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Forest land use responses to wood product markets

Taek Joo Kim[a,*], David N. Wear[b], John Coulston[c], Ruhong Li[a]

[a] U.S. Forest Service Southern Research Station, 3041 Cornwallis Rd., Research Triangle Park, NC 27709, United States
[b] U.S. Forest Service Southern Research Station, Center for Integrated Forest Science, 3041 Cornwallis Rd., Research Triangle Park, NC 27709, United States
[c] U.S. Forest Service Southern Research Station, 1710 Research Center Drive, Blacksburg, VA 24060-6349, United States

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ABSTRACT

Land use measurements collected by the Forest Inventory and Analysis (FIA) program allow for monitoring and modeling changes among a detailed set of land use categories. We analyze these data in the southeastern United States to test hypotheses regarding the influence of timber and other land rents, population growth, and various topographic position variables on transitions among rural and developed land uses. This region provides a complete and recent set of land use and forest measurement, is the most important and dynamic timber production region in the world, and increasingly is the focus of international policy debates regarding wood based bioenergy. This analysis is the first to link specific land use changes with forest conditions for modeling rural land use response. While previous studies have relied on aggregate measures of timber values, the detailed forest condition measures allow for site-specific estimates of timber quasi-rents, providing new and unique insights into the influence of timber market conditions on land use changes. Results provide an empirical analysis of the influence of timber rent on transitions to all other uses and specifically show that higher timber rents reduce transitions of forests to all other rural land uses as well as to developed land uses. The latter finding is unique and provides support for the claim that stronger timber markets enhance the area of forests and alter patterns of land use change including patterns of development in the southeastern United States.

1. Introduction

Land use patterns and changes are organized by numerous co-occurring factors related to human activities and the biophysical environment. In the southeastern United States, land use has been especially dynamic with a changing and diverse mix of agricultural, forestry, and developed uses in most areas. Over the past three decades, forest area has increased (Wear and Greis, 2013) while crop production has declined overall and become concentrated in several subregions, e.g. Florida, and the Mississippi Delta (Nickerson et al., 2011). At the same time, the South is among the fastest growing regional economies in the United States with commensurate growth in urban and other developed land uses (Wear, 2011). Assessments of forest conditions and likely future changes have raised questions about the long term trajectory of forest area as changing markets for goods and services from rural land uses interact with urban expansion (Wear and Greis, 2013). Recent policy debate regarding the sustainability of wood energy production from the region, especially in the form of pellets traded to Europe, raises questions about the potential for growing demands for forest products to stimulate derived demand for forest land and expansion in the overall forest land base (NRDC, 2015).

The objective of this study is to examine the influence of various factors, including timber, crop, and pasture rents on land use transitions in the southeastern United States with special attention placed on the potential response of existing forest land to changing forest market conditions. Like previous studies of land use changes (Plantinga et al., 1999; Hardie et al., 2000; Kline and Alig, 2001; Ahn et al., 2002; Plantinga and Ahn, 2002; Lubowski, 2002; Lubowski et al., 2008), we assume that land use choices are based on rent maximization consistent with the theories of Ricardo and von Thünen. Our study and its focus on forest transitions utilizes a previously unavailable dataset describing land use changes linked to the detailed forest condition metrics of the U.S. Forest Service FIA forest inventory, allowing for precise estimates of land use transitions and timber values and rents. Previous studies have utilized the National Resource Inventory dataset that cannot support a detailed assessment of forest conditions and valuations.

While the primary focus of FIA is on monitoring forest conditions, the sampling design covers all land uses across a regular grid and is assumed to produce an equal probability sample (Bechtold and Patterson, 2005). In our study area detailed land use has been collected on all inventory plots (including those with non-forest uses) since 2000. Inventory protocol now assigns detailed land use classes for the entire

* Corresponding author.
E-mail addresses: tjkim@ncsu.edu (T.J. Kim), dwear@fs.fed.us (D.N. Wear), jcoulston@fs.fed.us (J. Coulston), rnli@ncsu.edu (R. Li).

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FIA plot set at stationary fixed points. The area frame structure of the inventory allows for estimating the full areal extent of land uses and land use transitions. The National Resource Inventory Program (U.S. Department of Agriculture, 2015) used in previous studies, is built on a different sampling scheme focused on agricultural conditions, and is limited to nonfederal land ownership. The FIA land use measures are based on comparable land use categories but include federal lands.

Furthermore, FIA's detailed observations of forest conditions allow us to develop a much more precise accounting of implied timber rents for all forested plots. While previous studies have relied on a single hypothetical forest management option using a Faustman formulation for planted pine or average stumpage prices at county or regional scales to proxy for timber rents (Mauldin et al., 1999; Plantinga et al., 1999; Kline and Alig, 2001; Ahn et al., 2002; Plantinga and Ahn, 2002), our calculation of timber rents derives from detailed observations of forest attributes and relevant timber prices for each forest plot. This allows us to empirically assess the maximum expected net present value for each forest plot defined by specific harvest options, critical information for addressing our study objectives.

2. Study area

Our study area is the southeastern region of the United States defined by the thirteen states from Florida to Kentucky and Virginia, and including eastern parts of Oklahoma and Texas (Fig. 1). The southeast contains a wide variety of ecosystems sustaining diverse array of flora and fauna (Golladay et al., 2016). The physiographic regions of the southeast include portions of the Atlantic Coastal Plain, the Appalachian Highlands, the Interior Highlands and Piedmont, Mississippi Delta, and the Interior Plains (Alig et al., 2003). Forest is the dominant land use in the study area and several states were estimated to be > 65% forested. The southeast is the largest producer of timber in the country (Wear and Greis, 2013). About 89% of forests are privately owned, of which one third are corporate land owners and two thirds are individuals or families (Butler and Wear, 2013). Corporate forests are largely held by real estate investment trusts and timber investment management organizations, but also include forest industry. Urbanization and development in general have accelerated in recent decades in the vicinity of large metropolitan areas especially those along the Atlantic and Gulf coasts and throughout the Appalachian Piedmont region. At the same time, large portions of the rural South have experienced steady depopulation with attendant implications for land use changes (Wear, 2011; U.S. Department of Agriculture, 2015; U.S. Census Bureau, 2016).

3. Methods

3.1. Theory

We estimate a land use change probability model to gauge how the probability of observing a land use change is influenced by a variety of variables. The modeling approach is generally consistent with a Ricardian land rent approach where we assume that land use observed at the beginning and end of the period is consistent with a risk-neutral landowner seeking to maximize returns. We estimate the discrete choice of transitions for each beginning period land use — i.e., separate models for initial forest, initial cropland, etc. We assume that landowners choose from a restricted set of land uses so that their use of land maximizes rent accruing to productive activity:

$$y_{ijt} = 1 \; if \; R_{ijt}{}^{*} = \max(R_{1jt}, R_{2jt}, ..., R_{Kjt}) \tag{1}$$

where y_{ijt} is equal to one when land at location j is dedicated to land use i at time t. $R_{ijt}{}^{*}$ is the quasi-rent that accrues to land use i at location j which is a function of the marginal return to land in a multiple input profit framework for the selected land use (see Hardie et al. 2000).

A land use change implies a consequential reordering of quasi-rents across the land use options so that quasi-rent for a different use comes to dominate and land use switches accordingly. More precisely, a change from land use i to land use k implies that:

$$dR_{ik,t+1} = R_{k,t+1} - R_{i,t+1} - CC_{ik,t+1}(z) - A_{ik,t+1}(x) > 0 \tag{2}$$

That is, the difference between land rents accruing to land uses k and i, net of conversion costs (CC) which depend on site attributes (z), and a set of additional value changes in the vector A (e.g., related to biophysical, climate, or other factors (x) not accounted for in the rent calculations) as well as considerations that are outside the expected rent framework and may be essentially unobservable. Most clearly this includes option values forgone by executing the land use change when reversal costs are high. In general we expect that high option values would retard the adoption of land use switching otherwise indicated by the comparison of rents and net of conversion costs.

Translating Eq. (2) into an empirical model involves defining a discrete choice model that includes variables that proxy for the site specific rents, conversion costs, and other factors in Eq. (2):

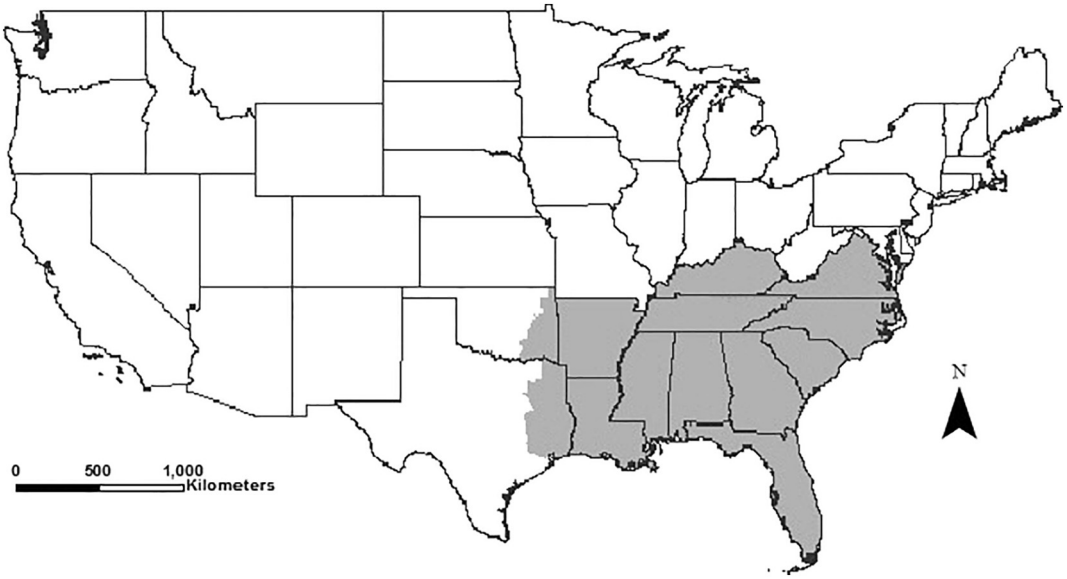

Fig. 1. Map of the study area.