ASSESSING THE ECONOMIC EFFECTS OF STREAMSIDE MANAGEMENT ZONES ON THE FORESTRY SECTOR

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ABSTRACT

This study assessed the economic effects of designating streamside management zones (SMZs) on current timber supplies and prices and projected those impacts into the future (2010). The study focused on southeast Alabama, a 21-county region identified as a unique FIA region by the USDA Forest Service. A Landsat MSS-based classified forest type map of southeast Alabama was used to calculate area in the SMZs by forest type and county. Combining FIA volume per acre estimates with the area in SMZs estimated in a GIS analysis, provided estimates of timber volumes in the SMZs. The Southeastern Regional Timber Supply (SERTS) model, an economic timber supply projection model, was used to assess the market effects of the set-asides due to establishment of the SMZs.

INTRODUCTION

Best Management Practices (BMPs) are forestry guidelines about the placement, construction, and maintenance of permanent and temporary logging roads, stream crossings, streamside management zones, and the choice of site preparation methods and equipment used. BMPs are designed to maintain and protect the physical, chemical and biological integrity of waters of the state as required by the Federal Water Pollution Control Act, the Alabama Water Pollution Control Act, the Clean Water Act, the Water Quality Act and the Coastal Zone Management Act.

Streamside forests are extremely complex ecosystems that help provide optimum food and habitat for stream communities as well as being useful in mitigating or controlling NPSP. Of all ecosystem variables, water is perhaps the most sensitive to the disturbance of vegetation and soils on the land's surface (Arnold 1985). Streamside forests can be effective in removing excess nutrients and sediment
from surface runoff and shallow groundwater and in shading streams to optimize light and temperature conditions for aquatic plants and animals (Welsch 1991). A streamside management zone (SMZ) is a strip of land immediately next to a stream or lake where soils, organic matter and vegetation are managed to protect the physical, chemical and biological integrity of surface water both on-site and downstream from forestry operations (Alabama Forestry Commission 1993).

Southern timber markets represent a major source of softwood stumpage production in the United States (USDA Forest Service 1988). With the establishment of SMZs, accessible timber volumes are effectively reduced. Since timber supply depends in part on available inventory and costs of production, SMZs will affect timber supply and timber prices in the market. Although the effects of establishing SMZs on water and environmental quality may be positive, they are very difficult to estimate. The impacts of SMZs on timber supply, timber price and local economy can be estimated with available methods.

The purpose of this study is to assess the economic effects of designating SMZs on current timber supplies and prices and project those impacts into the future (2010). The project focused on southeast Alabama and required five Landsat MSS scenes covering the area for use as a cartographic base. A supervised classification of land cover types within the study area was undertaken using the public domain Geographic Resource Analysis Support System (GRASS) GIS software package. From this, a MSS-based classified forest type map of southeast Alabama was generated. This map, in turn, was used to calculate area in SMZs by forest type and county. The timber supply model used in this study to project future timber inventory and price trends requires base line estimates of the timber inventory. These are obtained from the Forest Service through their Forest Inventory and Analysis (FIA) program. The base line projections are then compared to projections where the timberland base is adjusted to account for the reduction in available timber resulting from the establishment of SMZs. The amount of the adjustment comes from the GIS. The GIS-computed SMZ areas were combined with FIA volume-per-acre statistics, which when merged with SMZ area figures, yielded an estimate of total timber volume within the SMZs.

Satellite imagery and geographic information systems

Satellite imagery is recognized as a useful tool for forest protection, wildlife habitat identification, and forest mapping and inventory. Forestry oriented GIS/Remote Sensing applications by Karteris (1988), Kautz (1992), Hopkins et al. (1988), Stenback and Congalton (1990), Moore and Bauer (1990), and Bolstad and Lillesand (1992) among others, have demonstrated the utility of satellite remote sensing to forest science. Evans and Hill (1990) analyzed Landsat TM versus MSS data for forest type identification. They found that TM data were superior to MSS data for pine-type identification, but were not significantly better than MSS data for pine and hardwood separation.

GIS is also a good tool for environmental impact analysis. Shasko and Keller (1991) used GIS to assess large scale slope stability and failure. They concluded that it was possible and feasible to integrate sophisticated slope modeling in GIS using available digital inventories as input data at any scale. Engel et al. (1993) integrated the AGricultural Non-Point Source (AGNPS) pollution model with the GRASS GIS tool to develop a decision support tool to assist with management of runoff, erosion, and nutrient movement in agricultural watersheds. Preliminary results suggest that the integrated GIS/AGNPS model allows the rapid identification of problem areas in the management of non-point source pollution. Cheng (1992) applied GIS techniques in estimating soil erosion in the National Taiwan University experimental forest. He suggested that linking a GIS and the universal soil loss equation is a cost-effective and feasible approach to estimating soil erosion compared with the traditional ground survey approach.
The study area and data

This study focused on southeast Alabama (Figure 1), a 21-county region established as a unique FIA region by the USDA Forest Service. Map data required to conduct this study included an Alabama State Map (Scale 1:500,000) and 7.5 minute series quadrangle maps (Scale 1:24,000) for the entire area as well as parts of western Georgia and northern Florida.

Landsat MSS digital data in four different bands were also required. Band 4 records data in the green spectral region from 0.5 to 0.6 micrometers. Band 5 records visible red data between 0.6 to 0.7 micrometers. Band 6 and Band 7 records near infrared radiation at 0.7 - 0.8 micrometers and 0.8 - 1.1 micrometers, respectively. These bands were selected for studying agricultural landscapes. The large area coverage of Landsat MSS (31,450 square kilometers per scene) is particularly useful for general land cover classification and area estimates, especially when financial resources are limited (Hicks et al. 1993). Furthermore, archived Landsat MSS data are available at discounted prices, making this data source very cost effective. The project required five Landsat MSS scenes covering all of southeast Alabama. These scenes had mid January - early February acquisition dates ranging from 1988 to 1990.

TIGER/Line data were also used in this study. TIGER (Topologically Integrated Geographic Encoding and Referencing) files contain digital data that represent physical features and nonvisible boundaries, such as political boundaries and census statistical areas for the entire United States. TIGER files provide a cost effective source for line data with accuracy levels appropriate to work at a regional scale. TIGER files of Alabama, Georgia, and Florida were used in the study.

Figure 1. Southeast Alabama study region.

METHODS & RESULTS

Image classification

Supervised classification was used in this study. Training sites were taken using specific forest type location data supplied by Mead Corporation of Columbus, Georgia, or obtained from a pre-digitized stand classification map of The Dixon Forestry Education Center at Dixie, Alabama. All five classified MSS scenes covering the 21 counties in southeast Alabama were patched. The patching procedure allows the analyst to assign known data values from one raster map layer to the "no data" areas in another adjacent raster map layer. By masking the southeast Alabama region and then
patching the rectified maps, a patched map of southeast Alabama was created and analysis was focused on this region.

Forest types were reclassified as natural pine, planted pine, upland hardwood, bottomland hardwood, and mixed pine hardwood. All remaining categories were reclassified as nonforest and water. Because the maximum likelihood algorithm classified images pixel by pixel, there might be some individual pixels with different category values scattered among forest areas that might influence the classification agreement. Therefore, each cell was reclassified again using a neighborhood reclassification algorithm to improve classification results.

The primary goal for this aspect of the work was to be able to distinguish pine and hardwood types. When the pine types were combined as "Pine" and the hardwood types were combined as "Hardwood," the classification agreement results achieved were "Pine" agreement (76 percent) and "Hardwood" agreement (59 percent). The overall agreement was 67 percent.

Estimating the areal extent of and timber volumes in SMZs

Streams extracted from the TIGER files for Alabama (in vector format) were converted to raster format and combined with the classified images. The SMZs were delineated using GIS masking and buffering techniques. The information obtained from processing the data in this way allows for estimation of area in SMZs by forest type and county.

According to Brinker (1991), the required width of a SMZ depends on the type of groundcover, soil erodability, degree of slope, shape of the stream area, and type of stream. He suggested a minimum SMZ width of 50 feet on each side of the stream is adequate where stream-side slope is 10 percent or less. For each additional 10 percent of increased slope, add 20 feet of width to the SMZ. In general, the steeper the slope or more erodible the soil, the wider the SMZ needs to be. A landowner’s personal management objectives, on-site conditions or stream sensitivity may require wider SMZs and more stringent control of forestry operations within the SMZ. This study examined the effects of establishing SMZs at three different average widths, 10 meters (33 feet), 15 meters (50 feet), and 25 meters (83 feet). The average width of streams was assumed to be 10 meters. The 10 meter width SMZ (on each side of a stream) represents the minimum recommended by the Alabama guidelines. The 15 meter width includes additional area for addressing some secondary SMZ functions which include consideration for wildlife and recreation objectives. The 25 meter width represents a higher level of protection, possibly necessary to protect other environmental and aesthetic objectives.

Timberland areas for the 15 meter width SMZs are given in Table 1. For all SMZ widths analyzed, Barbour county was the biggest contributor in terms of area of timberland lying within SMZs and Geneva county was the most important in terms of percent of timberland in SMZs. The county with the least timberland area in SMZs was Houston, while Lee was the county with the lowest percentage of timberland in SMZs.

Assuming homogeneity of timber types throughout the county, area in SMZs by age class and forest type was calculated according to the proportion of total area for each age class in each forest type by county from the FIA statistics. Multiplying the area by volume per acre, the timber volumes in SMZs by forest type, age class and county were derived. These estimates (volumes in SMZs) were used to assess the economic effect of establishing SMZs on the forestry sector using an economic timber supply model.
Table 1. Summary of timberland area of 15 meter width SMZs on each side of streams.

<table>
<thead>
<tr>
<th>County</th>
<th>Timberland area (FIA)</th>
<th>Area in SMZ</th>
<th>Percent in SMZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>----- Thousand acres-----</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autauga</td>
<td>283.1</td>
<td>8.64</td>
<td>3.05</td>
</tr>
<tr>
<td>Barbour</td>
<td>409.5</td>
<td>13.59</td>
<td>3.32</td>
</tr>
<tr>
<td>Bullock</td>
<td>290.8</td>
<td>10.71</td>
<td>3.68</td>
</tr>
<tr>
<td>Butler</td>
<td>389.4</td>
<td>10.82</td>
<td>2.78</td>
</tr>
<tr>
<td>Chambers</td>
<td>316.0</td>
<td>7.74</td>
<td>2.45</td>
</tr>
<tr>
<td>Chilton</td>
<td>329.4</td>
<td>8.91</td>
<td>2.70</td>
</tr>
<tr>
<td>Coffee</td>
<td>262.4</td>
<td>9.32</td>
<td>3.55</td>
</tr>
<tr>
<td>Crenshaw</td>
<td>304.7</td>
<td>8.76</td>
<td>2.88</td>
</tr>
<tr>
<td>Dale</td>
<td>224.4</td>
<td>7.87</td>
<td>3.51</td>
</tr>
<tr>
<td>Dallas</td>
<td>354.3</td>
<td>10.53</td>
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<td>Elmore</td>
<td>245.9</td>
<td>6.19</td>
<td>2.52</td>
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<tr>
<td>Geneva</td>
<td>206.8</td>
<td>8.94</td>
<td>4.33</td>
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<tr>
<td>Henry</td>
<td>206.0</td>
<td>7.49</td>
<td>3.64</td>
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<tr>
<td>Houston</td>
<td>125.1</td>
<td>3.09</td>
<td>2.47</td>
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<tr>
<td>Lee</td>
<td>256.0</td>
<td>4.80</td>
<td>1.88</td>
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<tr>
<td>Lowndes</td>
<td>258.9</td>
<td>9.16</td>
<td>3.54</td>
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<tr>
<td>Macon</td>
<td>288.8</td>
<td>10.41</td>
<td>3.61</td>
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<tr>
<td>Montgomery</td>
<td>211.4</td>
<td>6.63</td>
<td>3.14</td>
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<tr>
<td>Pike</td>
<td>293.6</td>
<td>9.63</td>
<td>3.28</td>
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<tr>
<td>Russell</td>
<td>284.0</td>
<td>8.90</td>
<td>3.14</td>
</tr>
<tr>
<td>Tallapoosa</td>
<td>378.5</td>
<td>8.54</td>
<td>2.26</td>
</tr>
</tbody>
</table>

Timber supply modeling

Timber supply projections are very important to the investment decisions of forest industries and nonindustrial private forest landowners. Forest products firms make decisions on investments in plants, equipment, land, and trees that depend on assessments of current and future forest conditions. Other private landowners are also influenced by assessments of future conditions in making their forestry decisions.

The SERTS (Abt et al. 1993) model was used to assess the effect of establishing SMZs on a 20-year timber inventory and supply projection. Volume and acreage data for the SMZs from the GIS portion of the analysis were used to adjust the baseline FIA data to reflect the effect of withdrawals from the timberland base. Timber harvest levels for the case with SMZs were assumed to be the same as timber harvest levels for the base case (without SMZs) throughout the projection period.

The SERTS model was used because of its ability to project the market effects of changes in a regional timber supply situation. It combines a simple inventory model, GRITS (Cubbage et al. 1991), and an economic market model, SRTS (Abt 1989), to provide the timber supply and price projections necessary to evaluate the economic effects of designating SMZs. SRTS models supply as a function of price and beginning of period inventory. SRTS assumes that price is determined by the interaction of supply and demand in the aggregate market. This regional price is then applied to the supply curves of each individual subregion to determine harvest by subregion.

The model assumes constant elasticity of demand and supply equations rather than linear formulations (Abt et al. 1993). For a linear function, elasticity changes along the curve. To define the supply curve in SERTS, the user enters the supply price elasticity, the demand price elasticity, the supply inventory elasticity, and a projected harvest level. Given the supply parameters and an implicit
inventory shift, the location of the supply curve is known. Projected harvest level represents the equilibrium quantity. The supply curve location and harvest level are all that are required to calculate the market-clearing (equilibrium) price.

The future demand scenario reported here holds harvest and acreage constant at the latest (1990) forest survey (FIA) levels. The softwood harvest level was 198.472 million cubic feet and the hardwood harvest level was 98.115 million cubic feet. The acreage level was 5.919 million acres. Because supply price, demand price, and supply inventory elasticities reported in the literature vary so widely, we tested the model using four sets of these parameters considered both different and representative. The reason for testing different elasticity sets is to explore the sensitivity of timber inventory and price projections to these parameters in the SERTS model. Results from testing two of those sets are reported here.

The two sets of elasticities are:

(1) TAMM elasticities:
   Supply price elasticity = 0.35
   Demand price elasticity = -0.20
   Supply inventory elasticity = 1.00
   These are based on research done by Adams and Haynes (1980) and Haynes and Adams (1985) and are default elasticities in the SERTS model. In addition, Abt et al. (1993) have applied them in timber supply projections for North Carolina.

(2) Daniels and Hyde (1986) elasticities:
   Supply price elasticity = 0.267
   Demand price elasticity = -0.033
   Supply inventory elasticity = 0.162
   The Daniels and Hyde price elasticities are slightly more inelastic. The supply inventory elasticity is significantly different. Daniels and Hyde's analysis showed that harvest was relatively insensitive to inventory shifts (0.162).

PROJECTION RESULTS

Inventory projection

In the constant harvest/acreage scenario and using the TAMM elasticities, the year 2010 softwood inventory would be 84 percent of the 1990 inventory and hardwood inventory would be 132 percent of the year 1990 inventory (under the base case—no SMZs). The impact of establishing SMZs on timber inventory projections under the constant harvest/acreage scenario and TAMM elasticities is given in Figure 2 (inventory projections using the Daniels and Hyde elasticities are less than 0.5% different in each period). The impact of establishing SMZs on timber inventory projection increases as the projection proceeds through time. The impact of establishing SMZs on softwood inventory projections is greater than on hardwood inventory projections during the projection years. The wider the SMZs, the greater the impact will be on timber inventory projections. Compared to the base case without SMZs, softwood inventory with 15 meter width SMZs is 95.49 percent in 1990, 92.55 percent in 2000, 88.07 percent in 2010. Hardwood inventory with 15 meter width SMZs is 96.56 percent in 1990, 95.81 percent in 2000, 95.08 percent in 2010. Since the initial inventory and growth information and the aggregate harvest projections are the same despite the elasticities used, aggregate removals and growth
Figure 2. The impact of establishing SMZs on softwood and hardwood inventory projections under the constant harvest/acreage scenario and Tamm elasticities.

Projections are similar for both elasticity sets. Comparing growth projections to removals projections under the constant harvest/acreage scenario, growth projections are less than removals projections in each projection year for softwood. On the other hand, growth projections are greater than removals projections in each projection year for hardwood. This is why (in the face of a constant removals scenario) the softwood inventory projection keeps on decreasing and hardwood inventory projection keeps on increasing during the projection years.

Price projection

The price of stumpage is negatively correlated with stumpage inventory. As inventory increases, the costs of supplying stumpage decrease because access to stumpage is easier and logging and log transport costs are diminished (Daniels and Hyde 1986). Inventory increases (shifts) cause supply increase (shifts), and therefore, price will go down.

In the constant harvest/acreage scenario and using Tamm elasticities, the year 2010 softwood price would be 165 percent of the year 1990 price and hardwood price would be 45 percent of the year 1990 price. The constant harvest/acreage scenario led to a significant decrease in softwood inventory and a significant increase in hardwood inventory to the end of the projection period. Given the structure of the model, constant harvest in the face of decreasing softwood inventory will lead to a softwood price rise. On the other hand, constant harvest in the face of increasing hardwood inventory will lead to a hardwood price decline. Figures 3 and 4 illustrate these trends for the both sets of elasticities considered. Price trends for softwood and hardwood are relatively flatter for Daniels and Hyde (1986) elasticities. The effects of removing SMZ volumes from the timberland base on timber price projections are very obvious for softwood but less obvious for hardwood. The impact increases as the projection proceeds through time.
DISCUSSION

Although Landsat MSS data are much cheaper than Landsat TM or SPOT data, the spatial resolution is somewhat coarse for some tasks; however, the spectral resolution is relatively good. Landsat MSS imagery is not recommended for studying urban areas because of its spatial resolution limitation. Yet, Landsat MSS imagery is ideal for large area studies and general land cover classification, provided the image quality is high.

Generally, land cover classification results improve with higher image quality and increased amounts of training site information. In this study, one scene had 20 percent cloud cover, and another scene had 10 percent cloud cover. The acquisition date for both scenes was 1988. For some individual counties

For the base case without SMZs under the constant harvest/acreage scenario using four sets of elasticities, softwood price increases range from 11 percent to 91 percent and hardwood price decreases range from 16 percent to 65 percent to the end of projection period.

For the constant harvest/acreage scenario, the impact of establishing SMZs is significant for timber inventory projections. The impact of establishing SMZs on softwood inventory projections is greater than the impact of establishing SMZs on hardwood inventory projections. The wider the SMZs, the greater will be the impact of establishing SMZs on timber inventory projections. The longer the projection period, the greater will be the impact of establishing SMZs on timber inventory projections.

For example, using Tamm elasticities, the year 2010 softwood inventory would be 81 percent of the year 1990 inventory and hardwood inventory would be 132 percent of the year 1990 inventory. The year 2010 softwood price would be 213 percent of the year 1990 price and hardwood price would be 37 percent of the year 1990 price.
covered in these scenes, the cloud cover was even greater than 20 percent. All the areas covered by clouds were therefore classified as "nonforest". For this study, Landsat TM imagery would not have been significantly more effective, despite its higher resolution, since the TM sensor is on the same satellite and the images were obtained at the same time as the MSS images.

Establishing SMZs is an important best management practice for protecting environmental quality, but it is not a "free lunch" for the forestry community. The wider the SMZ, the more it will cost. For example, establishment of SMZs could cause higher timber prices or a lower timber inventory if the timber harvests do not decrease in the future. Thirty-five feet is the minimum recommended width for a SMZ. If wildlife, recreation, or other intangible (e.g., aesthetics) objectives are considered, a wider SMZ will be necessary.

Establishment of SMZs is an effective practice to protect water quality and provide a variety of other benefits for the landowners and society as well. However, establishment of SMZs will reduce available timber inventories and potential timber supplies in the future. Regarding future softwood supply dynamics, as inventory goes down and price goes up, the softwood demand could decrease, then, the harvest could decrease as well.

LITERATURE CITED


