ECOSYSTEM MODELS

Jack Pine / White Pine / Spruce Frame Model, Part 1

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Today we're going to build the Jack Pine, White Pine, Spruce frame model on a spreadsheet.

Let's start by entering our key in cell A1. We said that 'J' would represent a Jack Pine frame. That 'W' would represent a White Pine frame. And 'S' would represent Spruce. We're going to set up a model in which we track the state of a particular pixel - one pixel in the ecosystem. And that state can be Jack Pine, White Pine, or Spruce. And we will track these dynamics through time starting with year 0 and running through 120 years, with a 10 year time-step. So we'll start that series and then drag the corner down to 120.

Our state will be recorded down column B just as had done with the Markov model. In addition to the state, we are going to record some other factors. We're going to record the time since the last fire or 'TSF'. We're going to record and track the stand age. We're going to represent fire to indicate whether a fire occurred in that decade. And we're also going to be tracking whether we harvested in that decade.

So, this is the basics of our model. We'll go ahead and center everything. Then make sure that the top row is highlighted by some heading. This is where our outputs are going to be headed in this particular model.

With the frame-based model, we need to specify rules or inputs for every single frame. We'll start off by entering headings; Jack Pine, White Pine, and Spruce in cells I1 through K1. And this general section here is going to be our model inputs. You can shade cells I2 through K4 and give them a big thick border to represent our control panel.

The basic idea behind a frame model is that when you are in the Jack Pine frame you are dealing with inputs specific to Jack Pine. Let's start over in cell L1. And we're going to insert a comment, and that comment is going to contain some notes from our class. And, those notes are as follows. I just entered these into a comments section. And we are going to leave these up so that we can refer to them as we're writing our equations.

If you are in a Jack Pine frame: Jack Pine switches to White Pine if there is a fire and there has been no fire for 40 years, so time since fire is greater than 40. Or Jack Pine can switch to White Pine a second way if there is no fire for 80 years, and the density of deer is low. Jack Pine switches to Spruce if there is no fire for 80 years and the density of deer is high. So we know that for the Jack Pine we need to record the 'probability of fire'. We also need to be concerned about 'deer density'. Enter those as inputs in cells H2 and H3.

To display the comment so that it's always being shown, just right click on the cell. Then drop down and choose Show Comments. That will remain displayed until you choose to hide it again.

For the Jack Pine the input is .15 for a probability of fire. And remember this is a one decade time-step. Deer density has two options: Low and High. We can force the inputs to be either Low or High by choosing the Data tab, and then heading over to the Data Validation button. Then under settings we'll Allow values that come from a list. And our list is simply going to be High, comma Low. We press OK. And what that does is inserts a little dropdown box so the user is forced to choose between one of these two values. These are our inputs for the J or Jack Pine frame. Color those green because those are things that you enter as the modeler.

How about White Pine? Well, let's paste in our notes from class. White Pine switches to Spruce when it's harvested. Harvest occurs when the stand is a certain number of years old. And we'll let that be pasted in cell J4. Let me just fix my typo here. W never switches to J, because we assume that you do not clear cut when you harvest W. The only input we have to deal with when we talk about White Pine is harvest age. We'll enter Harvest Age and we'll harvest that at 120 years of stand age. That's our model input for White Pine.

Notice that in the White Pine, Tony mentioned that we aggressively will put out fires in the White Pine stand. We could in our model enter a zero here indicating the probability of a fire in this stand is zero. Or we could just make that implicit and focus strictly on harvest age. And that's what we'll do in this spreadsheet.

The last frame is Spruce. Spruce is perhaps the easiest transition. Spruce switches to J when there is a fire that is not controlled. And Spruce cannot switch to W. The only input that we need for Spruce is the probability of a fire. Tony indicated that was .5. That's our input for the Spruce frame.

Notice that each of these frames has specific inputs. Not every single input parameter is used in every single frame. That's the essential idea behind a frame-based model is once you are in that frame, you focus only on those parameters that really are important for those frame dynamics.

What we're going to do is build a model and we're going to start it at time-step t. We'll go ahead and enter Time t. At each of these time-steps we are going to be recording this information. So we'll just go over to cell B7 and copy and paste those into cell H7. I must have messed things up when I moved my, so I'm pressing my Ctrl C, and then Ctrl D. If you want to move your notes out of the way you can slide them over a bit. These are going to be our dynamics at time-step t.

What we're going to do is let you, as the modeler, input the starting state, the starting time since the fire, and the starting stand age. Those will all be model inputs. We'll shade those green. For example, if you wanted to start in J and you started it off as a stand that was 10 years old, and it was 10 years since the last fire then those would be your inputs.

At time-step t we also need to track whether there was a fire or whether there was a harvest. These are not inputs because we're going to be using equations that reference these parameters up here. These will be outputs and we'll shade those blue. This section here is going to represent our dynamics at time-step t. I'm going to give that a big thick border so that we know that this portion is about time-step t.

The first thing we need to do is to determine whether or not there was a fire in that particular time-step. The first thing that you have to notice is that the Spruce probability of a fire is .5 every ten years, whereas the Jack Pine probability of a fire is .15 every ten years. You can't just simply reference one of these values. You need to pay attention to what state you're in.

In order for us to enter an equation here we're going to use what is called an HLOOKUP function. And let me just tell you what the HLOOKUP function does before we move and actually start to use it. The HLOOKUP function has four arguments in it. The first argument tells you what do you want to look up. We're going to look up what our current state is, that's argument one. Argument two is to specify a table of data. The data that is being looked up must be in the top row of the table. That is our table here. The third argument is which row do you want to return. Once you find that J, you want to return the value in the first and second

row. So we're looking for this number here. We need it to be an exact match. And that's the fourth argument.

As Tony said, look up a random number. We're going to find a random number and we're going to determine if that random number is less than the fire probability, given a particular state that we are in. If that random number is less than that fire probability, we'll say there was a fire. If it's greater than that fire probability, we'll say that there was no fire.

So it's an IF function with a nested HLOOKUP function inside of it. Let's see how that would work. Go over to the Insert Function and find the IF. Our first test is we're going to determine if a random number is less than - and at this point we're going to use our HLOOKUP function to figure out which of these values we need to find. To do that within the Function dialog box we can head over to the left side of our spreadsheet, click the dropdown arrow, and search for the HLOOKUP function. If it doesn't appear on the short list you can choose 'more functions' and find it that way.

We're in the HLOOKUP function. We're going to look up our current state in a table that is provided in cells I1 through K1. It's going to find that J in this table. The J must be in the top row. And we're going to return the value in the second row. So the second index number, the Row Index number is 2. The Range lookup must be the exact correct answer and so we'll type the word FALSE in there. You can see that the spreadsheet is correctly finding the probability of fire for Jack Pine as .15. I press OK.

Now the spreadsheet provides an error and that's okay. It's complaining because we haven't finished our IF function. So press OK. We'll come back up and we'll click on the word IF itself. That puts us into the IF function. Now let's open up that dialog box again. And what you can see is that you've embedded the HLOOKUP function into the first Logical test - the first argument of the IF function. If our random number is less than the fire probability associated with whichever state we are in, we're going to say that there was a fire and give it a number 1. And if it is not less than that number, then we're going to say that there was no fire, and we'll enter a 0. Then we'll press OK.

In this particular spreadsheet we're going to be nesting quite a few functions together. One thing to keep in mind is that you can always split these formulas out into different pieces just to make sure that you're clear on how things are working. Just for the sake of space we're going to be nesting them in one long formula in this exercise.

Let's move on to harvest. The only state we're concerned about harvest is the White Pine. We need to know that we will be harvesting only if the state is W. And only if the harvest age, the stand age itself, is at least 120 years. Our equation there is going to be another IF function. This time we'll say IF, and two things have to be true; the state has to be W and the stand age must be greater than or equal to 120. If both of those are true we are going to have the spreadsheet return the number 1, otherwise it will return a 0.

Let's go ahead and do that. Start off with an IF function. Our Logical test includes two things that have to be true. So we're going to need to embed an AND function right here. Let's head up over to the left portion of our spreadsheet. Find AND. The AND contains a bunch of logical arguments. The first one is that the state must equal W. The second logical argument is that the stand age must be greater than or equal to the value in cell J4. Both of those tests must be true in order for the spreadsheet to return a TRUE, otherwise it returns FALSE. In this particular case it's returning FALSE because our state is J, not W, and because our stand age is 10, not 120. We're going to press OK.

Here's that error formula again which pertains to the IF function. So let's head back up to the IF. Click on the IF. Open up that dialog box. You'll see that the AND function has been embedded in the first argument of the IF function. Both of these are true then we're going to harvest, and if not, we're not going to harvest. Then we press OK. That's our basic model.

The next step is for us to understand what's going to happen in the next time-step. We're going to build a little rule-based model in this portion of the spreadsheet. So let's go ahead and type in Rule Based Model. What we're going to be tracking is our state at time t. And, that could be either Jack Pine, White Pine, or Spruce.

Given any of these we're going to then enter equations that would tell us what state we were at, at Time t+1. So these are going to be our headings. This is the state at Time t. This is our state at Time t+1. Here's our input. You don't have to input a value there. These are just what the current state is at. Then the spreadsheet will calculate whether or not you advance or change states in the next time-step. This whole thing is our rule-based model. Once again, I'm going to go ahead and put a thick red box around there. Once you know your dynamics at time-step t, the next step then is to run it through the rule-based model, and predict what the next time-step will be.

Let's start with S first, only because it's the simplest frame. S switches to J when there's a fire. If we are in S, we know that S will switch to J if fire is equal to 1. S cannot switch to W. This should be a simple IF function. Go ahead and try to enter that in and then come on back and we'll go through it together.

PAUSE the video: Enter an IF function into your spreadsheet.

This equation is an IF function. In this particular case S switches if there is a fire. If K1 is equal to 1, then Spruce will switch to Jack Pine, otherwise it stays Spruce. There is no option for it to change to W. That basically is all we need for the Spruce model. We press OK. Let's go ahead and center these values while we're thinking about it.

How about W? W switches to S when it's harvested. W never switches to J because we assume that you do not clear cut when you harvest W. So for the W model it's another IF function. It's simply going to be if the harvest is equal to 1 then we switch to J, otherwise we stay in W. Let's enter that one. The Logical test is if the harvest is equal to 1, we're going to change from W to S. Value is false if the White Pine is not harvested. We just stay in White Pine. And that is our White Pine model.

How about J? Jack Pine is the most complicated frame. And we have to go through several different scenarios here. Jack Pine can stay Jack Pine. It can switch to White Pine. And it can switch to Spruce. Let's go through these one at a time.

Jack Pine can switch to White Pine under two scenarios. Scenario number one is there is a fire and there has been no fire for 40 years. Scenario number two is Jack Pine switches to White Pine if there is no fire for eighty years and the density of deer is low. That's one case. The second case is Jack Pine can switch to Spruce if there is no fire for eighty years and the deer density is high.

You can see we're going to be building an equation that has AND equations, AND functions, as well as OR functions. And it's going to be a nested IF function. Here's where you can split this equation out. We're going to go ahead and nest them just to give you some more practice in doing that. But make sure you understand and can follow along.

Let's start with the Jack Pine case. We're in the Jack Pine case and we want to switch to W. So we'll start with an IF function. And our Logical test is going to be this or this. If either of

those are true, then we're going to return and switch from a Jack Pine to a White Pine. Now if those are not true then we have to be concerned about the switch to Spruce. That's going to come into play down here.

Now, let's go through this logical test. First we're going to have a case where this can happen or this can happen. So let's start off by entering an OR function. We'll head over to the left side and find OR. Let's just find it under all and then type in an 'O'.

Our first logical test is this one right here. This is Jack Pine switches to W if there is a fire and there has been no fire for 40 years. So our first logical test needs an AND function in it. So hopefully AND is in this little list here. Let's go ahead and say that the first logical test is; there is a fire so cell K8 must be equal to 1, and the time since fire must be greater than or equal to 40. That's our first OR function, is this AND statement.

Let's click up here on the OR function and we'll open up the dialog box. Our first logical test is it can switch under these conditions. It can also switch under these conditions here. J switches to W if there is no fire for eighty years and the deer density is high.

So for logical test two, we're going to insert another AND function. Time since fire needs to be greater than eighty. And the second thing that has to happen is the deer density must be low. And I'm going to put those in quotes.

Note: Add a third AND logical test that indicates there is no fire in this time-step, K8=0, before you press OK.

Now we press OK. That handles our OR function.

So let's click on the OR, the word OR, and then open up the dialog box. So now we have a case where, here's the condition it can change to White Pine. Here's the second case in which it can change to White Pine.

Now let's go back to the IF function. If either of those conditions are true we're going to let it be a White Pine. Now, what happens if it is not true? Well, we can have J switch to Spruce if the time since fire is greater than 80 and the density of deer is high. Here we're going to enter another IF function. And this one is going to say, if both of these conditions are true then we're going to let it switch to S otherwise we'll let it revert back to J. So it's another IF function.

Head over to the left side. Find an IF. Our first Logical test involves an AND function because two conditions must be true. The first one is that the time since the last fire is greater than 80. And the second condition is that the deer density must be high. And I'll go ahead and capitalize that just to be consistent with what we have entered in cell I3.

Note: Add a third AND logical test that indicates there is no fire in this time-step, K8=0, before you press OK

We click OK.

This error is about the IF function so let's head back up to this IF function. We'll click on the word IF. Open up the dialog box again. If both of those conditions are true, then J will switch to S. And if they are not true, then we are going to remain in J, and so we enter a J with quotation marks around it. Press OK.

Here's our formula. This is quite a doozie of a formula - lots of nesting. Again, if it helps you to split these things out and look at them piece by piece and then pull the pieces back together again, go ahead and do that. We've chosen to do this as a nesting just to show you how to nest the functions, but also to save some space for the spreadsheet demonstration.

The idea here is any state that you are in, in time-step t, you're going to look up. And you're going to find what state you're in, and then the spreadsheet will tell you what the next time-step would be. So if I change this to W, now I'm going to find the W here, and I'm going to apply the rule model in cell J14. If we're in state S, then we're going to look for S here, and we're going to apply the rule state model and return time-step t+1 as J.

At this point it's really useful for you to fiddle with some numbers here, and make sure that your rules are behaving exactly as you like to. And to really test your spreadsheet out, feel free to go ahead and change these values to whatever you want, and force your spreadsheet to go through these different scenarios. Once you're convinced that your equations are correct then we'll go ahead and move on.

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