Calculating Forest Values

Evaluating maple sap production potential

—by Glen Jordan

Introduction

Problem

How might a forest's value for maple syrup production be evaluated, aside from identifying sugar maple stands? Can a geographic information system (GIS) help?

Forest value is found not only in primary timber products, such as pulpwood and sawlogs, but in an array of nontimber forest products (NTFP) that also add value to forests in many locales. NTFP includes medicinal and herbal products, edible products, decorative products, and specialty wood products.

Maple sap, used for making maple syrup and other products, is one example in the edible forest products category. In central and northeastern North America, where sugar maple (*Acer saccharum*) trees are common on better sites, maple syrup production is a common and profitable enterprise. You can find much more information about maple syrup and its production on `Wikipedia`.

Location

A small, 1,400-hectare (ha) Woodlot in the Acadian-New England forest region of North America

Time to complete the lab

Three hours

Keywords: nontimber forest products; maple syrup; characterizing by numerical distribution; selecting features by attribute; buffering features; overlaying features; using VB code in Field Calculator; summarizing an attribute

Prerequisites

A basic working knowledge of GIS data, including use of a geodatabase, and ArcGIS® software in particular (Some knowledge of computer programming, Visual Basic [VB] in particular, would be helpful. A basic working knowledge of Excel, including pivot table calculation, is required. Familiarity with forest inventory data and terminology is also helpful but not essential.)

Data used in this lab

- Feature classes and rasters for a forest Woodlot (personal geodatabase)
- Geographic coordinate system: NAD 1983 CSRS New Brunswick Stereographic
- Datum: NAD83
- Projection: New Brunswick Double Stereographic Grid (unless otherwise stated)

Student activity

Is there a site or sites in the Woodlot where a viable maple syrup making operation, now or in the future, might be established? Where?

What would determine viability? Certainly, the presence of mature sugar maple in significant amounts would be critical. Equally important, however, from a sap-gathering point of view, would be distance to an existing trail or road.

As is often the case, an analysis does not have to seek a yes-or-no, black-and-white answer. In this case, you could produce a good analysis by compiling data for various classes of sugar maple amount and haul distances.

With these things in mind, your analysis will involve a two-way classification of Woodlot stands. Tolerant hardwood stands will be partitioned into three haul zones—25, 50, and 75 meters (m) from a road—and they in turn into three sugar maple content classes: sufficient presently, future potential, and limited potential. By combining the two pieces of information, a sap production potential by haul zone summary can be compiled.

Results expected

An Excel summary table of area totals (m^2) by 25 m haul zones and sap production potential—future potential (FP) and present potential (PP)

Sum of Shape_Area	Sap Potential		
Distance (m)	FP	PP	Grand Total
25	4713.37	9.97	4723.33
50	4173.07	3010.99	7184.06
75	2512.22	5404.46	7916.68
Grand Total	**11398.66**	**8425.42**	**19824.07**

Data available

- Cover types feature class: *cover*
- Stand volumes table: *volumes*
- Main road centerlines: *clines*
- Secondary roads feature class: *roads*

Solution steps

1. Create haul zones around roads and trails.
2. Associate haul zones with tolerant hardwood stands.
3. Classify stands by sap production potential.
4. Summarize sap production potential.

CREATE HAUL ZONES AROUND ROADS AND TRAILS

GIS is ideally suited for creating zones—that is, buffers—around linear features such as roads. In this case, you'll buffer main road centerlines and secondary road features as a run-up to partitioning Woodlot stands into three haul zones—25, 50, and 75 m. The road features can be found in the *cline* and *roads* feature classes.

RELATED CONCEPT: RECLASSIFY SPATIALLY—BUFFERING FEATURES

1 Start ArcMap™ and, if you haven't already done so, use *Environment Settings* to establish your *Woodlot* geodatabase as both your *Current Workspace and Scratch Workspace*.

2 Add the *roads* and *clines* feature classes as layers.

The map display should now show the network of main road centerlines, easements, and secondary roads.

You don't need the easement features in *Centre Lines,* so get rid of those.

3 Use *Definition Query* (right-click *clines » Layer Properties » Definition Query*) to exclude easement features from *Centre Lines* with the query expression:

```
[CLASS] <> 'PE' AND [CLASS] <> 'SE'.
```

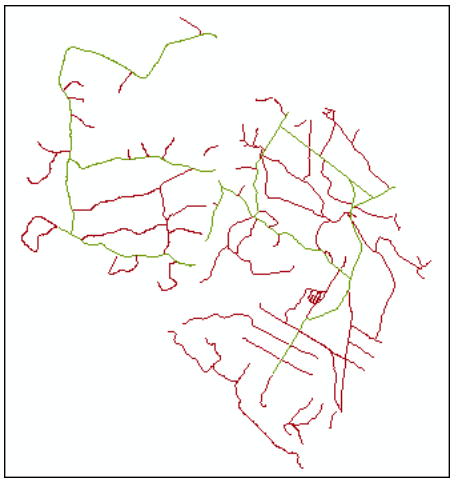

Figure 1. Main road centerline (green) and secondary road (red) networks.

If you open the attribute table, you should see records for 22 features.

To avoid confusion later, it's always good practice to change a layer name where features have been excluded.

4 Change the *Centre Lines* layer name to *Main Roads CL*.

Now you can start your analysis of sugar maple sap production potential in the Woodlot by creating haul zones around its main and secondary road networks.

ArcGIS makes it simple to create zones around features, like roads, with its buffer tools. In this case, you'd like three concentric buffer zones, each 25 m wide, around the networks of roads in the Woodlot.

Before you can buffer the road networks, however, it's probably easiest to collect all road features into a common feature class.

5 Use the *Merge* tool (*Data Management Tools » General*) *to* combine *Main Roads CL* and *Secondary Roads* into a feature class named *allroads*.

Now you can get on with the task of creating 25 m haul zones around roads.

Sap-producing trees that are 25 m from a road or trail could be easily accessed on foot and sap carried by bucket to the roadside for transport to a nearby processing facility. On the other hand, trees between 25 and 50 m from a road could be accessed on foot or on snowshoes and sap hauled to the roadside using a sled. Last, accessing trees beyond 50 m would be feasible only by using a snowmobile or a four-wheeler hauling a sled. This, however, would not be practicable beyond 75 m.

6 Use the *Multiple Ring Buffer* script in ArcToolbox™ (*Analysis Tools » Proximity*) to buffer road features in *allroads* to 25, 50, and 75 m. Name the new feature class *zones_allroads*.

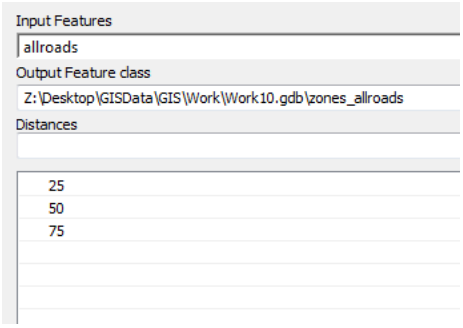

Figure 2. Buffering roads in three 25 m concentric rings.

This task may take a minute or so, depending, of course, on the processing speed of your computer.

If you zoom in on the result, you'll see that ArcMap has conveniently symbolized each zone with a unique color.

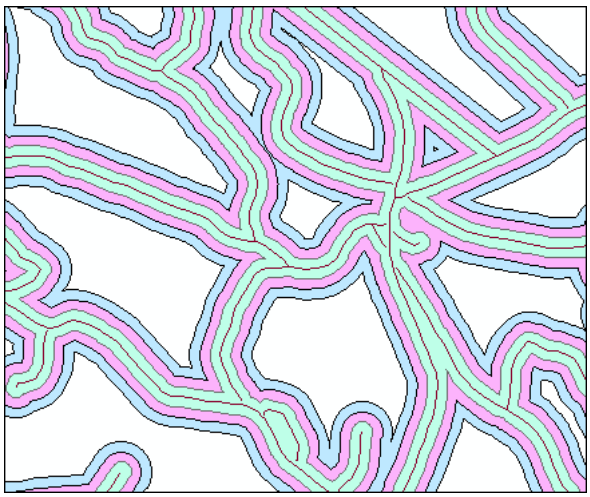

Figure 3. Zoomed in on 25 m (green), 50 m (pink), and 75 m (blue) haul zones around roads.

7 Open the *zones_allroads* attribute table for additional insight.

	Shape *	distance	OBJECTID *	Shape_Length	Shape_Area
▶	Polygon	25	1	109195.282247	2838661.925293
	Polygon	50	2	209975.610609	2631843.822798
	Polygon	75	3	191144.108246	2393817.021706

Figure 4. Haul zones attribute table.

The table has the usual pair of fields found for polygon features, *Shape_Length* and *Shape_Area*, plus a *distance* field. The latter records the distances of the outer boundaries of your three haul zones: 25, 50, and 75 m.

Watch out. In case you have forgotten, if you saved the buffer result as a shapefile external to a geodatabase, feature areas and lengths would not be calculated.

Surprisingly, the table contains only three records. There would certainly seem to be more features than that in *zones_allroads*.

Question 1: *Why are there just three features (records) in the* Multiple Ring Buffer *result?*

With haul zones created, it's now a matter of associating them with tolerant hardwood stands that contain sugar maple trees.

ASSOCIATE HAUL ZONES WITH TOLERANT HARDWOOD STANDS

Sugar maple, being a shade-tolerant tree species, is often found growing with other tolerant species, especially American beech and yellow birch. For that reason, tolerant hardwood stands have the greatest management potential for sap production. For one thing, these stands often contain significant quantities of sugar maple, and second, sap production potential can be increased over time through selective removal of nonsap species.

In this step, you'll first locate tolerant hardwood stands in the cover types feature class. These are easily identified; they'll be the ones composed of 50 percent or more tolerant hardwood species. Then you'll overlay the tolerant hardwood stands with your recently created haul zones in *zones_allroads*. This will partition the stands into three haul zones: 0–25 m, 25–50 m, and 50–75 m.

RELATED CONCEPT: RECLASSIFY SPATIALLY—OVERLAY

1 Add the *cover* feature class as a layer.

Now, you should also join the *volumes* table to the *Cover Types* attribute table.

The *volumes* table contains, among other things, volume percentages for various species groups, including tolerant hardwoods (*TH_*), for each of the Woodlot's 533 stands.

2 Join the *volumes* table to the *Cover Types* attribute table via the *STAND_ID* and *Stand#* fields, respectively.

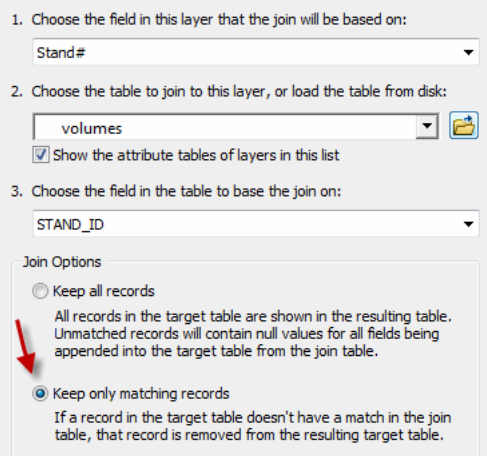

Figure 5. Joining the *volumes* table to the *Cover Types* attribute table.

Question 2: *What does the* Keep only matching records *option accomplish?*

3 Select tolerant hardwood stands in *Cover Types*—that is, `TH_ >= 50` using *Select By Attributes.*

This, of course, locates all tolerant hardwood stands in the Woodlot. If you open the attribute table, you'll see there are 54.

If you symbolize *Cover Types* polygons with a hollow fill, you'll see how the haul zone buffers in *zones_allroads* cut through Woodlot features, including the 54 tolerant hardwood stands.

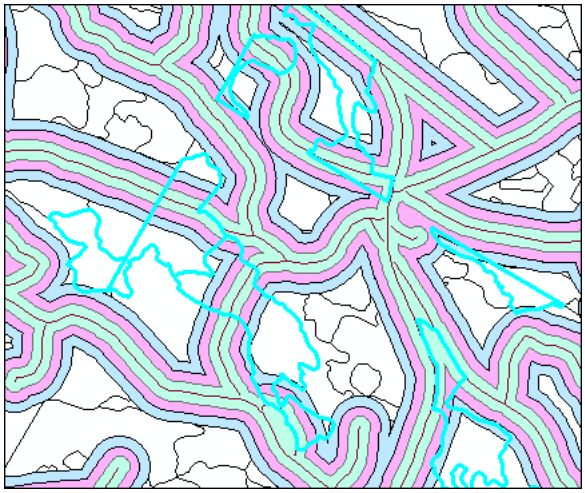

Figure 6. The 25 m haul zones superimposed on *Cover Types* features.

This is fine, but what you really need is a new feature class, derived by partitioning the 54 tolerant hardwood stands into different haul zones.

Either an *intersect* or *union* overlay would accomplish this. However, since you're only interested in the 54 tolerant stands, an intersect makes the most sense.

Question 3: *What's the difference between* intersect *and* union *overlays?*

4 Use the *Intersect* tool (*Analysis Tools » Overlay*) in ArcToolbox to intersect the 54 tolerant hardwood stands in *Cover Types* with *zones_allroads* and produce a new feature class named *sap_zones*.

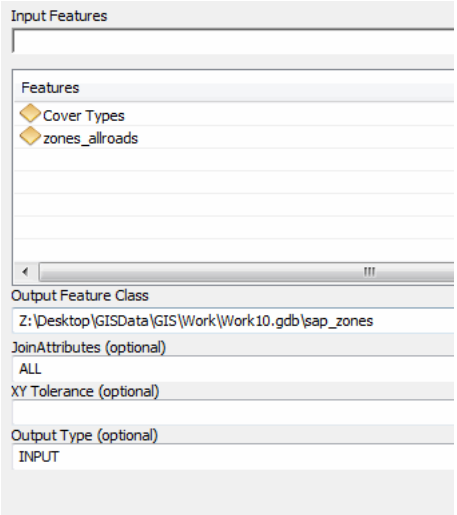

Figure 7. Intersecting 25 m haul zones and tolerant hardwood stands.

Most ArcToolbox tools limit processing to selected features, or all of them if none are selected.

To see *sap_zones* features clearly in the map display, you'll want to turn off *zones_allroads*, and then zoom in on one of the selected tolerant hardwood stands.

5 Turn off *zones_allroads* and then zoom in on the selected tolerant hardwood stands in *Cover Types.*

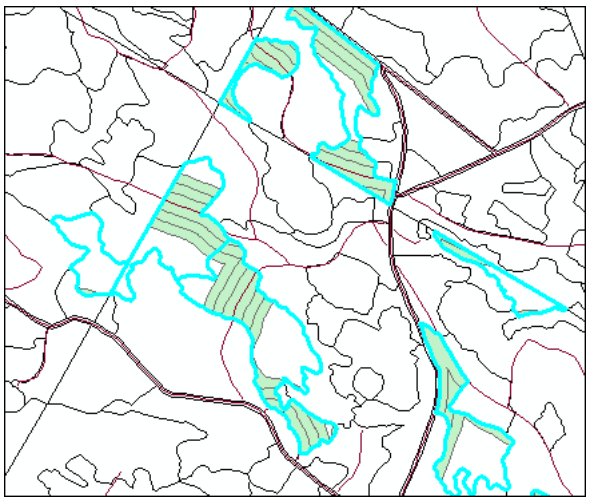

Figure 8. Tolerant hardwood stands partitioned into 25 m haul zones.

Features that you see in *sap_zones* were created wherever *zones_allroads* buffer features intersected tolerant hardwood stands.

Always bear in mind that the overlay tools can produce a result with multipart features, even where none exist in the inputs.

6 Check the attributes of some *sap_zones* features using the *Identify* tool.

You'll find that features have the attributes of both *Cover Types* (including the joined *volumes* table) and *zones_allroads*.

You'll also find multipart features in *sap_zones.* Polygons within the confines of a single tolerant hardwood stand that share the same distance value occur as a single feature. This will not hinder your analysis.

You now have the Woodlot's tolerant hardwood stands reclassified into three sap haul zones: *distance* values of 25, 50, and 75 m.

That brings you to your next task—classifying the sap haul zones by sap production potential based on their sugar maple content.

CLASSIFY STANDS BY SAP PRODUCTION POTENTIAL

Classifying tolerant hardwood stands by sap production potential is simply a matter of developing some sort of labeling scheme that reflects relative content of immature and mature sugar maple trees.

It doesn't take that many mature trees on a given hectare to produce economical amounts of sap. Experience suggests that just 150 mature trees per hectare is sufficient. Given that a fully stocked stand at maturity typically has between 1,000 and 1,500 trees per hectare, mature tolerant

hardwood stands with at least 10 percent sugar maple content are capable of economical sap production. On the other hand, immature tolerant hardwood stands with at least 10 percent sugar maple content would have future sap production potential, provided their long-term management favored development of sugar maple over other species such as American beech and yellow birch.

You could use an ordinal ranking scheme like the following to classify stands' sap production potential. Here, sugar maple amounts recorded in the *volumes* table fields are used to classify stands into three categories—*Present Potential*, *Future Potential*, and *Limited Potential*.

Label	Description	Stand condition
PP	Present Potential (large sugar maple trees present)	(SM_S + SM_V)/VH >= 0.10
FP	Future Potential (smaller sugar maple trees present)	SM_P/VH >= 0.10
LP	Limited Potential (limited sugar maple trees present)	None of the above

Table 1. A scheme for classifying sap production potential of stands based on sugar maple content

RELATED CONCEPT: RECLASSIFY USING THEMATIC ATTRIBUTES TO LABEL

1 Add a new two-character text field, called *Sap_Potential*, to the *sap_zones* attribute table.

It's now a matter of populating *Sap_Potential* with *PP*, *FP*, and *LP* labels. Doing this will involve selective queries and *Field Calculator*.

Start by finding all mature tolerant hardwood stands with sugar maple content at least equal to 10 percent. That means finding stands in *sap_zones* where *SM_S* (sawlog-size tree volume/ha) plus *SM_V* (veneer-size tree volume/ha) is 10 percent of total stand volume/ha (*VH* field).

2 Use the following query expression as a guide to find all mature tolerant hardwood in *sap_zones* with sugar maple content at least equal to 10 percent.

```
(SM_S+SM_V)/ VH >= 0.10
```

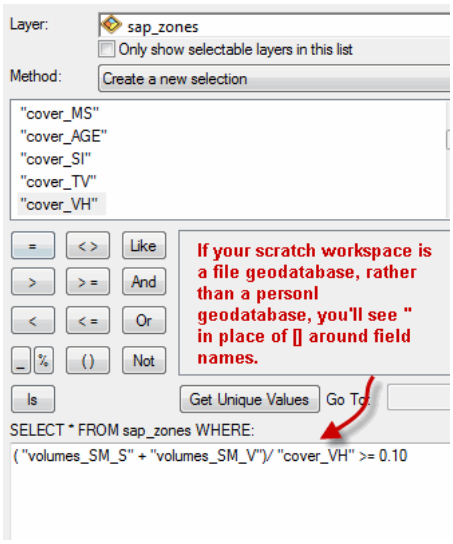

Figure 9. Selecting tolerant hardwoods where sawlog and veneer-size sugar maple trees make up at least 10 percent of stand volume yield.

Question 4: *What purpose do those parentheses ( ) serve in a* Field Calculator *expression?*

Three features satisfy your query and are selected.

If you zoom to selected features and look closer, you'll find that they represent three distinct haul zones—25, 50, and 75 m within part of stand 1046.

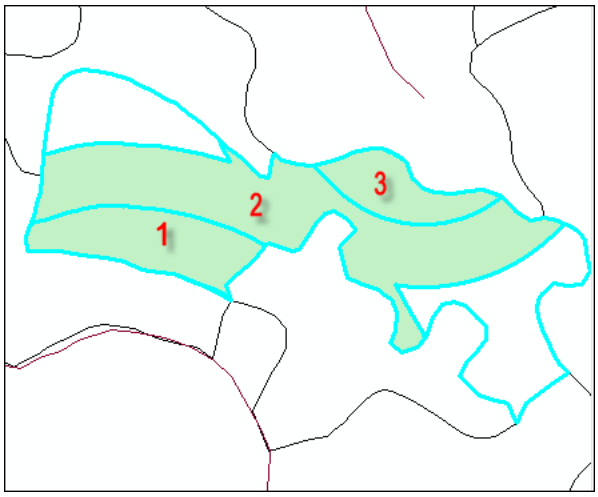

Figure 10. Present potential stand 1046 partitioned into three haul zones—25, 50, and 75 m.

It's time to label the three selected features.

3 Assign the three selected features a *Sap_Potential* of "*PP*"—that is, present potential—using *Field Calculator*. Remember to put quotation marks around "PP", or you will get an error.

Now you can locate sap zones with future potential and label them as *FP.* These will be zones not already labeled *PP* where *SM_P* (pulpwood-size tree volume/ha) is 10 percent of total stand volume per hectare (*VH field*).

4 Query *sap_zones* as follows and then label selected features as *FP* in the *Sap_Potential* field.

```
SM_P/VH >= 0.10 AND Sap_Potential Is Null
```

Again you'll find just three features. These sap zones have immature sugar maple trees in adequate amounts but will need more time to reach a size where sap production is sufficient for economic extraction.

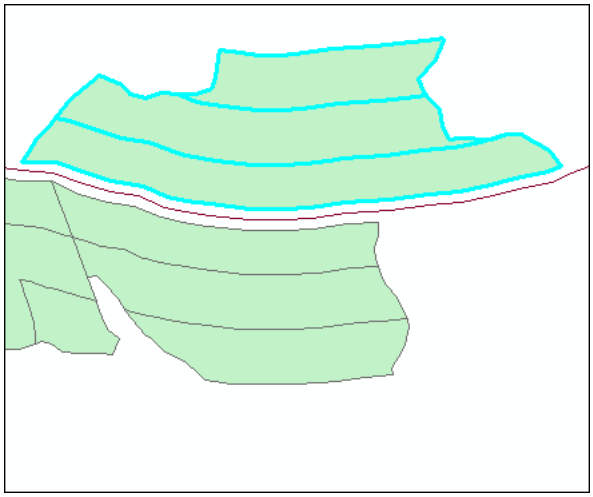

Figure 11. Future potential stand 817 partitioned into three haul zones—25, 50, and 75 m.

5 Select the remaining unlabeled sap zones—that is, `Sap_Potential Is Null`—and then label them *LP* for limited potential.

There should be 122. They have neither mature nor immature sugar maple trees in sufficient quantities. They have limited potential for sap production, except with intensive management.

6 Clear selected features.

The previous *Select By Attributes* and *Field Calculator* procedure is common practice in reclassifying. It can, however, get quite laborious, especially when the classification is quite complex or lengthy. There is an alternative. You can use VB code in *Field Calculator.*

Try it in calculating *Sap_Potential* values.

7 Use *Field Calculator* to clear the *Sap_Potential* field in *sap_zones*—that is, `Sap_Potential = ""`.

8 Right-click *Sap_Potential* and open *Field Calculator* as usual, but this time in the dialog box, select the *VB Script* and *Show Codeblock* options. Then enter the following VB statements and calculate `Sap_Potential = Label`.

```
Dim Label
'       Present potential - Sugar Maple sawlog and veneer-
sized trees at least 10%
 If ([volumes_SM_S] + [volumes_SM_V])/[cover_VH] >= 0.10
Then
   Label = "PP"
'      Future potential - Sugar Maple pulpwood-sized trees
at least 10%
ElseIf [volumes_SM_P]/[cover_VH] >= 0.10 Then
   Label = "FP"
'      Limited potential - none of the above
Else
   Label = "LP"
End If
```

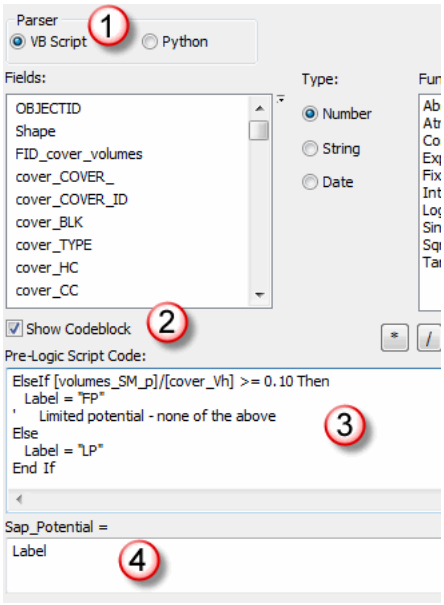

Figure 12. Labeling for sap potential using VBScript.

Hopefully, you can see the logic of the VB coding. A little Visual Basic programming know-how is a powerful thing.

One way or another, you've completed your two-way classification of tolerant hardwood stands in the Woodlot—haul zones by sap production potential.

There doesn't seem to be a lot of present potential for maple sap production in the Woodlot, with only one suitable stand occupying acceptable haul zones—25, 50, and 75 m.

The future doesn't appear much better, again with only one stand that's suitable for management. But perhaps the areas involved are large, or most of the area is within 25 m of a road. The next step is to find out.

SUMMARIZE SAP PRODUCTION POTENTIAL

How might you best summarize your results so that you have Woodlot area totals for each sap potential category and haul zone?

Computing a cross tabulation of area totals by your sap production classes (*Sap_Potential*) and 25 m sap haul zones (*Distance*), as illustrated below, would be ideal.

	Sap_Potential		
Distance	PP	FP	LP
25			
50			
75			

Table 2. Desired cross tabulation of haul zones (Distance) by sap production potential (Sap_Potential)

RELATED CONCEPT: CHARACTERIZE USING A NUMERICAL DISTRIBUTION

Unfortunately, the ArcMap summarize function does not support cross tabulations, at least not directly. For the above table, you'd have to calculate three summary tables, one each for 25, 50, and 75 m.

There is another option—Microsoft Excel.

1 Start Excel and use it to open the *sap_zones* attribute table in your geodatabase (*Data » From Access*).

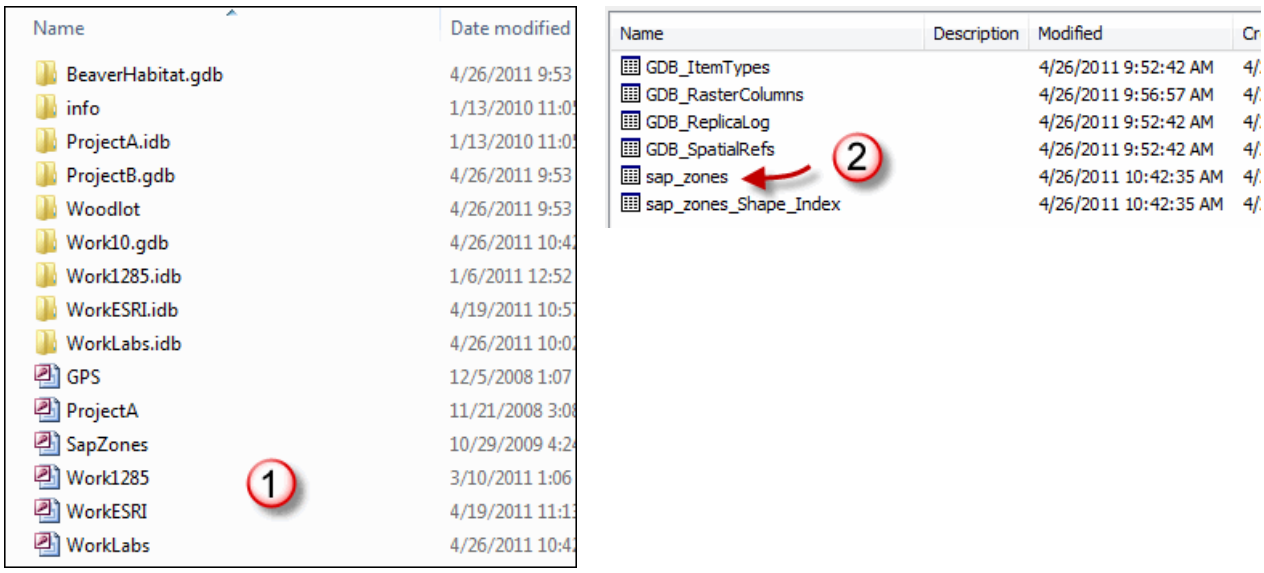

Figure 13. Accessing the *sap_zones* attribute table using Microsoft Excel.

Excel displays a spreadsheet that is pretty much a mirror image of the *sap_zones* attribute table.

	A	C	D	E	F	G	H
1	OBJECTID	distance	FID_cover_volumes	cover_COVER_	cover_COVER_ID	cover_BLK	cover_TY
2	1	25	65	66	213	2	FR
3	2	25	66	67	221	2	FR
4	3	25	149	150	316	3	FR
5	4	25	164	165	320	3	FR
6	5	25	290	291	401	4	FR
7	6	25	211	212	416	4	FR
8	7	25	247	248	423	4	FR
9	8	25	287	288	425	4	FR
10	9	25	366	367	436	4	FR
11	10	25	117	118	509	5	FR
12	11	25	223	224	517	5	FR
13	12	25	170	171	541	5	FR

Figure 14. The *sap_zones* attribute table opened as a spreadsheet in Excel.

2 Open *Pivot Table* functionality (*Insert » Pivot Table*) and define the desired cross tabulation. (Click in the upper-left corner of the spreadsheet to ensure that all columns and their rows are selected.)

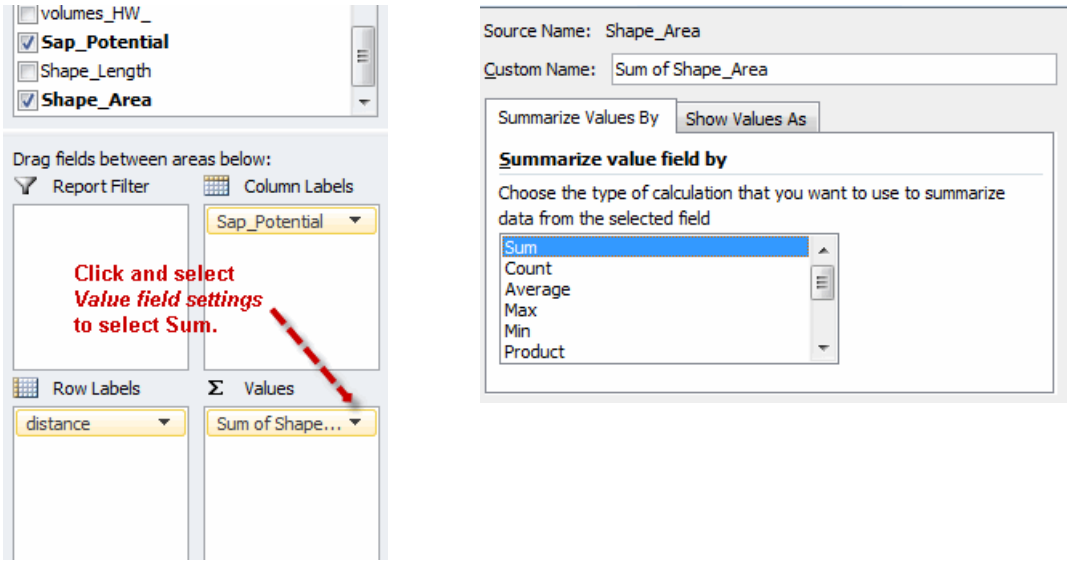

Figure 15. Computing a cross tabulation of *Shape_Area* totals by *Distance* and *Sap_Potential* using *Pivot Table*.

3 Format the resulting table as illustrated in the figure, substituting aliases for field names, dropping the LP category altogether, and reducing decimal places.

Sum of Shape_Area	Sap Potential		
Distance (m)	FP	PP	Grand Total
25	4713.37	9.97	4723.33
50	4173.07	3010.99	7184.06
75	2512.22	5404.46	7916.68
Grand Total	**11398.66**	**8425.42**	**19824.07**

Figure 16. Cross tabulation of area totals (m^2) by *Distance* and *Sap_Potential*.

You'll observe that overall there isn't a large amount of *Present Potential* (*PP*) tolerant hardwood area in the Woodlot—less than 1 ha in fact. There's a miniscule area within 25 m of a road, about 0.3 ha between 25 and 50 m, and 0.54 ha between 50 and 75 m. These amounts would not support a maple syrup-producing facility.

Is there better news in the *Future Potential (FP)* category?

There, overall, *FP* area totals just over 1 ha, with about 0.5 ha within 25 m, 0.42 ha between 25 and 50 m, and 0.25 ha between 50 and 75 m. These amounts would not justify the management expense needed to bring stands to a producing state.

Question 5: *How would you compile a cross tabulation in hectares rather than square meters?*

Conclusion

What have you learned, aside from the fact that the Woodlot can't support a maple syrup operation, now or in the future?

Your analysis used some of the same attribute reclassification and summarizing functionality often used in forest valuation, whether economic, social, or ecological. Visual Basic programming in *Field Calculator* proved helpful. In this exercise, however, you used locational attributes of proximity (buffering) and coincidence (overlay), as well as thematic attributes, in reclassifying stands.

Last, Microsoft Excel can be a useful ArcGIS companion.

Submit your work

- A cross tabulation of 25 m haul zones by three sap production potential categories—present potential, future potential, and limited potential
- Answers to the questions posed in the exercise:
  1. Why were there just three features (records) in the Multiple Ring Buffer result?
  2. When joining tables, what does the *Keep only matching records* option accomplish?
  3. What's the difference between intersect and union overlays?
  4. What purpose do parentheses ( ) serve in a Field Calculator expression?
  5. How would you compile your cross tabulation in hectares rather than square meters?
- A summary of the exercise, indicating where and how related reclassify and characterize concepts and analysis techniques are used (Your summary could take the form of a table that checks off each of these elements.)
- Calculation of sap production potential in another forest property using techniques similar to those used in this exercise

Credits

Sources of supplied data

Course Data

Data\cover, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\highway, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\newprop, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\tin, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Woodlot.mdb, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Codes\Woodlot_Codes.xls, courtesy of University of New Brunswick UNB Faculty of Forestry and Environmental Management

Data\Coordinate Systems\ATS 1977 New Brunswick Stereographic.prj, courtesy of ESRI
Data\Coordinate Systems\NAD 1983 CSRS New Brunswick Stereographic.prj, courtesy of ESRI

Data\GPS\Knowledge.shp, courtesy of University of New Brunswick
Data\GPS\towers.xls, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Layer Files\Age Classes.lyr, courtesy of Glen Jordan
Data\Layer Files\Air Photo Centre Points.lyr, courtesy of Glen Jordan
Data\Layer Files\Main Roads.lyr, courtesy of Glen Jordan
Data\Layer Files\Mgt Compartments.lyr, courtesy of Glen Jordan
Data\Layer Files\Non-forested.lyr, courtesy of Glen Jordan
Data\Layer Files\Secondary Roads.lyr, courtesy of Glen Jordan
Data\Layer Files\Streams.lyr, courtesy of Glen Jordan

Data\Mass Points\DTM.txt, courtesy of Service New Brunswick

Data\Models\Clearcutting.tbx, courtesy of Glen Jordan
Data\Models\Forest Analysis.tbx, courtesy of Glen Jordan
Data\Models\Forest Values.tbx, courtesy of Glen Jordan

Data\Orthophotos\Z45856650.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45856660.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45856670.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45906650.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45906660.tif, courtesy of Service New Brunswick
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Data\Orthophotos\Z45956670.tif, courtesy of Service New Brunswick

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