Forest Analysis Techniques

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Instructor notes

This lesson will show your students how they can leverage their existing GIS knowledge in analyzing forests, including reclassifying and characterizing, from several perspectives. It's assumed that students have at least intermediate ArcGIS® skills.

In the *Lesson background* and *Methods background* sections that follow, you'll find details on forest analysis, as well as reclassifying and characterizing. You can use this material when introducing your students to the lesson before they tackle the lab exercises. The background material will not expose your students to new ArcGIS functionality. In fact, the examples provided should be quite familiar, with the possible exception of spatial join and zonal statistics. The purpose of the background material is to establish the conceptual context for the lesson.

The lesson's four lab exercises are detailed in the *Lab exercises* section that follows. Labs are structured to engage students with the background material in real application settings. If this is your students' first lesson in the Forestry series, you can also use the examples in the background material to introduce the Woodlot inventory.

Lesson background

> Analysis: Detailed examination of the elements or structure of something, typically as a basis for discussion, interpretation, or management.

Forest analyses range from the simple to the complex, depending on the problem or issue at hand. Regardless, the process usually begins with one or more questions focused on "what" or "what is where" in a forest, and occasionally "why is what where?"

You might, for example, analyze timber supply in a forest. Some obvious questions might be, What types of stands are present? Young or old? High yield or low? High-value species or low? How much merchantable volume is there? Are volume amounts concentrated or widely distributed? and Are they operable and readily accessible?

On the other hand, you might examine habitat supply for some animal. In this case, questions might include, What types of stands are present? Young or old? Softwood, hardwood, or mixed wood species? How much desirable habitat is there? Where is the habitat located? and Is it a south- or north-facing slope, with high or low elevation?

So, how can GIS help?

Regardless of the complexity of the analysis, the same GIS *attribute query* and *summary* techniques can be brought to bear in answering the "what" or "what is where" questions that usually arise.

Thematic attribute query

Thematic attributes describe what forest features are. A typical GIS forest inventory stores numerous thematic attributes for individual features, such as cover type, vegetation composition, stand ages, silviculture treatments, and volume yield, in Excel-like tabular form.

GIS provides the ability to query these thematic attributes in a variety of ways using *Select By Attributes* and provides answers to questions about the "what" in a forest.

Here's a simple example:

Explore

Explore

What level of management activity is evident in the Woodlot? Calculating the percentage of Woodlot stands that have been recently harvested or silviculturally treated is one way of answering that question. We'll look for plantations, prescribed burns, partial cuts, and clearcuts.

In ArcMap, add the *cover* feature class as a layer.

Using Select By Attributes, select for TYPE = 'PS' or TYPE = 'PB' or TYPE = 'PC' or TYPE = 'CC'.

Open the attributes table and note the number of records selected. You should find 52 out of 569 Woodlot features selected.

What area do they occupy?

Right-click the *Shape_Area* field and select Statistics... . That will indicate 119 hectares (ha).

What percentage of all Woodlot stands does that represent?

Again using Select By Attributes, select for AGE <> -99. That selects the Woodlot's 533 stands.

Right-click *Shape_Area* and select Statistics... . That will indicate 1,397 ha.

So, a very small percentage, 8.5 percent, of Woodlot stands has had interventions recently.

That was a very simple example. Of course, "what" questions can be more complex, and so can thematic attribute queries. Look for lesson exercises to introduce those.

How about "what is where?"

Locational attribute query

Locational attributes describe the spatial characteristics of forest features. Unlike thematic attributes, you don't see many locational attributes recorded in a forest inventory; usually there are just feature dimensions. Other locational attributes, such as shape, nearness, containment, and overlap (intersection), are calculated as needed.

GIS makes spatial query easy, using *Select By Location*, *Spatial Join,* and *Clip*. These provide the ability to deal with the "what is where" questions in forest analysis.

Following are illustrations of these three:

Select By Location

Select By Location offers almost a dozen possibilities for selecting features based upon their relative position to others. For example, selecting features that are near others, within a specific distance of others, that intersect others, or contained by others, to name a few possibilities.

Here's an example of selecting features that are within a specified distance of selected others.

Explore

To what extent have Woodlot streams been compromised with clearcuts closer than 30 meters (m)? This is a classic "what is where" question dealing with nearness that GIS is especially good at answering.

Explore

In ArcMap, add the *cover* and *streams* feature classes as layers.

Using Select By Attributes, select clear-cuts with TYPE = 'CC'.

Using Select By Location, isolate streams features that "are within a distance of" 30 m of the selected features of *cover*.

Open the *streams* attributes table and note that 7 stream segments are selected out of a total of 54.

What length of compromised streams does that represent?

Right-click the *Shape_Length* field and select Statistics... . That will indicate 4.7 kilometers (km).

So, clearcutting has occurred rather close to a significant number of streams in the Woodlot.

It's apparent in the Select By Location dialog box that there is a large array of possibilities for selecting features based on their nearness, containment, or overlap.

Spatial Join

GIS provides another option for selecting features based on their spatial association, (relative positions). Similar to the more common attribute table join, features from two datasets may be joined based on nearness, containment, or overlap; for example, join forest stands to soils type polygons that they lie within, or join road segments to stands that they intersect, or join stream segments to stands they're closest to.

Based on join cardinality, as viewed from the destination features, lies within or intersect joins may result in either one-to-one or many-to-one associations. The latter case precludes actually joining source table attributes but allows summaries—average, for example—of source attributes to be appended to destination table records. So, using one of the examples above, the average volume of stands lying within each soil type could be appended.

The third spatial join possibility, closest to, will always be a one-to-one join, which appends the source attributes of closest features and records their actual distance to destination table records.

So, join by location offers some additional analytic possibilities. Following is an example:

Explore

Are old-growth habitat areas in the Woodlot well removed from well-traveled main and secondary roads? This is another “what is where” question that GIS can answer.

Explore

In ArcMap, add the *cover*, *clines*, and *roads* feature classes as layers.

Using Definition Query, select old-growth stands in *cover* with AGE >= 80 AND TYPE <> “BG”. Rename the layer “Old Growth.”

Using the Merge tool in ArcToolbox, merge *clines* and *roads* into a single road network feature class named “allroads.”

Right-click *Old Growth* and establish a spatial join with closest features in *allroads*.

Open the result attributes table.

You’ll see that each *Old Growth* polygon has the attributes of its closest road attached, along with the actual distance in meters.

Symbolize the distance field using a graduated color scheme and 30 m classes.

It’s apparent that most old-growth stands are in close proximity to roads. How close?

Right-click the *Distance* field and select Statistics... .

That provides a lot of information about distances between old-growth stands and roads, including a frequency distribution.

Many Woodlot roads are within 100 m of old-growth stands.

Clip

Clip bears a strong resemblance to an intersect overlay. Clipping uses feature boundaries in one map to extract features in another map. As such, it too is useful in addressing “what is where” questions in forest analyses.

Explore

In the Woodlot, a new city street, Knowledge Park Drive, was constructed across its northern portion. How much timber volume was removed in constructing the street, assuming a 50 m right-of-way?

Explore

In ArcMap, add the *cover* feature class then add the *Knowledge* shapefile (centerline feature) located in the *GPS* folder. Ignore the warning message about coordinate system differences.

Using the Buffer tool in ArcToolbox, create the 50 m right-of-way for the new road (25 m on either side).

Using Definition Query, limit *cover* to just stands with AGE <> -99.

Using the Clip tool in ArcToolbox, clip *cover* with the right-of-way. Make sure the result is directed to a geodatabase.

Open the result attributes table and note *Total Volume* field values.

The Total Volume values you see are for the original stands, not for the new polygons that were created with the clip operation. Correct values can be calculated, however, as area (ha) * m^3 / ha.

Using Field Calculator, calculate TV = Shape_Area / 10000 * VH.

Right-click *Total Volume* and select Statistics... .

That indicates that over 1,900 m^3 of timber were removed in constructing the Knowledge Park Drive through the Woodlot.

Summary statistics

Aspatial and spatial attribute queries, as illustrated previously, are usually just a prelude to some sort of quantitative summary. For example, calculating statistics for geometry fields, area or length, is a common means of summarizing features selected using Select By Attributes or Location.

There are, however, additional summary techniques available with GIS. These include traditional *tabular summary*, as well as spatial summaries using *spatial join* and *zonal statistics*.

Tabular Summary

GIS provides the means to summarize any discrete (coded) attribute field with the sum, mean, minimum, maximum, and so on, of corresponding values in one or more numeric fields. Here's a simple example:

Explore

Explore

Does there appear to be a more or less even distribution of stand ages within each of the Woodlot's 12 management compartments? How about volume yields? One can answer these questions by computing the range of ages and yields that occur in each compartment.

In ArcMap, add the *cover* feature class as a layer.

Using Select By Attributes or Definition Query, select for AGE <> -99. That leaves just 533 stands.

Open the attribute table, right-click the *Compartment* field, and select Summarize... . In the dialog box, specify standard deviation for both AGE and VH.

Open the result table.

You should see that standard deviation values are large for both AGE and VH, although less so for AGE. Obviously, delineation of the Woodlot's management compartments has little to do with corralling stands of uniform age or yield.

You can undoubtedly come up with all sorts of possibilities using this tabular summary technique. It's a great tool for answering those "what" questions. There's also an ArcToolbox tool that implements tabular summaries (Analysis Tools > Statistics > Summary Statistics).

Spatial Join Summary

Spatial joins, depending on the type of features being joined, provide the option of calculating summary statistics for the numeric fields of joined features. Here's an example:

Explore

Explore

Old growth is an important habitat type, but its value is degraded if it's isolated among recent cutovers or regenerating stands. What's the situation in the Woodlot, assuming old growth constitutes stands older than 80 years of age? There are a few ways one could proceed to answer this "what is where" question, but a spatial join gets to an answer quickly.

In ArcMap, add the *cover* feature class as a layer.

Then, using Definition Query, select for AGE >= 80 and TYPE <> 'BG'. Rename the layer "Habitat."

Add a second copy of *cover*, but this time limit it to the Woodlot's collection of 533 stands with AGE <> -99. Name it simply "Stands."

Spatially join *Stands* to *Habitat*, asking for minimum values to be calculated for all *Stands* fields, including AGE, for all adjacent (intersected) polygons.

Open the result attributes table and note the Min_AGE values recorded for each of the 54 habitat features.

Right-click the Min_AGE field and select Statistics....

This gives you the frequency distribution of ages of the youngest stands surrounding old-growth habitat in the Woodlot.

While there are a large number of recent cutovers adjacent to old-growth habitats, most of the youngest adjacent stands are beyond the regenerating stage. So it would seem that old growth in the Woodlot is not isolated among recent cutovers or regenerating stands.

Zonal Statistics Summary

Most features in a forest inventory are discrete features, taking the form of polygons and lines, but on occasion, continuous data, such as elevation or depth to water table, is encountered. These data are stored as rasters, opening up additional summary possibilities. One technique in particular is commonly used—calculating zonal statistics. Here's an example:

Explore

Harvesting economics is determined by a number of factors, but in areas of rugged terrain, slope is an important variable. Are there operable stands in the Woodlot that would be costly to harvest due to steep slopes? This is another "what is where" question.

In ArcMap, add the *cover* feature class and the *elevation* raster, located in the *Rasters* folder, as layers.

Using Definition Query, select for VH >= 75 to isolate operable stands. Rename the layer "Operable."

Enable the Spatial Analyst extension, if it is not already.

Using the Slope tool (Surface), compute a percent-rise slope raster.

Open the Zonal Statistics As Table tool (Zonal), and set it up to calculate summary slope statistics within each *Operable* stand.

That produces a summary table of various slope statistics.

Regardless of the harvesting system employed, there don't appear to be any operable stands in the Woodlot that are particularly challenging because of their slope conditions.

GIS has a rich collection of tools and functionality for dealing with "what" and "what is where" questions that arise in forest analyses.

That probably explains why GIS is commonly used in organizations charged with managing forests.

Methods background

While questions of "what" or "what is where" are the usual focus of most forest analyses, characterizing a forest in some fashion is the usual way to find answers. What's not so obvious is that to effectively do so more often than not requires some reclassifying of forest features.

Your students need to know about *characterizing* and *reclassifying* in forest analysis and applicable GIS techniques.

Characterizing forests

There are three ways to characterize forests: single numbers, numerical distributions, and geographic distributions (maps).

In a forest's timber volume, for example, you can calculate a single number—its total volume, or so-called growing stock. On the other hand, you could characterize the forest's volume in more detail with a numerical distribution, for example, the distribution of volume by broad stand type. Finally, you could characterize the geographic distribution of the forest's volume with a map, for example, a map of stand volume by volume classes.

Single Numbers

These are by far the easiest to calculate, limited only by the array of attributes stored in the forest inventory. Here's an example:

Explore

To characterize a forest by its growing stock amount—a single number—you would simply sum individual stand volumes.

In ArcMap, add the *cover* feature class.

Using Definition Query, limit cover to just the 533 stands (AGE <> -99).

Open the attributes table and calculate statistics on the *Total Volume* field.

You'll see that the Woodlot's total growing stock is 91,273.3 m^3, with an average stand volume yield of 171.2 m^3/ha.

A single number, like a forest's growing stock, is quantitative. A single number, however, lacks detail. The growing stock amount tells you nothing about how the timber volume is distributed. Perhaps most of it occurs in low-yield stands? Perhaps most occurs in hardwood stands? Perhaps most occurs in habitat conservation areas? You don't know. If knowing these things is important, then calculating the single number isn't enough, and you need a *numerical distribution*.

Numerical Distributions

Calculating a numerical distribution, such as growing stock by broad stand type, would require that the inventory have some sort of stand type attribute, as well as stand volume amounts, or that you first group stands into a number of classes by species composition or some other inventory attribute.

Explore

The Woodlot inventory doesn't have a stand type attribute, but it does include a cover type attribute (TYPE field in *cover*). You can use it as a proxy in calculating a numerical distribution of growing stock.

With ArcMap started and the *cover* feature class added, open the Summary Statistics tool in ArcToolbox.

In the dialog box, set Input table as *cover*, Output table as the default, Statistic Field as TV, Statistic Type as SUM, and Case field as TYPE.

With this summary table, you can see how the Woodlot's growing stock (m^3) is distributed across six different cover types. Not surprisingly, most is concentrated in the untreated forested areas.

But here too, some questions remain unanswered. Where are these cover types located? Where are the forested areas, the planted softwood, and so forth? Where do the larger, or smaller, amounts of volume occur? Maps, of course, provide insight into these sorts of questions.

Maps

Mapping a forest's growing stock distribution would also require that you first group stands into classes, in this case, volume classes. As illustrated below, you might organize the classes, from least volume to most, by grouping stands according to their volume content in cubic meters: 0–100, 100–400, 400–800, 800–1,800, 1,800–4,300.

Explore

With ArcMap started and the *cover* feature class added, map the *Total Volume* field with a graduated color scheme across five manually defined volume classes, as follows:

Symbol	Range	Label
	0.000000 - 100.000000	100
	100.000001 - 400.000000	400
	400.000001 - 800.000000	800
	800.000001 - 1800.000000	1800
	1800.000001 - 4300.000000	4300

This produces a map that provides a picture of the spatial distribution of growing stock, making it easy to see where concentrations are located.

Bear in mind, however, that maps are not quantitative, even though they may present quantitative data, like growing stock in this example. In this case, the map certainly gives you an idea where low- through high-volume stands are located, but you can't tell exactly how much of each there is.

Remember, a picture may be worth a thousand words, but numbers speak louder than pictures.

Reclassifying forests

Analyzing and characterizing forests, whether by map, numerical distribution, or single number, often involve first *reclassifying* their features aspatially or spatially. For example, an existing stand age attribute would allow you to repackage a forest's stands into broad seral stages—regenerating, immature, mature, and old. Or, stands could be repackaged spatially by removing boundaries between those sharing some attribute value—crown closure, for example.

Reclassifying is used to exclude certain data values, replace old values with new, assign preference or priority, or simplify.

How does GIS help?

Reclassifying is always a two-stage process of first selecting features based on their thematic or locational attributes then assigning them new attribute values that *label* (nominal), *rank* (ordinal), or *quantify* (ratio).

Thematic attribute filtering selects forest features solely on the basis of attribute values. Locational attribute filtering, on the other hand, selects features on the basis of their size, shape, and geographic position relative to other features (i.e., spatial relationships, including nearness, containment, and overlap).

So, how do you use *thematic* and *locational* attributes of features to *label*, *rank*, and *quantify*?

Reclassify—Labeling

Any existing nominal, ordinal, or ratio attribute(s) may be used, but the new attribute is always nominal.

Explore

Reclassify all Woodlot cover type features as either wet or dry land. Wet land would be those polygons with a TYPE value of BG, PD, or DU. All others would be dry land. In this reclassification, you'll use the thematic attributes of features.

Explore

In ArcMap, add the *cover* feature class as a layer.

Add a new text field (length 3) in *cover* called "LandClass."

Using Select By Attributes, select water features with TYPE = 'BG' or TYPE = 'DU' or TYPE = 'PD'.

Using Field Calculator, assign LandClass = "Wet".

Switch the selection and calculate LandClass = "Dry".

Clear the selection.

At this point, you could summarize the *LandClass* field into a single number, a numerical distribution, or a map.

Reclassify—Ranking

Reclassifying features by ranking (ordinal) may use any existing nominal, ordinal, or ratio attribute(s), but the new attribute is always ordinal.

Explore

Explore

Reclassify Woodlot stands (AGE <> -99) according to the road class that they are near or intersected by: 1—Within 15 m of a main road, 2—Intersected by a secondary road, and 3—Inaccessible. Here, you'll use locational attributes to complete the reclassification.

In ArcMap, add the *cover* feature class as a layer.

Add a short integer field, "AccessClass."

Using Definition Query, limit the *Cover Types* layer to just stands (AGE <> -99).

Using Select By Location, select all stands that are within 15 m of main road centerlines (*clines* feature class).

Calculate *AccessClass* = 1.

Using Select By Location again, select all stands that are intersected by one or more secondary roads (*roads* feature class) and calculate *AccessClass* = 2.

Using Select By Attributes, select for *AccessClass* Is Null and calculate *AccessClass* = 3.

Clear the selection.

If you summarized the AccessClass field by the TV field, you could get an idea of how stand volume amounts are distributed across (1) most accessible, (2) adequately accessible, and (3) inaccessible stands.

Reclassify—Quantifying

Reclassifying features by quantifying (ratio) may use any existing nominal, ordinal, or ratio attribute(s), but the new attribute is always ratio, calculated using ratio attribute values.

Explore

Explore

Reclassify each Woodlot stand (AGE <> -99) according to its percentage of spruce and balsam fir pulpwood.

In ArcMap, add the *cover* feature class as a layer.

Join the *volumes* table to the *cover* attributes table via the STAND_ID and Stand# fields, respectively.

Using Definition Query, limit *cover* to stands that have volume yield present (VH > 0). (This prevents division by zero later.)

Add a float field, "SpBF_Pulp."

Using Field Calculator, calculate SpBF_Pulp = ([S_P] + [BF_P]) / VH * 100.

How would you now show the numerical or geographic distribution of this new attribute?

Those are some reclassifying possibilities and how you can use them to characterize a forest with a single number, numerical distribution, or map.

But there's more. You can reclassify spatially.

As you've seen in a previous example, reclassifying features spatially involves their repackaging on the basis of spatial relationships (locational attributes). But reclassifying spatially may also involve the redrawing of features on the basis of their attributes. Here the possibilities include *dissolving* boundaries between features, *buffering* features to fixed or variable widths, and *overlaying* features.

Spatially—Dissolve

Creating new, larger features by combining adjacent polygon or line features that share a common attribute(s) is common practice in forest analysis. One example follows:

Explore

Explore

Reclassify Woodlot cover types spatially by merging stands (AGE <> -99) that share common crown closure values.

In ArcMap, add the *cover* feature class as a layer.

Using Definition Query, limit c*over* to just stands (AGE <> -99).

In ArcToolbox, use the Dissolve tool to remove boundaries where adjacent stands share common *CC* values without creating multipart features. Name the output "CC_Patches."

If you examine *CC_Patches*, it's apparent that many adjacent stands share a common crown closure in the Woodlot. As a result, you see many larger polygons when you redraw stands from this crown closure perspective.

Spatially—Buffer

Buffering redraws polygon or line features by expanding their boundaries to fixed or variable distances.

Explore

Explore

In ArcMap, define riparian zones of 50 m around Woodlot streams.

Add the *streams* feature class as a layer.

In ArcToolbox, use the Buffer tool to buffer *streams* features to a fixed distance of 50 m. Set Dissolve Type to *ALL*. Name the output "Riparian".

If you examine *Riparian*, it's apparent that buffering has created polygons by expanding the boundaries of streams by 50 m on either side.

Spatially—Overlay

In addition to dissolving and buffering, forest features may be reclassified spatially using two classic map overlay procedures—intersect and union.

An overlay uses overlaps (intersections) between features in two or more maps to create new features with the combined attributes of their parent features. While an intersect overlay retains only the area common to the inputs, a union retains the combined area of the inputs.

Following are examples that illustrate how intersect overlay is used to reclassify spatially:

Explore

In the Woodlot, on what soil types do you find the highest-yield (volume) conditions? You'll need to first label Woodlot stands by their soil type.

Explore

In ArcMap, add the *cover* feature class and the *s4551* and *s4552* shapefiles, located in the *Shapes* folder, as layers.

Using the Merge tool in ArcToolbox, merge the two soil types layers in a single feature class "soils."

Using Definition Query, limit *cover* to high-yield stands with VH >= 180.

Using the Intersect tool, overlay *cover* and *soils*. Make sure the result is directed to a geodatabase; otherwise, feature areas will be incorrect.

This forms new polygons where stands are intersected by soils polygons. These new stand polygons are classified by soil type.

Open the result attributes table and sort the SOILS field in ascending order.

It should be apparent that a majority of the Woodlot's high-yield conditions occur on HT (Harcourt) or RE (Reece) soil types. How much area is there in each case, though?

In the open attributes table, manually select HT records or use Select By Attributes with SOILS = 'HT'.

Right-click *Shape_Area* and select Statistics.... That will indicate 19 ha.

Repeat the process for RE records. You will find 15 ha.

But overlay is not limited to polygon-on-polygon overlays. Polygon-on-line is also a possibility. That allows you to spatially reclassify linear features.

Explore

Forest road density (amount/hectare) becomes an ecological concern where densities are high. What's the situation in the Woodlot? Do you have particularly problematic management compartments? In this case, you'll need to label roads by management compartment.

In ArcMap, add the *compart*, *clines*, and *roads* feature classes as layers.

Using the Merge tool in ArcToolbox, merge the *clines* and *roads* layers to create a single road network.

Using the Intersect tool, overlay *compart* and the road network. Make sure the result is directed to a geodatabase; otherwise, feature lengths will be incorrect.

Open the result attributes table.

It should be apparent that road features have been cut into new segments where intersected by compartment boundaries and have their enclosing compartment number attached (*Compart_ID* field).

This information allows you to examine the length of roads in each compartment.

For example, using Select By Attributes, select all road segments in management compartment 4 (*Compart_ID* = 4).

Right-click *Shape_Length* and select Statistics... . That will indicate a total length of roads of 8.7 km.

If you divide that by the compartment's area (*Shape_Area* in the *Management Compartments* layer), you'll find that road density is 0.05 km/ha, or 5 km/100 ha. That doesn't seem like a lot.

Lab exercises

The lesson comprises four lab exercises: Assessing Balsam Fir Tipping Potential, Evaluating Economical Timber Amounts, Comparing Fixed- and Variable-Width Riparian Buffers, and Determining Vulnerability to Spruce Budworm.

While the lab exercises present engaging and realistic applications, their main purpose is exposing students to a range of forest analysis techniques that involve reclassifying forest features in a variety of ways as a basis for characterizing using single numbers, numerical distributions, and maps. The following tables summarizes these:

	Assessing Balsam Fir Tipping Potential	*Evaluating Economical Timber Amounts*	*Comparing Fixed- and Variable-Width Riparian Buffers*	*Determining Insect Vulnerability*
Analysis				
Thematic attribute query	√	√		
Locational attribute query				
Select by location				
Spatial join				
Clip				
Summary statistics	Tabular	Tabular; zonal	Zonal	Tabular; spatial join
Reclassify				
Label	√			
Rank				√
Quantify		√	√	√
Spatial	Overlay; buffer	Buffer	Overlay; buffer	√
Characterize				
Number	√	√	√	
Numerical distribution	√	√		√
Geographic distribution	√	√		√

If your students will be completing multiple exercises in this lesson, it's probably wise for you to suggest that they start each lab exercise with a "fresh" copy of the Woodlot geodatabase; otherwise, their geodatabases will become quite cluttered. As an alternative, you could suggest to your students that for each exercise they use a scratch workspace different from the Woodlot geodatabase.

The following provide overviews of each lab exercise, including general procedure, concluding observations, suggested review questions, and assignments for your students.

Assessing Balsam Fir Tipping Potential

What is the Woodlot's potential as a source of branch tip harvesting for wreath making?

General procedure

1 Identify balsam fir tipping stands as those between 5 and 40 years of age, with a minimum of 50 percent balsam fir content.

2 Buffer the Woodlot's secondary and main road right-of-way features separately and combine them before intersecting with the selected tipping stands to isolate accessible areas.

3 Summarize accessible areas by crown closure classes—fully stocked, canopy gaps, and understocked. A pie chart is produced.

4 Map accessible tipping areas by crown closure classes.

Concluding observations

- The Woodlot, or any forest, can be characterized using single numbers, distributions (table and charts), and maps.
- Tables and charts are ideal for presenting the aspatial distribution of some forest attributes, while maps provide the spatial distribution. A single number tells you neither.
- A numeric forest attribute field may be summarized in some fashion—totaled or averaged, for example—for the unique values of another attribute.
- Forest features may be reclassified spatially using an overlay, such as overlaying buffered roads on balsam fir tipping stands, as in this exercise.
- The *Dissolve Type: All* setting is your best choice when buffering features.
- The Visual Basic *Round* function is handy for rounding numeric values to a specified number of decimal places.
- Caution: When you partition stands through an overlay, you'll need to recalculate stand amounts like total volume.
- There are 10,000 m^2 (100 x 100 m) in one hectare.

Suggested student deliverables

- Summary table, chart, and map of accessible balsam fir tipping areas by crown class
- Answers to the questions posed in the exercise
  - What happens if you don't set Dissolve Type to *All* when using the Dissolve tool?
  - What happens if Gaps Allowed isn't checked when using the Union tool?
  - How might you calculate balsam fir tipping amounts by Woodlot management compartment?
- A summary of the exercise, indicating where and how related reclassify and characterize concepts and analysis techniques are exposed (This could take the form of a check-off table that maps the exercise's coverage.)
- Using techniques similar to those encountered in assessing balsam fir tipping potential, assessment of the Woodlot for some other nontimber forest product

Model

A model, *Balsam Fir Tipping*, located in the *Analysis* toolbox inside the *Models* folder implements this exercise. Running the model while varying buffer width or the selection criteria for identifying balsam fir tipping stands may be instructive for students.

Evaluating Economical Timber Amounts

What is the tally of operable timber amounts by skidding distance in the Woodlot?

General procedure

1 Identify operable stands as those with a minimum-volume yield of 75 m^3/ha and less than 25 percent tolerant hardwood content.

2 Merge secondary and main road centerlines to form a road network, then use the Euclidian Distance tool to compute a skidding distance surface around it.

3 Use Zonal Statistics and a table join to associate each operable stand with an average skidding distance.

4 For each operable stand, compute a 50 m skidding class using the Python calculation: Round (skid distance / 50 + 0.499) * 50.

5 Summarize skidding classes by total volume and area. Chart the tabular results.

6 Map skidding classes using a layout template. Include the chart.

Concluding observations

- The Woodlot, or any forest, can be characterized using single numbers, distributions (tables and charts), and maps.
- Tables and charts are ideal for presenting the aspatial distribution of some forest attributes, while maps provide the spatial distribution. A single number tells you neither.
- More than one table may be joined to a destination table at one time.
- A numeric forest attribute may be summarized in some fashion—totaled or averaged, for example—for the unique values of another attribute.
- The Python (or VB) Round function in the Field Calculator is very handy for assigning a range of continuous data to fixed-width classes using the expression class = round (value/ class interval + 0.49) * class interval.
- Be careful when performing integer arithmetic in a VB or Python expression—truncation will occur.
- VB does not do Nulls; you will need to use Python instead.
- The Euclidian Distance tool, unlike the buffer tools, computes continuous distances around features.
- Using zonal analysis tools, polygon features may be summarized with the mean, maximum, minimum, and so on, of some underlying continuous data, like slope or elevation, for example.

Suggested student deliverables

- Summary table, chart, and map layout of operable stands by average skidding distance

- A summary of the exercise, indicating where and how related reclassify and characterize concepts and analysis techniques are exposed (This could take the form of a check-off table, as above, that maps the exercise's coverage.)
- An explanation why, when using the formula Round (*invalue*/*class interval* + 0.49), it's important to add a decimal place to *class interval* when *invalue* is a whole number
- Answer to the question posed in the exercise
  - What would happen if you didn't set the processing extent?
- Results using the suggested alternative solutions
  - Use the Multiple Ring Buffer tool to create concentric buffers of some width, for example, 50 m, around the road network, then overlay those on operable stands to partition them into distance zones.
  - Use the Reclassify tool to build a new raster of 50 m classes, then, using the Zonal Statistics As Table tool, compute operable stand volume totals (TV field) for each class (zone). Hint: You'll need to create a TV raster where each 10 m cell contains a volume amount (VH values - m3/ha * 0.01 ha).

Model

A model, *Skidding Distance*, located in the *Analysis* toolbox in the *Models* folder implements this exercise. Running the model while varying operable timber criteria or the selection criteria for identifying the road network (Do Woodlot trails really provide adequate harvest access?) may be instructive for students. How sensitive are results to changes in these inputs?

Comparing Fixed- and Variable-Width Riparian Buffers

Will buffering streams as a function of slope exclude more timber from harvest compared to the status quo?

General procedure

1. Using Zonal Statistics and a table join, associate mean slope values with each cover type feature in the Woodlot.
2. Overlay cover type features on the stream network.
3. Add a buffer width field in the result, then assign variable buffer widths depending on mean slope value.
4. Buffer streams according to buffer field values.
5. Overlay the buffer on Woodlot stands and calculate the total volume located within the buffer.
6. Buffer streams to a fixed width of 50 m, overlay on stands, then compute a total volume amount.
7. Compare volume amounts.

Concluding observations

- Using zonal analysis tools, polygon features may be summarized with the mean, maximum, minimum, and so on, of some underlying continuous data, like slope or elevation, for example.
- You can overlay polygons on lines as well as on polygons.
- Features may be buffered to a single fixed width or buffered to variable widths using the values of an attribute field.
- Overlays require caution. While resultant feature sizes will be recalculated when the overlay destination is a geodatabase, user attributes, like stand volume in the exercise, are not adjusted.
- Many geoprocessing operations produce multipart features. When in doubt about their suitability, use the Multipart To Singlepart tool to explode them.
- The Reclassify tool is very handy for classifying raster data. Unfortunately, there isn't a comparable tool for vector data.
- There are 10,000 m^2 (100 x 100 m) in one hectare.

Suggested student deliverables

- A tally and comparison of timber volume excluded from harvest using variable-width buffering versus fixed width
- A summary of the exercise, indicating where and how related reclassify and characterize concepts and analysis techniques are exposed (This could take the form of a check-off table, as above, that maps the exercise's coverage.)
- A discussion and explanation of multipart features (Why do they exist? Why might they be a problem?)
- Answers to the questions posed in the exercise
  - Why was it critical to use COVER_ID as the Zone field in the Zonal Statistics As Table tool?
  - What would happen if you didn't set Dissolve Type to *All* when buffering features?
- Results using the suggested alternative solution
  - Characterize cover type features using their most frequently occurring slope (by area) rather than mean slope.
- Implementation of the lab procedure for a forest situated on terrain more rugged than that of the Woodlot

Model

A model, *Variable Width Buffering*, located in the *Analysis* toolbox in the *Models* folder implements this exercise. Running the model with different buffering criteria or on a different forest where terrain is more of an issue may be instructive for students.

Determining Insect Vulnerability

In its present state, is the Woodlot particularly vulnerable to mortality losses, or is there little to worry about should an insect (spruce budworm) outbreak occur? How much timber volume, for example, is at risk?

General procedure

1. Calculate a vulnerability rating for each stand based on presence of spruce and balsam fir trees.

2. Calculate stand ratings based on the amount of mature balsam fir present.

3. Calculate isolation ratings based on presence of surrounding nonsusceptible species using a spatial join.

4. Multiply the three ratings to arrive at a vulnerability index for each stand.

5. Classify index values into ordinal defoliation classes—low, moderate, high, and so on.

6. Summarize defoliation classes by area and timber volume. Build a chart.

7. Map the defoliation classes.

Concluding observations

- In Field Calculator, a simple formula—Round (invalue / class interval + 0.499)—proves handy in sequentially numbering (i.e., 0,1,2,3, etc.) equal interval classes.
- Using VB code in Field Calculator is a time saver in reclassifying features.
- In the Field Calculator, or in VB code, text strings are always enclosed in double quotes.
- The Dissolve tool is useful in forming forest patches (clusters of like conditions that are adjacent) so long as you avoid multipart features.
- You can summarize, sum, find the mean of, and so on, the values of one or more attribute fields for each of the unique values of a selected field.
- You can also summarize using a spatial join, for example, the total volume of all stands adjacent to a lake.
- Rating or scoring schemes, like the vulnerability index calculated in this exercise, find common application in characterizing forests.

Suggested student deliverables

- A summary table, chart, and map of budworm vulnerability in the Woodlot
- A summary of the exercise, indicating where and how related reclassify and characterize concepts and analysis techniques are exposed (This could take the form of a check-off table, as above, that maps the exercise's coverage.)
- An implementation of the lab procedure, or something similar, for another insect or other forest disturbance

- An explanation why, when forming forest patches like the hardwood patches in this exercise, it's critical to disable multipart features with the Dissolve tool
- An explanation why, when using the formula Round (invalue / class interval + 0.49) * interval, it's important to add a decimal place to class interval when invalue is a whole number
- An explanation of the difference between *susceptible* and *vulnerable* when discussing forest insect problems

Model

A model, *Budworm Vulnerability*, located in the *Analysis* toolbox in the *Models* folder implements this exercise. Running the model with different rating criteria, especially the age of maturity for balsam fir, might prove insightful for students.

Lesson review questions

Short-answer written questions, where students are required to describe or explain in their own words, are a good way to demonstrate comprehension, especially of the conceptual material. Following are some possibilities:

- Forest analyses are usually focused on questions of "what" and "where is what." Can you think of timber and nontimber examples of each, beyond those provided in the lesson?
- Can you think of two examples each for characterizing a forest with a single number, a numerical distribution, and a map?
- What ArcMap functions are useful in characterizing forests with a numerical distribution?
- Are forest maps quantitative or qualitative?
- Reclassifying is a two-stage process. What are the steps? Can you identify examples from lesson exercises?
- Spatially reclassifying forest features, like aspatial reclassification, involves repackaging features. Can you distinguish between the two, though?
- Distinguish between thematic and locational forest attributes and provide examples of each.
- What GIS tools are involved in thematic attribute query? Which are used in locational attribute query?
- Can you explain a spatial join? How is it similar to, yet different from, a conventional tabular join?
- You can execute a tabular summary by right-clicking an attribute field, but what other possibility exists?
- How is raster data different from the more common vector data of shapefiles and feature classes?
- Provide an example of using Zonal Statistics in a forest analysis, other than the example used in the course material.
- Aside from polygon-on-polygon overlay, what other overlay possibilities exist? What ArcToolbox tool implements all these?

- What Field Calculator expression would you use to calculate five-year age classes using the Woodlot cover types AGE field as input?
- How is the result produced by the Euclidian Distance tool different from that produced by the Buffer or Multiple Ring Buffer tools?
- Describe a multipart feature, with an example.
- Where is VB used? When is it useful?
- What purpose do brackets serve in Field Calculator expressions? In query expressions?
- What does feature dissolving involve? What application does it serve?
- Aside from short integer, what other types of attribute fields are there?