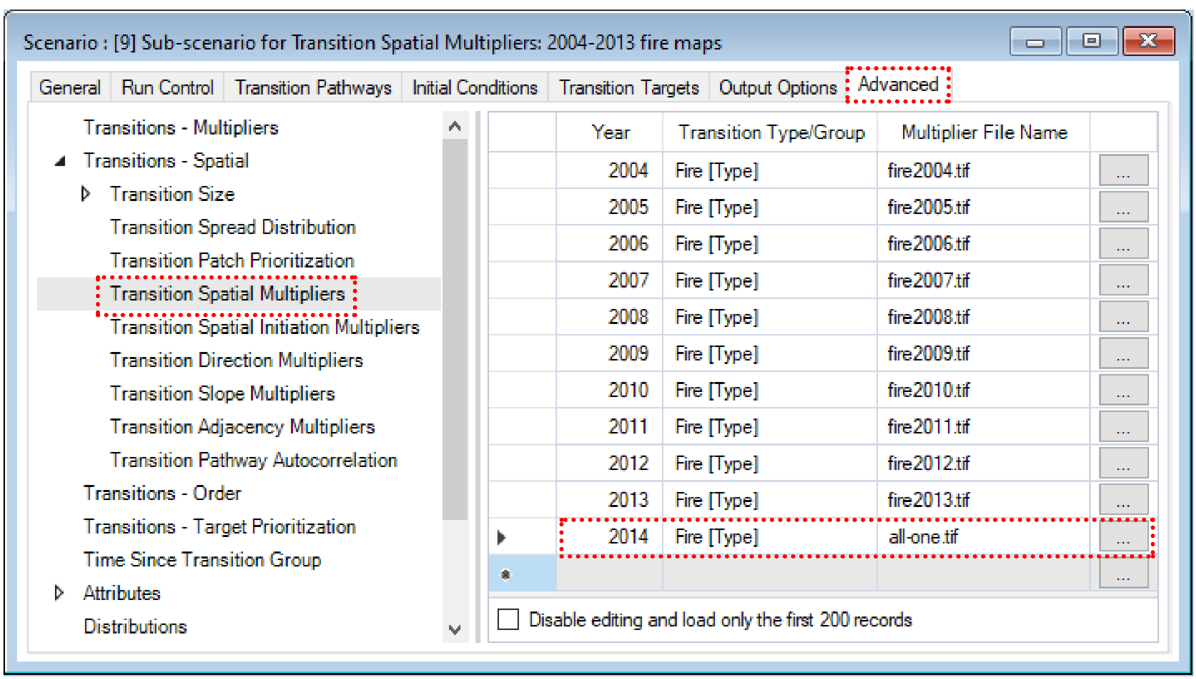
Task 2 – Future simulation based on historical area burned

1. We will now add to this historical scenario, projections of fire for 20 years into the future. Begin by making a copy of the scenario **2003-2013, historic fire spatial**. Call the new full scenario “2003-2033, historic fire spatial, future fire non-spatial”.

2. To run this new scenario over both historical and future periods, we need to make some changes to it. First, we need to add a spatial multiplier raster for the Year 2014 that will set the Fire multiplier value to 1 for all cells. This way the base pathway fire probabilities that we specified earlier to be used for Years 2014 and beyond will all be multiplied by 1 (and thus the spatial multipliers will no longer have any effect). As shown below, we've created such a raster file for you (called **all-one.tif**). Note that the white areas within the raster boundary are water bodies considered outside of the study area.

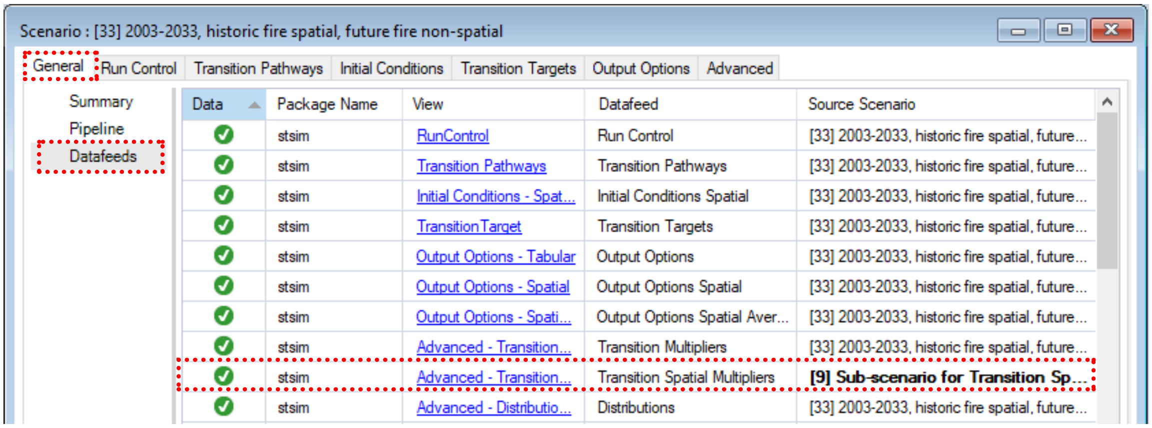


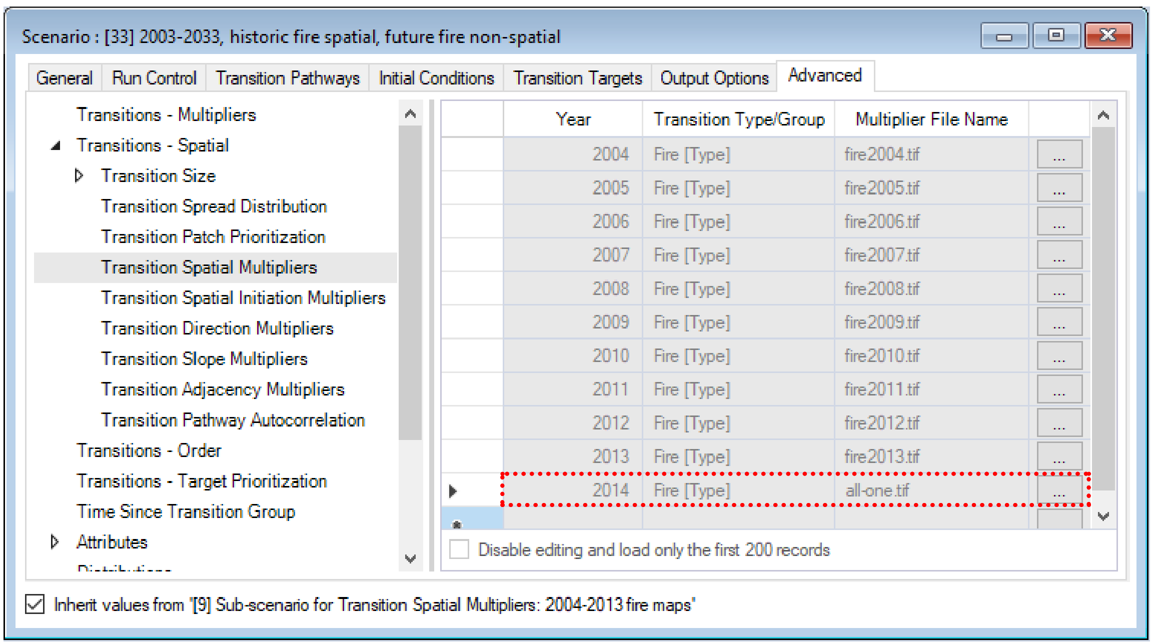
3. The simplest way to add this spatial multiplier is to update the existing spatial multiplier sub-scenario (**Sub-scenario for Transition Spatial Multipliers: 2004-2013 fire maps**). To do this, open the sub-scenario and, in the **Advanced** tab, navigate to **Transition Spatial Multipliers** under the **Transitions – Spatial** node on the left sidebar. Add a new row for the **Year** *2014*, selecting the file **all-one.tif** from the exercise folder **Documents\SyncroSim\Course\Exercise 5\Files**.



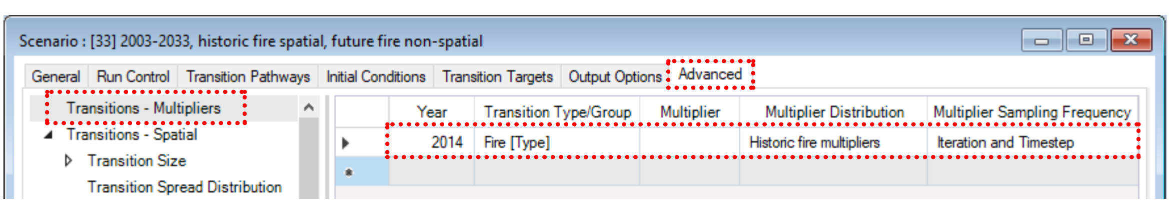
4. Now navigate to the **Transition Spatial Multipliers** Datafeed for your new full scenario (i.e., called **2003-2033, historic fire spatial, future fire non-spatial**). *Hint: the easiest way to do this is using the scenario's **Datafeeds** node under the **General** tab*. You should see the new row for

the Year 2014 appear automatically here also.

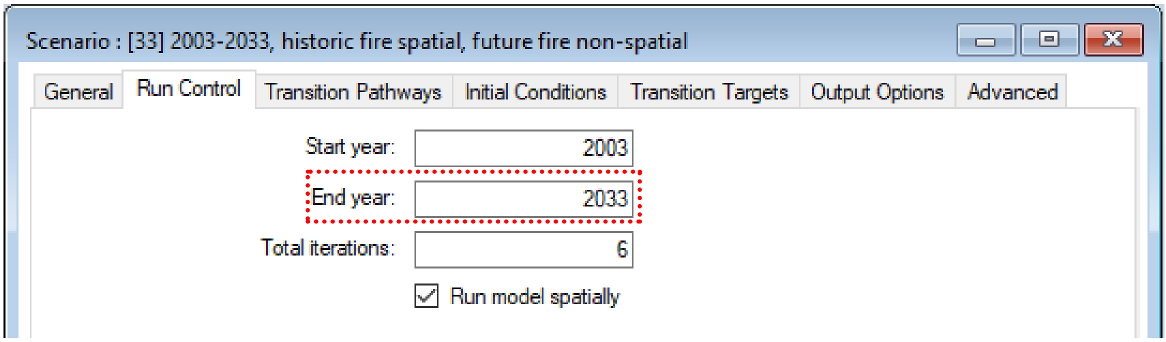




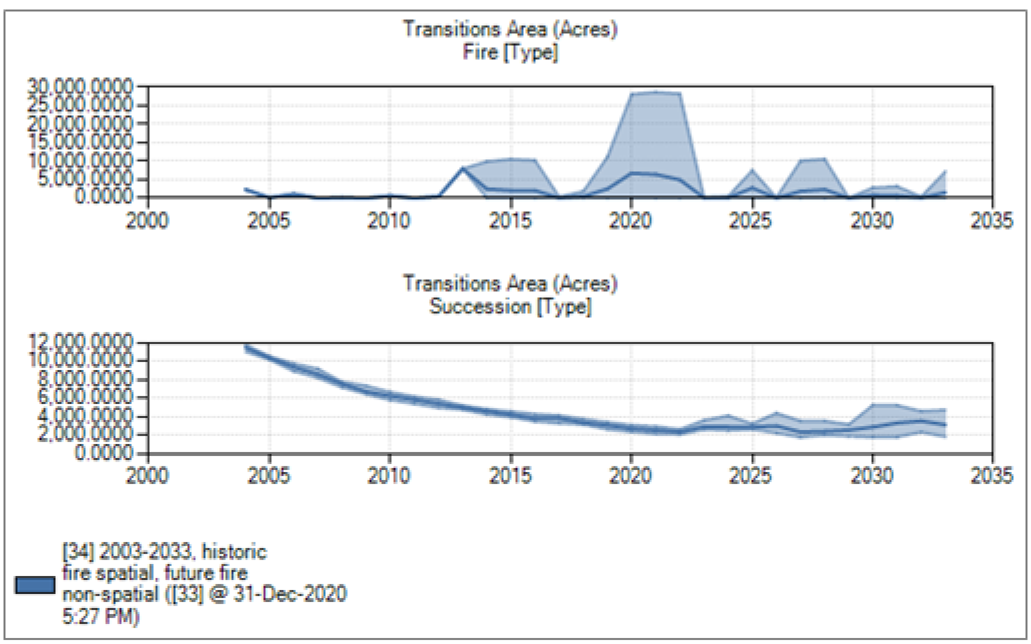
5. Next, we will add temporal transition multipliers (based on the 1984-2013 non-spatial area burned time series) so they apply only to timesteps in the future (as the past variability is now controlled using the Spatial Multipliers). Navigate to the **Transitions – Multipliers** Datafeed for this new scenario (under the **Advanced** tab) and set the non-spatial transition multipliers for *Fire* to begin sampling starting in *2014* from the historical distribution of normalized area burned. *Hint: You will need to add optional fields to the table from the context menu.*

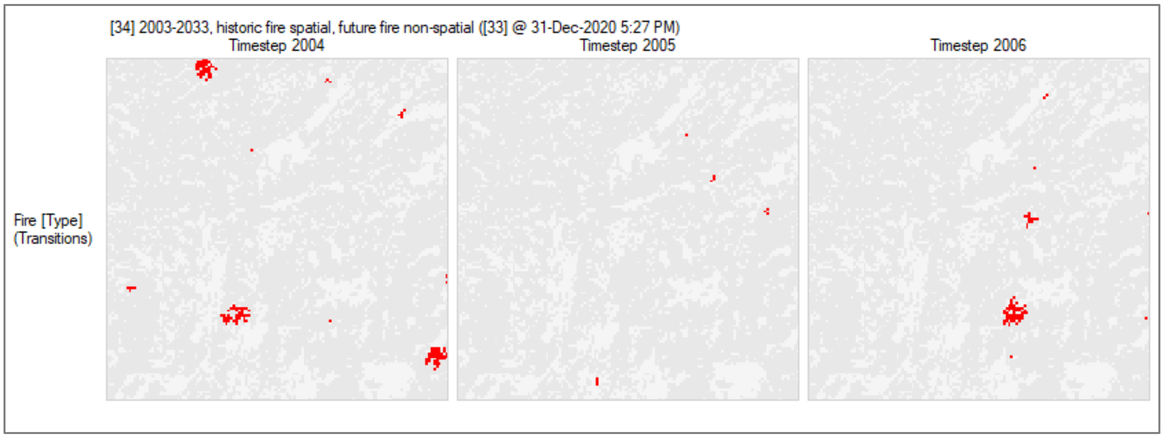


6. Finally, you will need to modify the **Run Control** Datafeed to end in the year *2033*. Close the **Scenario** window and **Save** your work.



7. **Run** the **2003-2033, historic fire spatial, future fire non-spatial** scenario. Remove the results of the **2003-2013, historic fire spatial** scenario from your Charts and Maps by right-clicking on the scenario and selecting **Remove from Results**. Now, display the **Transitions** Charts and **Fire** Maps for your **2003-2033, historic fire spatial, future fire non-spatial** scenario. Make sure to set the **Timesteps** to *2004-2033*.





Describe what happens to the variability in results starting in 2014 and explain why this is the case.

What difference is there in the spatial pattern of fire between the retrospective and future period?

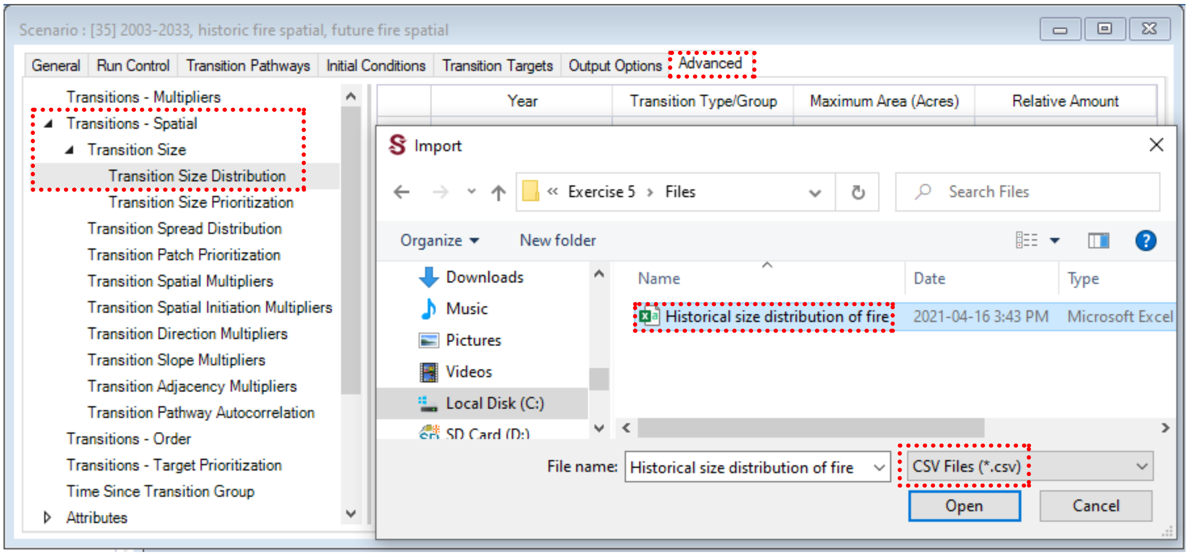
What would happen if we didn't include the all-one.tif file (with all 1.0 values) for Year 2014?

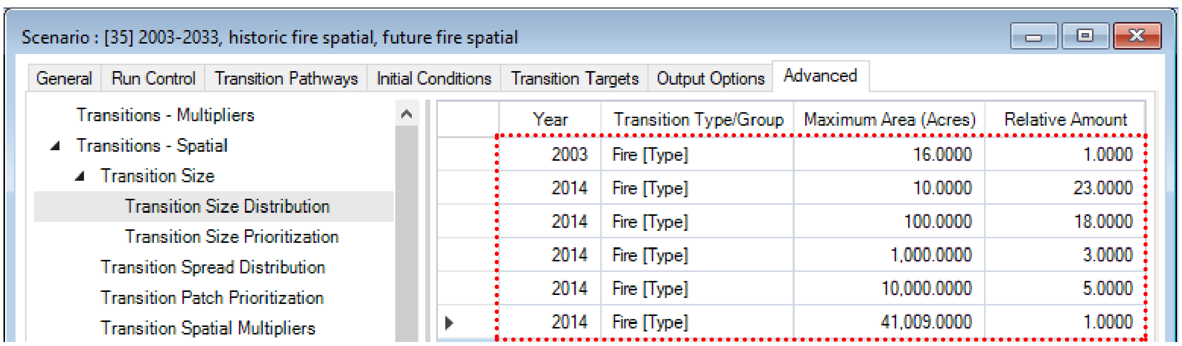
Task 3 – Add a fire size distribution for the future time period

In order to make the future Fire simulations more realistic, you will now simulate fire transitions for years 2014 and beyond such that they follow a specified fire size frequency distribution that matches the actual historical size distribution for fires in the region. The model will use this size distribution to initialize and spread Fire events on the landscape, rather than selecting individual simulation cells to burn at random.

1. Make a copy of the **2003-2033, historic fire spatial, future fire non-spatial** scenario from the previous task in this exercise, and rename the scenario "2003-2033, historic fire spatial, future fire spatial".

2. Right-click on this new scenario and select *Properties*. Navigate to the **Advanced | Transitions Spatial | Transition Size | Transition Size Distribution** Datafeed. Add a **Year** column to the table. Next, define the size distribution shown below for *Fire* by importing the CSV file called **Historical size distribution of fire.csv**. This size distribution corresponds to the historical area burned data for the landscape. Note below that from 2003 to 2013 the Fire size distribution is set to occur one cell at a time (16 acres) because the historical fire maps are being used to further define the spatial pattern of fires.





3. **Run** the model and display the Maps for **Fire** over time. Scroll across the full range of maps to see how the spatial pattern of fire changes over time.

*Describe differences in the spatial pattern of fire between the current scenario **(2003-2033, historic fire spatial, future fire spatial**) and the non-spatial scenario you ran previously.*

***Bonus Question:** Can you add timber harvest to this model for the prospective period? Assume the same harvest level and pattern as in the Bonus Question at the end of Exercise 3. Include a spatial pattern of clearcuts whereby only 10% of clearcuts can be larger than 500 acres, and the largest allowed clearcut size is 5,000 acres.*

Exercise 6: Adding attributes to states and transitions

Objectives

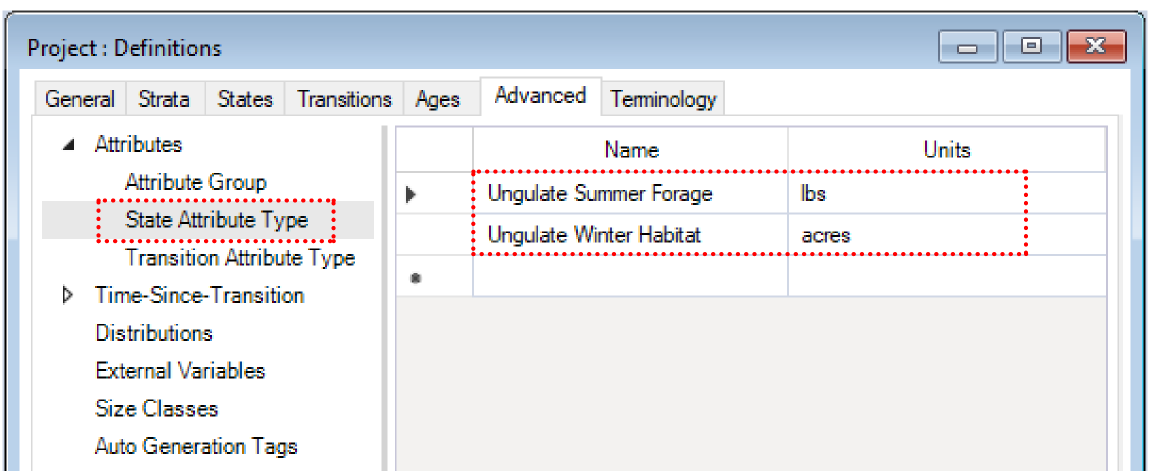
- Understanding how to define and apply different kinds of attributes in ST-Sim
- Using state attributes to generate indicators that are a function of the state class and age
- Using transition attributes to generate indicators that are a function of transitions
- Setting targets on transition attributes

Task 1 – Define attributes

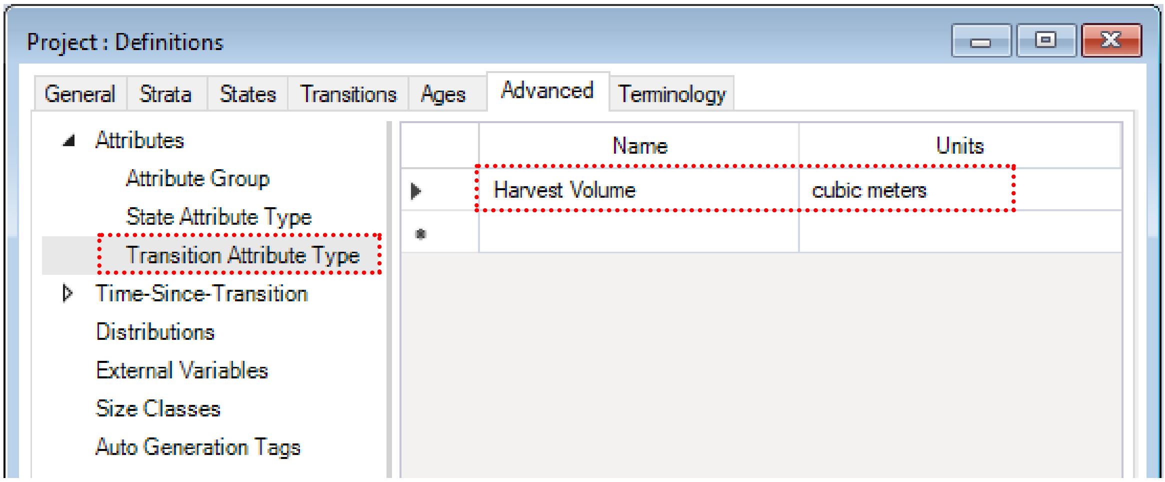
1. Open SyncroSim. Select **File | Open Library** and navigate to the file **Exercise 6.ssim**. If you installed your course materials to the recommended folder location, this file can be found in the folder **Documents\SyncroSim\Course\Exercise 6.** Click **Open**.

2. This library is the same as that used in Exercise 5, with a single scenario corresponding to the last scenario run in that exercise. Recall that this scenario uses historical fire maps to generate fire transitions from 2003 to 2013, and then reproduces the historical pattern of fire for its projections from 2014 onwards. No harvest was included. Select **File | Project Properties** to view the definitions for this library. Note that under the **Advanced** tab there is an **Attributes** node with three sub nodes. For this exercise we will be using two of these Project Datafeeds: **State Attribute Type** and **Transition Attribute Type**.

3. Click on **State Attribute Type**, and add the following: *Ungulate Winter Habitat* (set optional **Units** to *acres*) and *Ungulate Summer Forage* (set **Units** to *lbs*).



4. Similarly, for **Transition Attribute Type,** enter the following: *Harvest Volume* (set **Units** to *cubic metres*).



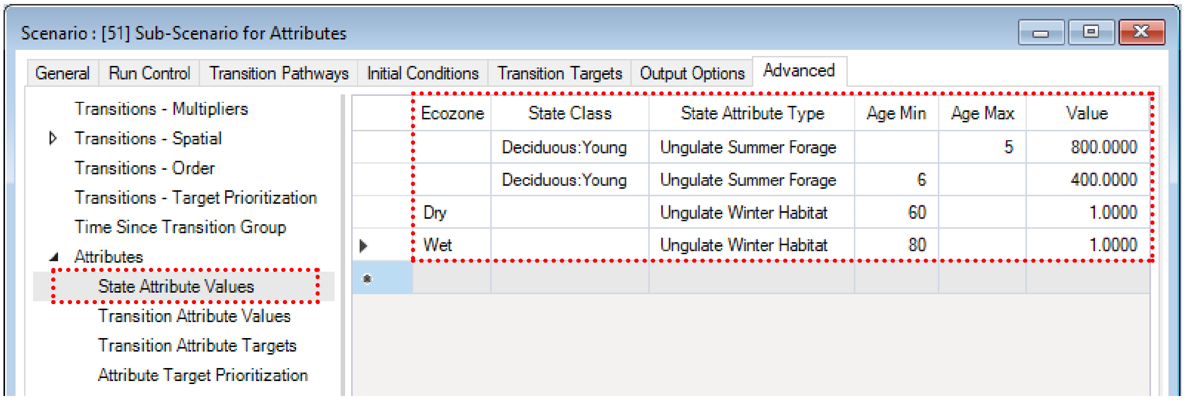
Task 2 – Create an attribute sub-scenario

1. The first step in this task is to create a new sub-scenario to hold the lookup calculations for each of your attributes. In the **Library Explorer** right-click on the **Sub-scenarios** folder, then select **New | Scenario** to create a new empty scenario within this folder. Name the new sub-scenario **Sub-scenario for Attributes**.

2. Open this new sub-scenario. You will now define the attribute values (i.e., lookup calculations) for Ungulate Winter Habitat and Ungulate Summer Forage. Both of these attributes are state attributes, as their calculations rely only on the state of each cell. The ecological rules for each attribute are as follows:

Attribute	**Condition**	**Value / ac**
Ungulate Winter Habitat (acres)	Dry Ecozone: Conifer age ≥ 60 Wet Ecozone: Conifer age ≥ 80 (due to deeper snow)	1 1
Ungulate Summer Forage (lbs)	Deciduous age ≤ 5 Deciduous age ≥ 6	800 400

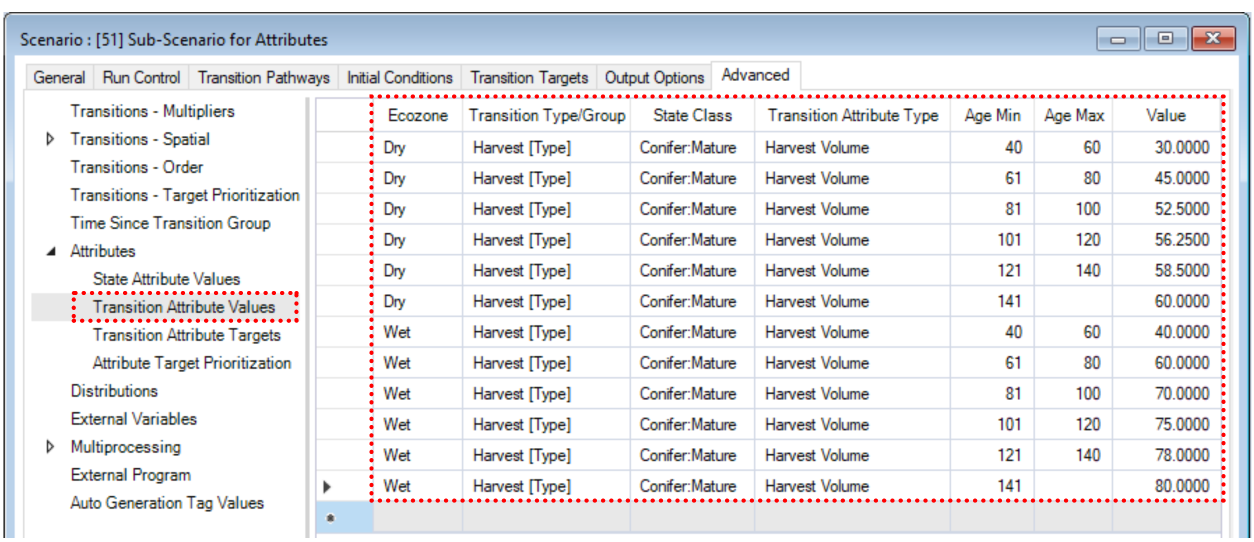
To add these rules to your sub-scenario, navigate to the **State Attribute Values** scenario property (found under **Advanced | Attributes),** right-click on the empty grid and select *Import***.** Make sure the file type in the bottom right of the *Import* screen is set to *CSV*, and then import the necessary attribute values from the file **State Attribute Values.csv** in the folder **Documents\SyncroSim\Course\Exercise 6\Files**.



3. Now use the **Transition Attribute Values** scenario property to define the Harvest Volume of merchantable timber by Ecozone**.** Recall that, according to the transition pathways, Harvest only occurs for Conifer with age ≥ 40. The yield curves for harvest are as follows:

Ecozone	Forest Type	Age	Volume (m³/ac)
Wet	Conifer	40-60	40
		61-80	60
		81-100	70
		101-120	75
		121-140	78
		≥ 141	80
Dry	Conifer	*75% of Wet Ecozone (due to lower productivity)*	

To add these rules to your sub-scenario, import the necessary attribute values from the file **Transition Attribute Values.csv** in the folder **Documents\SyncroSim\Course\Exercise 6\Files.**

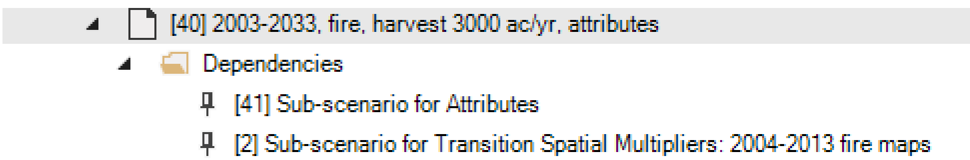


4. **Close** the sub-scenario and **Save** your work.

Task 3 – Create a new harvest scenario

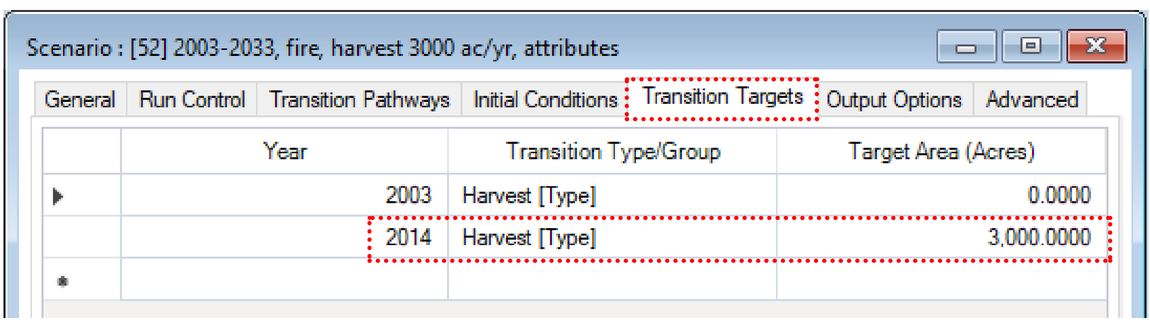
1. You will now add both attributes and harvest to your original full scenario (i.e., from the previous exercise). Make a copy of the existing full scenario (**2003-2033, fire, no harvest**) and name the new scenario"2003-2033, fire, harvest 3000 ac/yr, attributes**".**

2. To add the attribute values (as defined in the sub-scenario) to this new full scenario, use the **Library Explorer** to open the **Sub-scenarios** folder and drag and drop the sub-scenario (called **Sub-scenario for Attributes**) on top of the full scenario (called **2003-2033, harvest 3000 ac/yr, attributes**). This scenario now has two dependencies – the one you just created plus the one from Exercise 5 – which you can see if you expand the full scenario's view in the **Library Explorer**.

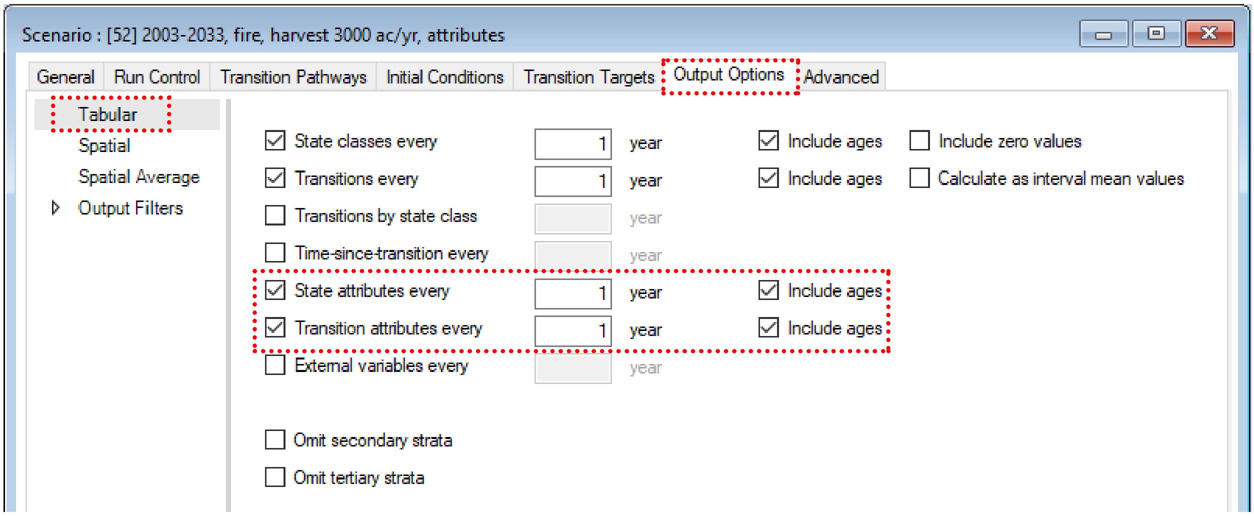


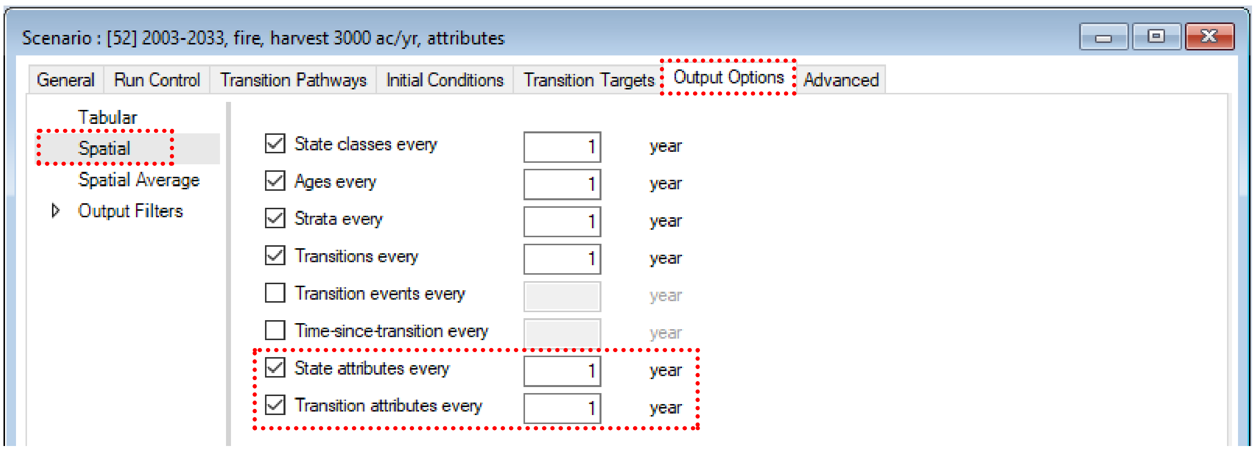
3. To confirm that the attributes are now included in the new full scenario, open the full scenario and navigate first to the **Datafeeds** node under the **General** tab, and then to the Datafeeds for both **State Attribute Values** and **Transition Attribute Values**.

4. Next add a target for harvest to this new scenario. We will assume that harvest only begins after the end of the historical period (i.e., in 2014). Under the **Transition Targets** Datafeed, add a new row to change the *Harvest* from 0 to *3000 ac/yr* starting in *2014* (leaving the existing row to keep the Harvest at 0 from 2003 to 2013).

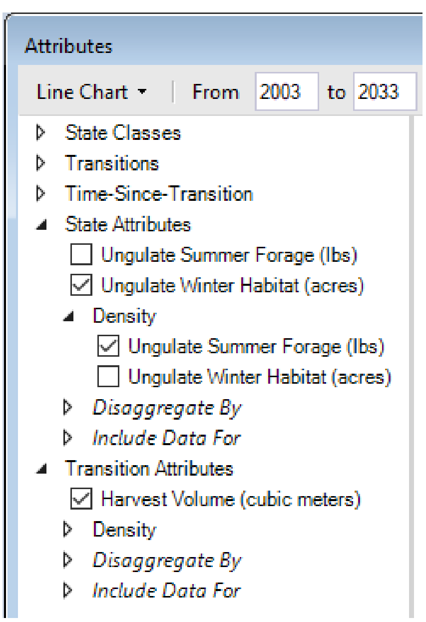


5. Edit the **Output Options** for this scenario to include State Attributes and Transition Attributes. Do this for both **Tabular** and **Spatial** forms of output.





6. **Run** the new full scenario, then add a new Chart showing the three attributes you created. Select the **Density** option to plot the *Ungulate Summer Forage* attribute in units of lb/ac.

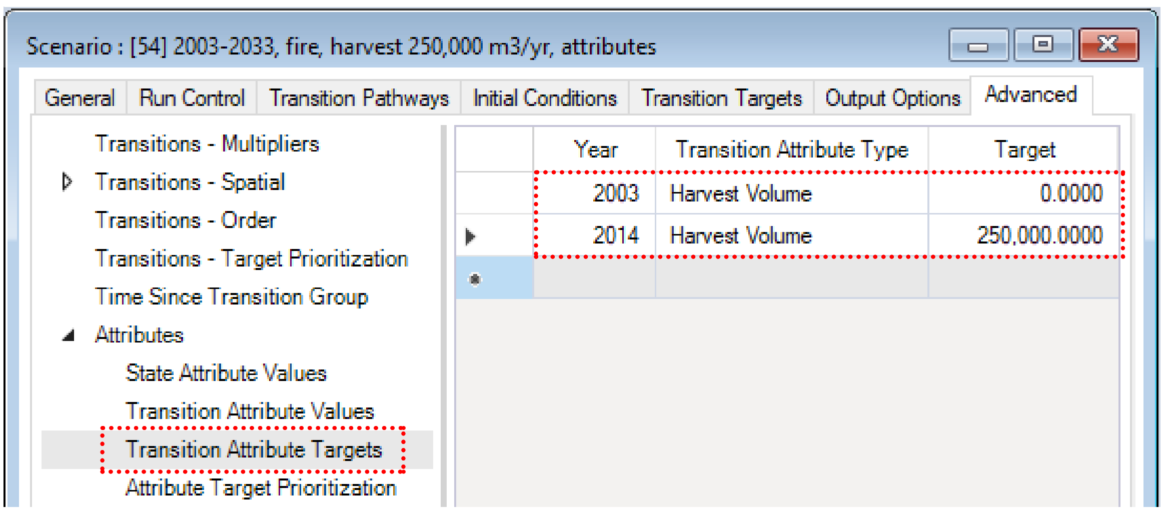


What is the average timber volume harvested each year? Is it relatively constant?

What is the average amount of Ungulate Summer Forage available in lbs/ac each year?

Is there a projected increase or decrease in Ungulate Winter Habitat? What is driving this change?

7. Copy the full scenario you just created (based on harvest area target of 3000 acres/yr) to create a new scenario (that will instead set the target for harvest based on volume). Modify this new scenario so that it has a **Transition Attribute Target** for the *Harvest Volume* of *250,000* cubic meters per year starting in *2014*, with a target of *0* prior to this (use **Advanced | Attributes | Transition Attribute Targets**). *Hint: Be sure to also delete the existing area-based **Transition Targets***. Change the name of the scenario to reflect the difference in harvest.



8. **Run** the scenario and compare the results to the previous scenario (with an area-based harvest target).

How does the area and volume of harvest compare between these two scenarios?

What happens to the ungulate winter habitat and summer forage?

9. Create a new map to compare spatial projections for Winter Ungulate Habitat for the two scenarios you have run.

Bonus Question: *Create and run a new scenario that uses the same harvest volume target of 250,000 m3/yr, but instead moves this harvest every four years from one Harvest Block to the next. Create a new Chart that confirms the harvest is moving correctly from one Block to another. Compare the spatial pattern of harvest for the two scenarios. Is there any difference in the total volume harvested over time?*

Hint: a CSV file containing additional Transition Multipliers for a 4-year Block rotation pattern can be found in the Exercise 6 file folder.

Exercise 7: Adding continuous stocks and flows

Objectives

- Learning how to define and apply different kinds of stock and flow state variables
- Understanding how state attributes are used in conjunction with a stock flow model
- Developing a simple stock-flow model of ecosystem carbon

Task 1 – Create Stock Flow and Attribute Definitions

1. Open SyncroSim. Select **File | Open Library** and navigate to the file **Exercise 7.ssim.** If you installed your course materials to the recommended folder location, this file can be found in the folder **Documents\SyncroSim\Course\Exercise 7.** Click **Open**.

2. Select **File | Library Properties** and click on the **Add-Ons** tab. Note that the *ST-Sim Stocks and Flows* Add-On Package is enabled. ST-Sim is modular and allows different add-ons to be included. When these are added the functionality of ST-Sim is extended beyond what is included in the core. Close the window.

3. To set the Stock Flow model definitions, right-click on **Definitions**, select **Properties**, then click on the **Advanced** tab. Note that there is a new **Stocks and Flows** node (at the bottom) with six sub nodes. These extra Datafeeds were added to ST-Sim by the Stock-Flow Module. For this exercise we will be defining **Stock Type**, **Stock Group**, **Flow Type** and setting the units of stocks under **Terminology**.

4. Create four **Stock Types**: *Atmosphere, Biomass, Soil* and *Wood Products.*

5. Create a **Stock Group**: *Total Ecosystem Carbon*. Stock Groups are used for aggregated reporting of Stock Types.

6. Create four **Flow Types**: *Emissions, Humification, NPP,* and *Timber Harvest.*

7. Under **Terminology** ensure the units are set to *tons C*.

8. You will also need to create three **State Attribute Types:** *Initial Biomass Carbon, Initial Soil Carbon,* and *NPP*. Units for all of these are *tons C*. (*Hint: right-click on the grid to turn on the Units columns)*.

9. Close the window.

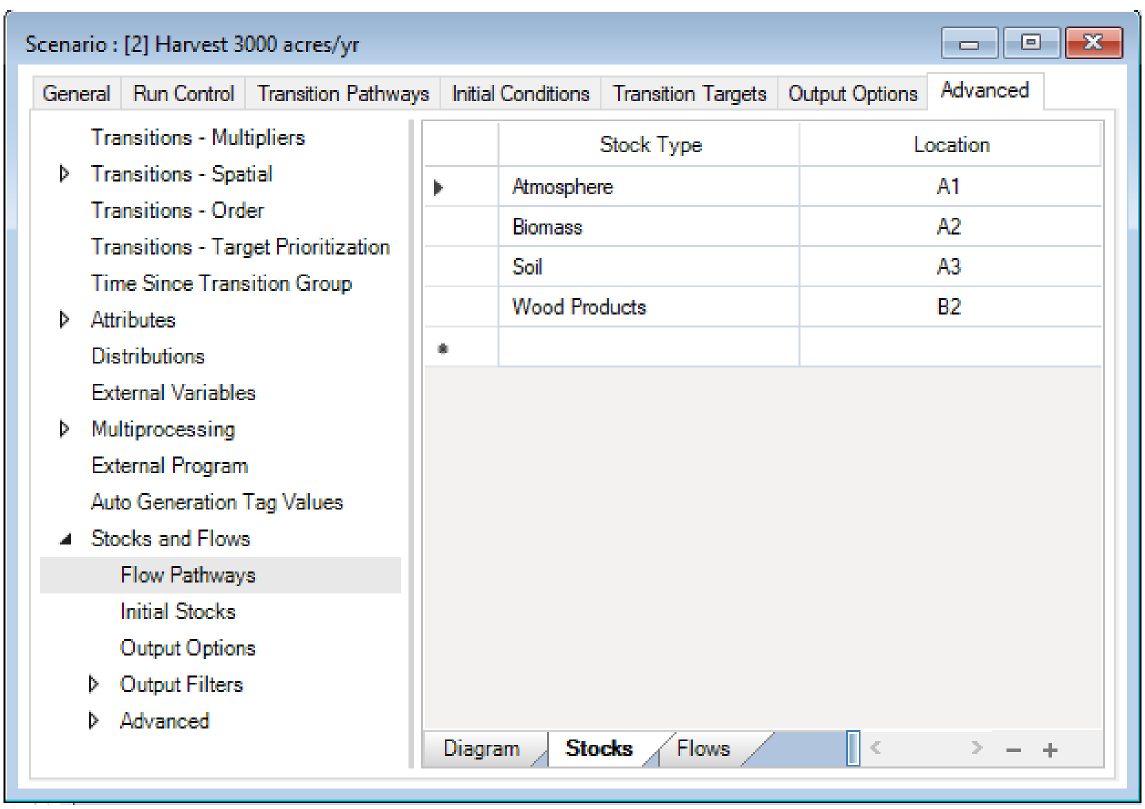
Task 2 – Create Scenario properties for required state attributes

1. Double-click on the scenario called **Harvest 3000 acres/yr** to open the properties window. Navigate to **Advanced | Attributes | State Attribute Values**, right-click anywhere on the grid and select **Import** to import the data provided in the accompanying file called **Exercise 7 State Attribute Values.csv** in the **Exercise 7\Files** course file folder. Note that if you made a spelling mistake in your definitions, this file may not load and you will get an error. The import function for SyncroSim works with both Excel and CSV files (just change the file type to CSV when specifying the file to import).

2. Look over these values (you may want to export them to Excel to sort and filter more easily) and note that we have essentially imported "curves" defining how each of these attributes varies as a function of age and other variables. For example, NPP is defined according to Ecozone and Age, whereas initial carbon is defined as a function *of* Ecozone*,* State Class, and for the Conifer Forest Type, Age. These values represent tons per acre.

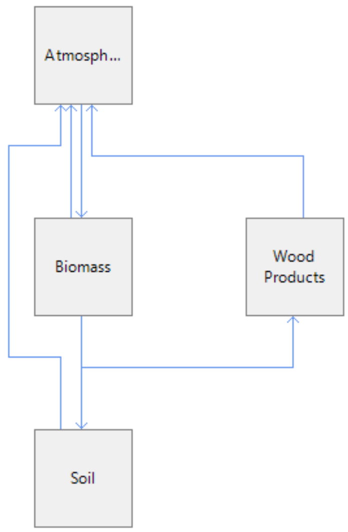
Task 3 – Create Scenario properties for stocks and flows

1. For this same scenario, navigate to **Advanced | Stocks and Flows | Flow Pathways**. The sheet will be blank until you specify the stocks to include and their locations in the diagram. This diagram works in a similar way to the **Transition Pathways** diagram. Click on the **Stocks** worksheet (at the bottom of the screen) and create a table like the one below, then return to the **Diagram** worksheet and look at the position of the boxes. (Alternatively, you can add and position the **Stocks** directly on the **Diagram** worksheet.)



2. Click on the **Flows** worksheet and create a table like the one below (by importing these values from the file **Exercise 7 Flow Pathways.csv** (in the **Exercise 7\Files** course folder), then return to the **Diagram** worksheet and look at the display of arrows.

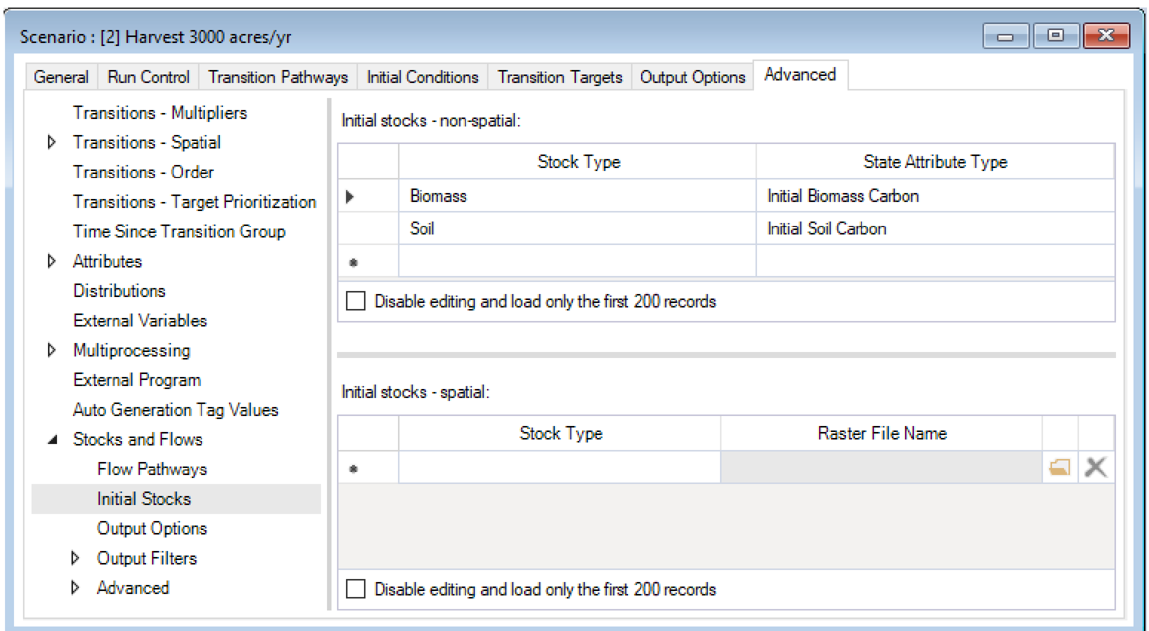
From Stock	To Stock	Transition Group	State Attribute Type	Flow Type	Multiplier
Atmosphere	Biomass		NPP	NPP	1.0000
Biomass	Atmosphere			Emissions	0.0100
Biomass	Atmosphere	Fire [Type]		Emissions	0.8000
Biomass	Atmosphere	Harvest [Type]		Emissions	0.1000
Biomass	Soil			Humification	0.0100
Biomass	Wood Produ...	Harvest [Type]		Timber Harvest	0.6000
Soil	Atmosphere			Emissions	0.0100
Soil	Atmosphere	Fire [Type]		Emissions	0.1000
Soil	Atmosphere	Harvest [Type]		Emissions	0.1000
Wood Produ...	Atmosphere			Emissions	0.0100



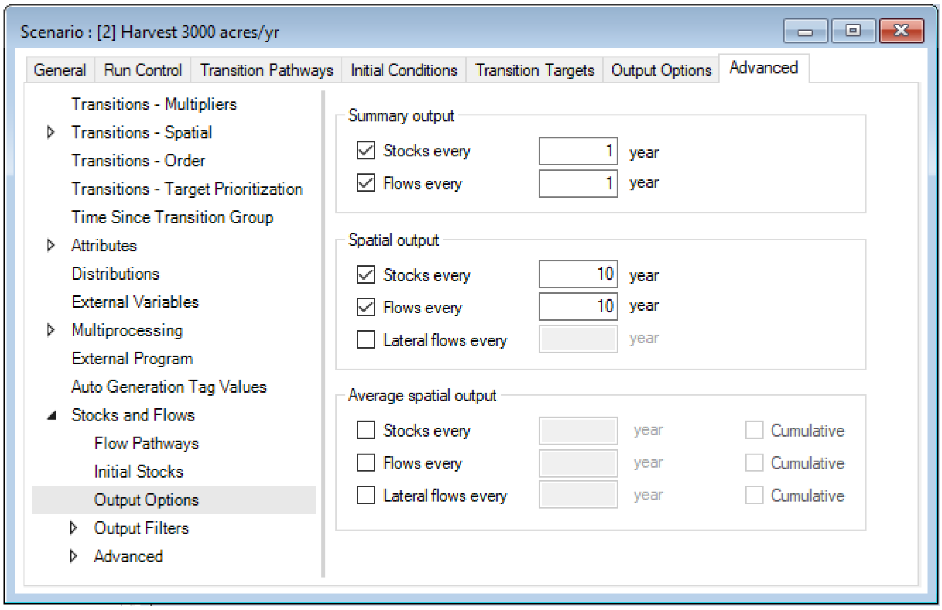
3. The **Flows** and **Diagram** worksheets above describe the movement of carbon from one stock to another. Return to the **Flows** worksheet to review the details of some of these flows:
   a. When a **State Attribute Type** is provided for a flow pathway, then the value of the state attribute for each cell defines the amount of carbon that moves as a result of this flow pathway. For example, for the flow pathway from Atmosphere to Biomass (which is referred to as the Flow Type NPP), NPP is also specified as a **State Attribute** (see the **Flows** worksheet). This means that the size of this flow is defined by the amount of the State Attribute NPP that is predicted to occur for each cell and timestep over in the state-and-transition simulation side of the model (and thus the **Multiplier** is set to 1). The State Attribute NPP, in turn, is defined on the **State Attribute Values** Datafeed to vary according to Ecozone and Age.
   b. When a **State Attribute Type** is not specified, the flow amount is defined simply as a proportion of the **From Stock**. The proportion is provided in the **Multiplier** column. This is the case for all of the flows in our model except the NPP.

c. When a value is provided for the **Transition Group** column, the flow only occurs in response to a particular transition in the model. In other words, these flows are “triggered” by transitions. In contrast, when a **Transition Group** is not defined, the flow occurs automatically each timestep. In this example, the occurrence of Fire on a cell triggers an Emissions flow of 80% of the Biomass stock to the Atmosphere stock, whereas there is an annual Emissions flow rate of 1% of the Soil stock that occurs automatically for every timestep of the simulation.

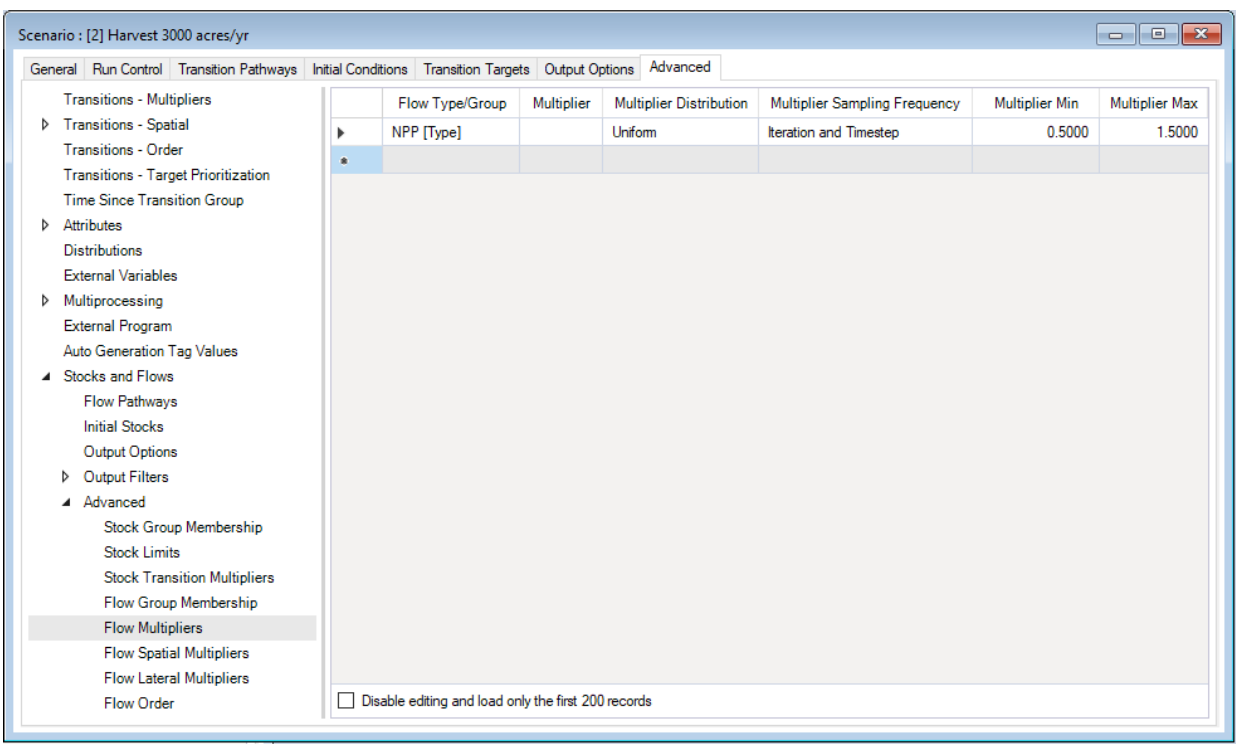
4. Now look at the **Advanced | Stocks and Flows | Initial Stocks** for the same scenario. Set the initial *Biomass* and *Soil* stocks non-spatially. Recall that we previously entered values for *Initial Biomass Carbon* and *Initial Soil Carbon* curves (as additional State Attribute Values – allowing them to be a function of state and age of each cell). Here we specify that these State Attributes should be used to initialize each of these two stocks. Note that on the lower portion of this screen you could optionally load raster files to initialize stock values for each cell. Note also, that we did not initialize the Atmosphere or Wood Products stocks; as a result these will get initialized to zero for each cell (stock values can be negative or positive). A negative Atmosphere value at the end of a simulation would therefore indicate the landscape is a net cumulative carbon sink for that scenario over the duration of the simulation.



5. Switch to the **Advanced | Stocks and Flows | Output Options** property. Set the model to produce summary stocks and flows every timestep and maps every ten timesteps.

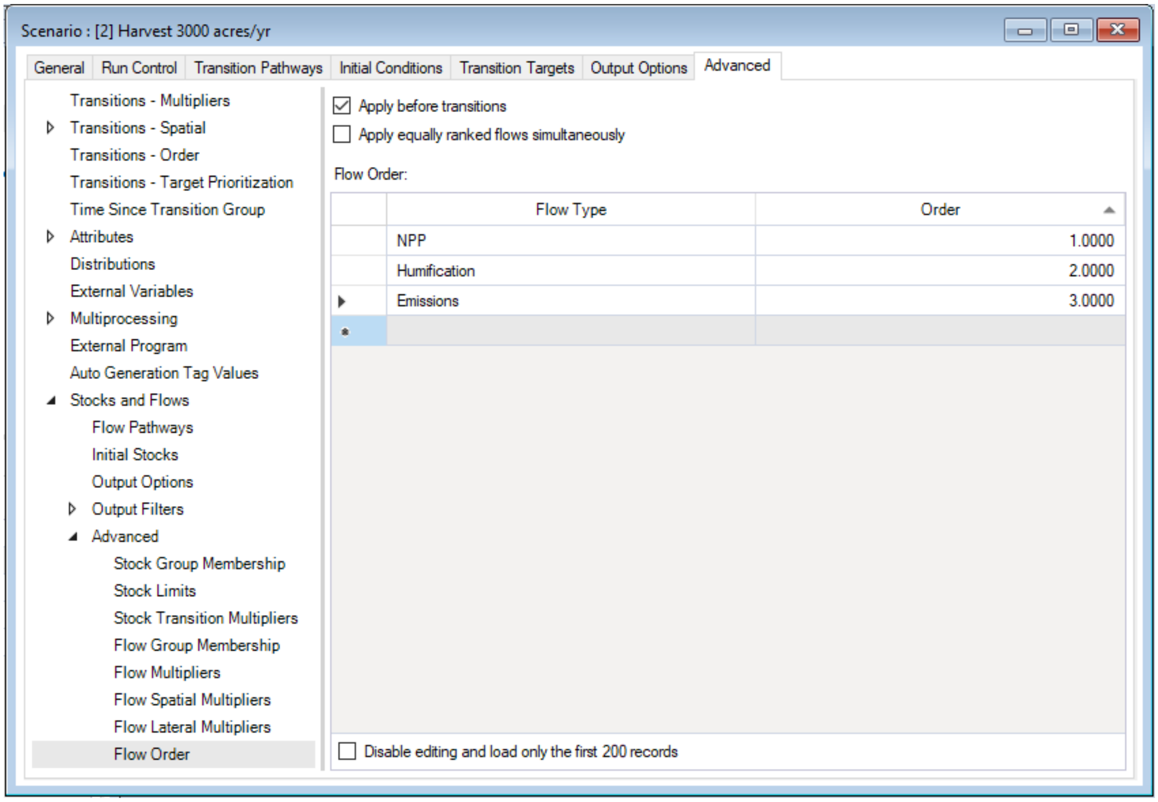


6. Under the **Advanced** tab, navigate to the **Stocks and Flows | Advanced | Flow Multipliers** node, and set the **Flow Multipliers** for the *NPP* **Flow Type/Group** to vary uniformly between *0.5* and *1.5* with a **Multiplier Sampling Frequency** of every iteration and timestep. (*Hint: right-click on the grid to turn on any hidden optional columns).* This tells the model to add some variability to the NPP flows.

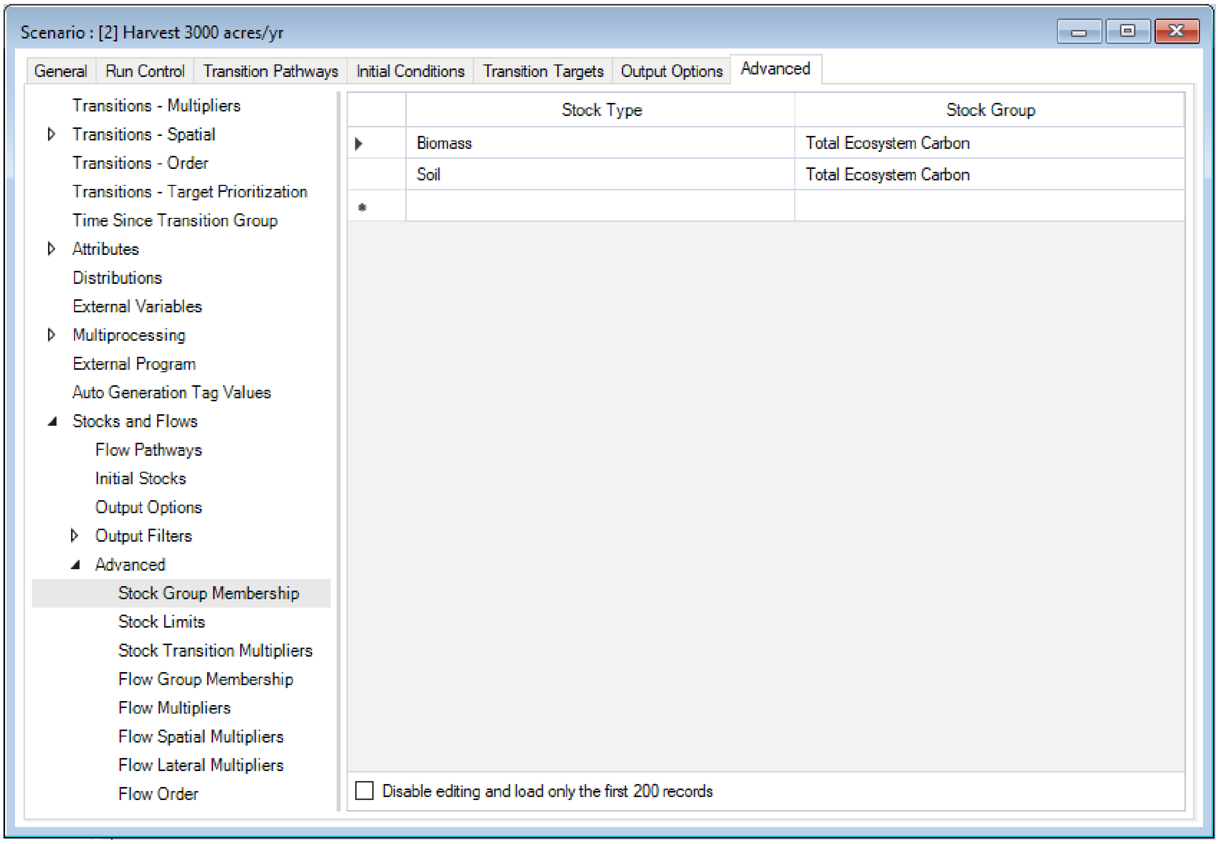


7. Under **Flow Order**, check the **Apply before transitions** box. This means that automatic flows (i.e., those not triggered by transitions) will occur before transitions. Set the flow order for the automatic flows to occur in the following order each timestep: (1) *NPP*, (2) *Humification*, (3)

Emissions (see below). Transition-triggered flows will occur in the order that their corresponding transitions occur in the model.



8. Set the **Stock Group Membership** for *Biomass* and *Soil* to belong to the *Total Ecosystem Carbon* **Stock Group**. This tells the model that Total Ecosystem Carbon will be calculated automatically as the sum of the Biomass and Soil **Stock Types**.



9. Close the properties window and **Save** your work.

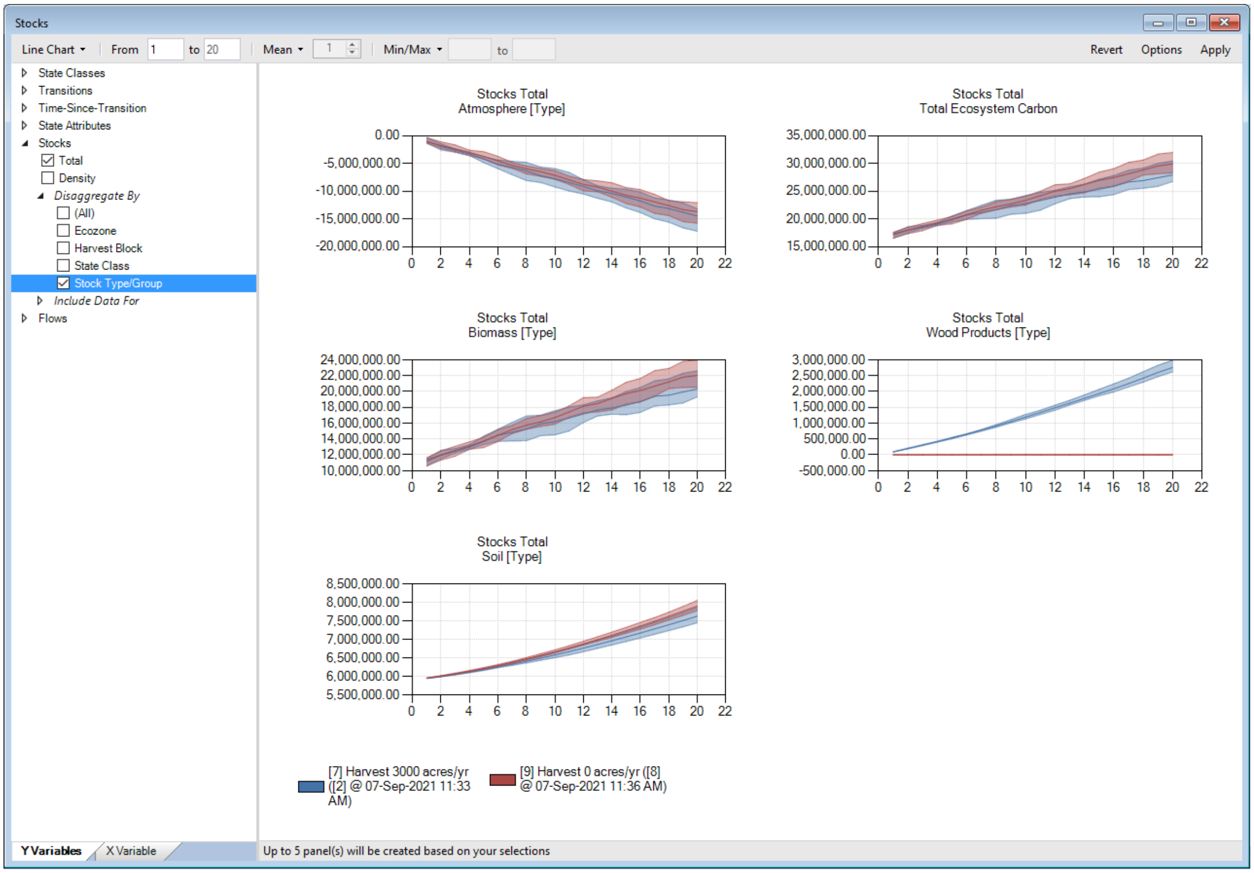
Task 4 – Run the model and view results

1. Run this first scenario (click on **Multiprocessing** to turn it on; set to 6 jobs, as this scenario contains 6 iterations).

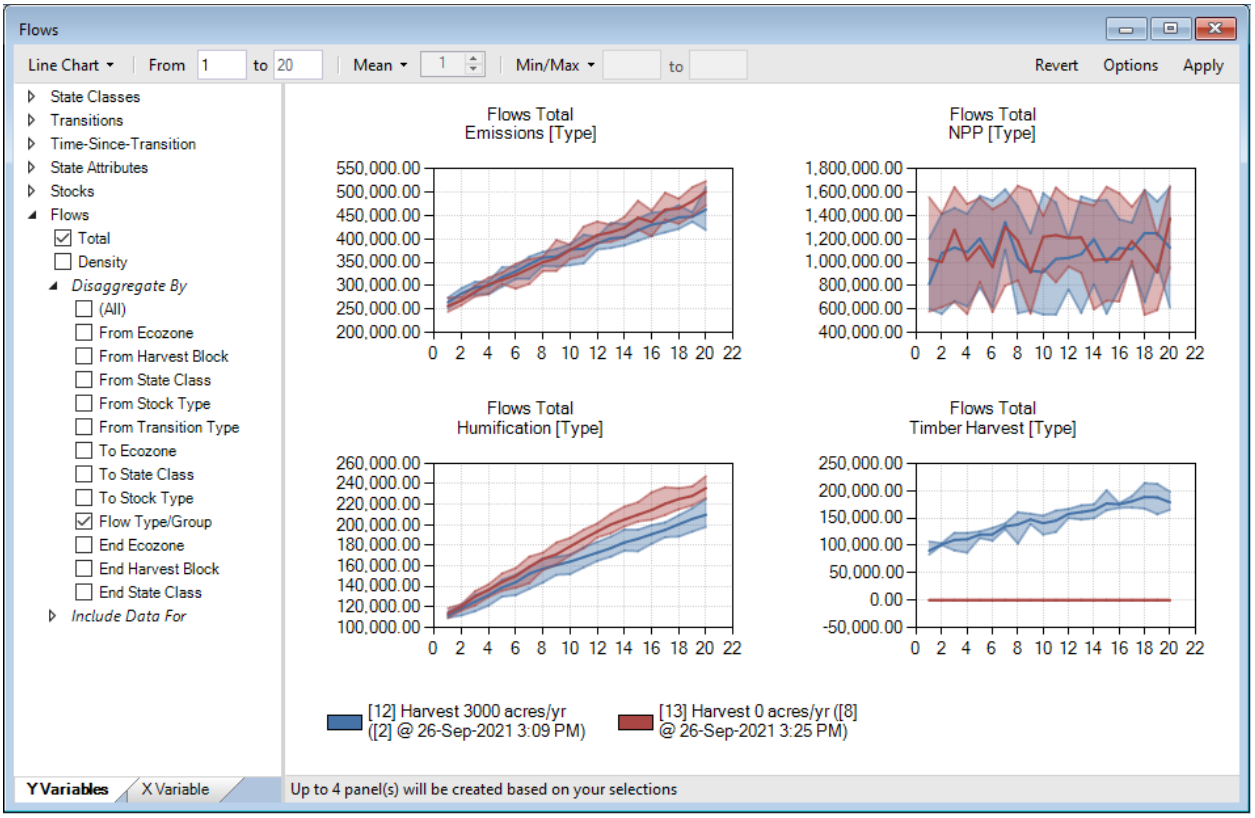
2. Make a copy of the scenario you just ran. In this copy, set the harvest to zero, and name it appropriately. Run this second scenario.

3. Check the pre-configured charts of *States* and *Transitions* to confirm that the non-carbon portion of your two scenarios results make sense. In particular check that the projected *Harvest* transition differs between the two scenarios.

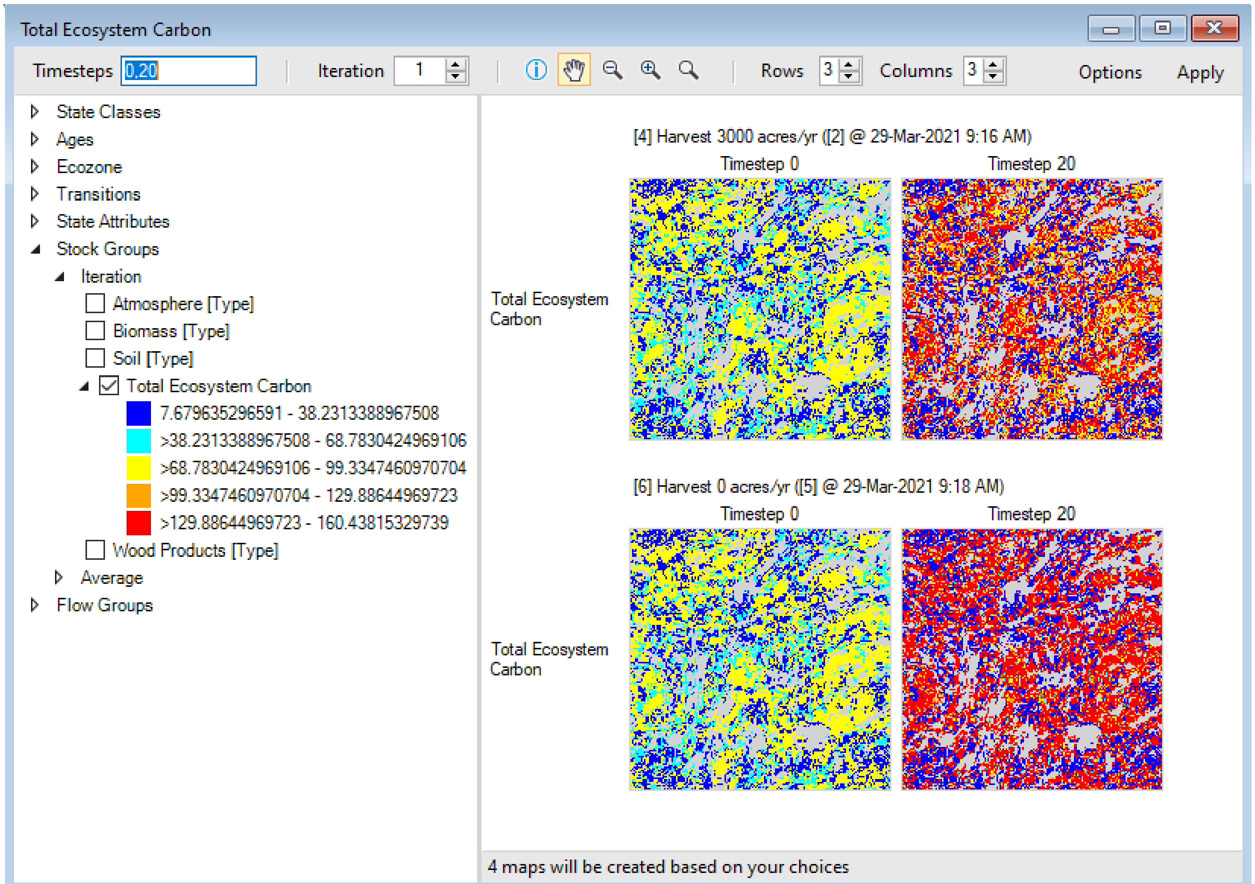
4. Create a new chart to display your Stocks (both Types and Groups), as shown below. These represent your projected carbon stocks (in tons C). You will need to select *Stocks - Total* as your variable and *Disaggregate By Stock Type/Group*. Note how Total Ecosystem Carbon has been calculated automatically as the sum of the Biomass and Soil stocks. Note also that the Atmosphere and Wood Products stocks show cumulative change since the start of the simulation.



5. Create a second chart to display your Flows by selecting *Flows – Total* as your variable and *Disaggregate By Flow Type/Group*. These represent your carbon fluxes (in tons C per year). Set the Range to *Min/Max* to see the variability in fluxes – in particular the variability in NPP that you introduced into your model earlier. Set the timesteps to *1-20* to avoid showing timestep 0 (for which there are no flows).



6. Create a map of the Total Ecosystem Carbon at the start (i.e., timestep 0) and end of the simulation (for the first iteration).



Bonus Question: *Do a simulation in which there is no order set for the automatic flows. How do the results change and why?*

Exercise 8: Running ST-Sim from R

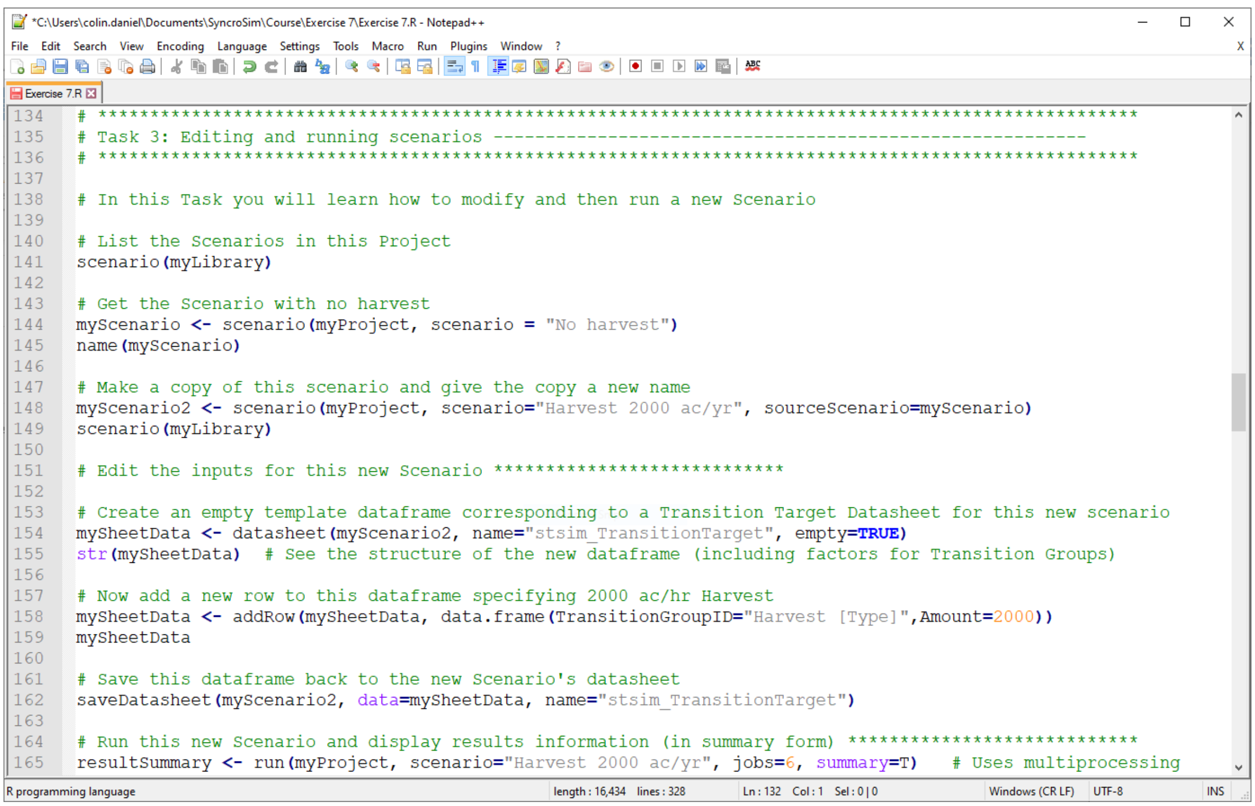
Objectives

- Post-processing model output using R
- Editing and running scenarios from R
- Creating new ST-Sim libraries and models from scratch in R

This exercise assumes you have some knowledge of the R programming language. The exercise will also require that you install the free R software on your computer (along with an R development environment such as the free RStudio). While the exercise will work with both the Windows and Linux versions of R and SyncroSim, the Windows versions are preferred, if possible.

To run this exercise, open the R script called **Exercise 8.R** (which by default can be found in the folder **Documents\SyncroSim\Course\Exercise 8**) using your favorite R development environment (e.g., RStudio).

Note: If you are unfamiliar with R you can still review the content of the exercise by opening the file **Exercise 8.R** in a standard text editor such as Notepad or Notepad++ *(if you use Notepad++, be sure to set the language to "R" using its menu item* ***Language | R****)*.




```
# ******************************************************************************************************
# Task 3: Editing and running scenarios -----------------------------------------------------------
# ******************************************************************************************************

# In this Task you will learn how to modify and then run a new Scenario

# List the Scenarios in this Project
scenario(myLibrary)

# Get the Scenario with no harvest
myScenario <- scenario(myProject, scenario = "No harvest")
name(myScenario)

# Make a copy of this scenario and give the copy a new name
myScenario2 <- scenario(myProject, scenario="Harvest 2000 ac/yr", sourceScenario=myScenario)
scenario(myLibrary)

# Edit the inputs for this new Scenario ***************************

# Create an empty template dataframe corresponding to a Transition Target Datasheet for this new scenario
mySheetData <- datasheet(myScenario2, name="stsim_TransitionTarget", empty=TRUE)
str(mySheetData)   # See the structure of the new dataframe (including factors for Transition Groups)

# Now add a new row to this dataframe specifying 2000 ac/hr Harvest
mySheetData <- addRow(mySheetData, data.frame(TransitionGroupID="Harvest [Type]",Amount=2000))
mySheetData

# Save this dataframe back to the new Scenario's datasheet
saveDatasheet(myScenario2, data=mySheetData, name="stsim_TransitionTarget")

# Run this new Scenario and display results information (in summary form) ****************************
resultSummary <- run(myProject, scenario="Harvest 2000 ac/yr", jobs=6, summary=T)   # Uses multiprocessing
```

Answers to Questions

Exercise 3: Task 6

Do some Harvest Blocks appear to harvest more timber over the 20-year timeframe than other Harvest Blocks? Why might this be? Could this have anything to do with the relative amount of Wet and Dry Ecozones within each Harvest Block?
Yes for example Block A is able to support 600 ha/yr for most of the simulation, while Block B is only able to support 600 ha/yr for about 8 Timesteps. This is because Block B runs out of old conifer area earlier in the simulation than Block B. Furthermore, because area that is harvested in the Dry Ecozone is twice as likely to transition to Grassland as area harvested in the Wet Ecozone. As a result, Blocks that contain more area in Dry will tend to have more area transition to Grassland over time, and areas that become Grassland, in turn, take longer to return back to mature Conifer again (at which point they can be harvested once again).

Bonus Question: Often timber harvest is aggregated in a portion of a landscape for several years before moving on to a new area. Can you create a new scenario that models harvest over time in such a way that the entire 3000-acre harvest target occurs in a single block for four consecutive years before moving on to the next harvest block? Is this pattern of harvest sustainable? Explain why.
This pattern of harvest is not sustainable. With the exception of Block A, none of the Blocks are able to sustain a 3000 ac/yr harvest for 4 successive years. This occurs because all of the harvest becomes aggregated in a very small area for a short period of time, rather than being spread across the entire landscape each year, and the blocks don't have enough old conifer to support this intensity of harvest.

Exercise 4: Task 1

Why is it necessary in this model to explicitly set the Harvest target to zero?
The probability of Harvest was set to 1. As a result if the Harvest target is not explicitly set to 0 then the model will assume that probabilities are to be used for this transition and will transition every eligible cell (i.e. the transition probability is 1!) in the first timestep. This is a common mistake and one to look for whenever you find that your initial results show too large a portion of our landscape transitioning in the first timestep of a simulation.

What do you notice about the variability across iterations for your area burned?
There is no difference in area burned between iterations, as we are using Transition Targets to force the Fire transitions to match the historical record.

What is the effect of the large area burned in 1998 on the composition of the landscape?
There is a marked increase in the Deciduous area as a result of the large Transition Target for Fire that year, as the model transitions cells to Deciduous after a fire.

Exercise 4: Task 3

What is the effect of sampling from this uniform distribution on your projections for fire after 2023?
It increases the within-year variability in projected area burned, as reflected by the widening of the range of projected area burned across iterations

Exercise 4: Task 4

How does the mean annual proportion area burned (over all 20 simulated years) compare between the scenario with only baseline fire and the scenario that adds to this historic variability?
As expected there is much greater variability in the area burned across years.

What is the effect of adding temporal variability in fire to our predictions regarding uncertainty as to the future amount of conifer old growth (i.e., age 80+)?
There is an corresponding increase in the uncertainty associated with old growth.

What do you think of the spatial pattern of projected fire?
The spatial pattern of fire is now speckled (i.e. the cells are all transitioning independently of each other).

Exercise 5: Task 1

How does the variability between years compare for the projected amount of Fire vs Succession? Can you explain why?
There is considerable variability between years in the amount of fire (yet no variability within years). This is because the fire transitions have been modelled to represent the historical pattern exactly, which naturally has considerable between-year variability. Succession, on the other hand, trends downward over the simulation; so there is less between-year stochasticity.

Exercise 5: Task 2

Describe what happens to the variability in results starting in 2014 and explain why this is the case.
Variability in fire increases dramatically in annual area burned as we switch from modeling the certainty of the historical period to the uncertainty of the future. For each future year we are sampling from the past size distribution of fires, so each future realization can have a projected area burned that ranges from 0 to the largest annual area burned on record.

What difference is there in the spatial pattern of fire between the retrospective and future period?
The historical period matches the historical maps of area burned, so the natural pattern of spatial autocorrelation in the historical data is reflected in the projections. However the future projections do not yet have any spatial autocorrelation specified for them, so each cell is burned independently of its neighbours. The result is a speckled pattern of fire for the future period.

What would happen if we didn't include the all-one.tif file (with all 1.0 values) for Year 2014?
Fire would only occur in the cells that burned in 2013 for all years after that: the cells burned in 2013 would all be assigned a transition multiplier value of 1, while all other cells on the landscape would be assigned a transition multiplier value of 0.

Exercise 5: Task 3

Describe differences in the spatial pattern of fire between the current scenario (2003-2033, historic fire spatial, future fire spatial) and the non-spatial scenario you ran previously.
There is now spatial autocorrelation in the pattern of future fires also that matches the historical distribution of fire sizes.

Exercise 6: Task 3

What is the average timber volume harvested each year? Is it relatively constant?
The average is about 160,000 m3/yr. It appears to be relatively constant for the first 8 years or so at about 170,000 m3/yr and then drops to about 150,000 m3/yr after that. As the area harvested is constant at the target of 3000 ha/yr, this suggests that over time the volume available per unit area is decreasing, which in turns suggests that the average age of the conifer forest eligible for harvest (i.e. age 40+) is decreasing over time.

What is the average amount of Ungulate Summer Forage available in lbs/ac each year?
It rises from a low of 12 lbs/ac at the start of the simulation to about 160 lbs/ac by 2033. If you display a chart of the State Class Area (Disaggregated by State Class), you'll see that the landscape starts with very little Deciduous forest, and thus very little Summer Forage; the amount of Deciduous forest increases steadily once harvesting begins, resulting in the corresponding increase in Summer Forage.

Is there a projected increase or decrease in Ungulate Winter Habitat? What is driving this change?
The Ungulate Winter Habitat also increases steadily, rising from about 20,000 ac at the start of the simulation to around 40,000 ac by 2033. If you display a chart of the State Class Area and play with Include Data For settings for Ecozone and Age, you'll see that the area of Dry Conifer Age 80+ and Wet Conifer Age 60+ steadily increases from the start of the simulation due to natural ageing of the forest.

How does the area and volume of harvest compare between these two scenarios?
The new scenario results in an increase in the volume harvested from about 150,000 m3/yr to the new target of 250,000 m3/yr; the new harvest is also steady over all years. As a result, the area harvested changes from a previously steady 3000 ha/yr (i.e. the old target) to slightly more variable amount ranging from about 4000-5000 ha/yr.

What happens to the ungulate winter habitat and summer forage?
The Winter Habitat decreases over time, while the Summer Forage increases due the additional harvest under the new scenario.

Bonus Question: Create and run a new scenario that uses the same harvest volume target of 250,000 m3/yr, but instead moves this harvest every four years from one Harvest Block to the next. Create a new Chart that confirms the harvest is moving correctly from one Block to another. Compare the spatial pattern of harvest for the two scenarios. Is there any difference in the total volume harvested over time? (*Hint:* a CSV file containing additional Transition Multipliers for a 4-year Block rotation pattern can be found in the Exercise 6 file folder.)
Under this new scenario there are years in which the harvest target of 250,000 m3/yr cannot be met in some blocks due to insufficient Older Conifer forest available in these blocks. If you display a chart of the Harvest Volume Disaggregated By Harvest Block you can confirm that the shortfalls occur in Blocks B and E.

Exercise 7: Task 4

Bonus Question: Do a simulation in which there is no order set for the automatic flows. How do the results change and why?
In this particular model the results do not change as a result of the change in flow order because our automatic flows are all very small (i.e. 1% per year). However the higher the flow rates in your model, the greater the effect will be of the flow order, as ST-Sim is essentially discretizing a continuous process when simulating stocks and flows. That is, ST-Sim is approximating the continuous flow of material between stocks using a discrete time step, rather than calculating the flows continuously using ordinary differential equations, which works best if the timestep is short relative to the size of the fluxes between stocks.