Urbanization Effects on Timberland by Ownership Class: A Modified Multinomial Logit Analysis

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ABSTRACT

In this study, a modified multinomial logit approach is used to examine the determinants of timberland by ownership class using county level data in Georgia from 1972 to 2000. We model timberland use by private industry ownership and nonindustrial private forestland ownership, in addition to agriculture, urban uses, and other land uses. Urbanization and other socioeconomic variables have different levels of influence on timberland ownership classes, private forest industry, and nonindustrial private forestland owners. The findings may have implications for land use modeling and projections.

Keywords: forest industry, NIPF, miscellaneous corporations, marginal effects, elasticities, multiplicative heteroscedasticity

High population levels and economic growth tend to stimulate urban development and concomitant loss of forest cover (Wear and Greis 2002). For example, between 1949 and 2002, urban land area in the United States increased by about 233%, from 18 million to 60 million ac, whereas commercial timberland declined by about 14%, from 760 million to 651 million ac (Lubowski et al. 2005). Forestland was the largest source of land converted to developed uses such as urbanization and other uses, with 83% of 7.2 million ac of forestland transitioned to urban development and other developed uses between 1997 and 2001, and the total forestland area is projected to decrease by 23 million ac by 2050, or a 3% reduction in the area from 1997 in the United States. (Alig et al. 2003, USDA Natural Resources Conservation Service 2003).

Such a rapid change in land use has implications for a wide variety of policy issues, such as maintenance of water quality, protection of the wildlife habitat, protection of biodiversity, preservation of open space, mitigation of global climate change, and socioeconomic issues such as outdoor recreation opportunities, rural–urban interface, urban–wildland interface, parcelization and fragmentation, self-sufficiency in forest products, and employment in forest product manufacturing (Society of American Foresters 2004). Changes in forest landownership reflect different motivations for owning forestland and hence could imply changes in forest management and services provided by forests. Therefore, predictions on forestland land use changes among various ownership classes within forest landowners are needed to better understand the implications of various factors for the future of timberland use.

Twenty-eight years ago, on the basis of subjective opinions of experts, reviews, comments and revisions at various levels, Wall (1981) projected that commercial timberland in Georgia by 2000 would be 23.91 million ac, giving a breakdown of timberland ownership under public, forest industry, and nonindustrial private forestland (NIPF) owners (farmers and miscellaneous private) at 1.47, 4.43, and 18.01 million ac, respectively. Although the projections are close under the circumstances, without the benefit of the data and analytical methods, the latest data show that there is a large gap between the projections and actual values. According to the latest statistics, in 2000, total timberland in the state declined to 22.76 million ac, showing a decline of 1.15 million ac, or about 4.79% less than originally anticipated (Table 1). Timberland owned by public and forest product industry, respectively, increased to 2.02 and 4.67 million ac, whereas that owned by NIPF declined to 16.08 million ac, indicating gaps of 37.20%, 5.45%, and −10.72% between the actual and projected values for the respective ownership classes.

Over the last two decades, a number of studies (e.g., Alig 1986, Mauldin et al. 1999, Hardie et al. 2000, Ahn et al. 2002, Alig et al. 2003, Lubowski et al. 2003) have dealt with modeling land use changes among aggregated groups, such as those for forestry, agriculture, and urban area. However, there has been little effort in modeling factors affecting land use with respect to more disaggregated timberland ownership classes. Although some aspects of timberland by ownership classes were studied by previous researchers (e.g., Alig 1986, Plantinga et al. 1990, Ahn et al. 2001), detailed analysis of the factors affecting timberland ownership classes has not been undertaken, especially in the wake of urbanization pressures in the U.S. South. This is also important as timberland ownership patterns have been changing dramatically during the last 10–15 years, with timberland investment management organizations (TIMOs), real estate investment trusts (REITs), and pension funds aggressively acquiring timberland from the traditionally timberland owning integrated forest products companies in the United States, driven mainly by federal tax laws and accounting procedures aimed at better economic performance (Wilent 2004, Clutter et al. 2007, Kant 2009).

By pooling timberland across all ownership classes, earlier studies may have assumed that various factors have equal effects on timber land use for all ownership classes with an implicit restriction: all

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Table 1. Changes in timberland land use by ownership classes in Georgia: 1972–2000 ($n = 795$).[a]

Land use/ownership	1972	1982	1989	1997	2000	Change 1972–2000	
	(1,000 ac)						(%)
Timberland	24,839	23,733	23,632	23,795	22,764	−2,075	−8.4
Public	1,572	1,584	1,645	1,751	2,015	444	28.2
Forest industry	4,318	4,964	5,870	4,891	4,666	348	8.1
NIPF	18,949	17,186	16,117	17,153	16,083	−2,867	−15.1
Miscellaneous corporations	1,451	1,885	2,049	2,827	2,543	1,092	75.3
Farmers	8,410	6,121	4,878	4,045	3,900	−4,520	−53.6
Miscellaneous individuals	9,088	9,181	9,190	10,382	9,640	552	6.1
Agriculture	7,914	7,435	6,511	6,185	5,984	−1,931	−24.4
Urban and other	2,923	4,418	5,443	5,492	5,594	2,671	91.4

[a] Number of total county observations in various years. Sources: Thompson 1989, 1998, Lubowski et al. 2006, US Forest Service 2006. NIPF, nonindustrial private forestland.

Table 2. Factors affecting timberland use, nonindustrial private forestland (NIPF) versus forest industry: A brief literature review.

Variables	Timberland ownership class		Studies
	NIPF	Forest industry	
Economic			
Timber price	+	+	Ahn et al. (2001)
Agricultural net returns/rent	−	−	Ahn et al. (2001)
Timber-to-crop income ratio	+		Alig (1986)
Personal income	−[a], +[b]	+[g]	Alig (1986)
Inflation		+[i]	Alig (1986)
Forestry programs	+[b]		Alig (1986)
Wood products income	+[c], −[d]		Alig (1986)
Demographic			
Rural population	−[e], +[f]	−	Alig (1986)
Urban population	−[a], +[f]	+[j], −[i]	Alig (1986)
Population density	−	−	Ahn et al. (2001)
Land quality			
Average LCC		−	Ahn et al. (2001)
Proportion of LCC1 and LCC2	−		Ahn et al. (2001)
Geographic			
Distance to city	+	+	Ahn et al. (2001)
Tree planting			
Own harvest	+	+	Kline et al. (2002)
Stumpage price	+		
Planting cost	−		
Land value	+	+	
Interest rate		−	
ACP acres	+		
Soil bank acres	+	−	
FIP acres		−	
CRP acres	+	+	

LCC, land capability class; ACP, Agricultural Conservation Program; FIP, Forestry Incentives Program; CRP, Conservation Research Program.
[a] farm forests
[b] miscellaneous private
[c] farm forests in coastal plains and piedmont regions
[d] farm forests in mountain regions and miscellaneous private in coastal plains and piedmont regions
[e] farm forests in mountain
[f] miscellaneous private in mountain
[g] piedmont region
[i] piedmont and mountain regions
[j] southeast and coastal plains

forest ownership classes respond in the same way and magnitude. Nagubadi and Zhang (2005) reported results using county level data for Alabama and Georgia states, by examining how various factors affected timberland use specifically by forest type (softwood, mixed, and hardwood forest types) and by ownership classes (forest industry, and NIPF ownerships) as opposed to the major uses of land, i.e., forest, agriculture and urban uses. The present study is an extension of Nagubadi and Zhang (2005) incorporating more urbanization and socioeconomic variables than were previously included.

Table 2 summarizes previous research with respect to the impact of various factors on the timberland owned by different private ownership classes (NIPF owners and forest industry owners). None of the studies examined the effect of urbanization variables, with the exception of urban population as a demographic variable in Alig (1986) and distance to city as a geographic variable in Ahn et al. (2001). Although Alig (1986) revealed that urban population had different effects on different timberland owners in different regions, Ahn et al. (2001) showed no differences in the effect of different variables on NIPF owners or forest industry owners, except that the land quality variables had significantly different effects on different timberland owners. Kline et al. (2002) showed that the effect of stumpage price, planting cost, interest rate, forest assistance programs, such as agricultural conservation program (Agricultural Conservation Program), soil bank acres, forest incentives program (Forestry Incentives Program) were significantly different between NIPF owners and forest industry owners. Nagubadi and Zhang (2005) noted that only the marginal effects and elasticities for population density and land quality variables were significant for the NIPF landowners, whereas all variables included had significant marginal effects and elasticities for the private forest industry landowners. The studies by Rogers and Munn (2003) and Arano and Munn (2006) indicated that the forest management behavior, intensity, and expenditures differed significantly between industrial landowners and TIMOs on the one hand, and the state and NIPF landowners on the other hand.

This study concentrates on Georgia, with its highest timberland area, large number of counties, rapidly increasing urbanization pressures, and consequent loss of timberland area to urban and developed uses in the southeastern United States. The contribution of this study is to specifically examine the impact of various urbanization factors (such as house values, metropolitan statistical areas, rural–urban continuity, and urban influence) and socioeconomic variables (such as the ratio of people below the poverty line and the ratio of educated persons to the total population), in addition to the usual variables related to economic returns, population pressures, incomes, and land quality measures, on the distribution of timberland by ownership classes (private forest industry and NIPF landowners).

The goal of this study was to develop a model of timberland use by ownership classes. We applied a modified multinomial logit technique using county-level data in Georgia and looked into the effects of urbanization and socioeconomic variables on timberland ownership classes. Although this study covers the period between 1972 and 2000, largely missing the transition from forest industrial timberland ownership to institutional ownership that took place afterward, the results are relevant from a historical perspective and in reference to future management intensity and timber supply behavior with increasing urbanization pressures. The next section presents the analytical framework used in the study, followed by a description of data. The remaining sections present the results by major land use category and by ownership classes and draw the relevant conclusions.

Methodology

Modern land use theory builds on the contributions of Ricardo, who developed the concept of land rent in rural land use, and von Thünen, who developed location rent model for urban land use. Miller and Plantinga (1999) and Hardie et al. (2000) develop a theory of land use change by combining Ricardo's rural land rent model and von Thünen's urban land rent model. The resulting model depicts landowners' decision problem of allocating a fixed amount of land to alternative uses.

The optimal land use shares, p_{ikt} (proportion of land in ith county in kth use at time t) 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:

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

The land use, k, can be private industry owned timberland use, NIPF-owned timberland use, agricultural use, and urban or other uses. The empirical model is formulated as a modified multinomial logit model (Amemiya and Nold 1975, Parks 1980, Hardie and Parks 1997). This specification is convenient because it constrains the predicted land use shares between 0 and 1 and requires that they sum to 1. If we normalize Equation 1 by one land use type (for example, $k = 4$) and constrain $\beta_4 = 0$, the modified multinomial logit model becomes

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

and the share of the omitted land use is recovered as

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

then a logarithmic transformation of Equation 2 yields a $K - 1$ equation system

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

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 by actual (or observed) land use proportions, y_{ikt}. Thus, additional error terms, ε_{ikt}, are introduced in the system. Equation 4 then becomes

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

Hardie and Parks (1997) interpret ε_{ikt} as errors induced by the use of county averages for the elements of X. The logarithmic transformation and use of cross-sectional data induce heteroscedasticity problems from one or more explanatory variables; hence, maximum likelihood estimates are obtained by using a multiplicative heteroscedastic regression method (Harvey 1976, Greene 1993, pp. 264–267) [1].

Since the dependent variable is the log of the ratio of the proportion of land uses, it is difficult to interpret the coefficients directly, and hence marginal effects (Greene 1993, p. 666) and acreage elasticities (Wu and Segerson 1995, p. 1037) are estimated at mean levels of continuous explanatory variables and with a value of 1 for dummy variables [2]. The standard errors for marginal effects and elasticities are computed using the delta method (Greene 1993, p. 297).

The empirical model is motivated by the general observations that the timberland use shares of the various ownership classes are influenced by economic returns, land quality, demographic, socioeconomic, and urbanization factors: Ln(SHAREi/URBAN& OTHER SHARE) = f(WTDSTPR, NETAGRET, FPD, PCINC, LCC1N2, MSA, MHVAL, CONTI, INFLU, POVERTY, and BDEGREE), where SHAREi is the shares of timberland by ownership/use classes (i.e., forestry and agriculture in the case of analysis by major land use, and private forest industry, NIPF, and agriculture in the case of timberland use by ownership classes), WTDSTPR is weighted stumpage prices; NETAGRET, net agricultural returns; FPD, forest population density; PCINC, per capita income; LCC1N2, proportion of land quality classes I and II; MSA, whether the county is proximity to a metropolitan statistical area or not; MHVAL, median house value; CONTI, rural-urban continuum code indicating adjacency of a county to nearby highest or lowest populated metropolitan areas; INFLU, urban influence code indicating economic opportunities adjacent to urban areas; POVERTY, the ratio of people below poverty level; and BDEGREE, percentage of people with a bachelor's degree or more in a county. Table 3 gives more complete descriptions of the variables used in the analysis.

Variables and Data Sources

For the purpose of this analysis, county land area is defined as the sum of acreage under timberland, crop, pasture, urban/other uses and excludes water area, unproductive forests, and productive reserve forests [3]. Timberland area by ownership classes is obtained from Forest Inventory and Analysis (FIA) surveys conducted in different years [4]. To conform to FIA data years, agricultural and other data are linearly interpolated. Although the public timberland increased from 1.57 million to 2.01 million ac between 1972 and 2000 (Table 1), public timberland was excluded from this analysis since changes in public timberland are not subject to market forces but governed entirely by a different decisionmaking process at federal, state, county, municipal, and native community levels.

We divided the remaining timberland into two groups of ownership. Private industry timberland includes timberland owned by companies or individuals operating commercial wood-using plants, and NIPF timberland includes timberland owned by individuals or companies, such as private individuals, private corporations, and farmer ranchers, who do not operate commercial wood-using plants. Land in agricultural use includes cropland, pastureland, and rangeland reported in various agricultural censuses. Land in urban and other categories includes urban land and land devoted to roads,

Table 3. Description, data sources, and descriptive statistics of variables used in the land use analysis, Georgia.

Variable	Description[a]	Source[b]	Mean (n = 605)	Minimum	Maximum	Coefficient of variation (%)
Ln(FOR/U&O)	Log of ratio of timberland to urban and other land	FIADB	1.79	−0.26	6.16	45.77
Ln(AGR/U&O)	Log of ratio of agricultural land to urban and other land	FIADB	0.43	−3.19	4.24	229.86
Ln(PRIV/U&O)	Log of ratio of forest industry timberland to urban and other land	FIADB	−0.33	−6.21	5.38	−442.20
Ln(NIPF/U&O)	Log of ratio of NIPF timberland to urban and other land	FIADB	1.50	−1.21	5.66	52.22
WTDSTPR	Real sawtimber price weighted by pine sawtimber and oak sawtimber removals (1982 $/MBF)	Norris Foundation	168.61	43.82	281.27	37.92
NETAGRET	Real value of net returns from crops and livestock in a calendar year (1982 $/acre)	USDA	133.23	−127.33	1730.53	160.48
FPD	Persons per thousand acres of forest land area of county	REIS of BEA	207.67	13.30	2664.90	143.23
PCINC	Real average per capita personal income in thousand 1982 dollars	Census Bureau, and BEA	9.97	5.65	16.71	21.43
LCC1N2	Proportion of highest land quality classes I and II in the total land (see end note 5)	USDA NRCS	0.33	0.00	0.73	55.48
MSA	Whether the county is adjacent to a metropolitan statistical area with a population of 50,000 or more (1) or not (0)	Census Bureau	0.26	0.00	1.00	167.62
MHVAL	Median housing value (thousand 1982 dollars)	Census Bureau	37.30	14.03	88.04	31.55
CONTI	Rural-urban continuum code indicating whether a county is adjacent to highest (1) or lowest (9) populated metropolitan areas (see end note 6)	USDA ERS	5.64	1.00	9.00	43.43
INFLU	Urban influence code indicating economic opportunities in urban areas (nearby = 1; faraway = 12) (see end note 7)	USDA ERS	4.64	1.00	12.00	62.55
POVERTY	Percentage of people below poverty line	Census Bureau	20.67	4.95	44.20	37.10
BDEGREE	Percentage of people with a bachelor's degree or above	Census Bureau	9.72	1.80	39.80	47.36

[a] The variables are measured at county level except that the variable WTDSTPR is related to one of the two Timber-Mart South regions in which the county falls. NIPF, nonindustrial private forestland; MBF, thousand board feet.
[b] FIADB (US Forest Service 2006); Norris Foundation (n.d.); REIS of BEA (Bureau of Economic Analysis n.d.); Census Bureau (n.d.); USDA NRCS (USDA Natural Resources Conservation Service 2003); USDA ERS, US Dept. of Agriculture Economic Research Service.

rural transportation, and other special uses, estimated as a residual by subtracting timberland and agricultural area from the total land area in each county (excluding water area).

During 1972–2000, timberland and agricultural land in Georgia declined, whereas land in urban and other categories increased dramatically (Table 1). However, even the changes in timberland across ownerships are not identical; timberland under NIPF ownership group declined, whereas that under public and private forest industry ownership increased. Again within the NIPF ownership group, the share of miscellaneous corporations increased dramatically, that of farmers declined, and that of miscellaneous individuals increased marginally.

Detailed descriptions of the dependent and independent variables, their statistics, and sources are shown in Table 3. The independent variables, Ln(FOR/URBAN), Ln(PRIV/URBAN), Ln(NIPF/URBAN), Ln(AGR/URBAN), are natural logs of the ratios of the shares of total timberland use, timberland under private forest industry ownership, timberland under NIPF ownership, and land under agricultural use normalized by the share of urban and other land, respectively.

To represent the returns to timberland use, a weighted sawtimber stumpage price of pine and oak sawtimber, weighted by their respective removals, was used. As county level prices are not available, we used prices for two TMS regions in the state (Norris Foundation n.d.). Three area prices reported before 1992 were converted to two area prices using conversion weights developed by Prestemon and Pye (2000). These prices are deflated using the producer price index for all commodities (1982 = 100). As proxy for agricultural returns, we used county-level net agricultural returns (interpolated to the FIA years) obtained from the National Agricultural Statistics Service (USDA NASS 2009). Net agricultural returns are computed as the total cash receipts from all crops and livestock and total government payments minus total production expenses. In line with previous studies (Alig 1986, Mauldin et al. 1999, Hardie et al. 2000, Ahn et al. 2002, Alig et al. 2003, Lubowski et al. 2003), economic returns are expected to help explain timberland, agricultural, or urban land use.

Forest population density (FPD) is estimated as the number of persons per 1,000 ac of forestland in a county using the mid-year population estimates by the Census Bureau's Regional Economic Information System (REIS) (Bureau of Economic Analysis n.d.). As FPD increases, we expected a negative impact toward all classes of ownership timberland use and toward agriculture land use (Wear 2002). It is also possible that FPD may positively affect NIPF timberland ownership when individuals bid up the land relative to forest industry because of their interest in nontimber amenity values. On the other hand, the FPD may also have a positive effect on the agricultural land use: As the population density increases, there will be more agricultural land near the populated areas for supplying vegetables and other fresh products.

County-level per capita personal income is also obtained from REIS. The income and median house value data are deflated using the consumer price index for urban areas (1982–1984 = 100). As in the previous studies (Ahn et al. 2002, Nagubadi and Zhang 2005), it was hypothesized that per capita income would negatively affect both timberland (including all ownership classes) use and agricultural land use relative to urban/other land use.

Ratings on land quality are obtained from the Natural Resource Conservation Service of the USDA, which range from land capability class (LCC) 1 to LCC 8, where 1 is the most productive and 8 is the least productive (Klingebiel and Montgomery 1961) [5]. The proportion of LCC 1 and 2 in the total land area was used in the analysis. The values of the land quality variable for each county are the same for all years. It was expected that a high proportion of good quality land leads to more agricultural land use (positive effect) and less timberland use (negative effect) relative to urban/other land use, as found by previous researchers (Hardie et al. 2000, Ahn et al. 2002).

Four variables in this model represent the urbanization process and real estate markets in the southern United States: whether a county has or is close to a metropolitan statistical area (MSA), median housing values (MHVAL), rural-urban continuum (CONTI), and urban influence (INFLU). MSA is a dummy variable representing counties that include both central and outlying areas of MSAs with a population of 50,000 or more. Data on MHVAL are obtained from the Census Bureau. Because the data pertain to different census years, interpolations are used. If a county is in an MSA, it is likely that county has less timberland, and if the MHVAL increases because of housing demand, it will likely reduce the timberland because of conversion to accommodate new housing projects. Hence, the variables MSA and MHVAL should affect the timberland ownership negatively. Data on CONTI and INFLU are obtained from the USDA Web site. CONTI is coded from 1 to 9 for counties that include or lie adjacent to most (1) to least (9) populated metro areas, and INFLU is coded from 1 to 12 for most (1) to least (12) populated counties [6, 7]. It was expected that these two urban influence variables would be positively related to all timberland ownership classes, as increase in the codes would mean increasingly nearer (or closer) to rural areas and hence more timberland ownership.

Two variables, POVERTY and BDEGREE, represent socioeconomic status of the counties and are obtained from the County and City Data Books Census Bureau (Census Bureau n.d.). POVERTY is defined as the ratio of people below the poverty level to the total population in a county, and BDEGREE is defined as the percentage of people in a county holding a bachelor's degree or more. The poverty ratio tends to be generally higher in rural areas away from urban areas, and an increase in the poverty ratio may be positively associated with rural areas and underdeveloped areas. A higher percentage of people with BDEGREE in a county may indicate higher development status of that county that could have a negative effect on the timberland ownership.

Results and Discussion

We estimated the equations using the maximum likelihood method with multiplicative heteroscedastic correction. Before implementing this method, we identified the variables or their forms (square or cubic forms) responsible for heteroscedasticity and incorporated them in the multiplicative heteroscedastic regression equations. To remove the effect of time periods, we included dummy variables for each FIA survey years. To avoid singular matrix problem, we excluded the dummy variable for 1972, which is represented by the intercept.

First, the equations were estimated for the major uses, i.e., timberland use and agricultural land use (Table 4). The coefficients for all year dummy variables, except 1997 and 2000 for the agricultural land use, are significant. As expected, the coefficient for weighted sawtimber price (WTDSTPR) is significant for both timberland use and agricultural land use. The net agricultural returns (NETAGRET) and per capita income (PCINC) had no significant effect on either agricultural or timberland use. The FPD has the expected significant negative effect on both timberland and agricultural land use. The proportion of good-quality land (LCC1N2) has a significant effect on the agricultural land use and timberland use, along the expected lines. The marginal effects and elasticities for the variables WTDSTPR, FPD, and LCC1N2 are significant in affecting the timberland use, whereas those for WTDSTPR and LCC1N2 are significant in influencing the agricultural land use.

As mentioned earlier, we used marginal effects and elasticities for ease of interpretation of the results. For example, the marginal effect of 0.001 for WTDSTPR, in the timberland use equation in Table 4, indicated that a $1 (1982 = 100) increase in the weighted sawtimber price results in an increased share of 0.001 in the timberland use. Similarly, the elasticity of 0.234 for the variable WTDSTPR in the timberland equation indicated that a 1% increase in the weighted sawtimber price (1982 = 100) results in an increase of 0.234% share in timberland use. The results for the other variables can be interpreted in a similar fashion.

Among the urbanization variables, the dummy variable metropolitan statistical area (MSA) has no significant effect on either timberland or agricultural land use. Median house values (MHVAL) have a significant negative effect on timberland use and no significant effect on agricultural land use. The rural-urban continuum (CONTI) has a significant effect on both timberland and agricultural uses, as expected. We also note that the marginal effects and elasticities are significant for MHVAL, but not for CONTI and INFLU variables, for both agricultural and timberland uses.

With respect to the socioeconomic variables, poverty ratio (POVERTY) and the proportion of people with a bachelor's degree or more (BDEGREE), the coefficients for timberland use are both significant, but only the POVERTY ratio is significant for agricultural land use. The marginal effects and elasticities are significant for BDEGREE in the case of timberland use and for POVERTY ratio in the case of agricultural land use.

Overall, according to major land use, the timber returns, land quality, and housing values have significantly differing effects in contributing to land use change toward timberland use or agricultural land use. The results also show that forest population density has a negative effect and poverty ratio has a positive effect on both timberland use and agricultural land use, whereas agricultural returns, per capita income, and metropolitan areas have no significant effect on either land use. These equations explain 46 and 56% of variation in the timberland use and agricultural land use, respectively. The predicted shares of timberland use and agricultural land use were 0.70 and 0.18, compared with the actual shares of 0.66 and 0.21, respectively, and the predicted share for urban and other uses was 0.12, compared with the actual share of 0.13.

Then, land use was estimated by dividing timberland into two groups according to ownership classes, private forest industry and NIPF-owned timberland use, and agricultural land use. Table 5 shows the results related to timberland uses based on the two ownership classes separately, along with the results for agricultural land use. The estimated results suggest reasonably good fits, with conventional adjusted R^2 values of 0.37, 0.43, and 0.56 for private forest industry timberland, NIPF timberland, and agricultural land use equations, respectively [8]. Although the coefficients for the agricultural land use equation are the same as in the major use analysis (Table 4), the marginal effects and elasticities are a little bit different in magnitude. The marginal effects and elasticities for the NETAGRET are now significant and positive in the agricultural land use equation, reflecting again the returns to agriculture and the higher productivity of the land under agriculture because of the good-quality land. Since we have already discussed the differences in the effects of different variables between the timberland use and

Table 4. According to major use: timber, agriculture, and other; Georgia.[a]

Variable	Coefficient (SE)	Marginal effect (SE)	Elasticity (SE)
Timberland use, dependent variable: Ln(Timberland/UrbanOther)			
Constant	2.766 (0.35)***	—	—
YR1982	−0.398 (0.09)***	−0.044 (0.02)*	−0.063 (0.03)*
YR1989	−0.376 (0.1)***	0.001 (0.02)	0.001 (0.03)
YR1997	−0.495 (0.16)***	−0.085 (0.04)**	−0.121 (0.06)**
YR2000	−0.504 (0.16)***	−0.083 (0.04)**	−0.119 (0.06)**
WTDSTPR	0.003 (0.001)***	0.001 (0.0002)***	0.234 (0.05)***
NETAGRET	−0.0001 (0.0001)	−0.00004 (0.00003)	−0.007 (0.01)
FPD	−0.001 (0.0001)***	−0.0001 (0.00002)***	−0.029 (0.01)***
PCINC	−0.028 (0.03)	−0.004 (0.01)	−0.059 (0.09)
LCC1N2	−1.753 (0.17)***	−0.629 (0.04)***	−0.296 (0.02)***
MSA	0.112 (0.08)	0.026 (0.02)	0.010 (0.01)
MHVAL	−0.020 (0.01)***	−0.005 (0.001)***	−0.246 (0.07)***
POVERTY	0.013 (0.01)**	−0.001 (0.001)	−0.035 (0.04)
CONTI	0.045 (0.02)**	0.002 (0.005)	0.018 (0.04)
INFLU	−0.021 (0.01)*	−0.001 (0.003)	−0.008 (0.02)
BDEGREE	0.031 (0.01)***	0.005 (0.002)**	0.067 (0.03)**
Adjusted R^2[b]	0.46	Observations	605
Predicted share	0.7025	Actual share	0.6611
Agricultural use, dependent variable: Ln(Agriculture/UrbanOther)			
Constant	−0.250 (0.38)	—	—
YR1982	−0.311 (0.1)***	0.004 (0.02)	0.025 (0.1)
YR1989	−0.626 (0.11)***	−0.045 (0.02)**	−0.250 (0.11)**
YR1997	−0.148 (0.18)	0.041 (0.03)	0.227 (0.19)
YR2000	−0.174 (0.18)	0.038 (0.03)	0.211 (0.19)
WTDSTPR	−0.003 (0.001)***	−0.001 (0.0002)***	−0.761 (0.17)***
NETAGRET	0.0001 (0.0001)	0.00003 (0.00002)	0.022 (0.02)
FPD	−0.001 (0.0001)***	−0.00002 (0.00002)	−0.023 (0.02)
PCINC	−0.014 (0.03)	0.001 (0.01)	0.083 (0.3)
LCC1N2	2.076 (0.19)***	0.528 (0.04)***	0.970 (0.06)***
MSA	−0.018 (0.09)	−0.017 (0.02)	−0.024 (0.02)
MHVAL	0.004 (0.01)	0.003 (0.001)***	0.647 (0.21)***
POVERTY	0.030 (0.01)***	0.003 (0.001)**	0.331 (0.14)**
CONTI	0.057 (0.02)***	0.003 (0.004)	0.083 (0.12)
INFLU	−0.024 (0.014)*	−0.001 (0.003)	−0.025 (0.07)
BDEGREE	0.014 (0.01)	−0.002 (0.002)	−0.106 (0.1)
Adjusted R^2[b]	0.56	Observations	605
Predicted share	0.1799	Actual share	0.2090

[a] The marginal effects and elasticities are computed at means of the variables, except for the dummy variables which are based on value of dummy variable = 1.
[b] Conventional.
*$P < 0.10$; **$P < 0.05$; ***$P < 0.01$. SE, standard error.

agricultural land use in the above paragraphs, we now focus on the differences in the factors affecting the ownership-based timberland use equations.

The results show that the private forest industry owners and NIPF owners respond in significantly different ways to the same variables. The private forest industry land owners respond positively to the timber returns (WTDSTPR) and negatively to agricultural returns (NETAGRET), FPD, and good land quality (LCC1N2), whereas the NIPF land owners respond negatively to the variables FPD and LCC1N2. However, the marginal effects and elasticities for these variables are also significant in the case of private forest industry timberland owners, but in the case of NIPF timberland owners, these are significant for the land quality variable (LCC1N2) only.

Among the urbanization variables, metropolitan statistical areas (MSA), median housing values (MHVAL), and urban influence (INFLU) variables are significant factors influencing private forest industry timberland owners, and the variables MHVAL and urban-rural continuum (CONTI) are significant factors affecting NIPF timberland owners. In terms of the marginal effects and elasticities, none of these urbanization variables matter for the NIPF timberland use.

Of the socioeconomic variables, the coefficients for both POVERTY ratio and ratio of people with a bachelor's degree (BDEGREE) are significant in the case of NIPF timberland owners, whereas the marginal effects and elasticities are not significant. However, the coefficient, marginal effect, and elasticity are all significant for the variable BDEGREE in the case of private forest industry timberland owners.

The estimated significant marginal effects indicate that the proportion of higher land quality (−0.241), followed by median house values (−0.007) have the highest negative effects, and the proportion of people with a bachelor's degree (0.006), followed by timber returns (0.001) have the highest positive effects for the private industry-owned timberland use. The estimated elasticities reveal that the median house value (−2.480), followed by the proportion of higher land quality (−2.440) have the highest negative impact, and the proportion of people with a bachelor's degree (0.628) and timber returns (0.007) have the highest positive effect for the private industry-owned timberland use. In contrast, both marginal effects and elasticity estimates show that the proportion of higher land quality is the lone variable that has a significant and negative impact on NIPF timberland use. This result is similar to Nagubadi and Zhang (2005). We also note the marginal effect of land quality is higher for NIPF ownership (−0.335) than for private forest industry ownership (−0.241), whereas the elasticity is higher for private forest industry ownership (−2.440) than for the NIPF ownership (−0.580).

Table 5. According to timberland ownership: private industry, NIPF, agriculture, and other; Georgia.[a]

Variable	Coefficient (SE)	Marginal effect (SE)	Elasticity (SE)
Private industry ownership, dependent variable: Ln(Priv/UrbanOther)			
Constant	2.311 (0.67)***	—	—
YR1982	−0.344 (0.15)**	0.002 (0.01)	0.023 (0.15)
YR1989	0.167 (0.17)	0.058 (0.02)***	0.584 (0.17)***
YR1997	−0.860 (0.29)***	−0.050 (0.03)*	−0.509 (0.28)*
YR2000	−0.868 (0.3)***	−0.0481 (0.03)*	−0.486 (0.29)*
WTDSTPR	0.008 (0.002)***	0.0007 (0.0002)***	1.153 (0.002)***
NETAGRET	−0.001 (0.0003)**	−0.00005 (0.00002)*	−0.061 (0.0002)***
FPD	−0.002 (0.0002)***	−0.0001 (0.00002)***	−0.204 (0.0002)***
PCINC	0.021 (0.05)	0.003 (0.005)	0.349 (0.05)***
LCC1N2	−2.961 (0.33)***	−0.241 (0.03)***	−0.807 (0.32)**
MSA	0.269 (0.151)*	0.018 (0.01)	0.049 (0.14)
MHVAL	−0.083 (0.01)***	−0.007 (0.001)***	−2.480 (0.36)***
POVERTY	0.004 (0.01)	−0.001 (0.001)	−0.172 (0.2)
CONTI	0.015 (0.03)	−0.002 (0.003)	−0.114 (0.18)
INFLU	−0.061 (0.02)***	−0.004 (0.002)**	−0.195 (0.1)**
BDEGREE	0.094 (0.02)***	0.006 (0.002)***	0.629 (0.17)***
Adjusted R^2[b]	0.37	Observations	605
Predicted share	0.0990	Actual share	0.1267
NIPF ownership, dependent variable: Ln(NIPF/UrbanOther)			
Constant	2.400 (0.34)***	—	—
YR1982	−0.471 (0.08)***	−0.060 (0.02)**	−0.105 (0.04)**
YR1989	−0.538 (0.09)***	−0.070 (0.03)***	−0.122 (0.05)***
YR1997	−0.411 (0.15)***	−0.035 (0.05)	−0.060 (0.08)
YR2000	−0.453 (0.16)***	−0.042 (0.05)	−0.072 (0.08)
WTDSTPR	0.001 (0.001)	0.0002 (0.0003)	0.066 (0.0004)***
NETAGRET	−0.0001 (0.0001)	−0.00001 (0.00003)	−0.001 (0.0001)***
FPD	−0.001 (0.0001)***	−0.00004 (0.00003)	−0.015 (0.00005)***
PCINC	−0.022 (0.03)	−0.005 (0.01)	−0.088 (0.01)***
LCC1N2	−1.102 (0.17)***	−0.335 (0.05)***	−0.192 (0.09)**
MSA	0.103 (0.08)	0.012 (0.02)	0.005 (0.04)
MHVAL	−0.015 (0.01)***	0.0005 (0.001)	0.030 (0.1)
POVERTY	0.010 (0.01)*	−0.001 (0.002)	−0.040 (0.06)
CONTI	0.040 (0.02)**	0.002 (0.01)	0.024 (0.05)
INFLU	−0.015 (0.01)	0.003 (0.003)	0.021 (0.03)
BDEGREE	0.029 (0.01)***	0.0003 (0.003)	0.005 (0.04)
Adjusted R^2[b]	0.43	Observations	605
Predicted share	0.5767	Actual share	0.5203
Agriculture, dependent variable: Ln(Agriculture/UrbanOther)			
Constant	−0.250 (0.38)	—	—
YR1982	−0.311 (0.1)***	0.011 (0.02)	0.056 (0.09)
YR1989	−0.626 (0.11)***	−0.041 (0.02)**	−0.210 (0.1)**
YR1997	−0.148 (0.18)	0.040 (0.03)	0.203 (0.17)
YR2000	−0.174 (0.18)	0.041 (0.03)	0.208 (0.18)
WTDSTPR	−0.003 (0.001)***	−0.001 (0.0002)***	−0.679 (0.001)***
NETAGRET	0.0001 (0.0001)	0.00004 (0.00002)*	0.026 (0.0001)***
FPD	−0.001 (0.0001)***	−0.000003 (0.00002)	−0.004 (0.0001)***
PCINC	−0.014 (0.03)	−0.0001 (0.006)	−0.005 (0.03)
LCC1N2	2.076 (0.19)***	0.509 (0.04)***	0.859 (0.18)***
MSA	−0.018 (0.09)	−0.020 (0.02)	−0.026 (0.09)
MHVAL	0.004 (0.01)	0.004 (0.001)***	0.770 (0.2)***
POVERTY	0.030 (0.006)***	0.004 (0.001)***	0.372 (0.13)***
CONTI	0.057 (0.02)***	0.004 (0.004)	0.119 (0.11)
INFLU	−0.024 (0.01)*	−0.001 (0.003)	−0.023 (0.06)
BDEGREE	0.014 (0.01)	−0.003 (0.002)	−0.149 (0.09)
Adjusted R^2[b]	0.56	Observations	605
Predicted share	0.1961	Actual share	0.2150

NIPF, nonindustrial private forestland.

[a] The marginal effects and elasticities are computed at means of the variables, except for the dummy variables, which are based on a value of 1.

[b] Conventional.

$^{*}P < 0.10$; $^{**}P < 0.05$; $^{***}P < 0.01$. SE, standard error.

Under this analysis, based on timberland by ownership classes (private forest industry, NIPF, agriculture, and urban/other uses), the gap between the actual and predicted shares for overall timberland use declined from 0.66–0.70 to 0.65–0.68, whereas that for agriculture narrowed from 0.21–0.18 to 0.21–0.20, compared with analysis by major land uses (timberland, agriculture, and urban/other uses), showing a definite improvement in the predictions. However, the gap between the actual and predicted shares within timberland based on ownerships, private industry, and NIPF landowners is still large. In the absence of detailed ownership data, it was necessary to extrapolate the timberland under private forest industry and NIPF owners for the year 2000, and these results should therefore be viewed with caution.

As is well known, several previous studies have confirmed that the objectives of private industry and NIPF landowners are significantly different (Clawson 1979, Kurtz and Lewis 1981, Hyberg 1987, Young and Reichenbach 1987, Newman and Wear 1993, Wicker 2002, Amacher et al. 2003). This analysis also confirms that the private forest industry timberland owners and NIPF timberland owners are significantly different in their response to changes in the variables with respect to land use. In terms of marginal effects and elasticities, land quality is the only variable that has a significant effect on NIPF timberland use, indicating that diverse objectives and multitude of nontimber values or factors, which have not been incorporated or captured in these equations, may have the predominant role in NIPF timberland use. On the other hand, private forest industry timberland owners are significantly affected by a host of factors, such as timber returns, agricultural returns, population density, land quality, housing values, urban influence, and educational level, as is evident from the results.

Using more detailed timberland ownership data available for a limited period between1970 and 1997, we attempted to analyze factors affecting timberland ownership by dividing NIPF owners further into two groups: farmers-ranchers, and miscellaneous private corporations. The adjusted R^2 values were 0.42, 0.22, 0.51, and 0.48 for the private forest industry, miscellaneous private corporations, farmer-ranchers, and agriculture equations. The gap between predicted and actual shares of various land uses further narrowed to actual versus predicted 0.67 versus 0.70 for timberland use, 0.19 versus 0.17 for agriculture use, and 0.14 versus 0.13 for urban/other use [9]. However, the balanced sample was restricted to 264 observations (out of the balanced sample of 605 used in Tables 4 and 5), as some counties had zero values for some ownership classes, restricting the scope of the analysis.

Conclusion

This study extended the land use modeling analysis by Nagubadi and Zhang (2005) to conduct an econometric analysis by including urbanization variables and socioeconomic factors, in addition to the regularly used variables, on the land use change in general and timberland by different ownership (forest industry and NIPF) categories in Georgia counties using data between 1972 and 2000. A modified multinomial logit approach with a multiplicative heteroscedastic correction was used. The results show that relative returns to respective land uses, demographics, heterogeneous land quality, urbanization, and socioeconomic variables are key factors in driving land use change. The predicted shares of timberland use, obtained by modeling the timberland use by ownership classes, are closer to the actual shares than those obtained by modeling with a single timberland ownership.

Among the major land uses for agriculture and timberland, the impact of forestry returns, positive for timberland and negative for agriculture land use, is more pronounced than the impact of agricultural returns. If the relative returns are more favorable to forestry land use, then this raises the possibility of further loss of land in agricultural use and its conversion to forestry use in addition to its loss due to urbanization pressures. Furthermore, higher land quality has a higher positive impact on the agricultural land use than the negative impact on the timberland use.

Different factors have different impacts on timberland use by private forest industry and NIPF timberland owners, as evidenced by the result that the land quality is the only major factor affecting the NIPF timberland owning class, whereas the same factors influencing the overall timberland use also influence the private forest industry timberland use. The results imply that different factors affect timberland by ownership classes in different magnitudes and timberland under different ownership classes cannot be treated as a homogeneous group for modeling purposes because of diverse objectives of the different timberland owner groups, as shown by the nonresponse of NIPF-owned timberland land use to most variables except land quality.

Urbanization factors (such as housing values, urban-rural continuum, and urban influence) and socioeconomic factors (such as poverty ratio and the educational level of the region) are also important variables in influencing the land use in counties. This result could lead to building better land use models to forecast timberland use by ownership class, forest type, forest conditions, and the products and services produced by forests. Omitting these variables could mean incorrect inference and prediction.

If the divestiture of timberland by private forest product industry continues, it is likely that the timberland ownership share of institutional timberland owners such as TIMOs, REITs, and pension funds could increase further. Although Rogers and Munn (2003) and Arano and Munn (2006) did not find any differences in forest management intensity between institutional investors (TIMOs and REITs) and private forest industry owners, the timber supply behavior of these institutional timberlands is bound to be different from that of NIPF ownership or forest products industry ownership. Future analysis of changes in timberland by ownership class could include a separate category of institutional timberland ownership wherever possible. Two limitations of this study that have not been taken into account are the timberland conversion to public timberland, which has increased by 0.44 million ac between 1972 and 2000, and that because of lack of detailed timberland ownership data for private forest industry and NIPF ownership for 2000, data were extrapolated assuming the same proportions as in 1997.

Endnotes

[1] In the multiplicative heteroscedastic regression model, ordinary least squares estimates are obtained in the first step. In the second step, maximum likelihood estimates are obtained using the set of variables or forms of variables causing most heteroscedasticity as weights.

[2] Marginal effects and acreage elasticities may vary in sign from the sign of the estimated coefficients because the complex equations involve several coefficients, values of independent variables, and land use proportions.

[3] FIA defines timberland as forestland producing or capable of producing more than 20 ft^3/ac/year of industrial wood crops under natural conditions, which is not withdrawn from timber utilization and not associated with urban or rural development.

[4] The FIA has since discontinued reporting ownership data by detailed categories; it reports detailed ownership of public timberland but combines all other into privately owned timberland without giving any breakdown by private industry and NIPF ownership categories. Therefore, we have extrapolated the private timberland into industry and NIPF ownerships for the year 2000 on the basis of their proportions in the nearest previous year, 1997, for each county, assuming that the proportion of timberland between these two ownerships has remained the same as in 1997.

[5] The LCCs are as follows: I. Soils have slight limitations that restrict their use; II. Soils have moderate limitations that reduce the choice of plants or require moderate conservation practices; III. Soils have severe limitations that reduce the choice of plants, require special conservation practices, or both; IV. Soils have very severe limitations that restrict the choice of plants, require very careful management, or both; V. Soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover; VI. Soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover; VII. Soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife; VIII. Soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, water supply, or aesthetic purposes.

[6] Rural-urban continuum codes are as follows: (1) Counties in metro areas of 1 million population or more; (2) Counties in metro areas with a population of 250,000 to 1 million; (3) Counties in metro areas with a population of less than 250,000; (4) Urban population of 20,000 or more, adjacent to a metro area; (5) Urban population of 20,000 or more, not adjacent to a metro area; (6) Urban population of 2,500–19,999, adjacent to a metro area; (7) Urban population of

2,500–19,999, not adjacent to a metro area; (8) Completely rural or with an urban population of less than 2,500, adjacent to a metro area; and (9) Completely rural or with an urban population of less than 2,500, not adjacent to a metro area (USDA Economic Research Service 2004).

[7] Urban influence codes are as follows: (1) In large metro area of 1+ million residents; 2) In small metro area of less than 1 million residents; (3) Micropolitan area adjacent to large metro area; 4) Noncore adjacent to large metro area; 5) Micropolitan area adjacent to small metro area; 6) Noncore adjacent to small metro area and contains a town of at least 2,500 residents; 7) Noncore adjacent to small metro area and does not contain a town of at least 2,500 residents; 8) Micropolitan area not adjacent to a metro area; 9) Noncore adjacent to micro area and contains a town of at least 2,500 residents; 10) Noncore adjacent to micro area and does not contain a town of at least 2,500 residents; 11) Noncore not adjacent to metro or micro area and contains a town of at least 2,500 residents; 12) Noncore not adjacent to metro or micro area and does not contain a town of at least 2,500 residents (USDA Economic Research Service 2004).

[8] This is a balanced sample of 605 containing data for all counties in all FIA years out of a total of 795 observations, since the observations with zero values for any ownership in any county during any year are excluded.

[9] The results of this exercise are available from the author.

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