Timberland Dynamics and Hunting Demand: Special Reference to Alabama

by

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Abstract

Alabama's rural lands are experiencing changing trends over the years. During the past few decades, the state has experienced dramatic land use and land cover as well as timberland changes due to rapid economic and population growth. These changes, though meet economic needs, may have impact of timberland management and eventually on hunting demand. This thesis include two essays and an introduction to address the impact of socio-economic and population on land use changes, timberland management, and hunting demand in Alabama.

The first essay (Chapter 2) presents an empirical analysis of the contributing factors that drive land use and its changes in Alabama by applying a weighted regression and seemingly unrelated regression model using the Forestry Inventory and Analysis (FIA) 1990-2018 land use data. Results indicate that land use, land use changes, and timberland management follow the classic land use-theory that higher economic returns cause lands to transit to or remain in a certain use. Population growth is another factor that results in the land use transition. The importance of each driving factor and the policy implications are discussed.

The second essay (Chapter 3) addresses the issue of timberland characteristics and management on hunting in Alabama using a two-stage least square econometric procedure. Results indicate that animals hunted in Alabama are influenced by socio-economic, timberland management, and species composition. Comparing the structural model and reduced-form model estimates, the results indicate that there is magnification of the exogenous variables on hunting demand due to adjustment of species composition. The importance of each driving factor and the policy implications are discussed.

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List of Abbreviations

BEA	Bureau of Economic Analysis
CRP	Conservation Reserve Program
FIA	Forest Inventory and Analysis
LCC	Land Capability Class
NIPF	Non-Industrial Private Forest
NRCS	National Resources Conversion Service
USDA	United States Department of Agriculture

CHAPTER 1

I. BACKGROUND

The total land in the United States is approximately 2.3 billion acres of which forestlands and non-forestland consist of 33% and 67% respectively (Bigelow and Borchers, 2017). The United States forests are dynamic and vary depending on geographical location. Forest in the Pacific coast and south are either made up of pure hardwoods, multispecies mixtures, or softwoods whereas forest in the west are usually old growth (Jefferies & Timber, 2016). The forest provides economic, ecological, and cultural benefits. For instance, forest products makes up approximately 1.5% of U.S. economy and contributes about 5% of the total manufacturing output (Alvarez, 2017). This highlights the importance of forestlands in the U.S economy and gives a strong basis for their studies.

The total forestland in Alabama is about 23.1 million acres, out of which 23 million acres, representing more than 99%, are classified as timberlands (Alabama Forest Resource, 2018). This represents the third largest commercial forestland in U.S. (Alabama Forest Resource, 2018). Approximately 94% of Alabama's timberland is privately-owned while 6% is publicly owned (Alabama Forest Resource, 2018). The majority of forest landowners are non-industrial private forest (NIPF) owners who constitute about 87% of total landowners and own about 19 million acres of timberland (Alabama Forest Resource, 2018). Forest industries constitute about 6% of total landowners and own about 1 million acres of timberland ownership (Alabama Forest Resource, 2018).

The objectives of the different landowners differ which influence how timberland are managed (Dennis, 1989). Non-industrial private timberland landowners may decide to either maximize benefits from timber harvesting, forest amenities, or jointly from both (Birch, 1996;

Pattanayak et al., 2002) while forest industries are mostly interested in timber production for profit (Butler, 2008). The differences in timberland use objectives influence timber supply and the overall timberland management and characteristics.

Timberland acreages have increased about 8% from 1972 to 2000 in Alabama (Nagubadi and Zhang, 2005). Initially, hardwoods constitute the highest proportion of timberland in the 1970's, but current timberland outlook show that softwood acreage has increased and overtaken hardwoods (Alabama forest resource, 2018). The dominant hardwood in the 1970s might result from the ecological systems in Alabama where hardwood would become dominant species if not adequate human- interruption like forest fires. Factors such as timber stumpage prices, government policies, market development, technical innovations, timberland production cost, and institutional innovations are the major determinants of timberland changes in Alabama (Alig and Plantinga, 2004; Majumdar et al., 2009). In addition, factors such as demand for ecosystem services like hunting, bird watching, and fishing have also introduced dynamics both into species composition and acreage over the years (Alig et al., 2010). The relatively high transaction cost of ecosystem services might lead to timberland fragmentation and influence timberland ownership and management (Zhang et al., 2005).

Timberland dynamics arise due to landowner's decisions, preferences, and changes in the socio-economic environment (Wear et al., 2002). Studies show that the demand for fast growing softwood species to meet housing and pulp and paper demands have caused the introduction of genetically modified and fast-growing tree species to be actively managed in the U.S south (Wear et al., 2002). This decision has caused both private timberland owners and industries to invest into timberlands resulting in increased timberland acreage. Notwithstanding, the expansion of timberland are manifested mostly in softwood species like loblolly pine relative to hardwood species.

Furthermore, the demand for recreational services partly contributes to timberland dynamics. Non-industrial private forest owners sometimes value recreation, wildlife hunting, and nature protection ahead of timber harvesting (Butler and Leatherberry, 2004). Again, hunting fees charged by NIPF owners act as additional benefit apart from income from timber harvesting (Butler, 2008). Private timberland owners are encouraged to lease their lands for recreational purposes as liability laws protect them from lawsuits arising from recreational use (Zhang et al., 2006; Conway, 2002; Mingie et al., 2018).

As timberland dynamics emanate due to different socio-economic, market demands, and geographical factors, it is imperative to identify factors that are contributing to the current changes in the timberland outlook and evaluate their resultant effect on recreational demand in Alabama.

2. TIMBERLAND CHANGES STUDIES IN THE UNITED STATES

The literature section entails studies on timberland in the United States and factors contributing to their changes over the years. Additionally, literature on the effect of timberland dynamics on recreational services, particularly animals hunted are evaluated as well. The literature looks at different methods of evaluating timberland dynamics, factors contributing to timberland changes, and how these factors influence animal’s hunted.

Various studies have tried to evaluate timberland in the United States. Some studies compare the objective of non-industrial and private timberland owners as their decisions are critical for future timber supply. For instance, Nagubadi and Zhang (2005) show that higher forest returns stimulate increase in industrial timberland acreage as compared to non-industrial private landowners. In contrast, Newman and Wear (1993) shows that both NIPF and industrial landowners respond equally to price shocks. Both studies highlight that the difference between NIPF and forest industry owners are due to the value attached to growing stocks for recreational purposes by NIPF owners. The amenities and bequest values of timberlands are confirmed by studies of Conway et al. (2002), Pattanayak et al. (2002), and Hodges and Cubbage (1990). These studies highlight the importance of modelling recreational value as part of NIPF owner's objective functions. Alig et al. (2002) notes that the rise in non-timber value is due to increasing wealth of the population as people intend to purchase leisure goods when their income level increase. All these studies recognize the importance of modelling recreation as part of landowner's objective function. However, the quest for timberlands to supply both services sometimes lead to trade-offs, resulting in timberland dynamics. This is because timberland owners are sometimes torn between leaving their lands to grow into old-growth forest or to harvest. This tends to influence species composition and management in the long run.

Furthermore, researchers have developed temporal, spatial, and quantitative methods to explain the factors contributing to timberland use dynamics (Majumdar et al., 2007). Studies that seek to model these effects can broadly be categorized using two main methods namely the aggregate approach and spatial approach (Majumdar et al., 2007). Firstly, the aggregated approach adopts socio-economic variables and land characteristics to evaluate the impact of land use change on agriculture, forest, urban areas, rural land (Alig 1986; Hardie and Park 2007; Majumdar et al., 2007; Zhou, 2010) or different forest types such as softwood, hardwood, and mixed hardwood (Nagubadi and Zhang, 2005). Researches adopt this aggregated approach as the coefficients of the statistical models capture both temporal and spatial effects of land use. Some notable findings from the aggregated by Alig (1986) and Majumdar et al., (2007) showed that variables such as population density, income, government programs, and regional dummies contributed to land use changes and were significantly different from zero. Additionally, Nagubadi and Zhang (2005) and Hardie and Park (2007) showed that variables such as timber prices, population density, agricultural prices, and land quality influenced land use changes and are significantly different from zero. The second approach adopts explicit spatial model to determine land use changes using pixels, land parcels, or sample points (Bockstael, 1996; Chomitz and Gray, 1996; Munn and Evans, 1998; Wear and Bolstad 1998; Kline et al, 2001; Lubowski, 2002). This approach is useful as it models the dynamic nature of the land using change decisions (Majumdar et al, 2007). However, the spatial modelling approach is sometimes difficult as it is unable to evaluate spatial socio-demographic variables in the modelling process. Some notable findings from this approach by Bockstael (1996) showed that spatial pattern and distribution of land use had important environmental impact on water quality and biodiversity. Again, Lubowski (2002) indicated that economic gains and land quality have diverse effects on land use transitions at different transition probabilities. Lastly, Munn and Evans (1998) indicated that slope, forest size, income, educational level, and distance to city center had negative effect on the probability of converting forest for agricultural purposes.

Again, researchers adopt different statistical and econometric methods to evaluate land use changes in the United States. Alig et al. (2004), Kline and Alig (2001), and Hardie et al. (2000) employed econometric analysis to evaluate land use changes and deforestation using Forest Inventory and Analysis (FIA) surveys and United States Department of Agriculture (USDA) data. Alig et al. (1986) adopted a seemingly unrelated regression estimation method to evaluate forest acreage changes in the southeast of the United States. Similarly, Plantinga and Ahn (2000) adopted a Markov model of forest and agricultural land use to estimate land conversion and retention in U.S. South Central. Both studies use different techniques of econometric analysis to evaluate how socio-economic indicators impact timberland use in the U.S south. Nagubadi and Zhang (2005) employed a heteroskedastic logistic regression method to evaluate determinants of timberlands use by ownership and type in Georgia and Alabama. The heteroskedastic method has also been applied to evaluate how urbanization influence land use change in U.S south (Zhang and Nagubadi, 2007). Bockstael (1996) use a Markov spatial econometric procedure to model both economic and ecological attributes in Patuxent. Majumdar et al. (2009) analyzed how urbanization influence forest land use and land cover change using a nested logit approach. Polyakov et al. (2008) analyzed how urbanization and population pressure affect land use changes using a conditional multinomial logit method.

Another school of research focus on timberland fragmentation and parcelization across the United States. In these types of studies, researchers either adopted economic model or decide to use sociological tools as the basis of their studies. Some researchers tested their hypothesis using regression analysis. For instance, Sampson and Decoster (2000) analyzed land holding size, timberland management, and timberland management plan in conterminous United States using a sociological survey. In addition, Novak and Walton (2005) studied the impact of urban expansion on forestland by overlaying the 1992 National land Cover Database (NCLD) with urban expansion zones to determine the percentage of urban growth that occurred in forestland within the United States. The study showed that urban growth will have significant impact on forest management, environmental quality, and human well-being. Zhang et al. (2005) adopted a transaction cost approach to analyze how the increase in small holder non-industrial private forest ownerships influence land fragmentation and their implication on timberland management in the United States. The study noted that income, cost of timberland management, ecosystem service demand influence timberland greatly resulting in fragmentation.

Various socioeconomic variables are adopted in evaluating land use changes, particularly on timberland use in the United States. In all land use studies, population density variable is employed as it has the tendency to shift a particular land type into an alternative use (Zhang and Nagubadi, 2005; Alig et al., 2003; Wear et al., 2002). Timber and agricultural price variables are adopted to evaluate the association with different land use changes (Zhang et al., 2007; Alig, 1986; Alig et al., 2003; Hardie et al., 2000; Wear and Murray, 2004; Ahn et al., 2000). Real income is an important variable that is employed in all land use studies in the United States. Sometimes, real income from either agricultural land use or timberland use are a good representation for landowner's propensity to continue with that type of land use or convert to alternative uses. For instance, Hardie et al. (2000) adopted timber rent and agricultural income as a proxy for real income to evaluate land use changes. Alig (1986) adopted beef income, crop income, and timber income to analyze the major land use changes in the southeast United States. Land quality is an important variable in land use analysis. Hardie and Parks (1997) evaluated how heterogeneous land quality influence their location using a base model approach. Nagubadi and Zhang (2005) adopted land quality variables in evaluating timberland determinants in Georgia and Alabama.

3. RESEARCH GAPS AND STUDY OBJECTIVES

Previous studies have examined timberland use changes using economic model and empirical analysis (Alig 1986; Conway et al., 2003; Amacher, 2003) in evaluating harvesting and reforestation decisions (Birch, 2002), and landowner's preference (Kuuluvainen et al., 1996). However, there are limited studies relating to how ecosystem services demand such as hunting influence timberland characteristics and timberland management. In particular, studies have not explicitly addressed how the demand for hunting influence landowner's decision to invest in a particular timber species. In this study, because landowners are assumed to value recreation from their timberlands, the study assumes that species composition influence biodiversity, food sources for wildlife, and aesthetic value (Stribling et al., 1992).

Some studies assume that landowners are much interested in optimizing total benefits or utilities, so timberland is very integral in landowner's decision to offer land for hunting purposes. A partial equilibrium model is adopted to evaluate the hypothesis on how animals hunted is influenced by timberland dynamics and management type in Alabama as most studies adopt utility maximization approach. The study further evaluated factors that are contributing to land use changes in Alabama. Different studies have evaluated how socio-economic factor influence land use dynamics (Nagubadi and Zhang, 2005; Wear et al., 2004; Kline and Garber, 2004a; Hardie et al., 2000). An additional factor such as Gini index is adopted to evaluate how income disparity affect the distribution of land use shares in Alabama. Two econometric approaches namely weighted regression and seemingly unrelated regression procedures are adopted for the evaluation. This is because land use studies either one for their empirical analysis.

The objectives of this study are as follows:

1. To evaluate factors influencing land use changes and intensity of forestland management in Alabama.
2. To determine the effect of timberland characteristics and management on animals hunted in Alabama.

The study achieves its objectives by using an economic model to develop hypothesis and later empirically testing the hypothesis using secondary data from different sources (e.g. Bureau of Economic Analysis, United States Department of Agriculture, and United States Census Data).

The study is organized into two essays and represent two chapters of this dissertation. Each chapter comprises of relevant background and literature. Each study's methodology framework is described in detail and the results are presented and discussed along with research implications. The final chapter of the thesis summarize key results from each of the two research chapters. In addition, the overall contribution of the chapters is discussed along with conclusions. Possible suggestions or recommendations future works are expiated alongside the concluding remarks.

CHAPTER 2. EVALUATING FACTORS INFLUENCING LAND USE IN ALABAMA

ABSTRACT

The objectives of the study were to firstly evaluate factors influencing timberland, agricultural land, and urban land use, and secondly further investigate factors influencing timberland management in Alabama. A landowner's allocation model was adopted as theoretical basis. A land use statistic was evaluated to ascertain land changes using county level data from 1990 – 2018. A weighted and seemingly unrelated regression were used to analyze land changes and timberland management based on factors such as population density, income per capita, timber prices, agricultural products value, and Gini index. Results showed that timber prices, and Gini index had positive effect on timberland while population density, income per capita, high land quality, and agricultural products value showed negative effect. Population density, income per capita, agricultural products value, and high land quality had positive effect on agricultural land while Gini index, and timber prices showed negative effect. Population density, income per capita, Gini index, and agricultural products value had positive effect on urban land shares while timber price, and high land quality showed negative effect. On timberland management, results showed that income per capita, softwood price, and Gini index had a positive effect on actively managed timberland shares while population density, hardwood price, high land quality, and agricultural products value showed negative effect. Hardwood price, and agricultural products value showed positive effect on less actively managed timberland shares while population density, high land quality, income per capita, softwood price, and Gini index indicated negative effect. Results from this research are useful for policymakers interested in knowing the factors contributing to land use changes in Alabama.

1. INTRODUCTION

Land use change studies are important in the southern U.S. as the region has accounted for a greater number of land use conversions over the years. The changes are usually found in the conversion of one land use type to the other (Wear and Greis, 2012). The land conversions are usually from agricultural land to timberland, agricultural land to urban land, or timberland to urban land (Zhou, 2010). Factors such as population growth, technological changes, economic expansion, and government policies are known to influence land use changes (Majumdar, 2005). These changes impact on environmental, social, regional, and economic development. Hence, it is important to study current land use trends in Alabama and factors that account for their changes.

About 90% of the total land surface area in Alabama is considered rural land (Zhou, 2010). Rural lands consist of farmland, timberland and transition land. Studies show that there are changing trend in the different land use types over the years (Wear et al. 2002; Zhou, 2010). For instance, farmlands have been characterized by changing trends over the years leading to decrease in farmland areas (Nagubadi and Zhang, 2005). Again, timberland and urban land acreages have increased in different proportions over the years (Nagubadi and Zhang, 2005). The changing trends in Alabama’s land use types can be attributed to socio-economic and economic pressures (Wear et al. 2002). It is therefore imperative to determine factors contributing to these land use changes.

Previous studies have investigated how socio-economic factors influence land use changes (Nagubadi and Zhang, 2005; Ahn et al., 2000, Plantinga and Miller, 1999; Park and Murray, 1994). Either classical land theory models or a landowner’s allocation models are adopted as the theoretical basis for the land use change evaluation (Polyakov and Zhang, 2008;

Alig, 1986; Ahn et al., 1999). These studies determine how the land types are undergoing changes using factors such as population density, income, timber and agricultural prices, land quality, and government programs by adopting methods such as seemingly unrelated regression, modified linear regression, and logistic regression for the land use change estimation. For instance, Nagubadi and Zhang (2005) indicated that higher forestry return and population density increase timberland shares while good quality land decrease timberland shares. Ahn et al. (2000) showed that agricultural rent tends to increase the share of agricultural land relative to forestland. The study further showed that higher average quality land tends to have more agricultural land relative to forestland. Plantinga and Miller (1999) indicated that population density had a positive effect urban land relative to other land types in Maine, South Carolina, and Wisconsin. Additionally, agricultural revenue had positive effect on agricultural land shares in Maine, South Carolina, and Wisconsin.

The purpose of this chapter is to evaluate factors influencing the conversion among the different land use types in Alabama. In particular, the study is interested in how population density, household income per capita, income inequality, timber prices, and agricultural products value affect the conversion of timberland, agricultural land, and urban lands. The study further evaluates how these explanatory variables influence timberland management in Alabama. In this study, a landowner's allocation model is adopted as the theoretical basis. A seemingly unrelated regression and weighted regression methods are adopted for the estimating the signs and magnitude of the coefficients for the empirical analysis.

The remainder of the paper is organized as follows. Firstly, the study introduces the landowner's allocation model and the econometric procedure that are adopted for the study. In the next section, the study presents the results estimating the land use changes, interpret the signs, and discuss the important variables for land use changes. Finally, the last section contains the conclusion and recommendation for future works.

2. LANDOWNER'S ALLOCATION MODEL

Consider a risk-neutral landowner who seeks to maximize the utility, which is a present value of the future streams of return to a plot of land. The landowner has the option to allocate this plot to one of several possible uses. The study limits the land use to two choices (forestry or agriculture) excluding recreation following Ahn et al. (2000).

$$\max \sum_{t=0}^{T} \delta^{t}[R_t^f(a_t)v_t + R_t^a.(1-u_t)v_t] + \delta^{T+1}V_{T+1}(a_{T+1}) \quad (1)$$

Subject to

$$u_t = \{0,1\};\ v_t = \{0,1\};\ a_{t+1} = a_t u_t(1-v_t) + u_t; a_t \geq 0;\ R_t^f(0) = 0$$

At the start of period *t*, the landowner either decides to harvest ($v_t = 1$) or continue to grow ($v_t = 0$) on an existing stand or whether to allocate the parcel to forest ($u_t = 1$) or agriculture ($u_t = 0$) during the period. The age of the stand at the start of period t is denoted by a_t. The expected net returns from harvesting a stand of age a_t in period *t* is $R_t^f(a_t)$ and the expected net return to agriculture in period t is R_t^a. The land must be cleared of tree at the start of a period ($v_t = 1$) in order for agricultural crops to be grown for returns. Land conversion cost is assumed to be included in the net return measures. The δ is a constant discount factor and $V_{T+1}(a_{T+1})$ is the expected salvage value. The solution to this equation is given by Bellman as:

$$V_t(a_t) = \max[R_t^f(a_t)v_t + R_t^a(1-u_t)v_t + \delta V_{t+1}(a_{t+1})] \quad (2)$$

for $t = 0,1,..T$ and subject to the above constraints. $V_t(a_t)$ is interpreted as the value of the optimally managed parcel of land. In period t, the decision to allocate the land to either forestry or agriculture depends on the relative magnitudes of W_t^f and W_t^a which are defined as:

$$W_t^f = R_t^f(a_t)v_t^* + \delta V_{t+1}[a_t(1-v_t^*) + 1] \quad (3a)$$

$$W_t^a = R_t^f(a_t) + R_t^a + \delta V_{t+1}(0) \quad (3b)$$

where v_t^* is optimal harvesting decision; and $V_t(0)$ is bare land value. The landowner allocates the parcel to forestry in time t if $W_t^f \geq W_t^a$ and to agriculture if $W_t^a \geq W_t^f$.

Under certain conditions, the allocation decision reduces to simple comparison of the present discounted value of the net returns (Plantinga, 1996). If the landowner has static expectations regarding future net returns $\left(R_s^f(a_s) = R^f(t,a)\ and\ R_s^a = R^a(t)\ for\ s = t, t+1, \ldots, T\right)$, the land is initially bare $(a_t = 0)$, and the time horizon is infinitely long $(T = \infty)$, the expressions for $W_t^a\ and\ W_t^f$ becomes:

$$W^f(t) = \frac{\delta^{a*}}{1-\delta^{a*}} R^f(t, a^*) \quad (4a)$$

$$W^a(t) = \frac{1}{1-\delta} R^a(t) \quad (4b)$$

Where a^* is the optimal rotation age given the net returns $R^f(t, a^*)$.

The study introduce different land qualities into the equation as land quality affect land allocation (Hardie and Parks, 1997). An index j $(j = 1, \ldots . J)$ to the net returns measures in equation 4a and 4b, where J is the measure of land quality. Landowners $n_i(n_i = 1, \ldots N_i)$ in county $i(i = 1, \ldots I)$, where N_i is the number of landowners in the county i and I is the number of counties. Thus, the equation 4a and 4b becomes:

$$W_j^f(t, n_i) = \frac{\delta^{a*}}{1-\delta^{a*}} R^f(t, n_i, a^*) \quad (5a)$$

$$W_j^a(t, n_i) = \frac{1}{1-\delta} R^a(t, n_i) \quad (5b)$$

After incorporating land quality, the landowner's net returns becomes

$$W_j(t, n_i) = \max\left\{W_j^f(t, n_i, a^*), W_j^a(t, n_i)\right\} \quad (6)$$

The study assumes the landowner n_i holds $H_j(t, n_i)$ acreage of quality j land in time t. In order for the landowner to maximize total profits from the land, the landowner selects the area of land $h_{jk}(t, n_i) \geq 0$ to allocate to forestry $(k = 1)$ and agriculture $(k = 2)$ in period t to maximize

$$\sum_k W_j(t, n_i) h_{jk}(t, n_i) \text{ Subject to } \sum_k h_{jk}(t, n_i) = H_j(t, n_i) \quad (7)$$

The Kuhn-Tucker solution to (7) is the optimal allocation presented as follow

$$h^*_{jk}\left(W_j(t, n_i), n_i\right) = \left\{0, H_j(t, n_i)\right\} \quad (8)$$

This indicates that all land of quality j is allocated to either forestry or agriculture. The optimal share of the landowner's total land then becomes:

$$f_k(X(t, n_i), n_i) = \frac{1}{H(t,n_i)} \sum_{j=1}^{J} h^*_{jk}\left(W_j(t, n_i), n_i\right) \quad (9)$$

The optimal shares are confined to the unit interval and are determined implicitly by land quality factors and embedded in the net returns functions. Thus, the study define $X(t, n_i)$ as a vector of decision variables that include the J functions $W_j(t, n_i)$ and composite measures of land quality.

3. ECONOMETRIC SPECIFICATION

In this section, the econometric specification of the landowner's allocation problem is presented linearly in the form:

$$Y = X\beta + \varepsilon$$

Where Y and ε are $n \times 1$ vectors of responses and errors respectively. X is a full column rank fixed $n \times p$ matrix of regressors $(\text{rank}(X) = p < n)$ and $\beta = (\beta_1, \ldots\ldots \beta_p)'$ is a p-vector of unknown regression parameters, n being the sample size. The ith error, ε_i, has mean zero and variance $\delta_i^2 (0 < \delta_i^2 < \infty), i = 1, \ldots. n$. The errors are pairwise uncorrelated. That is $E(\varepsilon_i \varepsilon_j) = 0 \; \forall \; i \neq j$. Thus, the covariance matrix of ε is $\Omega = \text{diag}(\sigma_1^2, \ldots \sigma_n^2)$. The OLS estimator of the parameter vector β can be written in closed-form as $\hat{\beta} = (X^T X)^{-1} X^T Y$. Its covariance matrix is of the form $\psi = P \Omega P^T$, where P is $(X^T X)^{-1} X^T$. Under homoskedascity, $\psi = \sigma^2 (X^T X)^{-1}$ and hence ψ can be estimated as $\hat{\psi} = \hat{\sigma}^2(\mathrm{X^T X})^{-1}$, where $\hat{\sigma}^2 = \frac{(Y - X\widehat{\beta})}{(n-p)}$. Hence, $\hat{\sigma}^2$ is the common error variance, that is, $\sigma^2 = \sigma_1^2 = \cdots = \sigma_n^2$.

Since cross-sectional data is used for the estimation, there is a high probability that the variance of the errors are not constant over observations. In order to correct this anomaly, a weighted regression is adopted for the study where weights are treated as analytical weights. When the error ε are uncorrelated, but have unequal variance of the form $\sigma^2 V = \sigma^2 W^{-1} = \sigma^2 \mathrm{diag}(W_1^{-1}, \ldots\ldots, W_n^{-1})$. The weighted least square estimator of $\hat{\beta} = (X^T W X)^{-1} X^T W y \sim MVN(\beta, \sigma^2 (X^T W X)^{-1})$ which is the minimizer of $\sum_{i=1}^{n} W_i (y - \beta^T X)^2$.

Furthermore, the study further adopts a seemingly unrelated regression (SUR) method to estimate the model. The study adopts the associated hypothesis of land use acreage estimated with a system of equations. The equation estimates three broad land use types namely timberlands, agricultural lands, and urban lands. The timberlands management are categorized into two areas namely actively managed timberland and less actively managed timberland.

Following Alig (1986), we express the seemingly unrelated regression (Sur) model as a system of equations expressed as M equations in the form:

$$y_j = Z_j \delta_j + u_j$$
$$j = 1, \ldots\ldots, M$$

Where y_j is a NT * 1, Z_j is NT * k_j', $\delta_j = (a_j, \beta_j')$, β_j is $k_j * 1$ and $k_j' = k_j + 1$ with $u_j = Z_\mu \mu_j + v_j$ $j = 1, \ldots\ldots, M$; where Z_μ, μ_j, and v_j are random vectors with zero means and covariance matrix of the form $E\begin{pmatrix}\mu_j \\ v_j\end{pmatrix}(\mu_l'/v_l') = \begin{pmatrix}\sigma_{\mu jt}^2 I_N & 0 \\ 0 & \sigma_{\mu jt}^2 I_N\end{pmatrix}$, for $j = 1, \ldots\ldots, M$.

County data are obtained from different sources for the periods 1990, 2000, 2010, and 2018 to estimate the empirical model. Timberland data is obtained from the Forest Inventory and

Analysis (FIA) database. Timberland data for 2010 is not available so the observations were interpolated using the observations from the other three periods. Agricultural and urban land data are obtained from the agricultural census data.

Socio-economic and price data are obtained from different sources. Data on population from 1990, 2000, 2010, and 2018 are obtained from the United States Census Bureau (Census Data, 2020). Data on timber prices for 1990, 2000, 2010, and 2018 are obtained from the Timber Mart Quarterly report (Timber Mart report, 2020). Income and income inequality data are obtained from Bureau of Economic Analysis (BEA, 2019). Agricultural products value and land quality data are obtained from United States Department of Agriculture (USDA, 2019). Timber prices, agricultural products value, and income are deflated using the producer price index (PPI) and consumer price index (CPI) respectively for all commodities.

4. DATA AND LAND USE STATISTICS

Table 1 presents the summary of the description of the variables, their sources, and mean values for the empirical analysis. The variables employed are population density, median household income per capita, timber price, Gini index, hardwood price, softwood price, agricultural product value per acre, and land quality. Table 2 present the variables for estimating the empirical model with their respective changes over the period.

Table 1. Description, Data Sources, and Mean values of Variables for Land Use Acreages

Variable	Description	Source	Mean
POP-DENSITY	Total population per thousand acres of total land area of county	Census Data	133.49
INCAPITA	Real median household income per person in each county	BEA	0.55
P_TIM	Real average price of oak and pine saw timber price ($/MBF)	Timber mart-South	168.02
P_HW	Real oak saw timber price ($/MBF)	Timber mart-South	185.36
P_SW	Real pine saw timber price ($/MBF)	Timber mart-South	150.69
lq_1	Dummy for average high land quality	-	-
lq_2	Dummy for average low land quality	-	-
GINI	Gini index	BEA	0.46
APV	Real agricultural product value per acre ($/acre)	USDA	335.7
District 1	Dummy for counties in District 1	USDA	-
District 2	Dummy for counties in District 2	USDA	-
District 3	Dummy for counties in District 3	USDA	-
District 4	Dummy for counties in District 4	USDA	-
District 5	Dummy for counties in District 5	USDA	-
District 6	Dummy for counties in District 6	USDA	-

The average Land Capability Class (LCC) rating, lq1, and lq2 LCC ratings represent land quality that (USDA, 2009) are derived from county-level soil surveys and based on twelve soil characteristics (e.g., slope, permeability). The rating for a land parcel ranges from I to VIII, where I is the most productive land and VIII is the least productive. A county with a lower value of lq1 has higher quality land, on average and vice versa. Land quality is not indexed by time since measurements remain essentially constant over time. The average LCC was found to be Table 2. All counties with land quality between 0 – 4.1 are dummied 0, and those above 2 are dummied 1. The two land qualities are put together in Table 1 for clarification; however, only the high land quality was adopted for the study in order to prevent multi-collinearity problems. The letter "M" stands for 1,000 in the lumber industry, so "MBF" is the abbreviation for 1,000 board feet. The unit is available in the Timber-Mart south report, (2020). The definition of BF refers to a base volume that must be adjusted according to the specific type of lumber that is being measured.

The study evaluates the land use statistics for each district in Alabama. The counties are grouped into six districts based on USDA groupings (USDA, 2019). Table 2 shows the different districts in Alabama.

Table 2. List of counties and their respective districts, Alabama

Particulars	Name of counties	No. of counties
District 1	Colbert, Franklin, Lauderdale, Lawrence, Limestone, Madison, Marion, Morgan, Winston	9
District 2	Blount, Calhoun, Cherokee, Cleburne, Cullman, DeKalb, Etowah, Jackson, Marshall, St. Clair	10
District 3	Bibb, Chambers, Chilton, Clay, Coosa, Fayette, Jefferson, Lamar, Lee, Pickens, Randolph, Shelby, Talladega, Tallapoosa, Tuscaloosa, Walker	16
District 4	Autauga, Bullock, Dallas, Elmore, Greene, Hale, Lowndes, Macon, Marengo, Montgomery, Perry, Russell, Sumter	13
District 5	Baldwin, Butler, Choctaw, Clarke, Conecuh, Escambia, Mobile, Monroe, Washington Wilcox	10
District 6	Barbour, Coffee, Covington, Crenshaw, Dale, Geneva, Henry, Houston, Pike	9
Total		67

The counties are grouped into six districts. The number of counties in each district ranges from 9 to 16. The districts help to evaluate county dynamics on land use changes in Alabama.

Furthermore, the land use statistics are computed for the different land use types for all the six county districts in Alabama. This is to evaluate the changes trends in the different land use types in Alabama. The Table 3 shows the computed land use statistics for the six districts in Alabama.

Table 3. Land Use Types, Acreages, Shares, and Changes in Alabama (acres = 1000 units)

ALABAMA	Particulars	1990	% Land use share (1990)	2000	% Land use share (2000)	2010	% Land use share (2010)	2018	% Land use share (2018)	% Δ (1990-2000)	% Δ (2000-2010)	% Δ (2010-2018)	% Δ (1990-2018)
	Timberland	**21925.4**	**67.4**	**22743.2**	**70**	**22917.7**	**70.6**	**22997.3**	**70.8**	**3.7**	**0.7**	**0.3**	**4.8**
	Hardwood	*9947.3*	*30.6*	*10543.4*	*32.5*	*10095.2*	*31.1*	*9674.8*	*29.8*	*6.0*	*-4.3*	*-4.2*	*-2.8*
	Softwood	*7456.6*	*22.9*	*8006.1*	*24.6*	*9308.8*	*28.7*	*10407.2*	*32.0*	*7.4*	*16.3*	*11.8*	*39.6*
	Mixed hardwood	*4521.5*	*13.9*	*4193.7*	*12.9*	*3513.7*	*10.8*	*2915.3*	*9.0*	*-7.4*	*-16.2*	*-17.0*	*-35.5*
	Agriculture	10011.5	30.8	8794.8	27.1	8591.3	26.4	8469.7	26.1	-12.2	-2.3	-1.4	-15.4
	Urban	434.9	1.3	480.9	1.5	592.9	1.8	779.5	2.4	10.6	23.3	31.5	79.2
	Cons. Res.	118.9	0.4	471.8	1.5	388.8	1.2	244.2	0.8	296.7	-17.6	-37.2	105.4
	Total area	**32491**	**100.0**	**32491**	**100.0**	**32491**	**100.0**	**32491**	**100.0**				
DISTRICT 1													
	Timberland	**1976**	**52.5**	**2058.2**	**54.7**	**2080.4**	**55.3**	**2063.1**	**54.8**	**4.1**	**1.08**	**-0.8**	**4.4**
	Hardwood	*1272.9*	*33.8*	*1299.7*	*34.5*	*1272.7*	*34.2*	*1249*	*33.2*	*2.1*	*-2.1*	*-1.9*	*-1.9*
	Softwood	*430.4*	*11.4*	*431.9*	*11.5*	*522.6*	*13.9*	*591*	*15.7*	*0.3*	*21.0*	*13.1*	*37.3*
	Mixed hardwood	*272.7*	*7.2*	*326.6*	***8.7***	*269.8*	***7.2***	*222*	*5.9*	*19.8*	*-17.4*	*-17.7*	*-18.6*
	Agriculture	1718.5	45.6	1575.6	41.8	1550	41.2	1583	42	-8.3	-1.6	2.1	-7.9
	Urban	60.7	1.6	67.5	1.8	81.2	2.3	91.2	2.4	11.1	20.5	12.3	50.3
	Cons. Res.	10.0	0.3	63.9	1.7	46.5	1.2	27.9	0.7	537.9	-27.3	-40.0	178.4
	Total area	**3765.2**	**100**	**3765.2**	**100**	**3765.2**	**100**	**3765.2**	**100**				
DISTRICT 2													
	Timberland	**2529.2**	**57.6**	**2650.5**	**60.3**	**2562.7**	**58.3**	**2438**	**55.5**	**4.8**	**3.3**	**-4.9**	**-3.6**
	Hardwood	*1360.1*	*31*	*1555*	*31*	*1456.4*	*33.2*	*1364*	*31.1*	*14.3*	*-6.3*	*-6.3*	*0.3*
	Softwood	*653.7*	*14.9*	*568.8*	*14.9*	*659.9*	*15*	*707*	*16.1*	*-13.0*	*16.0*	*7.1*	*8.1*
	Mixed hardwood	*515.4*	*11.7*	*526.8*	*11.7*	*446.5*	*10.2*	*367*	*8.4*	*2.2*	*-15.2*	*-17.8*	*-28.8*
	Agriculture	1777.4	40.5	1629	40.5	1721.7	39.2	1819	41.4	-8.4	5.7	5.7	2.3
	Urban	81.5	1.9	76.2	1.9	88.6	2	117.2	2.7	-6.5	16.3	32.2	43.8
	Cons. Res.	4.8	0.1	37.7	0.1	19.9	0.5	18.7	0.4	680.9	-47.1	-6.4	286.6
	Total area	**4392.9**	**100**	**4392.9**	**100**	**4392.9**	**100**	**4392.9**	**100**				
DISTRICT 3													
	Timberland	**5726.6**	**75.5**	**5858.9**	**77.2**	**5848.8**	**77.1**	**5866.3**	**77.3**	**2.3**	**-0.2**	**0.3**	**2.4**
	Hardwood	*2659.5*	*35.1*	*2559.8*	*33.7*	*2416.7*	*31.9*	*2293.5*	*36.1*	*-3.7*	*-5.6*	*-5.1*	*-13.8*
	Softwood	*1742.7*	*23*	*2079.3*	*27.4*	*2415.6*	*31.8*	*2736.1*	*11.0*	*19.3*	*16.2*	*13.2*	*57.0*
	Mixed hardwood	*1324.4*	*17.5*	*1219.8*	*16.1*	*1016.5*	*13.4*	*836.6*	*20.4*	*-7.9*	*-16.7*	*-17.7*	*-36.8*
	Agriculture	1777.7	23.4	1617.3	21.3	1630.3	21.5	1549.7	20.4	-9.0	0.8	-4.9	-12.8

	Urban	76.5	1	78.4	1	89.4	1.2	155.9	2.1	2.4	14.1	74.4	103.7
	Cons. Res.	6.1	0.1	32.4	0.4	17.5	0.2	15.1	0.2	429.8	-46.1	-13.6	146.6
	Total area	**7589**	**100**	**7589**	**100**	**7589**	**100**	**7589**	**100**				
DISTRICT 4													
	Timberland	**3871.5**	**63.9**	**4253.6**	**70.2**	**4325.2**	**71.3**	**4402.1**	**72.6**	**9.9**	**1.7**	**1.8**	**13.7**
	Hardwood	*1676.1*	*27.6*	*1984*	*32.7*	*1958.0*	*32.3*	*1931.5*	*31.9*	*18.3*	*18.3*	*-1.3*	*15.2*
	Softwood	*1392.2*	*23*	*1557*	*25.7*	*1787.5*	*29.5*	*2001.5*	*33*	*11.8*	*11.8*	*14.8*	*43.8*
	Mixed hardwood	*803.2*	*13.2*	*713.0*	*11.8*	*579.6*	*9.6*	*468.9*	*7.7*	*-11.2*	*-11.2*	*-18.7*	*-41.6*
	Agriculture	2023.9	33.2	1536	25.3	1479.1	24.4	1375	22.7	-24.1	-24.1	-3.7	-32.1
	Urban	102.2	1.7	125.1	2.1	144.8	2.4	205.3	3.4	22.4	22.4	15.7	100.8
	Cons. Res.	65.3	1.1	148.7	2.5	113.8	1.9	80.5	1.3	127.6	127.6	-23.4	23.2
	Total area	**6062.9**	**100**	**6062.9**	**100**	**6062.9**	**100**	**6062.9**	**100**				
DISTRICT 5													
	Timberland	**5316**	**78.9**	**5223.1**	**77.5**	**5424.3**	**80.5**	**5521.0**	**81.9**	**-1.7**	**3.8**	**1.8**	**3.9**
	Hardwood	*1836.3*	*27.2*	*1930.1*	*28.6*	*1834.2*	*27.2*	*1733.8*	*25.7*	*5.1*	*-5.0*	*-5.5*	*-5.6*
	Softwood	*2359.2*	*35*	*2325.2*	*34.5*	*2777.2*	*41.2*	*3107.7*	*46.1*	*-1.4*	*19.4*	*11.9*	*31.7*
	Mixed hardwood	*1120.5*	*16.6*	*968.4*	*14.4*	*813.0*	*12.1*	*679.4*	*10.1*	*-13.6*	*-16.0*	*-16.4*	*-39.4*
	Agriculture	1369.1	20.3	1416.8	21	1218.8	18.1	1141.8	16.9	3.5	-14.0	-6.3	-16.6
	Urban	43.9	0.7	47.6	0.7	47.7	0.7	56.4	0.8	8.3	0.2	18.5	28.6
	Cons. Res.	12.8	0.2	53.6	0.8	51.0	0.8	22.4	0.3	320.3	-5.0	-51.6	75.7
	Total area	**6741.8**	**100**	**6741.8**	**100**	**6741.8**	**100**	**6741.8**	**100**				
DISTRICT 6													
	Timberland	**2506.1**	**63.6**	**2698.3**	**68.5**	**2691.4**	**68.3**	**2707.7**	**68.9**	**7.7**	**-0.3**	**0.6**	**8**
	Hardwood	*1142.4*	*29*	*1215*	*30.8*	*1157.3*	*29.4*	*1102.6*	*28*	*6.4*	*-4.8*	*-4.7*	*-3.5*
	Softwood	*878.4*	*22.3*	*1044*	*26.5*	*1145.9*	*29.1*	*1263.7*	*32.1*	*18.8*	*9.8*	*10.3*	*43.9*
	Mixed hardwood	*485.3*	*12.3*	*439.1*	*11.1*	*388.3*	*9.9*	*341.4*	*8.7*	*-9.5*	*-11.6*	*-12.1*	*-29.7*
	Agriculture	1344.9	34.1	1021	25.9	991.3	25.2	1016.2	25.8	-24.1	-2.9	2.5	-24.4
	Urban	70.0	1.8	86.2	2.2	117.1	3	139.6	3.5	23.1	35.8	16.4	94.6
	Cons. Res.	19.8	0.5	135.4	3.4	141.1	3.6	77.4	2	582.4	3.5	-44.7	290.3
	Total area	**3940.9**	**100**	**3940.9**	**100**	**3940.9**	**100**	**3940.9**	**100**				

The Δ is adopted to represent change as it is an accepted mathematical sign to represent change in quantities. The study did not compute the county level changes for the dependent variables as the state level is equally a good representation of changes in the county level.

Timberland has the highest land shares as compared to the other land uses in District 1. Timberlands occupy about 55% of total land and have increased about 4% from 1990 to 2018. Timberland is classified into hardwood, softwood, and mixed hardwood. Softwood shares have increased about 37% while hardwood and mixed hardwood shares have decreased about 2% and 19% respectively. Agricultural land occupies about 42% of the total land shares but have declined about 8% from 1990 to 2018. Urban land occupy about 3% of the total land and have increased about 50% from 1990 to 2018. Conservation Reserve program (CRP) land shares have decreased to 178% from 1990 to 2018.

Timberland has the highest land shares as compared to the other land uses in District 2. Timberlands occupy about 56% of total land but have decreased about 4% from 1990 to 2018. Softwood and hardwood land shares have increased about 8% and less than 1% respectively while mixed hardwood shares have decreased about 29%. Agricultural land shares occupy about 42% of the total land shares and have increased about 2% from 1990-2018. Urban land shares occupy about 3% of the total land and have increased about 44% from 1990 to 2018. Conservation Reserve program (CRP) land shares have decreased to 287% from 1990 to 2018 and occupy less than 1% of the total land shares.

Timberlands have the highest land shares as compared to the other land uses in District 3. Timberlands occupy about 77% of total land and have increased about 2% from 1990 to 2018. Softwood shares have increased about 57% while hardwood and mixed hardwood shares have decreased about 14% and 37% respectively. Agricultural lands occupy about 20% but have decreased about 13% from 1990 to 2018. Urban lands increased about 104% from 1990 to 2018 and occupy about 3% of the total land. Conservation Reserve program (CRP) land shares have decreased to 147% from 1990 to 2018 and occupy less than 1% of the total land shares.

Timberlands have the highest land shares as compared to the other land uses in District 4. Timberlands occupy about 73% of the total land and has increased about 14% from 1990 to 2018. Softwood and hardwood shares have increased about 44% and 15% respectively while mixed hardwood shares have decreased about 42%. Agricultural lands occupy about 23% of the total land but have decreased about 32% from 1990 to 2018. Urban lands occupy about 3% of the total land and have increased about 101% from 1990 to 2018. Conservation Reserve program (CRP) land shares have decreased to 23% from 1990 to 2018 and occupy about 1% of the total land shares.

Timberlands have the highest land shares as compared to the other land uses in District 5. Timberlands occupy about 82% of the total land acreage and has increased about 4% from 1990 to 2018. Softwood shares have increased about 32%, while hardwood and mixed hardwood shares have decreased about 6% and 39% respectively. Agricultural land occupy 17% of the total land acreage, but have decreased about 17% from 1990 to 2018. Urban lands occupy about 1% of the total land acreage, and have increased about 29% from 1990 to 2018. Conservation Reserve program (CRP) land shares have decreased to 76% from 1990 to 2018, and occupy less than 1% of the total land shares.

Timberlands have the highest land shares as compared to the other land uses in District 6. Timberlands occupy 69% of the total land and has increased about 8% from 1990 to 2018. Softwood shares have increased about 32%, while hardwood and mixed hardwood shares have decreased about 4% and 30% respectively. Agricultural lands occupy about 26% of the total land but have decreased about 24% from 1990 to 2018. Urban land occupy about 4% of the total land acreage and have increased about 95% from 1990 to 2018. Conservation Reserve program (CRP) land shares have decreased to 290% from 1990 to 2018 and occupy about 2% of the total land.

Timberland acreage in Alabama have increased about 5% from 1990 to 2018 (Table 3). In 1990, timberland areas comprised about 67% of the total land use area in Alabama. However, there has been gradual increment over the past years as timberlands currently occupy about 71% of the total land area in Alabama (Table 3). Most of the increment in timberland areas emanate from the expansion in softwood shares relative to the other timberland types (hardwood and mixed hardwood). Softwood plantations occupy about 45% and 32% of the total timberland area and total land area respectively (Table 3). The highest growth in softwood shares emanate from the central and southern counties in Alabama. The expansion of the timberland base in the region is due to the contraction of the agricultural land base (Alig et al., 1988). Additionally, the prospect of forest-based profits are important incentives for many private timberland owners (Ahn et al. 2003; Alabama Forest Resource, 2018). Timberland owners have invested into genetically modified and fast growing softwood species either for timber supply and bioenergy purposes (Wear et al. 2002; Mei et al., 2020 in press). This has accounted for the increasing softwood shares over the years as compared to hardwood shares.

Agricultural lands are experiencing downsizing over the years in Alabama. Agricultural lands have decreased about 15% and currently occupy about 26% of the total land acreage (Table 3). However, not all counties within the various districts have experienced decline in agricultural lands. Some counties in north Alabama (District 2) have experienced slight increase in agricultural areas over the years (Table 3). Apart from that, the rest of the district have experienced decline, especially counties in central and south Alabama. Fluctuations in agricultural land are as a resultant effect of decline in agricultural prices, government policies and a net increase in forest land areas (Alig et al., 1998). Government policies towards agriculture has also played a critical role in agricultural downsizing. For instance, the conservation reserve programs of the 1956 Soil Bank had an adverse effect on agricultural land in the south as it retired and converted productive agricultural lands for forest cover improvement (Alig et al., 2003).

Urban lands occupies about 2% of the total land shares in Alabama (Table 3). However, urban lands have experienced the highest growth of 79% increase from 1990 to 2018. The growth are prominent in central Alabama, and counties closer to the Atlanta areas. The increase in urban areas is due to population growth and the demand of land for developmental purposes like home sites, commercial and industrial sites, roads and highways, parks, airports, and other uses to meet the needs of the growing population (Alig et al. 2003).

Additionally, the observational changes for the dependent variables are computed for Alabama. This is computed to estimate the trends in the socio-economic environment and further serve as a basis for the land use estimation. Table 4 presents the changes in the dependent variables.

Table 4. Dependent Variables and their Changes, Alabama

Variables	**1990**	**2000**	**2010**	**2018**	**% Δ (1990-2000)**	**% Δ (2000-2010)**	**% Δ (2010-2018)**	**% Δ (1990-2018)**
Population density (persons/acre)	88.860	98.332	111.002	116.922	10.658	12.885	5.334	31.579
Income/capita ($/person)	0.2501	0.294	0.306	0.333	17.459	4.278	8.631	33.056
Timber price ($/MBF)	115.657	274.970	130.617	150.866	137.745	-52.498	15.503	30.442
Gini index	0.442	0.454	0.459	0.472	2.484	1.124	2.745	6.48
Agricultural prod. value/acre ($/acre)	99.141	214.203	246.942	247.412	116.058	15.284	0.190	149.554
Hardwood price ($/MBF)	98.244	280.809	147.537	214.851	185.827	-47.460	45.626	118.691
Softwood price ($/MBF)	133.07	269.132	113.698	86.881	102.247	-57.754	-23.586	-34.710

The Table 4 shows that population density has increased from 88 persons per acre of land to 117 persons per acre of land, representing about 32% increment from 1990 to 2018. This shows that the population in Alabama has increased over the years. Again, real median household income per capita has increased from $0.25 per person to $0.33 per person, representing about a 33% increment from 1990 to 2018. Gini index has increased from 0.44 to 0.47, representing about 6% increase in income disparity among the populace in Alabama. Timber price has increased about $116 per MBF to $150 per MBF, representing about 30% increment in total timber prices across Alabama. Hardwood price has increased from $98 per MBF to $214 per MBF, representing about 119% increment from 1990 to 2018. However, softwood price has experienced fluctuation in prices during the time under study. Softwood price has dropped form $133 per MBF to $87 per MBF, representing about a 35% decrease from 1990 to 2018. Agricultural products value has increased about $99 per acre to $116 per acre, representing about 150% increment from 1990 to 2018. This shows that the overall value of agricultural products have increased in Alabama. Agricultural products value is equivalent to total agricultural product sales and includes sales by the producers as well as the value of any shares received by partners, landlords, contractors, or others associated with the operation.

5. ESTIMATION RESULTS

5.1. Regression Results for Aggregate Land Use

The aggregate land shares are categorized into timberland, agricultural land, and urban land. Timberland comprise of hardwood, softwood, and mixed hardwood shares. Agricultural land shares comprise of cropland, pastureland, and other agricultural shares. Lastly, urban shares comprise mainly residential and industrial areas, inner roads and highways, and lands for developmental purposes.

Table 5 presents the estimated results for timberland, agricultural land, and urban land. The weighted regressions are estimated using R-squared, and adjusted R-squared values while the seemingly unrelated regressions are estimated using adjusted R-squared, and chi-square values. The dependent variables are expressed as shares of the total land.

Table 5. Regression Estimates of Aggregate Land Use by Types, Alabama (obs. = 268)

Variable/Statistic	Weighted regression						Seemingly unrelated regression		
	Timberland		Agriculture		Urban		Timberland	agriculture	Urban
	Coefficient	elasticities	Coefficient	elasticities	Coefficient	elasticities			
Constant	0.8303***	-	1.1586***	-	-0.0938***	-	1.37592***	-0.6215***	0.1477***
	(0.2489)		(0.2340)		(0.0203)		(0.2013)	(0.1919)	(0.0172)
POP_DENSITY	-0.0003***	-0.0575***	0.00026***	0.01750***	0.0035**	1.4135	-0.0574***	0.0641***	0.004***
	(0.0004)	(0.0119)	(0.0005)	(0.0191)	(0.0021)	(1.849)	-(0.0204)	(0.0194)	(0.0019)
INCAPITA	-0.1250***	-0.0949***	0.1189***	0.3536***	0.0012*	-0.1026	0.0335*	0.0270***	0.0044***
	(0.0219)	(0.0164)	(0.0237)	(0.0766)	(0.0023)	(0.2089)	(0.0215)	(0.0205)	(0.0021)
APV	-0.0043	-0.0339***	0.0164***	0.0326***	0.0035***	1.4901	-	0.01395*	-
	(0.0072)	(0.0599)	(0.0066)	(0.1589)	(0.0006)	(1.0734)		(0.0076)	
lq_1	-0.0744***	-	0.0686***	-	-0.0043***	-	-0.0669***	0.0647***	0.0012***
	(0.0038)		(0.0114)		(0.001)		(0.0114)	(0.0109)	(0.0012)
GINI	0.5379***	-0.6819***	-1.6629***	-3.3209***	0.1918***	8.1756	0.6096***	-0.8439***	0.1404***
	(0.2612)	(0.3035)	(0.5371)	(1.1176)	(0.0439)	(6.5742)	(0.2295)	(0.2188)	(0.026)
P_TIM	0.0092***	0.0740***	-0.0001	-0.0644	-0.0032 ***	-1.4802	0.0021**	-	-
	(0.0166)	(0.1242)	(0.0001)	(0.0616)	(0.0013)	(0.1997)	(0.0013)		
District 2	0.05916***	-	-0.0498**	-	-0.0025**	-	0.064***	-0.0573***	-0.0007
	(0.0206)		(0.0197)		(0.0012)		(0.0195)	(0.0186)	(0.0017)
District 3	0.1647***	-	-0.1572***	-	-0.0025	-	0.1728***	-0.1578***	-0.0076***
	(0.0202)		(0.0193)		(0.0015)		(0.0183)	(0.0175)	(0.0016)
District 4	0.0463**	-	-0.0639***	-	0.0107***	-	0.0430***	-0.0519***	0.0041**
	(0.0218)		(0.0209)		(0.0022)		(.0212374	(0.0202)	(0.0018)
District 5	0.1997***	-	-0.1868***	-	-0.0067***	-	0.1861***	-0.1638***	-0.0151***
	(0.0635)		(0.0208)		(0.003)		(0.024)	(0.0227)	(0.002)
District 6	0.0635***	-	-0.0795***	-	0.0059**	-	0.0629***	-0.0783***	0.0049***
	(0.0210)		(0.0201)		(0.0031)		(0.0201)	(0.0192)	(0.0017)
R-squared	0.647		0.652		0.414		0.6624	0.6700	0.5030
Adj. R-squared	0.637		0.637		0.389		-	-	-
Root MSE	0.088		0.084		0.007		0.0846	0.0806	0.0072
Chi-square	---		---		---		524.84	544.70	268.22

Notes: *, **, *** indicate significance level at 0.1, 0.05, and 0.01 probabilities. Figures in parenthesis are standard errors. The coefficient and elasticities standard errors are calculated using delta method

5.1.1 Timberland estimation results

The timberland results are satisfactory in that most of the signs of the estimated coefficients agree with a prior expectation and most are statistically and significantly different from zero at 5% level. (Table 5). For the weighted regression, the R-squared and Adjusted R-squared values are 0.647 and 0.637 respectively while the adjusted R-square and Chi-square value for the Sur estimates are 0.662 and 524.84 respectively. The standard errors of the coefficients are estimated using delta method. The dependent variables exhibited different significant levels after the estimation.

The results show that coefficients of population density has a negative and significant effect on timberland shares in Alabama. This is an expected result and consistent with findings of other studies (Wear, 1999). The inverse relationship between population density and timberland shares emanates from the conversion of timberland for developmental purposes like roads, highways, and buildings when population rises. This emphasizes the finding of Alig (1986) that population density increase are consistent with land pressure in the U.S southeast. Again, studies show that population density results in the higher probability of converting timberlands for developmental and urban purposes, thus confirming the results obtained in the study (Polykov and Zhang, 2008; Ahn et al., 2001).

Additionally, the results show that coefficients of real timber stumpage price has a positive and significant effect on timberland shares, all else equal. The positive relationship is an expected result and consistent with findings of other studies (Nagudabi and Zhang, 2005; Wear, 2002; Ahn et al., 2000). Increments in timber stumpage prices have the potential to cause the conversion of other land use types for timber establishment.

Furthermore, the results show that Gini index has a positive and significant effect on timberland shares. The positive relationship is an expected result and consistent with findings of other studies (Huang et al., 2019; Pan et al., 2009). This indicates that increasing wealth disparities influence landowners to invest in timberlands. This is consistent with the 'permanent hypothesis income' as affluent landowners may invest into timberlands as it offers a productive financial and investment portfolio with lesser risk. Higher income disparities often mean that lower wage labor can be hired in forest plantation and other forest industry and attract forest investment.

Real median household income per capita has a negative and significant effect on timberland shares in Alabama. This is an expected result as studies have shown that decreasing income plays important role in retiring most forest lands from timberland investment and wood production. This brings about timberland fragmentation and parcelization as landowners prefer to owe small land holding sizes for non-timber purposes such as recreation rather than for timber production (Zhang et al., 2005; Nagubadi and Zhang, 2005).

Negative relationship between high land quality and timberland shares is expected, and consistent with the hypothesis that lands with lower quality are mostly dedicated for timber establishment purposes. Similarly, the results are consistent with Nagubadi and Zhang (2005) that average lower land quality promote tree planting initiatives in Georgia and Alabama.

The regional dummies indicate positive and significant effect on timberland shares. The coefficients of the regional dummies show that counties in District 5 are critical on timberland shares due to their large coefficient value (Table 5). Counties in District 4 contributes the least to timberland shares due to the small coefficient value (Table 5).

5.1.2 Agricultural land estimation results

The agricultural land results are satisfactory in that most of the signs of the estimated coefficients agree with a prior expectation and most are statistically and significantly different from zero at 5% level. (Table 5). For the weighted regression, the R-squared and adjusted R-squared values are 0.652 and 0.637 respectively while the adjusted R-square and Chi-square value for the Sur estimates are 0.67 and 544.7 respectively. The standard errors of the coefficients are estimated using the delta method. The dependent variables exhibited different significant levels after the estimation.

Estimation results for population density and agricultural land shares is positive relationship. This is an expected result and consistent with a prior findings of previous studies (Nagubadi and Zhang, 2005). Studies show that increase in population density in Alabama and Georgia tends to increase agricultural land use shares base in the two states (Nagubadi and Zhang, 2005). This confirms the findings of this study as the population density has a positive influence on agricultural land shares in Alabama.

As expected, real agricultural products value per acre has a positive effect on agricultural land shares. The finding is consistent with a prior expectations of previous studies (Ahn et al., 2000). This indicates that increasing agricultural product value has the potential to influence the conversion of other land use types for agricultural purposes (Majumdar et al., 2005).

Similarly, real median household income has a positive and significant effect on agricultural land shares. This is an expected result and confirms to a prior expectation of previous studies (Ahn et al. 2000; Plantinga and Mauldin, 2001). Perhaps, the short growth cycles of the major agricultural farm products such as legumes, soybeans, and groundnuts serve as a short to medium term investment portfolio for farmers and low income earners in Alabama.

Furthermore, the results show that there is a negative and significant effect of Gini index on agriculture land shares. The result is consistent with other previous studies (Huang, 2019). Gini index indicate that the demand for timberland and urban land types tends to grow faster as compared to agricultural land shares (Otsuka, 2013). Thus, increase in wealth tends to shift demand from agricultural land to other land use types such as timberlands. This explain the difference in coefficients signs relating to timberland and agricultural land shares on Gini index.

The results for land quality shows that lands with high quality has a positive influence on agricultural land use shares. This is an expected results and consistent with previous studies where land with good qualities have positive effect on agricultural land (Nagubadi and Zhang, 2005; Plantinga et al., 1999; Ahn and Plantinga, 2002). Landowners are likely to cultivate their rich and fertile lands with agricultural products.

Real timber stumpage price has a negative and significant effect on agricultural land shares. Timber price increment are estimated to cause a decline in agricultural land and further cause the conversion of agricultural lands to timberlands and other land use forms (Wear, 2002).

The regional dummies indicate a negative and significant effect on agricultural land shares. The coefficients of the regional dummies show that counties in District 2 have significant impact on agricultural shares due to their large coefficient value (Table 5). Counties in District 5 contributes the least to agricultural land shares due to the small coefficient value (Table 5).

5.1.3 Urban land estimation results

The urban land results are satisfactory in that most of the signs of the estimated coefficients agree with a prior expectation and most are statistically and significantly different from zero at 5% level. (Table 5). For the weighted regression, the R-squared and adjusted R-squared values are 0.414 and 0.389 respectively while the adjusted R-square and Chi-square value for the Sur estimates are 0.50 and 268 respectively. The standard errors of the coefficients are estimated using the delta method. The dependent variables exhibited different significant levels after the estimation.

As expected, population density has positive and significant effect on urban land share. The result is consistent with previous studies (Alig et al., 2003; Majumbar et al., 2009; Hardie et al., 2000). Studies have projected an increase in population within the Piedmont regions and other part of the Southeast. This has increased the demand for more lands for building and developmental projects. This further confirms the descriptive statistics findings for urban land shares. Alabama's population has increased about 32% from 2000 to 2018 (Table4.1), necessitating the demand of land for developmental purposes.

Additionally, the results show that there is a positive and significant effect of real median household income per capita on urban land shares. This is an expected results and consistent with earlier research findings (Alig and Healy, 1987). Empirical land use model studies indicate that land development rates are positively influenced by rise in income levels (Wear and Greis, 2012; USDA NRCS 2001). In particular, investment into urban lands are expected when income levels rise as urban lands are assumed to be the highest form of land use (Hardie et al., 2000).

Gini index has a positive and significant effect on urban land shares. This is an expected result and consistent with findings of previous studies (Watson 2009; Massey and Fischer, 2003). Increasing income disparity may influence residential segregation causing the need to establish more urban areas (Watson, 2009). Particularly, widening income disparity has the tendency to separate low- and high-income families from staying in the same neighborhood. When this happens, low income families may migrate into metropolitan areas thereby mounts pressure on existing facilities, and creating artificial demand for land for development.

Again, high land quality has a negative and significant effect on urban land shares. This is an expected result and consistent with a prior studies as land with higher qualities respond negatively in landowner's decision in converting other land types for urban purposes (Zhang and Nagubadi, 2005; Hardie et al., 2000).

Furthermore, the results show a positive and significant effect between real agricultural products value and urban land shares. The result is consistent with other previous studies (Alig et al., 2003). Studies show that urban sprawl unto agricultural lands have a possible positive influence on agricultural markets as farmers may shift their market commodity to satisfy the nearby market demand (Alig et al., 2003). Alig et al. (2003) showed that 15% of US farmlands consider urban lands to significantly influence the market value of their agricultural products.

The regional dummies indicate that counties in district 4 and 6 respond positively and significantly to urban land shares while counties in district 2, 3, and 5 respond negatively to urban land shares. This indicates that the regional dummies respond unequally to urban land conversion.

5.2. Regression Results for Timberland Management

The study further evaluates how the independent variables affect the intensity of timberland management in Alabama. The management structures are categorized into actively managed timberland and less actively managed timberland for the sake of simplicity.

Table 6. Timberland Management Classification

Categories	Description and notes
Actively managed timberland	Comprise mainly of plantation forest such as Loblolly pine, but includes some actively managed pine species such as shortleaf and longleaf pine.
Less actively managed timberland	Comprise mainly of hardwoods, and mixed hardwood pine shares that occur primarily by natural regeneration.

Less actively managed timberlands comprise of timberlands that are not artificially propagated using any silvicultural techniques, but regenerate naturally. This is very typical of hardwood species such as oak-gum-cypress, elm-ash-cottonwood, oak-hickory as well as pine species that are found within typical hardwood timberland stands. Hardwoods and mixed hardwoods make up about 42% and 12% respectively of the total timber landscape (Alabama Forest Report, 2018). Mixed hardwood stands are artifact of past management, often a lack of management and a landowner gets what nature provides. Pine shares among mixed hardwood occur by natural regeneration as most landowners do not plant pine among hardwood stands.

Actively managed timberland, predominantly softwood plantations, comprise mainly of artificially propagated softwoods, using genetically improved varieties that are fast growing with shorter rotation cycle (Hartsell and Conner, 2013). Softwood timberland accounts for about 48% of the total timberland shares in Alabama (Alabama Forest report, 2018). Out of that, loblolly pine accounts for about 36% of the total softwoods while species such as longleaf pine, and shortleaf pine account for about 9% (Alabama Forest report 2018). Additionally, softwood timberlands are actively managed and subjected to regular silvicultural management practices (Zobrist et al., 2005).

Table 7 presents the estimated results for timberland management. The weighted regressions are estimated using R-squared, and adjusted R-squared while the seemingly unrelated regressions are estimated using adjusted R-squared, and chi-square. The dependent variables are expressed as shares of the total land use

Table 7. Regression Estimates for Timberland Management (obs. = 268)

Variable	Weighted regression				Seemingly unrelated regression	
	Actively managed		Less actively managed		Actively managed	Less actively managed
	Coefficient	elasticities	Coefficient	elasticities	Coefficient	Coefficient
Constant	4.3116***	-	-0.8157***	-	1.5161***	-0.6256***
	(0.8315)		(0.3931)		(0.2077)	(0.2285)
POP_DENSITY	-0.0470***	-0.7579*	-0.0159**	-0.4087**	-0.0269*	-0.0318**
	(0.0094)	(3.5308)	(0.0083)	(0.2142)	(0.0186)	(0.0158)
INCAPITA	0.0455*	0.010*	-0.0314	-0.0056	0.0206*	-0.0123
	(0.0441)	(0.0620)	(0.0575)	(0.0103)	(0.0196)	(0.0167)
P_HW	-0.1886***	-2.768*	0.0671***	1.3393**	-	0.0384***
	(0.0537)	(0.782)	(0.0252)	(0.5045)		(0.0124)
P_SW	0.1859***	2.3035*	-0.1219	0.2109	0.0204*	-
	(0.0485)	(0.274)	(0.2495)	(0.3665)	(0.013)	
APV	-0.0073*	-0.0739*	0.0391***	0.5498**	-0.0042*	0.0015*
	(0.0047)	(0.4049)	(0.0031)	(0.0448)	(0.006)	(0.0051)
lq_1	-0.0138	-	-0.0683	-	-0.020**	-0.0525***
	(0.0097)		(0.0084)		(0.0104)	(0.0088)
GINI	4.9452***	-9.332*	-1.4025***	4.2798**	1.395***	-1.3264***
	(0.9961)	(1.796)	(0.4622)	(1.4108)	(0.2516)	(0.2227)
District 2	0.0836***	-	0.060***	-	0.04181**	0.0242
	(0.0128)		(0.0105)		(0.0177)	(0.0151)
District 3	0.1673***	-	0.0251***	-	0.1422***	0.0262**
	(0.0131)		(0.0103)		(0.0173)	(0.0148)
District 4	0.0653***	-	-0.0586***	-	0.0991***	-0.0614***
	(0.0158)		(0.0125)		(0.0196)	(0.0167)
District 5	0.2279***	-	-0.1182***	-	0.2310***	-0.0484***
	(0.0131)		(0.0109)		(0.0221)	(0.0188)
District 6	0.1119***	-	-0.0832	-	0.1081***	-0.0463***
	(0.0185)		(0.0191)		(0.0181)	(0.0154)
R-squared	0.776		0.657		-	-
Adj. R-squared	0.766		0.641		0.626	0.4165
Root MSE	0.041		0.018		0.076	0.0648

Notes: *, **, *** indicate significance level at 0.10, 0.05, and 0.01 probability. Figures in parenthesis are standard errors. The coefficient and elasticities standard errors are calculated using delta method

5.2.1 Actively Managed Timberland

The actively managed timberland results are satisfactory in that most of the signs of the estimated coefficients agree with a prior expectation and most are significantly different from zero at 5% level. (Table 7). The R-squared and adjusted R-squared values are 0.776 and 0.766 respectively for the weighted regression while the adjusted R-square value for the Sur estimates is 0.625. The standard errors of the coefficients are estimated using delta method. The dependent variables exhibited different significant levels after the estimation.

Population density has a negative and significant effect on actively managed timberland. This is an expected result and consistent with a prior studies (Lambin and Geist, 2005; Wear et al., 1999). Studies show that increase in population density is characterized by a decrease in overall timberland areas (Drummond and Loveland, 2010). The possible reason maybe that actively managed timberlands are converted for infrastructure and urban development purposes. The study shows that Alabama's population has increased about 32% from 1990 to 2018, thus necessitating the demand of land for development.

As expected, real median household income per capita has positive and significant effect on actively managed timberland shares. This result is consistent with Zhang et al. (2000) that increase in real income has the potential to encourage landowners to seek assistance to actively manage commercial timberland. Additionally, Zhang and Mehmood (2001) show that commercial timberland owners in Alabama seek assistance from consulting foresters as well as industrial foresters on tree planting, timber harvesting, and other forest related activities when their income levels rise.

A positive relationship between real softwood price and actively managed timberland is expected, consistent with the hypothesis that increase in softwood price is likely to have a positive effect on actively managed timberland. Softwood, particularly pine plantations comprise the majority shares of actively managed timberland in Alabama. Thus, an increment in softwood prices, particularly pine may encourage investment into seeking assistance for intensive management practices by timberland owners.

Again, the results show that there is a negative and slightly significant effect of real agricultural products value on actively managed timberland shares. This is an expected result and consistent with previous research studies (Zhang et al. 2000). The results imply that agricultural products compete for land with actively managed timberland. Thus, increasing agricultural value has the tendency to influence landowners to shift managed timberland for agricultural purposes.

Furthermore, there is a negative and significant relationship between real hardwood price and actively managed timberland. This is an expected result and consistent with the study's hypothesis. Actively managed timberland influence the conversion of natural regenerative timberlands, particularly hardwood and mixed hardwood stands into actively managed softwood plantations in the U.S south (Adams et al., 1996). The high propensity to convert all timberlands into actively managed softwood plantations has a dire consequences of hardwood demand as consumer are indirectly coerced to consume softwood products.

Gini index has a positive and significant effect on actively managed timberland. This is an expected result and consistent with a prior studies (Zhang, 2000; Adams et al., 1996). Studies show that landowner who earn more than $50,000 a year in Alabama are able to afford the cost of forest management services relative to timberland owners who earn lesser than $50,000 (Zhang and Mehmood, 2001). This shows that income disparity is an important factor in timberland management, indicating that rich landowners have the option to engage in active timberland management relative to less rich timberland owners.

High land quality has a negative and significant effect on actively managed timberland in Alabama. This is an expected result and consistent with the study's hypothesis. In general terms, timberlands have a negative relationship with land possessing high quality, especially in Alabama and Georgia (Nagubadi and Zhang, 2005).

The regional dummies coefficients show that there is a positive association between actively managed timberland and the county districts. All the counties in Alabama respond positively to actively managed timberland in Alabama. However, the magnitude of response differ for each county district (Table 7).

5.2.2 Less actively managed Timberland

The less actively managed timberland results are satisfactory in that most of the signs of the estimated coefficients agree with a prior expectation and most are significantly different from zero at 5% level. (Table 5.3). The R-squared and Adjusted R-squared values are 0.657 and 0.641 respectively for the weighted regression while the adjusted R-square value for the Sur estimates is 0.416. The standard errors of the coefficients are estimated using delta method. The dependent variables exhibited different significant levels after the estimation.

Population density has a negative and significant effect on less actively managed timberland. This is an expected result and consistent with a prior studies (Zhang, 2000). Studies show that population density rise is characterized by a decrease in forest cover (Drummond and Loveland, 2010). This leads to decline in timberland areas, especially less actively managed timberland shares.

The results show that there is a negative and significant effect of real median household income per capita on less actively managed timberland shares in Alabama. Timberland management studies in Alabama show that there is a low propensity for landowners to invest in timberland management when returns from forest are low (Henry and Bliss, 1994).

The results show that hardwood price has a positive and significant effect on less actively managed timberland. This is an expected result as most non-actively timberland comprise of timber species that are mostly hardwood. Thus, landowners are encouraged to convert their lands into hardwood stands as they are usually less actively managed and occur mainly due to natural regeneration.

Furthermore, the results show that softwood price has a negative and significant effect on less actively managed timberland. Softwood shares among less actively managed timberland are as a result of natural regeneration that emanates from natural seed dispersion and often a lack of management as landowner gets what nature provides.

Gini index has a negative and significant effect on less actively managed timberland. This is an expected result and consistent with a prior studies (Zhang, 2000; Wear et al., 1999). Timberland owners have shown a strong propensity to convert less actively managed timberland into planted pine after harvesting. This explains that there is strong investment towards actively managed timberlands as compared to less actively managed timberlands.

High land quality has a negative and significant effect on less actively managed timberland in Alabama. This is an expected result and consistent with previous studies (Nagubadi and Zhang, 2005). In general terms, timberlands have a negative relationship with land possessing high quality, especially in Alabama and Georgia (Nagubadi and Zhang, 2005).

The results show that there is a positive and significant effect of real agricultural products value on less actively managed timberland shares. A unit increase in real agricultural products value is associated with a 0.0391 increase in less actively managed timberland, all else equal.

This is an expected result and consistent with the study's hypothesis. The results imply that agricultural products and less actively managed timberland species are associated. The study shows that counties with higher shares of timber species that are less actively managed also tend to have a higher share of agricultural land.

The regional dummies coefficients show both positive and negative association between less actively managed timberland and the county districts. Counties in North Alabama respond positively to less actively managed timberland while counties in Central and South Alabama respond negatively to less actively managed timberland. Most timberland in North Alabama comprise of mainly hardwood species that occur through natural regeneration, exhibiting low silvicultural management. However, counties in central and south Alabama have growing shares of loblolly pine plantations that require active management.

6. CONCLUSION

In response to the persistent land use dynamics occurring in Alabama, the study analyzes factors that influence the conversion of lands for alternative use. The land types are categorized into timberland, agricultural land, and urban land. Additionally, timberlands are categorized into actively managed and less actively managed timberlands. A weighted and seemingly unrelated regression are employed to estimate the effect of population density, real timber stumpage price, real median household income per capita, Gini index, real agricultural product value per acre, land quality, and regional dummies on timberland, agricultural land, and urban land shares in Alabama. Secondly, the study evaluates the effect of population density, real hardwood and softwood stumpage price, real median household income per capita, Gini index, real agricultural product value per acre, land quality, and regional dummies on timberland management in Alabama using both weighted and seemingly unrelated regression.

Our results indicate that timberland shares are the dominant land use type in Alabama. The regression results show that timberland shares are positively related real timber stumpage price, low quality land, Gini index, and all the district dummies. However, there is a negative relationship between population density, real median household income per capita, and real agricultural product value per acre. The coefficients for the weighted regression and seemingly unrelated regression have the same direction, but differ in coefficient magnitudes.

Agricultural land has the second largest land shares in Alabama. The results indicate that agricultural land shares are positively related to population density, real household income per capita, real agricultural product value per acre, and high land quality. However, variables such as Gini index, real timber stumpage price, and the district dummies have a negative relationship with agricultural land use shares. The coefficients for weighted and seemingly unrelated regression has the same direction, but differ in coefficient magnitudes.

The study shows that urban lands have the smallest land shares in Alabama. The results indicate that urban land shares are positively related to population density, real household income per capita, Gini index, real agricultural product value per acre and dummies for counties in district 4 and 6. However, variables such as real timber stumpage price, high land quality, and dummies in counties 2, 3, and 5 have a negative relationship with urban land use shares. The coefficients for weighted and seemingly unrelated regression has the same direction, but differ in coefficient magnitudes.

In evaluating timberland management, the study shows that variables such as real median household income per capita, real softwood price, low land quality, Gini index, and district dummies are positively related to actively managed timberland shares. However, variables such as population density, real hardwood price, and real agricultural products value per acre are negatively related to actively managed timberland shares. Again, variables such as real hardwood price, real agricultural products value per acre, and low land quality have a positive relationship with less actively managed timberland shares. Population density, real median household income per capita, real softwood price, Gini index, and counties in district 4, 5, and 6 have are negatively related to less actively managed timberland shares in Alabama. Coefficients signs are the same, but differ in magnitude.

The study has implication for policies for better allocation of different land use types and timberland management in Alabama. Increment in population density has a dire consequences on timber supply, especially actively managed timberlands so there is the need to institute measures to regulate urban expansion into timberland areas in Alabama. Again, the demand for fast genetically modified and growing trees has influenced the timberland scape as agricultural land are converted for planted plantation, particularly, loblolly pine plantation. This situation has future implications on species composition and the supply of agricultural products. The level of intensity of timber management and investment, and land devoted to timber growing over time are determined by mostly non-industrial private timberland owners. Therefore, land use estimation must be strongly linked with timber inventory projections, investment modelling in determining aggregate timber supply.

From the study findings, one can draw few universal conclusions about the response of land use changes to socio-economic and price determinants as the econometric land use model was an effective tool. However, due to limited data on land rent, the study is not allowed to draw conclusive and exhaustive testing of the underlying land use changes Alabama. Thus, the results of this study should be interpreted with caution and should not be generalized for all land use changes. Again, both spatial and temporal land use model and changes are required to fully understand the dynamics of land use change. As this study focused on temporal and aggregate land use model approach without any emphasis on spatial approach, the results of this study should be interpreted with respect with to only aggregate land use.

For future works, researchers can develop a comprehensive land use model that seek to address challenges of biodiversity preservation, water quality protection, recreational demand, and timber supply when evaluating changes in land uses. Furthermore, researchers can integrate both spatial and aggregate land use model to evaluate land use change and statistically test if there are significant differences between the methods.

CHAPTER 3. EVALUATING HUNTING AND TIMBERLAND IN ALABAMA

ABSTRACT

The objective of the study was to determine how animals hunted are affected by timberland changes in Alabama using county data for the years 2000, 2010, and 2018. Structural and reduced-form models for animals hunted (defined as the number of large mammals species hunted and killed in year *t*) are developed to determine the sensitivity of animals hunted to key determinants when species composition (defined as the ratio of hardwood to softwood timber acreage) is held constant and alternatively, when species composition is permitted to adjust. Econometric estimates of the structural model indicate animals hunted are most sensitive to changes in the size of Alabama's population (elasticity = 5.89), the percentage of timberland actively managed (2.27), the Gini index (2.15), less actively managed timberland (1.35), and species composition (1.29). Inserting the elasticities estimated from the structural model into the reduced form, results suggest permitting species composition to adjust to shifts in demand magnifies the effects of key exogenous variables. In particular, the elasticity of animals hunted with respect to actively-managed timberland increases from 2.27 to 4.14, and the elasticity animals hunted with respect to less actively managed timberland increases from 1.35 to 2.35. The reason for the magnification effect is that timberland management increases species composition, which in turn increases animals hunted. The structural model holds species composition constant and thus fails to account for this induced effect of changes in management on demand.

1. INTRODUCTION

Hunting value is rising in the United States due to the benefits derived by timberland owners and local economies (Poudel et al., 2016). This situation is not different in Alabama as hunting generated a revenue of about $1.8 billion in 2019 (Alabama Department of Revenue, 2019). The sustenance of animals hunted and its ability to further generate revenue depend fundamentally on the decision by non-industrial private forest (NIPF) owners. Non-industrial private forest owners constitute about 87% of total timberland ownership and own about 18 million acres of timberland in Alabama (Alabama Forest Resource, 2018). Landowners seek new ways to generate income from their timberland, while maintaining ecologically diverse, and sustainable forest systems (Dyer, 2012). However, the ability of NIPF owners to meet these standards have trade-off effects. From a social planner perspective, the decision to enjoy recreational services from a timberland requires achieving a certain level of forest cover, timberland rotation cycle, age and structure of timberland, and purpose of timber after harvesting (Conway et al., 2003). These different decisions have trade-off effects on species composition and indirectly affecting animals hunted.

Timberland management is pivotal when the demand for intangible timberland products arise. Timberland owners are tasked with the ability to understand timber stand dynamics and wildlife behaviors when the demand for services such as hunting increase (Peitz et al., 1999). For instance, landowners are torn between choosing timber species that improve biodiversity, aesthetic, and support wildlife as against species that offer high timber revenue. This affects silvicultural practices that the landowner adopts to manage their timber stands. Studies show NIPF owners who own mixed hardwood-pine have to create enabling environment for deer browsing by thinning mid-story of hardwoods to encourage undergrowth for deer browse (Blair and Feduccia, 1977). Additionally, landowners who cultivate mostly loblolly pine (*Pinus taeda*) practice intense management such as controlled burning, brush control, and perhaps fertilization to attract wildlife animals (Hurst et al., 1982). Studies show that control burning promotes soft mast production, provides habitat, maintain grasses, and rejuvenate browse plants preferred by deer, elks, turkeys, and buffaloes (MacCleery, 1992). This practice improves hunting sites and also affect animals hunted positively.

The current and future demands of recreational activities go beyond timberland silvicultural practices and species composition. Economic theories suggest that the demand for a commodity depends on its own price, price of substitute, socio-demographics, and income (Hussain et al., 2004). Recreational activities outlook are dependent on prices and socio-economic indicators such as age, income, and education (Munn et al., 2011). Approximately 87% of the total timberland are privately owned (Alabama Forest Resource, 2018) and their decisions are not immune to socioeconomic factors, market demands, and government policies. As such, it is important to jointly determine how timberland practices and socio-economic factors affect animals hunted in Alabama.

Apart from the introduction, the remaining sections are organized as follows. Past studies on hunting are evaluated. Again, a partial equilibrium model is developed as theoretical basis for the study. The econometric model is presented, and afterwards and the results and discussions from estimating the model are expatiated. Finally, the last section makes up the conclusion and suggestions for future studies.

Species composition refers to the ratio of hardwood and softwood acreage. Softwood species comprise of pine related species such loblolly, shortleaf, and longleaf pines. Hardwood species comprise of oak, hemlock, elm, hickory, ash, etc. that are naturally occurring. Species composition informs the reader about the timberland diversity which has a great impact of animals hunted as wildlife attraction to timberland depends on the types of timber species. Timber management are classified as actively managed and less actively managed in the subsequent section of the study. Actively managed and less actively timberland are associated with softwood and hardwood plantation respectively. Further details about timberland management are highlighted in subsequent sections of the study.

2. STUDIES ON HUNTING

The demand and supply of recreational services like hunting is a combination of decision both from the timberland owner and the hunter. For instance, supplying hunting services to a hunter encompass the combination of natural amenities and enhanced hunting sites that are effective for game hunting and enjoying maximum hunting satisfaction (Marcouiller and Prey 2005). Researchers have evaluated recreational demand from different tangents. For instance, studies relating to NIPF owners sought to analyze tradeoffs between land uses for timber production, recreational service provision, or the use of timberland jointly for both activities (Amacher et al., 2003). Additionally, other studies have focused on the substitution between harvesting of timber against recreational preference (Conway et al., 2003; Pattanayak et al., 2002). However, Kline et al. (2000) evaluated the willingness of landowners to forgo timber production for the purpose of using timberland as a wildlife habitats. In all these studies, the decision of landowner to lease their timberland for recreational purposes is very paramount in their land decision making process.

Different methods are adopted in determining animals hunted. Methods such as hedonic pricing, contingent valuation, and travel cost are employed by researchers to evaluate the willingness to purchase lease for recreational services. For instance, Balkan and Kahn (1988) modelled animals hunted for United States using a nationwide data from the United States Fish and Wildlife Service (USFWS). Again, Luzar et al. (1992) studied deer hunting trip demand on Louisiana public land using a travel cost method. Lastly, Bergstrom and Cordell (1991) examined nationwide hunting trip demand on public land using contingent valuation. In all these studies, different socio-economics factors were considered. Balkan and Kahn (1988) found that increasing household income increased the demand for hunting trips as hunters purchased more hunting lisense. In contrast, Bergstrom and Cordell (1991) found that household income decrease trip demand. With respect to age, studies found that increasing age of hunter have negatively affected hunting trip (Offenbach and Goodwin 1994; Bergstrom and Cordell 1991). Education variables have been found to be insignificant factors in determining demand for hunting (Offenbach and Goodwin 1994; Balkan and Kahn 1988). Lastly, Kebede et al. (2008) found that changing lifestyle is a critical factor that influence the demand for outdoor recreation.

Timberland management matters to hunting decisions as timberland management activities affect wildlife habitat and food availability for wildlife. For instance, Boyle et al. (2001) found that Maine residents did not prefer forest management activities that resulted in extreme clearcutting of the forest as it does not encourage wildlife attraction unto the hunting sites. Stribling et al. (1992) examined hunter willingness to pay for hunting lease and found that hunter's willingness to pay decreased when landowners continuously harvested timberland without much attention to timber retention. However, both studies concluded that hunters preferred a mixture of uneven aged and mixed forest type.

Researchers have analyzed how tract and timberland size influence hunter preferences to purchase hunting services. Boxall and Macnab (2000) found that moose hunters and wildlife viewers in Saskatchewan actually favored small-scale forest management activities that helped to create wildlife openings. Additionally, Munn et al. (2011) found that tract size did not influence hunter's decision to purchase a hunting lease using a contingent valuation. A choice experiment approach adopted by Hussain et al. (2010) showed that tract size less than 1000 acres had positive effect on hunter's Willingness to pay for a hunting lease in Mississippi. Hedonic studies have also found that hunter's hunting preference is not usually influenced by tract size (Shrestha and Alavalapati, 2004; Zhang et al., 2006; Rhyne et al., 2009; Munn and Hussain, 2010).

Different statistical and economic approaches are adopted in evaluating animals hunted. For instance, a multinomial logit approach was adopted by Mehmood et al. (2011) to evaluate factors influencing hunting decline in Alabama. Poudyal et al. (2008) adopted a log-linear function to determine animals hunted in southern U.S. Conway (1998) used a two stage least square approach to evaluate population shift and preference effects on NIPF owner's behavior. Linear regression with different heteroskedasticty corrections are also adopted for evaluating animals hunted (Shrestha and Alavalapati, 2004; Zhang et al. 2006; Rhyne et al., 2009; Munn and Hussain, 2010). In all these studies, variables such as like age, sex, education, ethnicity, employment status, income, and location index are used to determine factors influencing hunting license purchase and preferences. Similarly, variables such as timberland characteristics, timber prices, agricultural prices, land slope, and demographic characteristics are adopted by Conway (1998) to determine factors that influence landowners to bequest their timberlands.

3. METHODOLOGY

3.1. Theoretical Model

The study adopts the structural model of the form:

$$\mathrm{H} = f\ (W, X) \tag{1}$$

$$\mathrm{W} = g\ (\mathrm{H}, \mathrm{Z}) \tag{2}$$

Where X is a representative exogenous variable that shifts the *f* function and Z is a representative exogenous variable that shifts the g function. Assume an increase in X increases H, which in turn increases W through the g function, i.e., $\frac{\partial H}{\partial X} > 0$ and $\frac{\partial g}{\partial H} \equiv \frac{\partial W}{\partial H} > 0$. At issue is the of an increase in X on H when W is permitted to adjust and $\frac{\partial f}{\partial W} \equiv \frac{\partial H}{\partial W} > 0$. To address the issue, the study write the structural model in proportionate change form to yield:

$$\mathrm{dH} = \frac{\partial \mathrm{Hd}}{\partial \mathrm{W}}.\mathrm{dW} + \frac{\partial \mathrm{H}}{\partial \mathrm{X}}.\mathrm{dX} \tag{3}$$

$$\mathrm{dW} = \frac{\partial \mathrm{W}}{\partial \mathrm{H}}.\mathrm{dH} + \frac{\partial \mathrm{W}}{\partial \mathrm{Z}}.\mathrm{dZ} \tag{4}$$

$$\frac{dH}{H} = \left(\frac{\partial \mathrm{H}}{\partial \mathrm{W}}.\frac{\mathrm{W}}{\mathrm{H}}\right).\frac{\partial \mathrm{W}}{\mathrm{W}} + \left(\frac{\partial \mathrm{H}}{\partial \mathrm{Z}}.\frac{Z}{\mathrm{H}}\right).\frac{\partial \mathrm{Z}}{\mathrm{Z}} \tag{5}$$

$$\frac{dW}{w} = \left(\frac{\partial \mathrm{W}}{\partial \mathrm{H}}.\frac{\mathrm{H}}{\mathrm{W}}\right).\frac{\partial \mathrm{H}}{\mathrm{H}} + \left(\frac{\partial \mathrm{W}}{\partial \mathrm{Z}}.\frac{\mathrm{Z}}{\mathrm{W}}\right).\frac{\partial \mathrm{Z}}{\mathrm{Z}} \tag{6}$$

Arranging eqn 5 and eqn 6 to establish the elasticities to get:

$$H^* = \alpha W^* + \alpha_X X^* \tag{7}$$

$$W^* = \beta H^* + \beta_Z Z^* \tag{8}$$

where α (> 0), α_X (> 0), β (> 0), and β_Z (> 0) are structural elasticities. Specifically, α_X tells the sensitivity of animals hunted to a 1% change in X holding W constant; β_Z tells the sensitivity of species composition to a 1% change in Z holding number of animals killed constant.

Species composition is employed to represent timberland diversity index. Diversity index are very broad and entail mortality index, species abundance, tree stocking, and similarity indices (Chen, 2019). For the sake of simplicity, the ratio of hardwood to softwood was adopted for species composition based on Pielou (1969) evenness index ratio method.

The effects of changes in X and Z on H and W when the endogenous variables are permitted to adjust are determined by solving equations (7) and (8) for the reduced form to yield:

$$H^* = \alpha(\beta H^* + \beta_Z Z^*) + \alpha_X X^* \quad (9)$$

$$H^* = \frac{\alpha_X}{1-\alpha\beta} X^* + \frac{\alpha\beta_Z}{1-\alpha\beta} Z^* \quad (10)$$

$$W^* = \beta H^* + \beta_Z Z^* \quad (11)$$

$$W^* = \frac{\beta\alpha_X}{1-\alpha\beta} X^* + \frac{\beta_Z}{1-\alpha\beta} Z^* \quad (12)$$

The effects of changes in exogenous variables on the number of animals killed depends crucially on the nature of the feedback between animals killed and species composition and vice versa. For the effects to be stable the feedback elasticities cannot both equal 1, as then the reduced-form elasticities $\frac{H^*}{X^*} = \frac{\alpha_X}{1-\alpha\beta}$ and $\frac{H^*}{Z^*} = \frac{\alpha\beta_Z}{1-\alpha\beta}$ are undefined. For an increase in X to increase H, the feedback elasticities α and β must individually be less than 1 (sufficient condition), or their product $\alpha\beta$ must be less than 1 (necessary condition). In this instance, $\frac{H^*}{X^*} > \alpha_X > 0$, i.e., feedback between H and W magnifies the effect of changes in X on H, with the magnification effect increasing as $\alpha\beta \to 1$. If feedback effects are “strong” such that $\alpha\beta > 1$ then $\frac{H^*}{X^*} = \frac{\alpha_X}{1-\alpha\beta} < 0$ and an increase in X *decreases* H. In this instance, the effect of changes in X on H are opposite what one would expect based on the sign of its structural elasticity structural elasticityα_X. The upshot is that the nature of the endogeneity between animals hunted and species composition as measured by $\alpha\beta$ is critical to understanding how exogenous shocks affect the market for hunting.

Timberland management comprise of actively managed and less actively managed timberland. Actively managed timberland comprise of mainly softwoods which make up about 46% of total timberland acreage, subjected to regular silvicultural practices, and artificially propagated. Less actively managed timberland is made up hardwood and mixed hardwoods species that occur through natural regeneration, not subjected to any silvicultural practices, and make up 54% of timberland acreage. Since there is no data on silvicultural practices, the management types are used as proxy for the study. For instance, controlled burning, thinning, and pruning usually occurs in actively managed timberland (softwood timberlands) as compared to unmanaged timberland (hardwood & mixed hardwood timberlands). The statistic quoted are available in the Alabama Forest Report, (2018).

3.2. Econometric Specification

The econometric specifications presents the structural equations for the theoretical model. A simultaneous system of equation is adopted to estimate the parameter for the factors determining animals hunted and species composition in Alabama. The structural equations must hold simultaneously for the empirical analysis to be deemed correct. A two stage least square statistical procedure is employed in the form:

$$y_1 = y_2'\beta_1 + Z_1'\gamma_1 + \mu_1 \quad (1)$$

$$y_2 = y_1'\beta_2 + Z_2'\gamma_1 + \mu_2 \quad (2)$$

The endogenous variables, which are the independent variables are present in both equations. The reduced form equation is of the form:

$$y = Z'\Gamma + \mu \quad (3)$$

The two stage least squares procedure initially estimates the reduced form equation by using an ordinary least square regression and obtaining the predicted values of the response variables. Afterwards, the predicted values from the first stage are used to estimate the structural equations (Greene, 2003). In estimating the model, there is a possibility of an inconstant variance over observations as the data is treated as cross-sectional in nature. Therefore, all equations are tested for possible heteroscedasticity and afterwards corrected to prevent bias estimation of the coefficients. The structural model of the first order conditions in stochastic reduced form is written as follow:

$$W = g\ (H, Z)$$

$$H = f\ (W, X)$$

Species composition, timberland management, and socio-economic indicators jointly influence animals hunted. Since the timberland management types are equivalent to the timberland acreage, the study deem it irrelevant to include hardwood, softwood, and mixed hardwood acreage as independent variables in evaluating their impact on animals hunted as this may result in multi-collinearity and spurious estimates.

Where:

W is species composition. Z is a set of independent variables such as timber stumpage price, agricultural products value, land quality, and county district. H is animals hunted. X is a set of independent variables such as unemployment, household income, gini index, and demographic characteristics comprising of variables like age, education, ethnicity, unemployment, and population.

3.3 Summarized Statistics

To estimate the empirical model, county level data are obtained from different sources for the periods 2000, 2010, and 2018. Income and price variables are deflated into the real values using consumer price index. The variables for the empirical are grouped according to demographic characteristics, animals hunted and timberland characteristics for easy explanation. The summary statistics of the variables are presented in Table 3.1.

3.4 Timberland and Animals hunted Characteristics

The species composition has an average value of 101. Similarly, the animals hunted has an average value of 5184. The number of animal's hunted value represents the total number of deer and turkey species that are hunted and killed in Alabama. Timberland management is categorized into actively managed and less actively managed timberlands. The average value of actively and less actively managed timberlands are 203663 and 137920 acres respectively. The average real price of timber stumpage price $185.4 per 1000 board foot (MBF). The average value of real agricultural products, which is equivalent to total sales of agricultural products is $385.6 per acre. The land quality is a dummy variable with either a high land quality (lq_1) dummied as 0, and low land quality (lq_2) dummied as 1.

3.5 Demographic Characteristics of Alabama

The average population for individuals above 18 years across all counties is 53262, out of which males and females make up a total of 25586 and 27676 respectively. Males make up about 48% whereas females constitute about 52% for populace above 18 years old. The statistic show that females constitute the majority of the population above 18 years in Alabama. The population ages are grouped as follows: 18-29 years, 30-49 years, 50-60 years, and ≥ 70 years. The average number of people with age 18-29 years, 30-49 years, 50-60 years, and ≥ 70 years and their respective percentages are 11761 (22.1%), 18905 (35.4%), 15865 (29.7%), and 6731 (12.6%) respectively. The results show that number of people with age of 30-49 years have the highest mean value and make up the highest age category in Alabama for populace above 18 years old.

The population ethnicity are categorized as white, black, and others. The other races consist of Asians, Native Hawaiians, and American Indian. The average number of people with white ethnicity or white combination is 50290, equivalent to 70% of the total ethnicity in Alabama. Similarly, black ethnicity or black combination is 18908, equivalent to 27% of the ethnicity in Alabama. Lastly, the number of people falling within the other ethnic group is 1819, equivalent to 3% of the total ethnicity in Alabama. This is an indication that the white ethnicity is dominant race for populace above 18 years old in Alabama.

The education variable is grouped as less than high school diploma, only high school diploma, and more than high school diploma or college degree. People with less than high school education constitute about 24.6% of the total populace above 18 years old. Similarly, people with only high school education constitute about 15.6% of the total populace above 18 years old. Lastly, people with college degree or more than high school education make up about 41.5% of the total populace above 18 years old. This shows that the general educational level in Alabama is increasing as majority of the population above 18 years who acquire high school education further their education by obtaining college degrees or upgrade upon their high school certificate by taking some college courses.

The average value of the real median household income for the total population in Alabama is 22620 U.S dollars. The average number for Gini index, a measure for income inequality, is 0.46. An average index of 0.46 indicates a wide income disparity among the populace in Alabama. Lastly, the county districts are treated as categorical variables and grouped as district 1, district 2, district 3, district 4, district 5, and district 6. Counties in district 1 and 2 are in Northern Alabama. Counties in district 3 and 4 are in the middle belt of Alabama while counties in district 5 and 6 are in Southern Alabama. The district grouping are computed following USDA's grouping protocols. The groupings are important as it identifies if geographical location influence the endogenous variables.

The unemployment rate is defined as the level of unemployment divided by the labor force. The employment rate is defined as the number of people currently employed divided by the adult population. The average value of unemployed rate in Alabama is 7.42%

The species composition, in particular the ratio of hardwood acreage to softwood acreage has no unit as the acreages cancel out when the ratio is computed to establish the timberland diversity index. The percentage of adults who are college graduates includes those who completed at four or more years of college regardless of degree earned. The percentage of education does not sum up to 100% as the data is for adults 25 years of age and older. The average Land Capability Class (LCC) ratings represent land quality that (USDA, 2009) are derived from county-level soil surveys and based on twelve soil characteristics (e.g., slope, permeability). A county with a lower value of lq1 has higher quality land, on average and vice versa. The average LCC was found to be 4.1. All counties with land quality between 0 – 4.1 are dummied 0, and those above 4.1 are dummied 1. Gini index a statistical measure of the degree of variation or inequality represented in a set of values, used especially in analyzing income inequality. It is between 0 and 1, where an increase in Gini index represents increasing income inequality. Apart from the population variable which was expressed as the number of people, variables like age categories and gender are expressed as percentage using the total population variable following Poudyal et al. (2008). Therefore, the variables cannot be expressed as dummies as the study uses data from secondary source. Data on gender, population, ethnicity, education are obtained from the United States Census Department, United States Department of Agriculture. The letter "M" stands for 1,000 in the lumber industry, so "MBF" is the abbreviation for 1,000 board feet. The unit is available in the Timber-Mart south report, (2020). The definition of BF refers to a base volume that must be adjusted according to the specific type of lumber that is being measured. Agricultural products value is equivalent to total sales and it includes sales by the producers as well as the value of any shares received by partners, landlords, contractors, or others associated with the operation. Animals hunted is classified as total number of deer and turkey hunted in year (t). The hunting data was obtained from the Alabama Hunting Survey.

Table 8 shows the mean values for the variables for 2000, 2010, and 2018 and their respective changes. This highlights on the changes occurring among the exogenous variables employed for the study.

Table 8. Dependent Variables and their Changes, Alabama

Particulars	2000	2010	2018	% Δ change (2000-2010)	% Δ change (2010-2018)	% Δ change (2000-2018)
Species composition	3740.76	2224.78	1751.53	-40.53	-21.27	-53.18
Number of animals hunted	7716.40	4423.69	3412.25	-42.67	-22.86	-55.78
Actively managed timberland	119494.03	138936.06	155330.85	16.27	11.80	29.99
Less actively managed timberland	219956.87	203117.99	187912.81	-7.66	-7.49	-14.57
Agricultural products value	332.43	412.18	412.39	23.99	0.05	24.05
Timber price	274.97	130.62	150.87	-52.50	15.50	-45.13
Gini index	0.45	0.46	0.47	1.13	2.74	3.90
Education						
Less than High school education	0.30	0.24	0.18	-20.68	-26.08	-41.37
Only High school education	0.13	0.16	0.18	15.61	13.50	31.22
College/more than High school education	0.37	0.42	0.46	12.95	11.47	25.91
Unemployment	5.51	12.35	4.41	124.29	-64.26	-19.84
Population	49619.22	53438.03	56729.97	7.70	6.16	14.33
Age						
year 18-29	11001.60	11635.90	12645.09	5.77	8.67	14.94
year 30-49	19565.24	18967.96	18181.39	-3.05	-4.15	-7.07
year 50-69	12923.55	16296.58	18376.15	26.10	12.76	42.19
year 70 and above	6128.84	6537.60	7527.34	6.67	15.14	22.82
Male population	23437.67	25465.57	27857.69	8.65	9.39	18.86
Female population	26181.55	27972.46	28872.28	6.84	3.22	10.28
Ethnicity						
White or with combination	48243.47	51049.15	51579.54	5.82	1.04	6.92
Black or with combination	17300.78	19231.87	20192.63	11.16	5.00	16.72
Other race with combination	858.59	2078.66	2522.01	142.10	21.33	193.74

Table 9. Summary Statistics of Data used to Estimate the Model, Alabama

Variables	Unit	Mean	Standard errors
Animals hunted	Number of animals hunted and killed	5184.113	2569.061
Species composition	-	101	4.1028
Actively managed timberland	Acreage	203663.6	4750.164
Less actively managed timberland	Acreage	137920.3	5974.849
Population	Number of people	53262	77840
Age			
18-29 years	Percentage	20.556	0.2795
30-49 years	Percentage	34.669	0.2771
50-69 years	Percentage	31.031	0.2719
70 years and above	Percentage	13.741	0.1572
Education			
Less than high school	Percentage	24.07	0.5179
Only high school	Percentage	15.60	0.4929
College or complete some college courses	Percentage	41.58	0.6747
Ethnicity			
White or with combination	Percentage	69.25	1.5360
Black or with combination	Percentage	28.71	1.5584
Other races with combination	Percentage	2.04	0.1206
Gender			
Male	Percentage	48.031	0.1416
Female	Percentage	51.968	0.1416
Real household median income	Dollars	22620.9	4839.047
Real timber stumpage price	Dollars per MBF	185.4846	63.9729
Gini index	Index	0.4615	0.0256
Real agricultural products value	Dollars per acre	385.6637	347.9288
Unemployment	Percentage	7.4228	0.2909
Land quality	Dummy variable	0 or 1	-

Figure 1 presents the map of Alabama with the different county districts. This highlights the relevance of regional variation impact on animals hunted in Alabama.

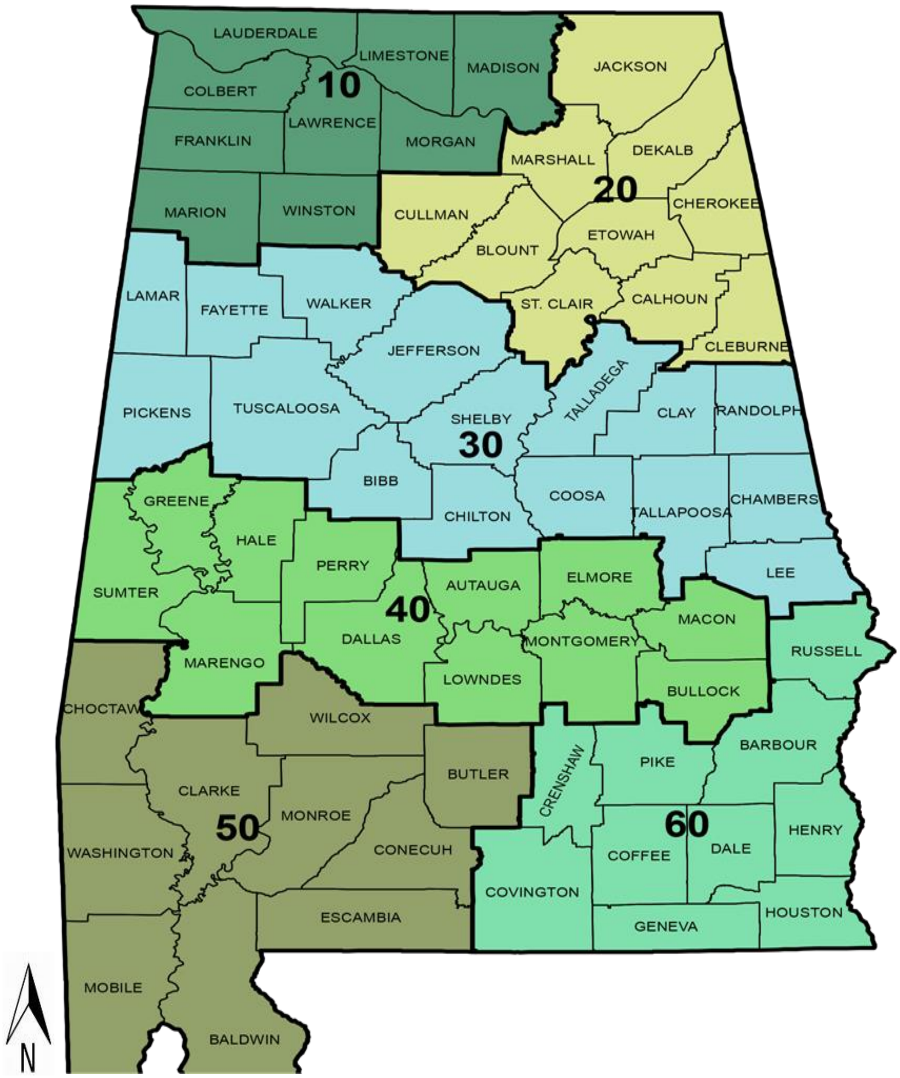

Figure 1. Map of Alabama Showing the Different County Districts
Source: USDA, 2016

5. ESTIMATION RESULTS

Table 10 presents results for estimating the equations established by the structural equations of the theoretical model. Results are satisfactory as most of the signs of the estimated coefficients agree with a prior expectations (Table 10). The chi-square values are 263.19 and 193.08 for animals hunted and species composition respectively, suggesting the model has good explanatory power given the cross-sectional nature of the data. The structural equations are estimated simultaneously using a 2 stage least square (Conway, 1998). The regression equations are expressed as double logs so the coefficients are interpreted as elasticities except the geographical locations as it is a categorical variable.

Species composition and animals hunted are the two endogenous variables employed in the model. Since the endogenous variables are a function of the exogenous variables, the predicted values of species composition and animals hunted are used as instruments in estimating the models. Other socio-economic variables are enlisted as instruments to satisfy the model condition. Variables such as age, ethnicity, and gender are expressed as percentages in estimating the empirical model. The data is treated as cross-sectional so all regressions are corrected for heteroscedasticity to prevent bias estimates of the coefficients (Greene, 2003).

Table 10. Regression Estimates of the Empirical Model (N = 201)

Variable	Animals hunted		Species composition	
	Coefficient	Standard error	Coefficient	Standard error
Constant	-3.4927	1.4615	-1.1998	0.9544
Species composition (pred)	1.2898***	1.4125	-	-
Actively managed timberland	2.3747***	0.4514	-	-
Less actively managed timberland	1.3481***	0.5051	-	-
Real median household income	0.1274	0.3810	-	-
18 – 29 years	-1.1463	0.8844	-	-
30 – 49 years	-0.2110	1.2211	-	-
50 – 69 years	-1.7490	1.1920	-	-
70 years and above	-0.9637**	0.4918	-	-
Population	5.8920*	3.5504	-	-
Male	1.4076	1.0163	-	-
White	0.2877	0.1892	-	-
Black	-0.0327	0.0612	-	-
Other race	-0.0488	0.0657	-	-
Gini index	2.1524*	1.6458	-	-
Less than High school education	1.2245	1.3607	-	-
Only high school education	0.6524	1.6275	-	-
College education or more than High school diploma	-1.0782	1.6447	-	-
Unemployment	0.5501*	0.0463	-	-
lq_1	-	-	-0.0281	0.0284
Animals hunted (pred)	-	-	0.3306**	0.1575
Real agricultural products value	-	-	-0.0438	0.0523
Real timber stumpage price	-	-	0.0566 *	0.1982
District 2	0.1984*	0.1634	-0.6603***	0.1582
District 3	0.5688***	0.2686	-1.4721***	0.1519
District 4	0.9407***	0.3847	-1.4099***	0.1601
District 5	1.1112***	0.4656	-1.9996***	0.1718
District 6	1.8780***	0.5817	-1.3986***	0.1685
R^2	0.5659		0.4898	
RMSE	0.4198		0.5875	
Chi-square	263.19		193.08	

Note: *, **, and *** denotes significance at the 10%, 5%, and 1% levels respectively.

5.1 Hunting Demand equation

The number of animal's hunted equation contains 201 observations and has a chi-square value of 263.19, indicating a significant regression. Aside the constant term, the regression produces good results with significance at different levels. The estimated coefficient for species composition is 1.289. This indicates that an acreage increase in species composition, particularly hardwood relative to softwood acreage, is associated with an increase in animals hunted by 1.28%, all else equal. According to the result, animals hunted is sensitive to changes in species composition. This is an expected result and consistent with the theoretical model of the study. Species composition influence diversity, aesthetics, and browse production for deer hunting (Hall, 1984). Additionally, studies show that hunters prefer timberland with a mixed pine-hardwood as it provides both aesthetics and improved browsing for wildlife hunting as compared to pure monoculture and clear-cut plantation (Stribling et al., 1994).

Turning to the age, the results show a negative relationship between age and animals hunted in Alabama. All the age categories are insignificant except, age above 70 years that is significant at 95% level. The estimated coefficient for age categories 18-29 years, 30-49 years, 50-69 years, and 70 and above years are -1.14, -0.21, -1.79, and -0.96. The results are consistent with Mehmood et al. (2003) which shows that people of ages of 18-39 years, 51-69 years, and 70 and above are not hunting inclined. However, the negative relationship between animals hunted and people with ages above 51 years is due to lost interest to hunt (Offenbach and Godwin, 1994).

Following Shulstad and Stoevener (1978), total population variable is included to capture the effect of absolute population on animals hunted. The results show that there is a positive and significant effect of total population on animals hunted in Alabama. The estimated coefficient for populace above 18 years is 5.8920. This shows that a 1% increase in populace above 18 years increase animals hunted by 5.8920%, all else equal. This indicates that populace above 18 years are very sensitive to changes in animals hunted. This is an expected result and consistent with previous studies (Poudyal et al., 2008). The growing population in Alabama is likely to help sustain the animals hunted alive, assuming all factors are constant.

In addition, the study evaluate education on animals hunted in Alabama. The estimated coefficient for people with less than high school diploma, only high school diploma, and college or more than high school diploma are 1.2245, 0.6524, and -1.0782 respectively. This shows that people with less than high school and only high school diploma have a positive, but insignificant relationship with animals hunted while people with more than high school diploma or college degree have a negative and insignificant relationship with animals hunted. Thus, a 1% increase in people with less than high and only high school diploma increases animals hunted by 1.22% and 0.65% respectively, all else equal while a 1% increase in college or more than high school diploma is associated with a decrease in animals hunted by 1.07%, all else equal. The education variable indicates that the populace with no college education tend to be sensitive to animals hunted as compared to the populace with college education. The reason behind the negative effect of people with college degree or higher education have greater opportunity cost of time implying that time is a critical in animals hunted. The college degree result is consistent with Balkan and Kahn (1988).

Real median household median income and Gini index have a positive relationship with animals hunted in Alabama. The estimated coefficient for income is 0.1274; however, the coefficient is not significant. This is an expected result and consistent with the theoretical model of this study (Balkan and Kahn, 1988). In addition, the estimated coefficient for Gini index is

2.1524 and also significant. Therefore, 1% increase in real income and Gini index increase animals hunted by 0.1274% and 2.1524% respectively, all else equal. A positive effect of income on animals hunted indicates that as income levels increase, the populace above 18 years tend to appreciate and spend time on outdoor activities like hunting. This result is expected and consistent with a prior expectation (Shaw, 1992; McConnell and Strand, 1981). The Gini index affirms this result as increasing wealth has a positive and significant effect on animals hunted.

The results show that white ethnicity has a positive relationship with animals hunted while black and other ethnicity show otherwise. The estimated coefficient for white, black, and others ethnicities are 0.2877, -0.0327, and -0.0488 respectively. A 1% increase in people with white ethnicity is associated with a 0.2877% in animals hunted, all else equal. In contrast, a 1% increase in black and other ethnicities is associated with a decrease in animals hunted by 0.0327% and 0.0488% respectively, all else equal. This indicates that animals hunted is sensitive to people with white ethnic background as compared to other ethnicities in Alabama. The result is expected and consistent with previous studies indicating that whites are more likely to purchase hunting license than African American and other ethnic groups (Floyd and Lee, 2002; Poudyal et al., 2008)

The male population has a positive and significant effect on animals hunted in Alabama. The coefficient of males is 1.4076, indicating a 1% increase in male population above 18 years is associated with increase in animals hunted by 1.407%, all else equal. This is an expected result as males have a higher propensity to hunt in Alabama (Floyd and Lee, 2002). Additionally, males are more likely to purchase hunting license for hunting purposes relative to females (Zinn et al., 2002).

Furthermore, the geographical location which enters the model linearly due to its categorical nature has a positive and significant effect on animals hunted in Alabama except counties in District 2 that are not significant. The estimated coefficients for districts 2, 3, 4, 5, and 6 are 0.1984, 0.5688, 0.9407, 1.1112, and 1.8780 respectively. From the estimated coefficients, it is noticed that counties in District 4 and 5, in particular, counties in southern Alabama have very strong response to changes in animals hunted as compared to counties in the northern Alabama that are less sensitive to changes in animals hunted.

The results show that unemployment rate has a positive and significant relationship with animals hunted in Alabama. The estimated coefficient for unemployment rate is 0.5501. A 1% increase unemployment rate increases animals hunted by 0.5501%, all else equal. This is an expected results and consistent with a prior expectations (Shaw, 1992). People who are not engaged in any form of employment may have enough time to spend on leisure activities such as hunting as their opportunity cost of time is not huge.

The results show that both actively and less actively managed timberland have positive relationship with animals hunted. The estimated coefficient for actively and less actively managed timberland are 2.3747 and 1.3481 respectively. Thus, a 1% increase in both active and non-active timber management practices are associated with a 2.3747% and 1.3481% increase in animals hunted, all else equal. Studies show that non-active timberland management have low carrying capacity for wildlife as unpruned trees tend to impede browse production and mast crops as compared to managed timberlands (Peitz et al., 1999). Again, the larger coefficient for active timberland management relative non-active timberland management is expected as the former has a high propensity to attract wildlife thereby making it a good choice for a hunting site.

5.2 Species composition equation

The species composition equation contains 201 observations and has a chi-square value of 193.08, indicating a significant regression. Aside the constant term, the regression produces good results with significance at different levels. The study shows a positive and significant relationship between animals hunted and species composition. The estimated coefficient for animals hunted is 0.3306. This shows that a 1% increase in animals hunted is associated with a 0.3306% increase in species composition, particularly hardwood relative softwood acreage. This is an expected result and consistent with the study's hypothesis as species composition and animals hunted are a joint product and compliment each other.

Turning to real agricultural products value per acre and species composition, the results show that there is a negative relationship between the two variables. The estimated coefficient for real agricultural products value per acre is -0.0438. This is indicates that a 1% increase in real agricultural products value per acre is associated with a decrease in species composition by 0.0438%. This is an expected results and consistent with a prior expectation (Nagubadi and Zhang, 2005). An increase in agricultural products and prices is likely to influence landowner's decision to convert their timberlands for agricultural purposes.

The result show that real timber price has a positive and significant effect on species composition in Alabama. The estimated coefficient for real timber price is 0.0566. This indicates that a 1% increase in real timber price is associated with a 0.0566% increase in species composition. This is an expected result and consistent with a prior expectation (Nagubadi and Zhang, 2005). Landowners are motivated to establish or allow timber species to grow on their land when the price of timber products begin to rise on the market.

Furthermore, the results indicate a negative effect of high land quality on species composition. The estimated coefficient for land quality is -0.0281. This shows that a 1% increase in high land quality is associated with a 0.0281% decrease in species composition. This is an expected result as increasing soil richness is likely to influence landowners to convert their lands for agricultural purposes instead of timber establishment (Ahn et al., 2000).

Lastly, the geographical location which enters the model linearly due to its categorical nature has a negative and significant effect on timberland ratio in Alabama. The coefficients of counties in District 2, 3, 4, 5, and 6 are -0.6603, -1.4721, -1.4099, -1.9996, and -1.3986 respectively. The results show that counties in District 3, 4, 5, and 6 are more sensitive to changes in timberland ratio whereas counties in District 2 are less sensitive to changes in species composition.

5.3 Reduced form elasticities

The empirical analysis indicates species composition and timberland management increase animals hunted in Alabama. However, the magnitude of timberland management practices differ based on whether it is actively managed or less actively managed. The study computes the reduced-form elasticities for animals hunted by inserting the elasticities estimated from the structural model into the reduced-form models. The study is silent on reduced-form elasticities for species composition as endogenous variable since it is not the focus of the study.

Table 11. Reduced-form Elasticities of Animals Hunted (H*) and Species composition (W*)

Endogenous variables	Exogenous variable								
	Timber price	Agricultural products value	Land quality	Income	Actively managed	Less actively managed	Population	Gini index	Unemployment
Hd*	0.1275	-0.0987	-0.0634	0.2222	4.140	2.3502	10.272	3.753	0.959
W*	0.0988	-0.0765	-0.0492	0.0734	1.3686	0.7770	3.3959	1.241	0.317

Hd* and W* are animals hunted and species composition elasticities respectively.

5.3. 1 Reduced-form elasticities analysis

Timberland management is important plays a pivotal role in animals hunted (Peitz et al., 1999; Poudyal et al., 2016). The results indicate that inserting the elasticities estimated from the structural model into the reduced form, permitting species composition to adjust to shifts in demand magnifies the effects of key exogenous variables. In particular, the elasticity of animals hunted with respect to actively-managed timberland increases from 2.27 to 4.14, and the elasticity of animals hunted with respect to less-actively managed timberland increases from 1.35 to 2.35. This is because the feedback between animals hunted and species composition magnifies the changes in the timberland management types on animals hunted. Additionally, the reduced-form results shows that the feedback mechanism of actively managed timberland on animals hunted is greater than less actively managed timberland. The induced effect of timberland management is not realized in the structural model as species composition is not allowed to adjust, but held constant. This highlights the importance of feedback mechanism between animals hunted and species composition. Again, silvicultural practices are important in achieving enormous impact on market for hunting as shown in actively managed timberland.

Turning to Gini index, the structural model had a positive and significant effect on animals hunted, so the study evaluates the reduced elasticity when species composition adjusts. Allowing species composition to adjust to changes between animals hunted and Gini index increases the elasticity of Gini index from 2.1524 to 3.753. This is because the feedback between animals hunted and species composition magnifies the changes in Gini index on animals hunted, highlighting the net effect of Gini index on hunting. This shows the relevance of allowing adjusting of species composition relative to holding it constant as observed in the structural model estimates.

The study shows that allowing species composition to adjust to changes between population and animals hunted increased the elasticity from 5.892 to 10.272. The magnification of the elasticity results from the feedback mechanism between animals hunted and species composition. This is because an increase in population on animals hunted in turn has a positive effect on species composition when allowed to adjust. The huge elasticity of Alabama's population on animals hunted attest to the fact that the market for hunting is popular among the populace.

Inserting the unemployment elasticity estimated from the structural model into the reduced form, permitting species composition to adjust magnified the effect from 0.5507 to 0.959. The magnification of the elasticity results from the feedback mechanism between animals hunted and unemployment when species composition adjust to those changes. Thus, the overall effect on unemployed increases when the reduced form elasticity is computed. This indicates that opportunity cost of time is less for people who are not engaged in a form of employment.

Income is a key determinant in animals hunted, thus the net effect on animals hunted was evaluated when the structural elasticity was inserted into the reduced-form model. The results show that the elasticity increased from 0.127 to 0.222. The magnified elasticity is due to the induced effect of species composition in turn increase animals hunted, indicating that the overall net effect of income increase animals hunted when species composition is allowed to adjust. However, the structural model does not account for such effects as all other factors including species composition is held constant.

Turning to timber stumpage price, inserting the structural the elasticity into the reduced-from increases the elasticity from 0.056 to 0.1275. This indicates that allowing animals hunted to adjust to changes in species composition magnifies the overall impact of timber price on species composition and in turn increase the overall net effect on animals hunted. The indirect benefit ensures that NIPF owners benefit from not only timber sales when prices rise, but also market for hunting.

Land quality and agricultural products value have negative effect on species composition and indirectly on hunting value. The elasticity results show that the variables decreased as their structural elasticities were inserted into reduced-form model. Agricultural products value elasticity decreased from -0.043 to -0.0987 while land quality elasticity decreased -0.028 to -0.063. The reason is that agricultural product value and land quality decrease species composition and in turn decrease animals hunted.

5.4 Model adequacy

The study further computes the model adequacy for animals hunted. A comparison of predicted and actual changes in demand is important as it provides the basis for assessing the model adequacy.

Table 12. Predicted Effects of Changes in Selected Exogenous Variables on Animals Hunted in Alabama, 2010-2018

Exogenous Variable	2010 (1)	2018 (2)	Percent change (3)	Reduced-Form Elasticity (4)	Predicted effect of variable on animals hunted (%)[a] (5)
Actively-managed timberland (acres)	138,936	155,331	11.8	4.14	48.9
Less actively managed timberland (acres)	203,118	187,913	-7.5	2.35	-17.6
Population (millions)	5.344	5.673	6.2	10.27	63.2
Unemployment rate (%)	12.35	4.41	-64.3	0.959	-61.7
Gini Index	0.46	0.47	2.2	3.75	8.2
Timber stumpage price ($/MBF)	131	151	15.3	0.098	1.51
Age – 70 years and above (%)	6537.60	7527.34	15.1	1.68	25.37
Predicted change in animals hunted 2010-18 (%)[b]					67.88
Observed change in animals hunted 2010-18 (%)					-22.9
Predicted/observed (67.88/-22.9 = -2.96)					

[a]Col. 3 x col. 4.
[b]Sum of column 5.

Note: Exogenous variables in the table are those found to be statistically significant in the econometric analysis.

6. CONCLUSION

The study examines the effect of species composition on animals hunted in Alabama. Using cross-sectional data from 2000, 2010, and 2018, the study attempts to understand how species composition response to animals hunted and vice versa using a two stage least square method. The study adopted a set of demographic characteristics such as age, education, ethnicity, unemployment, and income together with actively managed timberland, less actively managed timberland, and species composition as exogenous variables to determine their impact on animals hunted. Again, variables such as land quality, agricultural products value, and timber stumpage price serve as exogenous variable to evaluate effects on species composition. The structural elasticities were computed and later inserted into the reduced-from model to account for adjustment in the endogenous variables in determining total net effect of the exogenous variables.

The elasticities of species composition, actively managed, and less actively managed timberland increased animals hunted. Additionally, the elasticities of exogenous variables such as income, Gini index, unemployment, populace with no college education, total population, percentage of male population, and people with white ethnicity had a positive effect on animals hunted in Alabama. In contrast, the elasticities of exogenous variables such as age, people with black and other ethnicities, and people with more than high school education had a negative effect on animals hunted in Alabama. The district dummies which enter the model linearly have a positive effect on animals hunted.

The reduced-form elasticities permitting species composition to adjust to shifts in demand magnifies the effects of key exogenous variables. The elasticity of animals hunted with respect to actively-managed timberland increased from 2.27 to 4.14, and the elasticity of animals hunted with respect to less actively managed timberland increases from 1.35 to 2.35. Again, allowing species composition to adjust to changes between animals hunted and Gini index increases the elasticity of Gini index from 2.1524 to 3.753. Inserting the unemployment elasticity estimated from the structural model into the reduced form, permitting species composition to adjust magnified the effect from 0.5507 to 0.959. Additionally, allowing species composition to adjust to changes between animals hunted and Gini index increased the elasticity of Gini index from 2.1524 to 3.753. The study shows that allowing species composition to adjust to changes between population and animals hunted increased the elasticity from 5.892 to 10.272. Inserting the unemployment elasticity estimated from the structural model into the reduced form, permitting species composition to adjust, magnified the effect from 0.5507 to 0.959.

Suppose the goal is to increase animals hunted in Alabama, where must policies and recommendations instruments be of target so as to benefit both timberland owners and hunters? Firstly, the most important policy must be geared towards adopting timberland management practices that improve browse production and attract hunters to hunting sites. Actively managed timberland is important factor in the market for hunting; thus it is expedient for NIPF owners to institute silvicltural and timberland management practices that tend to attract wild animals onto the timberland and the same appeals to the public as a convenient hunting site.

Timberland owners respond positively to increase in timber prices; thus, it is imperative to introduce policies to sustain the prices of timber products in order to induce timberland owners to expand their timberland acreage which indirectly affect market for hunting positively.

CHAPTER 4. CONCLUSION

The thesis presents an econometric analysis that explains the effects of socio-economic factors, market dynamics, and population density on land use changes and timberland management. The studies combine land use information from Forest and Inventory Analysis (FIA) with county-level socio-economic and demographic factors to estimate land use allocation using a weighted and a seemingly unrelated regressions. Furthermore, the thesis presents how socio-economic factors, timberland dynamics, and species composition influence animals hunted in Alabama. The study evaluates the effects of county-level socio-economic and demographic factors, timberland management types and species composition on animals hunted using a two-stage least square method.

Chapter 2 captures land use information from FIA ten-year interval land use data to investigate land use transition in Alabama. A land use allocation model was adopted to expatiate on land use transition among non-industrial private forest (NIPF) owners and complex substitution pattern among land use based on county-level socio-economic factors, commodity prices, and population density. The results showed that land use, land use changes, and timberland management follow the classic land use-theory that higher economic returns cause lands to transit to or remain in a certain use. For instance, land use transitions are highly related to population density as it contributed to the decrease in timberland shares, but sped up the shares of urban lands. Additionally, timber price increases timberland shares while agricultural prices increase agricultural land shares. However, both prices had negative effect on alternative land use types (i.e. timber price decrease agricultural land shares). These are indications that land use transitions are highly related to land rents and population in Alabama and that the retention or shift of a particular land use type is dependent on socio-economic and market factors.

Turning to timberland management, the results indicate that rising income and Gini index afford NIPF owners the opportunity to invest into silvicultural and forest management practices as both variables increase the shares of actively managed timberland relative to less actively managed timberland. Additionally, price of softwoods increase the land shares of actively managed timberland relative to less actively managed timberland. This indicate that NIPF owners invest into fast growing trees that are intensively managed such as loblolly pine. Furthermore, population density had an inverse relationship with timberland management, indicating that rising population has a detrimental effect on timberland shares and equally timberland management in Alabama. Therefore, as population rise in Alabama, NIPF owners will have to convert the timberland to other land use types to accommodate the growing population.

Chapter 3 investigates how animals hunted is influenced by socio-economic factors, timberland management, and species composition using a two stage least square. The results indicated that animals hunted is most sensitive to changes in population as 1% increase in population causes animals hunted to rise by 5.89% in Alabama. Additionally, indicators such as animals hunted were sensitive to actively managed timberland, less actively timberland, and income. For instance, the structural model showed that a 1% increase in actively managed timberland, less actively timberland, and Gini index resulted in a 2.37%, 1.34%, and 2.15% increase in animals hunted. This highlights the importance of timberland management and wealth to hunting in Alabama. The reduced-form model magnified the structural model values as species composition was allowed to adjust to changes in animals hunted. The structural values of population, actively managed timberland, less actively timberland, and Gini index magnified to 10.27%, 4.14%, 3.75%, and 2.35%. The magnification expatiates on the importance of allowing adjustments in species composition in determining the total net effect of the independent variables on animals hunted in Alabama. From the results, population was most influential on animals hunted, indicating the importance and cultural values of hunting to the populace of Alabama. Additionally, actively managed timberland is important factor in the market for hunting; thus it is expedient for NIPF owners to institute silvicultural and timberland management practices that tend to attract wild animals onto the timberland and the same appeals to the public as a convenient hunting site.

Future Research

The land use change study focused on modelling land use changes using the aggregate approach without any consideration for spatial approach. Although the aggregate approach is useful for determining land use changes, better understanding of factors leading to land use transition will be highly appreciated if an integrated model comprising of both spatial and aggregate approaches are adopted. Additionally, researchers should adopt spatial econometric methods in evaluating land use changes alongside socio-economic and market decision variables. This will help to capture spatial decision variables that contribute to land use transition. Lastly, to address the future challenges of conservation, biodiversity, water quality, and demand for timber and recreation, researchers should use the different land use types as independent variables in predicting and forecasting their effects in timber supply, water quality, and biodiversity models.

The hunting demand study focused on evaluating factors influencing animals hunted in Alabama. Future studies can focus on administering questionnaires across the state in determining factors influencing animals hunted as this will help capture regional differences on the market for hunting. Additionally, researchers can focus on the different age structures of timberland species by including it as an independent variable and evaluate its effect on animals hunted. Lastly, researchers should adopt the number of hunting license sold by NIPF or bought by hunters as independent variables to better understand the factors influencing the engagement of hunting activities.

REFERENCES

Adams, D. M., Alig, R. J., McCarl, B. A., Callaway, J. M., & Winnett, S. M. (1996). An analysis of the impacts of public timber harvest policies on private forest management in the United States. *Forest Science, 42*(3), 343-358.

Ahn, S., Plantinga, A. J., & Alig, R. J. (2000). Predicting future forestland area: a comparison of econometric approaches. *Forest Science*, *46*(3), 363-376.

Akbari, H., Huang, J., Martien, P., Rainier, L., Rosenfeld, A., & Taha, H. (1988). The impact of summer heat islands on cooling energy consumption and global CO2 concentrations. In: Proceedings of ACEEE 1988 summer study in energy efficiency in buildings Vol 5. August 1988. Washington DC: *American Council for an Energy-Efficient Economy*: 11-23.

Alabama Department of Revenue (2018). https://revenue.alabama.gov/

Alabama Forest Resource Report (2018). https://forestry.alabama.gov/Pages/Management/Forms/Forest_Resource_Report_2018.df

Alabama Forestry Commission (2009). Forests at the crossroads: Alabama‘s forest assessment and resource strategy. State of Alabama Forestry Commission. Montgomery, AL. 181.

Alig, R. (1986). Econometric analysis of forest acreage trends in the Southeast. *Forest Science. 32*(1): 119–134.

Alig, R. J. (2003). Land use changes involving forestry in the United States, 1952 to 1997, with projections to 2050 (Vol. 587). Pacific Northwest Research Station.

Alig, R., & Plantinga, A. (2004). Future forestland area: impacts from population growth and other factors that affect land values. *Journal of Forestry 102*(8): 19–24.

Alig, R., & Plantinga, A. (2004). Future forestland area: impacts from population growth and other factors that affect land values. *Journal of Forestry. 102*(8): 19–24.

Alig, R., Lewis, D., & Swenson, J. (2005). Is forest fragmentation driven by the spatial configuration of land quality? The case of western Oregon. *Forest Management and Ecology. 217*(2-3): 266–274.

Alig, R., Stewart, S., Wear, D., & Nowak, D. (2010). Conversions of forest land: trends, determinants, projections, and policy considerations. In: Pye, John M.; Rauscher, H. Michael; Sands, Yasmeen; Lee, Danny C.; Beatty, Jerome S., tech. eds. 2010. Advances in threat assessment and their application to forest and rangeland management. Gen. Tech. Rep. PNW-GTR-802. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest and Southern Research Stations: 1-26, 802, 1-26.

Alig, R., Stewart, S., Wear, D., & Nowak, D. (2010). Conversions of forest land: trends, determinants, projections, and policy considerations. In: Pye, John M.; Rauscher, H. Michael; Sands, Yasmeen; Lee, Danny C.; Beatty, Jerome S., tech. eds. 2010. Advances in threat assessment and their application to forest and rangeland management. Gen. Tech. Rep. PNW-GTR-802. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest and Southern Research Stations: 1-26, 802, 1-26.

Alvarez M. (2017). The economic importance of U.S. forests. *https://www.arcgis.com/apps/Cascade/index.html?appid=3cd3bb86c2944b7faa172c0e2550489*

Amacher, G.S., Koskela E, Ollikainen, M., & Conway, C. (2002). Bequest intentions and forest landowners: theory and policy implications. *American Journal of Agricultural Economics 84* (4): 1103–1114

Balkan, E., & Kahn, J. R. (1988). The Value of Changes in Deer Hunting Quality: A Travel Cost Approach. *Applied Economics, 20(4),* 533-539.

Bariowe, R (1978). Land resource economics. 3d ed. Prentice-Hall, Englewood Cliffs, N J. p. 653.

Bergstrom, J. C., & Cordell, H. K. (1991). An Analysis of the Demand for and Value of Outdoor Recreation in the United States. *Journal of Leisure Research, 23(1),* 67-86.

Bigelow, D., & Borchers, A. (2017). Major uses of land in the United States, 2012 (No. 1476-2017-4340).

Birch, T.W. (1996). Private Forest-Land Owners of the Northern United States, 1994. USDA Forest Service Resource Bulletin NE-136.p.293.

Blair, R. M., & Feduccia, D. P. (1977). Midstory hardwoods inhibit deer forage in loblolly pine plantations. *The Journal of Wildlife Management*, 677-684.

Bockstael, N. (1996). Modeling economics and ecology: the importance of a spatial perspective. *American Journal of Agricultural Economics. 78*(5): 1168–1180.

Boxall, P. C., & Macnab, B. (2000). Exploring the Preferences of Wildlife Recreationists for Features of Boreal Forest Management: A Choice experiment Approach. *Canadian Journal of Forest Research, 30(12),* 1931-1941. 56

Boyle, K. J., Holmes, T. P., Teisl, M. F., & Roe, B. (2001). A Comparison of Conjoint Analysis Response Formats. *American Journal of Agricultural Economics, 83(2),* 441-454.

Bureau of Economic Analysis (2019). https://www.bea.gov/data

Butler, B., & Leatherberry, E. (2004). America's family forest owners. *Journal of Forestry. 102*(7): 4–9.

Butler, B., Swenson, J., & Alig, R. (2004). Forest fragmentation in the Pacific Northwest: quantification and correlations. *Forest Management and Ecology*. *189*: 363–373.

Chen, X. (2010). Trends of forest inventory data in Alabama, USA, during the last seven decades. *Forestry, 83*(5), 517-526.

Chen, X. (2019). Dynamics of forest composition and growth in Alabama of USA under human activities and climate fluctuation. *Journal of Sustainable Forestry*, *38*(1), 54-67.

Chomitz, K.M. & Gray, D.A. (1996). Roads, land use, and deforestation: a spatial model applied to Belize. *The World Bank Econ. Review 10*(3):487-512.

Cohen, M. A. (1983). Public cost-share programs and private investment in forestry in the south. In *Proceedings of the Symposium of Nonindustrial Private Forests, USA, 19-20 Apr 1983*. School of Forestry and Environmental Studies.

Conway, M. C. (1998). *Effects of shifting populations and preferences on nonindustrial landowner behavior: An example from Virginia* (Doctoral dissertation, Virginia Tech).

Conway, M. C., Amacher, G. S., Sullivan, J., and Wear, D. (2003). Decisions nonindustrial forest landowners make: an empirical examination. *Journal of Forest Economics*, *9*(3), 181-203.

de Steiguer, J. E. (1984). Impact of cost-share programs on private reforestation investment. *Forest Science*, *30*(3), 697-704.

Decker, D. J., & Connelly, N. (1989). Motivations for deer hunting: Implications for antlerless deer harvest as a management tool. *Wildlife Society Bulletin*, *17,* 455–463.

Donovan, G.H., & Butry, D. (2009). The value of shade: estimating the effect of urban trees on summertime electricity use. *Energy and Buildings. 41*(6): 662-668.

Drummond, M.A. & Loveland, T.R. (2010). Land-use pressure and a transition to forest-cover loss in the Eastern United States. *BioScience.* 60, 286–298.

Dyer, J. (2012). *Three essays on pine straw in Alabama: Needlefall yields, market demands, and landowner interest in harvesting* (Doctoral dissertation).

Floyd, M. F., & Lee, I. (2002). Who buys fishing and hunting licenses in Texas? Results from a statewide household survey. *Human Dimensions of Wildlife*, *7,* 91–106.

Greene, W. H. (2003). *Econometric analysis*. Pearson Education India.

Halls, L. K. (1984). White-tailed deer: ecology and management.

Hammer, R.B., Stewart, S., & Winkler, R.L. (2004). Characterizing dynamic spatial and temporal residential density patterns from 1940-1990 across the North Central United States. *Landscape and Urban Planning. 69*(2004): 183–199.

Hardie, I. W., & Parks, P. J. (1996). Program enrollment and acreage response to reforestation cost-sharing programs. *Land Economics*, 248-260.

Hardie, I., Parks, P., Gottlieb, P. & Wear, D. (2000). Responsiveness of rural and urban land uses to land rent determinants in the South. *Land Economics. 76*(4): 659–673.

Hardie, I.W. & Parks, P.J. (1997). Land use with heterogeneous land quality: an application of the area base model. *American Journal of Agricultural economics. 79*:299-310.

Hartsell, A. J., & Conner, R. C. (2013). Forest area and conditions: A 2010 update of Chapter 16 of the Southern forest resource assessment. e-Gen. Tech. Rep. SRS-GTR-174. Asheville, NC: US Department of Agriculture Forest Service, Southern Research Station. 32 p., 174, 1-32.

Haymond, J.L. (1988). NIPF opinion leaders: what do they want? *Journal of Forestry. 86*(4):30-35.

Henry, W. A., & Bliss, J. C. (1994). Timber harvesting, regeneration, and best management practices among west central Alabama NIPF owners. *Southern Journal of Applied Forestry, 18*(3), 116-121.

Hodges, D.G., & Cubbage, F.W. (1990). Nonindustrial private forest management in the South: Assistance foresters' activities and perceptions. *Southern Journal of Applied Forestry. 14*(1):44-48.

Hodges, D.G., & Cubbage, F.W. (1990). Nonindustrial private forest management in the South: Assistance foresters' activities and perceptions. *Southern Journal of Applied Forestry. 14*(1):44-48.

Huang, S., Zhang, Y., Zheng, Y., Su, S., & Zheng, J. (2019). Inequality and small landholdings: Path dependence, land use and wellbeing. *Forest policy and economics*, 98, 62-66.

Hurst, G. A., Campo, J. J., & Brooks, M. B. (1982). Effects of pre-commercial thinning and fertilizing on deer forage in a loblolly pine plantation. *Southern Journal of Applied Forestry*, *6*(3), 140-144.

Hussain, A. Zhang, D., & Armstrong, J. B. (2004). Willingness to Pay for Hunting Leases in Alabama. *Southern Journal of Applied Forestry*, *28*(1), 21-27.

Hussain, A., Munn, I. A., Hudson, D., & West, B. (2010). Attribute-based Analysis of Hunters' Lease Preferences. *Journal of Environmental Management*, *91(12)*, 2565-2571.

Kebede, E., Schelhas, J., & Haslerig, J. (2008). Alternative forest resource use-outdoor recreation and rural economics. *Journal of Environmental Monitoring & Restoration 5: 20-29*, *5*, 20-29.

Kline, J. D., Alig, R. J., & Johnson, R. L. (2000). Fostering the production of non-timber services among forest owners with heterogeneous objectives. *Forest Science*, *46*(2), 302-311.

Kline, J., & Alig, R. (2001). A spatial model of land use for western Oregon and western Washington. Res. Pap. PNW-528. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 24.

Kline, J., Alig, R., & Garber-Yonts, B. (2004a). Forestland social values and open space preservation. *Journal of Forestry*. *102*(8): 39–45.

Lambin, E.F. & Geist, H. (2005). Land Use and Land Cover Change: Local Processes, Global Impacts. Springer, New York.

Lee, K., Kaiser, F., & Alig, R.J. (1992). Substitution of public for private funding in planting southern pine. *Southern Journal of Applied Forestry*. *16*: 204–208.

Lubowski, R.N. (2002). The determinants of land use transitions in the United States. Cambridge, MA: Harvard University. Ph.D. dissertation.

Luzar, E. J., Hotvedt, J. E., & Gan, C. (1992). Economic Valuation of Deer Hunting on Louisiana Public Land: A Travel Cost Analysis. *Journal of Leisure Research, 24(2),* 99-113.

MacCleery, D. W. (1992). American Forests: A History of Resiliency and Recovery, FS-540. *US Department of Agriculture, Forest Service, Washington DC*.

Majumdar, I., Polyakov, M., & Teeter, L. (2005). Land Use Change Determinants in Alabama. In Emerging Issues along Urban/Rural Interfaces: Linking Science and Society. Conference Proceedings (pp. 67-70).

Majumdar, I., Polyakov, M., & Teeter, L. D. (2007). Effect of Urbanization on the Forest Land Use Change in Alabama: A Discrete Choice Approach. Emerging Issues in Forest Economics, 143.

Majumdar, I., Polyakov, M., & Teeter, L. D. (2007). Effect of Urbanization on the Forest Land Use Change in Alabama: A Discrete Choice Appproach. Emerging issues in forest economics, 143.

Majumdar, I., Polyakov, M., Teeter, L. D., & Butler, B. J. (2009). Effect of population pressure on forest land use change in Alabama: a nested logit approach. *International Journal of Ecological Economics and Statistics, 14*(P09), 77-93.

Majumdar, I., Polyakov, M., Teeter, L., & Center, F. P. (2005). Land Use Change Determinants in Alabama. In Conference Co-sponsors: Center for Forest Sustainability: A Peak of Excellence at Auburn University National Science Foundation USDA Forest Service, Southern Center for Wildland-Urban Interface Research and Information.

Marcouiller, D. W., & Prey, J. (2005). The tourism supply linkage: Recreational sites and their related natural amenities. *Journal of Regional Analysis & Policy*, *35*(1), 23-32.

McConnell, K. E., & Strand, I. (1981). Measuring the cost of time in recreation demand analysis: An application to sport-fishing. *American Journal of Agricultural Economics*, *63*(1), 153-156.

Mehmood, S., Zhang, D., & Armstrong, J. (2003). Factors associated with declining hunting license sales in Alabama. *Human Dimensions of Wildlife*, *8*(4), 243-262.

Miller, D. J., & Plantinga, A. J. (1999). Modeling land use decisions with aggregate data. *American Journal of Agricultural Economics, 81*(1), 180-194.

Mingie, J. C., Poudyal, N. C., Bowker, J. M., Mengak, M. T., & Siry, J. P. (2018). Comparing the Net Benefit of Forestland Access for Big-Game Hunting across Landownership Types in Georgia, USA. *Forest Science, 65*(2), 189-200.

Munn, I. A., & Evans, D. L. (1998). The southern commercial timberland base: changes and projections. In first international conference on geospatial information in agriculture and forestry, June, Florida.

Munn, I. A., & Hussain, A. (2010). Factors Determining Differences in Local Hunting Lease Rates: Insights from Blinder-Oaxaca Decomposition. *Land Economics*, *86*(1), 66-78.

Munn, I. A., Hussain, A., Hudson, D., & West, B. C. (2011). Hunter Preferences and Willingness to Pay for Hunting Leases. *Forest Science, 57(3)*, 189-200.

Nagubadi, R. V., & Zhang, D. (2005). Determinants of timberland use by ownership and forest type in Alabama and Georgia. *Journal of Agricultural and Applied Economics, 37*(1379-2016-112677), 173-186.

Nagubadi, R. V., & Zhang, D. (2007). 27 Urbanization and Timberland-use Change in the Southern USA. *Cross-Sectoral Policy Developments in Forestry*, 212.

Nowak, D. J., & Walton, J. T. (2005). Projected urban growth (2000–2050) and its estimated impact on the US forest resource. *Journal of Forestry*, *103*(8), 383-389.

Nowak, D.J., Crane, D.E., & Stevens, J.C. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry and Urban Greening. 4*: 115-123.

Offenbach, L. A., & Goodwin, B. K. (1994). A Travel-cost Analysis of the Demand for Hunting Trips in Kansas. *Review of Agricultural Economics, 16(1)*, 55-61.

Parks, P. J., & Murray, B. C. (1994). Land attributes and land allocation: nonindustrial forest use in the Pacific Northwest. *Forest Science*, *40*(3), 558-575.

Pattanayak, S., Murray, B. & Abt, R. (2002). How joint is joint forest production: an econometric analysis of timber supply conditional on endogenous amenity values. *Forest Science 48 (3)*: 479–491.

Peitz, D. G., Tappe, P. A., Shelton, M. G., & Sams, M. G. (1999). Deer browse response to pine-hardwood thinning regimes in southeastern Arkansas. *Southern Journal of Applied Forestry*, *23*(1), 16-20.

Plantinga, A. J., & Mauldin, T. (2001). A method for estimating the cost of CO_2 mitigation through afforestation. *Climatic Change, 49*(1-2), 21-40.

Plantinga, A. J., Mauldin, T., & Miller, D. J. (1999). An econometric analysis of the costs of sequestering carbon in forests. *American Journal of Agricultural Economics, 81*(4), 812-824.

Polyakov, M., & Zhang, D. (2008). Property tax policy and land-use change. *Land Economics, 84*(3), 396-408.

Poudel, J., Henderson, J. E., & Munn, I. A. (2016). Economic contribution of hunting expenditure to the southern United States of America. *International Journal of Environmental Studies*, *73*(2), 236-254.

Poudyal, N., Cho, S. H., & Bowker, J. M. (2008). Demand for resident hunting in the Southeastern United States. *Human Dimensions of Wildlife*, *13*(3), 158-174.

Rhyne, J. D., Munn, I. A., & Hussain, A. (2009). Hedonic Analysis of Auctioned Hunting Leases: A Case Study of Mississippi Sixteenth Section Lands. *Human Dimensions of Wildlife*, *14*(4), 227-239.

Sampson, N., & DeCoster, L. (2000). Forest fragmentation: implications for sustainable private forests. *Journal of Forestry*, *98*(3), 4-8.

Shaw, W. D. (1992). Searching for the Opportunity Cost of an Individual's Time. *Land Economics*, 107-115.

Shrestha, R. K., & Alavalapati, J. R. (2004). Effect of Ranchland Attributes on Recreational Hunting in Florida: A Hedonic Price Analysis. *Journal of Agricultural and Applied Economics, 36*(03), 763-772.

Shulstad, R. N., & Stoevener, H. H. (1978). The effects of mercury contamination in pheasants on the value of pheasant hunting in Oregon. *Land Economics, 54*(1), 39-49.

Stewart, S., Radeloff, V.C., & Hammer, R. (2003). The wildland-urban interface in U.S. metropolitan areas. In: Kollin, C., ed. Proceedings of the 2003 national urban forest conference. Washington, DC: American Forests: 254–255.

Stribling, H. L., Caulfield, J. P., Lockaby, B. G., Thompson, D. P., Quicke, H. E., and Clonts, H. A. (1992). Factors influencing willingness to pay for deer hunting in the Alabama piedmont. *Southern Journal of Applied Forestry*, *16*(3), 125-129.

Timber Mart Report – South (2020). http://timbermart-south.com/

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) (2001). National resource inventory. Unnumbered report. Washington, DC. p.178.

United States Census Bureau (2020). https://www.census.gov/data/data-tools.html

United States Department of Agriculture (2019). https://www.ers.usda.gov/data-products/county-level-data-sets/download-data/

US Department of Agriculture (2017). National Agricultural Statistics Service, Washington

Wear, D. N., & Murray, B. C. (2004). Federal timber restrictions, interregional spillovers, and the impact on US softwood markets. *Journal of Environmental Economics and Management*, *47*(2), 307-330.

Wear, D., Pye, J., & Riitters, K. (2004). Defining conservation priorities using fragmentation forecasts. *Ecology and Society. 9*(5): 4.

Wear, D.N., & Bolstad, P. (1998). Land-use changes in southern Appalachian landscapes: spatial analysis and forecast evaluation. *Ecosystems*. 1: 575–594.

Wear, David N. & Greis, John G., eds. (2012). The Southern Forest Futures Project: summary report. Gen. Tech. Rep. SRS-168. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 54.

Williams, M. (1989). Americans and Their Forests: A Historical Geography. New York, NY, Cambridge University Press.

Zellner, A. (1962). An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American statistical Association*, *57*(298), 348-368.

Zhang, D., & Mehmood, S. R. (2001). Predicting nonindustrial private forest landowners' choices of a forester for harvesting and tree planting assistance in Alabama. *Southern Journal of Applied Forestry*, *25*(3), 101-107.

Zhang, D., Hussain, A., & Armstrong, J. B. (2006). Supply of hunting leases from non-industrial private forest lands in Alabama. *Human Dimensions of Wildlife*, *11*(1), 1-14.

Zhang, Y., Zhang, D., & Schelhas, J. (2005). Small-scale non-industrial private forest ownership in the United States: rationale and implications for forest management. *Silva Fennica, Vol. 39* (3): 443-454.

Zhou, N. (2010). An econometric analysis of Alabama rural land values (Doctoral dissertation).

Ziemer, R. F., Musser, W. N., & Hill, R. C. (1980). Recreation demand equations: Functional form and consumer surplus. *American Journal of Agricultural Economics*, *62*(1), 136-141.

Zinn, H. C., Manfredo, M. J. & Barro, S. C. (2002). Patterns of wildlife values orientations in hunters' families. *Human Dimensions of Wildlife*, *7*, 147–162.

Zobrist, K. W., Hinckley, T. M., & Andreu, M. G. (2005). A literature review of management practices to support increased biodiversity in actively managed loblolly pine plantations. Rural Technology Initiative.