

Forest Inventory

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Instructor notes

This lesson takes a look at a typical forest inventory and examines how ArcGIS® might be used to store, organize, document, and update it in a geodatabase.

Students will need some background on the topic of forest inventory as well as spatial data formats, such as coverages, shapefiles, and rasters. 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 inventory, as well as spatial data formats. 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. The purpose of the background material is introducing the woodlot inventory and establishing conceptual context for the lesson.

The lesson's five 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. This lesson is an ideal place for your students to start the Forestry series, as it introduces the woodlot inventory that's used in all other Forestry lessons.

Lesson background

Management requires information about the system being managed. In forest management, the forest is the system, and forest inventory is the source of information. While forest inventory methods of collection, contents, and means of storage vary widely from organization to organization, all contain information that convey the thematic and locational attributes of forest features, and often underlying topography as well.

Maps, imagery, and related tabular data have always been the centerpiece of forest inventories. In the past, before the introduction of computers and geographic information systems (GIS), paper maps, aerial photos, and tally sheets were the principal media for storing forest inventories. A forest map might, for example, display contours, roads, water bodies, and vegetation types and symbolize them using numbers, colors, patterns, and labels. Tally sheets, on the other hand, provided detailed attributes of the mapped features, in particular, the characteristics of stands, such as area and species composition.

Today, of course, computer-based forest inventories are the norm. The imagery, digital maps, and tables they contain, however, include the same spatial data components and properties as their paper map and tally sheet counterparts of yesteryear.

Map components and properties include: *date*; *scale*; *datum* and *projection*; *features* and *attributes*; *metadata*; and *annotation* and *symbolology*. It's important to understand these things, since their characteristics limit what you can reasonably do with maps.

Begin by taking a look at an inventory for the woodlot, a 1,400-hectare (ha) forest in the Acadian-New England forest region of North America.

Date

This tells an inventory's age, and therefore how up-to-date it is. It's not uncommon for forest inventories to be several years old; some may be a decade or more old. In forest inventories covering large geographic areas, it's not uncommon to find several data ages.

The woodlot inventory was assembled in 1991, with only minor updates since.

Explore

Start ArcMap™ and add the *compart* shapefile located in the *Shapes* folder within *Woodlot*.

Explore

This displays the woodlot's boundaries and its 12 management compartments. If you open the attributes table and compute statistics for the *AREA* field, you'll see that the size of the property is actually 1,435.46 ha.

Scale

This tells the geographic precision, or resolution, of an inventory. Scales are usually expressed as representative fractions, for example, 1:250,000. This scale means that each millimeter on the map represents 250,000 mm, or 250 meters (m), on the ground.

Map scales are often described as large scale or small scale. The previous 1:250,000 example would be a small-scale map, since the fraction $1/250,000$ is small, and individual map features would appear small. A large-scale map, like 1:10,000, on the other hand, would display much more detail, as individual features would appear larger. In forestry, scales vary, but ones between 1:10,000 and 1:20,000 are common. It's good to bear in mind, then, that 1 mm of map at a scale of 1:20,000, a fine pencil line, may be as much as 20 m in the actual forest.

The woodlot inventory was compiled with the aid of aerial photography flown at a nominal scale of 1:12,500. The word *nominal* is important. Scale varies across an aerial photo, particularly where elevation variations are great.

Datum and projection

These define an inventory's coordinate system, the basis for defining the locations and extents of features on the earth's surface.

A datum incorporates a mathematical model of a spheroid (aka ellipsoid) that approximates the earth's spherical shape and identifies a location on the earth's surface where the fit is exact.

A projection, on the other hand, is a method for producing all or part of a round body, for example, the earth, on a flat map. This projection cannot be done without distortion, so you must choose which characteristic (distance, direction, scale, area, or shape) is to be shown accurately at the expense of the other characteristics. Depending on your intended application, one or more of these will be important. For example, if you're intent on calculating some forest landscape metrics, the degree of shape, area, and distance distortions are going to be important. Generally, though, distortions are likely to be small in forest inventories, since they cover relatively small regions of the globe.

Projections can be used with more than one datum; for example, the New Brunswick Double Stereographic projection could be used with the ATS datum of 1977 or the newer North American Datum (NAD) of 1983.

The woodlot inventory was digitized with the ATS datum of 1977 and the New Brunswick Double Stereographic projection, using ArcInfo® GIS.

Explore

In ArcMap, check *Coordinate System* properties via *Data Frame* properties (right-click anywhere within the map display), or alternatively, in the *Catalog* window double-click a shapefile (*Shapes* folder) to examine its properties.

Explore

This should confirm the ATS 1977 datum and the New Brunswick Double Stereographic projection.

Aerial photos (*Photos* folder) and other forest inventory imagery often do not have an associated coordinate system; they are not georeferenced. The woodlot's orthophotos, however, are georeferenced. Their datum, however, is NAD 1983.

For more information, see **Map Projections** at ArcGIS Desktop Help Online. That would be a good page to bookmark.

Features and attributes

You'll find both natural and non-natural features and attributes recorded in a forest inventory. Topography, ecological regions, stands, streams, and water bodies are some of the natural features you might find. Non-natural features might include roads, township grids, latitude and longitude lines, management compartments, ownership boundaries, timber supply areas, and harvest exclusion zones.

All other things being equal, features and attributes are the most critical content in a forest inventory. Ultimately, they limit your use of the inventory in characterizing and managing a forest.

First, you can't calculate a forest measure for which a corresponding stand or other feature attribute has not been recorded in the inventory. You can't, for example, calculate a forest's age class distribution if its inventory lacks stand ages. Second, you can't calculate a forest measure accurately if the corresponding feature attribute involves significant error. Unlike inventory scale, which tells something about an inventory's geographic precision, there is usually nothing in an inventory that indicates the reliability of its attribute data—*caveat emptor*.

Explore

In ArcCatalog™, or ArcMap, preview the geography and tables of the various shapefiles found in the Woodlot *Shapes* folder. Examine the various attribute fields, particularly those contained in the cover types shapefile (*cover*).

Explore

You'll find a typical collection of point, line, and polygon features that detail the location and attributes of streams, roads, stands, and a variety of other natural and non-natural features associated with a managed forest.

Preview the rasters in the *Rasters* folder. These provide a very different way of storing the location and attributes of forest features.

Preview the aerial photos in the *Photos* folder or the imagery in the *Orthophotos* folder. These capture attributes and features in photographs.

Metadata

Metadata is data about data. A complete and proper forest inventory will provide specifics for date, scale, datum and projection, and features and attributes, in the form of metadata. Traditionally, metadata has been provided in hard-copy form or through a website. With GIS inventories, on the other hand, it's possible to have it embedded.

Explore

Typical of forest inventories generally, the Woodlot inventory's embedded metadata is limited to the basics, and often not present at all.

Explore

In ArcCatalog, browse to the *Shapes* folder. Click any one of the shapefiles located there, and then click the *Description* tab. That will provide a summary and description of the shapefile's contents.

You can also access metadata via the *Catalog* window in ArcMap (*right-click » Item Description*)

Annotation and symbology

Annotation and symbology include text that names forest features like roads and streams; labels that describe stands; and patterns, colors, and symbols that help distinguish forest features. Annotation and symbology are not particularly useful in characterizing or managing forests but exist to annotate hard-copy maps produced for field use or inclusion in reports.

Explore

In ArcMap, clear your document, then add the *Main Roads* and *Secondary Roads* layer files (*Layer Files* folder).

Explore

You'll see the woodlot's road network symbolized by road class and annotated with road names.

That is well and good, but how are these forest inventory maps and related data actually stored on a computer using a GIS?

Methods background

ArcGIS stores geographic data digitally using several formats—coverage, shapefile, feature class in a geodatabase, triangulated irregular network (TIN), raster, and image. With its Data Interoperability extension, it can access geographic data stored using other formats.

The first three ArcGIS formats—coverage, shapefile, and feature class—model map features as collections of points, lines, and polygons. While there are significant differences in the manner in which each format stores features and their attributes, ArcGIS does a pretty good job of making the differences transparent, but there are some details that your students should note.

Shapefiles

In a shapefile (actually several files), point, line, or polygon features are digitally stored as collections of shapes (x- and y-coordinates of ground locations, that is, vertices, and optionally a z-value, like elevation) and their attributes.

Feature locations and attributes are stored in tables of rows (features) and columns or fields (location and attributes).

Explore

Using Windows Explorer, navigate to the *Shapes* folder.

Explore

Unlike an ArcCatalog listing, you'll see the individual files that comprise the shapefiles. You'll see extensions like .shp, .shx, .sbn, .dbf, and .prj.

To the typical ArcGIS user, it matters little what each file contains. Suffice it to say that the .shp file contains features (shapes), while the .dbf file contains associated attributes. The latter you can actually open in Excel. Try doing that with the *cover.dbf* file.

How are coverages different?

Coverages

The coverage is an older, but still common, GIS format. Like shapefiles, coverages involve point, line, or polygon features, but unlike shapefiles, coverages often contain multiple feature types.

So-called polygon coverages always expose at least two feature types: polygons and lines (polygon boundaries, often called arcs or edges). But there's more. All polygon coverages also contain point features called *label points*. These are the locations within the polygons where identifying labels might be placed. Last, you may even find annotation stored in a coverage. To the casual user, this multiple-feature characteristic of coverages isn't obvious.

Explore

Using ArcCatalog, or the Catalog window in ArcMap, examine the *cover* polygon coverage by expanding its contents.

Explore

This exposes several feature types typical of coverages, as noted earlier.

Preview each type in turn.

Warn your students that when moving or copying shapefiles or coverages, use ArcCatalog or the Catalog window in ArcMap and not Windows. That way, they can ensure that all the various parts are moved or copied.

Feature classes

This is the newest method for storing digital map information. You can think of feature classes as shapefiles stored in a database, a *geodatabase*. As with a shapefile, a feature class is simply a table of shapes and their attributes organized according to some schema.

Geodatabases are of three types: personal, file, or ArcSDE® multiuser.

Personal geodatabases are hosted by the Microsoft (MS) Access database management system (DBMS) and are limited to a database size not exceeding 2 gigabytes. A personal geodatabase exists as a single MS Access file with an .mdb extension. It's a good choice for small forest inventories or localized projects derived from large inventories.

File geodatabases are stored as conventional Windows file folders. Up to 1 terabyte of data may be stored for each enclosed dataset. The file geodatabase uses storage in a very efficient manner, using about one-third the storage required by shapefiles and personal geodatabases. For large forest inventories, the file geodatabase is the smart choice.

Multiuser geodatabases are hosted by an industrial-strength DBMS like Oracle, SQL Server, or Informix and are accessed using ArcSDE. This type of geodatabase stores extremely large and continuous databases like those maintained by federal, state, or provincial agencies.

In addition to coverages, shapefiles, and feature classes, forest inventories often include geographic information in GPS, raster, TIN, and image formats.

GPS data

GPS data is a very common source of geographic data for forest inventories. This data is captured in a variety of formats, depending on the brand and type of GPS receiver device used. The .gpx (GPS exchange) format is common. Most manufacturers of GPS receivers also provide software that allows captured data to be saved as shapefiles.

At version 10.1, ArcGIS can access .gpx data with the GPS To Features tool. Another alternative is the free ArcGIS Explorer program. Not only can it open .gpx files, but it can also retrieve data directly from a connected GPS receiver. Once opened in ArcGIS Explorer, GPS data can be saved as a layer package and opened in ArcMap.

Explore

Explore

There is a .gpx file in the *GPS* folder located in the Woodlot inventory.

- 1 Using ArcCatalog, browse to the *GPS* folder and open it.
You won't see a .gpx file listed. By default, neither ArcCatalog nor ArcMap will recognize the file type, but you can make them aware.
- 2 From the *Customize* menu in ArcCatalog, select *ArcCatalog Options*.
- 3 In the dialog box, click the *File Types* tab, then the *New Type* button.
- 4 Enter the .gpx extension and a description. Optionally, you can specify a special display icon.

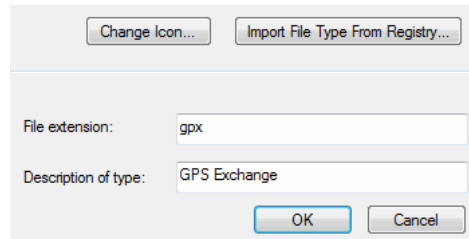


Figure 1. Add a file type in ArcCatalog.

Now, if you browse to the *GPS* folder, you will see the .gpx file listed, but, you won't be able to preview it or add it to ArcMap. You'll need ArcGIS Explorer for that.

- 5 Open ArcGIS Explorer, click the *Add Content* button, then select *GPS Data files*.
- 6 Navigate to the .gpx file in the *GPS* folder and open it.
- 7 In the subsequent dialog box, select just *Tracks*.

ArcGIS Explorer zooms in on the .gpx data, a linear feature in the area of the Woodlot property.

- 8 Add the *compart* shapefile (*Shapes* folder) for reference.

The GPS data identifies a new street recently built through the Woodlot property.

- 9 If you right-click the GPS layer in ArcGIS Explorer, you can save the data as a layer package for subsequent use in ArcMap.

Rasters

Rasters are a distinctly different way of representing geographic data. Rather than representing point, line, or polygon features as discrete entities (shapes) using x,y coordinates, rasters use a uniform grid of cells to capture spatial data. Each cell contains a number that identifies the value of some attribute, such as cover type, temperature, elevation, or soil type, at its location. The following diagram illustrates with a simple example:

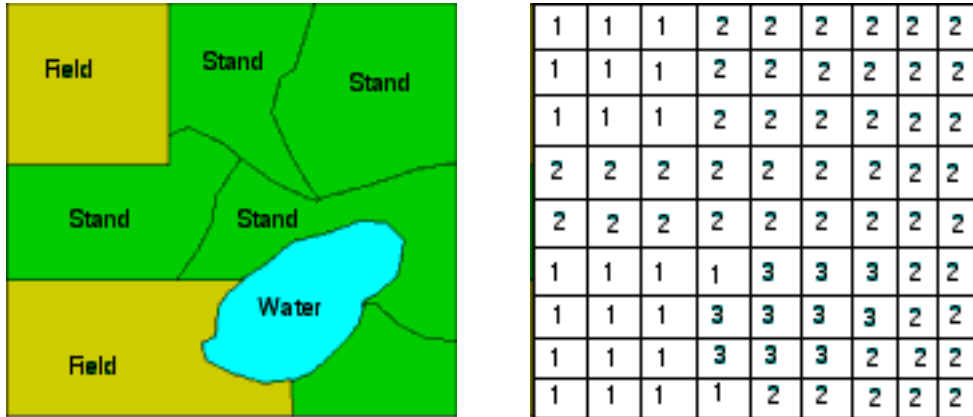


Figure 2. Digitize cover type as a raster.

Here, cell values of 1, 2, and 3 represent field, stand, and water cover types, respectively. Unlike coverages, shapefiles, or feature classes, feature boundaries are not explicitly defined in a raster.

Like coverages, shapefiles, and feature classes, though, rasters have some underlying map scale that tells something about their precision, but unlike the other formats, raster precision is also affected by cell size.

Explore

Using ArcMap, add the *accessibility* raster, located in the *Rasters* folder, as a layer.

Explore

This raster contains discrete data in 10 m by 10 m cells. There are just two cell values, 1 for timber accessible by main road and 2 for access by secondary road.

Rasters are most useful, though, for storing continuous 3D data: elevation, snow depth, or depth to water table, for example.

Triangulated Irregular Network (TIN)

This is a format designed specifically for constructing digital elevation surfaces, or digital elevation models (DEM). Using spot elevations (aka *mass points* or *point clouds*) recorded in an area, a TIN implements a linear interpolation by joining the points to form triangles of constant slope and aspect, as depicted for a portion of the Woodlot .

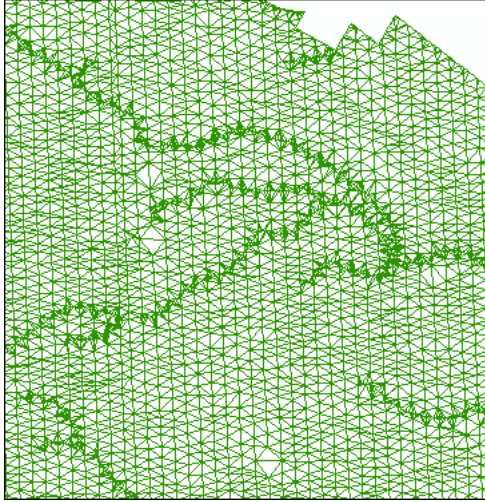


Figure 3. TIN for a portion of the Woodlot.

This network of triangles was derived using the *DTM.txt* file located in the *Mass Points* folder.

Explore

Using ArcScene™, add *tin*, located in the *Woodlot* folder, as a layer.

Double-click *Scene layers* and set the vertical exaggeration to 10.

Explore

Swivel using the  tool.

This provides an impressive 3D perspective of elevation relief in the *Woodlot*. Click anywhere with the *Identify* tool to see elevation, slope, and aspect values.

Images

Imagery takes many forms in forest inventories, ranging from aerial photographs to orthophotos to various types of satellite imagery. Sometimes the imagery is georeferenced using a coordinate system; often, it is not. The Woodlot inventory contains both.

Explore

In ArcMap, add the *cpoints* shapefile located in the *Shapes* folder and label the point features with NUMBER field values.

Explore

That displays the centerpoints for an array of aerial photos distributed across the Woodlot.

You can add and display georeferenced photos (names ending in “r” in the *Photos* folder). Since they have been georeferenced, they will align with their correct geographic position.

Add photo *L21-34r*.

If you were to try to add photos from the *Updates* folder, you’d find that they don’t display, since they have not been georeferenced.

Regardless, images are pictures, and extracting useful forest information requires some form of interpretation, computer assisted or otherwise.

But not all data in a forest inventory is spatial.

Aspatial tables

Not all feature attributes are stored in coverages, shapefiles, feature classes, rasters, or TINs. In many cases, the attributes found in these are minimal. For this reason, forest inventories often contain additional aspatial tables of attributes that describe forest features more fully. Records in these tables, however, may be associated—that is, joined—with coverage, shapefile, or feature class features via a common identifier attribute (e.g., stand number).

Explore

Use ArcCatalog to preview the *volumes* table found among the shapefiles within the *Shapes* folder.

Explore

You’ll notice that this, and some other tables, are in the dBASE (.dbf) format and can be opened with Excel just as easily as with ArcGIS.

The *volumes* table contains detailed volume amounts by species and product types for each of the Woodlot’s 533 stands. The *Stand-ID* field in *volumes* allows a join to the *cover* shapefile via its *Cover_ID* field.

Preview the *Woodlot_Codes* tables *CC\$*, *MS\$*, and *TYPE\$*. These are actually Excel worksheets. What purpose do they serve?

TYPE\$, for example, provides descriptions of the various two-letter codes found in the *TYPE* field in *cover*. Historically, this table and the other “Codes” tables provided documentation for the codes used in several *cover* fields and could be easily joined to *cover*. As you’ll discover later, there is a better way with ArcGIS and the geodatabase.

At this point, your students will know a few details about the Woodlot inventory and, generally, how a forest inventory is digitized into shapefiles, feature classes in a geodatabase, coverages, rasters, TINs, images, and attribute tables using GIS.

Lab exercises

The lesson comprises five lab exercises: *Building a Geodatabase*, *Documenting a Geodatabase*, *Building an Elevation Surface*, *Updating with GPS*, and *Updating with Imagery*.

In the first exercise, students collect the Woodlot inventory of imagery, digital maps, tables, and rasters into a personal geodatabase. In the second exercise, they encode domains and descriptions for forest attributes contained in the geodatabase. In the third exercise, students build a DEM raster from spot elevations and compare it to an existing TIN model. In the fourth exercise, students update the inventory with a new road, located with GPS. In the final exercise, students georeference an aerial photo and use it to correct an incorrectly digitized road and update the cover types feature class with two recent clearcuts.

You will need to decide whether all five labs are appropriate to your circumstances and the interests and needs of your students. All students should probably complete *Building a Geodatabase*, *Building an Elevation Surface*, and *Updating With GPS*, in that order. On the other hand, examine *Documenting a Geodatabase* closely and decide if your students really need to know the procedures introduced. If not, you can retrieve a documented geodatabase from the Inventory lesson dataset and make it available to your students for use in other lab exercises. In fact, you may want to ensure that all of your students end up working with that geodatabase for all lab exercises, rather than the one they created in *Building a Geodatabase*. Also, examine *Updating With Imagery*. Here again, depending upon student interest and need, you may want to cut the lab short, having your students complete just the georeferencing component.

While the lab exercises present engaging and realistic applications, their main purpose is exposing students to different sources of forest inventory data as well as the range of data types and techniques used in storing, manipulating, digitizing, and editing the data in a geodatabase.

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

Building a Geodatabase

Import the existing Woodlot inventory of coverages, shapefiles, rasters, tables, and images into a personal geodatabase. Convert feature classes to the newer NAD 1983 datum.

General procedure

- Create a personal geodatabase.
- Batch import shapefiles, delete their useless fields, transform them to the NAD83 datum, and assign aliases in place of their actual names.
- Import the *volumes* table.
- Import coverages into a feature dataset.
- Batch import raster datasets.
- Import orthophotos into a mosaic.
- Retrieve online data.

Concluding observations

- *Environment Settings* is used to establish geoprocessing input and output data locations, among other things.
- Digital maps are found in several formats—coverages, shapefiles, rasters, and feature classes in a geodatabase.
- A personal geodatabase stores digital maps as tabular objects using Microsoft Access.
- Geodatabase objects may include feature classes, feature datasets, tables, rasters, and images.
- Feature classes, like their shapefile and coverage counterparts, contain point, line, or polygon features and their attributes.
- Rasters capture location and attributes using a regular grid of cells.
- Feature datasets hold collections of feature classes that share a common spatial reference (coordinate system and geographic extent).
- Feature classes may be stored with their coordinate system details attached.
- Feature classes may be assigned aliases.
- Existing coverages, shapefiles, rasters, tables, and images are easily imported, one at a time or in multiples, into a geodatabase.
- Feature classes and shapefiles only contain one feature type, whereas coverages, and polygon coverages in particular, store both line (arc) and polygon features.
- When importing shapefiles or coverages into a geodatabase, selected attribute fields may be excluded.
- Feature geometry (fields *Shape_Area* and *Shape_Length*) is automatically computed for all shapes in a geodatabase feature class.
- Coordinate system assignments and changes are made using either a built-in definition or the definition associated with an existing geodataset as a reference.

Suggested student deliverables

- A personal geodatabase containing the Woodlot inventory of 10 feature classes, a table of stand volume yields, two rasters, a feature dataset containing two feature classes, and nine orthophotos collected into a mosaic dataset, all using the NAD83 datum.
- Answers to the questions posed in the exercise:
 - What happens if you try to delete the *Shape_Length* or *Shape_Area* fields in a feature class? Why?
 - Can you think of a way of importing and transforming (ATS77 to NAD83) a Woodlot shapefile into a geodatabase in one operation?
 - Why, when you transformed the Updates feature dataset to the NAD83 datum, were *_1* suffixes added to the enclosed feature class names?
 - How would you combine a collection of raster datasets into one large image?
- A paper describing the contents and characteristics of the Woodlot geodatabase using appropriate terminology including, among other things, discussion of its different data formats, as well as date, precision, and coordinate systems.
- A geodatabase for another collection of forest inventory information, assembled using techniques similar to those encountered in the exercise.
- Location of public ArcGIS servers and websites that provide useful forest and related data for your area of interest

Documenting a Geodatabase

Using ArcCatalog, assign numerous attribute field aliases and range and coded domains for various attributes in the Woodlot geodatabase.

General procedure

- Define and assign coded domains for selected fields in the cover types feature class (*cover*).
- Define and assign range domains for selected fields in the cover types feature class.
- Define and assign a coded domain for the *CLASS* attribute.
- Define and assign domains for the management compartment attribute.
- Assign attribute aliases to cover types feature class fields.
- Map a coded domain attribute in the cover types feature class.

Concluding observations

- Attribute field aliases and domains can be defined and assigned for feature classes in a geodatabase.
- Attribute field domains may be coded or range. Only numeric fields may be assigned the latter.
- A domain may be assigned to different fields in different feature classes or different fields in the same feature class.
- Aliases and domains make attribute mapping more efficient.
- Coded domain descriptions may be disabled when displaying attribute tables in ArcMap.

Suggested student deliverables

- A Woodlot geodatabase with coded and range domains, field aliases, and feature class aliases
- Answers to the questions posed in the exercise:
 - If you hadn't been told, how would you determine the data type of *TYPE*, or any feature class field?
 - If, after creating and saving a domain, you notice a mistake, such as a spelling mistake, how do you go about correcting the problem?
 - How might you actually create a *cover* field that distinguishes between forested and nonforested features in the woodlot?
 - Why use the Calculate Field tool and not Field Calculator?
- A paragraph describing, with examples, the different data types that ArcGIS supports for storing attributes
- A paragraph describing, with examples, range and coded domains
- A simple map that symbolizes Woodlot features using the Crown Closure *cover* field, but with nonstand features excluded
- A simple map that symbolizes Woodlot features using the Cover Type *cover* field.
- Location of some forest inventory data available for download via the web, then assembled into a geodatabase of feature classes and documented with feature class aliases, field aliases, and range and coded domains

Building an Elevation Surface

Build a DEM raster from mass points, and from that, a hillshade raster. Map this data in 2D and 3D using ArcMap and ArcScene. Compare the DEM raster with an existing TIN for the woodlot, derived from the same mass points. Last, derive a DEM raster from the TIN and compile slope degree and percent rasters, as well as a 5 m contour feature class.

General procedure

- Create a mass points (point elevation observations) feature class using the *ASCII 3D To Feature Class* tool.
- Build a DEM raster from the feature class using the *IDW* tool.
- View the DEM in 2D in ArcMap.
- View the DEM in 3D in ArcScene. Drape feature classes.
- Compare raster and TIN surfaces.
- View the TIN in ArcScene.
- Create an elevation surface raster from the TIN using *TIN To Raster*.
- Calculate slope surfaces and a contours feature class.

Concluding observations

- Shapefiles and feature classes may be 3D, storing z-values as well as x- and y-coordinate locations.
- The 3D Analyst™ (and the Spatial Analyst) extension provides several tools for creating elevation surfaces from mass point data. The *IDW* tool is frequently used, since elevation is distance correlated.
- A hillshade raster is used to produce a 3D effect in a 2D display.
- ArcScene produces 3D displays of surfaces but also allows 2D data and images to be draped over a 3D surface.
- A TIN is a superior means of creating a DEM but doesn't support the array of spatial analyses available for rasters.
- Unlike a raster DEM, a TIN stores aspect and slope values in addition to elevation.
- Aspect and slope surfaces may be derived from a raster DEM.
- A DEM, whether TIN or raster, is an approximation of reality.

Suggested student deliverables

- A DEM derived from mass points
- A DEM derived from the Woodlot inventory TIN
- Slope surfaces in degrees and percent derived from the DEM
- A 5 m contours feature class
- A paragraph describing the differences between a TIN DEM and a raster DEM
- A short paragraph discussing the pros and cons of TINs and rasters
- A short paragraph explaining the significance of the word *model* in a DEM
- Answers to the questions posed in the exercise:
 - Why, when running the *IDW* tool, were you instructed to use a cell size of 10 m?
 - What purpose does the *Power* value parameter serve when running the *IDW* tool?

- What does a z-factor, or vertical exaggeration, accomplish?
- In the *TIN To Raster* tool, how do you determine what cell size it uses? How would you force a specific cell size on the tool, such as 10 m?
- Location of a source of mass points data, or LiDAR (Light Detection and Ranging) data, to construct a DEM

Updating with GPS

Using GPS track data that identifies a new city street recently constructed through the Woodlot, update Woodlot roads and cover types feature classes.

General procedure

- Using the *GPS To Features* tool, save GPS track data (.gpx file) for a new city street as a shapefile.
- Using the *Points To Line* script, convert GPS track points to a line feature class.
- Merge GPS feature class with *basemap*, then use ArcMap Editor to connect its ends to existing roads.
- Copy and paste the new street from *basemap* into *roads* and connect to existing roads.
- Buffer the new street feature to 15 m, union overlay with *cover*, and remove polygons inside the buffer to create a 30 m right-of-way feature.

Concluding observations

- Shapefiles and feature classes may be edited, whereby new features are added or existing ones modified.
- When editing features, individual vertices or entire features may be moved.
- When editing features, adjacent polygons may be merged.
- When edited, feature classes in a geodatabase have their geometry automatically recomputed. Shapefiles do not.
- When editing is enabled, feature attributes are accessible from the map display using the *Attributes* tool.
- A union overlay identifies the parentage of input polygons in the output result by assigning *FID_input* values ≥ 1 .

Suggested student deliverables

- Woodlot public roads and cover types feature classes updated with the newly constructed Knowledge Park Drive city street
- Answers to the questions posed in the exercise:
 - How might you avoid the slight dogleg produced in connecting the western endpoint of Knowledge Park Drive to the existing street?
 - What would happen if *Dissolve Type* were left set to the *None* default when using the Buffer tool?
 - What exactly is a multipart feature, and what purpose does it serve?
 - How would you completely remove the Knowledge Park Drive right-of-way from the *cover_update* feature class, such that it appeared like the New Maryland Highway right-of-way that divides the Woodlot into left and right parts?

- If practical, a GPS .gpx track that identifies a new linear feature in a forest area for which you have an existing forest inventory (Apply exercise procedures to undertake the necessary updating.)

Updating with Imagery

Georeference a scanned aerial photograph and use it to digitize outlined clearcuts. Update the cover types feature class by overlaying the digitized clearcuts.

General procedure

- Using ArcMap's Georeferencing toolbar, georeference aerial photo *l20_114u*.
- Using ArcMap's Editor toolbar, correct the digitizing error in the secondary roads feature class .
- Create a new feature class and then digitize two recent clearcuts outlined on the photo.
- Update the cover types feature class with the clearcuts using a union overlay.

Suggested student deliverables

- Woodlot secondary roads feature class corrected for an out-of-place road feature.
- Woodlot cover types feature class updated with two recent clearcuts.
- Answers to the questions posed in the exercise:
 - When georeferencing an image, what does the RMS Error measure?
 - When using the Union tool, what happens if the XY Tolerance setting is set large?
 - When selecting the internal polygons in the 93 clearcut, only four were indicated, but it looked like there were 5. Why?
 - In *cover_clearcuts*, how would you remove the small leftover polygon that exists at the 10 o'clock position along the edge of the 93 clearcut?
- Using one of the other aerial photos in the Woodlot inventory, for example *l24_129*, update the cover types feature class (*cover_clearcuts*) for additional clearcuts.

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:

- A forest inventory records the thematic and ___ attributes of forest features.
- A map scale of 1:5,000 would be termed (larger or smaller) than a scale of 1:20,000.
- At a scale of 1:5,000, how much ground area would be represented by 1 mm on the map?
- What's a datum? What's a projection?
- Map projections distort one or more of the following: distance, ___, ___, ___, or ___.
- What's the datum of the Woodlot inventory? What's its projection?
- What's the area, in hectares, of the Woodlot?
- What's the scale of the Woodlot inventory?

- Metadata is ___ about data.
- A raster of elevation would contain continuous data, while a raster of cover types would contain ___ data.
- What does DEM stand for? LiDAR?
- What are mass points, aka point clouds?
- What distinguishes 3D data from 2D?
- What are the three geodatabase types supported by ArcGIS?
- A shapefile is actually several files. Identify at least four extensions you'll find attached to these files.
- What distinguishes coverages from shapefiles, or feature classes?
- What distinguishes feature classes from shapefiles?
- What distinguishes rasters from coverages, shapefiles, and feature classes?
- What's a multipart feature?
- What's a .gpx file?
- Not all feature attributes in a GIS inventory are stored in coverages, shapefiles, or feature classes. You'll often find attributes stored in ___ tables separate from these.
- What does it mean to say an image is "georeferenced"?
- What are control points? What makes for good ones?
- What purpose does the *Gaps Allowed* setting serve in a Union overlay?
- What do vertex and edge snapping refer to?