

Digital Mapping Alternatives: GIS for the Busy Forester

Aaron M. Bernard and Steve P. Prisley

ABSTRACT

Geographic Information System (GIS) technology is rapidly becoming one of the most useful and widespread tools in our profession. As capability of these systems increase, so does their complexity. While full-featured GIS systems require a substantial time investment for learning and keeping current, various low-cost and easy-to-use alternatives are now available. These systems offer forestry professionals an opportunity to take advantage of the capabilities that geospatial technologies can offer. This article reviews some of these "small-scale" GIS systems and presents recommendations for several types of forestry applications.

Keywords: GIS, forestry applications, consulting firms

Geographic Information System (GIS) capabilities have improved dramatically in the past decade, providing resource managers with an immensely powerful information management tool. With increased capability, however, comes increased complexity. If there are numerous choices for analysis approaches, tools, data formats, etc., then there are many options the user must be aware of and many choices to make to achieve the desired results. This power therefore comes at the expense of complexity, which translates into a substantial time investment for learning and mastering the system. Often, simpler solutions are appealing because they are easier to learn and become comfortable with, and have the capability to readily accomplish the most routine tasks faced by natural resources managers. The purpose of this article is to review some simpler, if less capable, GIS software packages from the perspective of a practicing forester.

For example, ArcGIS is a popular GIS software program used by many natural resource professionals. This program is a powerful tool that has the ability to manage and manipulate spatial resource data in an amazing variety of ways. It can be applied to tasks

such as harvest scheduling, fire mapping and modeling, monitoring trends in vegetation, or simply managing various parcels of land. Complex and powerful programs such as ArcGIS allow the user substantial functionality including capabilities such as displaying georeferenced topographic maps and aerial photos, the ability to select features based on characteristics (attributes) and spatial location relative to other features, the ability to integrate information from many layers that occupy the same spatial location, advanced spatial analysis such as reclassification and spatial interpolation, and the ability to perform simple tasks such as user-defined symbology, utilizing various map units (i.e., feet, meters, etc.), the ability to zoom to any extent, and the flexibility for the user to design their own map output. However, some fundamental functions may become increasingly difficult to accomplish in this environment. For example, in ArcGIS 8.3, the common task of digitizing a stand boundary and calculating acreage can get extremely complicated. Unless the user is taking advantage of recently added capabilities of geodatabase feature classes, this process requires the use of two ESRI programs (ArcMap and ArcCatalog), more than five different func-

tions, and requires that the user copy and run statements from the Visual Basic programming language. Furthermore, the user must know and understand the coordinate system used by the data, because area estimates will be computed in square units of the coordinate system, which may be meters, feet, or degrees of latitude and longitude. Thus, a seemingly simple task can be surprisingly complicated.

Hardware and software costs are sometimes viewed as a barrier to establishing and using a GIS. However, an extremely powerful GIS (hardware and software) can be purchased for less than a year's lease on a new pickup truck. But it may not be widely recognized that the hardware and software costs are just the price of entering GIS technology. After purchase and installation, weeks of training and concentrated experience may be necessary to use this software to its full potential. The skills developed through training and experience must then be kept fresh through frequent use. Every few years, hardware and software will change and systems must be updated, often requiring additional investment of time to learn new capabilities of the system. Subsequently, it may be difficult for small-scale consulting firms and private landowners, who may not have the time, resources, or manpower, to justify this investment and reap the benefits that GIS can provide.

Large organizations such as government agencies or industrial corporations are responding to this challenge by providing their employees with access to customized spatial data display and analysis tools across the Internet or corporate Intranets. Then, with minimal training or technical expertise, users of spatial data can learn and use only

the relevant features of a GIS that can meet their everyday needs. However, such customized and streamlined tools and data sets may not be available to small organizations and individuals.

Fortunately, an increasing number of GIS programs are oriented toward the small consultant or private landowner. These programs provide for 15–20 of the most commonly used functions essential to performing routine duties of a natural resource manager, including functions for data import, maintenance, analysis, and output (Croft and Kessler 1996). By limiting the available functionality to those features most commonly used in resource information management, these programs are affordable and user-friendly. We will refer to these programs as “small-scale GIS.”

The multitude of advantages associated with GIS software creates a situation in which small companies or firms cannot afford to ignore them. Customers and clients may be quite comfortable with using an Internet-based mapping program to find a route for their vacation trip. They may therefore come to expect that a professional forester should be able to use similar technology to integrate map-based information on client’s landholdings. Upgrading to and utilizing new GIS technology and other high-tech tools requires some diligence but promises natural resource managers new means to serve their customers (Nodine 1998). Our purpose is to review some of the small-scale GIS software choices currently available that may help extend the reach of spatial information technology in forest management. While every effort was made to be inclusive in this review, some well-equipped systems may have escaped our notice. In addition, the rapid pace of change in the small-scale GIS market means that some of the functions may have changed between the time the systems were reviewed and the time this article went to press.

Methods

In this review, the standard of comparison for all GIS programs evaluated was ArcGIS 8.3, because it is perhaps the most widely used, fully functional GIS software package. Therefore, it established a benchmark for comparison in terms of functionality, ease-of-use, and cost. A three-step process was then used to evaluate the software identified and create a final ranking of potentially useful small-scale GIS packages:

1. Platform and Cost—Since the goal of this study is to review GIS software packages that are user-friendly, widely applicable, and affordable, we specified that only Windows-based programs costing less than \$500 would be considered. This information was readily available without purchasing or downloading software, so this portion of the evaluation served as an initial filter.
2. Installation and Ability to Create New Data—For the purpose of this review, we believed that the ability of a software package to create new data in both vector and raster format was of paramount importance. For example, if a user could not create a new data layer containing forest stands delineated from global positioning systems (GPS) data or aerial photographs, the software would be of limited use for a consultant or landowner. Also, we chose to review only those programs that could be readily installed without substantial operating system or programming experience. These criteria served as a second filter for software to be further reviewed.
3. Functional Capabilities—Each software package that passed through the two filters was then evaluated and ranked using a checklist based on functional criteria and ease-of-operation.

Nine small-scale GIS software packages met the criteria of the first filter (platform and cost):

- ArcExplorer (Environmental Systems Research Institute)
- GRASS (US Government)
- 3DEM (Visualization Software by Richard Horne)
- Natural Resource Database (Bohol Environment Management Office)
- PC-GIS 3.8 (Corvallis MicroTechnology, Inc.)
- Global Mapper v6 (Global Mapper Software LLC)
- MapMaker Pro v3.5 (Map Maker North America Ltd.)
- FGIS (Wisconsin DNR—Division of Forestry)
- Manifold v6 (Manifold.net)

These nine software packages were then reviewed with respect to the second filter (installation and ability to create new data). The following four programs that did not meet the requirements of the second filter were removed from further consideration.

ArcExplorer, an ESRI product, is a “viewer” program used for display, query, and data retrieval purposes. ArcExplorer does not provide the ability to create new spatial data, and therefore would not be useful for many natural resource management applications.

GRASS (Geographic Resources Analysis Support System) is a government-developed GIS software package, and as a result its code is open source and free to the public. GRASS has been used for decades on Unix platforms, but the Windows version is still experimental. The download and installation of this software is also complicated due to its open source status, and would not be considered user-friendly to those who are not extremely proficient on computers.

3DEM was eliminated because it is solely used for creating three-dimensional (3D) maps and animated landscape visualization from two-dimensional (2D) images utilizing a multitude of terrain model formats. This software may be useful for determining potential erosion risk sites by identifying steep slope terrain, mapping fire paths, aesthetic management, and public education. There is not, however, any vector or digitizing capabilities in this software that would allow for stand map and tract creation, which resulted in its elimination from further analysis in this review.

Natural Resource Database was the final program eliminated from this review because to use this software you must have an existing database of your natural resource data. Many consulting firms and private landowners taking their initial steps with GIS software would not be likely to have this information readily available or want to take the time to learn another program such as Microsoft Access to use the Natural Resource Database software.

Discussion

To uniformly evaluate and compare the five remaining GIS software packages that contain varying degrees of functionality, a set of criteria was created. The initial criteria consisted of a list of over 50 functions, ranging from basic to advance, that ArcGIS 8.3 could perform and were deemed necessary or useful for managing natural resources. Two subjective criteria were also used that involved assessing each program’s user-friendliness and ease of installation.

Once these initial criteria were established, the list was further reviewed and evaluated to merge similar functions and con-

Table 1. Checklist used to review and assess GIS software for consulting firms and private landowners.

	PC-GIS v0.3.8 (\$395)	GlobalMapper v0.6 (\$219)	MapMaker Pro v3.5 (\$400)	Manifold v0.6 (\$245)	FGIS (free)
Ease of use	High	High	Low-moderate	Moderate	High
Ease of installation	High	High	High	High	High
Ability to import various base maps.	X	X	X	X	X
Ability to digitize boundaries/polygons	X	X	X	X	X
Computes area/length/perimeter	X	X	X	X	X
Ability to utilize GPS points	X	X	X	X	X
Attribute table functionality and adaptability	High	Low	High	High	High
Map printing customization capability (title, text, legend, north arrow, scale bar)	High	Low	High	High	High
Diversity of exportable file formats	Moderate	High	High	High	Moderate
Select by attribute/location	X	X	X	X	X
Buffering capability	X	X	X	X	X
DEM functionality	NA	High	Moderate	Moderate	Low
Georeferencing	X	X	X	X	X
Reclassify options	X				
Transparency		X	X	X	X
Ability to modify spatial projections and coordinate systems	Moderate	High	High	High	Moderate
3D mapping/imaging capability	NA	Excellent	Excellent	Excellent	Moderate

dense the list. A final list was then created containing 15 of the most important functions that small consulting firms and private landowners might require in a GIS software package (Table 1). The six remaining software packages were reviewed based on this checklist (Figure 1).

PC-GIS v3.8. PC-GIS v3.8 is an advanced software package produced by CMT. (An earlier version with reduced functionality, PC-GIS v3.2, has been offered by CMT at no cost). PC-GIS v3.8 utilizes an intuitive graphic user interface that aids in creating an environment that is easy to understand for users who are new to GIS technology. This software provides essential capabilities such as reclassifying, buffering, selecting by location, and importing GPS waypoints from CMT GPS units. While PC-GIS v3.8 imports data directly only from CMT GPS receivers, GPS data from other brands of receivers can be imported from files created by freeware GPS programs such as GPS Utility (www.gpsu.co.uk). An extension to PC-GIS v3.8 called “Forester’s Toolkit” is also included, which makes this version more customized for natural resources than PC-GIS v3.2. This extension allows the user to specify, when digitizing, whether the digitized area is a stand or a tract, subsequently loading the attribute data into the appropriate table. It allows the user to add or remove “island” stands within a tract, split or combine adjacent areas, automatically label areas according to designated attribute data, insert roads, streams, and structures, and insert natural features such as endangered species habitat locations.

The ability to georeference images is another function of this software and is a very important tool for assigning geographic locations to images without coordinate information, such as scanned aerial photographs. Coordinate system adaptability is also available in this program, offering UTM, SPC, LLA, and user-defined coordinate system creation.

On-screen digitizing is fairly uncomplicated in PC-GIS v3.8 and can be a very powerful tool when used in combination with the Forester’s Toolkit. A variety of digitizing options are available, such as “snapping” new lines or points to existing ones, and auto-creation of areas from point features.

Unlike v3.2, PC-GIS v3.8 includes printing and exporting capabilities. Printing options such as inserting north arrows, scale bars, legends, and titles are available to facilitate professional map appearance. There are a variety of exporting formats including ESRI shapefiles, ASCII text files, or formats for database software such as Microsoft Access and dBase.

PC-GIS v3.8 employs many of the major capabilities of ArcGIS 8.3 for a fraction of the price and in an environment that is much more user-friendly. This is a very well rounded GIS application program that allows the user to create professional digital maps while seamlessly integrating the data.

Global Mapper v6. Global Mapper v6 (developed by Global Mapper Software LLC) is more image-oriented than PC-GIS v3.8. This software provides limited flexibility with fewer icons and toolbars, which in turn produces limited functionality. Because

this software is oriented primarily toward digital elevation models (DEM) and images, vector capabilities seem to take a backseat to the ability to produce high-quality 3D maps and images. Global Mapper’s ability to interpret and manage raster products, however, has been recently upgraded and the user is now able to directly access the entire TerraServer database from within the Global Mapper interface.

Much of the functionality of this software is devoted to creating realistic 3D images from DEMs. Seven different options for developing shaded-relief maps are available as well as a custom shader used to create individual shading criteria. Other DEM landscape model calculations are also available such as line of sight calculations, viewshed analysis, 3D path profiles, and textured overlay map functions. Very impressive, image-oriented maps can easily be created with this software.

On-screen digitizing is less intuitive with Global Mapper than PC-GIS v3.8, however. Polygon area calculations are fairly simple and are available in a multitude of commonly used scales, such as acres, hectares, square feet, and square meters. The ability to manage various projections and coordinate systems is addressed in this program as well. Similar to the ArcGIS “project-on-the-fly” capability, the Global Mapper workspace will adopt the coordinate system of the first file that is loaded, and each subsequent file, if its coordinate system does not match, will be transformed so that it overlays properly in the display. Actual modification of a dataset projection can also be performed

Corvallis MicroTechnology, Inc.	http://www.cmtinc.com/software
Offers Pc-GIS 3.2 and 3.8. Also offers other mapping and CAD software.	
Digital Grove	http://www.digitalgrove.net
Offers Global Mapper, fGIS, 3DEM, Map Maker Pro, Natural Resource Database. Also offers many other programs for cartographic needs. Links to free aerial photos, topographic maps, DEM's, data for maps, software, and other resources.	
Manifold.net	http://www.manifold.net
Offers Manifold v6 along with other mapping utilities such as their internet map server, professional edition with debugger, and enterprise edition.	
ESRI	http://www.esri.com
Offers ArcExplorer and other digital mapping software for free download or purchase.	
GRASS	http://grass.baylor.edu/
Offers GRASS software for numerous PC platforms. Also offer programming codes due to Open Source status.	
GPS Utility	http://www.gpsu.co.uk
Free software to convert GPS waypoint and routes files into numerous data types such as ESRI shapefile and dBase files, to facilitate import into GIS.	

Figure 1. Web addresses for GIS software locations.

by setting the display to the desired projection and exporting the data, or by utilizing the convert/reproject function built into Global Mapper.

One of the most important shortfalls of the Global Mapper software is its attribute display. Entering attribute information can only be done on a feature-by-feature basis and can become very tedious and time-consuming if your data contains many attribute fields. Global Mapper also lacks a centralized attribute table for groups of features such as stands or tracts. Unlike many GIS programs such as ArcGIS 8.3 and PC-GIS v3.8 that can use attribute tables that contain similar features for ease of use when editing or analyzing data, feature attribute data in Global Mapper is only contained in its respective feature file and can be viewed only when an individual feature is selected. Thus, feature characteristics are only displayed on a feature-by-feature basis rather than as rows in a table. This can be a significant disadvantage over other software packages if the user has large data sets with many features.

Global Mapper also lacks functions such as buffering capability as well as map printing options. Options such as insertion of north arrows and legends are not available and the only customization that can be performed is the insertion of a header and

footer. This problem offers very little flexibility in regards to professional map output, and if map output is a primary concern for the user, this program may not be the best choice.

MapMaker Pro v3.5. MapMaker Pro v3.5 created by Map Maker North America, Ltd., is characterized as their premium mapping software. This software package has more functionality than all other software reviewed, but is also more complex and difficult to use. The user interface of this program is comprised of less icon-oriented "point and click" navigation and more menus and report-formatted navigation. MapMaker Pro contains many of the same functions as PC-GIS and Global Mapper but expands on them to add more flexibility and customization to the maps and data the user creates.

Unlike the PC-GIS software, which only imports GPS data from CMT GPS units, MapMaker Pro is very adaptable and will accept GPS waypoint and route/track data from many common GPS units such as Garmin and Magellan. This is a valuable feature for those who rely on GPS data for boundary work and area analysis. The use of GPS control points to perform image rectification of aerial photographs can also be done in this program.

Along with on-screen digitizing, MapMaker Pro also offers more advanced operations such as "Spaghetti Processing" (lines to polygons function), intuitive cutting and joining of polygons, intersecting and unions for overlapping polygons, and raster to vector conversions. When dealing with large amount of spatial data, these functions can dramatically decrease the time required to analyze large areas of land, because it is estimated that up to 80% of the time that is required to complete a GIS project is devoted to manually digitizing stands, tracts, and other features (Devine and Field 1986).

A significant advantage that MapMaker Pro has over all other software packages reviewed is its ability to manage data from different projections and coordinate systems. It offers numerous datums and coordinate systems options, as well as UTM, Lambert's Conical, and user-defined projections.

The complexity of this program may be a disadvantage for professionals that lack technical experience with GIS programs. However, a 257-page program manual and a separate 3D mapping manual provide a valuable cartography and GIS instructional resource.

Manifold v6. Manifold v6 is a very comprehensive GIS package that has just been released by Manifold.net. This pro-

gram incorporates many of the most important functional components for geographic analysis and many more. Manifold is extremely adept at handling both raster and vector data. It is capable of performing techniques such as georeferencing, calculation and automatic updates of “intrinsic fields” such as area, length, perimeter, vector digitization, geoprocessing capabilities, utilizing live GPS capabilities with NMEA-compatible GPS receivers, and an impressive suite of map symbology attributes and options that can significantly improve professional map development. Possibly most important is Manifold’s ability to handle data of varying spatial reference. Thousands of projections and datums are available for use when importing and reprojecting both raster and vector data, and its “project on the fly” capability aids in visually assessing spatial data.

Manifold also offers many advanced GIS techniques that may not be needed by the private landowner or consulting forester. These include image fusion for satellite and aerial imagery, 3D surface and terrain analysis, remote sensing image processing, an integrated Internet map server system, decision support systems utilizing “fuzzy” logic, and a powerful programming package for customized applications. These techniques offer an advantage to those users that have a priori experience in GIS, have developed large customer data sets that need enhanced calculation capabilities, or those users that are interested in creating custom analysis tools for particular applications.

Manifold is an exceptionally well-rounded and adaptable GIS program that, for the price, is better equipped than any other program reviewed for this article. Like MapMaker Pro, however, the high degree of functionality and the complexity of the program may be a disadvantage to those users that are taking their first step in GIS and desire a simple, functional, and quick method to manage their geospatial data.

fGIS. fGIS is a freeware GIS program designed by the Wisconsin Department of Natural Resources. fGIS is specifically designed for resource managers who need a quick and easy way to make decisions regarding planning, organizing, and employing resource management techniques and decisions. This program employs many of the same functions as PC-GIS 3.8 in a very similar visual format; however, additional functions such as increased attribute table adaptability, enhanced map printing capability, and transparency settings are also

available (Table 1). Recent program upgrades have included the addition of a very easy-to-use 3D mapping utility, the ability to load XY text files into shapefiles, a live GPS utility that will display GPS points as they are being acquired in the field (as long as the GPS unit is outputting NMEA-format data), select by location/attributes, the ability to join .dbf and MS Access files to shapefile attribute tables, and the capability to convert shapefiles between Geographic (Lat/Long), UTM NAD83, and WTM NAD83 coordinate systems.

Another advantage of using fGIS is its attribute table functionality. As discussed previously, without adequate ability to modify a feature’s attribute table, the program becomes difficult to update and becomes an ineffective management tool. Editing values and fields in fGIS is very straightforward. Common fields such as Area (acres, hectares), Perimeter/Length (feet, meters, miles), and Point Coordinates (X,Y) can be automatically updated within the features attribute table. fGIS also offers many unique database functions such as the ability to populate text fields easily and quickly using the Populate function, and the ability to filter the attribute table based on a selected record.

Surprisingly offered as a free suite of GIS tools, fGIS is a very functional software package that offers the perfect introduction to using GIS for practical applications in resource management. When used as a suite with other programs such as 3DEM (www.digitalgrove.net), to make up for its lack of DEM functionality, fGIS can become a powerful management tool.

Summary

The following programs are ranked in reference to suitability for use by private landowners and consulting foresters.

1. PC-GIS v3.8 incorporated many of the checklist criteria, excluding only DEM functionality, 3D mapping, and transparency. By using specialized tools such as those found in the Forester’s Toolkit, this software package caters specifically toward forestry professionals and allows quick and easy production and updating of stand and tract spatial information.
2. fGIS is a very good program offered at no cost that incorporates more functionality than many freeware GIS packages and has the potential to be used as a stand-alone system for resource man-

agement by consultants and private landowners that need simple, useful ways to perform land management.

3. Manifold v6 was the most fully featured program of all those considered, offering GIS, remote sensing, and programming capabilities all in one software package. Many of its capabilities may be beyond the scope of the private landowner or consulting forester who is new to GIS, but for those who have experience in managing spatial data and are interested in newer and more-streamlined geospatial technologies, this may be a perfect choice.
4. MapMaker Pro v3.5 was a highly functional GIS software package, as it employed more than twice as many functions as PC-GIS v3.8 and offers the ability to customize data to the user’s specifications. The major shortcomings of this software are its steep learning curve and complexity when used as a forest management tool. Many practicing foresters may find its breadth of functionality more than they require for their land management applications.
5. Global Mapper v5 makes it easy to create visually stimulating hill-shade and 3D maps. This program requires very little GIS experience to master and can be a very useful tool for tasks such as visualizing landscapes and communicating terrain conditions. The major shortcoming with this software is its lack of a powerful attribute table. Without the presence of a central attribute table, professionals that manage large areas of land may find this program tedious and ineffective.

GIS is one of the most technologically significant advances in the forestry and natural resources field, and it is rapidly becoming one of the most useful and widespread tools in our profession (Wing and Bettinger 2003). As the public encounters a wider array of Internet sites that provide simple mapping applications, their expectations for the use of these technologies by natural resource professionals will increase. Unfortunately, the price and complexity of GIS software such as ArcGIS may intimidate many prospective users. Land managers need to know that there are other options that can fulfill their needs for management and analysis of spatial information.

Literature Cited

- CROFT, F., AND KESSLER, B. 1996. Remote sensing, image processing, and GIS. *J. For.* 94(6): 31–35.
- DEVINE, H.A., AND FIELD, R.C. 1986. The gist of GIS. *J. For.* 84(8):17–22.
- NODINE, S.K. 1998. Information technologies: Overcoming challenges, capturing opportunities. *J. For.* 96(6):4–8.

WING, M.G., AND BETTINGER, P. 2003. GIS: An updated primer on a powerful management tool. *J. For.* 101(4):4–8.

Aaron M. Bernard (abernard@vt.edu) is graduate student and master's candidate, Virginia Tech, Blacksburg, VA 24061. Steve P. Prisley (prisley@vt.edu) is associate professor, Virginia Tech, Blacksburg, VA 24061. The

authors wish to acknowledge Paul Pingrey, with the Wisconsin Department of Natural Resources, whose website (www.digitalgrove.net) provides valuable, practical mapping resources for forestry professionals. We also acknowledge the helpful comments of anonymous reviewers who alerted us to additional small-scale GIS systems.

NOTE: In accordance with Title 17 U.S.C. section 107, any copyrighted material herein is distributed without profit or payment to those who have expressed a prior interest in receiving this information for non-profit research and educational purposes only. For more information go to:
<http://www.law.cornell.edu/uscode/17/107.shtml>