

Geospatial Technology Tools for Wildlife Management

By Wes and Leslie Burger

Aldo Leopold is credited with being the father of wildlife conservation. In his Sand County Almanac (published in 1949), Leopold said that the tools of wildlife management were “the cow, plow, ax, fire and gun.” Modern wildlife managers are certainly familiar with these tools, but today a manager’s most valuable wildlife management tool might be his desktop computer. A suite of technology tools, collectively referred to as geospatial technologies, can dramatically simplify evaluation, planning, and management of timber and wildlife resources. Geospatial technologies are used to collect, characterize, summarize, analyze, visualize and display spatial data. In this article, we want to illustrate how these technology tools can be used in an integrated fashion to help you manage wildlife, forest, and agricultural resources.

First, let’s consider what we mean by spatial data. Spatial data is data that is geographically referenced, meaning that data points, or observations, have attributes or characteristics (i.e., size, type, age, etc) and they occur at a specific and known location on the surface of the earth. A map is an example of spatial data. Features on the map (such as towns, roads, rivers, etc.) have attributes (size, population, length, road number, etc), and these features occur in a known and geographically referenced location (X-coordinate, Y-coordinate). We can define these locations with geographic coordinates, such as latitude and longitude, state plane, and Universal Transverse Mercator (UTM). A spatial database contains records of features, with their attributes and geographic coordinates. Spatial databases are different from ordinary or “flat” databases because they are relational; there is a live linkage between records in the table and features in the map. Also, in spatial databases, data can be displayed in both tabular and spatial (e.g., a map) formats.

In forestry, wildlife management, and agricultural, we deal with spatial data all the time, even if we have not recognized it as such. Timber stands have attributes (timber type,

stand age, basal area, volume, etc.), and they occur in a specific and known location that can be described with geographic coordinates. The same is true of crop fields, food plots, ponds and lakes, rivers, roads, deer stands, buildings and other structures. In fact, nearly everything we deal with in natural resource management has a spatial component. We can use geospatial technologies to help us visualize and manage the natural resources under our stewardship.

Geospatial technologies encompass a number of sub-disciplines, including remote sensing, Geographic Information Systems (GIS), Global Positioning Systems (GPS), and spatial modeling. Each of the specific sub-disciplines within geospatial technologies plays a unique role, but they are interdependent and most effectively used in an integrated fashion. Let’s briefly consider each of these sub-disciplines.

Remote Sensing

Remote sensing refers to the collection of information about the earth’s surface from a remote location or platform, such as aircraft and satellites. Satellite imagery (for example, Landsat, Ikonos, Earthwatch, Digital Globe) and aerial photography are 2 remote sensing products. The sensors that collect satellite imagery and aerial photography are based on technology that measures electromagnetic radiation reflected back from the earth’s surface. These sensors capture imagery in the visible light spectrum as well as in the ultraviolet and infrared ranges. Besides generating photographs, data collected by satellite and airborne passive sensors can also be used to locate heat emitting objects, create thermal maps of the oceans, measure plant vigor in crop fields, detect stress in trees and row crops, identify algal blooms in aquaculture ponds, measure cloud cover, and track hurricanes. Other remote sensing techniques, such as LIDAR (Light Detection and Ranging), use a laser signal to develop high-resolution topo-

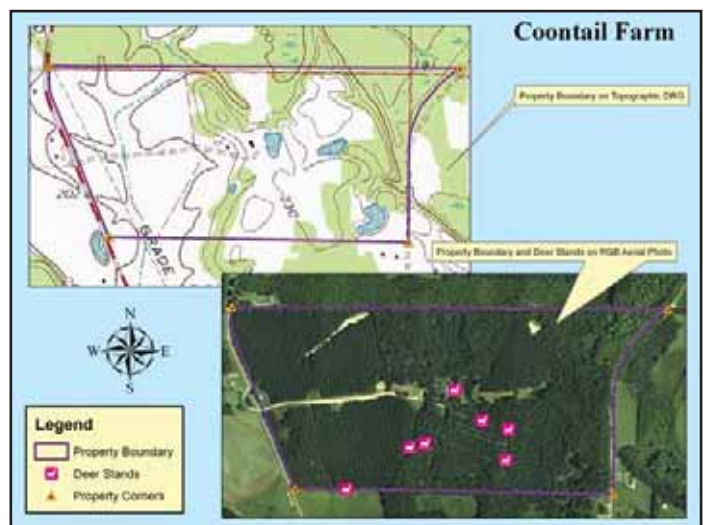
graphic surfaces, measure ozone levels in the atmosphere, and construct 3-dimensional models of timber stands.

Data captured by remote sensing devices is stored in images called rasters. A raster is made of rows and columns of square cells in a grid. The location of each cell is referenced by a row and column designation, and each cell has associated with it an attribute which describes the value (frequency, signal intensity, or color) recorded by the sensor at that location in the image. The overall raster is georeferenced to the earth's surface using control points that assign cell locations in the 4 corners of the image to geographic coordinates on the earth's surface. Since the overall image or raster is georeferenced, we can determine the coordinate locations of any cell within the image. In raster images, patches of a single habitat type (for example a timber stand) are delineated by a cluster of contiguous cells, all with the same attribute value (such as timber type = pine).

Remote sensing is an important tool for resource managers because it provides the background information for mapping the location, type, and condition of stands, fields, lakes, or other features of interest. Multiple remotely-sensed layers of the same location taken at different times (for example before and after hurricane Katrina) can be used to rapidly assess change associated with timber harvest, succession, growth, or catastrophic natural events. Remotely-sensed data, such as aerial photography, can be visually interpreted (photo-interpreted) to define management units, timber stands, habitat types, or land cover. Alternatively, sophisticated software can be used to classify images based on known relationships between reflectance and land cover type. Either way, remote sensing data provides the foundation from which GIS spatial databases are developed for use in natural resource management. Two of the more common products resulting from remote sensing are: Digital Elevation Models (DEMs), which describe topographic variation; and Digital Orthophoto Quarter Quads (DOQQs), which are scanned and georeferenced aerial photography of quadrangles or quarter quads. Digital Raster Graphs (DRGs) are scanned and georeferenced topographic quad maps and provide another useful raster product.

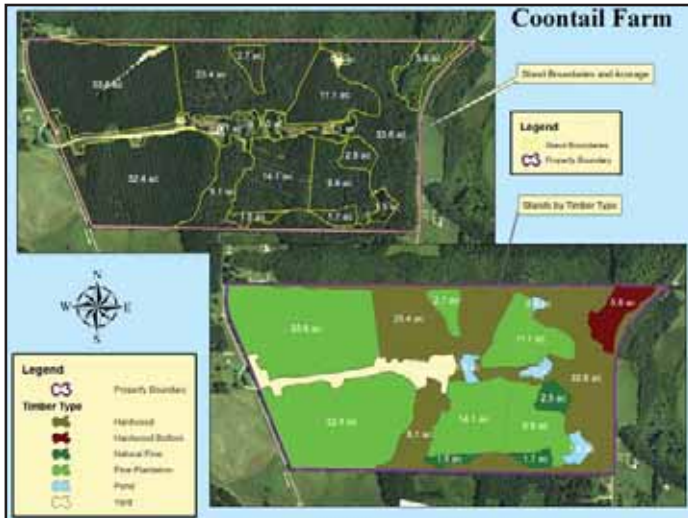
Global Positioning Systems

Today, nearly everyone is familiar with Global Positioning Systems or GPS. You may have one in your vehicle or use one to navigate while hunting. But GPS is also an important resource management tool. The component of the global positioning system that we are most familiar with is a hand-held, backpack, or vehicle-mounted receiver that is continually receiving signals from a constellation of 30 satellites in orbit around the earth. The GPS receiver calculates a position (coordinate location) by trilateration (3-dimensional triangulation) of the signals from the satellites. GPS receivers calculate their location based on time and distance relationships of radio signals coming from the satellite. The receiver receives two kinds of information from the satellite. One kind of information called ephemeris identifies the satellite by number and provides information about each satellite's location, velocity, and orbit. The second kind of information is a signal with a time stamp identifying when the signal left the satellite. GPS receivers also contain a very accurate clock. Since we know that radio-waves travel at the speed of light, if we know the time the signal left the satellite and the time it arrived at the GPS unit, we can determine the distance traveled by the signal (that is, the distance from the satellite to the receiver). Since the location of the satellite at the time it sent the



Property corners and boundaries for Coontail Farm overlaid on scanned, georeferenced quad map and aerial photo.

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Stand boundaries defined as polygons and attributed with stand type, overlaid on georeferenced aerial photo.

signal was known (from the ephemeris), using distance information from 4 or more satellites, we can determine the location of the receiver by solving simultaneous mathematical equations. This process is called trilateration. Fortunately, the receiver does this for you.

That's how it would work in a perfect world

(or a vacuum). In reality, interference from charged particles and water vapor in the atmosphere and physical objects on the earth slow the signal down. This interference introduces errors in determination of the signal travel time and, in combination with minute clock errors, introduces error in the estimate of location. A process called differential GPS (DGPS) can determine the magnitude of error and correct the locational estimate of the remote, or rover, GPS unit., thus improving the precision of GPS-determined locations. GPS locations can be differentially corrected back at the office after they are collected (post-processing) or, if the GPS is in continuous communication with a base station, corrections can be made on the fly (real-time). Many GPS units available today are WAAS-enabled. WAAS is a kind of real-time DGPS.

GPS are used to collect control points for georeferencing imagery and for mapping features that cannot be identified from aerial or satellite imagery. Roads, deer stands, timber stand boundaries, property corners, and boundary lines are often imperceptible on imagery, but easily located on the ground. GPS

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points collected at the feature can be overlaid on georeferenced imagery to determine their exact location and spatial relationship to other features. GPS can also be used to locate features and map boundaries of management activities (i.e., prescribed burn, timber harvest, food plots, etc) that occurred after the imagery was generated. Collection of GPS points while a management practice is being applied (i.e., herbicide or fertilizer application) will allow you to map precisely where the management was applied and, just as importantly, areas that might have been missed. GPS units on grain combines equipped with yield monitors allow farm managers to determine how yield varies spatially over a field. Such information helps to identify sources of variation that can be corrected (i.e., fertility, drainage, weed pressure) as well as low yielding portions of the field that might be better put in a conservation practice.

Geographic Information Systems

Geographic Information Systems (GIS) are computer software and hardware systems for creating, managing, manipulating, analyzing, summarizing, and displaying spatial data. Most GIS packages represent geographic features as points, lines, and polygons. We call this vector format, because features are illustrated by points or vertices connected by vectors (directional line segments). Each feature in the GIS spatial data base has associated with it attributes and geographic coordinates. Elements that really have no area, such as individual trees, deer stands, inventory plots, and property corners, are represented as points whose geographic location is defined by a pair of X and Y coordinates. Linear features, such as roads, streams, and rivers are represented by series of points (each with their own coordinate location) connected by line segments. At each point that the line bends or changes direction, a point called a vertex, designates the location of the change in direction. Areas such as timber stands, property boundaries, or crop fields are represented by closed polygons constructed of a series of vertices connected by line segments.

GIS software is used to construct spatial databases containing features represented as point, lines, and polygons. These features can be geolocated on the ground using a GPS, then

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imported into the GIS. They can also be created within the software by using the mouse to draw the features over a background layer (such as DOQQ aerial image or DRG topographic map) in a process called heads-up digitizing. After the geographic features are digitized, they can be attributed by entering information about each feature (for example, stand type, crop, management practice, etc.) as fields in the spatial database. Spatial databases created by heads-up digitizing inherit the spatial properties of the background layer (georeferenced image or topographic map). This means that the coordinate system of the background (Lat-Long, UTM, State Plane, etc) will be the coordinate system for the newly created spatial data layer. The GIS software can be used to measure characteristics of individual features, such as the area of a particular timber stand, or to produce summaries of all features in the database with a given characteristic (for example, the total acreage of pine).

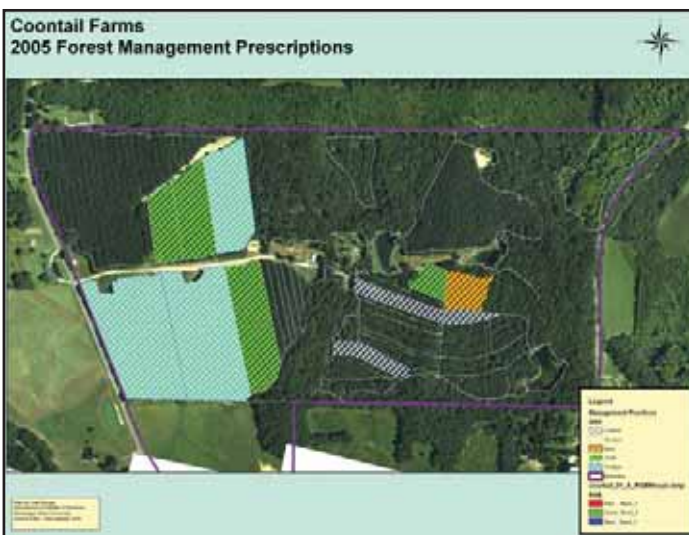
Geographic Information System software can also be used to conduct queries or searches of the database to find all records or features that meet specific criteria. For example, you might query the database to identify all timber stands with the attribute stand type = "hardwood". You can then generate a summary of total hardwood acreage in the database. Additionally, because the spatial database contains information about spatial location of each feature, you can conduct spatial queries to identify all features that exhibit a specific spatial rela-

tionship to other features in the database. An example of a spatial query would be to identify all timber stands that are adjacent to a stream, or all food plots within a given distance of a road.

Many GIS software packages also allow complex spatial tasks that would be difficult to accomplish by hand. These software functions are called geoprocessing tools and can dramatically simplify resource planning processes. An example of a geoprocessing task is buffering. Buffering allows the user to create a new polygon that contains all the area within a specified distance of an existing feature. To illustrate the utility of buffering, consider the following planning problem. A manager wants to create a 120' wide native grass buffer around the edge of a crop field and needs to know the area in the proposed habitat buffer. He could walk around the edge of the field, periodically measuring 120' off the field margin and staking this new boundary, then go back and GPS the new field boundary and subtract the area of the new polygon from the area of the entire field. Alternatively, he could create a polygon to represent the old field boundary in the GIS, buffer the inside of the polygon by 120' and instantly determine the area of the buffer without ever leaving the office.

Merging, clipping, unioning, and intersecting are other commonly used geoprocessing tools. Merging is used to combine 2 polygons into a single new polygon. Clipping is the use of one polygon to cut, or trim, the boundaries of another larger polygon or series of polygons. Union uses one polygon, or an entire spatial data layer, to cut another layer. The new unioned layer contains all the polygon boundaries and attributes of both the overlay and input layers. Intersection is used to find the area that is in common between 2 polygons. Collectively, this suite of geoprocessing tools allow managers to efficiently manipulate their spatial data for planning and analysis purposes.

There exist many different GIS software packages, most of which can be used to accomplish the same kinds of tasks. However, they differ in functionality, complexity, and cost. ESRI ArcMap is the professional, industry standard GIS software and is tremendously powerful. ArcMap can be purchased in one of 3 different configurations: ArcMap-ArcView, ArcMap-ArcEditor, and ArcMap-ArcInfo (in increasing order of cost, complexity, and func-



2005 forest management prescriptions for Coontail Farm.

tionality). ArcMap-ArcView will easily accomplish most tasks required by natural resource managers and can be purchased for about \$1300.00 (www.esri.com). There are also a number of less expensive or free GIS packages. For example, TatukGIS provides a powerful and easy to learn GIS software that is less expensive (\$350.00) than ArcMap-ArcView, but provides much of the functionality (<http://www.tatukgis.com/products/summary/products.aspx>). Both ESRI and Tatuk GIS provide a free GIS viewer that can be used to display and summarize spatial data and generate maps. However, these viewers cannot be used to create or edit spatial data layers.

Coordinate Systems

One of the strengths of geospatial technologies is the ability to integrate multiple sources of data describing various aspects of a landscape and display them as a series of layers in a single map. However, for these layers to display properly in the same 2-dimensional space, they must be in a common coordinate system. A coordinate system (for example latitude, longitude; UTM X, Y, etc.) is used to define the location of features in the map relative to their location on the earth's surface. In GIS terminology, a coordinate system has 3 components; a spheroid model, a geodetic datum, and a projection. The spheroid defines the mathematical model used to approximate the earth's surface. The most commonly used model today is the GRS-80 spheroid. A geodetic datum defines the size and the shape of the earth, and the origin and orientation of the coordinate system used to describe location. Commonly used geodetic datums include North American Datum 1927 (NAD27), North American Datum 1983 (NAD83), and World Geodetic Systems 1984 (WGS84). A projection is a mathematical model used to translate the 3-dimensional spherical surface of the earth into a 2-dimensional flat surface of a map. Universal Transverse Mercator (UTM) is an example of a projection. Because the earth is roughly a spheroid, we define location by geographic coordinates, latitude and longitude, measured in degrees, minutes (1/60th of a degree), and seconds (1/60th of a minute). Position north or south of the equator is measured by parallels of latitude that run parallel to the equator. Position east and

west is measured by meridians of longitude that run perpendicular to the equator and converge at the poles. When we make a map, we translate the spherical surface of the earth into a 2-dimensional surface using a projection. All points on the projected map are defined with coordinates that are referenced back to geographic coordinates (Lat, Lon) on the spherical surface. There are many kinds of projections. Each projection is linked to a geodetic datum and spheroid model that defines the assumptions about the size and the shape of the earth used in the projection.

Now, we understand that this is more than you wanted to know about spheroids, datums, and projections, so let's just cut to the chase. If you want data layers to properly overlay in a GIS, they must all be in the same datum and projection. If you are collecting spatial data with a GPS, you can choose which projection and datum the locational coordinates are expressed in. The datum and projection is typically defined in the configuration settings, often under a heading called COORDINATE SYSTEM. When you export the collected GPS points from your unit, the exported data set will be in the projection and datum specified in the configuration settings. Similarly, most GIS software packages can reproject data from one projection to another, if the original project is known. More sophisticated software packages will reproject "on the fly" if the original projection of the data layer is defined in a projection file associated with the data layer. The important point is make a conscious choice regarding datum and projection, then document these for each data set.

Case Study

To illustrate the integration of remote sensing, GPS, and GIS in a resource management scenario, we provide a simple case study of Coontail Farm. We contracted with a private service (Geodata Airborne Mapping and Measurement <http://www.maptheland.com/>) to collect high resolution (0.5 m) color and near-infrared georeferenced imagery for our site. We used a real-time, differentially corrected GPS (DGPS) unit to locate property corners. These were exported from our GPS and imported into ArcMap. In ArcMap, we overlaid the property corners on the georeferenced imagery and created a property boundary layer using heads-up digitizing by connecting the

corners along straight boundaries and tracing along curved boundaries (for example road frontage)(Figure 1). The total area of the property was 195.5 ac. We secured a georeferenced DRG of the topographic quad map from a Mississippi spatial data clearing house called MARIS (www.maris.state.ms.us) and overlaid the property boundaries on the quad map to illustrate topographic relief on the property (Figure 1). We then used photo-interpretation and heads-up digitizing to carve this property boundary polygon into individual stand boundaries, creating a unique polygon for each stand (Figure 2). From this stand layer we could determine the acreage of each individual timber stand. We created an attribute called "stand type". From photo interpretation, augmented by ground truthing, we determined the timber type or land use of each stand polygon. We assigned these timber types to the attribute "stand type" for each polygon. Using queries and summaries, we determined that the property consisted of 67 ac hardwood, 5.8 ac hardwood bottomland, 5.7 ac natural pine, 103.8 ac of pine plantations, 4.0 ac of pond, and 9 ac of yard and buildings. Although the high resolution imagery allowed identification of many ground features, the tree canopy obscured the location of several deer stands. We located these features with the DGPS and imported them into the GIS. From these data layers we developed year-specific forest management prescriptions for each stand (Figure 3). The precise acreage estimates allowed us to develop prescribed burn plans, order chemical and fertilizer, and plan a calendar of management activities. The maps and acreage estimates provided supporting documentation for reporting required by the various cost-share programs in which the owner had enrolled (CRP and WHIP).

Data Availability

Many geospatial data layers for your region have already been developed and are often free to download. Most states maintain a spatial data clearing house web-site where you can locate and download a myriad of layers including: DOQQs, DRGs, roads, streams, water bodies, political boundaries, physiographic region boundaries and many others. You can locate many of these sites by Googling the phrase "YOUR STATE NAME spatial data". Additionally, USDA-NRCS maintains a huge

spatial data inventory that includes county mosaics of aerial imagery and quads, at <http://datagateway.nrcs.usda.gov/>.

Summary

Geospatial technologies provide a powerful suite of software tools that can dramatically simplify the process of planning, implementing, and tracking natural resource management activities. Although, the price of software acquisition might seem high, when compared to other management (tools disks tractors, 4-wheelers, etc), the cost is quite reasonable. Relative to the time-savings that these tools can produce, the purchase cost is a real bargain. Some resource managers might be intimidated by the steepness of the learning curve associated with geospatial software. However, numerous colleges and universities offer continuing education courses in GIS and associated technologies. Mississippi State University's Department of Wildlife and Fisheries offers a 3-day introduction to Desktop GIS specifically tailored to natural resource managers. For more information, see <http://www.cfr.msstate.edu/>. Click on the Continuing Education link and go to Forestry. Geospatial technologies can make your natural resource management more efficient and effective.

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