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The influence of urbanization on timberland use by forest type in the Southern United States

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Abstract

We use a modified multinomial logit approach to quantify the influence of urbanization on timberland use in general and by forest type in eight southern states in the U.S. between 1992 and 1997. Our results show that urbanization, economic returns, demographics, economic growth, and land quality explain the decline in timberland use in general. However, these factors impact softwood, hardwood, and mixed forest-type timberland in different magnitudes, and treating all timberland as one category imposes undue restrictions on estimation models. Modeling timberland use by forest type can improve land use projections.

Keywords: Timberland; Urbanization; Metropolitan statistical area; Housing value; Road density; Modified multinomial logit; Multiplicative heteroskedastic regression

1. Introduction

Rates of population increase in the South are among the highest in the United States and have increased the demand for natural resources in the region. High population levels tend to stimulate urban development and concomitant loss of forest cover (Wear and Greis, 2002). Such a change in land use has implications for a wide variety of policy issues, from maintenance of water quality, protection of biodiversity, preservation of open space, to mitigation of global climate change. Changes in forest type reflect changes in forest conditions and services provided by the forests. Therefore, predictions on land use changes by forest type are needed.

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 for forestry, agriculture, and urban. However, there has been little effort in modeling land use with respect to more disaggregated use groups such as timberland by forest type.[1] By pooling timberland

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or capable of producing more than 20 ft^3/acre/year of industrial wood crops under natural conditions, which is not withdrawn from timber utilization and not associated with urban or rural development.

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across forest types, earlier studies may have assumed that economic and demographic factors have equal effects on land use by forest type and imposed an implicit restriction on timberland use changes—all forest types respond in the same way and magnitude to various factors.[2] This implicit restriction has not been tested.

In this study, we attempt to fill in this gap by developing a model of land use by forest type. We apply a modified multinomial logit technique using county-level data in eight states in the southern U.S. We generate marginal effects and elasticities for the variables on specific timberland use by forest type. Furthermore, in addition to population and income, we have included other urbanization variables in order to better capture the impact of urbanization on land use change.

Our results show that various factors have a significantly different impact on timberland use by forest type and that additional urbanization variables capture the urbanization process better than merely including population and income variables in the model. 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 forest type and draw some conclusions.

2. 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 a location rent model for urban land use.[3] Miller and Plantinga (1999) and Hardie et al. (2000) develop a comprehensive theory of land use change by combining Ricardian and von Thünen land rent models. The resulting model depicts landowners' land use decision problem as one of allocating a fixed amount of land to alternative uses.

In this study, 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:

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

The land use, k, can be softwood forest type, mixed forest type, hardwood forest type, agricultural land, and urban/other land. 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 population age; (c) land quality variables: average land quality and the proportion of land in the highest quality classes; (d) geographical variables: distance to city, slope of the land and travel time to the nearest city; 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, 1975; Parks, 1980; Hardie and Parks, 1997). This specification is convenient because it constrains the predicted land use shares between zero and one and requires that they sum to one. If we normalize the equation system (1) by one land use type (for

[2] Nagubadi and Zhang (2005) have attempted to verify whether the coefficients in the three different forest types equations were significantly different, with the help of dummy variables and dummy variable interactions with the variables from the softwood forest type equation by stacking the observations from dependent and independent variables one below the other. The results show that the dummy intercept and dummy variable interactions with pine stumpage price, oak stumpage price, and the land quality variable were significantly different from zero, all at the 1% significance level. For the mixed forest type equation, dummy variable interactions with pine stumpage price, and oak stumpage price were found to be significant at the 1% level, and dummy interaction term with cost share acres variable were found to be significantly different at the 5% level.

[3] While Ricardo attributes rent to differences in fertility, von Thünen develops a complementary theory of rent based on differences in location with respect to a central market and postulated that land rent decreased as distance from the urban centre increased in concentric rings. The Ricardian model has been extensively applied in agricultural economics literature, while the von Thünen model has served as a standard bearer in the analysis of urban economic growth.

example, $k=5$) and constrain $\beta_5=0$, the modified multinomial logit model becomes

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

and share of the omitted land use is recovered as

$$P_{i5t} = \frac{1}{1 + \sum_{k=1}^{K-1} \exp(\beta_k' X_{it})}. \quad (3)$$

A logarithmic transformation of equation system (2) yields a $K-1$ equation system

$$\ln\left(\frac{P_{ikt}}{P_{i5t}}\right) = \beta_k' X_{it} + u_{it} \text{ for } k = 1, \ldots, K-1, \quad (4)$$

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 due to random factors, they are replaced with actual (or observed) land use proportions, y_{ikt}. Thus additional error terms, ε_{ikt}, are introduced in the system. The system of equations in Eq. (4) then becomes

$$\ln\left(\frac{y_{ikt}}{y_{i5t}}\right) = \beta_k' X_{it} + u_{it} + \varepsilon_{ikt} \text{ for } k = 1, \ldots, K-1. \quad (5)$$

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 heteroskedasticity problems from one or more explanatory variables. From Eq. (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 using a multiplicative heteroskedastic regression method (Harvey, 1976; Greene, 1993, pp. 264–267).[4]

Since the dependent variable is the log of the ratio of the proportion of land uses, it is difficult to interpret the coefficients directly. Consequently, marginal effects and elasticities are estimated at mean levels of the continuous explanatory variables, and a value of one for dummy variables. Marginal effects are interpreted as the change in the probability of land being in a particular use for a unit change in the independent variable, other things remaining constant. Marginal effects are estimated as (Greene, 1993, p. 666)

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

where β_{kx} is the coefficient of x for land use k. The acreage elasticity of land use k with respect to x in county i and year t is given by (Wu and Segerson, 1995, p. 1037)

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

Acreage elasticities are to be interpreted as a percentage change in a particular land use due to a percent change in the value of the independent variable. Marginal effects and acreage elasticities may vary in sign from the sign of the estimated coefficients because the complex Eqs. (6) and (7) involve several coefficients, β_{kx}, values of x, and land use proportions, y_{ikt}. The standard errors for marginal effects and elasticities are computed using the delta method (Greene, 1993, p. 297).

3. Data

This study uses county-level data from eight states (Alabama, Arkansas, Florida, Georgia, South Carolina, Tennessee, eastern Texas, and Virginia) in the U.S. South for 1992 and 1997. The remaining southern states were not included since timberland data were not available for 1997. Between 1992 and 1997, timberland and urban and other land increased, while agricultural land declined (Table 1).

[4] In the multiplicative heteroskedastic regression model, ordinary least squares estimates are obtained in the first step and in the second step maximum likelihood estimates are obtained using the set of variables or forms of variables which cause most heteroskedasticity as weights.

Table 1
Land use in eight Southern States[a] of the United States (1000 acres)

Land use	1992	%	1997	%	% Change from 1992 to 1997
Timberland area[b]	131,390	57.44	132,736	58.03	1.02
Softwood	45,267	19.79	46,874	20.49	3.55
Mixed	20,058	8.77	20,129	8.80	0.35
Hardwood	66,065	28.88	65,734	28.74	−0.50
Agriculture[c]	62,763	27.44	60,753	26.56	−3.20
Urban and all other	34,602	15.13	35,266	15.42	1.92
Total land area[d]	228,755	100.00	228,755	100.00	0.00

[a] Alabama, Arkansas, Florida, Georgia, South Carolina, Tennessee, Texas (East), and Virginia.
[b] Data from forest inventory and analysis (FIA).
[c] From NASS; includes cropland, crop-pasture, idle, summer fallows, and pasture and rangeland.
[d] Total land area is total geographical area less water area.

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. Timberland area by forest types is obtained from Forest Inventory and Analysis (FIA) surveys conducted in different years.[5] To conform to agricultural census years, the FIA data are linearly interpolated. Land in agricultural use includes cropland, pastureland, and rangeland reported in the 1992 and 1997 agricultural censuses. Land in the urban and other category includes urban land and land devoted to roads, rural transportation, and other special uses and is estimated as a residual by subtracting timberland and agricultural area from the total land area in each county.

We have several variables in our model to represent the urbanization process and real estate markets in the southern U.S. such as whether a county has or is close to a metropolitan area, median housing values, housing densities, and road densities. A dummy variable is created to represent counties that include both central and outlying areas of metropolitan statistical areas (MSA) with a population of 50,000 or more. Data on median housing values (MHVAL) for years 1990 and 2000 are obtained from the Census Bureau and are interpolated for years 1992 and 1997 using a compound growth rate formula. Data on housing density (HUAREA) for 1992 and 1997 are derived by interpolation from Census Bureau's data on housing units for 1990 and 2000 using compound growth rates. The road density (MLAREA) is computed as the total number of highway miles per thousand acres for 1993 and 1997, obtained from the Department of Transportation. The highway mileage is represented by the highway road miles in the Interstate System, arterial and other roads, and connectors to major intermodal terminals. We expect these urbanization variables (MSA, MHVAL, HUAREA, and MLAREA) would be negatively related to all types of timberland use. On the other hand, since location theory states that agricultural land is located nearer or next to urban locations, the urban-related variables are hypothesized to have a positive influence on agricultural land use.

We use forest population density instead of population density (Wear, 2002). Forest population density is estimated as the number of persons per thousand acres of forest land in a county using the mid-year population estimates by the BEA's (2004) Regional Economic Information System (REIS).[6] Forest population density is a very general measure of human influence, but helps define where population effects may be most concentrated. As forest population density increases, we expect a negative impact towards all types of timberland, and a positive impact towards agriculture and urban land use. County-level per capita personal income is also obtained from REIS. The income and median housing

[5] FIA Program periodically collects, analyzes, and reports information on the status and trends of America's forests, i.e., how much forest exists, where it exists, who owns it, and how it is changing, as well as how the trees and other forest vegetation are growing and how much has died or been removed in recent years.

[6] Forest land is land at least 10% stocked by trees of any size or formerly having had such tree cover and not currently built-up or developed for agricultural use. The minimum area for classification as forest land is 1 acre.

data are deflated using the consumer price index (CPI) for urban areas (1982–1984 = 100). We hypothesize that per capita income would negatively affect timberland (including all forest types) use and agricultural land use relative to urban/other land use.

We use Timber Mart-South (TMS, 1992 and 1997) prices for pine sawtimber and oak sawtimber in dollars per thousand board feet to represent the returns to timberland use. As county level prices are not available, we use prices for two TMS regions for each state. These prices are deflated using the producer price index (PPI) for all commodities (1982 = 100). As a proxy for agricultural returns, we use county-level net agricultural returns obtained from the National Agricultural Statistics Service (NASS). Net agricultural returns are computed as the total cash receipts from all crops and livestock and total government payments minus total production expenses. Per acre net agricultural returns are obtained by dividing the county net agricultural returns with county acreage under crops and pasture. Economic returns are expected to help explain timberland, agricultural or urban land use.

Data on land quality are obtained from the United States Department of Agriculture (USDA). The land quality ratings for a land parcel range from land capability class (LCC) 1 to 8 where 1 is the most productive and 8 is the least productive (Klingebiel and Montgomery, 1961). The proportion of LCC 1 and 2 in the total land area is used in the analysis. The values of the land quality variable for each county are the same for all years. We expect that a high proportion of good quality land leads to more agricultural land use and less timberland use relative to urban/other land use. Table 2 presents some information on variables used in the analysis of the balanced sample of 766 counties (i.e., 383 same counties in each year). Some other counties from these states are excluded because of zero values for some land uses.

4. Results

Eq. (5) is estimated using a maximum likelihood method with a multiplicative heteroskedastic correc-

Table 2
Description, data sources, and mean values of variables ($n = 766$)

Variable	Description	Source	Mean	Std. dev.
MSA	Dummy variable: 1 if the county has Metropolitan Statistical Area (central and outlying area), 0 otherwise	Census Bureau	0.28	0.45
WTDSTPR	Real stumpage price of pine and oak sawtimber weighted by softwood and hardwood removals at county level	Timber Mart-South/FIA	187.66	53.12
PSTPR	Real pine sawtimber price ($/MBF)[a]	Timber Mart-South	199.27	61.92
OSTPR	Real oak sawtimber price ($/MBF)	Timber Mart-South	144.19	54.32
NETAGRET	Real value of total cash receipts from crops, livestock and government payments minus production expenses in a calendar year ($/acre)	NASS	77.92	101.52
FPD	Forest population density, persons per thousand acres of county forest land[b]	Census Bureau/FIA	364.72	979.19
INCOME	Real average per capita personal income of county ($1000) in 1982–1984 ($)	BEA	11.29	1.93
LCC1N2	Proportion of highest land capability classes I and II in the total land of the county (%)	USDA	0.27	0.17
MHVAL	Real median value of specified owner-occupied housing units ($1000)	Census Bureau	40.22	12.55
HUAREA	Housing units per area of county (units/1000 acres)[c]	Census Bureau	70.99	123.08
MLAREA	Highway road miles per area of county (miles/1000acres)[c]	Dept. of Transportation	3.00	1.42

[a] Abbreviations: MBF, thousand board feet; FIA, Forest Inventory and Analysis; NASS, National Agricultural Statistics Service; BEA, Bureau of Economic Analysis; USDA, United States Department of Agriculture.

[b] Forest land includes timberland, unproductive forests, and productive reserves.

[c] For the purpose of this analysis, area of a county is defined as the sum of acreage under timberland, crop, pasture, urban/other uses and excludes water area, unproductive forests, and productive reserve forests.

tion. State dummy variables are included to capture variation related to state-specific policies and regulations affecting land use. The estimated results suggest reasonably good fits with conventional adjusted R-square values ranging from 0.45 to 0.57. We discuss estimation results in terms of significant marginal effects and elasticities of variables towards the respective land use.

4.1. Major land use

Table 3 presents estimated coefficients, marginal effects, elasticities, and their standard errors for major land use categories—timberland and agricultural land. All variables with significant coefficients, marginal effects and elasticities, with the exception of the housing density variable (HUAREA) in both equations, have the expected signs. All elasticities and most marginal effects for the state dummy variables are significantly different from zero, indicating that the state specific factors are important in the land use changes. The effect of a county having a metropolitan area (MSA) has the expected significant negative impact on the timberland use and a significant positive impact on the agricultural land use. The median house value and road density have negative impacts on timberland use, while road density has a positive impact on agricultural land use.

In terms of estimated marginal effects, the land quality variable (LCC1N2) has the highest negative impact followed by the road density variable (MLAREA), while weighted stumpage prices (WTDSTPR) have a significant positive effect on the timberland use. Estimated elasticities, on the other hand, suggest that the variables MLAREA and LCC1N2 have the highest negative effect on the timberland. The results show that, for a given county, a 1% increase in weighted stumpage prices increases the share of timberland use by 0.08%, ceteris paribus. In contrast, a 1% increase in road density (MLAREA), the proportion of land in highest land quality classes (LCC1N2), and forest population density (FPD) decreases the share of timberland by 0.36%, 0.12%, and 0.08%, respectively.

As expected, forest population density, land quality, and road density have a significant and positive effect on agricultural land use. The land quality has the highest marginal effect in favor of agricultural land use. Housing density is the only variable that has a significant negative marginal impact on agricultural land use. In terms of elasticities, road density exerts the highest positive impact followed by land quality and forest population. For a given county, a 1% increase in road density, proportion of good land quality, and forest population density increases the share of agricultural land by 1.03%, 0.41%, and 0.24%, respectively, while a 1% increase in housing density decreases the share of agricultural land by 0.62%, ceteris paribus.

4.2. Timberland use by forest type

Table 4 provides the results related to land use distinguished by forest type—softwood, oak–pine mixed, hardwood and agriculture land uses. The significant elasticities for the MSA dummy variable indicate its negative effect on softwood and mixed type timberland use and positive effect on agricultural use. All the elasticities and most marginal effects for the state dummy variables are significant. Again, with the exception of the housing density variable in three of the four equations, all variables with significant coefficients, marginal effects, and elasticities have the expected signs in all equations.

The different signs of significant marginal effects and elasticities for pine stumpage price (PSTPR), oak stumpage price (OSTPR), and net agricultural returns (NETAGRET) in the softwood type, hardwood type, and agriculture land use equations indicate that returns to the respective land use significantly affect the probability of land use change between forestry and agriculture. Although we use stumpage prices as proxies for returns for timberland use instead of the theoretically correct forest returns as annualized values of discounted future returns, the estimated results are reasonably good.

Forest population density has a significant negative impact on softwood and mixed forest type timberland use and a significant positive impact on agricultural land use. Land quality impacts oak–pine mixed and hardwood timberland use negatively and agricultural land use positively. The marginal effects and elasticities for median housing value are significant for softwood timberland use only, despite the coefficients being significant in all the equations. Again, the effect of the road density variable is

Table 3
Estimation results according to major land use ($n=766$)

Variable	Coefficient (S.E.)	Margi. effects[a] (S.E.)	Elasticities[a] (S.E.)
(a) Timberland use (Dep. Variable: LN(Timber/Urban Other)			
Constant	3.3075 (0.187)***		
MSA	−0.2116 (0.064)***	−0.0456 (0.017)***	−0.0664 (0.007)***
AR	0.0711 (0.077)	−0.0377 (0.021)*	−0.055 (0.003)***
FL	−0.2087 (0.094)**	−0.0606 (0.025)**	−0.0882 (0.003)***
GA	0.0588 (0.062)	0.0265 (0.017)	0.0386 (0.008)***
SC	0.0436 (0.084)	0.0455 (0.022)**	0.0662 (0.003)***
TN	0.0272 (0.092)	−0.0562 (0.025)**	−0.0818 (0.002)***
TX	0.0638 (0.096)	−0.0803 (0.025)***	−0.1169 (0.002)***
VA	0.3093 (0.094)***	−0.0014 (0.025)	−0.002 (0.004)
WTDSTPR	0.0025 (0.0004)***	0.0003 (0.0001)***	0.0848 (0.03)***
NETAGRET	−0.00015 (0.0002)	−0.00007 (0.00005)	−0.0079 (0.006)
FPD	−0.0003 (0.0001)***	−0.0001 (0.00002)***	−0.07 (0.009)***
INCOME	−0.0593 (0.02)***	−0.0082 (0.005)	−0.1347 (0.085)
LCC1N2	−0.7222 (0.139)***	−0.3024 (0.037)***	−0.1173 (0.014)***
MHVAL	−0.0129 (0.003)***	−0.0014 (0.001)*	−0.0841 (0.048)*
HUAREA	0.0024 (0.001)***	0.0015 (0.0002)***	0.1587 (0.018)***
MLAREA	−0.2857 (0.033)***	−0.0828 (0.009)***	−0.3615 (0.037)***
Adj. R-squared[b]	0.57		
Pred. share	0.6867		
Act. share	0.6484		
(b) Agriculture use (Dep. Variable: LN(Agri/Urban Other)			
Constant	0.10979 (0.238)		
MSA	0.0005 (0.077)	0.0251 (0.013)*	0.1457 (0.022)***
AR	0.4479 (0.105)***	0.0555 (0.018)***	0.3218 (0.01)***
FL	0.1323 (0.123)	0.0436 (0.021)**	0.2528 (0.009)***
GA	−0.117 (0.082)	−0.0237 (0.014)*	−0.1371 (0.027)***
SC	−0.3046 (0.107)***	−0.0486 (0.018)***	−0.282 (0.01)***
TN	0.5238 (0.126)***	0.0715 (0.021)***	0.4148 (0.008)***
TX	0.7936 (0.125)***	0.1057 (0.021)***	0.6129 (0.007)***
VA	0.5737 (0.121)***	0.0452 (0.021)**	0.2624 (0.012)***
WTDSTPR	0.002 (0.001)***	−0.00002 (0.0001)	−0.0198 (0.098)
NETAGRET	0.0003 (0.0002)	0.00006 (0.00004)	0.0286 (0.02)
FPD	0.0005 (0.0001)***	0.0001 (0.00001)***	0.2423 (0.027)***
INCOME	−0.0385 (0.024)	0.0015 (0.004)	0.0995 (0.273)
LCC1N2	1.2414 (0.183)***	0.2627 (0.031)***	0.4056 (0.048)***
MHVAL	−0.0114 (0.004)***	−0.0001 (0.001)	−0.0211 (0.153)
HUAREA	−0.0085 (0.001)***	−0.0015 (0.0001)***	−0.6205 (0.055)***
MLAREA	0.1803 (0.039)***	0.0596 (0.007)***	1.0353 (0.12)***
Adj. R-squared[b]	0.45		
Pred. share	0.1725		
Act. share	0.1961		

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

[b] Conventional.

* $P<0.10$.

** $P<0.05$.

*** $P<0.01$.

Table 4
Estimation results according to land use by forest types ($n=766$)

Variable	Coefficient (S.E.)	Margi. effects[a] (S.E.)	Elasticities[a] (S.E.)
(c) Hardwood type (Dep. Variable: LN(Hard/Urban Other)			
Constant	1.9567 (0.24)***		
MSA	−0.4196 (0.083)***	−0.0631 (0.016)***	−0.2664 (0.019)***
AR	−0.0473 (0.114)	−0.0244 (0.022)	−0.1032 (0.01)***
FL	0.1976 (0.156)	0.0616 (0.031)**	0.2602 (0.009)***
GA	0.2199 (0.113)*	0.0387 (0.022)*	0.1637 (0.031)***
SC	0.2765 (0.124)**	0.0724 (0.024)***	0.306 (0.01)***
TN	−0.582 (0.166)***	−0.1133 (0.032)***	−0.4789 (0.009)***
TX	−0.1403 (0.185)	−0.1045 (0.036)***	−0.4415 (0.009)***
VA	0.2177 (0.142)	−0.0087 (0.028)	−0.0368 (0.012)***
PSTPR	0.004 (0.001)***	0.0008 (0.0002)***	0.6726 (0.177)***
OSTPR	−0.0002 (0.001)	−0.0005 (0.0002)**	−0.3207 (0.152)**
NETAGRET	−0.0006 (0.0003)**	−0.0001 (0.00005)**	−0.0397 (0.018)**
FPD	−0.0004 (0.0001)***	−0.0001 (0.00001)***	−0.1221 (0.023)***
INCOME	−0.051 (0.025)**	0.0013 (0.005)	0.063 (0.233)
LCC1N2	−0.2061 (0.192)	−0.0143 (0.038)	−0.0161 (0.042)
MHVAL	−0.0158 (0.004)***	−0.0014 (0.001)*	−0.2417 (0.136)*
HUAREA	0.0044 (0.001)***	0.001 (0.0002)***	0.2999 (0.048)***
MLAREA	−0.3532 (0.043)***	−0.0501 (0.008)***	−0.6343 (0.106)***
Adj. R-squared[b]	0.52		
Pred. share	0.2367		
Act. share	0.2461		
(b) Mixed type (Dep. Variable: LN(Mixed/Urban Other)			
Constant	1.5183 (0.242)***		
MSA	−0.2515 (0.08)***	−0.0105 (0.008)	−0.0984 (0.022)***
AR	−0.0023 (0.109)	−0.0062 (0.011)	−0.0582 (0.011)***
FL	−0.9933 (0.151)***	−0.0993 (0.016)***	−0.9307 (0.01)***
GA	−0.2566 (0.108)**	−0.0334 (0.011)***	−0.3129 (0.035)***
SC	−0.3501 (0.118)***	−0.0342 (0.012)***	−0.3206 (0.011)***
TN	−0.2348 (0.159)	−0.014 (0.017)	−0.1316 (0.011)***
TX	0.1467 (0.177)	−0.0165 (0.018)	−0.1544 (0.01)***
VA	−0.0769 (0.137)	−0.0354 (0.014)**	−0.3314 (0.014)***
PSTPR	0.0022 (0.001)**	0.0002 (0.0001)	0.325 (0.201)
OSTPR	0.0005 (0.001)	−0.0002 (0.0001)	−0.2184 (0.173)
NETAGRET	−0.0001 (0.0003)	−0.000008 (0.00003)	−0.0061 (0.02)
FPD	−0.0005 (0.00008)***	−0.00004 (0.00001)***	−0.1287 (0.028)***
INCOME	−0.0607 (0.025)**	−0.0004 (0.003)	−0.0471 (0.279)
LCC1N2	−1.0175 (0.184)***	−0.0931 (0.019)***	−0.2322 (0.048)***
MHVAL	−0.0096 (0.004)**	0.00002 (0.0004)	0.0079 (0.156)
HUAREA	0.0041 (0.001)***	0.0004 (0.0001)***	0.2818 (0.057)***
MLAREA	−0.2878 (0.042)***	−0.0156 (0.004)***	−0.4384 (0.122)***
Adj. R-squared[b]	0.47		
Pred. share	0.1067		
Act. share	0.1074		
(c) Hardwood type (Dep. Variable: LN(Hard/Urban Other)			
Constant	2.5608 (0.191)***		
MSA	−0.0893 (0.059)	0.0207 (0.015)	0.0638 (0.013)***
AR	0.0392 (0.086)	−0.0054 (0.022)	−0.0166 (0.007)**
FL	−0.2677 (0.116)**	−0.0664 (0.03)**	−0.2051 (0.006)***
GA	0.0173 (0.082)	−0.0126 (0.021)	−0.039 (0.022)*
SC	−0.1034 (0.088)	−0.024 (0.023)	−0.0739 (0.007)***

Table 4 (*continued*)

Variable	Coefficient (S.E.)	Margi. effects[a] (S.E.)	Elasticities[a] (S.E.)
(c) Hardwood type (Dep. Variable: LN(Hard/Urban Other)			
TN	0.0471 (0.123)	0.0487 (0.032)	0.1503 (0.007)***
TX	0.277 (0.136)**	−0.0078 (0.035)	−0.0241 (0.007)***
VA	0.4323 (0.105)***	0.0576 (0.027)**	0.1777 (0.009)***
PSTPR	−0.0007 (0.001)	−0.0004 (0.0002)**	−0.2672 (0.125)**
OSTPR	0.0034 (0.001)***	0.0005 (0.0002)*	0.2024 (0.108)*
NETAGRET	0.0001 (0.0002)	0.00005 (0.00005)	0.0114 (0.012)
FPD	−0.0002 (0.0001)***	−0.00002 (0.00001)	−0.0201 (0.016)
INCOME	−0.0967 (0.02)***	−0.013 (0.005)***	−0.4537 (0.174)***
LCC1N2	−0.7306 (0.141)***	−0.1896 (0.036)***	−0.1558 (0.03)***
MHVAL	−0.0084 (0.003)***	0.0005 (0.001)	0.0565 (0.094)
HUAREA	0.0006 (0.001)	0.00013 (0.0002)	0.0285 (0.033)
MLAREA	−0.1701 (0.031)***	−0.0092 (0.008)	−0.0854 (0.074)
Adj. R-squared[b]	0.53		
Pred. share	0.3240		
Act. share	0.2949		
(d) Agriculture use (Dep. Variable: LN(Agri/Urban Other)			
Constant	0.0977 (0.235)		
MSA	0.0106 (0.076)	0.03 (0.012)**	0.1638 (0.019)***
AR	0.2984 (0.113)***	0.0444 (0.018)**	0.2425 (0.01)***
FL	0.4553 (0.149)***	0.0948 (0.025)***	0.518 (0.009)***
GA	0.142 (0.108)	0.0157 (0.018)	0.0857 (0.032)***
SC	−0.1314 (0.116)	−0.0187 (0.019)	−0.102 (0.01)***
TN	0.2426 (0.162)	0.0633 (0.026)**	0.3457 (0.01)***
TX	1.2511 (0.178)***	0.1738 (0.029)***	0.9499 (0.01)***
VA	0.3888 (0.136)***	0.0246 (0.022)	0.1342 (0.012)***
PSTPR	−0.0018 (0.001)*	−0.0004 (0.0002)***	−0.4878 (0.184)***
OSTPR	0.0049 (0.001)***	0.0005 (0.0002)***	0.4184 (0.159)***
NETAGRET	0.0003 (0.0002)	0.00007 (0.00004)*	0.031 (0.017)*
FPD	0.0005 (0.0001)***	0.0001 (0.00001)***	0.2351 (0.021)***
INCOME	−0.0365 (0.024)	0.0037 (0.004)	0.227 (0.241)
LCC1N2	1.3584 (0.186)***	0.2752 (0.03)***	0.4005 (0.044)***
MHVAL	−0.0127 (0.004)***	−0.0005 (0.001)	−0.1144 (0.134)
HUAREA	−0.0082 (0.001)***	−0.0015 (0.0001)***	−0.5936 (0.046)***
MLAREA	0.1521 (0.039)***	0.0537 (0.006)***	0.8805 (0.106)***
Adj. R-squared[b]	0.46		
Pred. share	0.1830		
Act. share	0.1961		

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

[b] Conventional.

* $P<0.10$.

** $P<0.05$.

*** $P<0.01$.

negative on all types of timberland use and positive on agriculture land use.

Our analysis by forest type shows that a 1% increase in road density decreases the probability of land devoted to softwood, mixed, and hardwood types by 0.63%, 0.44%, and 0.09%, respectively, while it increases the probability of the land being in agricultural use by 0.88%. This is in contrast to the estimates of 0.39% for timberland use and 1.03% for agricultural land use under the major use approach (Table 3).

A comparison of predicted and actual shares of various land uses in both approaches, shown in Tables

3 and 4, indicates that the analysis of timberland use by forest type results in predictions closer to actual land use shares. The major land use approach predicts 69% in timberland use and 17% in agricultural land use against their respective actual land use shares of 65% and 20%. The analysis by forest types together predicted 67% in timberland use and 18% in agriculture use and thus narrowed the gap between the predicted and actual shares of land use. This illustrates an additional merit in modeling the changes in timberland use by forest type.

5. Conclusions

In this paper, we conduct an econometric analysis on the influence of urbanization on land use change and timberland by forest type in eight states of the U.S. South between 1992 and 1997. We use a modified multinomial logit approach with a multiplicative heteroskedastic correction. We have used additional urbanization variables in our model. Our results show that relative returns to respective land uses, urbanization, and land productivity are key factors driving the land use change. Furthermore, different factors have different impacts on timberland use by forest type.

The implications of this study are at least threefold. First, different factors impact timberland by forest type in different magnitudes and all timberland cannot be treated as one single entity in modeling land use effects. This result could lay a foundation for building a better land use model to forecast timberland use by forest type, forest conditions, and the products and services produced by forests.

Second, variables other than population density and income added to our model capture the urbanization process and the associated impacts on agricultural and timberland uses. Presence of a large urban area (a county has a metropolitan statistical area), road density, and median housing value are all significant in our models. Missing these variables could mean the models are misspecified and lead to incorrect inference and prediction.

Third, urbanization variables have a negative impact on timberland use in general. Specifically, they have the largest negative impact on softwood timberland use and least impact on hardwood timberland use. This result is consistent with casual observation that, with population increase and urbanization, forests get fragmented and are not managed for timber production, and people either prefer hardwood forests or allow hardwood trees to grow. Thus, urbanization and production forestry (represented by softwood timberland and timberland in general) appear to compete for lands. As population continues to increase in the South, production forests could be lost in the urban areas, and ensuring adequate timber supply from the timber basket of the country (where the South accounts for nearly 60% of the timber production) could be a challenge in the long-run. On the other land, if the real net returns to agricultural land use decline relative to other uses, agricultural land away from the urban areas is likely being converted to timberland, mitigating the loss of forest land in urban areas.

Further research could incorporate future expectations on returns to various land uses. In addition, land use models involving the nested logit approach with an appropriate nesting structure (Lubowski et al., 2003) and the random parameters logit model (Nelson et al., 2001) may yield improved results, and projections. Another line of research that could improve the results is examining the impact of variables on various types of timberland ownership.

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