

Econometric Analysis of the Factors Influencing Forest Acreage Trends in the Southeast

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ABSTRACT. Econometric models of changes in land use acreages in the Southeast by physiographic region have been developed by pooling cross-section and time series data. Separate acreage equations have been estimated for the three major private forestland owner classes and the three major classes of nonforest land use. Observations were drawn at three or four different points in time for the 21 Forest Survey Units in the Southeast. Of the variables examined, population and personal income measures were the major significant explanatory variables in the land use equations. *FOREST SCI.* 32:119–134.

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PROJECTING TRENDS in the amount of forestland by region has generally been based on expert opinion, with little systematic analysis of important determinants. However, with the trend downward in U.S. forest acreage since the 1960's and its importance for renewable resource policy formulation, analysts have increasingly turned their attention to this topic (Alig and others 1983). This study was designed to investigate interrelationships among the major land uses in the Southeast, focusing on the influences of economic forces and demographic shifts.

Econometric techniques were used to estimate relationships among explanatory variables, such as relative product income for competing land uses, and acreage trends for three nonforest land uses—crops, pasture/range, and urban and related uses—and three private forestland ownerships—farmer, forest industry, and miscellaneous private. The systems of estimated equations support a model for projecting acreages in each of the major land uses (discussed in Alig 1985), needed to support long-range assessments of forestry market trends (e.g., USDA Forest Service 1982). Modeling the relationships among changes in population, income, and socioeconomic variables and forest acreage improves the ability to project impacts on the supply of timber and other natural resources (e.g., wildlife habitat) from land use shifts.

One region of the United States where competition for use of rural land is expected to be particularly intense over the next several decades is the timber supply region known as the Southeast: Florida, Georgia, North Carolina, South Carolina, and Virginia. Acreage trends in southeastern private forestland were chosen for study because of the region's (1) relatively large holdings of private forestland and (2) importance in regard to both future timber and crop production expansion.

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One-sixth of the timberland in the U.S. is on Southeast private ownerships (USDA Forest Service 1982). Different sectors of the economy, including crop agriculture, pasture/range-based agriculture, and forestry, are looking to the Southeast to expand production (Healy 1982). Rising export demand for food and fiber products is of particular interest. The recent National Agricultural Lands Study identified 15 percent of the Southeast timberland base (more than 11 million acres) as having high or medium potential for conversion to cropland (Dideriksen and others 1977, USDA and Council on Environmental Quality 1981). This constitutes approximately 40 percent of the total U.S. forest acreage so identified.

LAND RENT FRAMEWORK

According to classical land rent theory, allocation among competing uses on a fixed land base is dictated by the associated relative land rents. Land rent is a residual economic surplus, the portion of the total value product or of the total returns that remains after payment is made for the total factor costs or total costs, respectively (Barlowe 1978). Land rent theory dates back several centuries to Ricardo's theory that land rents are related to soil fertility differentials, later extended by von Thunen to include transportation or locational considerations (Alonso 1964).

Figure 1 shows the relationship between land use capacity and rent-paying ability (Barlowe 1978). The diagram assumes a continuum of lands of decreasing use capacity, defined as the relative ability of lands to produce a surplus of economic returns above costs of utilization. In Figure 1A, use capacity decreases in moving to the right because of the use of the lower grade, less productive, and less advantageously situated lands. This shift to lower quality land corresponds to a gradual increase in production costs. The marginal acre associated with a net value (i.e., composite of economic rents expected over an infinite time horizon) of just zero identifies the extensive margin for each use.

When the price for the land output rises from Level L to Level N, the total volume of land rent increases from the area included within the triangle KLR to the area included within the triangle KNT. If the land rent triangle from Figure 1A is detached and turned over, this helps to illustrate the relationship between decreasing use capacity and the amounts of rent produced for any land use, as shown in Figure 1B. A set of land use profiles for competing uses defines a land use hierarchy for a particular site. The intensive margin of land use is reached with the last unit of variable input (nonland factors of production, e.g., capital and labor) that can be applied for a use before marginal costs exceed marginal returns. The margin of transference is the point at which intensive margins for alternative land uses intersect, i.e., economic value for alternative uses is positive and equal, as illustrated in Figure 1B at Point X.

Analysis of the competition for land among sectors is complicated by the different time patterns of income flows from various uses. For example, agricultural uses commonly entail annual investment and return cycles in contrast to timber's multiyear cycle. All else being equal, landowners may prefer (or require) annual returns to periodic ones and hence opt for the nonforest use. Land use comparisons also involve "expected" net incomes. This raises an additional complication because little is presently known about the processes by which landowners generate expectations of future prices and costs associated with alternative uses.

Regional land use studies in forestry have employed a variety of analytical approaches. Vaux (1973) relied on engineering functions that estimated future forestland use based on economically efficient conditions and long-run stumpage price stability. Because he did not explicitly consider competing land uses, he

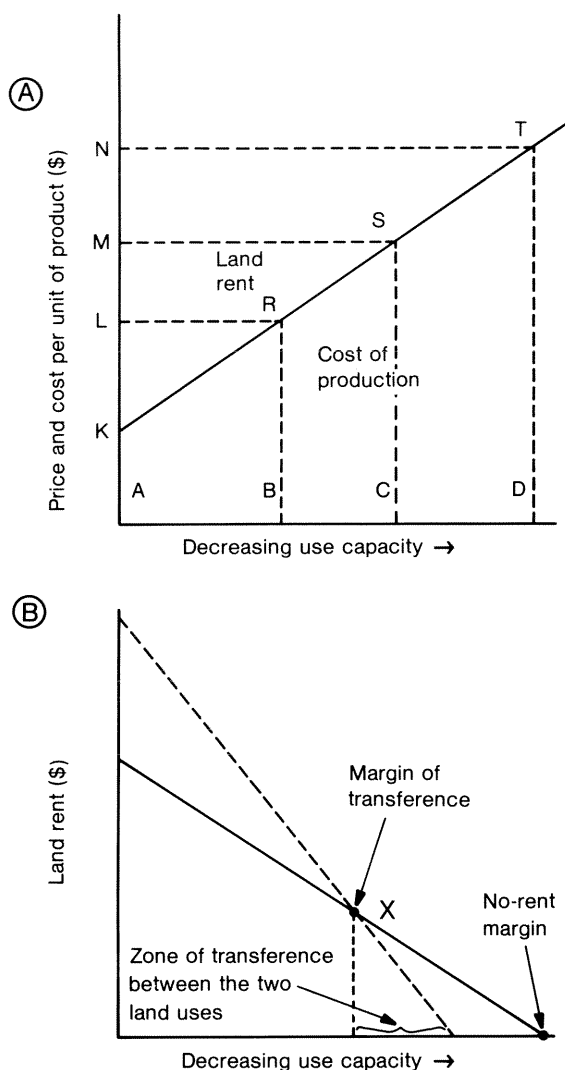


FIGURE 1. Relationship among use capacity of land resources, production costs, and land rent (adapted from Barlowe 1978). In B, the solid line above represents land rent triangle KNT from A and the dashed hypotenuse is associated with an alternative land use.

failed to include the opportunity cost of land uses other than growing timber. Hyde (1980) expanded Vaux's approach in analyzing the effects of changes in rotation lengths, level of inputs, and relative prices on efficiency of timberland management.

Viewing forestland as a residual use, or assuming a continuation of past transition rates from one use to another as employed in the Markov analysis by Burnham (1973), greatly simplifies the projection of long-term trends in land use. In the process, however, underlying causal relationships are obscured. The Markovian probabilities are aggregate measures of all influences acting on land use shifts. Effects of alternative policies on future area patterns can be examined only by means of very rough parametric shifts in land allocations, with uncertain relation to the policies of interest. In general we are forced to accept a view of

trends in future land use patterns that is a continuation of historic trends, even if we contemplate rather different future economic and social conditions.

Statistically based parameters that reflect relationships among ownership considerations, relative land product income trends, and other important determinants in regional forest acreage shifts have not been estimated. Econometric analysis for agricultural land uses have included both annual and perennial crops, and a variety of estimation techniques (e.g., simultaneous equation approaches). They provide some guidance for the development of statistical or econometric models for analyzing regional timberland use shifts. For example, White and Fleming (1980) estimated an equation for Georgia farm woodland acreage trends as part of a simultaneous equation analysis of the interrelationships among competing agricultural land uses. They interpolated between periodic Census of Agriculture surveys to derive annual series of forest acreage data.

MODEL SPECIFICATION

The economic theory of land rent provides guidelines for selection of independent variables in a regional model of land use acreages. Associated hypotheses of land use acreage determinants are specified next in the form of systems of land use equations. The equations are constructed with shares of the total land base occupied by the major land uses as functions of economic, demographic, and other important variables.

There are four major land uses in the Southeast for which a series of periodic historical acreage estimates are available: cropland, pasture/rangeland, forestland, and urban and other land. Private ownerships, which comprise 90 percent of the forestland base, are the focus of this study. Area in the small public forestland component has changed relatively little over the historical period, and was incorporated into the urban and other land category. Private forestland was separated into three ownership classes: farmer, forest industry, and miscellaneous private. Thus, the systems of econometric equations in Table 1 were specified for six land use/owner classes.

Because of insufficient series of land rent data, proxies were used. The proxies included real net income for land products or other measures that influence land rent (e.g., population) and which would cause significant shifts in land rent profiles. With real net income serving as a proxy for land rent derived from use i , R_i , the share of the land base in a particular land use, f_i , should be positively correlated with the ratio of expected real net income from that land use to expected real net income from alternative uses:

$$f_i = g_i \left(\frac{R_i}{\sum_j f_j R_j} \right) \quad i = 1, \dots, 6$$

where $g_i' > 0$, $g_i'' < 0$. The hypothesized positive correlation between the proxy for relative land rent and land use percentage in a region is based on economic theory that suggests individual owners tend towards maximizing land rent when managing a parcel of land.

Land income measures are only available, however, for the forestry and agricultural uses, so an average expected net income for all alternative uses could not be computed. Therefore, relative land income measures are represented as a ratio of expected income from two competing land uses. Though dictated by data limitations, this approach may be useful in isolating critical pairs of competing land uses. For urban and related uses for which there are no direct land income measures, urban and rural populations and regional per capita income are used as proxies.

TABLE 1. *Specification of relationships for six land use classes.*^a

$$\begin{aligned}
 C &= \beta_{10} + \beta_{11}Y_{F/C} + \beta_{12}Y_{C/P} + \beta_{13}UPOP + \beta_{14}RPOP + \beta_{15}Y_T + \beta_{16}G_o \\
 P &= \beta_{20} + \beta_{21}Y_{F/P} + \beta_{22}Y_{C/P} + \beta_{23}UPOP + \beta_{24}RPOP + \beta_{25}Y_T + \beta_{26}G_o \\
 U &= \beta_{30} + \beta_{33}UPOP + \beta_{34}RPOP + \beta_{35}Y_T \\
 FA &= \beta_{40} + \beta_{41}Y_{F/C} + \beta_{42}Y_{F/P} + \beta_{43}UPOP + \beta_{44}RPOP + \beta_{45}Y_T + \beta_{46}G_o + \beta_{47}I + \beta_{48}Y_s \\
 FI &= \beta_{50} + \beta_{53}UPOP + \beta_{54}RPOP + \beta_{55}Y_T + \beta_{57}I + \beta_{58}Y_s \\
 MP &= \beta_{60} + \beta_{63}UPOP + \beta_{64}RPOP + \beta_{65}Y_T + \beta_{66}G_o + \beta_{67}I + \beta_{68}Y_s
 \end{aligned}$$

$$\sum_{i=1}^6 \beta_{i0} = 100.0; \quad \sum_{i=1}^6 \beta_{ij} = 0.0 \text{ for } j = 1, \dots, 8$$

Where

- C = % of survey unit's land base occupied by crops
- P = % of survey unit's land base occupied by pasture/range
- U = % of survey unit's land base occupied by urban and other uses
- FA = % of survey unit's land base occupied by farm forestland
- FI = % of survey unit's land base occupied by forest industry forestland
- MP = % of survey unit's land base occupied by miscellaneous private forestland
- β_{ij} = parameters to be estimated ($i = 1, \dots, 6; j = 0, \dots, 8$)
- $Y_{F/C}$ = Ratio of expected forestry to crop income per acre
- $Y_{C/P}$ = Ratio of expected crop to pasture/range income per acre
- $Y_{F/P}$ = Ratio of expected forestry to pasture/range income per acre
- UPOP = Urban population
- RPOP = Rural population
- Y_T = Real per capita income
- G_o = Tree planting expenditures under government programs
- Y_s = Southern pine products income
- I = Inflation rate

^a Dummy variables to distinguish states are not shown, but would be included in each equation.

Two or three year moving averages for land incomes were tested to approximate income expectation formation by landowners. Appropriate lags (e.g., one year for agricultural incomes) were used to represent the time structure of landowner response to changes in major income determinants (Alig 1984).

Developed land uses are at the top of the economic hierarchy of land use. This is reflected by the general disparity in land prices for urban acreage versus less intensive land uses. Increases in population cause more demand for land development. Such pressures increase relative land rents for developed uses and lead to expansion of urban and related acreage. Some forestland may be converted directly to developed uses, and other forest acres may be converted to replace some agricultural acres that are developed because of the population increase. Therefore, changes in total forest acreage should be negatively correlated with changes in population. A priori, the specific net effect of urban and rural population changes on the distribution of forest ownerships is uncertain.

The rate of conversion of rural land to nonagricultural uses has increased during the last two decades, coinciding with some major sociodemographic trends. These trends include the decentralization of population and economic activities from metropolitan to nonmetropolitan areas, increased number of households formed, shifts of population from the North to the South and the West, and development of major infrastructure programs—for example, the interstate highway system (Brown and Beale 1981). The post-1980 rate of rural land conversion associated with demographic change and infrastructure development is expected to continue to be substantial. However, it is likely to be lower than during the last two decades

because of fewer major infrastructure programs and an expected decline in the rate of household growth.

Increasing per capita incomes are likely to cause upward pressure on land rents for developed uses. Changes in per capita incomes also can cause changes in the distribution of forestland among owner groups. The nonindustrial, private owner class has shifted notably in the past two decades toward a majority of nonfarmer owners. Increased capital availability may increase investment demand by miscellaneous private owners. Mullaney and Robinson (1980) suggest that business and professional individuals, who comprise a considerable proportion of such nonfarmer, nonindustrial owners, have relatively higher incomes and are more likely to invest in forestry than other nonindustrial owners. Therefore, miscellaneous private forest acreage should correlate positively with an increase in per capita incomes.

The relationship between changes in per capita income and forest acreage trends by ownership is important. Increases in real income may boost demand for forestland for nontimber uses. In addition, miscellaneous private acreage would likely vary inversely with farm timberland acreage. Because the ratio of farm income to nonfarm income in the Southeast is rather small, increases in total income should correlate positively with miscellaneous private ownership of timberland and negatively with farm ownership.

Some miscellaneous private owners view fixed assets, such as land, as better ways to hold and preserve wealth than alternatives such as financial assets. Miscellaneous private owners may respond to inflationary pressures by placing part of their investment portfolio in land as an apparent inflationary hedge. The influence of such macroeconomic variables on land ownership centers on changes in the (perceived) wealth of a diverse set of owners. Other land ownership considerations, such as desires to preserve heritage, undoubtedly influence length of land ownership tenure and distribution to some degree. However, they currently cannot be incorporated into this type of study because of data limitations and measurement problems.

The number of forested acres on farmer and miscellaneous private ownerships would be expected to correlate positively with government programs for tree planting. Government subsidies for tree planting reduce the private cost of forestry, thereby increasing private land rents for forest production and shifting the land rent profile for forestry favorably in comparison to alternative land uses (e.g., agriculture). Testing the significance of government programs as a determinant of nonindustrial forest acreage trends involves consideration of cost-sharing programs for tree planting. The major programs include the ongoing Agricultural Conservation Program (ACP) begun in 1936, the Soil Bank program that lasted from 1956 to 1964, and the ongoing Forestry Incentives Program (FIP) and state programs in South Carolina and Virginia that started in the early 1970's. Brooks (1985) reports a positive relationship between a subsidy program variable and pine planting on nonindustrial lands.

Land is acquired by the forest industry because of concern for availability of raw materials and expected returns from timberland investments. Industrial acquisition of timberland is hypothesized to be positively correlated with expected increases in investment returns, dictated by costs of timber conversion, productivity trends, and demand for the timber. In addition, tactical and strategic considerations may lead companies to acquire more land in the face of a reduced relative availability of raw materials from open market sources. Industry depends greatly on sources of timber from other ownerships, historically approximately 60 to 90 percent of industry's stumpage consumption. However, data were not available to test a suitable explanatory variable pertaining to the relative importance of raw material concerns.

METHODS

The USDA Forest Service surveys land use in the Southeast by state on a staggered 8- to 10-year cycle. The five southeastern states contain 21 Survey Units, which are multicounty aggregations, ranging from 4 million to 11 million acres in size. These surveys (e.g., Knight 1973) provide acreage estimates of the major land uses at either three or four points in time from approximately 1947 to 1984. The acreage estimates were transformed into 70 consistent observations for each owner/land use class. An observation represents the percentage or share of a survey unit's total land area occupied by a land use at a particular point in time. For example, in 1982 cropland occupied 17.7 percent of the land area in Georgia Survey Unit 3. This transformation to a percentage of the land base placed the observations on a more comparable scale, removing the influence of survey unit size. Using proportions or shares rather than acreages as the dependent variable helps to alleviate possible heteroscedasticity problems. In addition, the land use data were stratified by three physiographic regions (Coastal Plain, Piedmont, and Mountains) because of important physical and economic differences related to the types and quality of land in each physiographic region (Alig 1984).

The infrequent sampling of areas for land uses in the Southeast necessitates pooling data across time and Survey Units to generate degrees of freedom. Pooling cross-section and time series data in econometric modeling is a special case of the method of restricted least squares (Koutsoyiannis 1977). This pooling process imposes the restriction or assumption that the slope coefficients in the regressions are constant over the Survey Units and time. Dummy variables were used (i.e., a varying intercept term) to capture differences in behavior of Survey Units among physiographic regions.

The random error terms, e_{it} , are assumed to have zero mean and constant variance and to be independently distributed over time and Survey Units (Judge and others 1982). If the residual terms in the land use equations are correlated, a technique that uses estimates of the covariance of the residual terms across equations can increase the efficiency of the estimates over ordinary least squares (OLS). Correlation among the error terms or disturbances in the different land use acreage equations is inevitable because of the fixed total land base, transfers of land among uses/ownerships, and related patterns in economic determinants. This relates to the case of seemingly unrelated regression equations (SURE) described by Zellner (1962).

In comparison to OLS estimation, SURE estimation is more efficient in general when (1) the explanatory variables in the different equations are not highly correlated and (2) the disturbance terms in different equations are highly correlated (Judge and others 1982, p. 321). Under those conditions, theoretical and experimental results indicate that the SURE or two-stage Aitken estimator is unbiased and asymptotically efficient relative to the ordinary least squares estimator (Kmenta 1971). Because of the desirability of relatively small bias and low variance, the root-mean-square-error (RMS) percentage criterion was used—the smaller the percentage error, the better the goodness-of-fit.

Logarithmic transformations of the independent variables were performed because a concave functional form is posited for the relationship between the fraction of land in a particular use and land rent (or proxies). As a greater percentage of the total land area is concentrated in a particular use, it should require larger land rent differences to shift more land into that use. Capital requirements, cultural influences, and related factors would likely provide some resistance to larger or extreme shifts of land uses.

Because the land areas of the Survey Units are essentially fixed in size, changes among the dependent variables are interdependent. An increase in the share of

one land use necessarily entails a reduction in one or more other uses. If we let n equal the total number of land uses, implications of the interdependence for estimation are that values for the n dependent variables will sum to 100 percent of the land base. Thus, one equation in the system is redundant. Three estimation alternatives for addressing this were considered in view of the ultimate goal of developing a projection model: (1) using a multivariate logit approach that requires the same set of exogenous variables across each of $n - 1$ estimated equations, (2) estimating $n - 1$ equations and solving numerically for the predicted values in the n^{th} equation, and (3) using unrestricted proportions as dependent variables with a full set of n equations, but imposing restrictions on the coefficients of the independent variables to satisfy land base constraints.

The first estimation alternative was relatively expensive to execute in preliminary tests, in part because each variable appeared in all equations. The associated results were also more difficult to interpret because one land use class was excluded. The second alternative also had similar drawbacks. In addition, errors for all the other predictions are incorporated in the derivation of the n^{th} equation. Predicted values for the n^{th} equation excluded from estimation are very unstable and even negative in some cases. The third alternative was chosen because of its relative simplicity, smaller cost, and the direct provision of a complete set of land use equations for interpretation and projection purposes.

The alternative chosen provides results that satisfy the fixed land base constraint. The sum of the coefficients of any explanatory variable across all land use equations is identically equal to zero. In theory, the sum of positive changes for land use shares induced by a particular independent variable must be offset by a corresponding total reduction in other land use shares on the fixed land base. This exact prior information was imposed by using a set of linear equality restrictions across the complete system of equations.

A complete description of the various data sources for the independent variables is given by Alig (1984). The major sources for agricultural income data were periodic reports by the Economic Research Service and Statistical Reporting Service of the U.S. Department of Agriculture. Data for timber incomes were obtained from USDA Forest Service publications prepared for national studies and from price information supplied by the Forest Service's Southern Region office. Population and personal income data were obtained from periodic Bureau of Census reports and Economic Reports of the President.

RESULTS

Table 2 presents results for the Southeast by major land use for the SURE estimation approach. The equations exhibit the signs hypothesized for coefficients except for the personal income variable in the pasture/range equation and the urban population variable for forest industry owners. The equations with the logarithmic transformations, in terms of R^2 and percent RMS, outperform linear equations. This is consistent with the hypothesis regarding the form of the land use-rent relationship.

The SURE approach (with the logarithmic transformations) was tested at the physiographic region level to determine if data stratification would improve explanatory power. SURE results are presented for the Coastal Plain in Table 3, for the Piedmont in Table 4, and for the Mountains region in Table 5. In terms of weighted R^2 and percent RMS, the physiographic region models fit the data better and the associated results are discussed next in more detail.

Farmer Forest.—Results for the farm ownerships generally support the hypothesized behavioral relationships. Population and personal income are significant explanatory variables in the equations for farm forest acreage in all regions, except

TABLE 2. SURE results by major land use for the Southeast.^a

Variables	Crop	Pasture/ range	Urban/ other	Farm forest	Forest industry	Miscel- laneous private
Intercept	29.79* (8.03)	2.30 (0.54)	5.03* (4.76)	49.31* (8.22)	9.57* (2.65)	4.00 (1.15)
Crop-to-beef income ratio	5.37 (0.59)	-5.37 (-0.59)				
Timber-to-crop income ratio	-0.09 (-0.44)			0.09 (0.44)		
Timber-to-beef income ratio		1.32 (0.29)		-1.32 (-0.29)		
Personal income	-8.49* (-2.41)	7.00* (2.35)	4.44* (5.18)	-21.13* (-4.36)	-2.59 (-0.59)	20.76* (4.76)
Rural population	0.68 (0.34)	2.34 (1.46)	0.00 (0.00)	2.16 (0.97)	-8.84* (-4.10)	3.67 (1.77)
Urban population	-1.92* (-2.28)	-1.35* (-1.98)	0.92* (2.72)	-2.51* (-2.63)	4.77* (5.20)	0.09 (0.11)
Inflation rate				-1.31 (-0.38)	2.08 (0.67)	-0.77 (-0.28)
Government forestry programs	0.02 (0.02)	-0.70 (-1.40)				0.68 (0.98)
Wood products income				10.16* (2.38)	-2.91 (-0.77)	-7.25* (-2.16)
North Carolina dummy	2.95 (1.31)	-3.09 (-1.74)	0.79 (0.92)	-0.73 (-0.30)	3.10 (1.33)	-3.02 (-1.32)
Virginia dummy	-2.65 (-1.42)	7.27* (4.56)	-0.52 (-0.75)	7.50* (3.30)	-6.81* (-3.19)	-4.79* (-2.34)
Percent RMS ^b	59.0	138.7	42.4	29.7	727.6	116.8
Weighted R^2 for the system of equations = 0.37						
Sample size, $n = 70$						

^a Numbers in parentheses below coefficients are t -statistics.

^b Percent root-mean-square error.

* Significantly different from zero at the 0.05 level.

for personal income in the Mountains region. Variables representing the ratio of expected timber to agricultural incomes were not significant, except for timber-to-crop income in the Piedmont.

The results are consistent with earlier tests that indicated expected agricultural incomes per acre were generally not major determinants of changes in farm forest acreage (Alig 1984). White and Fleming (1980) also tested absolute land use income measures (e.g., crop income per acre) for Georgia farm ownership. Their results for Georgia differ from this study's in that agricultural income per acre was a significant explanatory variable in their equation for farm forest acreage, while forestry income was not.

The significance of the population and personal income variables are consistent with land use pressures on farm forests in the Southeast. Large changes in populations and personal incomes have coincided with large reductions in farm forest acreages. Comparison of the associated coefficient signs suggests that population and personal income have been the primary forces behind the large transfers of land between the farmer and miscellaneous private owner groups.

The negative correlation of real personal income to the percentage of total

TABLE 3. SURE econometric estimation results for the Coastal Plain region.^a

Variables	Crop	Pasture/ range	Urban/ other	Farm forest	Forest industry	Miscel- laneous private
Intercept	27.69* (7.47)	4.85* (1.96)	6.47* (3.97)	35.86* (6.56)	19.73* (4.17)	5.39 (1.50)
Crop-to-beef income ratio	2.88 (0.57)	-2.88 (-0.57)				
Timber-to-crop income ratio	0.10 (0.64)			-0.10 (-0.63)		
Timber-to-beef income ratio		-2.84 (-1.06)		2.84 (1.04)		
Personal income	5.62 (1.73)	4.85* (2.66)	4.24* (3.51)	-17.15* (-3.69)	-6.73 (-1.36)	9.18* (2.07)
Rural population	6.63* (3.35)	-1.41* (-1.98)	0.81 (0.83)	0.14 (0.07)	-4.83* (-1.99)	-1.34 (-0.79)
Urban population	-5.85* (-5.92)	0.49 (1.32)	0.49 (1.00)	-4.97* (-4.81)	6.54* (5.27)	3.32* (3.74)
Inflation rate				-2.71 (-0.92)	3.05 (1.06)	-0.34 (-0.13)
Government forestry programs	-1.31* (-2.14)	-0.55* (-1.99)				1.86* (2.90)
Wood products income				16.56* (2.21)	-2.94 (-0.40)	-13.62* (-2.10)
North Carolina dummy	-3.93 (-1.68)	-1.60 (-1.79)	0.17 (0.15)	-1.35 (-0.60)	4.50 (1.64)	2.21 (1.12)
Virginia dummy	-0.89 (-0.34)	-2.83* (-2.73)	1.69 (1.32)	16.21* (5.67)	-7.78* (-2.28)	-6.41* (-2.56)
Percent RMS ^b	24.8	56.0	34.9	15.7	58.6	130.9
Weighted R^2 for the system of equations = 0.61						
Sample size, $n = 36$						

^a Numbers in parentheses below coefficients are t -statistics.

^b Percent root-mean-square error.

* Significantly different from zero at the 0.05 level.

acreage in farm forest is related to growth in the proportion of nonfarm income over the last 50 years. Expanded incomes have contributed to the purchase of millions of acres of farm forest by miscellaneous private owners. Sizes of the personal income coefficients are similar across regions, with the more populated Piedmont region having the largest income coefficient.

Explanatory power of the farm forest equations is among the highest for the land uses across the regions. Percent RMS's for the farm forest equations fall in the range of 7 to 17 percent across regions, the lowest error percentages for the three forestland owner classes.

Forest Industry.—Results for the industry ownership of forest acreage differ notably across physiographic regions. The forest industry equations have lower explanatory power than the farm forest equations. This reflects in part the diverse strategic reasons behind industry's purchase of timberland.

No significant forestry-related variables appear in the forest industry equations. The hypothesized positive relationship between forest industry's share of the land base and the wood products incomes variables was rejected.

TABLE 4. SURE econometric estimation results for the Piedmont region.^a

Variables	Crop	Pasture/ range	Urban/ other	Farm forest	Forest industry	Miscel- laneous private
Intercept	34.92* (7.32)	12.07* (3.04)	13.29* (10.87)	35.43* (3.77)	-3.96 (-1.69)	8.25 (1.00)
Crop-to-beef income ratio	-1.73 (-0.19)	1.73 (0.19)				
Timber-to-crop income ratio	-0.85* (-4.25)			0.85* (4.07)		
Timber-to-beef income ratio		-3.21 (-0.93)		3.21 (0.89)		
Personal income	-12.32* (-3.04)	-0.35 (-0.11)	4.14* (6.13)	-22.36* (-2.64)	4.67* (2.09)	26.22* (3.32)
Rural population	-10.14 (-1.77)	0.24 (0.07)	13.68* (8.91)	-6.77 (-0.65)	-10.93* (-3.96)	13.92 (1.44)
Urban population	-1.07 (-0.72)	4.19* (4.42)	2.65* (6.93)	-4.89* (-1.90)	-3.14* (-4.65)	2.26 (0.95)
Inflation rate				-0.15 (-0.02)	3.09* (1.86)	-2.94 (-0.52)
Government forestry programs	-1.75 (-1.78)	0.37 (0.57)				1.38* (2.42)
Wood products income				7.06 (1.42)	-1.78 (-1.42)	-5.28 (-1.20)
North Carolina dummy	15.35* (3.05)	-3.07 (-0.96)	-11.64* (-8.38)	10.71 (1.11)	5.25* (2.07)	-16.59 (-1.86)
Virginia dummy	-8.94* (-2.55)	9.02* (3.96)	6.61* (7.29)	6.30 (1.01)	-11.02* (-6.73)	-1.98 (-0.34)
Percent RMS ^b	15.2	14.5	11.3	17.4	51.2	50.5
Weighted R ² for the system of equations = 0.88						
Sample size, n = 21						

^a Number in parentheses below coefficients are *t*-statistics.

^b Percent root-mean-square error.

* Significantly different from zero at the 0.05 level.

Industry's share of the land base was positively correlated with the rate of inflation in the Piedmont and Mountains regions. This indicates financial investment motives influence strategic planning by land-holding firms.

The estimated positive relationship between forest industry's share of the land base and urban population for the Coastal Plain is not consistent with the a priori hypothesis. The expected negative relationship held for population variables in all other cases. Urban and rural population variables were negatively correlated with forest industry's share of the land base in these regions. The same type of relationship held for rural population in the Coastal Plain. This suggests that population increases lead to expanded development of land, thereby reducing the industrial timberland base.

These findings suggest the importance of forces from outside the forestry sector in influencing forest acreage changes. This is true even for industry's acreage trends, which are shaped in a complex of strategic decision-making.

Miscellaneous Private Forest.—Important variables for the miscellaneous private class are similar to the farm ownership determinants: population and personal

TABLE 5. SURE estimation results for the Mountains region.^a

Variables	Crop	Pasture/ range	Urban/ other	Farm forest	Forest industry	Miscel- laneous private
Intercept	1.05 (0.10)	67.15* (6.67)	-5.51 (-0.61)	-66.00 (-1.60)	-32.27 (-1.91)	135.58* (2.85)
Crop-to-beef income ratio	99.60* (35.30)	-99.60* (-35.30)				
Timber-to-beef income ratio		1.01 (1.27)		-1.01 (-1.10)		
Timber-to-crop income ratio	-0.37 (-0.88)			0.37 (0.76)		
Personal income	-25.11* (-7.59)	9.85* (4.18)	6.39* (3.06)	-6.24 (-0.84)	-3.25 (-1.03)	18.36* (2.24)
Rural population	-6.17 (-1.69)	12.70* (3.84)	-0.90 (-0.27)	-37.61* (-2.32)	-13.86* (-2.11)	45.84* (2.42)
Urban population	-5.31* (-2.59)	14.63* (7.07)	-1.59 (-0.85)	-26.33* (-2.90)	-10.57* (-2.87)	29.17* (2.76)
Inflation rate				4.00 (0.64)	10.93* (4.58)	-14.93 (-1.90)
Government forestry programs	0.46 (0.98)	-0.55* (-5.42)				0.09 (0.16)
Wood products income				-46.06* (-2.18)	12.72 (1.59)	33.34 (1.25)
North Carolina dummy	-7.99* (-4.14)	4.06* (2.13)	-0.43 (-0.25)	22.85* (2.41)	5.20 (1.37)	-23.68* (-2.10)
Virginia dummy	-2.09* (-2.36)	14.60* (20.39)	-1.23 (-1.90)	1.30 (0.41)	-0.36 (-0.29)	-12.21* (-3.50)
Percent RMS ^b	7.4	5.8	20.2	6.9	136.9	15.7
Weighted R ² for the system of equations = 0.98						
Sample size, n = 13						

^a Number in parentheses below coefficients are *t*-statistics.^b Percent root-mean-square error.

* Significantly different from zero at the 0.05 level.

income. However, the coefficients are opposite in sign because miscellaneous private owners acquire many acres of farm forestland.

Positive correlation between the share of the land base in miscellaneous private ownership and personal income levels was expected, consistent with the hypothesis that higher income levels provide more investment capital. Rising personal incomes have played an important part in the shifts from farm to other nonindustrial ownerships. This is particularly true in the Mountains region, where timberland purchases are often motivated by nontimber production goals (e.g., recreation). Likewise, increases in population expand the pool of potential second-home and wildland purchasers, thereby increasing the proportion of miscellaneous private forestland owners among nonindustrial owners.

Preliminary testing indicated an insignificant relationship between the share of the land base in miscellaneous private ownership and expected timber incomes per acre. This suggests the prospect of future forestry returns is less important than for farmers, consistent with Binkley's (1981) findings that farmers are more stumpage price responsive. Several studies (e.g., Fecso and others 1982) have

shown that miscellaneous private owners often do not actively regenerate cutover areas, although projected financial returns appear relatively high.

Government forestry programs are significant variables in the miscellaneous private forest equations. This is consistent with Brooks' (1985) conclusions that government subsidies significantly increase tree planting on nonindustrial lands.

Nonforest Land Uses.—Major significant explanatory variables in the cropland share equations are population, personal income, and ratios of expected land use incomes per acre. Their individual importance varies by region. Urban population variables are significant in the Coastal Plain and Mountains. Personal income is likewise a significant negative force in inducing changes in Piedmont and Mountains cropland acreage.

As hypothesized, ratios of expected land use incomes were significant variables in the cropland equations for the Piedmont and Mountains. The Piedmont contains a relatively high proportion of marginal farmland. Land use shifts at this margin are sensitive to movements in expected relative land incomes. This is also true for the small cropland base in the Mountains. Cropland occupies a fifth of the land in the Coastal Plain and this proportion has changed very little over the last 25 years. Results indicate that a slight past decline in Coastal Plain crop acreage is probably due to urban population growth.

Output from cropland in the South has approximately doubled since the 1930's, although cropland area has declined somewhat. Cropland use has become more intensive, with the important changes at the intensive margin of land use. Shifts in land use at the extensive margin during the last 50 years have not been the key to the substantial increase in farm output. Clawson (1981) suggests that land shifts into and out of agriculture in the South have been due primarily to economic forces originating outside the region (e.g., expansion of cotton acreage on the High Plains and western irrigated areas led to reduced production on the hilly lands of the Piedmont).

Estimation results for the pasture/range equations were the least consistent with the hypothesized relationships. In large part, historical data for this land use class reflect a residual land classification that may not be truly reflective of use. Results for the hypothesized land rent relationships were mixed and significant explanatory variables were also not consistent across regions.

The insignificance of the beef income variable is consistent with White and Fleming's (1980) rejection of a related hypothesis. Although White and Fleming did not elaborate on their finding, beef income indexes may not fully reflect landowner motivations to shift land in and out of pasture/range uses. Many croplands and forests may be used for grazing when expected livestock incomes rise. The relationship between beef incomes and pasture/range use is also complicated by the use of feed grains in livestock production, associated land use shifts between cropland and pasture/range uses, and the influence of milk production goals and government dairy support programs.

Results for the urban/other use class are generally consistent with the hypothesized relationships. Significant variables in the urban/other equations are consistently population and personal income measures, except for no significant population variables for the Coastal Plain and Mountains. Urban population has grown rapidly in the Piedmont region, which contains Atlanta and other large cities in the Southeast.

Differences by Physiographic Region.—The explanatory power of the land use share equations was improved by the physiographic region stratification. Different types and quality of forestland lead to different competitive positions vis-à-vis other land uses (e.g., agriculture) across regions. The weighted R^2 and percent

RMS measures indicate the best fit was for the Mountains equations. The Piedmont equations also have relatively high explanatory power.

The absence of significant land income variables for the Coastal Plain is a somewhat surprising outcome when contrasted with the results for the Piedmont and Mountains. The Coastal Plain contains relatively more fertile land than the other two regions and has a higher percentage of crop use. But, as discussed before, land use shifts may be more sensitive to expected land income changes in the other regions because of more marginal land.

Misspecification is a major concern because of the exploratory nature of the study. However, candidates for omitted variables could not be tested because of the lack of additional time series (or proxies) for such variables. Data sources for most of the variables examined, and in particular for the forest acreage data, were probably among the best available in terms of regional statistics. In addition, analyzing the impact of changing government programs on crop acreage has been a central problem in agricultural supply analysis since World War II (Houck and others 1976). Government programs were often altered to reflect changing short-run views of economic conditions, which complicates the analysis of associated land use trends. Another important analytical shortcoming may be the inability to fully account for the diversity of landowner goals and the associated relevant returns, especially nonmonetary benefits, and costs for alternative land uses.

SUMMARY AND CONCLUSIONS

A system of land use equations was estimated for use in developing long-range projections of changes in forest acreage, including evaluation of the impacts of a broad range of exogenous forces (e.g., population growth). The econometric results indicate that demographic and macroeconomic variables have important influences on forest acreage trends. Population and personal income levels were the most consistent significant explanatory variables in the land use share equations in all three physiographic regions. Econometric results support the hypothesis that changes in timberland acreages are driven largely by demand forces outside the forestry sector (e.g., population) that influence land rents.

Demographic change increases the demand for housing and other developments, leading to higher land rents for urban uses. Rising relative values for urban uses exert pressure for direct conversion of forestland to those uses and to replace agricultural land lost to those uses. Rising populations and income levels over the next 50 years will likely cause further reductions in the farm forestland base. However, miscellaneous private forest acreage may increase, in part because real personal income is projected to increase greatly over the next fifty years.¹ This does not necessarily imply that the available timber supply will increase, at prevailing or even reasonably increased prices, to the same extent as any acreage expansion in the forestland base. The question of timberland availability on the forest acreage, including the importance of owner objectives and responsiveness to market forces, is outside the scope of this study.

Given the exploratory nature of the study and the imperfect measures of land rent, some of the limitations of the study procedures, and hence its results, should be noted.

1. The nature of the data precludes a clear-cut decision regarding the empirical superiority of alternative approaches to the formulation and estimation of a complete system of land use equations. The state of the art, including limitations

¹ The real income projections are based on similar income projections prepared for the 1980 RPA Assessment (USDA Forest 1982).

related to imperfect measures of land rent, do not allow for conclusive and exhaustive testing of the underlying land use theory. Representation of the linkages among land use classes needs careful study to minimize specification problems.

2. To fully analyze the possible pathways of land use conversions would require a model that is dynamic, both temporally and spatially. A reliable set of cost estimates or functions for possible conversion processes and estimates of the production potential of different land quality classes are needed. Further, current capabilities to cross-walk between quality measures for different land uses on a regional scale are quite limited.

3. The introduction of risk variables might improve the specification and estimation of regional land use shifts. Adaptation of related work in agriculture supply analysis should be investigated. Empirical investigations of risk need to consider differences in biological and economic uncertainty among land uses. The cost of bearing risk by landowners has the effect of increasing marginal costs (Cochrane 1955), which tends to reduce the supply of the associated product.

4. Complex strategic maneuvering, operation of woodlands as separate profit centers, and leasing of nonindustrial land are industrial aspects of timberland use that are difficult to model. Further research of key factors behind aggregate timberland investment strategy by forest industry should be part of a systematic study of the interrelated industry land acquisition, timberland management, and supply response decisions (Alig and others 1984). The question of changes at the intensive margin of land use needs to be analyzed more closely in relation to input substitution possibilities in timber production. Increased substitution of more intensive timber management and capital (e.g., improved genetic stock) for land in timber production on industrial ownerships is recent evidence of input substitution activities (Adams and others 1982).

5. Corporate owners from outside the forest products sector have purchased large amounts of timberland in the South. A quantitative examination is needed to indicate how different their land management is from the other private owner groups. Questions remain regarding to what degree they will invest in intensified management or divest of timberland after harvest. For example, timberland investments compete with more diverse corporate-wide investment opportunities for the "new diversified entrants" who have highly diversified product portfolios in comparison to the "traditional" wood-based companies (O'Laughlin and Ellefson 1982).

6. Finally, forest acreage estimation must be more strongly linked to forest type transition, timber inventory projection, harvest, and investment modeling in aggregate timber supply studies (Alig and others 1984). In theory, the levels of timber harvest, intensity of timber management and investment, and land area devoted to timber growing over time are determined simultaneously by the rational private owner. Ultimately, research may provide an overall model capable of handling this broad problem. However, given the state of the art and data deficiencies, analysts will be forced in the interim to separate the overall problem into smaller, more tractable components, as in this investigation of forest acreage trends.

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