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Journal of Agricultural and Applied Economics, 37,1(April 2005):173–186
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Determinants of Timberland Use by Ownership and Forest Type in Alabama and Georgia

Rao V. Nagubadi and Daowei Zhang

Land use changes and timberland use by ownership and forest type in Alabama and Georgia between 1972 and 2000 are analyzed using a modified multinomial logit approach. Low average land quality, federal cost-share incentives, and favorable returns to forestry relative to agriculture were the main factors associated with timberland increase. Higher forestry returns helped increase industrial timberland but not nonindustrial private forests. An increase in hardwood forests at the expense of softwood and mixed forests was driven by increasing hardwood returns. Increasing softwood returns and tree planting assistance programs alleviated declines in softwood forests. Because factors influencing timberland use changes differ by ownership and forest type, treating all timberland as one major category may lead to incorrect predictions.

Key Words: forest type, land use determinants, modified multinomial logit, timberland ownership

JEL Classifications: Q15, Q23, R15

Changes in land use have implications for water quality and biodiversity (Basnyat et al.; Powell et al.). Changes in forest types could imply a significant impact on the condition of forests and their ability to provide timber, wildlife habitat, recreation, and environmental amenities (Wear and Greis). Furthermore, changes in forest ownership have implications for forest management intensity, timber supply, and hunting leases. Better predictions of land use changes by forest type and ownership are therefore needed in order to take measures necessary to protect biodiversity and water quality and meet increasing demands for recreation and timber production.

In the last two decades, a number of studies have attempted to model land use changes by major uses, i.e., forestry, agriculture, and urban land (Ahn, Plantinga, and Alig 2000, 2001; Alig; Hardie and Parks; Hardie et al.; Plantinga, Mauldin, and Alig). However, few studies have dealt with changes in timberland by ownership and forest type.[1] By pooling data across ownerships and forest types, earlier studies have imposed a restriction on land

Rao V. Nagubadi is postdoctoral fellow and Daowei Zhang is professor, School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL.

The authors wish to acknowledge financial support from the Center for Forest Sustainability and the Environmental Institute of Auburn University and to thank Changyou Sun, Jeffrey Kline, and two anonymous reviewers of this journal for helpful comments and insights.

[1] To our knowledge, Ahn, Abt, and Plantinga and Plantinga and Buongiorno are the exceptions. Plantinga and Buongiorno studied nonindustrial timberland use by ownership based on state-level data prior to 1977 in the United States, and Ahn, Abt, and Plantinga analyzed timberland use by ownership using county-level data in the south-central United States. However, neither study considers timberland use by forest type.

Table 1. Changes in Land Use in Alabama and Georgia (1,000 Acres)

	Alabama			Georgia		
Particulars	1972	2000	% Change	1972	1997	% Change
All land by major use:						
Timber land	21,333.1	22,926.5	7.5	24,839.0	23,795.3	−4.2
Agricultural land	7,177.3	5,251.6	−27.0	7,851.1	6,188.1	−21.2
Urban and other land	3.965.8	4,247.1	7.1	3,957.9	6,460.2	63.2
Misc. area	1,072.0	1,136.6	6.0	1,383.8	1,588.2	14.8
Total area	33,548.2	33,548.2	0.0	38,031.9	38,031.9	0.0
Timberland by ownership:	21,333.1	22,926.5	7.5	24,839.0	23,795.3	−4.2
Public	1,020.5	1,230.0	20.5	1,571.5	1,751.2	11.4
Forest industry	4,204.9	3,740.4	−11.0	4,318.2	4,890.7	13.3
NIPF	16,107.7	17,956.1	11.5	18,949.3	17,153.4	−9.5
Timberland by forest type:	21,333.1	22,926.5	7.5	24,839.0	23,795.5	−4.2
Softwood	7,863.7	8,089.0	2.9	12,325.2	10,805.3	−12.3
Oak-pine mixed	5,016.9	4,193.7	−16.4	4,142.9	3,613.3	−12.8
Hardwood	8,456.5	10,577.9	25.9	8,370.9	9,376.9	12.0

Note: Miscellaneous area includes water area, unproductive forests, and productive reserve forests.

use changes—all ownerships and forest types respond in the same magnitude to various factors. In this study, we develop an analytical framework that can be used to model and predict land use changes by forest ownerships and forest types. We apply the framework to Alabama and Georgia, two of the largest timber-producing states that are subject to population increases and urbanization pressures. The results of this study can help policy makers predict future timberland use changes and formulate appropriate policies to deal with potential problems.

Land use changes are related to demographics, market forces, and policy interventions. Between 1972 and 2000, timberland increased by 7% in Alabama but declined by 4% in Georgia (Table 1). Land in agricultural use declined, and land in urban and other uses and miscellaneous uses increased in varying proportions. The ownership pattern of timberland changed. In Alabama, while timberland under public and nonindustrial private forest (NIPF) ownerships increased by 20% and 11%, respectively, forest industry ownership declined by 11%. In Georgia, the timberland under public and forest industry ownerships increased by 11% and 13%, respectively, but that under NIPF ownership declined by 9%.

Changes also took place in timberland areas by forest type. Hardwood forests increased at the expense of softwood and mixed forests. In Alabama, softwood timberland increased marginally by 3%, timberland classified as mixed forests declined by 17%, and hardwood timberland increased by 25% between 1972 and 2000. In Georgia, the softwood and mixed forest timberland each declined by nearly 13%, while hardwood timberland increased by 12% in the same time period.

Our primary findings are that various factors influence timberland use changes in different ways based on timberland use classification. The next section briefly reviews previous studies and presents the analytical framework used in this study—a modified multinomial logit model. The third section describes the data used. The fourth section presents and discusses the results separately by major use, ownership, and forest type. The final section concludes.

Literature Review and Analytical Framework

Previous studies (e.g., Ahn, Plantinga, and Alig 2001, 2002; Alig) have found that forest returns, timber price, and timber-to-crop income ratio encourage an increase in timberland and that increases in timber establishment costs discourage timberland use. Similarly, increasing farm expenditures discourage agricultural use and promote conversion into either urban land or timberland. Personal income, household income, and per capita income negatively affect timberland and agricultural land use and favor urban land use. Increasing inflation favors the conversion of land into forestry use (Alig; Hardie and Parks).

Population density is a key factor in the conversion of timberland and agricultural land to urban use (Alig; Hardie and Parks; Hardie et al.). As the population increases, more land is needed for home sites, roads, and parks; airports, school, commercial, and industrial sites; and open space to satisfy the demands of urbanized areas (Reynolds; Vesterby and Heimlich). The proportions of rural and urban populations also affect land use (Alig).

The quality of land has a major influence on the use of land for agricultural or forestry purposes (Ahn, Plantinga, and Alig 2001; Hardie and Parks; Mauldin, Plantinga, and Alig; Parks and Murray; Plantinga, Mauldin, and Alig). Higher-quality land is naturally used for agriculture, and lower-quality land is used for forestry. The U.S. Department of Agriculture (USDA) classifies land into eight land capability classes (LCC) in decreasing order of land quality (Klingebiel and Montgomery). Empirical analyses show that the proportion of two higher land quality classes in the total land affects whether the land is put into agricultural or forestry use.

Previous studies have also shown that the distance to a city has a negative influence on the agricultural and urban land use and a positive influence on the timberland use under NIPF and forest industry ownership (Ahn, Plantinga, and Alig 2001, 2002). The distance to interstate highways may act positively on timberland use and negatively on agricultural and urban land uses. The slope of land has also been an influence on how land is used; agricultural land often has a lower slope than timberland (Parks and Murray). Finally, several federal programs, such as the Soil Bank Programs, the Forestry Incentives Programs, the Conservation Reserve Programs, and the Stewardship Incentives Programs, have encouraged landowners to plant trees and to convert marginal agricultural land to forestry use (Kline, Butler, and Alig; Li and Zhang).

Following Hardie et al. and Miller and Plantinga, a model of land use is developed from the viewpoint of landowners in allocating a fixed amount of land to alternative uses. Optimal (or expected) land use shares, p_{ikt} (proportion of land in i-th county, in k-th use, at time t), in the total land are specified as multinomial logistic functions of a linear combination of a vector of explanatory variables, X_{it}, and a vector of unknown parameters, β_k:

$$(1) \qquad p_{ikt} = \frac{\exp(\beta_k' X_{it})}{\sum_{k=1}^{K} \exp(\beta_k' X_{it})}.$$

The land uses, for example, can be nonindustrial-owned timberland, private industry–owned timberland, agricultural land, and urban/other land (i.e., $k = 1, \ldots, K - 1, K$). The vector of explanatory variables, X_{it}, used in literature often includes (a) economic variables: forest returns, agricultural returns, urban rent, and per capita income; (b) demographic variables: population density, urban/rural population ratio, and average age; (c) land quality variables: average land quality and the proportion of two higher-quality classes; (d) geographical variables: distance to city, slope, and travel time; and (e) policy variables: government forestry cost-share programs and farm assistance programs.

The empirical model is formulated as a modified multinomial logit model (Amemiya and Nold; Hardie and Parks; Parks). This specification is convenient because it constrains the predicted land use shares between zero and one and their sum to one. If we normalize Equation (1) by one of the land use shares (for example, $k = 4$), constraining $\beta_4 = 0$, the modified multinomial logit model becomes

$$(2) \qquad p_{ikt} = \frac{\exp(\beta_k' X_{it})}{1 + \sum_{k=1}^{K-1} \exp(\beta_k' X_{it})} \quad \text{for } k = 1, \ldots, K - 1$$

and the share for the omitted land use is recovered as

$$(3) \quad p_{i4t} = \frac{1}{1 + \sum_{k=1}^{K-1} \exp(\beta_k' X_{it})}.$$

Logarithmic transformation of Equation (2) yields a $K - 1$ equation system

$$(4) \quad \ln\left(\frac{p_{ikt}}{p_{i4t}}\right) = \beta_k X_{it} + u_{it} \quad \text{for } k = 1, \ldots, K - 1$$

where u_{it} are random errors. Since the optimal land use proportions, p_{ikt}, are not observable and may be different from actual land use proportions because of random factors, they are replaced with actual (or observed) land use proportions, y_{ikt}, and additional error terms, ϵ_{ikt}, are introduced in the system. The system of equations in Equation (4) then becomes

$$(5) \quad \ln\left(\frac{y_{ikt}}{y_{i4t}}\right) = \beta_k X_{it} + u_{it} + \varepsilon_{ikt}$$
$$\text{for } k = 1, \ldots, K - 1,$$

which is linear in parameters. Hardie and Parks interpret ε_{ikt} as errors induced by the use of county averages for the elements of X. The logarithmic transformation and use of both time-series and cross-sectional data may induce the heteroskedasticity problem from one or more explanatory variables. From Equation (5), it is clear that the error terms are related to the parameters and are subject to heteroskedasticity. As a correction to this problem of heteroskedasticity, maximum likelihood estimates are obtained by the multiplicative heteroskedastic regression method (Greene 1995, pp. 264–67; Harvey).[2]

Since the dependent variable is the log of the ratio of proportions of land uses, interpreting the coefficients directly is difficult. Consequently, marginal effects and elasticities are estimated at mean levels of variables. Marginal effects are estimated as (Greene 1993, p. 666)

$$(6) \quad \frac{\partial y_{ikt}}{\partial x_{ikt}} = \left(\beta_{kx} - \sum_{k=1}^{K-1} y_{ikt}\beta_{kx}\right) y_{ikt}$$
$$\text{for } k = 1, \ldots, K - 1,$$

where β_{kx} is the coefficient of x for land use k. The marginal effects for the multinomial logit function are not monotonic but depend on the point of evaluation, and they can differ in sign from the coefficients, since Equation (6) involves the values of the estimated coefficients, β_{kx}, from all equations in each category of analysis and the proportions of land uses, y_{ikt}. The acreage elasticity of land use k, with respect to x, in county i, in year t, is given by (Wu and Segerson, p. 1037)

$$(7) \quad e_{iktx} = \frac{\partial y_{ikt}}{\partial x_{ikt}} \frac{x_{it}}{y_{ikt}} = \left(\beta_{kx} - \sum_{k=1}^{K-1} y_{ikt}\beta_{kx}\right) x_{ikt}$$
$$\text{for } k = 1, \ldots, K - 1.$$

The acreage elasticities may also vary in sign from the estimated coefficients because Equation (7) contains terms for the estimated coefficients, β_{kx}, values of x, and proportions of land use, y_{ikt}. The standard errors for marginal effects and elasticities are obtained by the Delta method, which involves pre- and postmultiplying the covariance matrix for the estimated modified multinomial logit parameters by the gradient vector of marginal effects and elasticities with respect to the parameters (Greene 1993, p. 297).

Data

This study used data for 67 Alabama counties for the years 1972, 1982, 1990, and 2000 and for 159 Georgia counties for the years 1972, 1982, 1989, and 1997, obtained from Forest Inventory and Analysis (FIA) surveys.[3] Be-

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[2] In the multiplicative heteroskedastic model, ordinary least-squares estimates are obtained in the first step, and in the second step, maximum likelihood estimates are obtained using variables (in various forms) that cause heteroskedasticity as weights.

[3] FIA surveys define timberland as forestland that has not been withdrawn from timber utilization and that produces or is capable of producing more than 20 cu. ft./acre/year of industrial wood crops under natural conditions.

Table 2. Description, Data Sources, and Mean Values of Variables Used in the Land Use Analysis

Variable	Description	Source	Mean (n = 893)
WTDSTPR	Real sawtimber price weighted by pine sawtimber and oak sawtimber removals ($/MBF)	Timber Mart-South	151.29
PSTPR	Real pine sawtimber price ($/MBF)	Timber Mart-South	168.13
OSTPR	Real oak sawtimber price ($/MBF)	Timber Mart-South	96.66
AGRET	Real value of gross returns from crops and livestock in a calendar year ($/acre)	BEA	578.75
PD	Persons per thousand acres of total land area of county	Census Bureau	163.32
INC8284	Real average per capita personal income of county in thousand dollars	BEA	9.63
AVLCC	Weighted average land capability class of counties	USDA	4.04
LCC1N2	Proportion of highest land quality classes I and II in the total land of the counties	USDA	0.28
CSACRES	State annual average of tree planting acres in thousands for the preceding period between FIA survey periods	NRCS	42.69

cause of the zero values of some land use, the total number of observations was reduced to 893 for analysis by major use, 833 by ownership, and 878 by forest type. Table 2 presents the variables used, their mean values, and data sources.

Land in agricultural use includes cropland, pastureland, and rangeland available from agricultural censuses at 5-year intervals. To make these numbers conform to FIA survey years, they were interpolated for 1972 and 1990 for Alabama and for 1972 and 1989 for Georgia, using annual compound growth rates between the relevant agricultural census years. The area under agricultural land use for the year 2000 for Alabama was obtained by extrapolating from 1997, using annual compound growth rates between 1992 and 1997. The implicit assumption is that the agricultural land use changed at the same compound growth rates between the relevant years.

Land in the other category includes urban land, roads, and rural transportation and was estimated by subtracting water area, productive and unproductive reserve forestland, timberland, and agricultural land from the total land area of counties. Total land and water area were obtained from the 2000 population census, while timberland area statistics were obtained from FIA surveys.

To represent the returns to timberland use, a county-level weighted sawtimber price (dollars per MBF) was calculated using Timber Mart-South prices available from 1977 and county-level sawtimber removals for softwoods and hardwoods available from the FIA survey as weights. For the period before 1977, pine sawtimber and oak sawtimber prices were obtained by tracing backward from 1977, using the percentage of changes in Louisiana sawtimber prices (Howard). Three area prices before 1992 were converted to two area prices, using conversion weights developed by Prestemon and Pye. The sawtimber prices were deflated, using the Producer Price Index (PPI) for all commodities (1982 = 100).

The data on county agricultural returns were obtained from the Regional Economic Information System (REIS) of the Bureau of Economic Analysis (BEA), the Census Bureau. Agricultural returns were defined by the REIS as the value of gross revenues received from the marketing of agricultural commodities, both livestock and crops, during a calendar year. Per acre agricultural returns were obtained by dividing the county agricultural returns by the county acreage under crops and pasture. These values were deflated, using PPI for all commodities (1982 = 100).

Population density was estimated as the number of persons per acre of total land area of a county, using the Census Bureau's mid-year estimates from the REIS of the BEA. County-level per capita personal income numbers were also obtained from the REIS of the BEA. These numbers were deflated, using the Consumer Price Index (urban, 1982–1984 = 100).

Two land quality variables were used in the analysis.[4] The ratings for a land parcel range from 1 to 8, in which 1 is the most productive and 8 the least productive. The average land quality index (AVLCC) was calculated as a weighted average of acres in each land class in the county. The second variable is the proportion of LCC 1 and 2 in the total land area. The values of the two land quality variables in each county were the same for all years.

For acreage under cost-share programs, a state-level variable for the annual average number of acres of trees planted under various cost-share programs was constructed using the cost-share acres for the preceding 7 to 10 years for each FIA survey.[5] These numbers change over the years but are the same for each county in a state in each particular year. Cost-share acres for tree planting for the period 1962–1985 were obtained from Williston and the USDA Forest Service and, for subsequent years, from the USDA serial *Agricultural Statistics,* the Farm Service Agency, and the Natural Resource Conservation Service.

Estimation Results

The analysis is accomplished at three levels. First, major land use including timberland, agricultural, and urban/other uses is considered. The total area of land in this analysis is the sum of the three. This includes public timberland. Second, timberland ownership is studied. The total area of land in this category is the sum of timberland owned by the private forest industry, by NIPF landowners, land used for agriculture, and urban/other land and excludes all types of public land. Third, three timberland types are examined. Softwood timberland includes longleaf-slash pine and loblolly-shortleaf forest species groups. Mixed forest type is composed of the oak-pine forest type group. Hardwood timberland includes oak-hickory, oak-gum-cypress, elm-ash-cottonwood, and nonstocked forest species groups. The total land area in this category is the sum of land under softwood, mixed, and hardwood timberland; agricultural land; and urban/other land.

We have identified the variables or their forms (square or cubic), which differ by equations, responsible for heteroskedasticity by regressing them on the residuals generated from ordinary least-squares regressions. We have then incorporated one or two of the most important variables in the multiplicative heteroskedastic regression equations and estimated the coefficients in each of the equations.

Major Land Use

The estimated coefficients, marginal effects, and elasticities and their standard errors by major land use are presented in Table 3. Since direct interpretation of the coefficients is difficult, we discuss the results in terms of marginal effects and elasticities for the variables. As mentioned earlier, the signs of the marginal effects and elasticities need not be the same as those of the coefficients.

[4] Although the two land quality measures are collinear by construction, we have used both measures following other researchers who have found it useful for predictive purposes. The results were not significantly different when we used only one land quality measure. We also find that using two land quality variables increases the predictive power of equations in this study.

[5] For 1972 and 1982, the annual average of cost-shared tree planting acres from 1962 to 1971 and from 1972 to 1981 was used for Alabama and Georgia, respectively. For 1990 and 2000 for Alabama, the annual average of cost-share tree planting acres from 1982 to 1989 and from 1990 to 1999 was used. For 1989 and 1997 for Georgia, the annual average of cost-share tree planting acres for 1982 to 1998 and for 1990 to 1996 was used.

Table 3. Land Use Determinants according to Major Use, Alabama and Georgia ($K = 3$; obs = 893)

	Ln(Timberland/Urban and Other)			Ln(Agri/Urban and Other)		
Variable	Coefficient	Marginal Effects[a]	Elasticities[a]	Coefficient	Marginal Effects[a]	Elasticities[a]
Constant	3.34503***			2.53735***		
	(0.344)			(0.396)		
WTDSTPR	0.00237***	0.00049***	0.10473***	0.00004	−0.00026***	−0.24762***
	(0.0004)	(0.0001)	(0.023)	(0.0005)	(0.0001)	(0.079)
AGRET	−0.00005	−0.00003***	−0.02533***	0.00019***	0.00003***	0.11054***
	(0.00004)	(0.00001)	(0.008)	(0.00005)	(0.00001)	(0.027)
PD	−0.0007***	0.00001	0.00125	−0.00133***	−0.0001***	−0.10241***
	(0.00007)	(0.00002)	(0.004)	(0.0001)	(0.00001)	(0.015)
INC8284	−0.14081***	−0.02237***	−0.30556***	−0.06122***	0.00766***	0.46115***
	(0.014)	(0.004)	(0.049)	(0.018)	(0.003)	(0.173)
AVLCC	−0.05356	0.0352**	0.20175**	−0.41056***	−0.04915***	−1.24126***
	(0.062)	(0.015)	(0.0874)	(0.071)	(0.012)	(0.299)
LCC1N2	−1.27762***	−0.39719***	−0.16044***	1.16581***	0.3009***	0.53553***
	(0.32)	(0.078)	(0.032)	(0.362)	(0.061)	(0.1078)
CSACRES	0.00066	0.00105***	0.0638***	−0.00812***	−0.00117***	−0.31107***
	(0.001)	(0.0003)	(0.016)	(0.001)	(0.0002)	(0.056)
Obs. Shares[b]	66.5			19.2		
Pred. Shares	70.5			16.0		
Conv. R^2	0.36			0.50		

Notes: *, **, and *** indicate significance levels at 0.10, 0.05, and 0.01 probability. Figures in parentheses are standard errors.
[a] The standard errors for marginal effects and elasticities are calculated by the Delta method.
[b] The observed and predicted shares for urban and other land use are 15.3% and 13.5%.

Table 4. Land Use Determinants by Ownership, Alabama and Georgia (K = 4; obs. = 833)

	Ln(Industry/Urban and Other)		
Variable	Coefficient	Marginal Effects[a]	Elasticities[a]
Constant	3.27922***		
	(0.625)		
WTDSTPR	0.0042***	0.00029***	0.42839***
	(0.001)	(0.0001)	(0.124)
AGRET	−0.00031***	−0.00004***	−0.19955***
	(0.0001)	(0.00001)	(0.042)
PD	−0.00305***	−0.00018***	−0.2201***
	(0.0003)	(0.00003)	(0.032)
INC8284	−0.23302***	−0.01391***	−1.2906***
	(0.033)	(0.003)	(0.306)
AVLCC	−0.24782**	−0.00342	−0.13571
	(0.11)	(0.011)	(0.435)
LCC1N2	−2.82001***	−0.21296***	−0.5931***
	(0.555)	(0.055)	(0.154)
CSACRES	0.00769***	0.00102***	0.42819***
	(0.002)	(0.0002)	(0.087)
Obs. Shares[b]	14.3		
Pred. Shares	10.2		
Conv. R^2	0.35		

Notes: *, **, and *** indicate significance levels at 0.10, 0.05, and 0.01 probability. Figures in parentheses are standard errors.

[a] The standard errors for marginal effects and elasticities are calculated by the Delta method.

[b] The observed and predicted shares for urban and other land use are 15.4% and 14.0%.

The signs of marginal effects for all variables in the timberland use equation are as expected. Weighted sawtimber price has a significant positive marginal effect, and agricultural returns have a significant negative effect on the share of timberland use. These same variables have opposite significant effects on the share of agricultural land use when compared to the share of timberland use. The opposing marginal effects signify that relative returns play a vital role in land use by switching from one use to another. The marginal effects for both land quality variables are also as expected in both timberland and agricultural land use equations. The marginal effects for per capita income are positive toward agricultural land use but negative toward timberland use. The cost-share policy variable has a significant positive effect on the timberland use share and a significant negative effect on the agricultural land use share. This result should be interpreted with caution since cost-share acres are the same for all counties in a state and hence capture the fixed effects of the state.

Elasticity estimates show that per capita personal income and LCC1N2 have the largest negative effects, while average land quality and weighted sawtimber price exert the highest positive influence on the timberland share. For the agriculture land use share, average land quality, cost-share acres, and weighted sawtimber prices have the largest negative effects, while land quality and per capita income have the most positive impact. These results are generally in line with our prior expectations and the findings of previous studies (e.g., Ahn, Plantinga, and Alig 2000, 2001; Mauldin, Plantinga, and Alig).

Table 4. (Extended)

Ln(NIPF/URBAN and Other)			Ln(Agri/Urban and Other)		
Coefficient	Marginal Effects[a]	Elasticities[a]	Coefficient	Marginal Effects[a]	Elasticities[a]
3.51776***			2.66369***		
(0.399)			(0.428)		
0.00178***	0.00024	0.06277	−0.00056	−0.00034***	−0.29007***
(0.0005)	(0.0001)	(0.038)	(0.0006)	(0.0001)	(0.083)
0.00007	0.00001	0.01392	0.00019***	0.00003***	0.08761***
(0.00005)	(0.00001)	(0.013)	(0.00005)	(0.00001)	(0.028)
−0.00107***	0.00011**	0.02226**	0.0018***	−0.0001***	−0.06757***
(0.0001)	(0.00004)	(0.009)	(0.0002)	(0.00003)	(0.02)
−0.11183***	−0.00886	−0.14422	−0.04439**	0.00925**	0.49376**
(0.02)	(0.006	(0.095)	(0.022)	(0.004)	(0.207)
−0.19377***	0.01192	0.08302	−0.43131***	−0.03847***	−0.87833***
(0.07)	(0.02	(0.138)	(0.075)	(0.013)	(0.302)
−1.08415***	−0.20513**	−0.10026**	1.05057***	0.31583***	0.50582***
(0.357)	(0.1009)	(0.049)	(0.383)	(0.068)	(0.108)
−0.00277**	−0.00025	−0.01834	−0.00854***	−0.0011***	−0.26487***
(0.001)	(0.0004)	(0.027)	(0.001)	(0.0002)	(0.06)
53.3			20.4		
58.1			17.7		
0.26			0.44		

Timberland Ownership[6]

Table 4 presents the results related to land use by ownership. The marginal effects for all variables, except for average land quality, are significant in the case of private industry–owned timberland share. However, the marginal effects for only two variables—population density and LCC1N2—are significant in the equation for the NIPF timberland share. The marginal effects for timber price and agricultural returns for the industry-owned timberland share have the expected signs and are significant.

Population density has a significant, negative impact on the industrial timberland share, but it has a significant, positive effect on the NIPF timberland share. The per capita income has the expected negative influence on the share of private industry–owned timberland but no significant effect on the NIPF timberland share. Apparently, increases in population and income levels have different effects on the timberland shares under different ownerships.

The LCC1N2 has the same significant, negative impact on the timberland shares of both industrial and NIPF ownerships. The AVLCC has no significant impact on the timberland shares of either ownership. The public cost-share variable has a significant, positive effect on the timberland share of the forest industry but an insignificant impact on the NIPF timberland share.

Elasticity estimates indicate that sawtimber prices and cost-share acres have the highest positive effect, while per capita income and proportion of higher land quality classes have

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[6] To see whether the coefficients in the two forestry ownership equations were significantly different, an attempt was made with the help of a dummy variable and dummy variable interactions with the variables from the NIPF forestry ownership equation by stacking the observations from dependent and independent variables one below the other. All coefficients, except for the dummy intercept and dummy variable interaction term with average land quality (AVLCC), were significantly different from zero at the 1% level, indicating that the independent variables have significantly different responses in the two forestry ownership equations. We thank one anonymous reviewer for suggesting this method.

the highest negative effect on the share of forest industry timberland ownership. For the share of NIPF timberland, per capita income and LCC1N2 have the highest negative effect, and declining AVLCC and timber prices have the highest positive effect.

Forest Type[7]

The results related to forest types are presented in Table 5. Again, we note significant differences in the marginal effects for variables under different timberland types. The marginal effects for all variables, except for population density, are significant for the share of softwood timberland. While pine stumpage price and cost-share policy variables have a significant and positive impact, all other variables (except for population density) have significant and negative impacts on the softwood timberland share.

On the other hand, only two variables have a significant influence on the oak-pine mixed forest type timberland share; oak sawtimber price affects shares positively, and LCC1N2 affects shares negatively. The hardwood timberland share is affected significantly by four variables. The two land quality variables and oak sawtimber prices affect shares positively, and the pine sawtimber prices affect the hardwood timberland share negatively.

Estimates of elasticities indicate that softwood returns (PSTPR) have the highest positive impact and that the per capita income and two land quality variables have the highest negative impact on the softwood timberland share. Hardwood returns (OSTPR) have the highest positive impact, and LCC1N2 has the highest negative impact on the mixed forest type timberland share. In the case of hardwood timberland use, average land quality and hardwood returns have the highest positive influence, while softwood returns have the highest negative influence.

Our analysis shows that various factors affect timberland use in a distinctly different manner by ownership and forest type. Accordingly, better predictions of timberland use share can be made by the approach adopted in this paper. For example, the discrepancy between actual and predicted shares of timberland was 6% based on analysis by major land use, while the discrepancy narrowed down to 1% and 5%, respectively, when estimations were conducted by ownership and forest type.

Conclusions

This paper analyzes the determinants of land use change using county-level data from Alabama and Georgia for the period 1972–2000. Three levels of analysis were conducted: major land use, ownership, and forest type. Lower average land quality, federal incentive programs that promote tree planting, and favorable returns for forestry use over agricultural land use are the main factors in increasing the proportion of timberland share in Alabama and Georgia. Higher income levels and a higher proportion of good-quality land might drive the land away from forestry use.

Higher forestry returns increase the share of timberland use under private forest industry ownership. However, the factors that help increase the share of timberland use under NIPF ownership may be nontimber values. Increases in population density could increase the NIPF share of forestry land use, and a higher proportion of good-quality land may lead to a declining share of timberland ownership by NIPF landowners.

The factors that drive changes in the land use share of softwood forest type do not act the same way in the land use changes toward hardwood or mixed forest types. The trend of increasing hardwood forest type land use at the expense of oak-pine mixed and softwood

[7] A procedure similar to the one explained in note 6 was conducted to see if the coefficients are significantly different among the three different forest types. The results show that the dummy intercept and dummy variable interactions with pine stumpage price, oak stumpage price, and both land quality variables were significantly different from zero, all at the 1% significance level, in the hardwood timberland equation. For the mixed forest type equation, dummy variable interactions with pine stumpage price and oak stumpage price were significant at the 1% level, and dummy intercept and dummy interaction terms with cost-share acres variable were significantly different at the 5% level.

Table 5. Land Use Determinants by Forest Types, Alabama and Georgia ($K = 5$, obs. = 878)

Variable	Ln(Soft/Urban and Other) Coefficient	Marginal Effects[a]	Elasticities[a]	Ln(Mixed/Urban and Other) Coefficient	Marginal Effects[a]	Elasticities[a]
Constant	4.10999***			2.7288***		
	(0.428)			(0.432)		
PSTPR	0.00428***	0.00129***	0.74441***	−0.00114	−0.00011	−0.16775
	(0.001)	(0.0002)	(0.105)	(0.0009)	(0.0001)	(0.139)
OSTPR	−0.00149*	−0.00113***	−0.37347***	0.00444***	0.00023**	0.19995**
	(0.0008)	(0.0002)	(0.06)	(0.001)	(0.0001)	(0.078)
AGRET	−0.0001**	−0.00004***	−0.713***	0.00001	−0.000001	−0.00622
	(0.00005)	(0.00001)	(0.02)	(0.00005)	(0.000005)	(0.027)
PD	−0.00082***	−0.000011	−0.00586	−0.00094***	−0.00002	−0.02534
	(0.0001)	(0.00002)	(0.013)	(0.0001)	(0.00001)	(0.017)
INC8284	−0.21463***	−0.01801***	−0.5943***	−0.18206***	−0.00323	−0.281
	(0.022)	(0.005)	(0.158)	(0.022)	(0.002)	(0.206)
AVLCC	−0.28158***	−0.03503**	−0.48714**	−0.16575**	−0.00048	−0.01749
	(0.073)	(0.016)	(0.227)	(0.074)	(0.008)	(0.291)
LCC1N2	−2.5865***	−0.49625***	−0.48045***	−2.30573***	−0.15703***	−0.40121***
	(0.381)	(0.084)	(0.081)	(0.384)	(0.041)	(0.104)
CSACRES	0.00368***	0.00073**	0.1641**	−0.00003	−0.00013	−0.05185
	(0.001)	(0.0003)	(0.046)	(0.001)	(0.0002)	(0.059)
Obs. Shares[b]	28.2			11.1		
Pred. Shares	29.2			11.0		
Conv. R^2	0.31			0.34		

Notes: *, **, and *** indicate significance levels at 0.10, 0.05, and 0.01 probability. Figures in parentheses are standard errors.

[a] The standard errors for marginal effects and elasticities are calculated by the Delta method.

[b] The observed and predicted shares for urban and other land use are 15.1% and 14.2%.

Table 5. (Continued)

Variable	Ln(Hard/Urban and Other)			Ln(Agri/Urban and Other)		
	Coefficient	Marginal Effects[a]	Elasticities[a]	Coefficient	Marginal Effects[a]	Elasticities[a]
Constant	2.05621***			3.29528***		
	(0.329)			(0.388)		
PSTPR	−0.00115*	−0.00029***	−0.1693***	−0.0056***	−0.00091***	−0.91752***
	(0.0007)	(0.0001)	(0.05)	(0.0008)	(0.0001)	(0.118)
OSTPR	0.00417***	0.00052***	0.17389***	0.00666***	0.00072***	0.41503***
	(0.001)	(0.0002)	(0.051)	(0.001)	(0.0001)	(0.067)
AGRET	0.00004	0.00001	0.0119	0.00023***	0.00003***	0.1201***
	(0.00003)	(0.00001)	(0.017)	(0.00004)	(0.00001)	(0.022)
PC	−0.0008***	−0.00004	−0.00247	−0.00127***	−0.00008***	−0.07732***
	(0.0001)	(0.00002)	(0.01)	(0.0001)	(0.00001)	(0.014)
INC8284	−0.16548***	−0.00364	−0.12147	−0.13432***	0.00309	0.17824
	(0.016)	(0.004)	(0.129)	(0.019)	(0.003)	(0.1731)
AVLCC	0.03741	0.05737***	0.80627***	−0.43027***	−0.04488***	−1.09002***
	(0.057)	(0.014)	(0.194)	(0.067)	(0.01)	(0.252)
LCC1N2	−0.46173	0.12191*	0.11927*	1.54353***	0.40531***	0.68526***
	(0.298)	(0.07)	(0.069)	(0.348)	(0.025)	(0.041)
CSACRES	0.00268**	0.00043	(0.06358)	−0.00393***	−0.00085***	−0.21824***
	(0.001)	(0.0003)	(0.039)	(0.001)	(0.0002)	(0.051)
Obs. Shares[b]	26.6			19.0		
Pred. Shares	28.9			16.7		
Conv. R^2	0.36			0.53		

forest types is likely driven by increases in hardwood returns. Increasing softwood sawtimber prices and tree planting under cost-share programs have been favorable toward increasing the share of land in the softwood forest type.

The practical and policy implications of these results are that pooling all types of timberland use in one major category would mask the differences among timberland under different ownerships and forest types and would lead to incorrect predictions of future land use change. To address the future challenges of preserving biodiversity, protecting water quality, and meeting increasing demands of timber and recreational amenities, an accurate prediction of various timberland uses is needed. The prediction can be improved if the underlying model is built on a detailed analysis of timberland by ownership and forest type. With a better prediction of timberland use by forest type, researchers could use it (as independent variables) in their timber supply, water quality, and biodiversity models to forecast future changes in timber supply, water quality, and biodiversity. An integrated model from socioeconomic drivers to land use changes to regional ecosystem function and productivity (in terms of water quality, biodiversity, and timber supply) can be built.

[Received May 2003; Accepted June 2004.]

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