An Analysis of Losses to the Southern Commercial Timberland Base[1]

by

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Abstract

Demographic and physical factors influencing the conversion of commercial timberland iu the south to non-forestry uses between the last two Forest Inventory Analysis (FIA) surveys were investigated. GIS techniques linked Census data and FIA plot level data. Multinomial logit regression identified factors associated with losses to the timberland base. Conversion to agricultural uses represented the largest loss (1.48%) to the commercial timberland base. Slope, forest size, distance to the nearest city, as well as median income and education level were all negatively related to the probability a plot would be converted from forestry to agricultural uses. Conversion to urban uses (1.13%) represented the second largest loss. Forest size, distance to developed areas and distance to the nearest city were all negatively related to the probability a plot would be converted to urban uses. Conversions to a number of miscellaneous uses accounted for an additional 0.38% loss.

INTRODUCTION

Timber supply projections play an important role in both public and private arenas. Forest industries utilize timber supply projections as key components in long-term capital investment decisions and corporate planning. Government policies, regulations and legislation concerning public timberlands, landowner assistance programs, and forest taxation are based in large part on the long-term timber supply outlook. Yet timber supply projections are notoriously inaccurate. Timber supply famines have been predicted repeatedly but have failed to materialize. Consequently, timber supply projections must be refined and updatedconstantly.

A key component of estimating future timber supplies is predicting changes in the land area devoted to timber production. A nuinber of studies focused on this issue. Alig et al. (1983) highlighted the need for new approaches to long range forecasts of forest area change. Parks and Alig (1988) provided a critical review of land-based models for forest resource supply analysis. Alig et al. (1986) examined changes in ownership and cover-type for timberland in the south based on Forest Inventory and Analysis (FIA) data. They found forest farm acreage decreasing, forest industry land holdings steadily increasing and a sharp decrease in natural pine forest types, partially offset by increases in planted pine. Alig (1985, 1986) developed an econometric model of land-use changes for the southeast and examined shifts between timberland aud cropland, rangeland and urban uses. Population and personal income were found to be the major determinants of land-use changes. Variations of Alig's basic model have been used iu a number of subsequent studies projecting various components of the timberland base. For example, Alig et al. (1987), compared forest acreage changes and the underlying causes for northern and southern regions. Alig et al. (1988) applied the procedure developed for the southeast to the south-central United States. Alig et al. (1990) tracked timberland changes from 1952 through 1987 and projected future changes iu the timberland base through 2040 for the entire United States. Total timberland was predicted to decrease by 4% by 2040. Alig and Wear (1992) focused on changes in the private sector of the timberland base through the year 2040.

Information recently compiled for the 1992 Resource Planning Act (Powell et al., 1992) provided au opportunity to refine and update the current timberland change projections. Rather than replicate Alig's model utilizing current FIA data, a fundamentally different approach was utilized. Geographic Information Systems (GIS) make it possible to combii raw un-aggregated data from a variety of sources such as Census and FIA data. Plot-level data can easily be linked with the appropriate Census-Tract level data, providing a much more detailed data base with which to investigate changes

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iu the forest land base. This report focuses on losses to the timber land base.

DATA

The first step in developing the geographic database was to import Census Tract boundaries and associated data for the Southern Region: Alabama, Arkansas, Louisiana, Mississippi Eastern Oklahoma, Tennessee, and Eastern Texas. The Census Bureau subdivides counties into Census Tracts[3], areas of similar population characteristics, economic status, and living conditions. Census Tracts average 4,000 people but range from 2,500 to 8,000.. Tracts vary widely in area depending on population density. Each Census Tract has an associated set of demographic data. The US Department of Agriculture, Forest Service FIA plots are located on a 3-by-3 mile grid pattern. Each FIA plot that is currently forested, or was previously forested, has an associated set of physical data which is remeasured on roughly an 8-year cycle. Data for plots that have never been forested are limited to the latitude aud longitude coordinates. Arc/Info was used to overlay FIA plots on the Census-Tract base map based on plot coordinates given in latitude aud bngitude. The number of FIA plots in each Census Tract depends on the size of the tract. The FIA and Census data were merged, resulting in a combined set of demographic (Census) and physical (FIA) data for each FIA pbt. Finally, the straight line distance from each FIA plot to the nearest urban area with a population of 30,000+ was determined using Arc/Info. A total of 32,050 plots are included in the data set.

Census variables include population density (people per square mile), population growth rate, median household income (1989 dollars), aud the percentage of the population with a bachelor's degree or higher. The FIA variables include current ground use, past ground use, ownership class, site class, slope, forest size, physiographic type, distance to a truck-operable road, and distance to a "built-up*' area of 10 acres or more. "Built-up" land is comprised of areas of intensive human use with much of the land covered by man-made structures. Current and past ground uses are categorized for this study as commercial forest land, non-commercial forest land, -urban land, agricultural land, or waste laud. Ownership is classified as National Forests, other public, industrial and non-industrial private (NIPF). Site class is the land's potential timber yield measured in cubic feet/acre/year and is ranked from 1 (lowest) to 7 (highest). Slope is measured in percent. Forest size is the contiguous forest area, measured in acres, surrounding the FIA plot. Forest-area boundaries iuclude public roads, railroads, non-forest uses, and major waterways. Owner&p boundaries and power and pipeline right-of-ways are not considered. Physiographic types iuclude pine, upland hardwood aud bottomland hardwood types. For this study, distance to a paved or truck-operable road is classified in three categories: less than a mile, between one and three miles, or greater than or equal to three miles. Distance to built-up areas is categorized similarly.

Land-use change is classified on the basis of two FIA variables: current ground use and past ground use. All plots with past ground use identified as commercial forest land are included in the analysis. Four outcomes were possible: no change (current ground use is commercial forest land), commercial forest land converted to agricultural use, commercial forest land converted to urban use, and commercial forest land converted to miscellaneous uses. Miscellaneous uses iucbde areas legally removed from commercial forestry such as National Parks or Wilderness Areas, poor quality forest lands unable to support commercial forestry, and waste land.

[3] The Census Bureau calls these county subdivisions Census Tracts in urban areas and Block Numbering Areas in rural areas. In this paper, the term Census Tract is used for both.

METHODS

Changes in, land-use were hypothesized to be a function, of the physical and demographic characteristics of the pbts as follows:

Probability (USE CHANGE$_i$ = J) = f(SITE$_i$, SLOPE$_i$, SZFOR$_i$, PINE$_i$, UPHDWD$_i$, BHDWD$_i$, ROAD1$_i$, ROAD2$_i$, ROAD3$_i$, NF$_i$, PUB$_i$, IND$_i$, NIPF$_i$, DEVELOP1$_i$, DEVELOP2$_i$, DEVELOP3$_i$, INCOME$_i$, POPDEN$_i$, POPGROW$_i$, PCTED$_i$, DISTANCE$_i$)

where, for the ith plot,

USE CHANGE is the loss from commercial forest land-use, if any, since the previous survey and J is a categorical variable indicating the specific type of loss, i.e., J = 0 for no land-use change, J=1 for losses to agricultural use, etc.

SITE is the site class, ranked from highest (1) to lowest (7);

SLOPE is the slope measured in degrees;

SZFOR is the size in acres of the contiguous forest area **surrounding** the plot:

PINE, UPHDWD, BHDWD are dummy variables representing difkrent **physiographic** types: softwoods (PINE), upland hardwoods **(UPHDWD)**, and bottomkind **hardwoods** (BHDWD);

ROAD1, ROAD2 and ROAD3 are dummy **variables for** the distance **from** the plot to the nearest paved **road:** one mile or less **(ROAD1),** between 1 and 3 **miles (ROAD2), and three miles or more (ROAD3);**

NF, PUB, **IND,** NIPF are dummy variables representing **ownership categories:** National Forests **(NF), other** public (PUB), industrial **(IND),** and **non-**industrial private **(NIPF);**

DEVELOP1, DEVELOP2, DEVELOP3 are dummy **variables representing distance from the plot to the nearest developed area of ten acres or more: less than** 1 mile **(DEVELOP1),** between 1 and 3 miles **(DEVELOP2),** and **three** miles or more **(DEVELOP3);**

INCOME is the median household **income** in 1989 **dollars for the surrounding Census Tract;**

POPDEN is the population density in people **per square mile;**

POPGROW is the population growth rate;

PCTED is the percentage of the population with a bachelor's degree or higher;

DISTANCE is the distance in kilometers from the plot to the **nearest** urban **center** of **30,000+** people.

EMPIRICAL MODEL

The probabilities of land-use change were estimated **using a multinomial logit model as follows:**

$$\Pr(Y_i = j) = \frac{e^{\beta_j' x_i}}{\sum_{k=0}^{J} e^{\beta_k' x_i}} \qquad 1)$$

The estimated equations generate a set of probabilities for the J + 1 land-use change outcomes for **FIA** plots with physical and demographic **characteristics,** x_i. As **written,** the model **is** indeterminate. **and** the **standard procedure** is to normalize 'the **system by assuming** $b_0 = 0$ **resulting in** the following **probabilities:**

$$\Pr(Y = j) = \frac{e^{\beta_j' x_i}}{1 + \sum_{k=1}^{J} e^{\beta_k' x_i}} \quad \text{forj} = 1,2,\ldots,J.$$

$$\Pr(Y = 0) = \frac{1}{1 + \sum_{k=1}^{J} e^{\beta_k' x_i}}. \qquad 2)$$

The estimated coefficients provide little insight into the relationships between the regressor variables and **the** outcomes so the marginal effects of **the regressors are also presented. These are readily computed from** the parameter estimates as **follows:**

$$\frac{\partial P_j}{\partial x_i} = P_j\left[\beta_j - \sum_k P_k \beta_k\right] \qquad 3)$$

The multinomial logit model defined by **equation 2 was estimated using maximum likelihood estimation** procedures. The statistical package ***LIMDEP Version 7*** **(Greene** 1995) was used to estimate the models. **The** dummy variables for **National Forests (NF), bottomland physiographic** type (BHDWD), and the distances to roads or developed areas less than a mile **(ROAD1, DEVELOP1)** were **omitted from the model to permit inversion of the X'X matrix. The coefficients for the corresponding dummy variables are interpreted as the change in the** multinomial **logit** function 'value **versus** the omitted variable.

RESULTS ANDDISCUSSION

During the period between the last two Forest Service FIA **surveys,** 97% of the plots classified **as commercial forest land in the prior survey remained in commercial forest land-uses,** 1.5% were converted to agricultural **uses,** 1.1% **were** converted-to urban uses *and 0.4% were* ***cohverted*** *to* ***miscellaneous*** *uses* **before the most recent survey.** Becauseoftheway the Forest Service **conducts** the **FIA** survey, plots do not **necessarily represent** equal acreages. However, the trends demonstrated above hold.

The results of the multinomial **logit** model **estimating** losses **from commercial** forest land are shown **in** Table 1. The **chi-square** test statistic for the **estimated model is 602 with 51 degrees of freedom,** which is **significant** at the 0.01 level. The null hypothesis, that the non-intercept **coefficients** are **jointly zero, is rejected.** Themodelpredictslossesto **commercial** forest **land better** than predictions based solely on the sample means. Marginal effects calculated at the mean of the data are presented in Table 2.

Conversions to agricultural uses account for the greatest loss to the commercial forest land base. Suitability for timber production use is a key factor determining the probability of conversion to agriculture. The better tbe land is for timber production, the less likely the tract will be converted to agricultural uses. The estimated coefficient for SITE is positive and significant. Recall that larger values for SITE represent lower site qualities; therefore, increases in the land's timber productive capability (lower SITE values) decreases the probability of conversion to agricultural use. Steep terrain is less likely to be converted to agricultural use as indicated by the negative and significant coefficient for SLOPE. As the size of the surrounding forest increases, the probability of conversion to agricultural uses falls. The estimated coefficient for SZFOR is negative and significant. In short, conversion to agriculture is more likely to occur on sites less suitable for timber production and where forestry is less dominant as evidenced by the smaller tract sizes. Increases in population density decrease the probability of conversion to agricultural uses as indicated by the negative and significant coefficient for POPDEN. Conversion to agricultural uses are more likely in rural, less populated areas. In the South, these areas have a history of agricultural use.

Conversions to urban uses account for the second largest loss to the commercial forest land base. SLOPE, PINE, NIPF, DEVELOP2, DEVELOP3, DISTANCE, POPDEN, PCTED, and SZFOR are all significant predictors of whether or not a plot will be converted to urban uses. Not surprisingly, 'these variables reflect either the plot's suitability for urban uses or are measures of the degree of urbanization. Conversions to urban uses are more likely to occur on relatively flat sites more suitable for construction as indicated by tbe uegative coefficient on SLOPE. Similarly, pine sites are more likely to be converted to urban uses as indicated by the positive and significant coefficient for PINE. Hardwood types are less suitable for urban uses because of drainage and/or flooding problems (bottomland hardwoods) or rough terrain (upland hardwood sites). compared to National Forests, NIPF owners can more readily sell or convert their lands to urban uses. The estimated coefficient on NIPF is . positive and significant. Factors reflecting the degree of urbanization axe lcey indicators of a plot's probability of conversion. Most conversion to urban uses occurs on the urbau fringe. Plots within one mile of built-up areas are more likely to be converted than are plots outside one mile as indicated by the negative and significant coefficients for DEVELOP1 and DEVELOP2. A similar *relationship holds* for distance from urbau centers of 30,000+. More remote plots are less likely to be converted to urban uses as indicated by the negative and significant coefficient for DISTANCE. Population density and education level are demographic factors reflecting the degree of urbanization Estimated coefficients for POPDEN and PCTED are positive and significant. Large forested tracts are less likely to be converted to urban uses. The estimated coefficient for SZFOR is negative and sign&ant. Forest fragmentation is more prevalent near urban areas, leading to smaller tract sizes so it is not surprising tbat decreasing tract size increases tbe probability of conversion to urbau uses.

Conversions from commercial forest land to miscellaneous uses are most likely to occur on poor sites, steep terrain, or bottomland hardwood sites. The estimated coefficients for SITE and SLOPE are positive and significant while tbat for PINE is negative and sign&ant. National Forest land is the most likely ownership to be converted to miscellaneous uses as indicated by the uegative coefficients on PUB, IND, and NIPF. Finally, plots one to three miles from an all-weather road are more likely to be converted to miscellaneous uses than are plots within one mile as indicated by the coefficient for'DEVELOP2. Conversions to miscellaneous. uses most frequently occur as a result of reclassification, for example, forest lands set aside as Wilderness Areas. Relatively inaccessible sites, e.g., steep terrain, bottomlands, or areas more than a mile from a road, are prime candidates for reclassification on National Forest lands.

This study has demonstrated that factors associated with land-use changes can be identified. Furthermore, the model developed iu this study more accurately predicts land-use change than merely projecting current trends. The next step is to obtain forecasted values for the exphnatory variables aud project land-use changes for the next survey period.

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