LAKE STATES TIMBER SUPPLY AND ANALYSIS MODEL: LASTISA

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ABSTRACT.—The Michigan prototype for a timber stumpage supply model for the Lake States is designed to project timber supply by forest type, ownership, geographic region and product through 2020. The model is composed of inventory, growth, harvesting, management, yield, timberland availability and output modules. Results include estimates of timber inventory and harvest trends and distributions among ownerships and forest types.

INTRODUCTION

The Lake States Timber Supply Analysis (LASTISA) is a cooperative research project among researchers at Michigan State University, Department of Forestry and the North Central Forest Experiment Station, USDA Forest Service, East Lansing, MI. The objective is to develop analytical supply models for major forest types in the Lake States (Michigan, Minnesota and Wisconsin). The structure of the LASTISA model is discussed below and initial results from simulations of the aspen cover type are presented for Michigan.

Background

As in many parts of the United States, timber supply is an important issue in the Lake States. The most recent forest inventories (1983 for Wisconsin, 1990 for Minnesota, and 1993 for Michigan) show that there are 47.4 million acres of timberland in the region. Most of this timberland is in non-industrial private ownership (55%). Public ownership is also significant (13% federal, 15% state and 10% county), while forest industry holds 7%. The patterns of ownership vary across the region, however, all states contain significant interspersed state, federal, industrial and non-industrial private lands. Lake States' forests are remarkably diverse and dominated by stands characterized by multiple ages and mixed species. A wide range of timber products are harvest ed ranging from softwood and hardwood pulpwood to very high value veneer logs. The timber supply problem in the Lake States requires consideration of multiple ownerships, diverse forest types, all-aged stands, multiple products and sub-regional production areas.

The primary research need is for a regional model capable of accounting for timber growth and projecting changes in timber supply due to shifts in harvesting and management practices and availability of timberland for harvest.

Harvest levels have steadily increased for the past several decades. Pulpwood production in the Lake States was 8.7 million cords in 1995. This production is 2.22 times that of 1970 (Vasievich et al. 1996). Total sawlog production also increased since the mid-1970's to a mid 1990s level of 1.6 billion board feet (3.3 million cord equivalents). Sawtimber trends, however, are more difficult to identify, due to sparseness of common measurement data across the Lake States.

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Objectives

The objectives of the LASTISA supply modeling project are to: 1) predict the volume (ft^3) of growing stock timber in each forest type for five-year periods from 1995 to 2020 and for each sub-state region of the Lake States; 2) predict how the inventory is allocated among physical products in each projection period for each sub-state region, and 3) project the potential timber inventory impacts of changes in timberland available for harvest by ownership, harvest practices and management strategies.

LASTISA - A STAND-LEVEL MODEL

Framework

LASTISA is an aggregate stand-level inventory model for projecting available timber supplies and simulating effects of management. Simulation units (SUs), or aggregates of similar stands, are the operational units of the model. Simulations are performed through manipulation of simulation units through growth, yield, timberland availability, and harvesting sub-models (Figure 1). Databases from the USDA Forest Service Forest Inventory and Analysis (FIA) periodic inventories of Lake States forests form the basis for the stand simulation unit records and the development of empirical growth and yield equations used by the model.

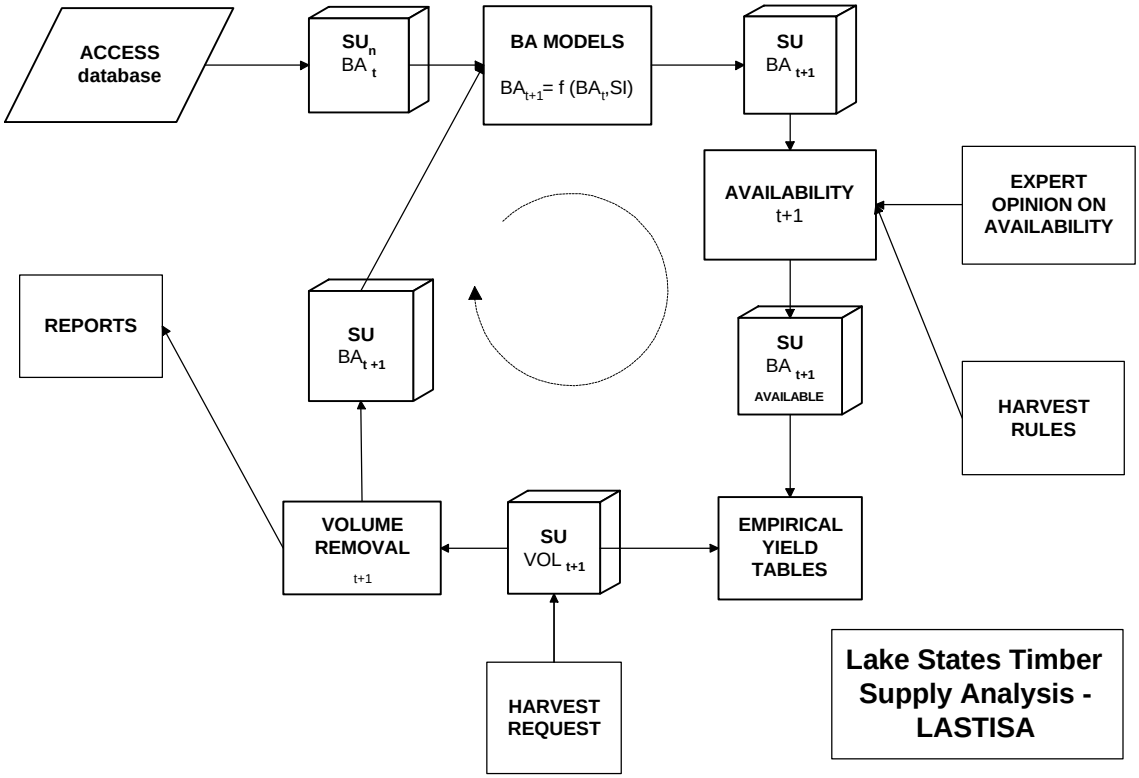

Figure 1.--LASTISA model components.

LASTISA was developed to meet the following predetermined performance criteria.

1. Models should be based on empirical data.
2. Required data should be readily available to timber supply researchers and analysts.
3. Models should be conceptually sound with respect to biometric relationships.
4. Model calculations should be operable on a desktop microcomputer.
5. The number of equations required should be small.
6. Volume projections should achieve an acceptable level of accuracy.
7. Models should adequately reflect the mixed-age and mixed-species forest types common in the region.

These criteria led the authors to develop an empirical model based on recent FIA data rather than adapt existing age-class based models such as ATLAS (Mills and Kincaid 1991) or SERTS (Cubbage, et al. 1991).

Simulation Units

Unique SUs represent groups of similar areas and are defined by FIA unit, forest type, site indes class, basal area class, and ownership (Table 1). FIA units (Figure 2) provide the geographic context for analysis since they reflect logical boundaries of sub-state projection regions. Sorting of the 1993 Michigan FIA data into SUs produced 3042 simulation units, averaging 6,099 acres. Areas for Michigan SUs ranged from 200 to 94,000 acres. Each SU record carries associated values for mean basal area (ft^2/acre), mean site index (ft at 50 years), area (acres), and mean age (years). These variables are used for growth, yield and harvest calculations, and reports.

Table 1.—Stand characteristics defining simulation units

Region - FIA unit	Forest Type	Ownership	Site Index Class (ft. at 50 years)
Michigan	White-Red Pine	National Forest	< 26
Western UP	Jack Pine	State Forest	26-35
Eastern UP	Upland Conifers	County/Municipal	36-45
Northern LP	Oak-Hickory	Other Federal	46-55
Southern LP	Lowland Hardwoods	Forest Industry	56-65
Minnesota	Maple-Beech-Birch	Non-industrial private	66-75
Northern Pine	Aspen-Birch	(and other industrial)	76-85
Aspen-Birch	Lowland Conifers		86-95
Central-Hardwood	Nonstocked		>95
Prairie			
Wisconsin			
Northwest unit			
Northeast unit			
Central unit			
Southwest unit			
Southeast unit			

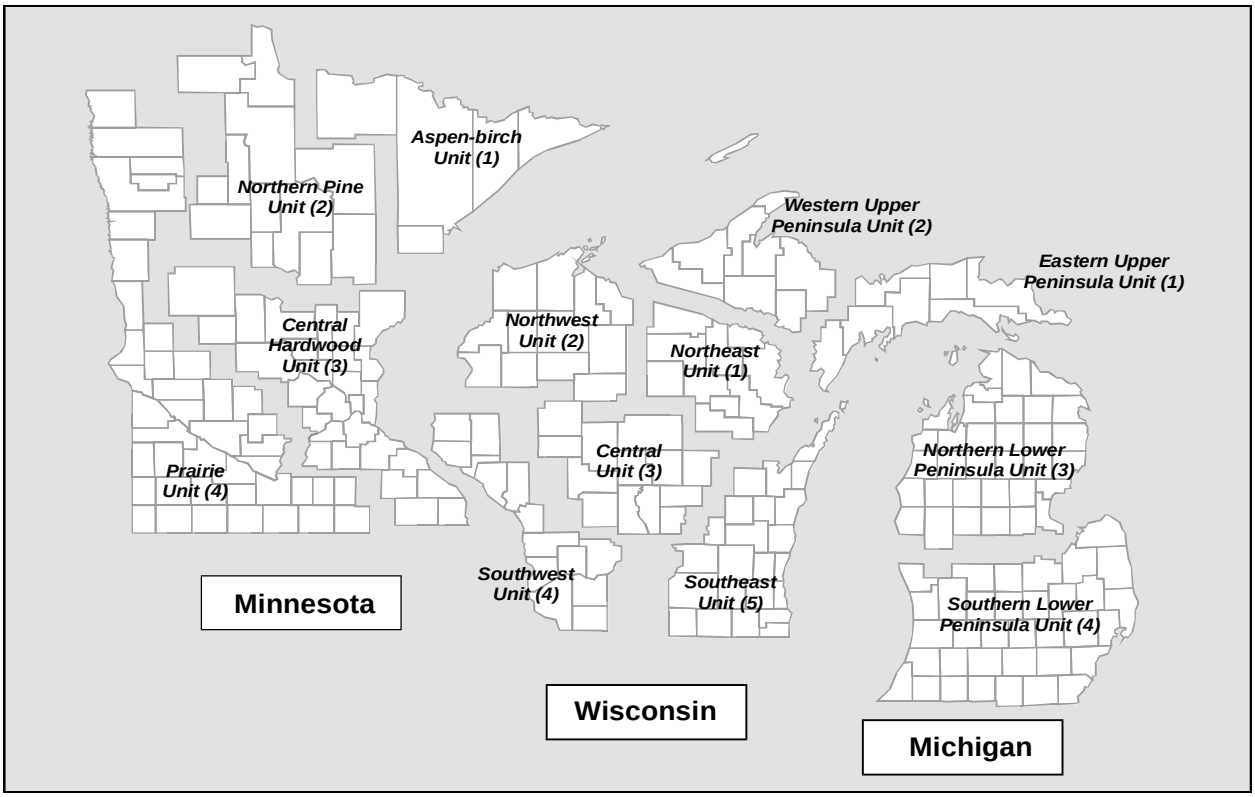

Figure 2.—FIA units in the Lakes States study region.

Basal Area Growth Model

The FIA data set was used for net basal area growth model development due to its data richness, ready availability, and comparability across the region. Models were developed first for Michigan to verify model form and for testing purposes. The modeling database consisted of re-measured plots extracted from the 1980 and 1993 Michigan FIA data. The records in this database were a sub-sample of the simulation unit database described above.

Empirical growth models were developed for each of the nine forest types to estimate net change in basal area from the first inventory cycle (1980 for Michigan) to the second (1993 for Michigan). This design, as opposed to one based on age classes, was chosen in order to better reflect uneven-aged stands and partial cutting. Also, individual tree models, such as STEMS (Belcher et al. 1983), were not used to reduce data requirements in this aggregate stand model. Descriptive statistics were calculated and plot data graphed. Initially non-linear models were investigated but unsuccessful results led the researchers to examine multivariate linear models[3]. Several multivariate linear models were built for each forest type. Models were examined for adjusted R^2, standard error and F statistics (α= 0.05). The best model form for all forest types was determined to be $BA_1 = b_1(BA_0) + b_2(SI_{spp})$, where BA_1 is basal area in cubic feet for time period two; BA_0 is initial basal area, and SI_{spp} is the site index for the dominant species. Adjusted R^2 s for the models ranged from 0.941 to 0.994. Examination of residuals showed no problematic patterns.

[3] The authors gratefully acknowledge the assistance of Carl Ramm, Department of Forestry, Michigan State University in the development of the net basal area growth models and the suggestions of Joseph Buongiorno, Department of Forestry, University of Wisconsin-Madison.

Yield Models

Empirical yield models were also developed for each forest type from the Michigan FIA database. The purpose of these relationships is to estimate standing and harvested volume for each forest type. The most recent inventory (1993) for Michigan was used to estimate regression equations relating basal area to merchantable pulpwood volume (cords), sawtimber (MBF) and total volumes (cords). To estimate yield equations, data derived from FIA plot records were fit for the model $Y = bBA + \varepsilon$ where Y is the yield component and BA is the plot basal area (square feet). Although simple linear relationships are quite good for the aspen-birch type ($R^2 > 0.95$), other model forms are better for other forest types. Further refinement of these yield models is in progress to more accurately fit the data. Regression results for the aspen-birch forest type are presented in Table 2.

Table 2.—Linear yield coefficients (basal area) for the aspen-birch forest type in Michigan

Product	Units	Basal Area Coefficient
Total Yield	cords	0.22805
Pulpwood	cords	0.13981
Sawtimber	MBF	0.04330

Timberland Availability

Timberland available for harvest plays an important role in determining the sustainability of timber production in the Lake States. The Lake Sates Forestry Alliance (1991) identified factors influencing forest use trends in the Lake States: (1) demographic change, (2) resource trends, (3) technologic developments, (4) economic forces, and (5) geopolitical forces. Resh (1994) asked resource managers to quantify the implications of these forces on the availability of timberlands for harvest on various ownerships in the Lake States. Over 300 responses were received. Although the range of responses was wide, on average, more than one-quarter of the current timberland base is perceived as being unavailable for harvest due to constraints related to management objectives (Table 3). This figure is expected to increase in the future. Availability, as a function of ownership, location within the region and time, is an exogenous variable in LASTISA. The percentage of timberland available for harvest in each SU can be reduced to enable simulations of alternative scenarios. This construct in the LASTISA model provides a mechanism to estimate the supply implications of management constraints on harvests.

Table 3.—Timberland availability estimates for Michigan

Ownership Class	Sub-state Region or FIA Unit	Estimated Percent Availability (from Resh 1994)	
		1994-95	2020
State	Eastern Upper Peninsula	70	59
State	Western Upper Peninsula	81	70
State	Northern Lower Peninsula	78	67
State	Southern Lower Peninsula	66	60
NIPF	Eastern Upper Peninsula	78	72
NIPF	Western Upper Peninsula	79	68
NIPF	Northern Lower Peninsula	65	59
NIPF	Southern Lower Peninsula	87	79
Industry	All regions	90	90
National Forest	Eastern Upper Peninsula	52	46
National Forest	Western Upper Peninsula	61	51

National Forest	Northern Lower Peninsula	55	49

Harvesting

Harvest requests are exogenous to the model to allow for testing the effects of different production requirements on inventory. For Michigan, researchers set requests to historic levels as determined by Timber Product Output reports of the USDA Forest Service (May and Pilon 1995). The harvest requests for each five-year projection period are processed first on the basis of proportional harvest shares among ownerships derived from FIA data. If the request cannot be met, the model searches for volume available on the SUs richest in basal area on other ownerships. That is, unmet harvest requests are spread proportionally among other ownerships, drawing the most from the SUs with greatest stocking. These shifts in harvest shares are one of the main features of LASTISA reports.

Simulation models usually apply prescriptive (i.e. normative) or descriptive (positive) harvesting rules. In the first instance, normative harvest rules can be used to predict the implications of specific silvicultural guidelines. The alternative is to craft positive rules which describe the actual patterns commonly used on different ownerships or in different regions. Harvest rules can be based on any combination of SU attributes, such as basal area stocking, forest type, location, ownership, site index, or mean stand age. Harvesting rules used by LASTISA describe how to select SUs for harvesting and how to change the attributes of the SU to simulate harvests and volume production. For normative rules the researchers reviewed and compiled prescriptions from sources such as USDA Forest Service Managers' Handbooks (e.g. Brinkman et al. 1975, Perala 1977). Rules were written for each prescription which translated harvests to prescribed residual basal area or percent basal area of the stand removed. For positive harvest rules, management practices from public lands were compiled and the practices similarly translated into basal-area based rules. After harvest removals are calculated, the SU records are updated to reflect new inventory conditions. Then the cycle is repeated for the next five-year period until the year 2020 is reached. For the initial testing phase, harvests were allowed only if basal area exceeded a minimum amount. The capability to apply a variety of harvest rules enables users to test a wide range of harvest strategies with the LASTISA model.

RESULTS

The initial implementation of LASTISA was developed using Microsoft Visual Basic 5® (Fig. 2). The aspen-birch forest type, which totals over 3.1 million acres in Michigan, was used for the initial trials. Harvest targets were based on historic timber production trends. The five-year production level of 5.5 million cords (combined pulpwood and sawlogs) was set as a constant harvest level for each production period. Four FIA units in Michigan were modeled and volumes harvested were calculated for each SU. Ownerships included were: national forests, state forests, county/municipal forests, other federal forests, forest industry, and non-industrial private forests. Harvests were modeled for five five-year projection periods (i.e., 1996-2000, 2001-2005, etc.). Shifts among ownerships for aspen-birch supply were allowed every five years, if needed. Reductions in timberland availability for harvest were included for the initial trials.

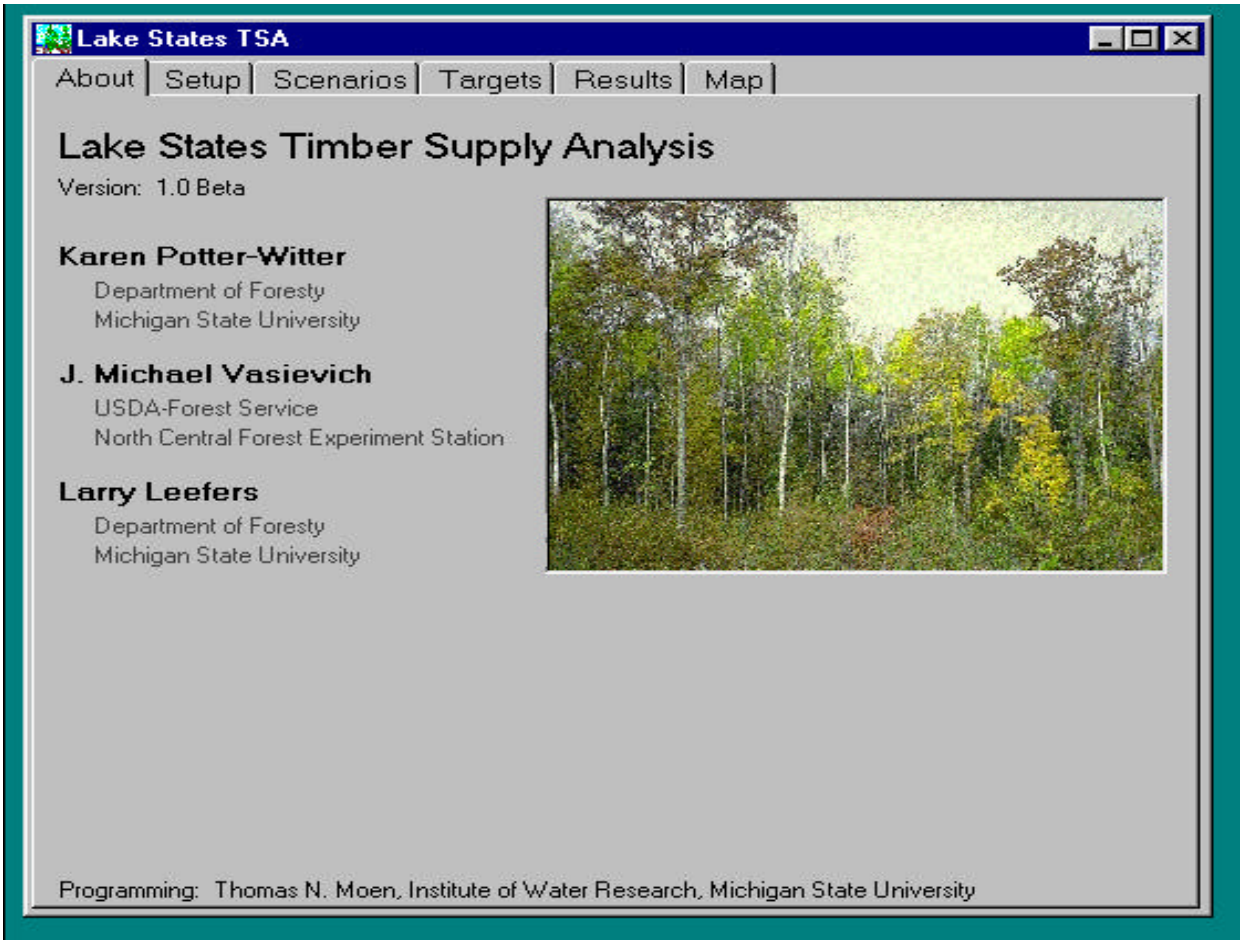

Figure 2. LASTISA

Results showed that the 5.5 million cords five-year harvest request from the aspen-birch type was met for each of the projection periods (Fig. 3). Harvest shares, however, shifted over time as timber became less available on public lands. In 2010, state forest lands could not meet their harvest request share, and the NIPF share increased. State forest share increased for the 2015 and 2020 periods, but still did not reach their 2000 levels. These results are likely due to two factors - an unbalanced age-class distribution for aspen-birch forests, and changes in anticipated timberland availability. In a similar fashion, national forests show a decline of aspen-birch timber harvest over time due to reduced availability.

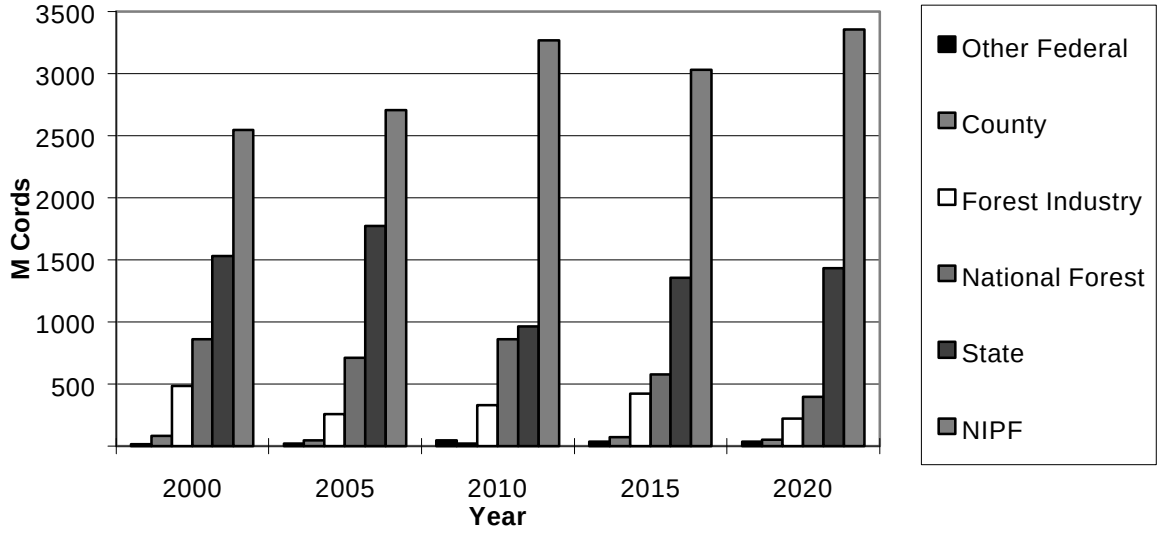

Figure 3.--Estimated aspen harvest by ownership and year.

CONCLUSIONS

LASTISA is an empirically based timber supply model with major components that are often missing in other models. Notably, its is designed to model shifts in supply from one ownership to another. This provides a better approach for assessing regional supply which often depends on individual ownerships' management plans. LASTISA explicitly incorporates timberland availability changes so that expert's views of their implications can be modeled. Unlike other aggregate timber supply models, LASTISA's growth and yield projections are based on basal-area growth and yield models developed from empirical data rather than an individual tree model of even-aged stand.

Initial results of simulations from the LASTISA model are promising. They demonstrate the potential of the model for testing the effects of differences among ownerships and harvest policy on timber supply. The LASTISA model continues under development. Additional work to extend the model to the full set of Lake States production regions and to validate model performance is in progress.

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