Journal of the Arkansas Academy of Science

Volume 54 Article 10

2000

Method to Predict the Potential Regional Long-Term Timber Supply Using GIS and Other Publicly Available Data

Jeffery Earl
University of Arkansas at Monticello

Richard A. Kluender
University of Arkansas at Monticello

Robert Brewington
University of Arkansas at Monticello

A Method to Predict the Potential Regional Long-Term Timber Supply Using GIS and Other Publicly Available Data

Jeffrey Earl, Richard Kluender, and Robert Brewington
School of Forest Resources
P.O. Box 3468
Monticello, AR 71656

Abstract

While the global demand for wood products is on the rise, timber production has shifted from the Pacific Northwest to the southeastern United States in recent times. The increase in harvesting makes accurate assessment of the South's wood supply essential. A new method is proposed for looking at the potential supply of raw woody material. The test area was three southeastern Arkansas counties. A geographic information system (GIS) using ArcView software incorporates two sources of public information. First, Forest Inventory and Analysis (FIA) data from the USDA Forest Service were queried to find land areas and volumes by timber type, as well as growth and removals. Second, Gap Analysis Program (GAP) data were included to delineate land cover patterns. FIA growth rates were applied to the corresponding timber types. Additionally, vector layers such as roads, streams, and power lines were buffered, and those areas were then subtracted from forested land cover types. The losses to buffered areas were approximately 7 percent. The FIA data were manipulated to determine a cubic meter growth rate per year. The study revealed that the study area is capable of supplying 2,034.7 thousand cubic meters of wood per year, while the FIA data for the same area showed 2,150.9 thousand cubic meters. With both the FIA and GAP data being updated every 5-10 years, values can easily be updated to reflect changes.

Introduction

Global demand for wood products is on the rise. Timber production has shifted from the Pacific Northwest to the southern and eastern United States in recent times. The increases in harvesting make accurate inventories of the South's wood supply essential. This report looks at a method for determining the potential raw woody material supply in three southeastern Arkansas counties: Drew, Ashley and Bradley (situated within the coastal plain). All three counties have private industrial forest (timber company) lands, non-industrial private forest (NIPF) land ownerships and various state and federal holdings. The area is under intensive forest management, predominantly loblolly pine production. Several primary wood processing facilities are located within the counties, and these require a constant flow of raw materials. Accurate assessments of the timber supply within the procurement zones of these facilities are critical to the long term sustainability of the mills and the timber resource.

There are two sources of public information that are available to help predict the timber supply. The USDA Forest Service conducts its forest inventory and analysis (FIA) program approximately every 8 years to provide forest statistics for each state; the latest available data for Arkansas is 1995. Their reports include the hectares and volumes by timber type and county, as well as the growth and removals. Published tables enable one to calculate the potential average volume growth per hectare by county and timber type. The other source of information is the Gap Analysis Program (GAP). The GAP data are sponsored by the Biological Resources Division of the U.S. Geological Survey and are produced from Landsat Thematic Mapper (TM) satellite imagery. Arkansas GAP data were completed in 1998, and the project's mission is to update the imagery (and data) every 5-10 years (Scott and Jennings 1997). The GAP coverages are in the form of delineated polygons that represent different land cover patterns. The objectives of this paper are to use both sources to determine the productive timber-growing areas of the three counties, attach a growth rate to those regions, and finally to estimate the annual sustainable timber supply.

Methods

Using the Geographic Information Systems (GIS) software ArcView 3.1 (ESRI, Redlands, CA), the data for the land cover classes was analyzed and manipulated. All the data files used in the process are available on the internet from the Natural State Digital Database (NSDD) at the University of Arkansas at Monticello (Weih 2000). Most county coverages are at a spatial resolution of 1:100 000 but some of the statewide data is 1:250 000. USDA data for growth rate is also available on the worldwide web at the Southern Region Forest Inventory and Analysis (USDA Forest Service 2000). At their website, one can specify the county(ies) of interest and either get the standard forest statistics tables or request custom ones.

Several steps were involved in determining productive timber-growing regions in the three county area. Our approach was to use a 1:100 000 land cover file from the GAP data to group the timber into our areas of interest. In our three-county area, there were 10 or 12 categories of forested land, and we collapsed those into three: pine, hardwood, and swamp hardwood. Pine includes loblolly and shortleaf pine areas, as well as any oak/pine polygons. The oak/pine category was lumped in with pine because it is assumed that these primarily upland sites will be converted to pine production in the future. Hardwoods are generally those species represented in bottoms, such as willow oak, sugarberry, nuttall oak, and anything else that cannot survive in swampy areas. Swamp hardwoods include cypress, gum, and overcup oak. These categories were chosen in part to correspond with the FIA data. After collapsing the timber categories, the next step was to clip out urban areas since there were some timber areas that overlapped these boundaries (Fig. 1). At this point, there are three timber types and the areas representing each are computed.

There are interruptions in the form of roads, power lines, railroads, and streams that need to be removed from timber-growing consideration. The vector coverages for these linear features were available from the NSDD; they were therefore incorporated into the analysis. A line itself does not do an adequate job of representing the space taken up by one of these corridors, so buffering was necessary. We decided to use 18.3 meters total width for all roads and railroads and 61.0 m for utilities. A common practice along streams is to leave a management zone approximately one tree height on either side, so we chose 20.1 m on each side for a total width of 40.2 m along streams. As each vector coverage is buffered, the software computes the total area inside the new boundaries. Although this buffered area is spread over the entire county, and our interest lies only inside the polygons represented by non-urban forests. Fortunately, there is an extension for ArcView called Xtools available from the Oregon Department of Forestry (DeLaune 1999) that allows one to clip out the buffered areas by timber type. For each of the three timber types, all four buffers are clipped out separately (Fig. 2), and the result is twelve new coverages. Now all that is required is to subtract the buffered areas from each timber type to get productive hectares (Fig. 3). The ability to account for this reduction in usable hectares is what provides the accuracy to this method of supply analysis.

Attaching a growth rate to the productive timber was our next goal. One technique that was considered (but not used) required the determination of a productivity measure such as site index. Soils coverages from the NSDD were available at a 1:100 000 level, but we felt that this was too coarse a resolution to accurately assign productivity. For each soil type, an average site index could have been gathered from soil surveys and applied to the tree timber types. Instead, the FIA data were manipulated to get a cubic meter growth per year. The FIA website supplied customized tables for "Areas of Timberlands" and "Growth of Growing Stock" for each forest type group (Appendix A). By grouping the FIA forest types to match ours, it was possible to create the basis for computing a growth rate. The FIA "Growth" table represents net annual growth, so dividing forest type growth by the number of hectares yields net annual growth per hectare.

The accuracy of the data is always of some concern. In

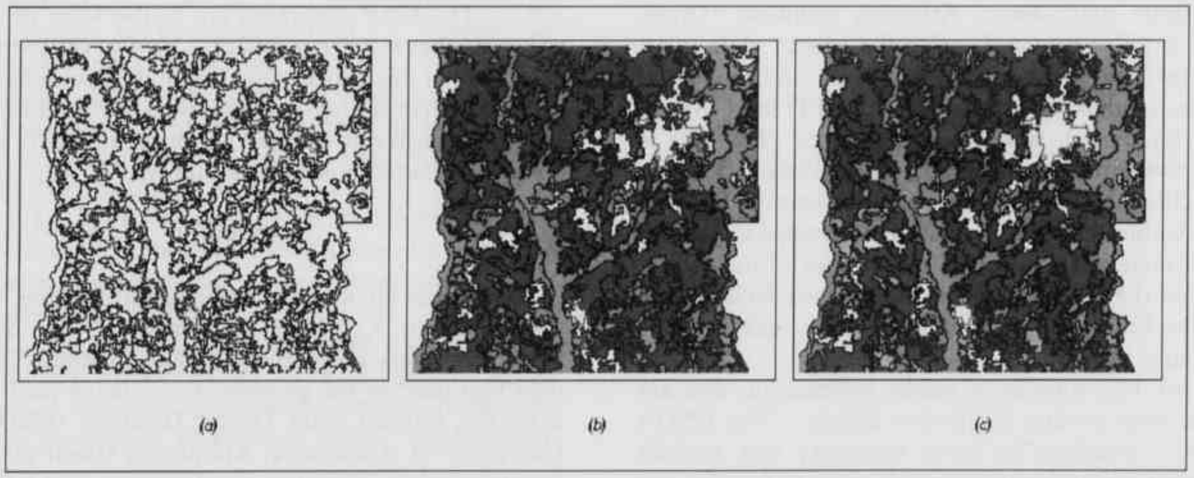

Fig. 1. Assigning timber types to the GAP data. Each land cover class is represented by a polygon in (a). In (b), the timber cover classes have been collapsed down into three categories: pine, hardwood and swamp hardwood. Note that the blank areas represent non-timber classes such as agriculture, pasture, water, or bare ground. Also, the urban areas are outlined and you can see that there is some overlap with the timber types. Therefore, (c) shows urban areas clipped out of the timber. The clipped timber regions represent the starting point for determining productive timber-growing areas.

Fig. 2. The process of removing buffered areas from timber types. In (a), the streams, roads, utilities and railroads are assigned buffers of 40.2 m, 18.3 m, 61.0 m, and 18.3 m, respectively. Next, you can see the overlay of the pine timber type in (b). Finally, the buffered areas are clipped to the boundaries of the pine areas (c). The areas for the buffers can then be subtracted from timbered areas to get only timber areas in production, and this step is repeated for all three timber types.

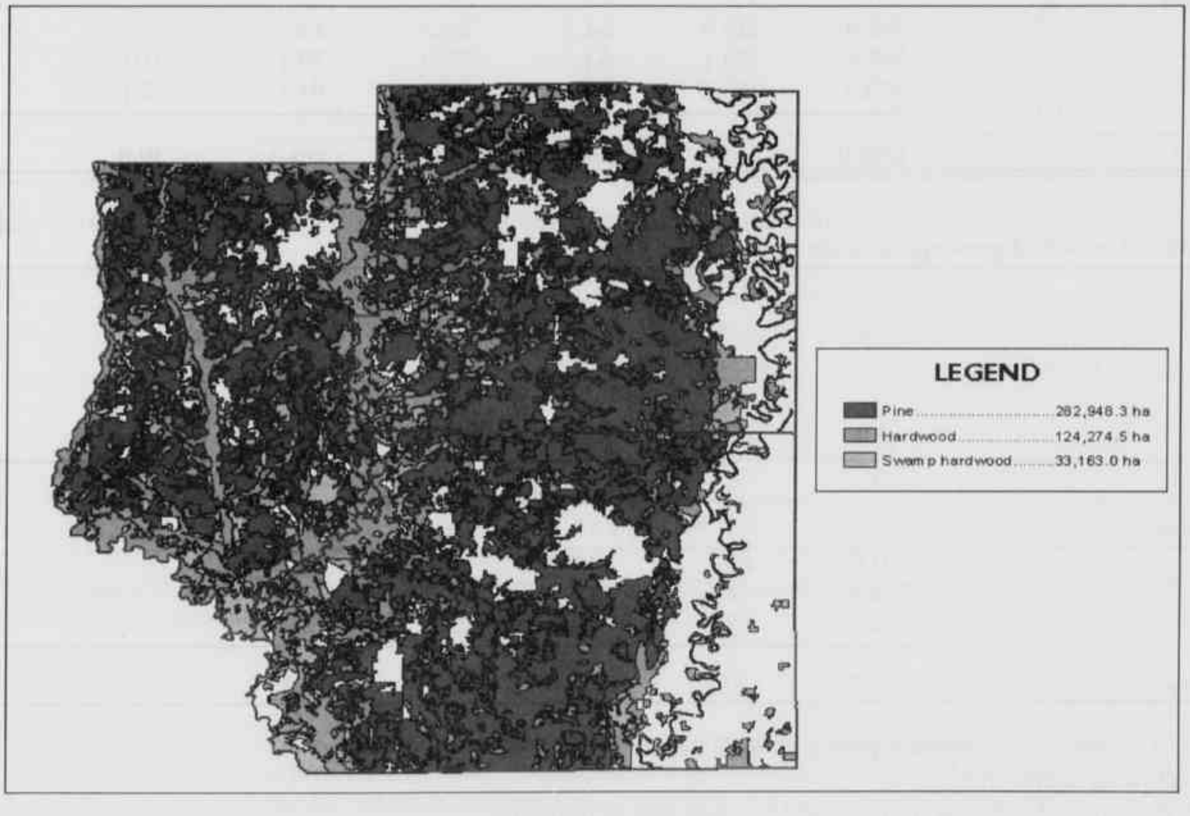

Fig. 3. Three counties showing areas classified as pine, hardwood, and swamp hardwood. Areas are based on original GAP data with subtractions for buffered corridors and cities.

the FIA publication, the sampling error (for one standard error) of growing stock growth in all southwest Arkansas counties is 2.7 percent (Rosson and others 1995). If we narrow that to the three counties of interest, the sampling error is approximately 6.7 percent (Appendix B). The GAP data certainly has error, but it is more difficult to quantify because each state uses different techniques to meet the national GAP standards. Because the original source is Landsat TM imagery, there will always be the problem of mixed pixels, where each pixel from the satellite image does not represent a homogenous cover type. According to Burrough and McDonnell (1998), this occurs when the size of the grid cell is larger than the feature on the ground. Error is associated with both the positional accuracy as well as classification of land cover types. According to the CAST report (1998), the positional accuracy is 50 m, and several of the forest categories were at least 75% accurate. While that is not great, we feel that by grouping the GAP categories together, the accuracy improved because we were only interested in the areas of forests associated with upland, bottomland, and swampy sites.

Appendix A. FIA Database Retrieval System Output

Custom table - Area of timberland

		Forest type group				
County	All	Loblolly-shortleaf pine	Oak-pine	Oak-hickory	Oak-gum cypress	Elm-ash-cottonwood
				-thousand acres-		
Arkansas						
Ashley	387.0	218.0	54.5	54.5	54.5	5.5
Bradley	377.4	170.4	54.8	73.0	79.1	0.0
Drew	373.5	163.7	87.0	56.3	61.4	5.1
All counties	1138.0	552.2	196.3	183.8	195.0	10.6

Custom table - Growth of growing stock on timberland

		Forest type group				
County	All	Loblolly-shortleaf pine	Oak-pine	Oak-hickory	Oak-gum cypress	Elm-ash-cottonwood
				-million cubic feet-		
Arkansas						
Ashley	31.6	23.7	2.8	2.4	2.7	
Bradley	22.4	14.4	3.3	1.9	2.9	
Drew	22.5	12.1	5.4	2.7	2.3	
All counties	76.6	50.2	11.4	7.0	8.0	

- Timberland consist of nonreserved land only in this table for the following states: (AR).
- Numbers in rows and columns may not add to totals due to rounding.
- The data are derived by sampling and are subject to statistical error.
- Source Southern FIA : Asheville, NC
  States:(AL,AR,FL,GA,KY,LA,MS,NC,OK,SC,TN,TX,VA)
  For assistance contact: Joe Glover 704-257-4350
  homepage http://www.srsfia.usfs.msstate.edu

Appendix B. Calculation of Sampling Error for Counties of Interest

Custom table - Growth of growing stock on timberland on Southwest Arkansas counties

County	All	Loblolly-shortleaf pine	Oak pine	Oak hickory	Oak-gum cypress	Nontyped
		Forest type group				
			-million cubic feet-			
Ashley	31.6	23.7	2.8	2.4	2.7	0.0
Bradley	22.4	14.4	3.3	1.9	2.9	0.0
Calhoun	25.8	17.6	5.2	1.4	1.5	0.0
Clark	26.6	16.7	6.5	2.6	0.8	0.0
Cleveland	24.5	12.1	6.1	4.2	2.1	0.0
Columbia	30.3	18.7	4.2	4.7	2.7	0.1
Dallas	27.5	19.5	4.4	2.0	1.7	0.0
Drew	22.5	12.1	5.4	2.7	2.3	0.0
Grant	26.7	20.2	2.0	3.2	1.3	0.0
Hempstead	27.0	15.2	4.1	6.2	1.6	0.0
Hot Spring	23.5	13.1	6.0	2.2	2.3	0.0
Howard	22.5	15.6	3.6	2.5	0.9	0.0
Lafayette	16.4	10.8	1.9	3.2	0.5	0.0
Little River	13.4	7.7	2.1	1.6	2.1	0.0
Miller	10.4	4.3	3.2	1.2	1.7	0.0
Nevada	22.7	14.2	3.8	4.1	0.5	0.0
Ouachita	25.2	14.7	5.8	1.5	3.3	0.0
Pike	23.3	18.0	1.6	3.5	0.2	0.0
Sevier	11.5	5.8	1.7	3.0	1.0	0.0
Union	40.8	24.7	7.2	3.2	5.6	0.0
All counties	474.5	298.9	80.8	57.0	37.6	0.1

Custom table - Growth of growing stock on timberland in Ashley, Bradley, and Drew counties

County	All	Loblolly-shortleaf pine	Oak pine	Oak hickory	Oak-gum cypress	Nontyped
		Forest type group				
			-million cubic feet-			
Ashley	31.6	23.7	2.8	2.4	2.7	
Bradley	22.4	14.4	3.3	1.9	.9	
Drew	22.5	12.1	5.4	2.7	2.3	
All counties	76.6	0.2	11.4	7.0	8.0	

The overall sampling error (SE_t) for Growing Stock Growth in southeast Arkansas is 2.7 percent. To compute sampling error for only the three counties of interest, this formula may be used:

$$SE_g = SE_t \frac{\sqrt{X_t}}{\sqrt{X_g}}$$

where

SE_g = standard error of the estimate (expressed as a percentage) for the group of counties
SE_t = standard error of the estimate (expressed as a percentage) for the total counties
X_g = total volume for the group of counties
X_t = total volume for the total counties

If you insert the total growth volume from the two tables above into the formula, you get the following:

$$SE_g = 2.7 \frac{\sqrt{474.5}}{\sqrt{76.6}} = 6.7$$

Table 1. Areas and usable areas by timber type for three counties

	Ashley County Hectares		Bradley County Hectares		Drew County Hectares	
Pine area	114,088.0		82,027.9		105,772.4	
Buffers:						
Streams		4,398.8		2,454.8		4,957.9
Roads		2,493.7		1,795.6		1,904.1
Railroads		110.2		69.6		75.2
Utilities		250.9		187.7		223.6
TOTAL Buffers	7,253.6		4,507.7		7,160.8	
Usable pine area	106,834.4		77,520.2		98,611.6	
Hardwood area	37,075.7		56,827.6		42,060.8	
Buffers:						
Streams		2,479.4		3,784.9		3,265.2
Roads		524.2		708.0		571.5
Railroads		36.8		57.0		15.6
Utilities		56.0		87.4		95.7
TOTAL Buffers	3,096.4		4,637.3		3,948.0	
Usable hardwood area	33,979.3		52,190.3		38,112.8	
Swamp hwd area	12,547.3		15,509.5		7,024.4	
Buffers:						
Streams		552.7		470.6		297.3
Roads		167.9		262.9		115.5
Railroads		10.3		11.8		3.8
Utilities		0.0		23.3		0.0
TOTAL Buffers	730.9		768.6		416.6	
Usable swmp hwd area	11,816.3		14,740.9		6,607.8	
Total Timber hectares	163,710.9		154,365.0		154,857.6	
Total Usable hectares	152,630.0		144,451.5		143,332.3	
Percent usable	93.2%		93.6%		92.6%	

Results and Discussion

Areas by county and timber type (using the GAP data), as well as the areas removed by buffered corridors are shown in Table 1. The three-county area has approximately 283,000 hectares of pine and 157,000 hectares of hardwoods in productive use (after the buffered areas were subtracted). The percent of total pine contained in the buffers ranged from 5.5 to 6.8 percent. Hardwood losses were from 8.2 to 9.4 percent, while swamp hardwoods lost 5.0 to 5.9 percent to buffers. Overall, buffers accounted for between 6.4 and 7.4 percent

Table 2 shows the production volumes for using both the FIA and GAP data, although the GAP volumes are based on the usable area. Because of this, there may be an overestimation of the timber supply using FIA hectare estimations. For instance, there is a discrepancy of over sixteen thousand cubic meters between the FIA and the GAP methods of determining supply for pine, and this is based solely on the differences between our method of area calculation and the FIA's method. By delineating the areas which are not in production, the GAP method should provide more accuracy, although it still relies on the FIA data for growth rates. So for the three counties, our annual projection for timber supply is 1,620.8 thousand cubic meters of pine, 318.0 thousand cubic meters of hardwood, and 93.5 thousand cubic meters of swamp hardwood. The inclusion of the 6.7 percent sampling error in these estimates using a 95

Table 2. Comparison of FIA and GAP data for three counties

FIA Data

Timber type	Ashley	Bradley	Drew
		County	
		Land Area (ha)	
Pine	110,236.5	91,175.8	101,495.3
Hardwood	22,014.9	29,542.1	22,783.8
Swamp	24,362.1	32,010.7	24,847.7
		Production (m^3/yr)	
Pine	744,737.6	498,379.6	489,884.5
Hardwood	67,960.8	50,970.6	73,624.3
Swamp	79,287.7	84,951.1	59,465.7
		Growth rate (m^3/ha/yr)	
Pine	6.8	5.5	4.8
Hardwood	3.1	1.7	3.2
Swamp	3.3	2.7	2.4

GAP Data

Timber type	Ashley	Bradley	Drew
		County	
		Land Area (ha)	
Pine	106,827.6	77,515.3	98,605.4
Hardwood	33,977.1	52,187.0	38,110.4
Swamp	11,815.6	14,740.0	6,607.4
		Production (m^3/yr)	
Pine	721,446.4	423,556.1	475,763.4
Hardwood	104,850.5	90,008.6	123,106.4
Swamp	38,440.5	39,103.3	15,807.2

percent confidence interval yields the following computations:

Pine: $1620.8 \pm 1.96(.067*1620.8) = 1620.8 \pm 212.8$ thousand cubic meters
Hardwood: $318.0 \pm 1.96(.067*318.0) = 318.0 \pm 41.8$ thousand cubic meters
Swamp Hardwood: $93.4 \pm 1.96(.067*93.4) = 93.4 + 12.3$ thousand cubic meters

The usable areas have the potential to produce these amounts of raw woody materials available for purchase. Another big assumption is that this production will remain constant, which may or may not be realistic given the nature of forest cutting trends.

Conclusions

This model allows resource managers to look at the growth trends for an area from one period to the next. Comparing growth to removals gives insight to the sustainability of the area's timber resources during the period. There is a definite imbalance in hardwood production and hardwood removals. The removals were far greater than the growth for all counties at the time the FIA data were published. This is due largely to the fact that pine plantations are replacing hardwoods on sites that are suitable for pine growth (mostly industrial forests), and this trend will probably continue until the sites able to grow pine have been converted. At that time the hardwood areas should stabilize and growth will remain fairly steady. It remains to be seen if there will be a large enough hardwood base to supply the wood needs of the hardwood processing facilities. Clearly the burden will fall on NIPF lands to make up for any shortcomings in hardwood supply. Comparing this period with future periods should uncover long-term trends in timber supply. With the GAP update every 5 to 10 years and the FIA data published every eight years, the two sources should never be more than five to eight years apart and can be used for future updates to a model like this.

Another potential use of supply information could be locating new mills. Timber companies could find areas with a potential wood supply that would sustain a new mill. It could also play a part in whether a mill decides to expand its current operation or keep operating at the same capacity. Accurately predicting the capabilities of an area to produce raw materials will be of increasing concern to mill operators in the coming years as the demand for wood products increases. This technique combined with FIA or some other method of determining growth could help to better predict an areas production potential.

We found this method to be fairly easy using ArcView and the resources of the worldwide web. It can also be customized to look at specific areas and specific species. Because the method uses FIA data, it does represent a dynamic growth model since FIA incorporates the previous survey's data with its newest data to produce the statistical reports. As noted earlier, caution should be taken when extracting individual counties or small groups of counties from the FIA data because the potential for sampling error is high.

Literature Cited

Burrough, P. A., and **R. A. McDonnell.** 1998. Principals of Geographical Information Systems. New York: Oxford University Press Inc. p 231-32.

[CAST] Center for Advanced Spatial Technologies. 1998. "Landcover Classification and Mapping". <http://web.cast.uark.edu/gap/chap2.htm>

DeLaune, M. ODF State Forests GIS Data & Tools. Oregon Department of Forestry. 18 Oct. 1999. <http://www.odf.state.or.us/sfgis/>

Rosson, J. F., A. J. Hartsell, and **J. D. London.** 1995. Forest statistics for southwest Arkansas counties–1995. Resour. Bull. SO-194. New Orleans, LA: U.S. Dept. of Agriculture, Forest Service, Southern Research Station. p 2.

Scott, J. M. and **M. D. Jennings.** "A Description of the National Gap Analysis Program". U of Idaho. March 1997.<http://www.gap.uidaho.edu/About/Overview/GapDescription/default.htm >

USDA Forest Service. 2000. Southern Region Forest Inventory and Analysis. <http://www.srsfia.usfs.msstate.edu/>

Weih, RC. 2000. Natural State Digital Database. U of Arkansas–Monticello <http://sal.uamont.edu/sal/nsdd/default.htm>