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Title: Forest Acreage Trends in the Southeast: Econometric Analysis and Policy Simulations.

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The objective of this study was to develop a system based on economic criteria for projecting changes in land use areas. The total land base was partitioned among three classes of private forest owners and crop, pasture/range, and urban/other uses in the southeastern United States. The fraction of the land base in an owner/use was hypothesized to be a function of the ratio of the land rent for that owner/use relative to an average rent index for all owners/uses. Systems of econometric equations for the six owner/use classes were estimated by physiographic region: Coastal Plain, Piedmont, and Mountains. The data comprised a pooled cross-sectional/time series, with observations drawn at four time points from the 21 forest survey units in the Southeast.

Population, personal income, and land commodity incomes were the major significant variables in the land owner/use equations. Changes in population and personal income levels have contributed to a decline in farm forest acreage and a corresponding increase in miscellaneous private forest acreage. Projections of forest acreage trends with the

systems of land owner/use equations indicate a continued drop in farm forest acreage. Miscellaneous private forest acreage is projected to continue to increase, in part because of real personal income levels that are forecast to triple by the year 2040.

Projections of acreage changes for the five major forest types by ownership in each physiographic region, using a Markov type model, point to a substantial reduction in natural pine acreage. Transition probabilities among forest types were estimated from forest survey remeasurement data and are conditional with respect to the application of certain management practices.

The importance of exogenous forces (e.g., population) for forest acreage trends suggests the need to improve coordination with land use modeling for other sectors. Also needed are the integration of forest acreage modeling with that for forest type transition, timber inventory projection, and harvest estimation in an interregional framework.

Forest Acreage Trends in the Southeast:
Econometric Analysis and Policy Simulations

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FOREST ACREAGE TRENDS IN THE SOUTHEAST: ECONOMETRIC ANALYSIS AND POLICY SIMULATIONS

PROBLEM IDENTIFICATION

Projection of regional and national forest acreage trends in timber supply studies has been based on expert opinion, with few attempts to model the relationship of the area in forest use to economic and social determinants. With the declining trend in U.S. forest acreage since the 1960's and given the importance of area changes for renewable resource policy, however, analysts have increasingly turned their attention to this topic (Alig et al. 1983a). This study investigates key factors that influenced forest acreage patterns in the southeastern U.S. over the last four decades. Econometric equations are developed for the relationships among land use determinants (such as income from competing land uses), and changes in acreage in three physiographic regions (Coastal Plain, Piedmont, and Mountains) for the three private forest ownerships (farmer, forest industry, and miscellaneous private). A Markov model was used to develop disaggregated area projections by forest type (planted pine, natural pine, oak-pine, upland hardwood, and lowland hardwood) within each physiographic region.

BACKGROUND

Rural land use competition is expected to be particularly intense over the next several decades in the five southeastern states: Florida, Georgia, North Carolina, South Carolina, and Virginia.

Approximately three-fifths of the land in the Southeast in 1980 was classified as timberland, capable of growing at least 20 cubic feet of industrial wood per acre annually. Several sectors of the economy, including crop agriculture, pasture and range based agriculture, as well as forestry, are looking to this land as a base for expanded production (Healy 1982, Schenarts 1981).

Land use shifts will increasingly impact natural resource production trends as national and world needs for food, fiber, and other products expand. Rising export demand for food and fiber products is of particular interest (Crosson 1981), given that the recent National Agricultural Lands Study identified over 11 million acres of forest in the Southeast, 15 percent of the timberland base, as having high or medium potential for conversion to cropland (Dideriksen et al. 1977, USDA and Council on Environmental Quality 1981). Loss of land to urban uses through the continued net migration of the population into the Southeast will also alter natural resource production trends.

Policy analysts need an explicit model of forest land use to examine the resource impacts of trends in population, income, and other socioeconomic variables. Such a model would improve the evaluation of prospective land base shifts and their effects on the supply of timber and other natural resources (e.g., wildlife habitat).

OBJECTIVES

This study has the following objectives:

1. Develop and test a theory of private forest acreage trends, using the Southeast as a study area.
2. Project southeastern forest acreage trends by owner group, physiographic region, and forest type under alternative assumptions for key policy variables.

The study is designed so that results will contribute to preparation of the 1990 RPA Assessment by the USDA Forest Service. Emphasis is placed on developing and testing a prototype analytical system and identifying additional data and analysis needs for possible application of a similar analytical system to other regions.

JUSTIFICATION

The USDA Forest Service is required to conduct periodic assessments of long-range forest and range market trends by the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974, the Renewable Resources Research Act, and the Cooperative Forestry Assistance Act of 1978 (USDA Forest Service 1982a). These assessments are important for nationally coordinated long-range planning involving publicly owned forest resources as well as for state level resource planning. Analysis required by RPA legislation involves two primary tasks:

1. The Assessment, which analyzes present and anticipated uses, demand for and supply of renewable resources, with consideration of the pertinent trends in supply, demand, and price relationship.

2. The Program, which is an evaluation of opportunities for improving the yield of tangible and intangible goods and services, together with estimates of investment costs and direct and indirect returns to the Federal Government.

Based on the likely future market conditions projected in the RPA Assessment, the RPA Program in turn may propose actions to affect future supply, demand, and prices.

One problem area that has been identified as a high research priority in critiques of past RPA planning is the modeling of forest acreage trends (Beuter 1979, USDA Forest Service 1982a). Systematic and explicit modeling of forest acreage patterns is needed as a basis for projecting likely responses to future market and resource conditions. Projections of future private forest acreage trends play an important role in both the analytical and policy aspects of the RPA process. Land use shifts influence both short-term timber supply and long-term timber investment behavior. When acres leave the timberland base, part of their inventory is marketed and contributes to current harvest, i.e., stumpage supply. Second, in the longer term, loss of these acres reduces the aggregate growth potential of the resource. Supply may be lower than it would have been had these acres been retained, depending in part on changes in timber investment in response to higher stumpage prices because of acreage reductions. The higher stumpage prices would drive up resource costs in the region, resulting in shifts in regional production of forest products. Therefore, forest acreage is a major factor in long-term stumpage supply, and hence, the supply of lumber and plywood.

Southeastern private forest acreage trends are analyzed because of the region's (1) relatively large holdings of private forest land, (2) importance in regard to future timber, crop, and forage production expansion, and (3) complement of data and research results. Private forest ownerships in the Southeast comprise one-sixth of the commercial forest land in the U.S. and nearly one-fourth of all private commercial forest land in the U.S. (USDA Forest Service 1982b). The Southeast also contains approximately two-fifths of the U.S. forest acreage identified in the National Agricultural Lands Study as having medium or high potential for conversion to cropland.

In this study, three private ownership classes are recognized: farmer, forest industry, and miscellaneous private. In the Southeast, these ownerships account for over 90 percent of the timberland. No distinction between the farmer and miscellaneous private classes has been made in previous regional timber supply studies. However, factors influencing the two classes in terms of landownership are likely to be quite different.

Important physical and economic differences among the three physiographic regions are due in part to the types and quality of land in each physiographic region (Appendix A). These regions are defined as the basis of geological factors and differ in terms of soils, topography, and associated groups of plants and animals (Vance 1935). This has led to different competitive positions for forest land vis a vis other land uses (e.g., agriculture) across regions.

Five broad forest management types are considered in this study: planted southern pine, natural southern pine, oak-pine, upland hardwood, and lowland hardwood. Southern pine is the most commercially important forest type in the Southeast, and occurs on two-fifths of the southeastern timberland. Lack of regeneration efforts after harvest, however, has led to substantial conversion of southern pine acreage to oak-pine and hardwood types (Boyce and Knight 1979, 1980). Future shifts among these forest types is of prime concern in regard to future southeastern timber supplies.

REVIEW OF LITERATURE

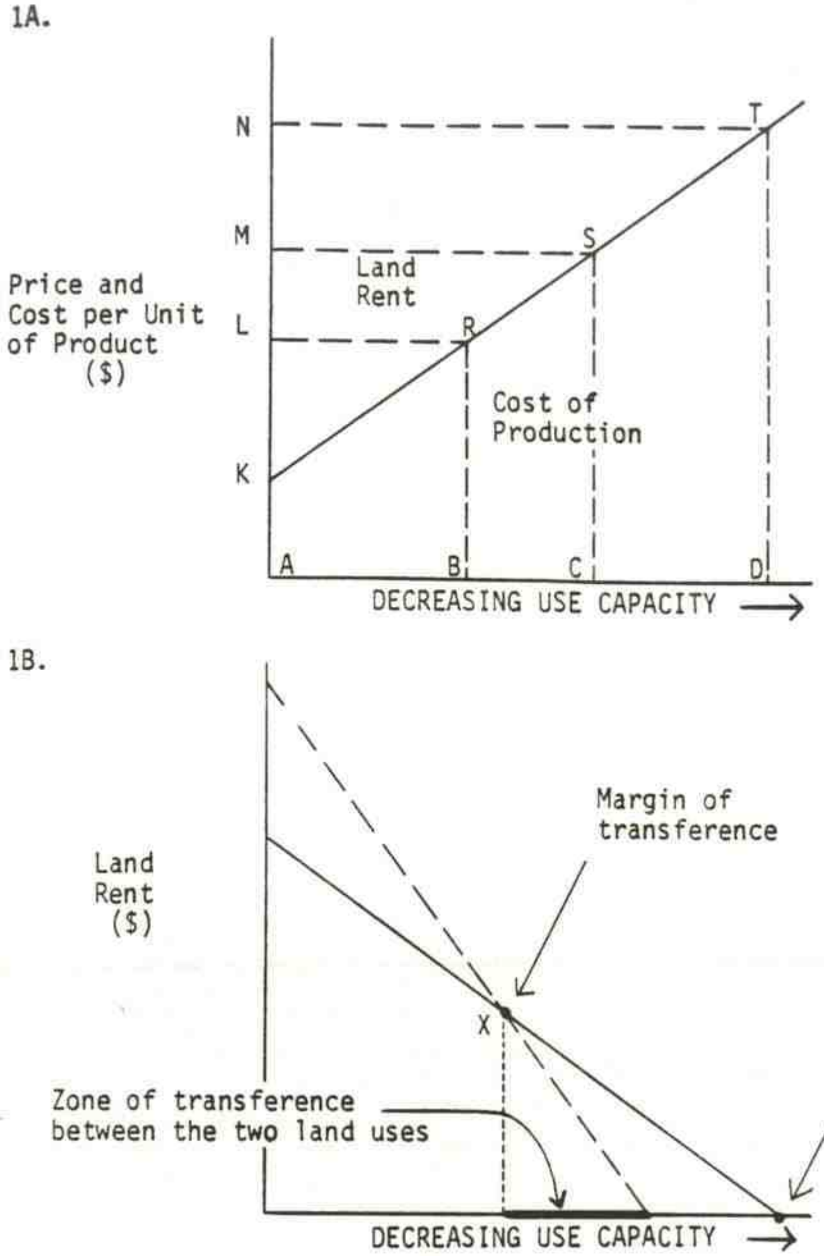
Forest acreage projections in previous timber supply assessments have been exogenous, based on opinions of regional experts. The most recent example is Wall's (1981) projection of commercial forest land acreage by region in the 1980 RPA Assessment. To estimate future commercial forest land, Wall subtracted the number of acres estimated to be withdrawn for uses of perceived higher economic (e.g., agriculture) or social value (e.g., wilderness) from the potential commercial forest land base. These exogenous projections of commercial forest area were then used in estimating stumpage supply in the Timber Assessment Market Model (TAMM). Adams and Haynes (1980) recognize that the acreage devoted to timber production or allowed to remain in a forested state is not independent of the timber price and growth projections made in TAMM, but they conclude that the decisions involving the many possible uses of land are too complex for direct inclusion as endogenous processes in TAMM.

Total forest acreage in the U.S. (including non-timberland) was also projected to the year 2030 in the 1980 RPA Assessment (USDA Forest Service 1981). These estimates were based largely on simple trend analysis, with no clear indication of the estimated influence of market and other forces on changes in land use.

THEORY OF FORESTLAND UTILIZATION

The economics of land utilization is based on the theory of land rents from various production enterprises. Land rent is a residual economic surplus--the portion of the total value product that remains after payment is made for the total factor costs (Barlowe 1978). Land rent theory dates back several centuries to Ricardo's theory that land rents are related to soil fertility differentials, which was later extended by von Thunen to include transportation or locational considerations (Alonso 1964, Jones 1978). Von Thunen (1966) used distance as a proxy for all factors influencing the net economic value of homogeneous land. This was used to construct land value profiles, where land values for alternative uses drop as one moves away from the center of a city or village. This drop in land values results from increasing transportation and commuting costs, all other factors being assumed constant.

Figure 1 shows the associated relationship between use-capacity and rent-paying ability (Barlowe 1978). The diagram assumes a continuum of lands of decreasing use capacity, which is defined as the relative ability of lands to produce a surplus of returns above costs of utilization. In Figure 1A, the extensive margin of land use shifts to the right with the use of the lower grade, less productive, and less advantageously situated lands. This shift corresponds to a gradual increase in production costs. When prices for the land output rise 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. Figure 1B depicts the land rent triangle from Figure 1A which was detached and turned over, illustrating the relationship between decreasing use-capacity and the amounts of rent produced for any land use.



The solid line above represents land rent triangle KNT from 1A. The dashed hypotenuse is associated with an alternative land use.

Figure 1. Relationship between use-capacity of land resources, production costs, and land rent (adapted from Barlowe 1978).

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. Second, the intensive margin is reached with the last unit of variable input that can be applied before marginal costs exceed marginal returns. The additional land rent triangle in Figure 1B associated with an alternative land use illustrates the margin of transference, the points at which intensive margins intersect, i.e., economic value for alternative uses is positive and equal (Ely and Wehrwein 1964, Barlowe 1978).

Tools of modern economic analysis have been used to significantly improve certain aspects of von Thunen's land utilization theory; however, other areas of the theory have not been advanced much beyond von Thunen's original work. Ledyard and Moses (1976) proposed a formal dynamic model to extend von Thunen's framework to include the interaction between time and transport cost in determining rents, land uses, and intensities of cultivation at varying distances from a marketing center. They combined capital theoretic considerations and von Thunen's theory of rent and land use in a long-run, steady-state, competitive equilibrium model of forest land use. Ledyard and Moses conclude that time is substituted for labor in forest production as distance from the processing mill increases, leading to larger outputs at harvest time. In essence, their model points to smaller working circles and less acreage managed for timber production in contrast to that implied by traditional sustained yield models in forestry. Bradley (1972) also discusses transportation costs in forestry in relation to access considerations, focusing on the improvement of forest survey procedures.

Dynamic economic conditions can impact alternative land uses on both sides of the land use margins (Waggener 1983). Healy (1982) discusses the consequences of revised land value expectations and the generally low ranking of forests in the economic hierarchy of land use. The case of "replacement demand," where a sequence of land conversion occurs in the land use hierarchy, is exemplified by converting forestland to "replace" cropland that was urbanized. While it is helpful to isolate the influence of one economic change at a time, in practice land use reflects the composite impact of numerous changes occurring simultaneously (Healy and Short 1981). Expectations concerning the future are capitalized into higher land prices, both for land which remains in its current use (e.g., timber production) or land subject to future changes in use (Bare and Waggener 1980).

Externalities in land use may cause distortions in land allocation patterns. An example is acreage devoted to forestry at the extensive margin that is socially submarginal because of off-site siltation, but which appears to be economically productive from a private perspective (Waggener 1983). Another example is Musser et al.'s (1982) estimate of the $13.70 per acre of recreation annual surplus value lost when forestland was converted to cropland in Georgia.

A set of land use profiles for competing uses defines a land use hierarchy for a particular site, which represents the highest and best use (Hoover 1975). Land acquires its value from a series of anticipated net returns. Land value represents capitalization of these future net returns. However, a number of factors influence the value of land, most of which are subject to change over time. Most of the demand for land is derived, in which case the demand results from the productive potential, its location, or other advantages rather than the land itself (Barlowe 1978). Any change which increases the present value of returns or reduces the present value of costs will increase land value.

The land market does not possess the usual characteristics of a purely competitive market (Reynolds and Timmons 1969). Land is a heterogeneous resource that varies greatly in quality, with parcels often differentiated by unique factors such as location of transportation facilities or adjacent land holdings. Some land classification problems are caused by the subjective nature of the classes. For example, some classifications are oriented toward farm valuation and are not necessarily consistent with those for urban or commercial uses. The land productivity classifications used for agriculture and forestry likewise, do not allow meaningful cross-checking or joint use.

Another characteristic of land markets that deviates from the purely competitive market is the frequent lack of a large number of buyers and sellers. These conditions and ownership patterns may also affect free entry and exit from the market. The fixed location of land also tends to localize the market for it.

Forestry is an activity that requires a large land area relative to value of output and is sensitive to transportation cost considerations. It is similar in this regard to agriculture. Neither effectively compete for urban land, where the locational element of land cost is high. Because spatial patterns for forestry are strongly affected by competitive uses, forest land utilization patterns and associated rent levels reflect geographic differences with respect to market.

Institutional influences on forestland use include taxes, land use controls, and forestry practice regulations. A tax policy as a mechanism for land use control has the explicit goal of altering land use decisions at the intensive margin by impacting perceived values in order to prevent or delay changes in land use that are viewed as undesirable (Waggener 1983). Tax burdens can lead to differential changes in land use values, thus causing unintended allocation consequences at both the intensive and extensive margins. Taxation and zoning influence forest acreage patterns in varying ways across the country. Hauenstein and Siegel (1980) assert that timberland is generally less able to absorb tax increases than are most other types of properties. This arises because many tracts offer little prospect of early income from which to meet annual taxes. McKetta (1980) suggests, however, that tax policies overall have minor impacts on land allocations involving forestry. Of the three important operating margins--extensive, transfer, and intensive--McKetta concludes that the greatest effect of taxes, with minor exceptions, is on the propensity to invest on an existing forest acre. Land use controls and forestry practice regulations are less developed in the South than other parts of the country, and have relatively minor impacts on private land allocation in the South.

Ownership Studies

Many studies pertaining to the motivation for owning and managing forestland have focused on physical, sociological, and psychological factors. These have tended to be descriptive studies, focusing on ownership characteristics (e.g., Birch et al. 1982, Holemo and Brown 1975), and are often based on surveys of owner intentions or objectives (e.g., Marler and Graves 1974). Few have formulated the question of why owner groups manage their land differently in economic terms, and even fewer have conducted empirical tests of theories.

Nonindustrial Owners

Behavior of nonindustrial owners has been studied to a much wider extent than that for industrial owners, primarily because nonindustrial owners own three-fifths of the timberland in the U.S., including three-fourths of the southeastern timberland. McMahon's (1964) critical review of research on the nonindustrial owner situation points out that there has been inadequate problem formulation and a general lack of theoretical development. This accounts for the absence of a theoretically sound, unifying explanation of forestland ownership that is based on causal relations. McMahon calls for an elaboration of a theory based on economic principles, which seeks to interpret economic implications found in a wide array of evidence from available ownership studies.

Empirically based studies of regional forestland ownership that address McMahon's earlier recommendations still do not exist 20 years later. However, related work that addresses the question of timber supply from existing timberland provides some guidance in the identification of candidate variables for inclusion in a forest acreage model. For example, Binkley's (1981) economic analysis of timber harvest decisions by New Hampshire woodland owners indicated that farmers are much more price responsive than non-farm nonindustrial owners in terms of timber harvest decisions. The probability of timber harvest was negatively associated with the income of the owner. Other empirical investigations of private timber supply behavior include estimates by Adams and Haynes (1980) for stumpage supply elasticity with regard to price and timber inventory variables. Elasticities for forest industry owners in the Southeast were equal to 0.5 for both price and inventory (proxy for capital costs). The corresponding estimates for nonindustrial owners were 0.3 and 0.7, respectively. Lange (1983) estimated elasticities for hardwood sawlog supply from nonindustrial lands, and similar to Adams and Haynes (1980), found that the supply responses were all inelastic. The forest industry price elasticity was estimated at 0.2 and inventory elasticities at 0.3. Corresponding nonindustrial estimates were both 0.2.

Fecso et al. (1982) found that a key motive of nonindustrial private owners in the South for owning and managing land was the building of an estate, a long-term family-oriented investment, rather than deriving short-term profits. Much of the land was inherited and is held as part of family-oriented ownerships. Many landowners also do not perceive the need to actively regenerate lands back to pine after harvest, attributed in part to the limited influence of professional foresters on forest management decisions.

Forest Industry

Ownership of timber resources is a critical consideration in the strategic planning of most forest industry firms. Timberland investment has been an important means of improving profitability (Clephane 1980) and limiting competition in a region (Gilligan 1972). The importance of timberland ownership is reflected in a firm's cost of production, and only those companies with a relatively large low-cost timber base have grown at faster-than-average rates in the wood products sector (Clephane 1978a,b). Delivered wood costs in the lumber and wood products portion of the forest products sector (SIC 24) represent about 30 to 35 percent of the manufacturing cost, considerably higher than for the paper and allied products major industry group (SIC 26). Rich (1980) reports that wood products firms place greater emphasis on assuring a company timber base and maximizing the return from it than those who are primarily pulp and paper producers.

The squeeze on the availability of accessible timber has been accompanied by rapid rises in both western and southern timber prices. Clephane and Carroll (1981) suggest that southern timberland is significantly undervalued relative to western timber, which should lead to greater investments in southern timberlands and in conversion plants. Farmer and miscellaneous owners control approximately three-quarters of the commercial timberland base in the South, while forest industry owns the vast majority of the rest (18 percent of the southern total). Thus, in general, forest industry in the South is heavily dependent on other private lands for a large portion of its timber resource supply, in contrast to the relatively small contribution to timber supply of other private lands in the Pacific Northwest.

Analyses of trends for industrial ownership of forest land have generally consisted of the reporting of descriptive statistics, with little analysis of underlying relationships. This is due in part to the secrecy surrounding industry's strategic planning as few companies reveal specific figures pertaining to timberland ownership, such as land values or commercial timber inventories. One of the few studies of corporate timberland acquisition strategies is Enk's (1975) examination of the strategic land-use decisionmaking by 20 large forest products corporations in 1968 and 1969. Enk's interviews with executives of wood-based companies indicated that land was owned for a variety of reasons. A source of raw material was given as the primary reason in about a third of the responses; however, the executives apparently divulged few of their strategic concerns. Timberland acquisition and use decisions of nine companies as parts of overall corporate strategies were similarly examined by O'Laughlin and Ellefson (1982), but their behavorial hypotheses were not statistically tested.

Studies of corporate decision-making in general either rely on the industrial organization economics or corporate strategy approaches (Porter 1979). Given that the essence of strategy formulation is coping with competition in an industry, which is rooted in the underlying economics, a blend of these approaches would seem to be more useful. The literature dealing with strategic planning by companies is quite voluminous, much of it based more on opinion than systematic study of the questions involved. The question of how timberlands fit into the strategic planning processes of wood-based companies has been addressed in a similar manner (e.g., Rich 1980), with few firm conclusions provided so far in this steadily evolving area of study.

FOREST TYPE SUCCESSION

The extent and composition of a region's forests have dynamic properties that are influenced by forces of succession. These successional trends are shaped by a mix of natural and man-induced disturbances. Economic and social forces underlying the man-induced disturbances tend to be much more ordered than the randomly triggered natural forces (Loucks 1970). The man-caused disturbances occur largely near urban areas or on sites preferred for agriculture, pasture, or amenity settlement (Johnson and Sharpe 1976). Further, some actions, such as the abandonment of cropland, favor the invasion of pines, while others (e.g., owner investment in hardwood conversion) promote directions of change that are opposite those of natural forest succession.

The several studies of forest succession at regional levels have concentrated on undisturbed states of nature. Shugart et al. (1973) constructed a model for the western Great Lakes region of the United States which simulated the amounts of forested land in different successional stages in the absence of natural and man-caused disturbances. They used ordinary linear differential equations that reflected stand dynamics and silvics in order to determine rates of change. Waggoner and Stephens (1970) developed a comparable model using a Markov process, assuming stationary transition probabilities for forest type shifts. Binkley (1980) rejected the stationary Markov process as an adequate model of mixed hardwood forest succession, but the stationarity assumption has not been tested for southern tree species or for areas receiving management treatments. Johnson and Sharpe (1976) used nonstationary transition probabilities in a differential equation model in order to examine a number of land use scenarios. Forest management effects on forest type shifts in the northern Georgia Piedmont were simulated. Rates of growth, mortality, harvesting, and land use change were based on average conditions for the preceding 1961-72 period.

Brooks (1983b) incorporated a conditional transition probability matrix in a timber inventory projection model of the South in order to reflect the outcome of both management practices and natural succession tendencies. This included, for example, a probability distribution for the different possible destinations for an acre harvested in a natural pine type. Brooks' research demonstrated that natural tendencies of forest succession are significant forces to be considered in analysis of acreage trends for forest types. More importantly, they need to be considered in the context of underlying trends in the level and kind of man-induced disturbances. Man substantially reduces the impact of certain natural disturbances, such as fire, while generating new impacts related to land utilization. The study of the economics of man's activities, which have supplanted natural disturbances as a major force in forest type acreage trends, is fundamental to understanding the structure and dynamics of the regional forest system.

ANALYSIS OF FOREST ACREAGE TRENDS

Economic Optimization Approaches

Economic analysis of the allocation of land as an input or factor of production to timber growing has typically used the soil expectation value approach (e.g., Vaux 1973, Hyde 1980). Hyde (1980) applied the concept of soil expectation value to demonstrate the use of a variable land production function. This function represents land used for timber production at various prices and the associated efficient harvest levels. Access costs, dependent on distance to a site and topography, influence the degree of timber management applied to different land classes at the intensive margin. This approach assumes that higher stumpage prices will attract less economically productive acres into timber production. Competition with other land uses is not directly considered, as land is assumed to be either used for timber or is idle.

Georgia Supply (GASPLY) is (Montgomery et al. 1975, 1976; Robinson et al. 1978) similar in theory to those models employed by Vaux (1973) and Hyde (1980), but GASPLY can examine the relative profitability of agricultural and timber production uses. GASPLY assigns to a given land parcel the use with the highest economic rent. Limits are set on the amount of land that can shift between timber production and agriculture. Only the most productive timberland found in farmer ownerships is considered to be feasible for conversion to agriculture, while the amount of farmland available for conversion to timberland is restricted to idle farmland.

GASPLY accounts for expected population growth and certain property tax changes by shifting timberland to urban-related land uses. A limitation of the GASPLY and Vaux-Hyde approaches is that they do not include a land use adjustment theory or mechanism. Therefore, those models are limited in terms of explaining development over time and they cannot be readily tested against empirical observations.

No forestry-based optimization models contain interregional linkages for analyzing land allocation patterns involving forestry. The Center for Agricultural and Rural Development (CARD) model of large-scale, interregional, agricultural land allocation considers conversion of forest to cropland in estimating least-cost agricultural expansion to meet exogenous agricultural currently commodity requirements (Huang et al. 1981). However, the CARD model is not designed to estimate the possible reversion of cropland to forest.

Statistical Models

Few statistically based models of land use acreage trends have been employed, due in part to data problems. Time series data on forest land use are difficult to construct because of irregular and infrequent measurements or estimates of timberland. Attempts to augment periodic forest acreage data with other major data sources are confronted with differing criteria used in past classifications of forest lands.

Burnham (1973) used a Markov model to simulate intertemporal land use shifts in estimating future United States cropland availability. Forest land was one of six land uses projected, based upon land uses in the Southern Mississippi alluvial valley between 1950 and 1969. The finite Markov chain process employed probabilities of land use shifts based on movements between use groups over a historical time period. These probabilities were then used to project future land uses at alternative points in time. MacDonald et al. (1979) also applied a Markov chain model to project bottomland hardwood acreages in the Lower Mississippi alluvial plain to 1995. Projecting the future implications of past land use trends in this manner masks the causal variables and, therefore, does not allow quantification of the processes underlying land use shifts. In addition, the stationarity assumption for land use transitions may be unrealistic in light of irregular economic conditions.

The interaction of demand and supply in the land market establishes land prices. Studies of forestland prices are fragmentary in scope. The bulk of published data on forestland market values is for farm forests, which has been compiled using mail surveys (e.g., USDA Economic Research Service 1971). This type of data, collected between 1971 and 1979, was examined by de Steiguer (1982), with the focus on value levels rather than the reasons behind the value changes. De Steiguer showed that, despite recent values increases, forestry remains a relatively low-valued land use. The average values for the Southeast were the highest in the U.S. but were only 66 percent of agriculture values per acre.

Econometric Models

White and Fleming (1980) modeled crop, forest, and pasture/range acreage patterns on Georgia farm ownerships based on a land rent framework, using a system of simultaneous equations. Regression results were used in a simulation model to investigate the impact of government land diversion programs on land use patterns from 1980 to 2000. White and Fleming used interpolations to generate annual land use, based on data reported every five years in the Census of Agriculture (e.g., USDC, Bureau of the Census 1977).

The White and Fleming approach is noteworthy because of its foundation on land rent theory and use of simultaneous equations to explain the interrelationships among competing land uses. They hypothesized that forest acreage would be negatively correlated with stumpage prices because timber harvesting was expected to be greater when sawtimber stumpage prices were high. This implied that some forest acreage would not be regenerated after harvest and would be taken out of forestry. The econometric results showed, however, that stumpage price was not a significant determinant of forest acreage trends on Georgia farms. They did not distinguish among forest types in their study, and used southern pine sawtimber stumpage prices in all cases.

Land in farms and crop acreages were isolated as the most significant determinants of forest acreages. White and Fleming found timber acreage to be negatively related to endogenous crop and pasture acreages, as expected. The estimated coefficient for the highly significant land in farms variable was 0.73. Forestland is the largest component of farmland in Georgia and the finding that it varies similarly with land in farms is expected. But the coefficients for the land in farms variable across all three land use equations sum to 1.2, which reflects underlying land use definitional problems or estimation shortcomings. White and Fleming also reported a negative coefficient for beef income in their pasture acreage equation, but did not offer an explanation.

Studies of agricultural supply response have examined the sensitivity of acreage planted in major crops to various economic, technical, and institutional stimuli, in an effort to understand the influence of government farm programs on production decisions. Econometric analysis of time series data and/or cross-sectional data has led to an extensive literature pertaining to individual agricultural commodity and sector models. For example, Houck and Subotnik (1969) utilized market and effective support prices for soybeans and competing crops to estimate linear equations representing regional soybean acreage functions. In contrast to the use of prices for single land products as independent variables by Garst and Miller (1975) and Houck et al. (1976), Morzuch et al. (1980) expressed price relative to the prices of competing crops as an explantory variable. This led to significant relative price variables in wheat acreage equations in eight of thirteen states examined.

In general, time series supply analyses of crops have been limited because of the operation of supply-restricting acreage controls. Crop acreage response studies have typically also not considered changes in major categories of land use, but have concentrated on shifts among agricultural crops. Of particular interest are the behavioral models at aggregate levels, which represent several different approaches to modeling producer formulation of expectations of price and yield. Nerlove's (1958) dynamic supply model is based on a distributed lag mechanism, a refinement of the hypothesis that farmers respond simply to last year's price. The partial adjustment model attributes the lags in response to technological and psychological inertia and to the rising cost of rapid change. The adaptive expectations model attributes the lags to uncertainty and discounting of current information (Griliches 1967). The adaptive expectations model has been widely used in agricultural supply analysis, and less so in forestry (e.g., Brooks 1983a). A theory of expectations and risk specific to forestry is not well developed.

The special problems associated with formulating supply models for perennial crops have received little attention in comparison to the advance made in examining factors influencing acreage response for annual crops (French and Matthews 1971). Perennial crop production is distinguished from the production of annual agricultural crops in part by the long gestation period between initial input and first output. This is similar to the timber production case, although important differences are the annual output of perennial crops for an extended period and the generally shorter life of the investment. The supply response models for some perennial crops also account for planting, removal, yield, and time dimensions not similarly encountered in annual crops. These are details which often cannot be incorporated in analyses of regional forest production processes because of data limitations.

Supply response models for perennial crops must explain the removal and replacement of plants, considering the lags between input and outputs and the effects of populations of bearing plants on production (French and Matthews 1971). French and Matthews (1971) suggest expected profitability of the particular commodity and expected profitability of alternative land uses as the major determinants of production (as individual variables). A major problem encountered in estimating these types of relationships is that data simply are not available on important variables. Basic models must be modified to utilize kinds of information typically available. Various expectation mechanisms for prices and costs have been examined in perennial crop studies (e.g., average value for several preceding years), along with the partial adjustment hypotheses discussed earlier.

Econometric models for the livestock sector also commonly employ aspects of investment or inventory adjustment that may be relevant in guiding the development of forest acreage models. The length of lag in production response is a function of the characteristics of the particular industry (Nerlove 1972). It has changed over time in some cases such as for broilers because of market structure and production technology changes (King 1975). Econometric models of regional pasture and/or range acreage responses have not been reported, although related work has apparently been recently incorporated into the National Interregional Agricultural Projections Modeling System (Quinby 1983).

Examination of risk influences in agricultural supply analysis by Just (1974) showed that the variance of gross returns (as risk terms) is important in explaining acreage response for California field crops. One of the few studies of risk behavior by forestry investors used mathematical programming to analyze choice among central hardwood investments and farm options (Mills and Hoover 1982). A positive analysis using similar portfolio and diversification considerations in forestry has not been reported.

SUMMARY

The fundamental question of the prospective number of acres in forest use has been addressed using expert opinion in regional and national timber assessments. Such projections are not sensitive to likely future stumpage price paths, and systematic analysis of the dynamic relationships among major economic variables (such as income trends for competing land uses) and forest acreage changes has also been lacking. In sum, forecasting the availability and accessibility of forest acreage remains a major problem in aggregate timber supply analyses.

Other methods used to project area change include the Markov analysis as employed by Burnham (1973) which assumes a continuation of past transition rates from one use to another. As with the expert opinion approach, this simplifies the development of long-term acreage trend projections, but in the process, underlying causal relationships are obscured. The 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 which is a continuation of historic trends, even if we contemplate rather different future economic and social conditions.

Other analytical approaches include the soil expectation value framework employed by Vaux (1973) and Hyde (1980). These economic efficiency models can estimate long-term steady-state outcomes, but lack mechanisms for modeling the dynamics of forest acreage changes. The Vaux and Hyde approaches also do not consider conversion of forestland to major competing uses (e.g., agriculture). GASPLY (Montgomery et al. 1975) is another static economic model, and while it does model conversions between forest and agriculture uses, it is also untested because it likewise lacks intertemporal adjustments that would allow empirical testing.

No regional forest acreage projection models have been estimated that reflect historical relationships among ownership considerations, relative land product price trends, and other important land use determinants. Land use models have typically not projected all major land uses simultaneously, so that total land base constraints are not explicitly met. An equation for Georgia farm woodland acreage trends was estimated by White and Fleming (1980) as part of a simultaneous equation analysis of the interrelationships among competing land uses. It is based on land rent theory but does not consider nonagricultural land use influences.

The paucity of statistically-based models is due in part to difficulties in constructing adequate time series of data for historical land use patterns. Classification criteria used in defining timberland differ among major data sources, and the most reliable series of forest acreage data consists of irregular periodic estimates for survey regions within a state.

Econometric analyses for agricultural land uses that have included both annual and perennial crops provide some guidance for the development of statistical or econometric models for analyzing regional timberland use shifts. A variety of estimation techniques, including simultaneous equation approaches, have been employed. The absence of a specific body of theory to guide the analysis of forest acreage trends, however, has been compounded by data limitations.

SOUTHEASTERN LAND USE AND IMPORTANT INFLUENCES

LAND USE

Analysis of the trends in competition among land uses relies upon data from many diverse sources. Land use data has been collected over the years by a number of organizations, who have employed differing sampling techniques and definitions in some cases (Clawson and Stewart 1965). Agricultural land use data is collected every five years in the Census of Agriculture (e.g., USDC, Bureau of the Census 1977). The Census of Agriculture only reports farm woodland data, including information on whether the woodland has been pastured. USDA Forest Service Forest Inventory and Analysis (FIA) surveys (e.g., Knight 1975) are the only other source of readily accessible forest acreage data on a state basis from which to construct historical time series for years prior to 1950. Forest land acreages for a particular state are estimated approximately every ten years, but timing of survey cycles among states differs. Timberland is the only land use reported by ownership class in the FIA surveys.

Forest land classification criteria and timing of forest acreage estimation have not been consistent between the Census of Agriculture and FIA surveys. Also, the Census of Agriculture provides estimates for farm lands only. In contrast, total forest acreage coverage by the FIA surveys is divided into seven ownerships, including a farmer category. Even for the common coverage on farm land, the sampling methods vary markedly between the two data sources. The Census of Agriculture has used personal interviews and mail enumerations. FIA surveys depend on aerial photography interpretation and on-the-ground checks. Sampling errors for the Census of Agriculture estimates appear to be well below 5 percent (relative standard error) on a state basis. Sampling errors for estimated FIA forest acreage are generally specified to be less than (plus or minus) 1 percent on a state basis.

Other data sources that may be useful for augmenting Census of Agriculture and FIA agricultural land use data include a series compiled by the SCS for the years 1958, 1967, 1975, and 1977. This series was tailored for specific SCS applications, however, which may limit their comparability and use as a time series for other analytical purposes (Brewer and Boxley 1981). The 1958 Conservation Needs Inventory (CNI) was a 2 percent sample of nonfederal rural lands designed to identify areas needing conservation treatment (USDA 1962). The CNI effort was updated in 1967 (USDA 1971), and the 1975 Potential Cropland Study (PCS) was based on a subsample of data points from the 1967 CNI (Dideriksen et al. 1977). The 1975 PCS estimated land use changes since 1967 and potential new cropland. The 1958 and 1967 CNI's were statistically reliable at the county level, but budget limitations resulted in the PCS only having statistical reliability at the farm production region, which is multi-state in size (Brewer and Boxley 1981). The 1977 National Resources Inventory (NRI) was a 1 percent sample, designed to be statistically reliable at the state level (USDA 1982).

The SCS surveys differ notably in methods and definitions, both among themselves and with surveys of other agencies (Frey 1979). Further, because no single agency surveys the use of all land in the U.S., comprehensive land use estimates are generally synthesized by adjusting data from several different sources. Frey (1979) presents an overview of the major land-use data series, along with some of the problems in synthesizing comprehensive land-use estimates which arise from differences among surveys in regard to scope, methods, definitions, timeliness, frequency, and reliability.

In the survey unit classification by the USDA Forest Service's Forest Inventory and Analysis Unit (Appendix A), the Coastal Plain covers the largest area in the Southeast (57 percent), including 11 of the 21 survey units (Figure 2). The Piedmont region contains most of the population centers and extends over seven of the survey units (30 percent of the land area). The Mountain region covers portions of three of the southeastern states, and is part of the Appalachian mountain system that stretches from the St. Lawrence Valley to Central Alabama.

The following synopsis of land use in the Southeast, based on FIA data for consistency purposes, cannot address the question of the magnitude of flows in acres among major land uses. Only (net) land use acreages at different points in time are reported. Figure 3 shows the historical changes in the percentages of the Southeast land base occupied by the six major land uses over the last four survey cycles of the USDA Forest Service. The survey cycles approximately represent the last four decades, over which the farm forest acreage has dropped almost by half. In contrast, the miscellaneous private forest acreage has more than doubled, and is now the most extensive of the six land use classes. Crop acreage has been declining at a decreasing rate, while the urban/other acreage has steadily increased. Forest industry

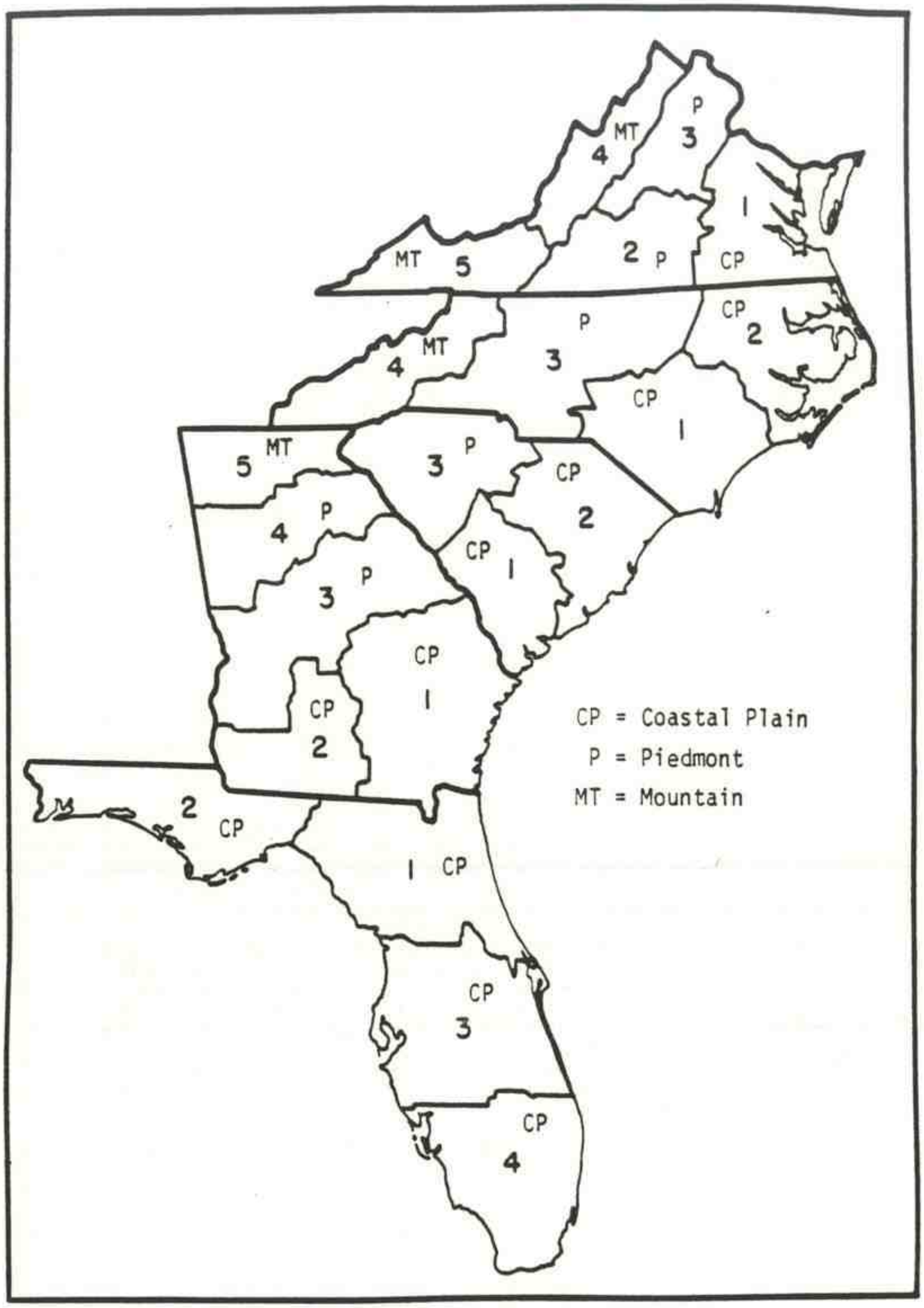


Figure 2. 21 Survey units in the Southeast.

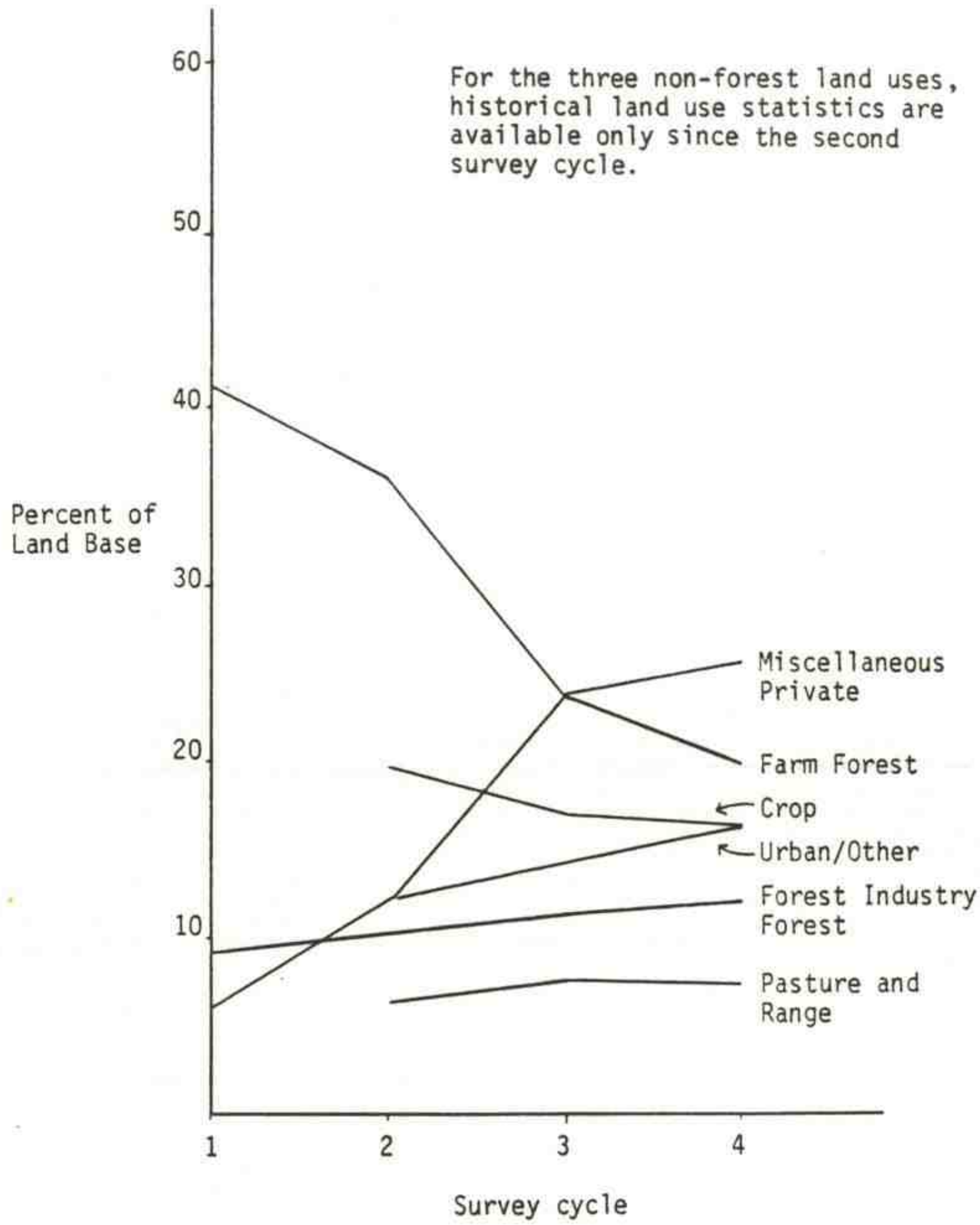


Figure 3. Trends in land use percentages in the Southeast.

acreage has also steadily increased, but at a slower rate than the urban/other class. The acreage change in the pasture/range class has been rather small over the last four decades.

Forest Acreage Trends

The importance of forest resources in the Southeast can be better appreciated by assessing them in a wider perspective (Table 1). Forests occupy 62 percent of the land in the Southeast (Table 2); almost all of which is classified as timberland that is capable of growing at least 20 cubic feet of industrial wood per acre per year. The importance of forestry in the Southeast as a major land use will be discussed in more depth in the next section.

Southeastern forests have supplied timber continuously for almost 400 years, although the original southeastern forest was more often an obstacle than a useful resource, as land clearing for crops was a necessity for early settlers (Southern Forest Resource Analysis Committee 1970). During the nation's peak lumber production around 1910, the South produced approximately half of the U.S. total. However, during the next several decades, southern lumber production declined as lumber companies migrated to the West. The Cutover Land Conference of the South in 1917 considered constructive utilization of more than 100 million acres of cutover land (Southern Forest Resource Analysis Committee 1970). But uncontrolled wildfire and increasing taxes were important factors in limiting the development of southern forestry. As fire protection grew, state forestry agencies and industrial associations were formed. Millions of acres regenerated

Table 1. Percent of land in forests, percent of forests classed as timberland, and estimated annual rate of deforestation, worldwide, United States, and Southeastern U.S. (Knight 1982).

Scope	Percent of land in forests	Percent of classed as timberland	Average annual rate of deforestation[1]
Worldwide	20	61	27.5
United States	33	66	2.0
Southeast, U.S.	62	96	0.2

[1]Given in millions of acres

Table 2. Area by major land classes in the Southeast, for the most recent surveys for each state (based on USDA Forest Service FIA statistics).[1]

	Timberland[2]	Other Forestland	Cropland	Pasture and Range	Other Land
Florida	15.664	1.470	3.785	6.992	6.622
Georgia	23.734	.508	6.774	2.505	3.316
North Carolina	19.545	.480	6.402	1.808	2.820
South Carolina	12.503	.076	3.607	1.007	1.926
Virginia	15.973	.445	3.099	3.642	2.138
Total	87.419	2.979	23.667	15.954	16.822
Percent of Southeast Land Base	59.5	2.0	16.1	10.9	11.5

[1]Given in millions of acres

[2]Timberland is synonymous with the term commercial forestland in this study.

naturally, and the second forest developed in the period since 1945. It developed under conditions that probably will not be repeated, including low market pressure on small timber and lightly stocked stands. This includes the planting of almost two million acres of retired agricultural lands under the Soil Bank Program (Alig et al. 1980).

The first comprehensive forest inventory of the Southeast was initiated in Florida and Georgia in the early 1930's and completed in Virginia in 1940. During this initial inventory, forests occupied 88.8 million acres, or about 60 percent of the land. Although there was no systematic inventory of the original forests in the Southeast, it was estimated that they occupied about 138 million acres (Parkins 1938). From the first settlement up to the early 1900's, forest acreage gradually decreased. Statistics from the Census of Agriculture indicate that agricultural uses of the land, expressed in terms of acres of improved land in farms, peaked in the region sometime between 1910 and 1920--probably just prior to World War I. At that time, there were approximately 40 million acres of improved land in farms, and forest acreage was probably at its lowest level (Knight 1982).

Between World War I and the mid 1960's, the decline in agriculture in the Southeast relinquished about 14 million acres of cropland to other uses. Although the region also experienced rapid industrial and urban development during the latter part of this period, the reversion of idle cropland to forest was so extensive that by 1963 the acreage in forests had expanded to 95 million acres. By 1965, the decline in cropland had bottomed out and has since turned upward, significantly reducing the primary source of new forest land. Because industrial and urban development continues, forest acreage is again decreasing. As of the latest surveys for each state, 78.4 million acres in the Southeast were classed as timberland (see Glossary), which comprises approximately 95 percent of the forestland in the Southeast. Robinson et al. (1981) report that approximately 12 million acres of timberland in the Southeast are inaccessible or inoperable for practical forestry because of year-round water problems, slopes exceeding 40 percent, or terrain where roads are difficult or impractical to build.

The five major forest management types in the Southeast and the percentage of timberland occupied by each for the most recent FIA state surveys were: planted pine (10.7), natural pine (29.8), oak-pine (12.3), upland hardwoods (32.0), and lowland hardwoods (15.3). The area in pine has decreased over the last several decades, partly as a result of increased cutting and better control of wildfire, which favors hardwoods. The drop in pine acreage has occurred in the face of planting, seeding, and natural regeneration of millions of acres to pine.

Fire has greatly influenced the development of the southern forest. In 1936, 22 percent of the total forest area in the South was burned over to some degree (Regional Committee on Southern Forest Resources 1938). Most of the fires are man-caused, but continuing fire control efforts have reduced the average annual burn to less than a million acres. Fire tends to favor invading species such as southern pine. Fire can be a useful management tool, as prescribed burning is used to kill thin-barked juvenile hardwoods in pine management. Therefore, fire protection measures have contributed to the replacement of pine by hardwoods on many sites.

Since the first FIA surveys in the early thirties, southern pine volume has increased by 33 percent, while the volume of hardwoods and other species increased by 58 percent (Knight 1977). Likewise, the percentage of timberland area in hardwoods has increased from 40 to approximately 60 percent. Hardwood encroachment occurred on 20 million acres of pine sites in the Southeast during this period. Tables 3 to 5 show the successional trends for the major forest types between the most recent two surveys for the states of Florida, Georgia, and South Carolina (this type of information is not available for forest surveys before 1970). The data in Tables 3 to 5 indicate the differences in forest type transition for the major categories of management practices, including differences among ownerships.

Forest Ownership

One of the most challenging problems for timber supply analysts associated with the Southeastern forest resource is the region's complex pattern of ownership. There are over 700,000 private, nonindustrial landowners who collectively own nearly three-fourths of the timberland (Knight and McClure 1974). Farmers own 34 percent, and miscellaneous private owners hold 39 percent. Forest industry holds 18 percent, and public forest land ownership in the Southeast comprises about 10 percent of the total.

Table 3. Forest type transitions on farm ownerships between the most recent two FIA surveys for Florida, Georgia, and South Carolina.[1]

Forest Type During Earlier Survey	Primary Disturbance	Forest Type During Latest Survey				
		Natural Southern Pine	Planted Southern Pine	Oak-Pine	Upland Hardwood	Lowland Hardwood
Natural Southern Pine	None	90.8	0.0	6.7	2.0	0.5
	Harvest	39.1	9.3	17.5	25.6	8.5
	Other	85.8	1.2	8.8	3.2	1.0
	Weighted Average	76.1	2.8	10.2	8.2	2.7
Planted Southern Pine	None	4.6	80.7	9.0	2.5	3.1
	Harvest	41.5	12.8	4.1	38.7	2.9
	Other	5.8	91.1	1.1	1.2	0.7
	Weighted Average	12.2	74.8	3.1	8.4	1.5
Oak-Pine	None	27.9	0.6	51.6	14.5	5.4
	Harvest	7.5	2.8	21.6	48.2	19.9
	Other	23.6	2.7	43.1	24.4	6.2
	Weighted Average	22.6	1.8	43.0	24.2	8.4
Hardwood	None	1.7	0.0	8.2	40.7	49.4
	Harvest	3.3	1.8	4.3	42.9	47.7
	Other	4.7	0.8	11.0	47.2	36.3
	Weighted Average	2.9	0.5	8.5	43.3	44.8

[1]Given in percentages

Table 4. Forest type transitions on miscellaneous private ownerships between the most recent two FIA surveys for Florida, Georgia, and South Carolina.[1]

Forest Type During Earlier Survey	Primary Disturbance	Forest Type During Latest Survey				
		Natural Southern Pine	Planted Southern Pine	Oak-Pine	Upland Hardwood	Lowland Hardwood
Natural Southern Pine	None	92.9	0.5	4.7	1.7	0.2
	Harvest	34.2	18.6	19.9	22.5	4.7
	Other	85.0	3.1	7.3	3.3	1.3
	Weighted Average	75.3	6.0	9.5	7.4	1.8
Planted Southern Pine	None	4.1	93.2	2.7	0.0	0.0
	Harvest	31.4	29.8	10.5	24.8	3.5
	Other	4.2	92.9	2.1	0.8	0.0
	Weighted Average	8.7	82.3	3.8	4.6	0.6
Oak-Pine	None	30.8	1.8	45.2	15.2	7.0
	Harvest	8.7	11.1	23.1	43.9	13.2
	Other	28.1	2.8	36.8	28.0	4.3
	Weighted Average	25.9	3.8	38.4	24.7	7.2
Hardwood	None	1.6	0.1	8.6	43.3	46.4
	Harvest	3.4	8.1	13.4	43.7	31.4
	Other	3.7	3.6	8.0	46.9	37.8
	Weighted Average	2.4	1.9	8.9	44.3	42.5

[1]Given in percentages

Table 5. Forest type transitions on forest industry ownerships between the most recent two FIA surveys for Florida, Georgia, and South Carolina.[1]

Forest Type During Earlier Survey	Primary Disturbance	Forest Type During Latest Survey				
		Natural Southern Pine	Planted Southern Pine	Oak-Pine	Upland Hardwood	Lowland Hardwood
Natural Southern Pine	None	92.9	0.7	4.8	0.0	1.6
	Harvest	16.4	61.2	7.7	9.0	5.7
	Other	72.8	16.6	6.0	3.0	1.6
	Weighted Average	54.0	31.5	6.4	4.8	3.4
Planted Southern Pine	None	1.8	94.6	2.1	0.8	0.7
	Harvest	13.7	57.7	9.5	16.9	2.2
	Other	1.4	95.8	2.0	0.8	0.0
	Weighted Average	3.0	90.7	2.9	2.9	0.5
Oak-Pine	None	21.6	6.7	46.1	12.0	13.6
	Harvest	5.6	25.5	17.4	34.2	17.3
	Other	31.3	32.1	14.5	13.0	9.1
	Total	19.2	18.7	29.6	18.9	13.6
Hardwood	None	2.6	0.1	6.1	21.0	70.1
	Harvest	1.1	25.1	4.4	29.0	40.4
	Other	4.7	25.1	7.4	19.2	43.6
	Total	2.8	10.5	6.2	22.0	58.5

[1]Given in percentages

Public ownership of southeastern forest land has changed relatively little over the last several decades. The majority of this is National Forest (4.8 million acres). Other federal ownerships contain 2.1 million acres, and State and other public owners hold 1.6 million acres. Public lands are of minor importance in this study because of the relatively small amount of southeastern acreage held by public owners and the institutional factors that guide their management.

Ownership patterns of private southeastern forests have changed markedly since the 1930's (Figure 3, Appendix B). The ongoing fifth cycle of the Southeast forest survey shows that total timberland over that period in South Carolina, Florida, and south Georgia decreased by just over 1.0 million acres. However, acreage owned by farmers and other private individuals decreased by 3.1 million acres (Knight 1982). Acreage in the other private-corporate ownership class increased by 1.8 million acres. This other private-corporate class includes a wide range of owners, among them financial and other investment institutions such as pension funds with large sums of money to invest.

By far the largest accumulation of forest holdings in the Southeast are held by farmers and miscellaneous private owners. These two groups of nonindustrial private owners have generally not been differentiated in regional or national timber supply studies, e.g., USDA Forest Service (1982b). But diverging trends in their forest acreage patterns over the last four decades (Figure 3) indicate the need to consider them separately in this study. Farm ownership of forestland has steadily declined, falling from 61.8 percent of the total in 1952 to 34.2 percent in 1977. In contrast, the miscellaneous private share has risen 13.6 percent to 38.6 percent over that same period. Many forested acres that were once parts of farms are now held by other private owners, in part because many farmers have found other work or sold property to individuals with higher incomes.

Forest industry slowly increased its share of fee simple timberland from 16 to 18 percent from 1952 to 1977. Forest industry has purchased land from all types of private owners, including other companies. Pulp and paper company ownership or control by leases and cutting rights increased from 5 million acres in 1945 to more than 25 million in 1966 (Southern Forest Resource Analysis Committee 1970).

Ownership of pine acreage by forest industry has generally increased in the Southeast over the last half century, although there was a decline in most states in the late 1950's and early 1960's. That dip in forest industry pine acreage followed a drop in product prices, and the subsequent rise also corresponds loosely with product price trends. These trends hold for both the southern pine and oak-pine forest types.

While nonindustrial land ownership is dominant in the South, outright ownership of land is only one of three major categories of land and timber resource control available to forest industry. Long-term land leasing and long-term harvesting rights are also used, although the most significant form of land control is outright ownership (Davis 1976).

Timberland under long-term lease agreements by forest industry has been increasing in the Southeast. Data are not available on the extent of leased acreage before 1970 but long-term leasing of southern pine timberland in the Southeast increased by approximately 22.1 percent over the last decade. In 1978 about 1.4 million acres of southern pine were under lease, close to 15 percent of industry's fee simple ownership of southern pine acreage. At that time, forest industry controlled about 28 percent of the southern pine land in the region either through outright ownership or long-term leasing. Approximately 85 percent of the leased southern pine acreage is in Florida and Georgia, with most of the remainder in North Carolina. Southern pine accounts for approximately two-thirds of the acreage leased by forest industry in the Southeast, with bottomland hardwoods comprising the majority of the remainder.

Conversion patterns of forestland to other uses vary by ownership (Table 6). Cropland claims the majority of converted acres on farm ownerships. The dominant use of converted forestland on the other two ownerships is urban and associated uses. This type of conversion or forest withdrawal information can only be extracted from the most recent FIA surveys in three southeastern states. The data also reflect certain FIA classification assumptions (e.g., farm forest is not converted to the "urban and other" use).

Table 7 presents the percentage distribution of forest recruitments by forest type for each ownership. Table 6 indicates that most recruitments to the forestland base originate from cropland. Therefore, the majority of recruited acres move into the southern pine type, which is favored in planting and which oftens seeds in on abandoned fields. The southern pine acres that occupy recruited

Table 6. Private acreage shifts to and from timberland between the most recent two FIA surveys for Florida, Georgia, and South Carolina.[1]

	Forest Ownership					
	Farmer		Forest Industry		Miscellaneous Private	
Non-Forest Land Use	To Forest	From Forest	To Forest	From Forest	To Forest	From Forest
Cropland	177.2	755.3	30.3	0.0	238.5	0.0
Pasture/Range	87.4	299.5	13.8	0.0	184.9	398.7
Other	35.7	0.0	11.4	65.6	75.7	802.8
Total	300.3	1054.8	55.5	65.6	499.1	1201.5
Net Loss from Timberland	754.5		10.1		702.4	

[1]Given in thousands of acres

Table 7. Destination of acres shifted to and from forest use by forest type between the most recent two FIA surveys for Florida, Georgia, and South Carolina.[1]

Non-Forest Land Use	Forest Ownership: Farmer, To Forest	Farmer, From Forest	Forest Industry, To Forest	Forest Industry, From Forest	Miscellaneous Private, To Forest	Miscellaneous Private, From Forest
Natural S. Pine	45.1	33.9	29.8	31.1	43.2	37.7
Planted S. Pine	19.0	12.7	64.7	23.4	20.4	12.1
Oak-Pine	13.9	12.8	0.0	17.7	6.1	12.9
Upland Hardwood	10.3		5.5		15.3	
		40.6[2]		27.8[2]		37.3[2]
Lowland Hardwood	11.7		0.0		15.0	
Total	100.0	100.0	100.0	100.0	100.0	100.0

[1]Given in percentages

[2]Percentages are for the combination of upland and lowland hardwoods

nonindustrial forest land are primarily the result of natural seeding, while the majority of forest industry recruitments are planted.

Non-Forest Acreage Trends

Crop agriculture uses about 16 percent of the land in the Southeast (Table 2). The most extensively planted agricultural field crops in the Southeast are soybeans and corn. They occupied 4 percent and 3 percent, respectively, of the Southeast land base in 1979. The most striking historical change has been the decline in cotton acreage. Cotton occupied less than 0.5 percent of the Southeast in 1979, as much cotton production has shifted to irrigated lands in the West. The soybean has become the South's most important crop. It is either first or second in terms of market value in all southeastern states except Florida, where citrus crops dominate.

Eleven percent of southeastern lands are used for pasture and range. The livestock industry in the Southeast consists primarily of grass-fed animals that are shipped to feeding lots in Texas and Okalahoma. Seven percent of the cattle and calves on U.S. farms in 1981 were in the Southeast, with 30 percent of this total in Florida. Severe disease and parasite problems have historically held back livestock production in the South, but southern cattle herds have recently grown faster than anywhere in the U.S. (Healy 1982).

Urban and other uses (e.g., parks) occupy approximately 11 percent of the land in the Southeast according to the latest FIA estimates. This has increased notably since FIA state surveys in the 1950's, which indicated only 2 percent of the land was in urban and other uses. Between the two most recent FIA surveys, roughly 1970 to 1980, urban and other uses increased by about 3 million acres, an expansion equal to 2 percent of the land base.

POPULATION

The Southeast's population has steadily grown since the turn of the century. Figure 4 depicts the population trends by state for the period 1930 to 1980. Florida's population has grown much faster than the other states over the past 50 years. The urban component of the total southeastern population rose dramatically from 1940 to 1970. The rural portion increased during the last decade, although the number of farms in the region continues to decline.

The South had the largest population increase of all U.S. regions between 1950 and 1980. Recent net migration into the South indicates the population shift is continuing as the South greatly outranked other regions of the country in percentage increase in population between 1970 and 1980 (USDC Bureau of the Census 1981). Populations in the South grew more than 20 percent over this period.

The Southeast has had a substantially larger proportion of its population in rural areas than the nation as a whole. With the exception of Florida, all the southeastern states have a larger rural proportion than the national average. The largest rural percentage (52 percent) is in North Carolina, which is double the U.S. average. Southern settlement patterns have also led to relatively low urban densities, with a region-wide 1980 average of 0.40 acres per urban-area resident compared to 0.28 acres for the U.S. average (Healy 1983).

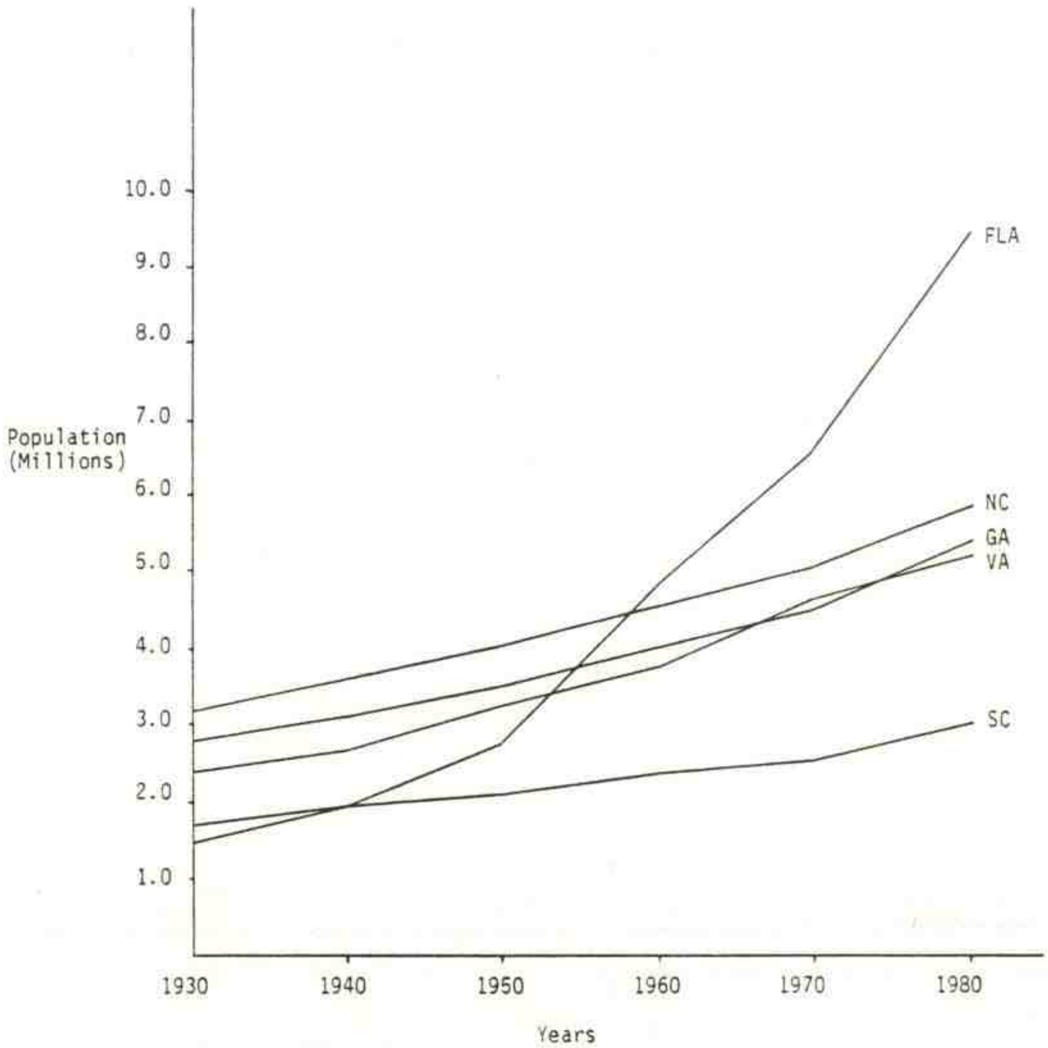


Figure 4. Population trends by state for the Southeast.

PERSONAL INCOME

Population growth generally signals economic expansion, and this is particularly true in the Southeast. Increases in total southeastern income payments between 1946 and 1948 were slightly below the national average (Schwartz and Graham 1949). In contrast, the Southeast's increases between 1981 and 1982 were the highest in the country. Personal income (Appendix C) has grown steadily in the Southeast and has doubled in the last 20 years. This growth rate has been one of the highest in the country, particularly for Florida (Figure 5).

Despite rapid growth, per capita personal incomes in the region are still relatively low. Per capita personal income in the Southeast ($6,810) was well below the U.S. average ($7,840) in 1978 (USDC Bureau of Economic Analysis 1981). The southeastern states fall in the bottom one-quarter among states in terms of 1982 per capita income, and none are in the top quarter. Only Florida and Virginia, at the southern and northern regional boundaries, are close to the national average.

The ratio of farm income to non-farm income in the Southeast is small and continues to decline. In 1952, the ratio ranged from 0.05 to 0.13 for the five southeastern states. By the early 1970's, the range was 0.01 to 0.03.

LAND USE INCOMES

Historical trends in product income indices (see Appendix C for descriptions) differ notably for crop, pasture/range, and forest uses (Figure 6). Trends in crop income are similar across states, except

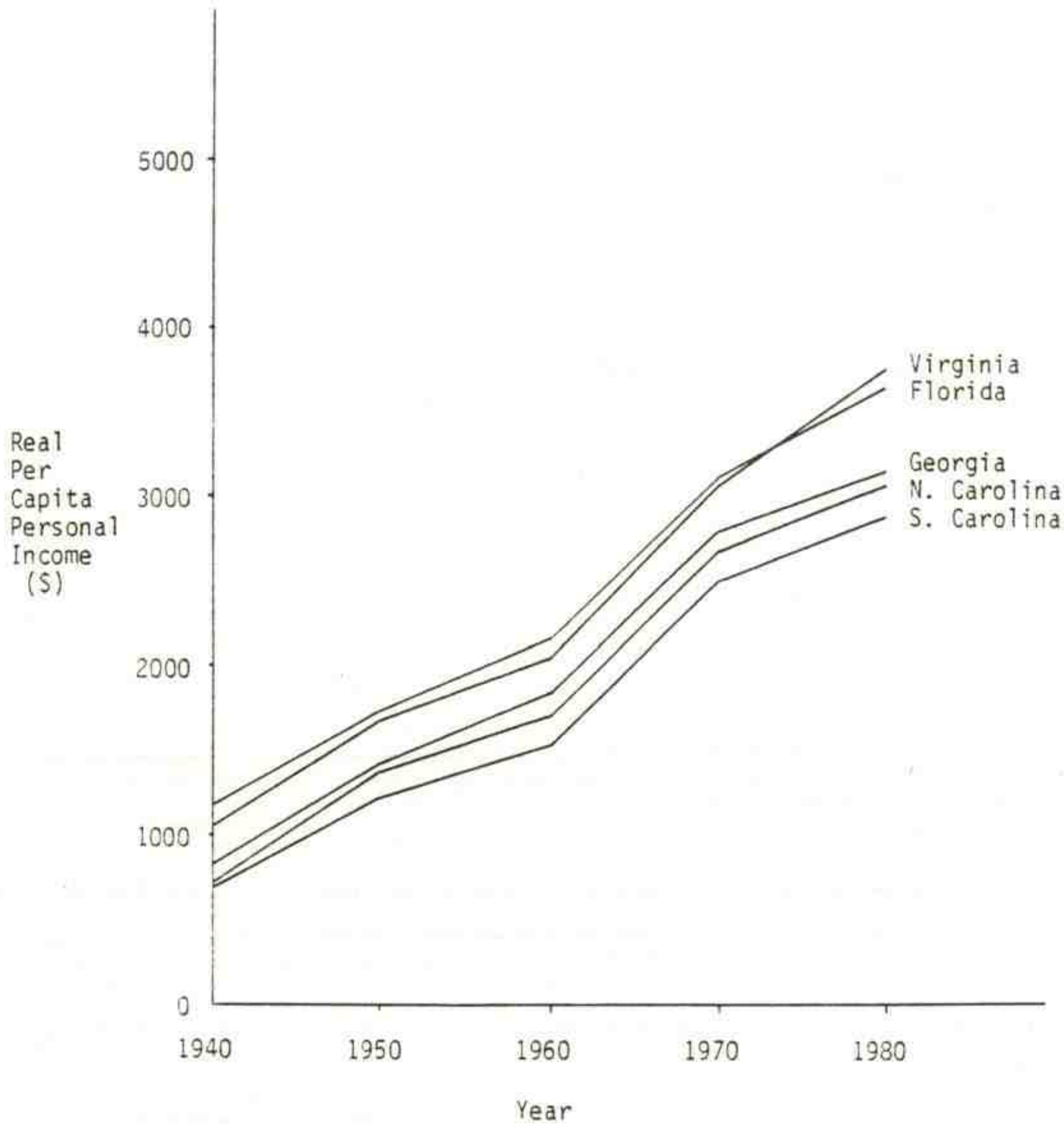


Figure 5. Real per capita income trends by state in the Southeast.

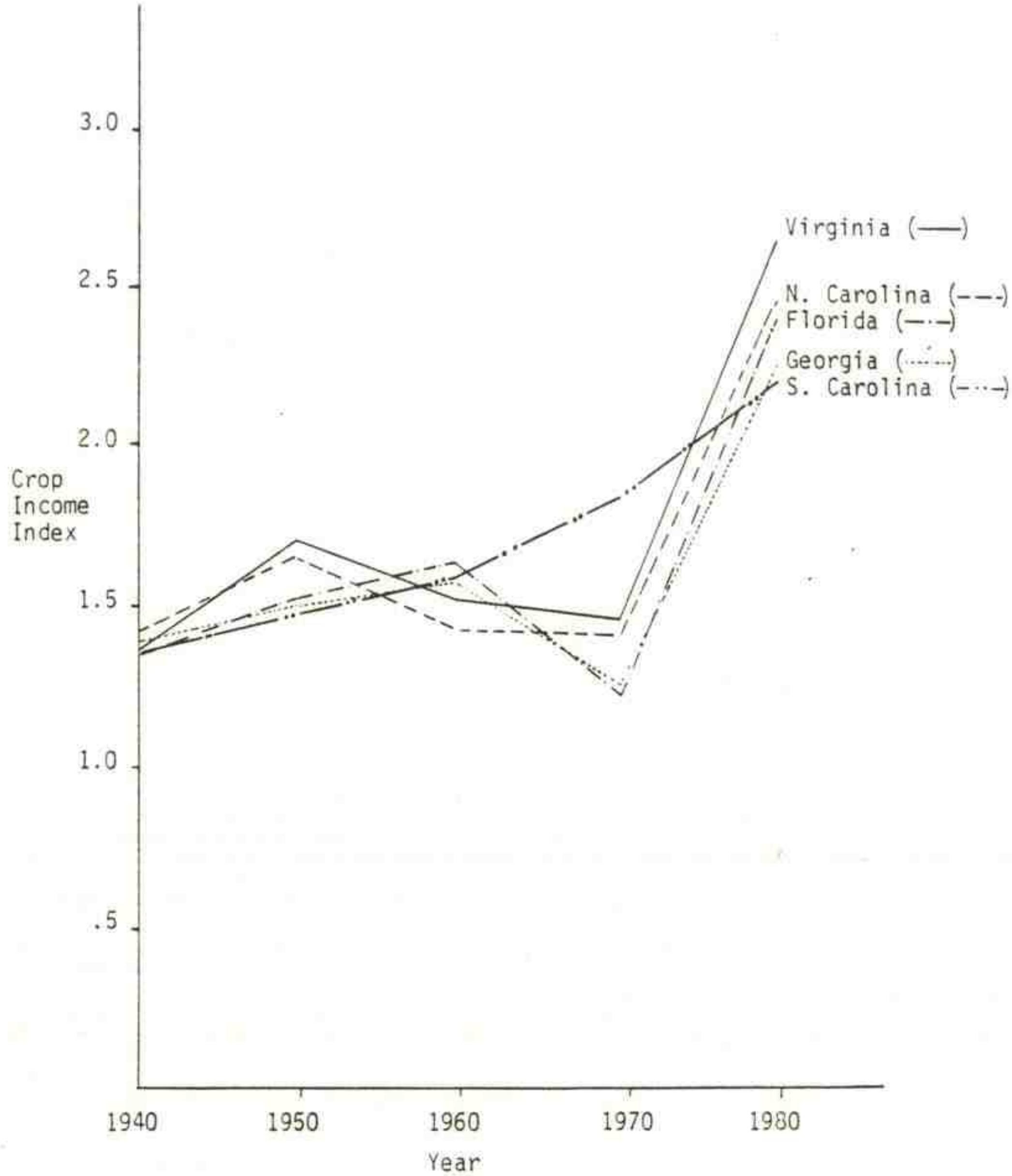


Figure 6. Trends in crop income indices by state in the Southeast.

for the steady increase in per acre income for South Carolina. Crop income indices changed little between 1940 and 1970 but have grown rapidly in the past decade.

Income indices for wood products and stumpage are not available by state and Figure 7 presents region-wide indices for the forestry sector. Incomes from stumpage production have risen sharply in the South since 1940, although there was little change in this index between 1950 and 1970 (Figure 7). The income index for wood products had a similar steep increase in the 1940's, but the decline from 1950 to 1970 reflects higher costs of stumpage and market loss to the West. This trend reversed itself somewhat in the 1970's as the South's market share stabilized and increased relative to the West.

Since cost surveys were initiated in the 1950's, increases in timber management costs in the South have substantially exceeded price increases for southern pine lumber and sawtimber (Moak et al. 1983). Rising labor expenses have been the most significant factor in pushing up forest management costs. While cost increases have exceeded lumber and sawtimber price increases, those prices have risen faster than the wholesale price index for all commodities over the same period. For example, southern pine sawtimber prices have increased annually about 2.4 percent faster than the wholesale price index (Moak et al. 1983). Economies of scale in timber production hinge on the extent of acreage treated (Row 1978). Profitability of intensive management on timberland, even on higher site land, depends on tract size (Row 1973). Fixed costs cause diseconomies of scale that severely limit the level of profitable management on small tracts.

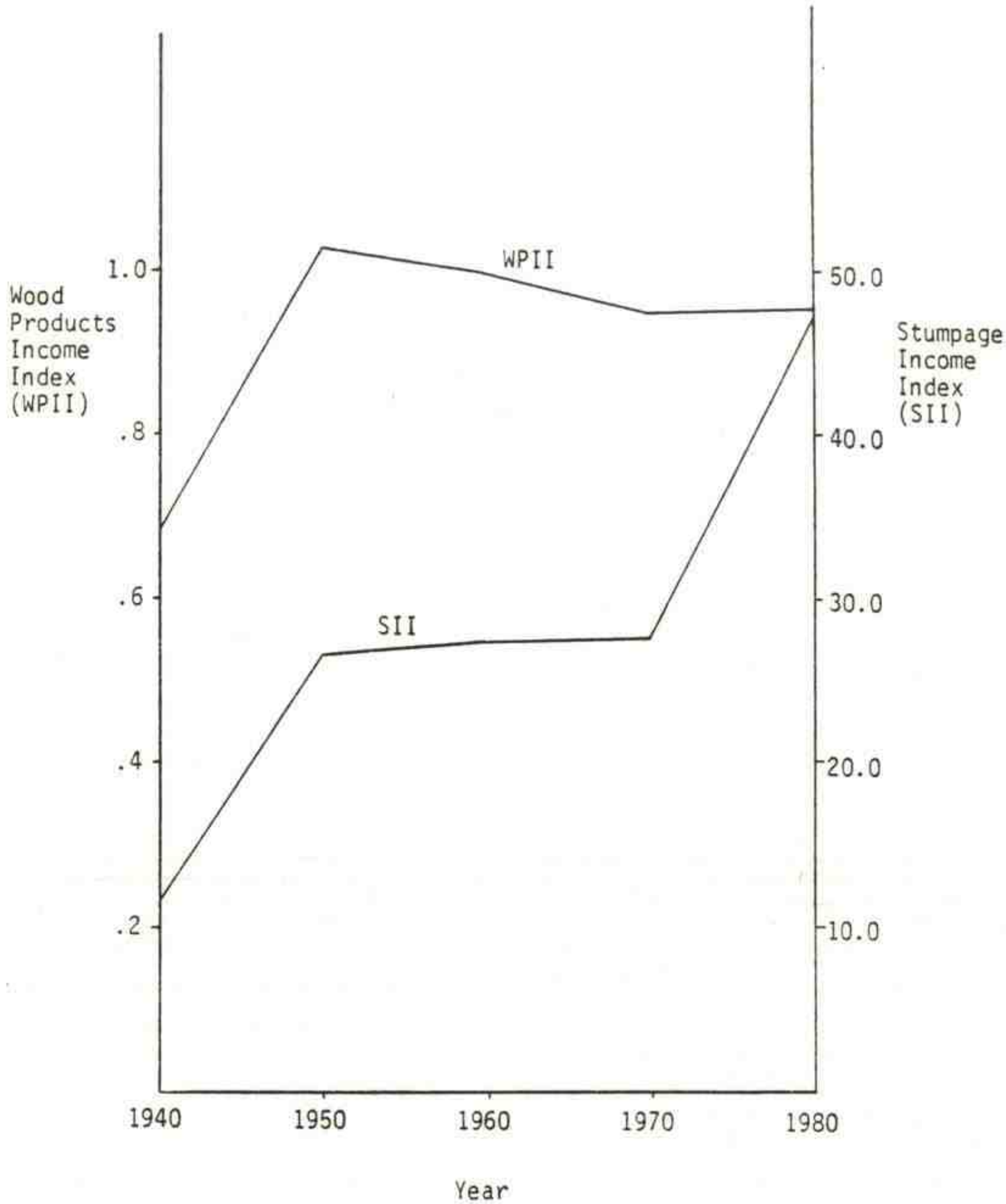


Figure 7. Trends in forestry income indices in the Southeast.

Livestock income trends have been downward since 1950 (Figure 8). The steepest drop was from 1950 to 1960. Real livestock values in 1980 were the lowest over the historical period because of the decline in real cattle prices in the 1970's.

Consumption of nontimber forest products in the Southeast has been rising in response to increases in population, economic activity, and income. Because landowners derive utility from nontimber attributes of forests (such as recreation), nontimber outputs influence land use decisions. However, because these outputs are generally not traded through markets, it is difficult to estimate the degree of importance of non-timber values in forestland use decisions. Estimating the physical quantities of these different outputs is itself problematic. One apparent trend is that forested areas are becoming more important sources of recreation opportunities, especially near population concentrations, such as Atlanta. Recreational opportunities in the forested areas of the Appalachian Mountains often attract visitors from outside the region. Many other forested areas throughout the Southeast are locally important for camping, hunting, hiking, and other outdoor recreational activities.

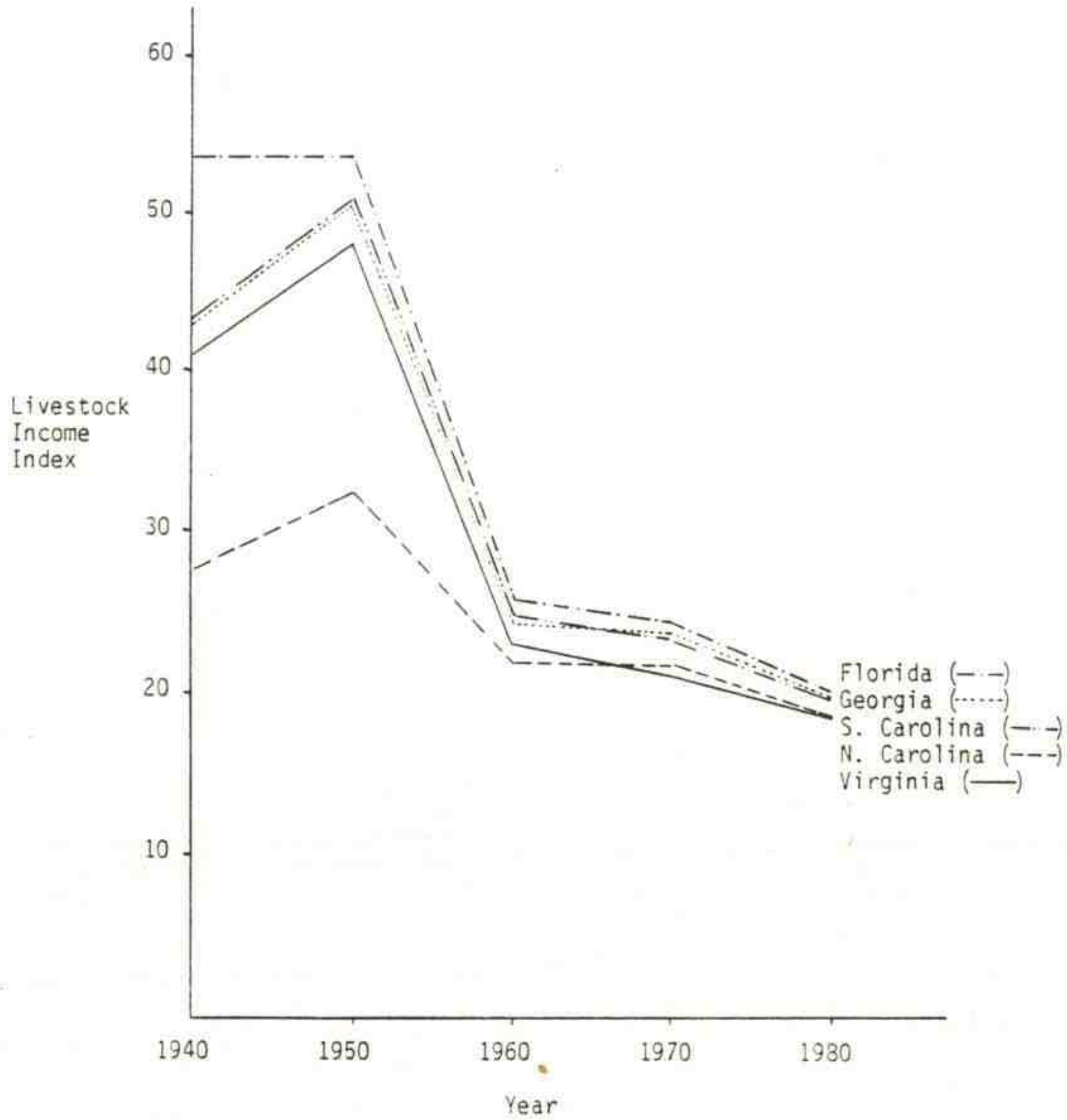


Figure 8. Trends in the livestock income by state in the Southeast.

MODEL STRUCTURE

THEORETICAL FRAMEWORK

The classical theory of rent-determined land use can be restated to provide a framework for analyzing forest acreage shifts on a fixed total land base. Land rent theory suggests that the fraction of the land base devoted to use i, f_i, will be positively related to rents derived from use i, R_i, relative to rents from competing uses:

$$f_i = g_i \left(\frac{R_i}{\sum_i f_i R_i} \right) \qquad i = 1, \ldots, 6 \qquad [1]$$

where:

$$g'_i > 0, \quad g''_i < 0.$$

In the above model, the function g_i is hypothesized to have a positive first derivative, so that as the rent in use i rises relative to the average rent from all uses, the fraction of the land base in that use rises as well. As illustrated in Figure 9, however, it seems likely that the supply of land to forest use becomes quite inelastic before it reaches the fixed land base limit. As more and more land is concentrated in a given use, it would require larger relative rent differences to shift more land into that use. Therefore, it is reasonable to hypothesize that the function g_i has a negative second derivative.

The positive correlation between relative land rent for a use and acreage in that use in a region follows from the tendency of individual owners to maximize land rent when managing a parcel of land. Since only limited measures of land rents, R_i, are available in terms of historical data, however, proxies for the R_i's or measures of

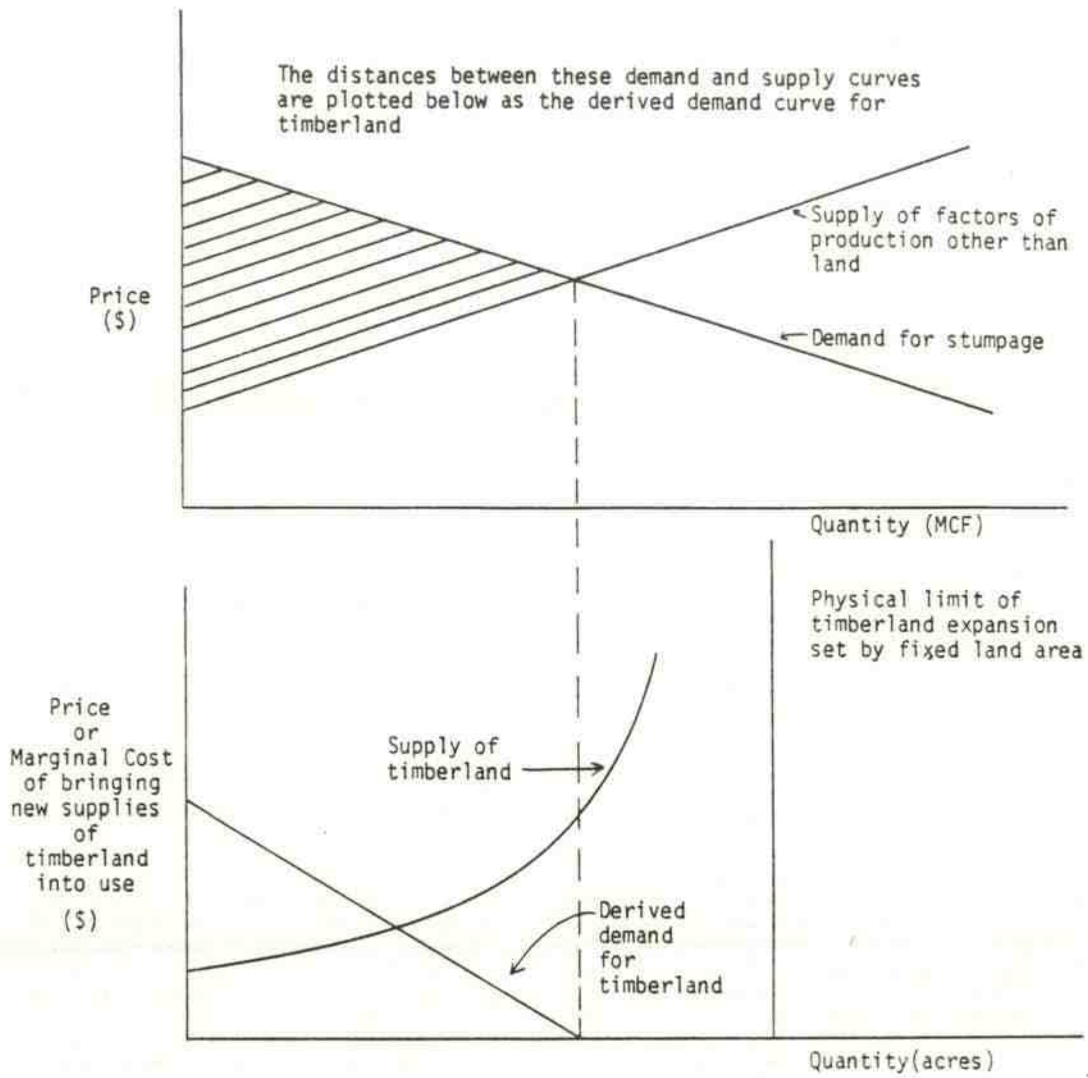


Figure 9. Derived demand and supply curves for timberland.

other factors that influence the R_i's (e.g., population) must be assembled. These proxy measures must reflect factors that would cause significant shifts in land rent profiles (Figure 1).

Modifications of the Basic Theory

The fraction of the total land base in a given use should be positively correlated with the ratio of rent from that use to the average rent possible from all uses. Because rent measures are not available, a proxy measure is the ratio of expected net income from a land use to expected average net income from alternative uses. Income measures are only available, however, for the forestry and agricultural uses and hence the average expected net income from all alternative uses can not be computed. As a further simplification 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 an attempt to isolate critical pairs of competing land uses. For urban and other uses for which there are no available income measures, urban and rural populations and average regional per capita income are used as proxies.

The variables included in the modified framework vary also by the land use or owner group to reflect their specific circumstances. For example, industrial acquisition of forest land is influenced by strategic and wood procurement concerns that also can't be reflected directly in income measures. Finally, additional influences (such as government programs) or supplemental income measures which influence rent but can not be reflected in basic income measures are incorporated for the uses or forest owner groups as appropriate. Resulting equations are shown in Table 8.

SPECIFICATION OF RELATIONSHIPS

There are four major land uses for which consistent historical acreage estimates are available: cropland [Equation 2], pasture/rangeland [Equation 3], forestland, and urban and other land [Equation 4]. The private forestland base is the focus of this study, and the much smaller public forestland was incorporated into the urban and other land category. Private forestland was separated into three ownership classes: farmer [Equation 5], forest industry [Equation 6], and miscellaneous private [Equation 7]. Thus, land use equations based on the model of Equation [1] were specified for six land use or owner classes.

The equations for cropland [2], pasture/range [3], and farm forest [5] contain interrelated land income ratios because land should migrate to its "highest and best" use based on the cost of producing various mixes of outputs from that land (i.e., production possibilities) and the associated relative land income. Relationships between land incomes and use are 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 forestry's multi-year cycle. All else being equal, land owners may prefer (or require) annual to periodic returns and hence opt for the non-forest use. This is consistent with White and Fleming's

Table 8. Specified relationships for the six land owner/use classes.[1]

$$C = a_1 + b_1 Y_{F/C} + c_1 Y_{C/P} + d_1 UPOP + e_1 RPOP + f_1 Y_T \quad [2]$$
$$P = a_2 + b_2 Y_{F/P} + c_2 Y_{C/P} + d_2 UPOP + e_2 RPOP + f_2 Y_T \quad [3]$$
$$U = a_3 + d_3 UPOP + e_3 RPOP + f_3 Y_T \quad [4]$$
$$FA = a_4 + b_4 Y_{F/C} + c_4 Y_{F/P} + d_4 UPOP + e_4 RPOP + f_4 Y_T + g_4 G_s \quad [5]$$
$$FI = a_5 + b_5 R + c_5 Y_s \quad d_5 UPOP + e_5 RPOP + f_5 Y_T + h_5 S \quad [6]$$
$$MP = a_6 + b_6 I + d_6 UPOP + e_6 RPOP + f_6 Y_T + g_6 G_o + h_6 S \quad [7]$$

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 misc. private forestland
- $a_i b_i c_i d_i e_i f_i$ = parameters to be estimated (i=1,...,6)
- $Y_{F/C}$ = 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
- S = Southern pine stumpage income
- G_s = Tree planting expenditures under the Soil Bank program
- G_o = Tree planting expenditures under other government programs
- R = Percentage of forest industry softwood removals to total removals
- Y_s = Southern pine products income
- I = Inflation rate

[1]Dummy variables to distinguish major geographical areas are not shown, but would be included in each equation.

(1980) finding for Georgia farm ownerships that agricultural income per acre was a significant determinant of forest acreage trends; however, forestry income was not.

It should also be noted that these land use relationships 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. Two or three year moving averages for land incomes will be tested to approximate landowner income expectation formation, with appropriate lags (e.g., one year for agricultural incomes) used to represent the time structure of landowner response to changes in the explanatory variables. See Appendix C for a discussion of the specific distributed lag structures for each explanatory variable.

Considerations noted above may help to explain the observation that despite historical increases in real stumpage prices far in excess of prices for most natural resources, the overall reduction in farm forest area has continued. Real stumpage prices for southern softwood sawtimber, for example, have increased approximately 140 percent from 1962 to 1977, while southern nonindustrial private forest area declined by approximately 6 percent. However, expected relative land rents may not have changed proportionally because of the periodic nature of forestry returns.

The equations for the agricultural and forestry uses contain population and personal income variables because changes in these socioeconomic variables influence the demand for land in housing and other developments. For example, increased population would likely cause urban and suburban land rents to rise. Subsequently, this change in relative land rents may prompt conversion of some acreage to urban and other uses. Further, this process may initiate secondary use shifts among the more extensive land uses because of replacement demand according to the economic hierarchy of land use.

Acreage changes for urban and other uses [Equation 4] are hypothesized to correspond to changes in population and income measures. 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 household formations, shifts of population from the North to the South and West, and development of major infrastructure programs--for example, the interstate highway system (Brown and Beale 1981). Growth in the southeastern population has increased the demand for housing and other developments, which has subsequently increased land rents for such urban uses. The post-1980 rate of rural land conversion associated with demographic change and infrastructure development is expected to continue to be substantial, but is likely to be lower than during the last two decades because of fewer major infrastructure programs and a decline in the rate of household growth.

Forest industry land acquisition [Equation 6] is hypothesized to be influenced largely by concern for raw material supply and contributions of timberland ownership to a company's overall profitability. Pulp and paper mills involve large fixed investments and, while less expensive, lumber and plywood mills still represent considerable capital commitments. Industrial acquisition of timberland is hypothesized to be positively correlated with the ratio of industrial timber removals to total removals. Industry is expected to acquire more land as that ratio rises because of wood availablity concerns in a strategic context. That is, as the relative availability of raw material from non-captive sources drops, industry would be expected to acquire more land to bolster their dependable sources of timber. Historical industry fee timber proportions differ notably by survey unit in the Southeast. They reflect industry dependency on other sources of timber, ranging historically from approximately 60 to 90 percent.

Forest industry ownership of timberland is also thought to be governed in part by the expected changes in a company's profitability from adjusting their timberland holdings. A proxy for profitability that will be tested is a wood products income index, derived as a composite measure for softwood lumber, plywood, and pulp products (adjusted by a labor cost indexsee Appendix C). If land rents for forestry increase, this should be reflected in a company's profitability in the short-run.

Miscellaneous private acreage [Equation 7] would likely vary inversely with farm timberland acreage. Increases in real income may boost some purchases of forestland for nontimber uses, as increases in current income tend to increase permanent income or wealth status and thereby trigger additional consumption. 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. Because the ratio of farm income to non-farm income in the Southeast is rather small, increases in total income should correlate positively with miscellaneous private ownership of timberland, but will not necessarily be correlated with farm ownership.

A positive relationship between miscellaneous private forest acreage and an inflation index is expected. Increases in the interest rate imply that alternative rates of return are probably rising as well for forest-owning individuals and companies. Duerr (1960) stresses that alternative rates of return vary with income levels, with the rate apt to be set by the premium that owners place upon current consumption (i.e., time rate of preference). Financial investment motives often prompt land purchases for use as inflation hedges. When inflation rates are increasing, miscellaneous private investors may look to purchasing an asset such as land which has held its value well in past inflationary periods.

The significance of government programs as a determinant of nonindustrial forest acreage trends will also be tested. Cost-sharing programs for tree planting 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. The Soil Bank program accounted for approximately two million acres of pine plantings in a relatively short period of time (Alig et al. 1980). Brooks (1983a) reports a positive linear relationship between a subsidy program variable and pine planting on nonindustrial lands, and this suggests that forest acreage should increase with expenditures for cost-shared tree planting. The estimated relationship between forest acreage and government expenditures is expected to reflect some slippage (since the Soil Bank Program) because some plantings involve the conversion of less desirable forest types.

An Almon distributed lag structure for the government cost-sharing variables will be tested because tree planting is likely to have long range effects on vegetative cover in an area. Tree planting subsidies increase the percentage of land occupied by forests for at least one rotation period, provided the plantation does not fail or is not converted to another use. The high retention rates for government subsidized tree plantings reported in several studies (e.g., Alig et al. 1980) suggest that a large majority of the subsidized acres in the South will remain forested for at least 10 to 15 years. Further, the planted stands may contribute, through natural regeneration, to either expanded forest acreage or longer occupation of the same acres. See Appendix C for a discussion of the weights used in the distributed lag structure for these variables.

Soil Bank expenditures will be examined separately from those for other government programs. The Soil Bank program lasted less than a decade and the structure of payments under the program included a series of annual payments for up to 10 years, in contrast to the one payment (at planting time) under other programs. This may have increased the retention rate of the Soil Bank plantations. Tree planting opportunities on diverted cropland for the Soil Bank also differed markedly from those in other programs, which often include areas with substantial tree and brush competition. In addition, as discussed above Soil Bank plantings added acreage to the forestland base, in contrast to some plantings under more modern assistance programs which represent conversion of forest types and no net acreage changes.

A logarithmic functional form for the land use equations is suggested by the hypothesized positive first derivative and negative second derivative for the land use-rent relationship discussed earlier. An alternative formulation that can be easily tested is the linear equation form, which implies a constant first derivative. These two functional forms can be written as:

$$Y = \beta_1 + \Sigma\beta_k \log X_k \text{ (natural log)} \qquad [8]$$

$$Y = \beta_1 + \Sigma\beta_k X_k \text{ (linear)} \qquad [9]$$

where
- k = Independent variable ($k = 2, \ldots, K$)
- Y = Observation on the dependent variable, land use acreage
- X_k = Observation on the k^{th} explanatory variable
- β_k = Slope coefficient
- β_1 = Intercept term.

ESTIMATION

This section describes the econometric procedures for estimating the direction and the magnitude of the specified relationships in the southeastern land use processes. Results are discussed by land use, and historical simulations for the sample period are described.

DATA STRUCTURE

Land use in the 21 survey units in the Southeast is surveyed by the USDA Forest Service at periodic intervals, and acreage estimates are available by major land uses at four points in time. Demarcation of the time period for which the land use acreage data was assembled was dictated by constraints on consistency in definitions and level of detail available. This set of forest acreage data is one of the better ones in the U.S. However, for a particular state, forest acreage has been estimated at irregular intervals. In addition, survey years differ across states in a region.

Acreage observations were transformed into variables that represented the percentage of a survey unit's total land area occupied by a land use, corresponding to the land base fractions (f_i's) discussed in the theory section. 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 total land base also placed the observations on a more comparable scale, by removing the influence of survey unit size.

METHODOLOGY

In the absence of a tested theory of land use shifts, the challenge of choosing the way to express land rent-use relationships and defining variables is compounded by the absence of a comparative evaluation of alternative models for testing these relationships. Therefore this study tested different econometric models, functional forms, and data stratification in order to provide methodological guidance for further studies of land use. In particular, testing alternative econometric models is useful because of the limited knowledge available to guide specification of the random error term in the system (e.g., contemporaneous correlation).

Information pertaining to interrelationships of the major land uses can be utilized to improve the estimation of forest acreage relationships. Although Equations [2] through [7] are not jointly interdependent in the several dependent variables (f_i's), and hence is not a simultaneous system, correlation among the error terms or disturbances in the equations is likely because of the relationships among land use trends on a fixed land base, transfers of land among ownerships, and related patterns in economic determinants. For these cases the disturbances for econometrically estimated equations, at a given point in time, are likely to reflect some common unmeasurable or omitted factors and exhibit some correlation (Judge et al. 1982). The possible gain in efficiency obtained by jointly considering all the equations prompted Zellner (1962) to describe them as a set of seemingly unrelated regression equations (SURE).

Zellner (1962) indicated that if the set of explanatory variables is identical across all equations, $X_1 = X_2 \ldots = X_m$, the least squares and generalized least square (GLS) estimators will be identical and there will be no gain in efficiency. In general, the efficiency gain tends to be higher 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 et al. 1982). The explanatory variables in the different equations in this study are notably correlated. However, if the disturbance terms are also highly correlated, then significantly more efficient estimates are possible with GLS regression than with ordinary least squares (OLS) regression. Because this is an exploratory study, the relative efficiency of the OLS and SURE approaches will be examined. The Time Series Processor (TSP) Version 3.5 was used to perform OLS and the multivariate SURE regressions.

Pooling of Cross Sectional and Time Series Data

The infrequent sampling of forest area in the Southeast necessitates the use of pooled data across time and survey units to expand the number of 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). Combining these two types of data extends the sample base, but the model must be specified to adequately allow for differences in behavior over the cross-sectional units (survey units), as well as any differences in behavior over time for a given cross-sectional unit.

Approaches for combining time series and cross-sectional data include five cases discussed by Judge et al. (1982).

1. All coefficients are constant and the disturbance is assumed to capture differences over time and survey units.
2. Slope coefficients are constant over time and survey units and the intercept varies over survey units.
3. Slope coefficients are constant and the intercept varies over survey units and time.
4. All coefficients vary over survey units.
5. All coefficients vary over time and survey units.

The models in Cases 2 and 4 can be classified further depending on whether the variable coefficients are assumed to be random or fixed. Random coefficients vary across observations, such as in Case 5 where all the coefficients are assumed to be random.

The second approach above was used in this study, where all slope coefficients are assumed constant and the intercept varies over the cross-sectional units. Data limitations precluded testing other pooled cross-sectional/time series models. Dummy variables were employed to differentiate among the five southeastern states.

Equation Form

The equation form for each of the six land uses is:

$$Y_{it} = \beta_{1i} + \sum_{k=2}^{K} \beta_{ki} X_{kit} + e_{it} \qquad [10]$$

where i = Cross-sectional unit ($i = 1, \ldots, N$)

t = Given time period ($t = 1, \ldots, T$)

k = Independent variable ($k = 2, \ldots, K$)

Y_{it} = Observation on the dependent variable, land use acreage, for the i^{th} survey unit and t^{th} time period

X_{kit} = Observation on the k^{th} explanatory variable for the i^{th} Survey Unit and t^{th} time period

e_{it} = Random error for the i^{th} Survey Unit and t^{th} time period

β_{ki} = Slope coefficients

β_{1i} = Intercept term

Thus, Y_{it} is the land use percentage for survey unit i in year t and X_{kit} is the value of the k^{th} explanatory variable for survey unit i in year t. The stochastic term e_{it} is assumed to have mean zero, $E[e_{it}] = 0$, and constant variance, $E[e_{it}e_{it}'] = \sigma^2$.

With the more restrictive assumption that the slope coefficients are constant (over time and the survey units) and that the intercept varies only over survey units, equation [10] can be rewritten as:

$$Y_{it} = \beta_{1i} + \sum_{k=2}^{K} \beta_k X_{kit} + e_{it} \qquad i = 1,2 \ldots, N \quad [11]$$
$$t = 1,2 \ldots, T.$$

Efficient estimation in the case of correlated disturbances in the six land use equations requires consistent estimators of the variances and covariances of the regression disturbances, assuming that the variance-covariance matrix is unknown. Using matrix notation, and letting $S = N\text{x}T$, the system of six land use equations can be written as:

$$\underline{Y}_m = \underline{X}_m\underline{\beta}_m + \underline{\varepsilon}_m \qquad (m = 1,\ldots,6) \qquad [12]$$

where $\underline{Y}_m$ = (Sx1) vector of the sample values of the dependent variable

$\underline{X}_m$ = (SxK_m) matrix of the sample values of the explanatory variables

$\underline{\beta}_m$ = (K_mx1) vector of the regression coefficients

$\underline{\varepsilon}_m$ = (Sx1) vector of the sample values of the disturbances (Kmenta 1971).

Other assumptions are that $\underline{\varepsilon}_m$ is normally distributed with mean:

$$E(\varepsilon_{ms}) = 0 \qquad (s = 1,2,\ldots,S)$$

and that its variance-covariance matrix is:

$$E(\underline{\varepsilon}_m\,\underline{\varepsilon}_m') = \sigma_{mm}\underline{I}_s$$

where $\underline{I}_s$ is an identity matrix of order (SxS).

Further, the mutually correlated regression disturbances in different equations are given by:

$$E(\underline{\varepsilon}_m\,\underline{\varepsilon}_p') = \sigma_{mp}\,\underline{I}_s \qquad (m,p = 1,2,\ldots,6)$$

where σ_{mp} is the covariance of the disturbances of the m^{th} and p^{th} equations, assumed to be constant over all observations. This covariance represents the relevant link between the m^{th} and the p^{th} equations in terms of estimation efficiency.

A consistent estimator of the matrix ($\hat{\underline{\Omega}}$) of variances and covariances of the regression disturbances suggested by Zellner (1962) involves estimating the variances and covariances from ordinary least squares. In the first stage, the resulting residuals from the ordinary least squares estimation of each equation are used in constructing $\hat{\underline{\Omega}}$. The second stage involves using $\hat{\underline{\Omega}}$ to obtain estimates of the elements of $\underline{\beta}$, using the estimator:

$$\tilde{\underline{\beta}} = (\underline{X}' \, \hat{\underline{\Omega}}^{-1} \, \underline{X})^{-1} \, (\underline{X}' \, \hat{\underline{\Omega}}^{-1} \, \underline{Y}). \qquad [13]$$

This two-stage Aitken estimator is asymptotically efficient (Kmenta 1971), and theoretical and experimental results indicate that this estimator is unbiased and efficient relative to the ordinary least squares estimator (Zellner 1963, Kmenta and Gilbert 1968).

RESULTS

Estimation results for the Southeast are presented by major land use for the OLS and SURE approaches in Tables 9 and 10, respectively. The two approaches produce similar results in terms of adjusted coefficient of multiple determination (R^2) and mean absolute error (MAE) criteria. Some of the coefficient sizes differ notably between the two approaches, especially for the relative land income variables; however, the two sets of equations exhibit the anticipated signs for coefficients except for the crop/beef income ratio variable, and the timber income variable for miscellaneous private owners. The OLS equation for forest industry acreage also contains a negative coefficient for wood products income; however, the t-statistic indicates that the variable was insignificant.

The equations in Tables 9 and 10 are based on logarithmic transformations of the independent variables and their performance in

Table 9. OLS results by major land owner/use for the Southeast.[1]

Variables	Crop	Pasture/ Range	Urban/ Other	Farm Forest	Forest Industry	Misc. Private
Intercept	.82 (.09)	20.17* (6.39)	27.85* (10.44)	22.54* (2.35)	19.35* (4.70)	21.53* (2.29)
Crop to Beef Income Ratio	-1.79 (-.69)	3.56* (3.21)				
Crop to Timber Income Ratio				-4.75* (-1.88)		
Personal Income	-4.33 (-1.36)		3.22* (1.95)	-13.64* (-2.77)		7.76* (1.85)
Urban Population	-4.31* (-4.48)		3.31* (4.77)	-3.50* (-3.50)		2.43* (2.80)
Rural Population		-3.50* (-3.29)				
Inflation Rate				-8.95* (-2.24)		3.03 (.86)
Timber Income						-3.54 (-1.36)
Government Forestry Program						3.26* (4.03)
Wood Products Income					-1.81 (-.51)	
Industry Removals Percentage					9.24* (4.13)	
Coastal Plain Dummy	16.93* (7.52)	-11.05* (-9.29)	-14.11* (-8.69)		10.56* (5.74)	-7.26* (-3.09)
Piedmont Dummy	15.51* (6.05)	-2.94* (-2.15)	-19.03* (-10.28)	8.57* (4.38)	2.67 (1.35)	-5.78* (-2.35)
MAE[2]	4.53	2.66	3.29	5.20	4.31	3.94
Adjusted R^2	.55	.64	.66	.66	.52	.70
Sample Size, n = 70						

[1]Number in parentheses below coefficients are t-statistics.

[2]Mean absolute error.

*Significantly different from zero at the .05 level.

Table 10. SURE results by major land owner/use for the Southeast.[1]

Variables	Crop	Pasture/ Range	Urban/ Other	Farm Forest	Forest Industry	Misc. Private
Intercept	15.54* (5.83)	8.06* (4.59)	25.97* (10.87)	38.49* (11.33)	11.95* (4.03)	26.60* (3.58)
Crop to Beef Income Ratio	-53.10* (-2.42)	53.90* (3.90)				
Crop to Timber Income Ratio				-65.27* (-2.78)		
Personal Income	-4.13* (-1.95)		3.82* (2.48)	-8.80* (-2.39)		8.14* (2.43)
Urban Population	-1.84* (-2.78)		2.84* (4.51)	-2.10* (-2.55)		.97 (1.41)
Rural Population		-2.06* (-2.51)				
Inflation Rate				-13.45* (-4.82)		9.93* (3.50)
Timber Income						-5.30* (-2.66)
Government Forestry Program						1.25* (2.69)
Wood Products Income					1.11 (.52)	
Industry Removals Percentage					5.43* (3.53)	
Coastal Plain Dummy	12.59* (6.95)	-10.96* (-9.58)	-12.95* (-9.14)		12.35* (7.66)	-2.28 (-1.85)
Piedmont Dummy	10.36* (5.05)	-3.46* (-2.67)	-17.83* (-10.57)	6.98* (4.29)	3.89* (2.13)	
MAE[2]	4.82	2.74	3.25	5.35	4.46	4.37
Adjusted R^2	.50	.63	.66	.64	.49	.64
Sample Size, n = 70						

[1]Number in parentheses below coefficients are t-statistics.

[2]Mean absolute error.

*Significantly different from zero at the .05 level.

terms of adjusted R^2 and MAE exceed equations that are linear in the variables. This is consistent with the earlier hypothesis regarding the form of the land use-rent relationship.

The SURE approach (with the logarithmic transformations) was then tested at the physiographic region level in order to determine whether greater explanatory power might be possible via data stratification. The dummy variables that were tested above to isolate physiographic region differences in the Southeast (Tables 9 and 10), indicate some significant differences in land use relationships among physiographic regions. The SURE approach was chosen for testing at the physiographic region level because of the likely correlation of disturbance terms in the set of equations for all the major land uses and the related possible gain in efficiency by jointly estimating a set of equations for each physiographic region.

SURE results for the Coastal Plain are presented in Table 11, Piedmont results are shown in Table 12, and the Mountain equations are given in Table 13. Based on the adjusted R^2 and MAE criteria and the estimation of coefficient signs suggested by economic theory, these physiographic region models were selected as the basis for the projection model discussed in the next section. The associated econometric results are discussed next by major land use, followed by a comparison of findings across the three physiographic regions.

Farmer Forest

Estimated equations for the farm ownerships generally confirm the behavioral hypotheses. Population and personal income are important

Table 11. SURE econometric estimation results for the Coastal Plain Region.[1]

Variables	Crop	Pasture/ Range	Urban/ Other	Farm Forest	Forest Industry	Misc. Private
Intercept	19.02* (7.37)	9.27* (3.64)	11.46* (8.28)	37.30* (4.53)	25.45* (6.00)	5.12* (2.50)
Timber Income				.69 (.25)		
Beef Income		-1.37 (-1.73)				
Personal Income	-1.11 (-.45)		6.28* (4.59)	-19.61* (-6.28)		8.94* (3.43)
Urban Population	-5.37* (-6.02)		1.16* (2.02)	-3.98* (-4.63)		2.00* (2.71)
Rural Population					-3.49* (-2.22)	
Wood Products Income					11.15* (1.74)	
Industry Removals %					6.69* (2.92)	
Government Forestry Program						1.91* (3.53)
Georgia Dummy			-5.40* (-4.37)		-5.71* (-2.92)	
North Carolina Dummy		-3.48* (-5.68)	-2.18 (-1.77)			
South Carolina Dummy		-2.78* (-4.76)			-7.33* (-4.03)	
Virginia Dummy		-3.22* (-4.00)	-2.54 (-1.82)	11.34* (4.52)		
MAE[2]	4.89	1.30	2.62	3.68	5.05	2.83
Mean of Dependent Variable	22.58	3.25	13.59	28.44	15.72	16.43
Adjusted R^2	.54	.28	.53	.82	.32	.75
Sample Size, n = 36						

[1]Number in parentheses below coefficients are t-statistics.
[2]Mean absolute error.
*Significantly different from zero at the .05 level.

Table 12. SURE econometric estimation results for the Piedmont Region.[1]

Variables	Crop	Pasture/ Range	Urban/ Other	Farm Forest	Forest Industry	Misc. Private
Intercept	17.99* (5.76)	5.28 (1.09)	4.87* (4.13)	25.87* (3.52)	6.66* (10.95)	15.37* (4.17)
Beef Income		1.27 (.87)				
Crop Income	8.12* (2.56)					
Timber Income				9.11* (4.45)		
Personal Income	-15.96* (-7.87)		6.04* (5.31)	-23.15* (-6.59)		23.02* (6.97)
Rural Population	-15.42* (-4.24)					21.91* (7.22)
Urban Population			1.25* (2.15)	-6.34* (-7.62)	-1.87* (-3.36)	
Inflation Rate				-7.94* (-3.43)	6.31* (7.44)	
Government Forestry Program						1.07* (1.75)
Georgia Dummy				-5.76* (-3.43)		
North Carolina Dummy	18.78* (5.51)				-5.05* (-5.28)	-21.74* (-5.71)
South Carolina Dummy		-2.53* (-2.05)	3.33* (4.25)	-14.64* (-7.68)		
Virginia Dummy	-8.17* (-3.48)	4.75* (4.04)			-3.35* (-4.20)	
MAE[2]	2.45	2.55	1.97	3.49	1.71	4.34
Mean of Dependent Variable	19.45	10.18	9.96	33.15	6.69	20.57
Adjusted R^2	.76	.31	.73	.84	.60	.73
Sample Size, n = 21						

[1]Number in parentheses below coefficients are t-statistics.
[2]Mean absolute error.
*Significantly different from zero at the .05 level.

Table 13. SURE econometric estimation results for the Mountains Region.[1]

Variables	Crop	Pasture/ Range	Urban/ Other	Farm Forest	Forest Industry	Misc. Private
Intercept	19.22* (18.64)	23.51* (5.79)	67.55* (17.46)	-13.84 (-1.11)	2.20 (.77)	-27.72 (-1.80)
Crop Income	5.57* (2.03)					
Beef Income		-7.44* (-5.74)				
Timber Income				10.84* (3.01)		1.89 (.41)
Personal Income	-12.46* (-8.88)			-17.55* (-4.82)	-2.26 (-1.45)	22.71* (4.37)
Urban Population		-4.29* (-3.17)	21.25* (11.21)	-11.40* (-3.18)	-2.42* (-2.05)	-9.94* (-2.86)
Inflation Rate					3.91* (3.70)	
Government Forestry Program						2.29* (4.06)
North Carolina Dummy	-4.30* (-5.66)		1.82 (1.89)			
Virginia Dummy		13.13* (15.85)	-6.61* (-5.65)		-3.71* (-4.74)	-3.09 (-1.73)
MAE[2]	.82	1.15	1.91	3.45	1.24	3.32
Mean of Dependent Variable	9.70	14.71	24.50	24.98	3.59	22.51
Adjusted R^2	.89	.94	.87	.74	.56	.70
Sample Size, n = 13						

[1]Number in parentheses below coefficients are t-statistics.

[2]Mean absolute error.

*Significantly different from zero at the .05 level.

determinants of farm forest acreage in all regions. Expected timber income is a significant determinant of farm forest acreage trends in the Piedmont and Mountains regions; however, agricultural incomes are not significant.

The significance of the population and personal income variables are consistent with historical land use pressures in farm forests in the Southeast. Historically, there have been large changes in populations and personal incomes, which have contributed to large reductions in farm forest acreages (Appendix B). A comparison of the coefficient signs for population and personal income variables in the farmer and miscellaneous private equations suggests that these variables have been the primary forces behind the large transfers of land between the two owner groups.

The estimated relative influence of population on farm forest acreage trends across physiographic regions is as expected. The larger population coefficients for the Piedmont and Mountains regions are consistent with the increasing concentration of the Southeast urban population in those two regions. That growth in urban population has led to relatively more acquisition of land by miscellaneous private owners, in part because of non-timber land management objectives.

Real personal income is negatively correlated with farm forest acreage in all regions. Growth in the proportion of non-farm income over the last 50 years has contributed to the purchase of millions of acres of farm forest by miscellaneous private owners. The size of the personal income coefficients are similar across the three regions, with the more populated Piedmont region having the largest income coefficient and a significant inflation rate relationship as well.

The general insignificance of agricultural incomes in regard to farm forest trends was unexpected, including insignificant land income ratio variables (e.g., expected crop to timber income per acre). This may be related to problems in constructing proxy variables to represent expected land income which is discussed further under misspecification possibilities, including the use of state averages for cost and return information.

Forests are by far the most widespread land use and transfers between other land uses represent relatively small forestland base changes. Timber income variables in all the physiographic regions exhibited expected positive coefficient signs on this ownership; however, the timber income variable in the Coastal Plain equation is insignificant as indicated by a low t-statistic.

The explanatory power of the farm forest equations, in terms of the adjusted R^2, is the highest for the land uses in the Coastal Plain and Piedmont regions. The mean absolute error is approximately 10 percent of the farm forest land use percentage in each region, which is the lowest error percentage for the forest owner classes.

Forest Industry

Results for the forest industry ownership of forest acreage are notably different across physiographic regions. The hypothesized relationships held for the Coastal Plain, with positive relationships for wood products prices and the industry removals proportion. The lower explanatory power of the forest industry equations, in comparison to those for farms, reflects in part the diverse strategic reasons for industry purchase of timberland.

The significance of the measure for industry's share of timber removals reflects the need for industry to assure a steady flow of wood into processing facilities. These future wood supply concerns lead to a positive relationship between land acquisition and removals percentage because industry moves to acquire more timberland when the relative availability of open market timber sources is reduced and some of their own cutover lands are slowly restocking themselves.

Forestry related variables were not significant determinants of forest industry acreage in the Piedmont and Mountains. Urban population was negatively correlated with industry acreage in these regions, in comparison to the same type of relationship for rural population in the Coastal Plain. Industry ownership was positively correlated with the rate of inflation in both regions, indicating that financial investment motives influence strategic planning by land-holding firms.

Results for the Piedmont and Mountain regions indicate the importance of forces outside the forestry sector, even for industry's acreage trends, which are shaped in a complex of strategic decision-making. Industry land ownership has slowly increased in the Southeast over the past several decades. The alternative of leasing nonindustrial timberland also undoubtedly helps to shape industry's land-holding strategy. Leasing by industry has steadily increased during the last several decades, but insufficient data were available to examine it in this study.

Miscellaneous Private Forest

Results indicate that ownership of forest acreage by this miscellaneous private class is influenced the least of any owners by the prospect of forestry returns. Important variables are essentially the same ones as for the farm ownership: population and personal income. However, the coefficients are opposite in sign for the two ownerships, given that substantial transfers of forestland occur between the two owner classes.

The positive correlation between acreage and personal income levels was expected, based on the hypothesis that higher income levels would provide more investment capital and increase the demand for land by miscellaneous private owners. With rising overall personal incomes, many acres have shifted from farm to other nonindustrial ownerships. This is particularly true in the Mountain region, where timberland purchases by this class of owners are often dictated by non-timber production motives.

The urban population variable has a negative coefficient in the Mountain region, where a large number of timberland acres are shifted to other uses for residential and second-home sites. In contrast, the positive coefficients for urban population in the Coastal Plain and rural population in the Piedmont region are related to increases in the proportion of miscellaneous private owners among non-industrial owners in those regions.

The finding of an insignificant relationship between forest acreage trends for this ownership and timber incomes per acre in each region suggests that the prospect of future forestry returns is less important than for farmers. Several studies have shown that miscellaneous private owners often do not actively regenerate cutover areas (e.g., Fecso et al. 1982), although projected financial returns are relatively high.

However, government forestry programs are a significant determinant of miscellaneous private forest acreage trends. This finding is consistent with Brooks' (1983a) conclusions that government subsidies significantly increase tree planting on non-industrial lands.

Cropland

The major determinants of crop acreage trends are population, personal income, and expected crop income per acre, but their individual importance varies by region. Urban population is significant in the Coastal Plain and rural population is likewise a significant negative force in regard to Piedmont cropland. Population was not important in regard to crop acreage trends in the Mountains, as cropland only occupies approximately 5 percent of the land base in the Mountains. Urban and other uses in that region extract significant amounts of land from the other four uses.

Personal income levels are significant explanatory variables in the Piedmont and Mountains and contributed to the relatively high explanatory power of the cropland equations for those regions. Once again, the dwarfing of farm income by income from non-farm sources in the Southeast has fueled a steady decline in cropland acreage over time.

As hypothesized, expected crop income was a significant variable in the Piedmont and Mountains. The Piedmont contains a relatively high proportion of marginal farmland and land use shifts at this margin are sensitive to movements in expected crop income. 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. The results indicate that the slight decline in Coastal Plain crop acreage that has occurred is due to urban population growth and furthermore, expected crop income is not a significant factor in this region's land use shifts.

Output from cropland in the South has approximately doubled since the 1930's, although cropland area has declined somewhat (Clawson 1981). Cropland use has become more intensive, with the important changes at the intensive margin of land use. Thus, shifts in land use at the extensive margin for agriculture during the last 50 years, which which are examined in this study, have not been the key to the substantial increase in farm output. Clawson (1981) suggests that land shifts into and out of agriculture 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 in the Southeast).

Pasture/Range

Estimation results for the pasture/range equations were the least satisfactory of all the major land uses. Results pertaining to the hypothesized land rent relationships were mixed and the important determinants of pasture/range acreage trends were also not consistent across regions.

The explanatory power of the pasture/range equations were the lowest among land uses in the Coastal Plain and Piedmont regions. The percentage of the total land area occupied by this use has never exceeded 4 percent in the Coastal Plain. That is a comparatively small percentage in relation to the 16 percent occupation of the Mountain region. All other land uses in the Coastal Plain occupy at least five times more area than the pasture/range use, and changes in pasture/range are minor in relation to other land use changes. Furthermore, Florida contains a much higher proportion of pasture/range land than the Coastal Plain areas in the other states.

A significant negative coefficient was estimated for beef income in the Mountains, which has the highest percentage of pasture/range use. This finding is consistent with the results of White and Fleming (1980), who did not discuss the contradiction with their original hypothesis. Using beef income indices may not fully reflect landowner motivations to shift land in and out of pasture/range uses because 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 diary support programs.

Urban/Other

Results for the urban/other use class were consistent with the hypothesized relationships. Significant variables in the urban/other equations are consistently population and income measures, with the exception of the absence of personal income in the Mountains.

Urban population has grown rapidly in the Mountain region, as reflected by the size of the associated coefficient, and this use occupies over a quarter of the land in that region. The uniform positive coefficients for the population and income variables in all regions reflects a steady historical increase in this land use in the Southeast.

Differences by Physiographic Region

The explanatory power of the land use acreage equations is greater for the physiographic region stratification as compared to the aggregate Southeast equations. The explanatory power of the forest acreage equations is similar across regions, except for the forest industry equations. The highest adjusted R^2's and lowest prediction errors (as a percentage of the dependent variable values) for the nonforest land uses are associated with the Mountain equations. The Piedmont equations are also generally high in explanatory power, except for the pasture/range equation. The Coastal Plain equations for forest industry and pasture/range are the least satisfactory.

The absence of significant crop and timber income variables for the Coastal Plain is a 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 at the extensive margin may be more likely or sensitive to expected land use income changes in the other regions because of more marginal land.

The results for the Piedmont and Mountain regions compare more closely in general than when either is compared with the Coastal Plain. This is consistent with the physical attributes of the regions, given that the flat and often wet terrain of the Coastal Plain present quite different land use possibilities and production costs.

Differences in land use relationships among states within a physiographic region are indicated by the presence of significant state dummy variables. The miscellaneous private forest acreage relationships vary the least by state, while differences by state are most apparent for the pasture/range and urban/other uses. These differences are represented in the econometric equations as shifts in the intercept, with the dummy variables used as proxies for other state-level variables that are important but cannot be measured with existing data (e.g., tax laws). The use of dummy variables to measure changes in the slopes of the equations was not possible because of degrees of freedom problems.

MISSPECIFICATION POSSIBILITIES

Misspecification in a model such as this is a major concern because of the exploratory nature of the study. However, candidates for omitted variables could not be tested in this study because of the lack of additional readily accessible time series (or proxies) for such variables. The data sources for most of the variables examined, and in particular for the forest acreage data, were probably the best available in most cases across the country in terms of regional statistics.

Data in some cases were not available at the survey unit level, and state or region-wide information had to be utilized. For example, historical stumpage price information is only available on a regional basis. This was adjusted by physiographic region within each state to reflect historical differences, using price variation information from Hunter (1982).

Significant structural change over the historical period is a distinct possibility, but could not be tested satisfactorily for all regions because of the small sample sizes. The need to conserve degrees of freedom also precluded the estimation of equations for different time periods to reflect changing government programs for agricultural crops. Use of a trend variable to capture the effect of omitted variables that may have exerted systematic effects over time did not seem appropriate for this exploratory study.

Examination of forest industry capacity in relation to timberland investment strategies in this study was precluded by the lack of reliable time series on capacity measures. The relationship between forest industry capacity and available log supplies has been studied in the Douglas-fir region (Fedkiw 1964), but no similar studies have been reported for the South. Roundwood utilization by industry has increased substantially in the South since the 1940's, and plywood production capacity in particular has greatly expanded.

The influence that competitive maneuvering by companies has on timberland acquisition strategies is not well suited for testing in a study such as this. The opportunities for gaining a competitive advantage via land purchase in certain locales may influence land values more than the actual acreage acquired industry-wide. The operation of a company's woodlands as a separate profit center may also alter land acquisition or divestiture in a manner that differs from management for raw material supplies. Conduct, such as mergers, that result in substantial additions to a company's timberland holdings may influence performance, but effects on industry-wide timberland acreage patterns would probably be more long-term and less visible.

Plotting of the residuals for the land use equations suggested possible correlation of error terms that correspond to the geographical alignment of the cross-sections in the pooled cross sectional/time series data sets. Examination of the Durbin-Watson statistics for the associated equations confirmed the presence of significant correlation patterns in some cases. The correlation or unexplained systematic variation is most likely due to omitted variables. However, the degree of autocorrelation may be influenced by (1) related errors across time for the cross-sections (which are a series of repeated measurements) and (2) the sequence of the cross-sections in estimation. It is not practical to correct the autocorrelation patterns in each of the numerous cross-sections because of degree of freedom limitations and the complications involved in selected autocorrelation correction in a system of SURE equations. The cross-sections were reordered in estimation to investigate the degree to which the data sequence might be contributing to the autocorrelation problem. This test suggested that the autocorrelation is caused primarily by omitted variables that are related to the systematic variation over time.

The plausibility of the assumption of homoscedasticity was examined by plotting the residuals from estimation against the appropriate independent variables and also by applying the Spearman rank-correlation test (Koutsoyiannis 1977). These tests indicated that heteroscedasticity was not a significant enough problem to warrant transformation of the original model (in order to obtain a form in which the transformed disturbance term has a constant variance).

The degree of the collinearity among the major independent variables was investigated by using a chi-square test for detecting the strength of the multi-collinearity over the set of explanatory variables (Koutsoyiannis 1977). This was supplemented by the use of simple correlation tests for specific pairs of crucial independent variables such as population and income variables. No significant collinearity was detected and the danger of misspecification because of multi-collinearity (e.g., rejection of a variable because the inflated standard error appeared too high) appeared insignificant.

Formulation of the complete system of land use equations for a region implies a constraint across the equations, specifically that the predicted values of the six dependent variables (land use percentage) sum to 100 percent. The problem amounts to the redundancy of one equation in the system, analogous to the adding-up condition in demand theory (Barten 1977). Attempts to estimate the systems of equations with one unestimated land use class proved unwieldy. In theory, it should be possible to indirectly derive the coefficients of an unestimated equation from those of the other five. However, the estimated land use percentages for the three regions using the full system of six equations all summed to approximately 100 percent for each observation. This seems satisfactory in view of the estimation error associated with regression techniques. Estimation of all six land use equations in a complete formulation also avoids any asymmetry in deriving coefficients and provides information that will be useful in guiding further land use studies. The total land base constraint is applied in the projection phase of the study, using a reduction of the differences across the land uses in proportion to their relative sizes.

HISTORICAL SIMULATIONS

Ideally, to evaluate predictive ability, several observations would be excluded from use in parameter estimation and employed in *ex post* forecast evaluation. However, because of the limited number of available observations, it was necessary to use all the observations for parameter estimation. This hampers evaluation of the model's predictive ability, but the performance of the model over the sample period still provides some assessment of predictive capability.

The predicted and actual values over the sample period for the three forest ownerships are plotted in Figures 10 through 12 by physiographic region. The survey cycles represented on the horizontal axis refer to land area remeasurement periods, with the surveys for the five states added together at those four points in time to provide a basis for evaluating the historical simulations.

The predicted trends for the farm forest ownership follow the actual trends closely, except for the Survey Cycle 3 dip in the Piedmont region (Figure 10). The predicted forest industry trends do not as closely follow the actual trends, especially in the Piedmont and Coastal Plain (Figure 11). The miscellaneous private forest equations closely track the actual trends, except for underestimating the Survey Cycle 3 level in the Piedmont (Figure 12). This deviation is the converse of the overestimated Piedmont dip for the farm ownership during the same period.

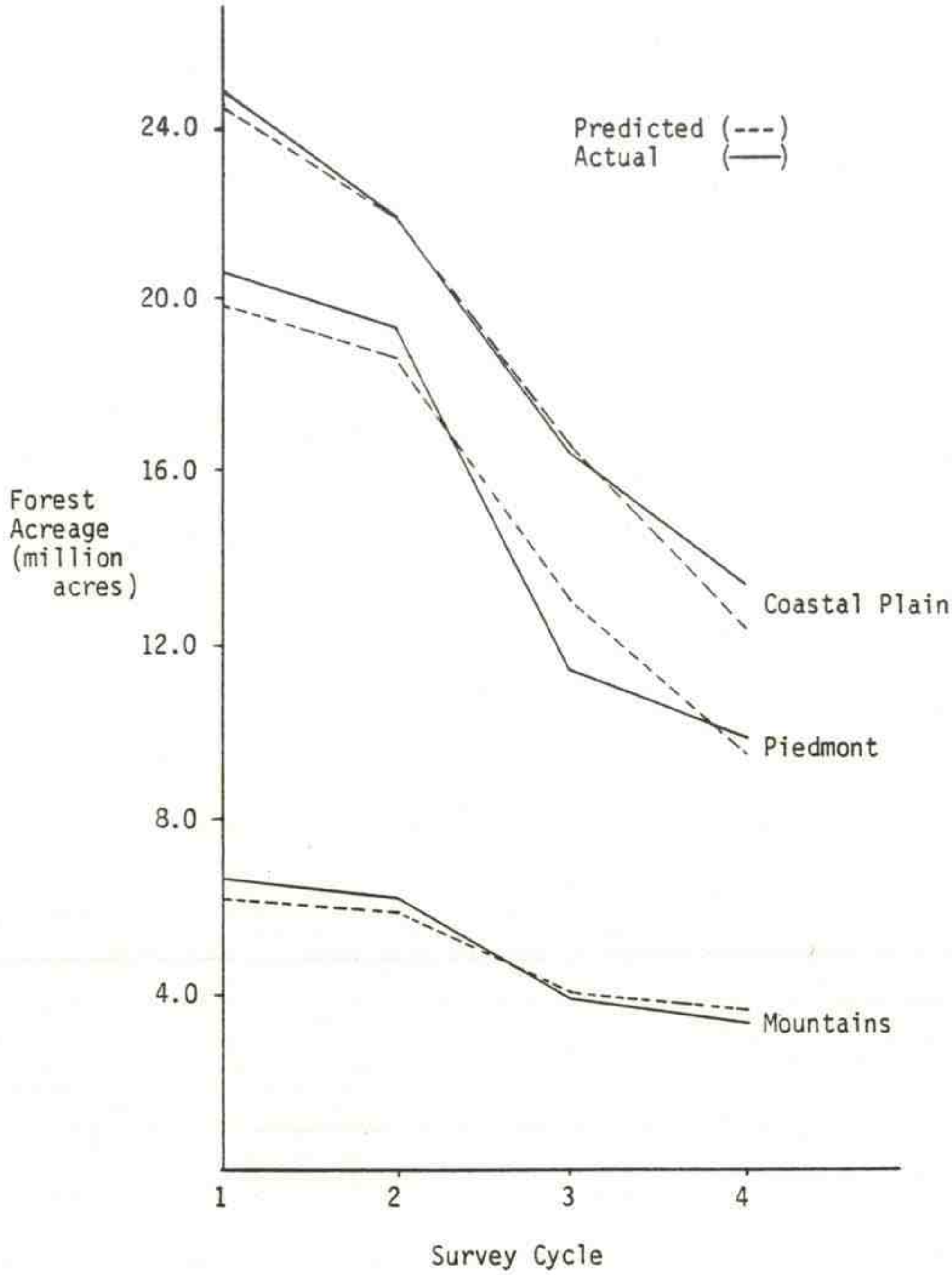


Figure 10. Actual and predicted farm forest acreage by physiographic region.

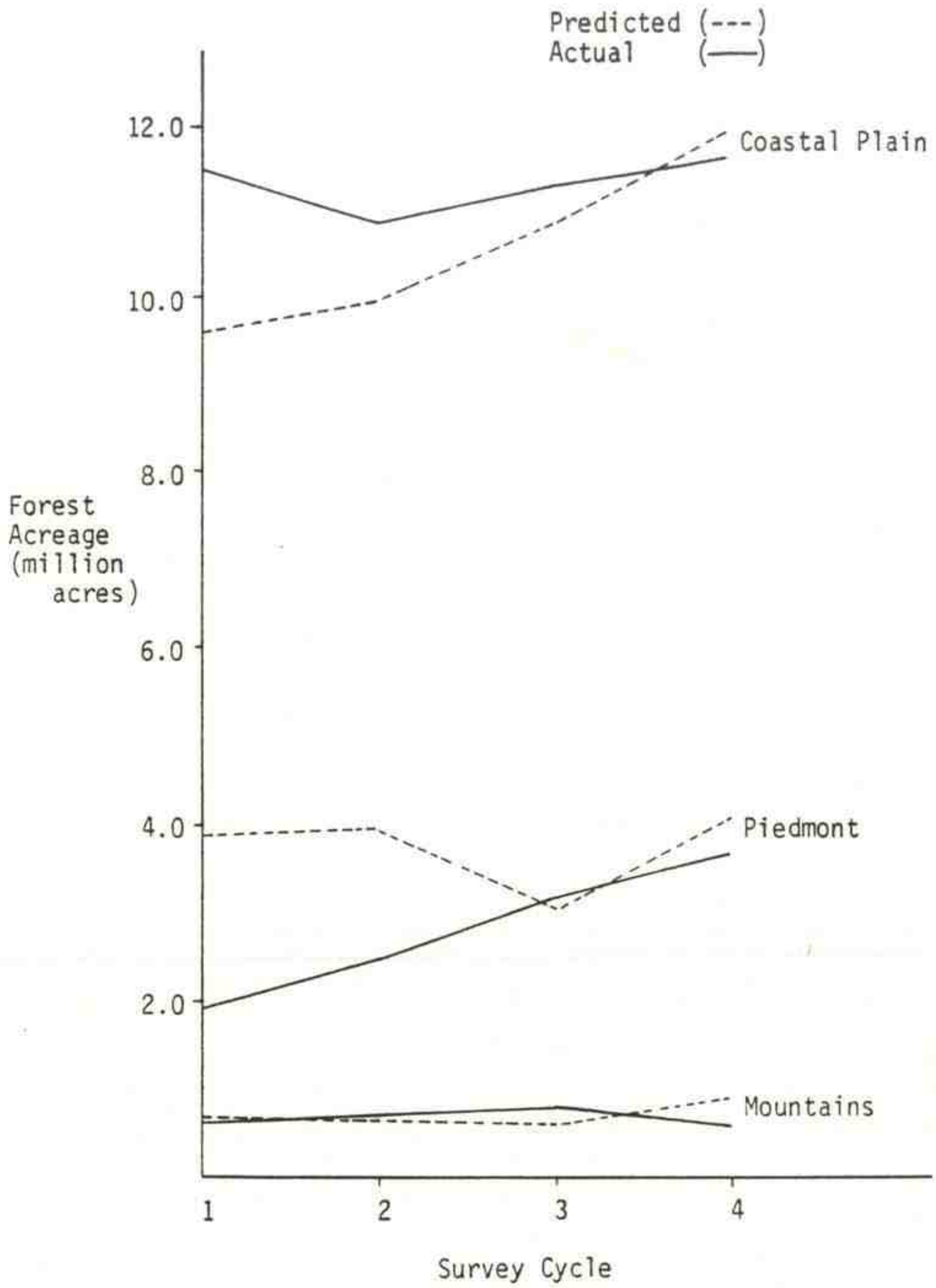


Figure 11. Actual and predicted industry forest acreage by physiographic region.

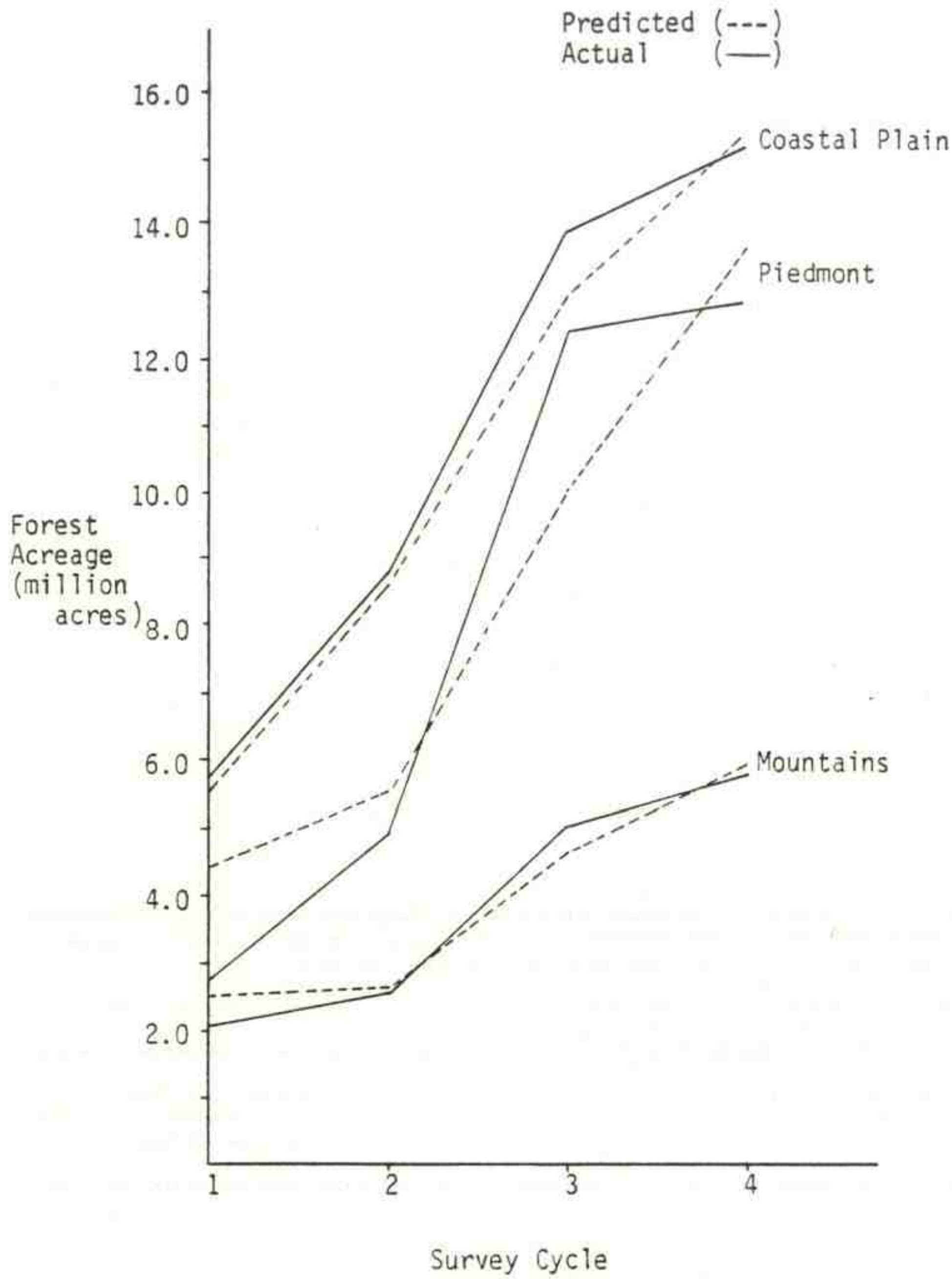


Figure 12. Actual and predicted miscellaneous private forest acreage by physiographic region.

POLICY SIMULATIONS

The estimated econometric equations were incorporated into a model that projects acreages of the major forest ownerships in the Southeast by decade to 2040. This projection period corresponds with the current RPA planning horizon. The major land uses are projected simultaneously, with a total land base constraint imposed so that all land uses sum to a particular state's land area total. Initial estimation differences are apportioned according to weights that correspond to the relative percentage of the land base occupied by a use.

Future forest type acreages are also projected (Appendix D) using transition probabilities for forest types based on historical trends given in Tables 3, 4, and 5 by ownership. Three primary treatment classes corresponding to FIA estimates of broad management practices applied to the forestland base are considered: harvest, no treatment, and other disturbances. An important land management concern is the lack of active forest regeneration efforts after harvest in many cases on non-industrial private lands. Many acres have shifted from pine to hardwood types, primarily after harvests that are not followed by pine regeneration efforts (Boyce and Knight 1979). As Tables 3, 4, and 5 indicated earlier, there is a gradual conversion of pine to oak-pine, and then to hardwoods if natural successional processes are not arrested or reversed.

The alternative acreage simulations involved sets of projections for major exogenous variables: population, personal incomes, and land use incomes. The first step in the simulation process involves the development of a baseline projection of forest acreages for the period 1984 through 2040, against which the outcomes of the other simulations are measured. Projections of key independent variables for the baseline simulations are described in Appendix E.

BASELINE SIMULATION

The baseline simulation represents a "most likely" scenario, based on projected levels of exogenous variables (see Appendices D through F for sources). Projections for the six major land uses are shown for three selected years in Table 14, along with projections of forest type acreages on private lands. Projections are shown only for the entire Southeast because the broad trends are similar across physiographic regions.

Wall (1981) projected total southeastern forest area to the year 2030 by two private forest owner classes, using 1977 as the base year. Wall's 2030 total private forest acreage estimate is about 6 percent lower than that projected by the simulation model. Wall's 2030 acreage projections for a combined farm and miscellaneous private class is 2 percent lower than the model's in the year 2030. Forest industry projections vary more, with Wall's estimates being approximately 17 percent lower. The higher forest industry acreage projected by the simulation model account for most of the total acreage differences between the two sets of projections.

Projections of total forest acreage in the first half of the forecast period are quite close between the two studies. Projections

Table 14. Projections of forest acreage in the Southeast for the baseline case.[1]

Aggregate	Year 1984	2000	2020	2040
Non-Forest Land Uses				
Crop	22.702	19.312	18.452	17.708
Pasture/Range	16.021	16.181	16.137	15.998
Urban/Other	29.739	33.020	34.681	35.198
Private Forest Owner Totals				
Farmer	25.266	17.684	14.230	13.928
F. Industry	15.898	17.346	18.070	18.895
Misc. Private	37.214	42.970	44.614	44.133
TOTAL	78.378	77.999	76.915	76.956
Private Forest Types				
Planted S. Pine	10.451	14.382	16.277	17.419
Natural S. Pine	21.914	18.241	16.328	15.587
Oak-Pine	9.634	9.632	9.179	9.061
Upland Hardwood	24.486	23.595	23.255	23.184
Lowland Hardwood	11.893	12.149	11.876	11.704
TOTAL	78.378	77.999	76.915	76.956

[1]Given in millions of acres

in the year 2000 diverge by two percent. Wall's projections for forest industry acreage decline after the year 2000, in contrast to steadily increasing acreage projections in the present.

Although the largest differences between the two sets of acreage projections pertain to industry's acreage trends, the largest projected changes in acreage are for the two owner classes that are combined in Wall's nonindustrial class. Farm acreage is projected to continue to drop, with the projected 2040 value 45 percent lower than the 1984 acreage. In contrast, miscellaneous private acreage is projected to increase 19 percent by 2040. These divergent trends are similar to historical patterns; however, most of the miscellaneous private gain occurs by the year 2000, while the farm acreage loss is relatively constant throughout the projection period.

The projected forest acreage trends are similar across the three physiographic regions. The exception is a decline in miscellaneous private acreage in the Piedmont after 2020. The non-forest land use trends are also consistent across the three regions, except for a projected increase (0.4 million acres) in crop acreage in the Mountains and a reduction (0.8 million acres) in pasture/range acreage in the Piedmont. The largest acreage changes in the farm forest (6.1 million acre reduction) and miscellaneous private (3.7 million acre increase) classes are projected to occur in the Coastal Plain. The largest acreage change for forest industry, a 2 million acre increase, is projected to occur in the Piedmont region.

Projections of private acreage by forest type indicate that the largest changes will occur in the southern pine types. Natural pine acreage is projected to drop 29 percent by 2040. Planted pine acreage increases 67 percent over the same period, mostly on forest industry lands. This shift in pine types results in little net change in southern pine acreage over the projection period.

ALTERNATIVE POPULATION TRENDS

The preceding baseline simulation was conducted using Bureau of Census population projections over the next 50 years. In this simulation these population levels were increased 20 percent in each future decade. Table 15 displays the associated projected land use acreage trends.

The increased future population levels have little net effect on projected forest acreage estimates in the year 2040. The largest reduction is on farm ownerships, with a 2 percent decline. Miscellaneous private acreage in 2040 would increase by 1 percent, while forest industry acreage would drop by a similar amount.

These results indicate that the land use acreage projections are not very sensitive to a 20 percent increase in projected population levels. Three contributing factors are (1) the logarithmic functional forms of the land use relationships, (2) the small size of the incremental change relative to projected levels of change for the major land use determinants, and (3) the constraints placed on the land use changes to preclude changes that would deviate significantly from historical trends. The 20 percent change was selected because it was thought by the author to represent a realistic margin of error for Bureau of Census population projections; however, population is

Table 15. Projections of forest acreage in the Southeast for high level population assumptions.[1]

Aggregate	Year			
	1984	2000	2020	2040
Non-Forest Land Uses				
Crop	22.702	19.322	18.383	17.410
Pasture/Range	16.021	16.228	16.143	15.890
Urban/Other	29.739	33.185	34.831	35.554
Private Forest Owner Totals				
Farmer	25.266	17.455	14.182	13.685
F. Industry	15.898	17.229	17.907	18.790
Misc. Private	37.214	43.094	44.739	44.530
TOTAL	78.378	77.777	76.828	77.005
Private Forest Types				
Planted S. Pine	10.451	14.335	16.211	17.380
Natural S. Pine	21.914	18.216	16.345	15.627
Oak-Pine	9.634	9.612	9.184	9.080
Upland Hardwood	24.486	23.505	23.224	23.215
Lowland Hardwood	11.893	12.109	11.863	11.703
TOTAL	78.378	77.777	76.828	77.005

[1]Given in millions of acres

projected to increase by over 350 percent in Florida over the projection period and over 50 percent in several other states. These are large changes relative to the alternative 20 percent increase. In addition, upper level constraints on rates of land use change in some cases further mitigate the impact of increasing population levels.

CHANGES IN REAL INCOMES

Anticipated per capita income trends are an important influence on changes in land use. These factors could have large indirect effects on the timber economy via competition on the land base (Alig et al. 1983a). Table 16 presents acreage projections based on a 20 percent increase by decade in baseline personal incomes.

Increases in personal incomes would tend to reduce both farm and forest industry forestland holdings, but total forest area would be approximately the same because of increases in miscellaneous private acreage. Miscellaneous private acreage would be 1 percent higher than the baseline in 2040, as forestland purchases would increase because of enhanced incomes.

Real personal incomes are projected to more than triple over the next 50 years across the Southeast. As with the population trends, the incremental change from the baseline examined in this alternative simulation is relatively small by comparison. Such large baseline changes contribute to the small degree of sensitivity displayed by the alternative projections.

Table 16. Projections of forest acreage in the Southeast for high level personal income assumptions.[1]

Aggregate	Year 1984	2000	2020	2040
Non-Forest Land Uses				
Crop	22.702	19.288	18.088	17.297
Pasture/Range	16.021	16.158	16.212	16.023
Urban/Other	29.739	33.520	35.193	35.565
Private Forest Owner Totals				
Farmer	25.266	17.280	14.101	13.812
F. Industry	15.898	17.232	17.950	18.782
Misc. Private	37.214	43.033	44.642	44.381
TOTAL	78.378	77.546	76.693	76.974
Private Forest Types				
Planted S. Pine	10.451	14.322	16.204	17.360
Natural S. Pine	21.914	18.158	16.303	15.623
Oak-Pine	9.634	9.584	9.171	9.084
Upland Hardwood	24.486	23.402	23.178	23.223
Lowland Hardwood	11.893	12.079	11.837	11.684
TOTAL	78.378	77.546	76.693	76.974

[1]Given in millions of acres

CHANGES IN COMPETING LAND USE INCOMES

Projected per acre crop income levels in the baseline case were increased 20 percent and timber incomes lowered 20 percent each decade to examine the sensitivity of land use trends to alternative returns from agricultural and forestry land uses. Table 17 presents the associated land use acreage projections.

The change in relative major land use incomes would cause forest acreage to decline only slightly. Farm forest acreage in 2040 would be 1.5 percent lower than the baseline case. The earlier econometric results indicated that competing land use incomes were not significant land use variables in the Coastal Plain, which contains three-fifths of the land in the Southeast. This sensitivity analysis reflects the limited influence of agricultural and forestry returns on southeastern land use trends.

Table 17. Projections of forest acreage in the Southeast for lower forestry and higher agricultural income (per acre) assumptions.[1]

Aggregate	Year 1984	2000	2020	2040
Non-Forest Land Uses				
Crop	22.702	19.364	18.456	17.810
Pasture/Range	16.021	16.196	16.160	15.996
Urban/Other	29.739	33.057	34.693	35.218
Private Forest Owner Totals				
Farmer	25.266	17.418	14.113	13.732
F. Industry	15.898	17.359	18.062	18.881
Misc. Private	37.214	43.118	44.702	44.223
TOTAL	78.378	77.895	76.877	76.836
Private Forest Types				
Planted S. Pine	10.451	14.391	16.277	17.316
Natural S. Pine	21.914	18.229	16.336	15.599
Oak-Pine	9.634	9.623	9.182	9.065
Upland Hardwood	24.486	23.513	23.205	23.152
Lowland Hardwood	11.893	12.140	11.876	11.703
TOTAL	78.378	77.895	77.312	76.836

[1]Given in millions of acres

SUMMARY AND CONCLUSIONS

The objective of this study was to develop a Southeast forest acreage model to support forest resources planning in RPA Assessments. The primary application is for long-range projections of trends in forest acreage, including evaluation of the impacts of a broad range of exogenous forces (e.g., population growth) on these trends.

Forest acrege trends are modeled for three major private owner groupings, using pooled cross-sectional and time series data. The data are for 21 survey units in the Southeast, based on periodic remeasurements that differ in interval length and timing across states. Econometric forest acreage equations were estimated simultaneously with the three other major land uses, both for the entire Southeast and with the data stratified according to the three major physiographic regions.

Several modeling approaches were examined because of the exploratory nature of the study. Ordinary least squares and seemingly unrelated regression estimation produced similar results at the region level. The seemingly unrelated regression approach was utilized to estimate sets of land use equations for each of the physiographic regions in order to capture any possible gain in efficiency from jointly estimating equations that are likely to have correlated disturbance terms.

The econometric results indicate that demographic and macroeconomic variables have important influences on forest acreage trends. Population and personal income levels were the major determinants of land use acreage trends in all three physiographic regions. Thus, the econometric results suggest that changes in timberland acreages are driven largely by exogenous demand forces (e.g., population).

Demographic change increases the demand for housing and other developments, raising urban/suburban/other land rents, and thereby exerting pressure for conversion of forestland to those uses and to replace agriculture land lost to those uses as well. It is likely, therefore, that rising populations over the next 50 years will cause further reductions in the farm forestland base. However, miscellaneous private forest acreage is projected to continue to increase, due in part to the three-fold increase projected for real personal income by 2040.

Expected timber incomes influence forest acreage trends to the largest degree on farm forest ownerships. The positive relationship for farm ownerships is consistent with Binkley's (1981) findings that farmers are more stumpage price responsive than other non-industrial owners when managing their forested properties. Expected agricultural incomes per acre in general were not isolated as major determinants of forest acreage trends. This latter finding is not consistent with the findings of White and Fleming's (1980) agricultural land use study for Georgia. However, they did not include population and personal incomes in their analysis, nor did they examine all major land uses simultaneously.

Government forestry programs (e.g., Forestry Incentives Program) do significantly influence miscellaneous private forest acreage trends. In contrast, the programs' influence is apparently dominated by other factors for the steadily decreasing farm forest category. The question of why this difference occurs for the two non-industrial owner groups cannot by resolved here, but at least several related aspects should be considered. First, past studies suggest business and professional persons are more likely to be willing and able to invest in forestry than other non-industrial owners (Mullaney and Robinson 1980), and may be more likely to participate in govenment programs. Second, determining the net effect of government cost-sharing on changes in forest acreage is problematic. One major question is whether government cost share payments replace private capital that would have been invested without the subsidy (de Steiguer 1983). However, investment in reforestation is not common for many owners with modest to extensive woodland holdings (USDA Forest Service 1983). Cost-shared forest acreage also often involves conversion of one forest type to another, with little, if any, net change in total forest acreage.

It was not possible in this study to differentiate among the several major types of miscellaneous private owners, particularly the corporate owners who are an increasingly large part of this class. These questions require careful study in order to more fully isolate crucial factors involved in the interplay of market and public policy forces and the resultant forest investment tendencies of nonindustrial owners. Related research will be discussed below.

Several economic studies have estimated the potential for converting forest land to agricultural uses (Davis 1972, Dideriksen et al. 1977, and Shulstad and May 1980). The fact that many of these land use conversion or investment opportunities have not already been undertaken suggests that the behavior of the diverse class of private landowners is not fully explainable by models based solely on present value maximization. The timing of conversions is also complicated by the severely inelastic short-run supply relation for the typical farm firm, with family labor, land, and many forms of capital treated as fixed inputs in the short run (Cochrane 1955).

Modelers in general have had limited success in projecting patterns of land use (Voelker 1975). Reasons for the apparent deviation of private landowner behavior from optimal economic guidelines have not been clearly identified, but the deviations may be the result of several combined characteristics of the market, owners, and analyses themselves. Imperfect market information, uncertainty, "noneconomic" goals, and lack of technical skills (Holley 1979) are examples of possible confounding market and owner-related factors. Analyzing the impact of changing government programs (e.g., USDA ERS 1983) on crop acreage has been a central problem in agricultural supply analysis since World War II (Houck et al. 1976). Government programs were often altered to reflect changing short-run views of economic conditions. An important analytical shortcoming may also be the inability to fully account for relevant returns, especially nonmonetary benefits, and costs accruing to a landowner from alternative land uses. This includes the influences of nontimber outputs on timberland management decisions, which have not been extensively tested (Binkley 1981).

The estimated forest industry equations in each region are the least powerful among the forest acreage equations in explaining historical trends. Proxy variables for profit and self-sufficiency proved significant in the Coastal Plain, but population and macroeconomic variables are the significant determinants in the other two regions. Complex strategic maneuvering, operation of woodlands as separate profit centers, leasing of nonindustrial land, and changes at the intensive margin of land use are aspects of industry land holding behavior that are poorly understood and difficult to model with the available data.

Projections of forest acreage by ownership imply a continuation of historical trends, including a considerable stability in total private forest acreage that is similar to long-term historical rates of change in land use as described by Clawson (1979). The simulation of different future scenarios for population trends, per capita incomes, and land use incomes showed a relatively narrow range of future forest acreage trends.

The only previous forest acreage projections are those based on expert opinion (Wall 1981). General trends in the two sets of projections compare closely in the earlier years of the projection period, but the simulation model projects higher forest industry and total forest acreage after the year 2000. As noted also in an earlier section, the model tracked better over the sample period for the farm and miscellaneous private classes than for the forest industry ownership.

An agenda for further research would include examination of forest acreage trends on a less aggregated basis, possibly by state in order to isolate key factors underlying subregional forestland ownership strategies. Unavailability of data may preclude analyses at the state level (i.e., degrees of freedom problem), but at a minimum, aggregate studies should be augmented with descriptive studies at lower levels. The infrequent measurement or estimation of forest acreages has notably limited the analysis of historical land use relationships involving timber production. Implementation of more frequent, and perhaps less intensive, forest acreage surveys (e.g., increased updating with remote sensing techniques) would aid in improving land use analyses needed for forest policy decision-making.

The southeastern land use equations should be evaluated for use in the other southern region, the Mid-South (Alig and Birdsey 1983). Data problems for the Mid-South may preclude separate estimation of similar equations for that region. Applicability of the southeastern equations can be tested by using them to simulate Mid-South land use trends (using the available FIA data, which appears to exist only for several states over the last two decades). The land use conditions in the Mid-South are similar to those in the Southeast, although there are some notable differences such as the more rural character of the Mid-South.

The introduction of risk in econometric analysis of timber supply patterns is another advance that may be possible through careful adaptation of related work in agriculture supply analysis. Substantial risk differences exist among forestry and competing land uses because of the biological and economic uncertainty inherent in the long maturation periods for forest production. The role of product price uncertainty is important when the associated rish involves a major portion of a landowner's income. The cost of bearing risk by landowners has the effect of increasing marginal costs (Cochrane 1955), and hence contracting the supply relation for the associated product.

More refined classification in the periodic forest surveys of the owner groups and their timber resource holdings would also aid future analyses of timberland investment patterns. For example, corporate owners from outside the forest products sector have purchased large amounts of timberland in the South and a quantitative examination is needed to indicate how different their land management is from the other private owner groups. Questions remain regarding the degree to which they will invest in intensified management or the divestiture of timberland after harvest. For example, timberland investments compete with more diverse alternative 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).

In addition, forest acreage response models need to be constructed for other regions of the U.S. to improve natural resources policy formulation. In the longer term, coordination of forest acreage modeling with that for major competing land uses (e.g., agriculture) would improve analyses in terms of consistency of assumptions and underlying data definitions. Given the fixed land base, it is imperative that analysts knowledgeable about different major land uses coordinate land use competition studies so that the multiple claims on the land are addressed jointly in an analytical framework (Healy 1982).

The question of changes in timberland acreages at the extensive margin also needs to be analyzed more closely in conjunction with other input substitution possibilities in timber production (Alig et al. 1983c). The elasticity of input substitution in timber production involves the relative responsiveness of the ratio of non-land factors of production to land when economic parameters change and is dictated by the marginal rate of technical substitution. As land becomes relatively more expensive, theory suggests capital and labor are substituted for land in timber production. The general level of management intensification on non-industrial private lands has been much lower, even on the better lands, which is suggestive of a different management philosophy. The increased substitution of more intensive timber management and capital (e.g., improved genetic stock) on forest industrial lands has been recent evidence of such substitution activities (Adams et al. 1982). An investigation of the important factors influencing tree planting would provide insights into trends in forest land management at the intensive margin.

Further research involving 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. Analysis of the potential for further substitution on industry lands and on non-industrial lands could also be enhanced by improved survey information (e.g., more frequent surveys) pertaining to timber management opportunities and investment trends on all lands.

Finally, forest acreage estimation must be more strongly linked to forest succession, timber inventory projection, harvest, and investment modeling in aggregate timber supply studies (Alig et al. 1984). In theory, the levels of timber havest, intensity of timber management or 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. If so, this modeling will require better understanding of owner objectives, including the nature and extent of interest in market and nonmarket forest products (Binkley 1981) and the role of the forest enterprise in the overall operations of a forest owner. 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.

Forest type transition research is needed to provide better estimates of the likely successional responses of forest types to management activities and better information on the forest type distribution on acres that passively revert to forests (Alig et al. 1983b). The next step would be to combine forest land acreage and forest type shift research to improve forest type acreage projections. These forest acreage projections must, in turn, be integrated with timber inventory projection modeling to insure that timber management modeling is incorporated into this overall land use modeling framework. Although improving this type of linkage may be a long-term venture, it is necessary for adequate modeling of timber supplies that are being produced on a shrinking timberland base.

Simulation of stumpage price and quantity impacts resulting from forest acreage changes would involve interactive links among a land projection module, timber stand (inventory) projection module (currently being revised elsewhere), and stumpage price modeling of TAMM. Regional stumpage prices, number of acres devoted to forestry, and the timber management schemes on those acres are all interrelated, suggesting that a simultaneous solution network or feedback loops are needed. Because revisions are currently being contemplated for the timber inventory projection module and stumpage supply relations in TAMM, it is not presently possible to specify in detail the nature of the linkages in this overall framework.

Linking of the Southeast forest acreage model to the Timber Assessment Market Model could facilitate the analysis of interregional timber production shifts related to different forest acreage trends. This would improve forest resource policy simulations in RPA Assessments, espcially in terms of evaluating alternative assumptions regarding levels of major exogenous variables.

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APPENDICES

APPENDIX A

PHYSIOGRAPHIC REGIONS

Table A1. Acreage of FIA survey units in the Southeast, by physiographic region and state.[1]

State/Survey Unit	Physiographic Region		
	Coastal Plain	Piedmont	Mountain
Florida			
1	9,664.6		
2	7,276.1		
3	9,916.7		
4	7,674.9		
Georgia			
1	10,578.5		
2	5,597.1		
3		10,337.6	
4		6,129.5	
5			4,193.8
North Carolina			
1	8,341.1		
2	6,634.7		
3		10,447.6	
4			5,631.8
South Carolina			
1	5,095.9		
2	7,379.7		
3		6,643.8	
Virginia			
1	6,224.9		
2		5,578.0	
3		4,398.5	
4			4,287.9
5			4,787.3
Total	84,404.2	43,525.0	18,900.8

[1]Given in thousands of acres

DESCRIPTION OF PHYSIOGRAPHIC REGIONS

The Coastal Plain is physiographically the youngest region, with the oldest part of the plain lying along the inner border. The Coastal Plain is also the flattest land in the Southeast, comprised of gentle slopes with little local relief. Marshes, lakes, and swamps are common in this lowland, which developed from a mass of soft sands, silts, and clays that was deposited, as the sea receded from the land.

The Piedmont plateau is higher and drier than the Coastal Plain. Its flat surface, like that of the Coastal Plain, facilities man's movements, and it is really a plain with only a few hills rising above the otherwise gently rolling surface. As in the Coastal Plain, the soils of the Piedmont are usually strongly leached, rich in iron and aluminum oxides, and deficient in many of the plant nutrients essential for successful agricultural production (USDA Forest Service 1981).

The Mountain region is comprised of the southern Appalachian Mountains and lies mostly in western North Carolina and northern Georgia. The mountains are a mixture of short ridges and isolated peaks separated by large open valleys and basins (Parkins 1938). This region is relatively steep with much relief up to 3000 feet, and peaks exceeding 6,000 feet.

APPENDIX B

HISTORICAL SHIFTS IN LAND USE ACREAGES

Table B1. Historical changes in the extent of each land use by state in the Southeast (based on the author's analysis of FIA data).[1]

State	Period	Land Use					
		Crop	Pasture/ Range	Urban/ Other	Farm Forest	Forest Industry	Misc. Private
Florida[2]	1949-1980	-1.60	5.13	3.83	-24.11	2.14	14.61
Georgia	1952-1982	-7.70	2.37	4.99	-25.82	2.06	24.10
North Carolina	1937-1974	-12.14	2.69	3.65	-16.77	3.58	18.99
South Carolina	1947-1978	-11.75	2.65	6.57	-15.88	3.10	15.31
Virginia	1957-1976	-8.18	-1.91	1.44	-19.42	0.86	27.20

[1]Given in percentages.

[2]Changes are based only on historical values for Florida FIA Survey Units 1 and 2 because of definitional and classification problems in Survey Units 3 and 4.

APPENDIX C

VARIABLE DESCRIPTIONS AND SOURCE NOTES

INDEPENDENT VARIABLES

AGRICULTURAL INCOMES

Crop Incomes

The crop income index is a lagged index, based on two-year weighted moving averages of soybean and corn incomes in the Southeast. The soybean and corn components are weighted by the annual value of production, which equals price per bushel multiplied by the number of bushels produced. Weights applied to the lagged incomes are 0.67 in year t-1 and 0.33 in year t-2.

Annual prices per bushel obtained from the Crop and Livestock Reporting Service in each state were multiplied by an annual output/input ratio from ERS Statistical Bulletin 679. The productivity measure for the ERS Appalachian Farm Region applied to Virginia and North Carolina and the Southeast Farm Region one was for Florida, Georgia, and South Carolina. These values were then divided by prices paid by U.S. farmers for farm inputs, which were taken from the Handbook of Business Statistics.

Livestock Incomes

The livestock income index is based on a three-year moving average of beef cattle incomes, with a one-year lag. Equal weights are applied to all three years used in the distributed lag.

Annual prices for beef cattle were obtained from the Crop and Livestock Reporting Service in each state. These prices were multiplied by an annual output index for farm meat animals. These values were then divided by an input index for feed, seed, etc. on farms from the same source. The output and input measures were for the same Appalachian and Southeast farm regions used in deriving the crop incomes. The values were then divided by prices paid by U.S. farmers for farm management inputs published in the January 1982 issue of the Handbook of Basic Economic Indicators.

Timber Income

This timber income variable is a lagged index, computed using a two-year moving average [with weights of 0.67(t-1) and 0.33 (t-2)]. Prices for southern pine sawtimber and pulpwood stumpage were weighted by the respective harvest volumes during the historical period. This composite price was then converted to constant dollars using the all commodity PPI. Regional price variation indices based on Hunter's (1982) analysis of regional difference in stumpage prices were used to adjust prices by survey unit. Data on productivity trends in stumpage trends were not available.

The sawtimber prices are based on National Forest sales, and the 1934-70 values were obtained from the Historical Statistics of the U.S. and the 1971-82 prices were supplied by the USDA Forest Service Region 8 office in Atlanta, Georgia. The southern pine pulpwood prices for 1934-54 were supplied by the Louisiana State Forestry Commission, and the 1955-82 prices are from USDA Forest Service Misc. Pub. WO-1408.

The weights for sawtimber and pulpwood stumpage production were derived from information in the USDA Forest Service Resource Report 23 (1980 Timber Assessment report) and Misc. Publication WO-1408. Extrapolations based upon this information provided weights for years before 1950. A conversion of 2.75 cord per MBF was used in deriving the weights, based on converting factors in Louisiana State University Bulletin 626.

GOVERNMENT PROGRAMS

Soil Bank

Annual expenditures for tree planting under the Conservation Reserve Program of the Soil Bank were weighted over a ten year period to derive a moving weighted average. The current year's expenditures were not included because of the small probability that those expenditures resulted in plantations that were sampled that year. This is because new plantations are difficult to detect in the aerial photo phase of FIA survey sampling. Weights were assigned according to a humped time structure of the response of forest acreage to government payments, representative of a second-degree polynominal Almon distributed lag. The weights decline with time to account for acreage losses due to failures, conversion, and other disturbances (Alig et al. 1980, Kurtz et al. 1980). The ten weights employed were: .08, .12, .15, .13, .12, .10, .09, .08, .07, and .06.

Estimates for each survey unit were derived by multiplying a state's expenditures by the survey unit's percentage of total state land area. The all commodity producer price index was used to derive constant dollar estimates. The annual expenditure values at the state level were obtained from an unpublished final report on the Conservation Reserve Program issued by the USDA Agricultural Stabilization and Conservation Service, Washington, D.C.

Other Government Tree-Planting Expenditures

This variable is similar in structure to the Soil Bank variable, and is also a moving weighted average over a ten-year period. It is a composite of direct tree-planting cost-share expenditures by state under three groups of government programs: (1) Forestry Incentives Program (FIP), (2) Agricultural Conservation Program (ACP), and (3) state programs for South Carolina and Virginia. The units are thousands of constant dollars, and the all-commodity producer price index (PPI) was used to drive the constant dollar estimate. The FIP and ACP expenditures for practice A-7 were taken from various program summaries published by the Agricultural Stabilization and Conservation Service in Washington, D.C. The state program expenditures were obtained from miscellaneous sources in the literature.

INFLATION RATE

Description

A two-year moving average (with equal weights) of the Consumer Price Index for all goods.

Source

Economic Report of the President for 1982 and 1983.

PERSONAL INCOME

Description

Real personal per capita income measures by State are computed as total personal income divided by the state's mid-year population. They were converted to constant dollars by adjusting them by the Consumer Price Index.

Source

Economic Report of the President for 1982 and 1983.

POPULATION

Description

Total population by survey unit was separated into urban and rural components. The population variables were constructed as three-year moving averages (with equal weights).

Source

Decadal U.S. Census, with linear interpolation for intercensus estimates.

WOOD PRODUCTS INCOME

This is a weighted lagged income index for lumber, plywood, and pulp softwood outputs. The index is a two-year moving average (with equal weights) for years t-1 and t-2. Price indices for southern pine lumber and plywood for 1950-82 were obtained from USDA Forest Service Misc. Publication WO-1408. The 1934-49 price indices are based on an all-lumber producer price index from the Handbook of Basic Economic Statistics. The source for the paper price index was the 1983 Economic Report of the President.

The production weights for 1950-76 were derived using times series data published by Adams et al. (1979). Values for 1934-1949 and 1977-82 were derived using extrapolation of the 1950-76 set of weights.

The output price index was divided through by the all commodity PPI and then a 1967 based manufacturing labor cost index to account for cost differentials by state. No adjustments were made for productivity trends in the forest products sector because of the unavailability of a full set of historical data.

REMOVAL PERCENTAGE

Description

This variable represents industry softwoods removals as a percentage of total (all owners) softwood removals. It is calculated from the periodic FIA surveys and therefore could not be lagged or computed as a moving average.

Source

Periodic inventories by the USDA Forest Service FIA Unit at Asheville, NC.

DEPENDENT VARIABLE

The dependent variable represents the percent of a survey unit's land area occupied by a major land use (e.g., forest acreage on a particular ownership). The land acreage estimates are from periodic FIA surveys. The acreage estimates were converted to percentages of the total land base in a survey unit in order to account for (acreage) size differences among the survey units. Area sampling is done at the survey unit level.

See the glossary for definitions of the land uses and ownership categories used in this study. Land use area estimates for four inventories in each State were provided by Herbert A. Knight of the USDA Forest Service FIA Unit at Asheville, NC.

The classification of land use over the historical period in the two southern Florida survey units has been complicated by land use definitional problems. A large acreage of forest and range land is borderline between the two uses, and other land use patterns in this area are also quite different from the rest of the Southeast. Therefore, land use observations for southern Florida were not used in developing the econometric models in this study and analysis of the land use trends in those two units was accomplished separately with the assistance of Herb Knight.

APPENDIX D

SIMULATION OF FOREST TYPE ACREAGES

The forest acreage model can project forest type acreages out to the year 2040 under three options that reflect different assumptions regarding the application of land management practices. Timber inventory projection models used in regional timber supply appraisals have based their simulation of future timberland management on these several different assumptions (Alig et al. 1984): extrapolation of management implicit in measured stand growth rates (e.g., TRAS model), analysis of positive investment behavior, (e.g., SPATS) (Brooks 1983b), and analysis of treatment opportunities (e.g., TRIM). The three options for incorporating future land management patterns in the forest acreage model are structured to simulate these categories of timber management currently simulated by inventory projections models. The first option was used for the forest type acreage projections in this study.

EXTRAPOLATION OF MANAGEMENT

This option simulates forest type transitions for three different categories of (FIA defined) land management practices, based on historical rates of transition among major forest types. Two sets of probability distributions by owner and physiographic region are required as input: 1) probability of application of the three management classes and 2) transition (conditional) probabilities for a forest type's destination in response to receiving one of the three types of management. The conditional forest type transition probabilities are multiplied by the management probabilities and the resultant acreage estimates are summed by owner, forest type, and physiographic region. The probabilities are based on FIA remeasurements made approximately a decade apart. Projection of forest type acreages on this basis is predicated on the continuation of a similar future mix of land management practices.

Historical rates of forest type transition by physiographic region were estimated from the most recent periodic FIA surveys for

Florida, Georgia, and South Carolina (Tables 6, 7, and 8) because consistent transition information is only available for the most recent FIA surveys in this East Gulf area. Therefore, the same transition rates were applied across all states, with distinct transition probabilities by physiographic region.

POSITIVE INVESTMENT BEHAVIOR

Projections of timberland investment activity by forest type can be simulated under this option. Of particular interest are estimates of acreage planted to southern pine. Investment behavior by forest type can be combined with extrapolation of historical management (the option above) for the other forest types.

An example of applying this option is to incorporate planted southern pine acreage that is estimated by the SPATS investment equations (Brooks 1983a). The exogenous acreage estimates of planted southern pine are entered by decade for each ownership. Historical forest type transition probabilities are used to model the source of acreage converted or replanted to pine. Transitions among other forest types are also based on historical transition rates.

ANALYSIS OF INVESTMENT OPPORTUNITIES

Economic analysis has shown that there are over 50 million acres of timberland in the Southeast that could respond with at least a 4% real rate of return under more intense levels of management (Vasievich 1981). Treatment opportunities by forest type have been grouped into broad land management classes (e.g., site preparation followed by planting), and these can be evaluated by the TRIM model (Tedder et al. 1983).

Complete linkage of a forest acreage model and a timber inventory projection model would require an iterative processing of the two models. Therefore, the two models are currently run separately and vectors of management estimates from the inventory projection model are utilized as decadal input in the forest acreage model. There are three broad management categories for which timberland acreage trends can be simulated: (1) no active management, (2) partial cutting or other disturbance, and (3) final harvests. Incorporation of more detailed management classes depends on development of related models (Alig et al. 1984).

APPENDIX E

PROJECTION MODEL CONSTRAINTS

CONSTRAINTS FOR LAND USE PERCENTAGES

Constraints based on historical rates of transition are applied in the southeastern land use acreage projections to preclude illogical or unreasonable trends in projected land use percentages. Two types of constraints are imposed: (1) bounds on percentage changes by decade for each land use, in terms of the percentage of land area occupied by a particular land use, and (2) limits on the absolute percentage of land that may be occupied by a particular land use. These constraints are applied at the physiographic region level within each state for each of the six major land uses.

DECADAL CHANGES

Bounds on changes in land use percentages by decade given in Table E1 were constructed from analysis of historical trends and expert opinion. The probability of rapid changes in land use percentages is small because of the capital limitations of owners, the inertial nature of land management, and the slowly changing trends in relative land product incomes.

The current extent of land use was also taken into account when constructing the percentage bounds. For example, forests generally have covered 60 to 80 percent of the Southeast and changes over a decade are typically in the range of 2 to 15 percent. Parallel changes in pasture range land use are 0.5 to 5 percent, as pasture/range typically only occupies 2 to 15 percent of the land in a survey unit.

FLOORS AND CEILINGS

Limits on the upper and lower percentage ranges for each land use presented in Table E2 are based on expert opinion and historical low and high percentages for each land use, by physiographic region within a state. All land use percentages are constrained to fall between 0 and 55 percent.

Table E1. Bounds on rates of change in land use percentages by decade.

	Coastal Plain						Piedmont						Mountains					
	FA	FI	MP	C	P	O	FA	FI	MP	C	P	O	FA	FI	MP	C	P	O
Positive Rates of Change[1]																		
Florida	.032	.014	.027	.028	.026	.029	*	*	*	*	*	*	*	*	*	*	*	*
Georgia	.030	.019	.038	.037	.028	.026	.021	.023	.042	.041	.028	.030	.023	.020	.046	.044	.028	.032
N. Carolina	.038	.016	.038	.037	.024	.029	.037	.015	.041	.041	.030	.038	.039	.019	.045	.038	.027	.033
S. Carolina	.031	.016	.038	.029	.019	.026	.033	.023	.046	.036	.038	.032	*	*	*	*	*	*
Virginia	.034	.016	.038	.034	.018	.026	.040	.021	.040	.031	.031	.027	.036	.019	.041	.032	.029	.027
Negative Rates of Change[1]																		
Florida	.032	.026	.031	.026	.026	.013	*	*	*	*	*	*	*	*	*	*	*	*
Georgia	.042	.010	.033	.031	.026	.013	.050	.011	.026	.031	.030	.013	.048	.017	.016	.030	.028	.011
N. Carolina	.045	.014	.036	.029	.021	.013	.040	.013	.030	.036	.026	.017	.043	.026	.034	.033	.028	.011
S. Carolina	.051	.019	.030	.035	.019	.013	.050	.021	.036	.036	.028	.016	*	*	*	*	*	*
Virginia	.047	.017	.031	.031	.018	.013	.046	.019	.034	.031	.030	.016	.043	.013	.031	.032	.030	.111

[1]Percentage of total land base

*Indicates a nonexistent state - physiographic region combination

FA: Farm Forest
FI: Forest Industry Forest
MP: Miscellaneous Private Forest
C: Cropland
P: Pasture/Range
O: Urban/Other

Table E2. Limits on the percentage of the land base that can be occupied by the major land uses.

	Coastal Plain						Piedmont						Mountains					
	FA	FI	MP	C	P	O	FA	FI	MP	C	P	O	FA	FI	MP	C	P	O
Floors[1]																		
Florida	.022	.175	.165	.058	.023	.092	*	*	*	*	*	*	*	*	*	*	*	*
Georgia	.085	.072	.095	.125	.021	.035	.065	.060	.195	.074	.056	.059	.050	.038	.210	.048	.043	.190
N. Carolina	.165	.087	.115	.188	.011	.081	.175	.011	.145	.138	.031	.098	.095	.015	.220	.036	.041	.200
S. Carolina	.102	.098	.131	.165	.015	.111	.115	.070	.187	.078	.038	.091	*	*	*	*	*	*
Virginia	.123	.100	.124	.141	.016	.080	.165	.052	.147	.086	.078	.091	.084	.011	.055	.039	.126	.160
Ceilings[1]																		
Florida	.193	.410	.417	.217	.182	.285	*	*	*	*	*	*	*	*	*	*	*	*
Georgia	.323	.300	.295	.361	.168	.207	.196	.240	.520	.283	.185	.220	.190	.140	.492	.187	.177	.376
N. Carolina	.360	.210	.340	.368	.085	.210	.387	.092	.347	.385	.136	.206	.281	.105	.435	.169	.179	.402
S. Carolina	.290	.210	.325	.295	.086	.223	.296	.167	.382	.356	.178	.242	*	*	*	*	*	*
Virginia	.327	.208	.319	.267	.076	.234	.389	.168	.358	.237	.219	.205	.285	.096	.398	.186	.274	.386

[1]Percentage of total land base

*Indicates a nonexistent state - physiographic region combination

FA: Farm Forest
FI: Forest Industry Forest
MP: Miscellaneous Private Forest
C: Cropland
P: Pasture/Range
O: Urban/Other

APPENDIX F

PROJECTIONS OF EXOGENOUS VARIABLES

POPULATION

Projections of population through the year 2000 by state prepared by the U.S. Department of Commerce, Bureau of the Census (Series P-25, No. 937, 1983) were used for the baseline case. Population projections for years after 2010 were based on extrapolation of the Bureau of Census projections. Population levels were then increased 20% each decade in an alternative set of projections to examine the effects of higher future population levels on land use trends.

Projected total population estimates were apportioned into rural and urban components throught the use of historical proportions. These were specific by physiographic region within a state, and constant proportions were assumed throughout the projection period.

PERSONAL INCOME

Personal income projections are based on GNP projections developed by the USDA Forest Service for RPA Assessment analyses. These GNP projections were provided by Adrian Haught of the Forest Service's RPA Staff. Personal income levels were then increased by 20 percent each decade in an alternative set of projections to examine the consequences of higher income levels on land use.

LAND USE INCOMES

Projections of income per acre for crop and pasture/range uses were based on agricultural price and productivity projections in the Soil Conservation Service's RCA analysis and separate projections prepared by the Economic Research Service (ERS). Constant real future crop prices are projected, with productivity growth of 1.1 percent annually to the year 2000 and .9 percent thereafter. Projections by state were applied across physiographic regions in each state.

Future timber incomes were projected using southern pine stumpage prices projected by the Timber Assessment Market Model (TAMM).

Stumpage prices were adjusted by physiographic region and state using results from Hunter (1983). Timber product prices and industry removal percentages were also projected using TAMM projections.

INFLATION RATE

Projected inflation rates were based on Wharton's 1983 baseline long-term forecast of interest rates. Wharton's projections up to the year 2002 were extrapolated to the year 2040.

OTHER GOVERNMENT FORESTRY PROGRAMS

Current funding levels for government cost-share programs for tree planting were projected using annual rates of real increase equal to 1%. Historically, real rates of funding increases have been greater than 3% annually (over some decades), but the projected values are based on slower increases because of anticipated reductions in such domestic programs.

GLOSSARY

Census of Agriculture. Gathering and compilation of statistics on farms and agricultural operations for each state conducted by the Bureau of Census every five years.

Cropland. Land under cultivation within the past 24 months, including orchards and lands in soil-improving crops, but excluding land cultivated in developing improved pasture. This also includes idle farmland.

Farm. Land on which agricultural operations are conducted and the sale of agricultural products exceeds (or normally would exceed) $1,000.

Forest Industry Lands. Lands owned by companies or individuals operating wood-using plants.

Forest Inventory and Analysis (FIA). Units of the USDA Forest Service that conduct and report on comprehensive surveys of State forest land resources on a continuing basis, with years between surveys of states differing. The nation-wide RRE program was authorized by the McSweeney-McNary Forest Research Act of 1982.

Forest Land. Land at least 16.7 percent stocked by forest trees of any size, or formerly having had such tree cover, and not currently developed for nonforest use.

Idle Farmland. Includes former croplands, orchards, improved pastures and farm sites not tended within the past 2 years, and presently less than 16.6 percent stocked with trees.

Land Area. The area of dry land and land temporarily or partly covered by water such as marshes, swamps, and river flood plains (omitting tidal flats below mean high tide), streams, sloughs, estuaries, and canals less than 1/8 of a statute mile in width, and lakes, reservoirs, and ponds less than 40 acres in area.

Lowland Hardwood. Forests in which elm-ash-cottonwood or oak-gum-cypress types singly or in combination, comprise a plurality of the stocking, except where pines comprise 25 to 50 percent, in which case the stand would be classified oak-pine. (Common associates include cottonwood, willow, ash, elm, hackberry, and maple.)

National Agricultural Land Study (NALS). An interagency study sponsored by the USDA and President's Council on Environmental Quality to investigate the availability of the nation's agricultural lands, the extent and causes of their conversion to other uses, and ways in which those lands might be retained for agricultural purposes.

Oak-Pine. Forests in which hardwoods (usually upland oaks) comprise a plurality of the stocking but in which pines comprise 25 to 50 percent of the stocking. (Common associates include gum, hickory, and yellow-poplar.)

Pasture/Rangeland. Land used primarily for the production of forage plants for livestock (this includes domesticated forage plants and native grasses, grasslike plants forbs, and shrubs).

Site Class. A classification of forest land in terms of inherent capacity to grow crops of industrial wood based on fully stocked natural stands.

Class 1. Sites capable of producing 165 or more cubic feet per acre annually.

Class 2. Sites capable of producing 120 to 165 cubic feet per acre annually.

Class 3. Sites capable of producing 85 to 120 cubic feet per acre annually.

Class 4. Sites capable of producing 50 to 85 cubic feet per acre annually.

Class 5. Sites incapable of producing 50 cubic feet per acre annually, but excluding unproductive sites.

Southern Pine. Forests in which loblolly, shortleaf, longleaf, slash, or other southern yellow pines, singly or in combination, comprise a plurality of the stocking. (Common associates include oak, hickory, and gum.)

Timberland. Land which is producing or capable of producing crops of industrial wood in excess of 20 cubic feet per acre per year and is not withdrawn from timber utilization by statute or administrative regulation.

Upland Hardwood. Forests in which upland oaks or hickory, singly or in combination, comprise a plurality of the stocking, except where pines comprise 25 to 50 percent, in which case the stand would be classified oak-pine. (Common associates include yellow-poplar, elm, maple, and black walnut.)

Unproductive Forest Land. Forest land incapable of producing 20 cubic feet per acre of industrial wood under natural conditions, because of adverse site conditions.

Urban and Other Areas. Areas within the legal boundaries of cities and towns; suburban areas developed for residential, industrial, or recreational purposes; school yards; cemeteries; roads; railroads; airports; beaches, powerlines, and other rights-of-way; public forest land and unproductive forestland; or other nonforest land not included in any other specific land use class.

<u>Wilderness</u>. An area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions.