DETERMINANTS OF LAND-USE TRANSITIONS IN THE UNITED STATES: ECONOMETRIC ESTIMATION OF A MARKOV MODEL

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Abstract

In an effort to better understand the factors affecting land-use changes and the potential impact of different land-use policies in the United States, this paper expands upon existing studies by (1) providing the first national econometric analysis of land-use changes to include all major land-use categories (crops, pasture, forests, urban, range, and Conservation Reserve Program); (2) developing a consistent framework for modeling changes in urban and non-urban land uses; and (3) modeling a comprehensive set of transitions among land-use categories. Refinements in data gathering allow for this expanded analysis. Using repeated parcel-level observations of land-use changes and land quality from 1982 to 1997 and measures of county-level profits for the alternative land uses, I estimate an econometric model representing land-use change as a first-order Markov process. The results are used to calculate land-use transition probabilities for different land qualities and elasticities for these probabilities with respect to land-use profits. I also conduct a series of simulations to quantify the impact of historical changes in land-use profits on the different land-use transitions. I highlight the implications of selected results for policy issues, including forestry policies for carbon sequestration and tax policies for restraining urban growth. The full set of results provides a basis for future simulations of nationwide land-use transitions under different economic and policy scenarios. Outcomes of such analyses can be used in the development of economic incentive-based land-use policy approaches.

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1. INTRODUCTION

Changes in the use of land in the United States produce significant economic and environmental effects with important implications for a wide variety of policy issues, including protection of wildlife habitat, management of urban growth, and mitigation of global climate change through carbon sequestration in forestry and agriculture. Private landowners account for about sixty percent of the total U.S. land base, including fifty-eight percent of the country's forests and ninety percent of the nation's farmland (USDA ERS 2000; USDA FS 2001). Private land-use decisions are thus central to concerns over the social costs and benefits associated with different land-use changes. Private land-use decisions generate environmental and other social costs and benefits that typically are not reflected in the incentives faced by the individual landowner. These pervasive externalities represent opportunities to increase social welfare by developing policies that focus on more closely aligning private land-use decisions with social objectives.

In order to help in the successful development of such policies, this paper expands upon existing studies of the determinants of land-use changes in the United States in three principal ways. First, and most significantly, the paper is the first national econometric analysis of land-use changes to include all major land-use categories. Second, this study is the first econometric land-use study to employ a consistent framework for modeling changes in both urban and non-urban land uses. Third, in contrast to other studies that are restricted to the analysis of *net* changes in the areas under different land uses, this paper examines a comprehensive set of transitions among the different land-use categories.

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I am able to pursue this expanded analysis as a result of refinements in the data and the introduction of a nested logit model. Previous studies have been restricted in part because of a lack of data This study is the first econometric analysis to examine national-level data on a variety of different land uses. In particular, this study is the first to exploit the comprehensive national coverage of the plot-level data on private land use and land characteristics from the U.S. Department of Agriculture's National Resources Inventory (NRI).[1] In addition, this study involved an extensive process of data assembly from diverse state and national sources to construct county-level estimates of the profits to the different land uses for the forty-eight contiguous states. My focus on the comprehensive set of transitions among land-use categories, however, raises a number of econometric challenges, including the need to take into consideration the possibility of different substitution patterns among land-use categories. In order to address this difficulty, I develop a nested logit specification for the probability of transition from one land-use category to another.

To date, econometric-based analyses of private land-use choices have focused on relatively small geographic areas such as regions or single states. The few previous studies with national-level data have examined changes in a single land-use category—namely, urban areas (Alig and Healy 1987), government conservation programs (Parks and Kramer 1987; Poe 1998; Plantinga *et al.* 2001), and timberland (Plantinga and Buongiorno 1990)—without modeling the full range of land-use alternatives that simultaneously influence land-use changes at the national scale. By conducting an analysis that includes data on all major land uses for the forty-eight contiguous U.S. states, I provide evidence on the determinants of land-use changes for examining a broad set of nationwide policy issues. In moving to a national scale, I extend the methodology used in previous studies in several ways. First, my broader geographical scope requires consideration of a comprehensive menu of land-use alternatives. Earlier studies generally examine a small subset of land-use categories. While focusing on a particular type of land-use change, such as forest to crop conversion (Stavins and Jaffe 1990), might capture the most significant direction and type of change in a particular region, land

[1] Using plot-level data from the NRI, Claassen (1993) examines land-use changes between crops and pasture and crops and forests in South Carolina while Claassen and Tegene (1999) model changes between crops and pasture in the Corn Belt region. Schatzki (1998) uses NRI plot-level data to study the effects of uncertainty on transitions between crops and forests in Georgia. Hardie *et al.* (2000) aggregate NRI data to the county-level in their study of net changes in the area of farms, forests and urban uses in the U.S. South.

exchanges between a variety of land-use categories are important in determining land-use changes the national level.

In this paper, I consider changes among six major land uses: crops, pasture, forest, urban, range, and the Conservation Reserve Program (CRP).[2] Other studies have considered comprehensive sets of land categories for particular states (Mauldin *et al.* 1999a; Mauldin *et al.* 1999b) or regions (Alig 1985, 1986; Alig *et al.* 1988; Hardie and Parks 1997; Hardie *et al.* 2000). These studies generally aggregate land-use possibilities into relatively broad categories. I consider a greater number of land-use alternatives than previous authors with the exception of work that distinguishes among different forest ownerships in the U.S. South (Alig 1985, 1986; Alig *et al.* 1988).[3]

In addition to examining choices among a full set of land-use alternatives, to my knowledge this study is the first econometric land-use analysis to use a consistent framework for modeling changes in both urban and non-urban land uses. As Hardie *et al.* (2000) discuss, previous land-use studies have generally focused on either rural or urban uses alone or treated one set of uses as a residual category.[4] Hardie *et al.* provide a more integrated analysis of rural and urban uses, and provide evidence for the importance of simultaneously modeling changes among urban and rural categories. Nevertheless, they use proxy measures for the profitability of urban development, while using more direct estimates of the net returns to farms and forests. Econometric studies that use proxies for urban development rents, such as population density, do not provide estimates of landowners' responsiveness to urban profits that can be used to model financial incentives to prevent conversion to urban uses.

In contrast to previous work, my study treats urban and non-urban land development decisions in a consistent econometric framework by including estimates of the annual net returns per acre of urban development along with estimates of the annual net returns per acre

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[2] While total acreage in the CRP is small relative to the other land-use categories, changes into the CRP have been large compared to changes among other land-use categories (Tables 1.1-1.4).

[3] In studies of county-level land shares in different Southern regions, Alig (1985, 1986) and Alig *et al.* (1988) analyze changes among crops, pasture/range, urban/other, and three forest groupings (forests on farms, industrial forests, and other private forests). Other studies examine changes among a variety of crop types but do not consider non-crop uses (*e.g.* Lichtenberg 1989; Wu and Segerson 1995).

[4] In modeling rural land-use changes, authors include direct estimates of the net economic returns to farm and forest uses but, to the extent that urban uses are considered, they employ proxies for urban development returns such as population growth and/or density (Alig *et al.* 1988; Mauldin *et al.* 1999a; Mauldin *et al.* 1999b). In contrast, the empirical literature on urban development includes studies of the timing and location of urban development choices that employ spatially explicit data on parcel characteristics and house prices (Bockstael and Bell 1997; Geoghegan and Bockstael 2000; Hite *et al.* 2001; Irwin and Bockstael 2002). While carefully modeling urban development values, these authors do not differentiate between changes on alternative non-urban uses, which are generally treated as an aggregate category of undeveloped land.

of crops, pasture, forests, and range. This methodology has the advantage of maintaining theoretical consistency in the modeling of the different uses. Moreover, this approach provides estimates of landowners' responsiveness to changes in profits from both urban and non-urban land uses that can be used for the analysis of taxes and other policies that might affect the profitability of urban as well as non-urban land-use options.

Changes in land-use patterns are the net result of flows in between the different categories and, as the number of relevant land-use alternatives increases, the number of potentially important land-use transitions increases exponentially. Using repeated plot-level observations of land use from the National Resources Inventory (NRI), this study extends the methodology in previous papers by modeling a comprehensive set of transitions among the different land-use categories rather than just the net changes in these categories.[5] Consideration of a broad range of land-use transitions becomes important at the national level in accordance with the increase in land-use options faced by landowners. Tables 1.1, 1.2., and 1.3 show the flows of land between the different major land-use categories considered in this study at five year increments from 1982 to 1997. Across any of the time periods, while net changes in a single category such as forests are relatively small, there are substantially greater gross flows of land between all of the major land-use categories (with the exception of the negligible flows out of urban areas and flows out of the CRP, which are restricted by contracts for at least ten years). Understanding the pattern of flows, rather than just the net changes in a particular category, is important for a variety of policy issues. For example, conversion from crops to urban uses may be of concern to policy-makers while conversion from crops to forests may not be of concern from the perspective of maintaining open space. Similarly, newly planted forests have different ecological characteristics than older forests with implications for the provision of environmental benefits such as wildlife habitat and carbon sequestration.[6]

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[5] Authors have examining net changes in county land shares using county-level Census land-use data (Mauldin *et al.* 1999; Plantinga *et al.* 1999) or by choosing to aggregate plot-level data (Hardie *et al.* 2000) or aerial photographs (Stavins and Jaffe 1990). Those studies modeling land-use choices at the plot level have focused on very particular land-use transitions in relatively small geographic regions. Using data from the NRI, Claassen (1993) examined changes between crops and pasture and crops and forests in South Carolina; Schatzki (1998) modeled changes from crops to forests in Georgia; and Claassen and Tegene (1999) analyzed changes between crops and pasture in the Corn Belt. Using data from U.S. Forest Service survey plots, Munn and Cleaves (1999) analyze transitions out of timberland areas in the South while Kline and Alig (1999) study changes from forest to urban areas in the western Washington and Oregon states. A series of studies with spatially explicit data models urban development choices in a Maryland watershed (Bockstael and Bell 1997; Geoghegan and Bockstael 2000; Irwin and Bockstael 2002).

[6] While clearing of forests will lead to carbon releases, planting of forests initiates a process of carbon sequestration that takes place over future years of forest growth. Increases in carbon sequestration on newly planted forests will also be different

This paper is the first to estimate parameters for a full matrix of land-use transition probabilities among the major land-use categories in the United States.[7] My econometric modeling approach follows the land-use literature in identifying profits per acre and land quality measures as the driving factors of landowner decisions and in using a random utility specification for landowner returns. I use this framework to specify an econometric model representing land-use change as a first-order Markov process. Markov transition probabilities are specified as functions of county-level land-use returns, plot-specific land quality measures, and parameters to be estimated. Modeling transitions among a broad set of land-use options introduces the econometric challenge of accounting for potentially different substitution patterns among the various choices. I estimate the parameters of the transition probabilities using a nested logit as well as a conditional logit model to partially relax the restriction of independence of irrelevant alternatives (IIA) and thus allow for more complex patterns of substitution among land-use alternatives.

Empirical studies of land-use changes can inform public policy formulation by providing evidence on actual patterns of landowner behavior. Econometric estimates of landowner responsiveness to economic returns are particularly important given increased attention to economic incentive-based land-use policy approaches. While land-use policies traditionally have been implemented through zoning and other regulatory means, interest has grown in using policies to affect land-use decisions by increasing the economic benefit of the socially desired land-use choices. State and federal programs have been created both to increase the incentives for conversion to desired uses as well as to discourage landowners from converting to undesired alternatives. Most notably, the nationwide Conservation Reserve Program (CRP), started in 1985, pays landowners about $1.7 billion per year to voluntarily retire more than thirty million acres of environmentally-sensitive cropland for ten to fifteen year periods (USDA ERS 2000). Increased concern over the threat of global climate change has also led to discussion of national-level policies to provide incentives for

depending on the previous land use since different uses imply different amounts of carbon storage in biomass as well as the soil. As a result, even if net forest areas remain unchanged, the particular pattern of flows into and out of forests will imply different amounts of carbon sequestered.

[7] In related work, Miller and Plantinga (1999) develop a maximum entropy estimation approach to recover the parameters of unobserved transition probabilities from aggregate data and estimate a model of crop choices in three Iowa counties. Plantinga and Ahn (2002) similarly employ aggregate data on forest and agricultural land to estimate respective transition probabilities.

maintaining forest areas as a means of sequestering carbon dioxide (NAS 1992; Bruce *et al.* 1996; Watson *et al.* 2000).[8]

The remainder of this paper consists of four sections. Section 2 establishes the theoretical framework based on the dynamic optimization problem for an individual landowner faced with the choice of allocating land among a set of alternative uses. In Section 3, I use the solution to the landowner's decision problem to specify an econometric model of land-use change as a Markov process. Section 4 presents estimation results with a discussion of the estimated parameters, land-use transition probabilities, and elasticities of the probabilities with respect to land-use profits. To better illustrate the estimated effects, Section 5 discusses results from a series of historical simulations that quantify the impact of historical changes in land-use profits on the different land-use transitions. I focus my discussion on the changes in forest areas and highlight some policy implications. Section 6 presents concluding remarks on the potential application of my model to examine a broad range of land-use policy issues.

[8] Forested land generally stores more carbon than land in other uses, such as agriculture, and thus the conversion of non-forest land to forest provides a means of increasing terrestrial carbon storage.

2. THEORETICAL FRAMEWORK

In this section, I describe the dynamic optimization problem for an individual landowner faced with the choice of allocating a parcel of land among a set of alternative uses.

2.1 DYNAMIC OPTIMIZATION MODEL OF LANDOWNER DECISION MAKING

Previous theoretical treatments of land-use decision-making have generally focused on land conversion between two uses (Stavins and Jaffe 1990; Plantinga 1996; Parks 1995).[9] In this section, I develop a theoretical model of a landowner's decision to allocate a parcel of land among a variety of possible uses. I cast the landowner's decision-making problem in a general dynamic programming framework so as to identify the effects of a broad range of factors that may affect the timing of land-use changes. I subsequently impose more restrictive assumptions and discuss the implications.

I focus on the problem of a landowner choosing how to use a small parcel of land of homogeneous quality, given multiple land-use options. I posit that the landowner chooses the use at each point in time in order to maximize the present discounted value of the stream of expected future net benefits. Assuming that land-use returns are linear in the quantity of land, the size of the parcel will not affect the relative profitability of alternative land-use options. Assuming no spatial externalities, the land-use decision does not depend on the choices made for other parcels. Thus, the land-use decisions for a larger area of heterogeneous quality can be viewed as the sum of land-use decisions regarding constituent uniform-quality parcels.

Consider a profit-maximizing landowner with a parcel of land of size *L*, with multiple land-use options *j (j=1,...,J)*. The stock of land on the parcel in use *j* at time *t (t=0,..., ∞)* is S_{jt} and thus $\sum_{j=1}^{J} S_{jt} = L$ at all points in time. At starting time *t=0*, the parcel contains an initial stock S_{jt_0} of land in use *j*. At each point in time *t*, the landowner's problem is to choose how much of

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[9] A notable exception is Claassen (1993) who presents a theoretical model of land use choice with three uses in a deterministic setting. He uses a static optimization framework and views land as an input into production functions corresponding to different land-use options. Although his qualitative results are similar, my model differs from Claassen's in that the parcel size is fixed and the optimization problem is set in a dynamic framework in my approach. Lichtenberg (1989) and Hardie and Parks (1997) model the decision of a landowner choosing how to divide a heterogeneous land base among multiple crops and multiple land uses respectively. They highlight the importance of land quality in determining the optimal use for a parcel but do not specify the landowner's condition for converting from one use to another. Albers (1996) derives numerical solutions for a model with three land uses in a dynamic programming framework with uncertainty and spatial externalities.

his land in each use to allocate to every other use so as to maximize the present discounted value of the stream of expected net benefits net of conversion costs:

$$\max_{a_{jkt}} \int_{t=0}^{\infty} \left\{ \sum_{j=1}^{J} E_t \left[R_{jt} \right] S_{jt} e^{-rt} - \sum_{j=1}^{J} \sum_{k=1}^{K} E_t \left[C_{jkt} \left(a_{jkt} \right) \right] e^{-rt} + E_t \left[V_{t+1} \right] e^{-r(t+1)} \right\} dt \qquad (1)$$

subject to:

$$\dot{S}_{jt} = \sum_{k=1}^{K} \left(a_{kjt} - a_{jkt} \right) \qquad (2)$$

$$\sum_{k=1}^{K} a_{jkt} \le S_{jt} \qquad (3)$$

$$a_{jkt} \ge 0 \qquad (4)$$

where:

$J = K$ = number of different land uses and $(j=1,\ldots, J)$, $(k=1,\ldots, K)$;

S_{jt} = stock of land on the parcel in use j at time t $(t=0,\ldots, \infty)$, as noted above;

a_{jkt} = number of acres converted from use j to k at time t;

R_{jt} = the instantaneous net benefits from an acre of land in use j at time t;

$C_{jkt}(a)$ = total costs of converting a acres of land from use j to use k at time t;

r = discount rate $(r>0)$;

V_{t+1} = the continuation value of the optimal program starting at time $t+1$.

The landowner's problem at time t is thus to choose JK control variables a_{jkt}, denoting the number of acres from each of the J stocks S_{jt} of land in use j to convert to possible use k at time t. By switching from use j to use k at time t, the landowner can earn returns R_{kt} rather than R_{jt} per acre but will incur a one-time conversion cost $C_{jkt}(a)$ for a acres converted. Landowners do not know variables R_{jt}, C_{jkt}, and V_{t+1} with certainty. For simplicity, I assume that landowners are risk-neutral and thus base their decisions on expected values.[10]

As expressed by equation (2), there are *j* state variables, S_{jt}, which evolve according to the net effect of all conversions to use *j* from every other land-use category minus all the conversion away from use *j* to every other category. Constraints (3) and (4) indicate that at most the entire stock of land in use *j* can be converted from *j* to any other use (or maintained in use *j*) and that the amount of land converted must be non-negative.

Letting $V_t(a_{jkt})$ equal the instantaneous payoff plus the continuation value given the choice of a_{jkt} at time t, the optimal solution is to choose a_{jkt} if $V_t(a_{jkt}) \geq V_t(a_{jk't})$ for all $k \neq k'$. Until now, I have imposed no restrictions on the continuation value V_{t+1}. How landowners view this value will be a critical determinant of their land-use choice. If land-use change is irreversible, then the expected continuation value which is obtained from converting to another use is the expected net present value of the stream of returns from staying in that use forever. The landowner's decision problem here is to choose a single optimal time of conversion T^* and a single optimal use to which to convert. If conversion is reversible, the problem becomes more complicated as V_{t+1} includes the maximum value of all future conversions which remain possible (including a return to the original use).

With multiple and reversible conversions, the dynamic programming problem requires identifying the sequence of conversions (a sequence of optimal conversion times and of uses to which to convert at each stage) which will maximize the current payoff plus the continuation value.[11] In addition to the possibility of future conversions, flexibility in terms of delaying land-use changes will alter the value of V_{t+1} in the case of uncertainty over the value of land-use choices. When land-use conversion is irreversible (or at least there are costs of conversion), the presence of uncertainty generates an option value, which is part of the continuation value V_{t+1} from remaining in a particular use. As Titman (1985) first noted in the context of vacant land for urban development, the possibility of converting land to another use can be thought of as a call

[10] Parks (1995) discusses the case in which landowners are risk-averse and shows that a landowner will not convert all lands of a given quality to a single use as per condition (10) below. Instead, the landowner has an incentive to create a diversified portfolio of different land uses. In Park's model, risk aversion introduces an additional term on the left hand side of equation (11), which captures the cost (benefit) from adding (reducing) risk by converting a marginal acre from use *j* to *k*. This term will be negative if moving lands from *j* to *k*. This term increases the variance of returns to the land portfolio and positive if this decreases the variance.

[11] Amin and Capozza (1993) consider the problem of sequential conversions in terms of developing urban land and different levels of intensity. They find that allowing flexibility in terms of multiple allowable conversions increases land values and leads to earlier development at lower intensities than in the single conversion case.

option, that is an option to purchase an asset with a different return for a given price (the conversion cost).[12]

In order to highlight other aspects of the land-use conversion problem in this paper, I do not incorporate option values. I model landowners' land-use choices as if they ignore the value of information to be gained by delaying irreversible decisions. More generally, I assume that landowners do not account for future conversion possibilities when evaluating alternative land-use options, including remaining in a given use. In other words, they only plan ahead one conversion at a time, acting as if all land-use choices are irreversible. This is not to say that land remains in a given use forever, but that landowners do not take into account future conversion possibilities when choosing a particular land use at a given time.[13] As emphasized below, these restrictions are consistent with a model of land use choice based on static expectations as in Stavins and Jaffe (1990) and Plantinga (1996).[14]

Given these assumptions, the maximization problem in equation (1) becomes:

$$\max_{a_{jkt}} \int_{t=0}^{\infty} \left\{ \sum_{j=1}^{J} E_t\left[R_{jt}\right] S_{jt} - \sum_{j=1}^{J}\sum_{k=1}^{K} E_t\left[C_{jkt}\left(a_{jkt}\right)\right] \right\} e^{-rt}\, dt \tag{5}$$

subject to constraints (2), (3), (4).

Dropping the expectations operators for notational simplicity, the current value Hamiltonian with shadow prices $\mu_j(t)$ $(j=1,\ldots, J)$ is:

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12 More specifically, this option is an American option because generally there is no set date by which the land must be converted. Authors examining urban development have considered the case of conversion from an initial use with certain returns to a developed use with stochastic returns (Clarke and Reed 1988; Capozza and Helsley 1990; Williams 1991; Capozza and Li 1994; Capozza and Sick 1994). Schatzki (1998) considers the case of conversion between two land uses (forestry and agriculture) when returns to both uses are stochastic. Geltner, Riddiough, and Stovanovic (1996) examine the option to convert a parcel of land to the best of two developed uses with stochastic returns. Theoretically, the value of the option on one or more risky assets (land-use alternatives) will increase with the number of assets, the price of the assets, the interest rate, and the time to maturity and will decrease with the strike price (the conversion cost). Moreover, higher volatility and lower correlation among asset prices increases option value (Stultz 1982; Geltner *et al.* 1996).

13 This assumption will be more problematic, the greater the differences in the continuation values of different land uses as determined by the differences in conversion costs. For example, if forestry is irreversible but cropping is not, then failing to consider this will lead the solution of the model to diverge from the true dynamic programming solution more than in the case where both uses are equally reversible.

14 As discussed in section 3.2.1, in order to yield an empirically tractable model, I assume that landowners base their future expectations of land-use profits on current and lagged values of these profits. Alternative approaches that involve estimating the parameters of a dynamic programming problem (*e.g.* Rust 1987) are infeasible given the size of the data set and the choice problem considered.

$$\tilde{H} = \sum_{j=1}^{J} R_{jt} S_{jt} - \sum_{j=1}^{J} \sum_{k=1}^{K} a_{jk}(t) C_{jk}(t) + \sum_{j=1}^{J} \mu_j(t) \left\{ \sum_{k=1}^{K} \left[a_{kj}(t) - a_{jk}(t) \right] \right\} \tag{6}$$

The necessary and sufficient conditions for an optimum are:

$$-\frac{\partial \tilde{H}}{\partial S_{jt}} = \dot{\mu}_{jt} - r\mu_{jt} = -R_{jt} \tag{7}$$

$$\frac{\partial \tilde{H}}{\partial a_{jkt}} = -C'_{jkt}(a_{jkt}) + \mu_{kt} - \mu_{jt} \leq 0 \tag{8}$$

$$a_{jkt} \frac{\partial \tilde{H}}{\partial a_{jkt}} = a_{jkt} \left[C'_{jkt}(a_{jkt}) + \mu_{kt} - \mu_{jt} \right] = 0 \tag{9}$$

for all *j* and *k* along with constraints (2), (3), (4).

These conditions imply that if marginal conversion costs are constant ($C'(a_{jkt})=0$) or decreasing ($C'(a_{jkt})<0$), the following "bang-bang" solution will be optimal:[15]

$$a_{jkt} = \begin{Bmatrix} 0 \\ a^*_{jkt} \\ a^{\max}_{jkt} \end{Bmatrix} \text{ whenever } \frac{\partial \tilde{H}}{\partial a_{jkt}} = -C'_{jkt}(a_{jkt}) + \mu_{kt} - \mu_{jt} \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 0 \tag{10}$$

Thus, when conversion from use *j* to *k* is desirable, the landowner should convert $a^{\max}_{jkt}$, the maximum amount of land in use *j* available for conversion.[16] In the model presented here,

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[15] If conversion costs are increasing in acreage so $C'(a_{jkt})>0$, there is a threshold level of a_{jkt} beyond which conversion costs rise high enough so that the inequality in equation (10) will no longer hold. If this threshold level is below $a^{\max}_{jkt}$, then lands will only be converted up to this threshold and the bang-bang solution will no longer be optimal.

[16] If the landowner has no land currently in use *j*, then $a^{\max}_{jkt}=0$, so no land will be converted from *j* to *k* at time *t*.

$a_{jkt}^{\max}$ simply equals S_{jt}, the total stock of land in use *j* at time *t*. However, as per Stavins and Jaffe (1990) and Parks (1995), some technical or resource constraint on conversion could be imposed so that $a_{jkt}^{\max} \leq S_{jt}$.

Rearranging, the condition for conversion from use *j* to *k* becomes:

$$\mu_{kt} - C'_{jkt}\left(a_{jkt}\right) > \mu_{jt} \tag{11}$$

Thus, the optimal policy calls for the landowner to convert all land in use *j* to *k*, when the shadow value of the land in use *k* (after deducting the costs of conversion) exceeds the shadow value of the land in use *j*. If the shadow value of the land in use *k* net of conversion costs is less than the shadow value in use *j*, then no land will be converted. If $\mu_{kt} - C'_{jkt}(a_{jkt}) = \mu_{jt}$ then the landowner is indifferent between the two land uses and the optimal conversion amount from use *j* to *k* is the singular solution a_{jkt}^{*}.

The difference between the multiple-use and the two-use models is that equation (11) is a necessary but not a sufficient condition for conversion to a particular use *k* when there are multiple uses. To see this, note that with multiple uses, equation (11) might hold for more than one use *k*. For example, the shadow value of land in forests minus the costs of conversion as well as the shadow value of land in urban use minus conversion costs might both exceed the shadow value of land in crops. The additional condition for conversion from use *j* to *k* is:

$$\mu_{kt} - C'_{jkt}(a_{jkt}) = \max\left\{\mu_{1t} - C'_{j1t}(a_{j1t}), \mu_{2t} - C'_{j2t}(a_{j2t}), \ldots, \mu_{Jt} - C'_{jJt}(a_{jJt})\right\} \tag{12}$$

All the land in use *j*, $a_{jkt}^{\max}$, will be converted to the use *k* that has the highest shadow value net of conversion costs. Once all land is converted to the use with the highest value net of conversion costs, then no other use will dominate, so condition (8) will hold for all uses *j*. Thus, while forestry and urban uses might both be better options than maintaining a parcel in crops, the parcel will be converted to the option that is best.[17]

Restricting attention to the steady state, $\dot{\mu}_{jt} = 0$, then equation (7) becomes $\mu_{jt} = \frac{R_{jt}}{r}$, the present discounted value of an infinite stream of (expected) net returns R_{jt} from use *j*. This restriction is equivalent to assuming that landowners have static expectations. Substituting this

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[17] Note that the first order conditions imply that a_{jkt} can only be positive for only one use *k* at time *t* (unless the shadow values of the two uses minus the conversion costs are identical).

value in equation (11) and rearranging terms yields the following condition for conversion from use *j* to *k*:

$$\frac{R_{kt}}{r} - C'_{jkt}\left(a_{jkt}\right) > \frac{R_{jt}}{r} \tag{13}$$

Conversion from use *j* to *k* is optimal only if the (expected) present discounted value of an infinite stream of net returns to use *k* minus conversion costs exceeds the (expected) present discounted value of an infinite stream of net returns to use *j*. This decision rule for the landowner provides a starting point for developing an empirically tractable model of the probability of choices among multiple land uses discussed in the next section.

3. ECONOMETRIC FRAMEWORK

In this section, I develop a framework for using observed data on land-use decisions to estimate the probabilities that a landowner allocates his land to various uses based on the anticipated economic returns from those land-use alternatives and observed characteristics of the land. In Section 3.1, I present a general method for estimating parameters for the transition probabilities using a conditional or nested logit model that treats land-use change as a first-order Markov process. Section 3.2 briefly describes the data used for estimation and develops the specification of plot-level profits and conversion costs for the conditional and nested logit models. Section 3.3 discusses how I use this data to estimate the parameters.

Particularly, I rely on cross-sectional variation in the land-use profits to obtain separate parameter estimates for the land-use choice probabilities for the three observed five-year transitions periods, spanning 1982 to 1997, and for lands in four different starting land uses at the start of each period (crops, pasture, forests, and range). I do not consider transitions for land starting in urban as there are virtually no lands that leave an urban state (Table 1.1-1.3). For the CRP, no land exits the program until the last 1992-97 period, when the contracts from the first CRP signups began to expire. I do not consider estimates for transitions from CRP due the relatively small number of observations and of the land area affected and my lack of data on the exact signup dates and lengths of contracts for particular plots.[18]

[18] With assumptions, I do include transitions from the CRP for consistency in my simulations, as discussed in Section 5.

3.1. CONDITIONAL AND NESTED LOGIT FORMULATION OF MARKOV TRANSITION PROBABILITIES

In moving to the econometric model, I consider the case of the landowner's decision rule summarized in (13). According to this rule, the landowner will choose the use yielding the highest expected present discounted value of an infinite stream of net returns minus conversion costs. Given the assumption of static expectations, this rule is equivalent to:

$$R_{kt} - rC'_{jkt}\left(a_{jkt}\right) > R_{jt} \tag{14}$$

where the landowner chooses the use with the highest current one-period return minus the current one-period opportunity cost of undertaking conversion. Using this last formulation and considering a year as the time period, for a landowner with a parcel of land *i* (*i*=1,…, *I*) starting in use *j* at the start of time *t* and facing land-use choices *k* (*k*=1,…, *J*), the annual profit function is:

$$\pi_{ijt} = \max(R_{i1t} - rC'_{ij1t}, R_{i2t} - rC'_{ij2t}, ..., R_{iJt} - rC'_{ijJt}) \tag{15}$$

where R_{ikt} is the annual value of net returns from allocating parcel *i* to use *k* in time *t*, *r* is an annual interest rate, and C'_{ijkt} is the total cost of converting parcel *i* from use *j* to use *k* in time *t* ($C_{ijjt} = 0$).

Given that we do not have perfect data on all variables that might affect the landowner's returns to the different uses, I write the landowner's profit function to include both observed and unobserved components. Using a general random utility expression, I specify the one-period expected net profit (utility) to the landowner on parcel *i* from switching from use *j* to *k* at time *t* as:

$$U_{ijkt} = R_{ikt} - rC'_{ijkt} = \beta_t' z_{ijkt} + \varepsilon_{ijkt} \tag{16}$$

where $z_{ijkt} = [x_{ijkt}, w_{it}]$ is a vector of observed variables, β_t are parameters on each of these variables allowed to vary over time and potentially over transition,[19] and ε_{ijkt} is a random error term. In this general specification, the vector z_{ijkt} can include variables x_{ijkt}, which are "attributes" of the land-use choices that vary over the different choices as well as potentially

[19] Note that while β_t is only subscripted by *t*, the parameters will vary by land-use transition depending on the way the variables z_{ijkt} are defined. If profits are considered a single attribute that varies across choices, then a single coefficient on this variable can be estimated. As discussed in the next section, I model profits to each use as a separate attribute (positive for that use and zero for all others) and estimate a separate coefficient for the net returns to each land use alternative.

over the individual parcels (and starting uses and time). The vector of observed variables z_{ijkt} also may include elements w_{it} which are individual "characteristics" that vary only over the land parcels (and time).[20]

The probability that the owner of parcel *i* in use *j* will convert the land from use *j* to *k* during time *t* is then:

$$pr(\beta_t' z_{ijkt} + \varepsilon_{ijkt} \geq \beta_t' z_{ijlt} + \varepsilon_{ijlt}) \tag{17}$$

for *l*=1,…,*J*. Assuming that the error terms ε_{ijkt} are independent and identically distributed with the type I extreme value distribution (also called the log Weibull distribution) yields a conditional logit model for estimation (McFadden 1974). Using this specification, the probability that parcel *i* changes from use to *j* to use *k* between *t* and *t+1* can be written as:

$$P_{ijkt} = \frac{\exp(\beta_t x_{ijkt})}{\sum_{l=1}^{J} \exp(\beta_t x_{ijlt})} \tag{18}$$

P_{ijkt} embodies the first-order Markov property since the probability of the parcel changing use depends only on decision variables in time *t*. Characteristics w_{it} which vary only over individuals and not over alternatives drop out of the probability expression. In order to include the individual charactersitics, it is necessary to interact them with dummy variables for each of the land-use choices or other variables that vary with the alternatives. These interactions yield a model that allows for variables that are specific to the choices as well as the individuals. This model is structurally analogous to (18) so I maintain the "conditional logit" terminology.[21]

[20] In the most general theoretical framework, the "individual" characteristics would include socioeconomic characteristics of the individual landowner--as well as characteristics of the individual land parcel--that exert different influences on each of the land-use choices. For example, a landowner's characteristics including age, skill, income, and risk preferences might affect the choice of alternative land uses in different ways. In the empirical application discussed in the next section, however, landowner characteristics are not observed and I model their influence on expected net returns as part of the random error term.

[21] The term "conditional" logit or "discrete choice" logit (Greene 1998) is sometimes used to distinguish a logit model in which the independent variables vary only over the alternatives. This model contrasts with the "multinomial" logit model which is a logit model with more than two choices in which the independent variables vary only over the individuals but not over the choices. The more general version of the model presented in this section, which includes terms varying over both choices as well as individuals, is sometimes called "McFadden's choice model" or a "mixed model" (Long and Freese 2001). I maintain the terminology "conditional" logit for this more general model as it is structurally analogous to the conditional logit where the variables vary only over the alternatives once the individual characteristics are interacted with choice-specific dummy variables. The terminology "mixed" model is potentially confusing as this is also used to refer to the "random parameters" multinomial logit model, which has a different specification (*e.g.* McFadden 2001). Note that the terminology

The conditional logit model has the appealing property that the transition probabilities for any starting use *j* will always lie in the unit interval and will sum to one. However, the assumption of independent disturbances implies that the ratio of the probabilities of any two choices must be independent of the other alternatives. This assumption of "independence of irrelevant alternatives" (IIA) is a potentially important restriction on the admissible types of choice behavior as it precludes differences in the degree of substitutability between the different choices.[22] In terms of land use, it is possible to imagine a given land-use option as being more and less similar to others along different dimensions, as I discuss further in Section 3.2.2. The pattern of substitution is theoretically ambiguous and the degree to which some land uses are closer substitutes to each other than others is ultimately an empirical question.

Of the discrete choice models that can relax the IIA assumption, the nested logit is the most tractable for problems with a large number of choices--such as the landowner decision problem with six choices specified in the next section.[23] In the nested logit model, alternatives are grouped into subgroups and the variance of the disturbance term in (16) is allowed to vary across but not within subgroups. This imposes IIA within but not across the subgroups. Thus, changes in the characteristic of an alternative in a particular subgroup will have an estimated effect (cross-elasticity) on the probability of choosing another alternative

"conditional" logit does not refer to the fact that the probabilities are estimated conditionally on a particular starting land use or on a particular subset of choices as in the nested logit model discussed later in this section.

[22] The classic "red bus/blue bus" problem illustrates how the conditional (or multinomial) logit model can lead to unrealistic predictions if IIA is not a reasonable assumption for the choices under consideration (*e.g.* Train 1986). This example describes a commuter faced with equal probabilities of traveling by bus (a blue one) or by car so that P(blue bus)=P(car)=1/2. Suppose the choice of a red bus also becomes available. If the two buses are perfect substitutes, one might predict the new choice probabilities to be P(blue bus)=P(red bus)=1/4 and P(car)=1/2. However, the IIA property will require the original odds ratio P(blue bus)/P(car)=1 to be unchanged so a conditional or multinomial logit model will predict P(blue bus)=P(red bus)=P(car)=1/3.

[23] In order to further relax the IIA assumption of the conditional logit model, however, more general discrete choice models are available. Multinomial probit models, which assume a normal distribution of the disturbances in (16), allow an unrestricted covariance matrix for the errors that can generate differential patterns of substitution among the choices. Nevertheless, these models require numerical computation of multivariate integrals and large models with more than four choices still face computational limits (Greene 2001). The most general model for relaxing the IIA property is the random parameters logit (also called the "mixed" or "kernel" multinomial logit) which has recently received increasing attention and application (e.g. McFadden 2001; Train 1998; Berry, Levinsohn and Pakes 1995). This model incorporates random coefficients (with a normally distributed disturbance) into the conditional logit model in (18) and contains all other logit and probit models as special cases. The random parameters logit model allows disturbances that are both non-independent and non-identically distributed and can approximate any set of choice probabilities consistent with a random utility model (McFadden and Train 2000). Despite the theoretical appeal of this model, estimation requires simulation methods to estimate the unknown distribution created by the different random components. While various simulation techniques have been proposed, simulation bias is a potential problem that will be exacerbated in the case of relatively small probabilities and large numbers of observations (Revelt and Train 1996).

that potentially varies depending on whether the other alternative is in a different subgroup. Models with various levels of nesting can be specified. For the most simple two-level model, the nested logit requires the decomposition of the choice probability in (18) into two components: the probability P_{ijst} of choosing a particular subgroup or "nest" *s* *(s=1,…,S)*; and the probability $P_{ijkt|s}$ of choosing a particular alternative *k* within the alternatives *(l=1…J$_s$)* in nest *s* conditional on the choice of that nest. The transition probability defined in (18) becomes:

$$P_{ijkt} = P_{ijst} \cdot P_{ijkt|s} = \frac{\exp(\gamma_t z_{ijst} + \tau_{st} I_{ijst})}{\sum_{s=1}^{S} \exp(\gamma_t z_{ijst} + \tau_{st} I_{ijst})} \cdot \frac{\exp(\beta_t x_{ijkt})}{\sum_{l=1}^{J_s} \exp(\beta_t x_{ijlt})} \tag{19}$$

where observed variables z_{ijst} describe attributes of each nest, τ_{st} and γ_t are parameters, and *I* is termed the "inclusive value" for nest *s*:

$$I = \ln \sum_{l=1}^{J_n} \exp(\beta_t x_{ijlt}) \tag{20}$$

If the parameters γ_t are zero and inclusive value parameters τ_{st} =1, then the model will collapse to the conditional logit model shown in (18).

If the initial land uses *j* are known,[24] with observations of *I*×(*T*-1) land-use transitions, I can form the likelihood function:

$$L = \prod_{i=1}^{I} \prod_{j=1}^{J} \prod_{k=1}^{J} \prod_{t=2}^{T} [P_{ijkt}]^{y_{jk}} \tag{21}$$

where y_{jk} equals 1 if parcel *i* changes from use *j* to *k* during period *t* and is 0 otherwise (The specification for the transition probabilities in (21) will be (18) and (19) for the non-nested and nested models respectively). Maximum likelihood procedures are used to derive parameter estimates, and the estimated parameters can be used to form estimates of *J*×*J* sets of non-stationary Markov transition probabilities $\hat{P}_{ijkt}$ (Amemiya 1985). The general specification of

[24] Amemiya (1985) presents the more general likelihood function when the initial probabilities are not known constants. This requires specifying a second term for the initial probabilities which multiply the probabilities in equation (25). Heckman (1981) discusses the "initial conditions" problem that arises in estimating such initial probabilities; he proposes an instrumental variables approach for estimating these probabilities which are generally not exogenous and are difficult to estimate given the typical lack of data going back to the very beginning of the Markov process.

the likelihood function in (21) permits simultaneous estimation of transition probabilities across all starting states j and time periods T.

3.2 Data and Specification Issues

In this section, I provide a brief discussion of my data sources, which are explained in detail in the Data Appendix, and present my specifications combining plot and county-level variables in the conditional and nested logit models. Section 3.2.2 reviews the land-use data while 3.2.3 discusses the use of county and plot-level measures to specify the profits to the different land uses and conversion costs. Section 3.2.4 discusses issues particular to the specification of the nested logit model.

3.2.2. Land-Use Data

My source of land-use data is the National Resources Inventory (NRI), which provides repeated plot-level observations of the six considered land uses on privately-owned land in all 3,014 counties in the contiguous forty-eight states. Observations for each plot are for 1982, 1987, 1992, and 1997. For each transition, I consider a total 803,303 different plots, each of which is given an acreage weight that is inversely proportional to the sampling intensity for that particular use and region. I thus observe a total of three plot-level land-use transitions, each over a five-year time frame. Aggregate national outcomes for each transition period are summarized in tables 1.1, 1.2, and 1.3. The diagonal elements of these tables show that land areas tend largely to remain in their previous use.

3.2.1 County-Level Profits Data and Specification of the Plot-Level Profits to Alternative Land Uses

In this section, I present the specification for the land-use profits of the different uses, which combines county and plot-level variables. Table 2 shows descriptive statistics for these different variables for the three transition periods considered.

Returning to the landowner's decision rule presented in (16), the landowner for plot i will choose the use that yields the greatest expected future stream of discounted net returns minus conversion costs. It seems reasonable that landowners base at least part of their expectations of future net returns on current levels of returns.[25] Rather than relying on data on net returns information from a single year, I assume that landowners use the average of annual profits per acre to each land use over the preceding five years in making their land-use choices at a given time period.[26] I observe land-use choices at five year increments and do not have information on the year within that time frame that a particular land-use choice was made. Letting the time t denote a year, I specify land-use choices observed at time $t+5$ as a function of the average land-use profits between years t and t-5.

I consider six major U.S. land uses: crops, pasture, forest, range, urban, and the Conservation Reserve Program (CRP). Although the CRP is not a major use in terms of nationwide acreage, the program is included because land enrollment in the CRP accounts for a large percentage of the land-use changes in each period. I construct county-level estimates of annual per acre profits to crops, pasture, forest, range, and urban uses for all 3,014 counties in the contiguous forty-eight states. This provides county-level observations for five of the six major land uses considered, with the exception of the CRP which is treated differently. The Data Appendix contains a detailed discussion of the construction of the different per acre profit measures. County-level profits for crops, pasture, and range are naturally computed in annual terms from data on annual yields of major crops and forage. My estimates of county-level crop profits include estimates of county-level direct government payments to cropland owners from all programs (excepting the CRP as this is treated as a separate category).[27]

To estimate forest returns, I calculate the net present value of an infinite stream of timber harvests and multiply this value by an assumed interest rate of five percent to obtain an annualized measure.[28] For returns to urban uses, I construct county-level estimates of the

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25 In an analysis of models of farmland price changes, Just and Miranowski (1993) report that a naive expectations model based on lagged values performs better than models based on forward looking price expectations.

26 Particularly, I include average profits from 1978-82, 1983-87, and 1988-92 as explanatory variables for the land-use decisions from 1982-87, and 1987-92, and 1992-97, respectively. I use lags of five years to capture the general trends in the movements of land-use profits and minimize the effects of possible outlier estimates in my data by using information from all the years in between the transition periods. For the conditional logit model, I examined results for alternate expectations structures with current and lagged three year returns and obtained qualitatively similar estimates.

27 The effects of crop insurance and other government programs aimed at reducing the variability of crop returns are not addressed in this analysis.

28 Annualizing timber profits in this way is consistent with an assumption of perfect credit or land markets. Under perfect land markets, the land price will perfectly capitalize the future value of timber production. In addition, perfect credit markets imply that the lumpiness of income streams does not matter to landowners since they can use credit markets to smooth out any income stream. Estimates of recreational and non-timber values from forests are not included in my estimates of forest profits. I highlight the potential role of these factors in my discussion of the estimated coefficients on forest profits in Section 4.

average per-acre price of recently developed land.[29] These data measure the average value of a developed parcel less the value of structures, and thus correspond to the present discounted value of the stream of rents from improved bare land.[30] I multiply this net present value times a five percent interest rate to obtain an annualized per acre estimate of the profits from urban development.

Before estimating the non-nested model in (18), I develop a specification that includes conversion costs in a general way and that accounts for the fact that estimates of net returns to the different land uses are at the county level while a landowner's decision is based on the net returns specific to his plot.[31] While the landowner presumably acts after comparing the returns to the different uses on his particular plot of land, we do not have observations on the profits from each land use particular to each plot. Instead, we observe county-level returns, which reflect the average characteristics of the area in each land use in each county.

To account for the variation in net returns at the plot-level, I interact the profit variables for each land use with a set of dummy variables indexing plot-level land quality. In particular, I consider the Land Capability Class (LCC) of the plot, which is a summary measure of the suitability of the land for crop production.[32] To ensure sufficient observations in each group, I combine LCC classes into four groupings: LCC 1 and 2, LCC 3 and 4, LCC 5 and 6, and LCC 7 and 8. Higher LCC ratings indicate poorer soils for crop production.

Land quality will affect land-use profits principally through its effect on biomass yields. As discussed in the Data Appendix, the annual profits to crops, pasture, forests, and range are computed as price times annual yield per acre minus annual costs per acre, with forest profits based on the net present value measure discussed above. Output and input prices will not

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[29] This measure of urban profits reflects cross-county differences in urban development profits. Within counties, spatial variables, particularly distance from cities, are likely to be important factors creating within-county variation. I did not model the effect of these determinants of urban profits because the NRI does not release the spatial coordinates of the sample plots to maintain confidentiality. One way to address this problem without obtaining this location data would be to specify a distribution for the urban profits parameter generated by the unobserved heterogeneity in urban profits due to location. This model could then be estimated in a random parameters multinomial logit framework, but would introduce potential bias through the use simulation methods for estimation as previously noted.

[30] Because I do not include the costs of improvements, such as planning fees, sewer and power lines, driveways, and landscaping, my measures of urban development profits will tend to overestimate the returns to a landowner from urban development. To the extent that these costs are constant across counties, however, my estimates will still reflect county-level differences in urban development profits.

[31] I do not include more explicit estimates of conversion costs, such as the costs of uprooting tree stumps, due to the lack of nationwide data for the majority of possible transitions. Instead, as discussed further below, I estimate conversion costs using alternative-specific constants that vary with land quality and the starting land use.

[32] The LCC system is based on a ranking of twelve different soil characteristics that are critical for crop production. The overall LCC score consists of the lowest ranking given to any of these twelve soil features based on the principle that this factor will be limiting for crop production (USDA 1973).

vary with land quality. However, total per acre costs could vary with land quality if higher quality land is used for more input-intensive production.

While the LCC system is designed specifically for crops, the LCC rating is highly correlated with the forest productivity index and ratings of the suitability of soils for pasture and forage production provided by the National Cooperative Soil Survey (NCSS). I use the LCC index for all land uses instead of these alternative measures for consistency and because the other ratings are not available for the soil types on all plots. I also consider the interaction of the LCC dummies with the urban profit variable to test for its potential significance. One would expect urban development decisions to be insensitive to soil fertility and, compared to decisions for other land uses, to be generally less dependant on soil quality. Nevertheless, the LCC includes some criteria such as slope and depth of bedrock which one would expect to have some degree of effect on the suitability of land for urban development.

Combining county-level returns and the plot-level LCC group dummies, I thus specify equation (16) for plot-level returns and conversion costs to use *k* on land plot *i* in use *j* and county *c* as follows:

$$U_{icjkt} = \alpha^0_{jkt} + \alpha^q_{jkt} LCC^q_{it} + \beta^0_{jkt} R_{kc} + \beta^q_{jkt} LCC^q_{it} R_{kc} + \varepsilon_{ijkt} \qquad (22)$$

where α^0_{jkt} is an alternative-specific intercept, α_{jkt} and β_{jkt} are parameters, R_{kc} denotes the county-level measure of net returns to use *k*, and LCC^q_{it} is a dummy variable indicating whether land plot *i* is in land quality *q* at time *t* where *q* refers to either LCC 3 and 4, LCC 5 and 6, or LCC 7 or 8.[33] For identification purposes, I normalize to zero the coefficients on the dummy variables for the crop alternative and for LCC 1 and 2. Given this specification, to the extent that the LCC rating captures variation in plot-level land quality that is relevant to the land-use returns in question, one would expect the sum of the coefficients β^0_{jkt} and β_{jkt} to be decreasing in land quality. Plots with land qualities above the county average for a given land use (embodied in the county-level return measures for that use) should have their returns scaled up by the coefficient on the interaction with the LCC dummies while plots with land quality below this average should have their returns scaled down.[34]

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[33] While LCC^q_{it} is subscripted by *t*, in practice the LCC rating changes over time on only about 1% of the sample of plots.

[34] The distribution of land quality across counties will differ. By estimating a single set of coefficients for all counties, the parameters I estimate reflect the nationwide average degree of divergence of each LCC category from the county average land quality for each land use considered.

As noted above, I do not include a measure of CRP profits per acre.[35] Instead, I model profits to the CRP as a function of the LCC dummy variable using the specification in (22) with R_{kc} set at zero. While the criteria for CRP eligibility have varied from signup to signup period, the LCC rating has always been one of the potential criteria for enrollment, with cropland in LCCs 6-8 qualifying for the program. Other CRP criteria, such as susceptibility to erosion, are also likely to be related to lower land quality (higher LCC rank). Thus, I would expect the dummies for the lower land qualities to be positively related to CRP enrollment.

For a given starting land use *j*, the parameter α^q_{jkt} in (22) is an intercept term that varies for each alternative use *k*. In combination with $\alpha^q_{jkt} LCC^q_{it}$, these provide an intercept that varies by land quality and captures unspecified factors that affect the profitability of changing from use *j* to *k* which are not measured by the terms for the plot level returns as a function of R_{kc}. In this sense, I interpret these constants as a measure of "conversion costs," broadly defined as the opportunity costs of moving to a different land use. Estimates of these constants would thus be expected to be negative. In general, I expect conversion costs to increase as land quality declines with factors such as steeper slopes, rockiness, more waterlogged soils.

3.2.2 Specification of the Nested Logit Model

As discussed in Section 3.1, potential differences in substitutability among different land-use alternatives provide a motivation for relaxing the IIA assumption of the conditional logit model by moving to a nested specification. There are different dimensions along which one can imagine patters of substitutability for different land-use choices.[36] Different land quality requirements are potentially a key determinant of the substitutability among land uses. Land uses vary distinctly in terms of where they are found on the spectrum of land quality

[35] While data on government payments per acre in the CRP program are available, I did not use these as CRP enrollment criteria continued to evolve with each signup, making it unclear that past returns would be an appropriate measure for the payments offered in each signup. In addition, the program has been shifting away from a broad-based market-based program towards a strategy of targeting payments to enroll lands with particular environmental characteristics (USDA ERS 2000).

[36] To the extent that farmers operate joint crop and livestock operations, farmers may already have skills for pasture and range uses—rather than forestry, for example—so crops, pasture and range uses may be closer substitutes to each other than to other uses. Claassen (1993) argues that a landowner without access to credit might view crop and pasture production as more similar in terms of producing an annual return in contrast to longer term investment in forestry. At the same time, he points out that forest and pasture land uses may be similar in terms of lower labor requirements.

classes. Lands in crops have the highest average land quality (as measured by the LCC system), followed by CRP, pasture, urban, forests, and range lands. Land uses with more similar land quality requirements may be considered closer substitutes for a landowner considering choices for a particular land plot.

Following this reasoning, I specify a nested logit model with three separate nests: 1) the "farm" nest containing crops, CRP, and pasture uses; 2) the "non-farm" nest containing forests and range; and 3) the "urban" nest containing only the urban choice. I include pasture in the nest with crops and CRP as it lies closer to these uses in the land quality spectrum.[37] I model urban development as a distinctly different choice due to its much greater degree of irreversibility and because land quality is likely to be a less important determinant of the profitability of urban development. Due to the limited number of observations for some choices in some time periods, it was not possible to estimate all the parameters of a model with three nests for all of the starting land uses and time periods considered. In four out of the twelve cases, I estimate a model with two nests, including the urban choice within the farm nest.[38] I include the urban use in the farm nest because urban uses occur on lands with average LCC ratings closer to the average of the farm rather than the non-farm nest.

In specifying the nest-level equations that enter into the first term of (19), I include constant terms for each of the nests interacted with the different land quality groupings to capture differences in the choice of nests based upon land quality. In particular, for land plot *i* in use *j* and county *c*, the profit to choosing a use within nest *s* is specified as:

$$U_{icjst} = \gamma_{jst}^{0} + \gamma_{jst}^{q} LCC_{it}^{q} + \tau_{st} I_{ijst} \tag{23}$$

where *s* identifies either the farm, non-farm or urban nests, and *q* indexes the LCC grouping. γ_{jst}^{0} is an intercept term specific to each of the three nests,[39] γ_{jst}^{q} is a coefficient on the LCC grouping at the nest level, and I_{ijst} is the inclusive value of the nest with coefficient τ_{st} in (20). For identification, I normalize to zero the coefficients on the farm constant; the crops

[37] Assigning values 1 through 4 to the ratings of LCC 1 and 2, LCC 3 and 4, LCC 5 and 6, and LCC 7 and 8, respectively, yields the following average land qualities for private lands in the contiguous forty-eight states: 1.5 (crops), 1.9 (CRP), 2.0 (pasture), 2.2 (urban), 2.7 (forests), and 3.0 (range).

[38] In particular, I estimate a model with two nests for land starting in pasture for the 1992-97 period, land starting in forest for the 1987-92 and 1992-97 periods, and land starting in range for the 1987-92 period.

[39] In the case of the urban nest equation, I include the constant for the urban alternative at the level of the nest equation (23) and not in the equation for the urban choice in (22).

constant; the range constant; and the dummy for LCC 1 and 2 in both the nest and choice-level equations.

3.3. ESTIMATION APPROACH

Using the NRI observations on landowner decisions for each plot, I estimate parameters for both a conditional and a nested logit model. I separately estimate parameters for transition probabilities for each of four starting land uses (crops, pasture, forest, and range) and each of the three observed transition periods (1982-87, 1987-92 and 1992-97). In total, I thus estimate twelve separate models (three time periods times four starting uses) under each of the two specifications. For each specification, this approach entails separately estimating the parameters of the probabilities in each row of the matrices in Tables 1.1 to 1.3 that describes transitions out of land in one particular use. For each different transition period, the parameters are estimated on the basis of the cross-sectional variation among the plots. The data set provides a large number of cross-sectional observations and we have no theoretical reason for imposing equality restrictions on any of the parameters over land-use transitions or over time.

An alternative approach would be to use pooled observations of the same panel over multiple time periods. This approach raises a particular set of econometric challenges in the context of a logistic specification of the transition probabilities. Any unobserved variables that are specific to an individual will commonly be serially correlated, thus violating the assumption of independently distributed disturbances that underlies equation (18). As a result, without modeling the individual-specific effects, a logit model with pooled panel data is likely to produce inconsistent and inefficient parameter estimates (Maddala 1987).[40]

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[40] Recent computational advances allow random effects versions of logit models which were previously considered infeasible (Greene 2001). These models, however, require the assumption that the unobserved individual-specific heterogeneity is uncorrelated with the included independent variables. Moreover, estimation of these models with numerical estimation techniques is still intractable for large models, such as the one estimated in this paper. A possible option is to use simulation methods to estimate random effects in a random parameters framework, although this will introduce simulation bias which will be exacerbated as the number of observations increases. Instead of a random effects specification, logit models with two or more choices can also accommodate a particular fixed effects model proposed by Chamberlain (1980, 1985). This approach involves removing the individual-specific heterogeneity by treating the T_i observations for a particular individual as a group and estimating the probability of an outcome conditional on number of times the outcome occurs over the T_i periods. A shortcoming of this approach is that observations for individuals for which the outcome does not vary over the T_i periods contribute nothing to the likelihood function. Thus, to the extent that individuals that change are different from those who do not, the estimated probabilities from this model will not be applicable to the entire population. In terms of modeling land-use choices, the great majority of land parcels remain in the same use over time so this model would involve estimation based on a very restricted sample of the data. Land parcels that do change use over time—from crops to urban uses, for example—may well have unobserved spatial attributes, landowner characteristics, and other factors that distinguish

4. ESTIMATION RESULTS

This section presents the estimation results for the conditional and nested logit models for the land-use transition probabilities that are based on the data, specification, and estimation strategy just discussed. In Section 4.1, I review the parameter estimates. To gain a better understanding of the total effects implied by these estimates, I construct estimates at the mean of the transition probabilities for different land quality classes and estimates of the elasticities of these probabilities with respect to the different land-use profit variables. These probabilities and elasticities are discussed in Section 4.2.

4.1 PARAMETER ESTIMATES

Tables 3.1, 3.2, 3.3, and 3.4 report the complete set of parameter estimates for the conditional and nested logit models for each of the three time periods depending on the plot of land starting the period in crops, pasture, forest, and range respectively. [41] For the nested and non-nested specifications, all time periods, and all starting land uses, the estimation results indicate a good model fit and the estimated parameters are generally highly significant with intuitive interpretations. Likelihood ratio tests reject the hypothesis that all of the coefficients are simultaneously equal to zero at the .01 level. Similarly, likelihood ratio tests of the conditional logit model and Wald tests of the nested logit models strongly reject the hypothesis that just the coefficients associated with the profit variables are simultaneously equal to zero at the .01 level. Pseudo R^2 values (McFadden's likelihood ratio index) ranging from 0.68 to 0.95 for both specifications indicate that the explanatory variables yield better predictions of the transition probabilities P_{jk} than the mean value of these probabilities.[42]

Results of the Hausman tests of the conditional logit model are consistent with several different potential IIA violations, reinforcing the theoretical arguments for a less restrictive

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them from the majority of parcels that do not change. In this case, Chamberlain's fixed effects logit model could lead to misleading estimates of transition probabilities applied to the entire land base.

41 Estimation of the nested logit model proved to be computationally intensive, taking up to 24 hours to converge using Stata 7.0 on a workstation computer (1.7 GHz processor; 2,000 MB of RAM).

42 McFadden's likelihood ratio index equals 1–[(log likelihood value)/(log likelihood value of constant only model)]. Higher values suggest improved model fit but will increase with the number of parameters and do not have a natural interpretation. Values of this measure are not comparable across different samples, such as my different time periods and starting uses, or models not nested within each other (McFadden 1974).

model such as the nested specification (Hausman and McFadden 1984).[43] Test results suggest that none of the land-use choices may be completely "irrelevant" to the other choices. Nevertheless, the results varied across starting land uses and across time periods and provide no clear guidance regarding how serious the IIA violation might be or of what nesting patterns might be superior.[44]

Likelihood ratio tests of the nested model against the corresponding conditional logit model reject the hypothesis of homoskedasticity of the error across land uses at the .01 level in support of the nested specification. Estimates for the inclusive value parameters are also generally significant and different than one. These results do not provide evidence for my chosen nesting structure against other potential nested specifications with this same data. However, the results support this particular nested model over the conditional logit for this application (including in the five out of twelve cases when only the two-nest model was feasible).

In the next sections, I discuss the parameter estimates associated with the different independent variables. I review the coefficients on profits in Section 4.1.1 and on the interaction terms between profits and land quality dummies in Section 4.1.2. Section 4.1.3 discusses the estimated inclusive value parameters in the nested logit model.

4.1.1 Profit Coefficients

As listed in Tables 3.1 to 3.4, the profit coefficients for all the different land uses are generally significantly different from zero at the 0.1 level or higher and in the expected positive direction in the two specifications and across all different land qualities, time periods, and starting land uses. In particular, across all of the regressions, there are a total of 240 and 235 profit coefficients, including the interaction terms, for the conditional and nested logit specifications respectively.[45] Of these coefficients, 163 (68%) and 139 (60%) have a significantly positive net effect in the conditional and nested specifications respectively (where

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[43] This test involves re-estimating the model with one alternative excluded (and observations dropped if that alternative was actually chosen) and comparing the parameter estimates $\hat{\beta}_F$ and $\hat{\beta}_R$ of the full and restricted models respectively. Intuitively, if the change in the coefficients between the unrestricted and restricted models is systematic, this rejects the null hypothesis that IIA is true.

[44] For each of the twelve sets of estimates (four starting uses and three time periods), excluding at least one of the categories led to a rejection of the null hypothesis that IIA is valid. Exclusion of each land-use alternative led to rejection of the null in at least two cases (for the crop choice) and as many as six cases (for the urban choice).

[45] There are five uses (since CRP profits are not explicitly considered) times four land qualities times four starting uses times three time periods minus the terms that had to be dropped in the nested case.

the net effect for an interacted coefficient is given by its sum with its respective non-interacted term and significance is at the .1 level).[46] Seventeen coefficients in each specification represent anomalous results with significantly negative net effects. These coefficients represent about 7% of the total number in each specification.

The coefficients on crop and forest net returns have significant and positive net effects more frequently than the coefficients on the other land uses, except for the urban returns in the conditional logit model. While urban returns have a positive net effect across almost all starting uses and land qualities in the conditional logit model, this coefficient is not nearly as significant in the nested model. In the conditional logit specification, aggregating across all time periods and starting uses, the percentage of the profit coefficients for each land use having a significant and positive net effect are 69% (crops), 50% (pasture), 63% (forests), 98% (urban) and 64% (range). In the nested logit case, the percentages are 77% (crops), 52% (pasture), 70% (forest), 39% (urban), and 56% (range).

The coefficients suggest that higher profits to a particular land use lead to greater conversion to that use regardless of the land quality class or the starting land use. However, of all starting uses and land quality classes, lands starting in range and lands in the lower land quality category (LCC 7 and 8) have the lowest number of profit coefficients with significantly positive net effects across both specifications. In particular, for land starting in crops, pasture, and forest, at least 70% and 60% of the profit coefficients have a positive net effect in the conditional and nested logit specifications respectively. For land starting in range, however, the percentages are 47% and 45% respectively. Across all land quality classes, at least 58% and 50% the profit coefficients have a positive net effect in the conditional and nested logit specifications respectively with land in LCC 7 and 8 at the lower end of this range.

The coefficients with unexpectedly significantly negative net effects are associated chiefly with the pasture profit variables for land starting in crops and pasture as well as among the range profit variables for land starting in range. While the coefficients associated with range profits have generally positive net effects for the other starting land uses, for land starting in range, the net effect is negative for the majority of land quality classes in both equations. For the conditional logit model, other anomalous results include the coefficient on crop profits for land in LCC 5 and 6 and starting in crops and land starting in range during

[46] The significance of this net effect is indicated by the crosses in Tables 3.1-3.4.

the 1992-97 period only. In addition, for both specifications, the coefficient on forest profits with no interaction is significantly negative for land starting in forest during the 1982-87 period only. In the nested logit model, the net effects of the coefficients on forest profits for LCC 3 and 4 and LCC 5 and 6 are significantly negative for land starting in pasture during the 1992-97 period.

4.1.2 Coefficients on the Interaction Terms of Profits and Land Quality

The significance of a number of the interaction terms in all of the equations in which they are included (crops, pasture, forest, urban, and range) suggests that the LCC class does reflect variation in the plot-level returns for all of these different uses. However, as is reasonable given the focus on crops of the LCC system, variation in the significance of the interaction terms across the different land-use choices suggests that the LCC class captures more of the variation in the profitability of crops, and possibly pasture, rather than of the other uses.

For every land-use alternative, across all the different time periods and starting land uses, there are thirty-six and thirty-one interaction terms for the conditional and nested logit specifications, respectively. Of these, twenty, twenty-one, seven, fourteen and eighteen are significant in the conditional logit specification for the crops, pasture, forest, urban and range equations respectively. There are twenty-five, eighteen, twenty-one, five and nine significant terms in the nested logit specification for the crops, pasture, forest, urban and range equations respectively.

About 76% of the significant interaction terms are negative in both specifications, implying that county-level land-use profits are generally scaled down on plots of lower quality. In both specifications, more than two thirds of the significant interaction terms are negative for each of the different land-use choice equations, with the exception of the interactions with forest profits in the conditional logit specification.[47] As hypothesized, this suggests that lower land quality as specified by LCC categories implies lower returns for all of the different uses. The number of negative and significant interaction terms is distributed evenly across all the land quality classes in both specifications, suggesting that all of the different LCC groupings are associated with different land-use profits.

[47] Only one of the seven significant forest profit interaction terms is negative in this specification compared to fourteen out of twenty-one in the nested model.

In addition to being predominantly negative, the interaction terms are also increasingly negative with declining land quality, as one would expect if the LCC ratings reflect gradations of land quality that are relevant to the different uses. In the conditional and nested specifications, respectively, 70% and 60% of the significant interaction terms are more negative than the corresponding interaction term for the next best land quality class. More than 50% of the significant interaction terms are increasingly negative in this way across all the land quality classes and across all the different land-use alternatives for both specifications.[48]

4.1.3 Constant Terms and Land Quality Dummy Variables

The coefficients on the constant and land quality dummy variables are large and highly significant in almost all cases, suggesting that there are large conversion costs or other large unobserved costs and benefits to the different land uses that are not captured by my profit variables and which vary with land quality.[49] In addition, the land quality dummy variables are generally highly significant in the CRP equations. In particular, 20 out of 35 and 27 out of 33 land quality dummy parameters are significant in the CRP equations for the conditional and nested logit specifications, respectively. All of the coefficients on these dummies are positive. 18 and 16 of these become progressively larger at higher LCC classes in the conditional and nested specifications, respectively. This indicates that, as expected given the CRP eligibility requirements, lands of lower qualities are increasingly likely to enroll in the CRP as land quality declines. While all of the dummies on land quality are significantly positive in the CRP equations for land starting in crops, some coefficients are significantly negative for land starting in other uses, including all for land starting in forest in the nested logit specification. An explanation could be that this land needed first to be converted into cropland so as to qualify for the CRP and thus had to be of significantly high quality to make some crop production possible. Additional effects of the estimated constant terms and dummy variables are illustrated in the discussion of the role of land quality in modifying the estimated transition probabilities in Section 4.2.1.

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[48] An exception is the forest equation in the nested model where exactly 50% of the significant interaction terms are increasingly negative.

[49] The constants specific to each land use choice need to be interpreted relative to the coefficient on the crop-alternative constant that was normalized to zero while land quality dummies need to be interpreted relative to the dummy for the highest land quality category (for LCC=1 and 2) that was normalized to zero.

4.1.4 Inclusive Value Parameters in the Nested Logit Specification

In the nested model, the inclusive value parameters are generally positive and significant as we would expect given that higher profits to the uses within a nest should increase the likelihood of choosing a use in that nest. The inclusive parameters are negative but not significantly different than zero for the urban nest for land starting in either crops and in pasture in the 1982-87 period and for the non-farm nest for land starting in pasture in the 1987-92 period. One anomalous result is that the inclusive value parameters are significantly negative for the farm nest during the 1987-92 period for land starting in pasture and the 1982-87 period for land starting in range. This suggests, rather implausibly, that higher profits to one of the uses in the farm nest should make pasture and range lands less likely to move into that nest.

4.2 PROBABILITIES AND ELASTICITIES

To illustrate the total impact of the different variables, I evaluate land-use transition probabilities and elasticities for the profit variables at the means of the data using the estimated coefficients from Tables 3.1-3.4 and compute standard errors using the Delta Method. I first discuss the probabilities and then the elasticities.

4.2.1 Probabilities

Tables 4.1 to 4.4 contain estimates of the transition probabilities by land quality classes evaluated with the parameters from the nested logit specification at the means of the data.[50] These estimates show that land quality has an intuitively plausible effect on the transition probabilities. The tables reveal a set of probabilities that is consistent with crops being most competitive on the highest quality lands (as measured by LCC), followed by pasture, forest, and range. The effect of land quality on the profitability of urban uses is more ambiguous.

Table 4.1 shows the estimated land-use transition probabilities for lands in crops. The probabilities of these lands staying in crops increase in land quality across all the time periods. For example, over the 1982-87 period, probability of remaining in crops was about 96% for lands in LCC 1 and 2 but only 85% for lands in LCC 7 and 8. The flip side of this is that the

[50] The estimated probabilities using the conditional logit parameters are qualitatively similar.

probability of cropland switching to pasture, forests, range, and CRP increases as land quality declines.[51]

The probability of cropland switching to urban use is highest on the lowest quality lands (LCC 7 and 8) but is second highest on the highest quality lands (LCC 1 and 2). This suggests that lands in higher quality land (as measured by LCC) have characteristics which make them more desirable for urban development, as well as crop production. Nevertheless, though higher quality croplands are relatively favored for urban development, these lands still have the highest total probability of remaining in crop production.

Table 4.2 includes the estimated probabilities for lands in pasture. As would be expected, pasture land is more likely to convert to crops at higher land qualities. Overall, pasture land is more likely to remain in pasture as land quality declines. This suggests that pasture lands at the upper end of the land quality margin are the ones most likely to convert, which is consistent with the fact that the majority of land converting from pasture moves into crops. Conversion of pasture to urban uses also increase with land quality, though the lowest probabilities are on LCC 5 and 6 rather than LCC 7 and 8. This again indicates that higher quality lands (lower LCC rank) are more likely to be converted to urban uses. The results for land switching from pasture to CRP are mixed, though conversion to CRP is highest in either the highest or second highest land quality groupings. This is consistent with the fact that land must first be in cropland before qualifying for the CRP. Transitions from pasture to forests are more probable as land quality declines, confirming that pasture lands are more competitive relative to forests on higher quality lands. There is no clear pattern in terms of the pasture to rangeland probabilities, though the highest probability of switching to range is never on the highest quality land.

As shown in Tables 4.3 and 4.4, lands in forest and range reflect most of the same trends as lands in pasture. Forest and range lands are more likely to switch to crops and pasture as land quality increases. Changes to urban use also tend to increase in probability with land quality. Changes to CRP lands are most likely on lands in LCC 1 through 4. Land in both forests and range is most likely to remain in its current state as the LCC declines. As with pasture, this suggests that changes to other uses are more frequent on the upper end of the quality margin. Forest lands are more likely to switch to range as land quality declines

[51] The probability of switching to CRP also increases as land quality declines but peaks at the second lowest (LCC 5 and 6) rather than the lowest land quality class (LCC 7 and 8).

while rangelands are generally more likely to switch to forests as land quality increases. This is as expected if forests tend to be more profitable than range on higher quality soils.[52]

4.2.2 ELASTICITIES

Tables 5.1 to 5.4 contain the estimated elasticities evaluated at the means of the data for land of all qualities using the nested logit parameter estimates.[53] While elasticities can also be calculated separately for the different land quality groupings, I present the aggregate elasticities to indicate the general direction of effects. The elasticities indicate the percentage change in the probability of the specified transition for a 1% change in the profits to the indicated land use. The elasticities highlighted in bold text are the elasticities for the probability of choosing a particular use with respect to the profits to that use. In the majority of cases (35 out of 60), these own-profit elasticities are positive and significant as expected at the .05 level. This supports the expectation that higher profits for a particular land-use are associated with higher probabilities of switching into that use.

In the 7 out of 60 cases that the own-profit elasticities are negative, they are never significantly different from zero at the .05 level. The cross-elasticities (the elasticities of the probability of choosing a particular use *j* with respect to the profits of a different use *k*) vary depending on whether or not use *j* is in the same nest as use *k*. This results from the (partial) relaxation of the IIA property in the nested logit. The cross elasticities are generally opposite in sign to the own-profit elasticities and thus usually negative, as expected.[54]

These estimated elasticities indicate that landowners with lands in either crops or pasture are responsive as expected to the economic returns from all alternative uses. For land

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52 The probability of rangeland converting to forests increases with land quality for the 1982-87 and 1987-92 periods but decreases with land quality for 1992-97. However, for this last period the estimated probabilities are not significant at either the 1% or 5% levels.

53 In the nested logit model, the elasticity of the probability of choosing *j* with respect to x_{km} denoting attribute *m* of choice *k* is: $\frac{\partial \ln P(\text{choice } j, \text{branch } s)}{\partial \ln x_{km} \text{in choice } K \text{ and group } S} = x_{km}\left\{1(s=S)\left[1(j=K)-P_{j|S}\right]+\tau_S\left[1(s=S)-P_S\right]P_{j|S}\right\}\beta_{km}$ for $k=1,\ldots J,$ where the terms *(s=S)* and *(j=K)* equal one when *s* equals *S* and *j* equals *K*, respectively.

54 The cross-elasticities can be of the same sign as the own profit elasticities only when the inclusive value parameters are negative. However, this will depend on the relative strength of the variable's effect on the probability of choosing the nest versus the probability of choosing the particular land use conditional on the choice of nest. In my results, the elasticities and cross-elasticities with the same sign are with respect to crops, pasture, and forest profits for lands starting in pasture during 1987-92 and with respect to crops for land starting in range in 1982-87. This anomalous result implies that rising profits to one land use increases the probability of choosing a different use. A possible explanation could be the relatively poor data on the pasture and range profits.

starting in crops (Table 5.1), all of the own-profit elasticities are positive and significant, except for the elasticity with respect to pasture profits for 1982-87 which is negative but not significant. For land in pasture (Table 5.2), most of the own-profit elasticities are also positive and significant. One exception is the elasticity with respect to pasture choices for 1992-97 which is negative but not significant; the other exceptions are the elasticity of the probability of choosing forests with respect to forest profits for the last two periods which are positive but not significant.

Table 5.3 shows the elasticities with respect to profits for forest lands. The own-profit elasticities for crops and urban profits are all positive and significant, suggesting that these are the uses most competitive with forested lands. Two out of three of both the pasture and range own-profit elasticities are positive but none are significant. The elasticities for the probability of choosing forests with respect to forest profits are positive but not significant. As I discuss further in Section 5, these result suggests that the decision to retain lands in forests is relatively insensitive to timber profits. This is plausible given the variety of possible non-timber benefits enjoyed by non-industrial forest landowners.

For land in range (Table 5.4), the elasticities of the urban choice with respect to urban profits are all positive and significant. For range lands, none of the other own-profit elasticities are significant, though most are positive except for the elasticities of the range choice with respect to range profits which are all negative though not significant. These results suggest that lands in range are relatively insensitive to the profitability of alternative uses with the exception of urban development. This is reasonable given that range lands tend to be the lands of the lowest quality and thus unsuitable for any uses that depend on land quality.

5. HISTORICAL SIMULATIONS

The reported parameter, probability, and elasticity estimates demonstrate the importance of land-use returns and land quality in driving conversions among the six major land uses. The relative importance of the different effects, however, is difficult to assess based on the elasticity estimates as the magnitude of the elasticities will vary with the size of the probability of the choice and the size of the economic profit variable considered. Simulations provide one way to compare the importance of the different profit variables in driving changes between the different land-use categories. In this section, I describe and summarize the results of historical simulations that explore how changes in land-use returns have influenced land-use changes in the lower forty-eight states from 1987 to 1997. I focus my discussion on results relating to the impact of land-use returns on changes in forest areas to highlight policy applications of the model.

5.1 Simulation Methodology

Using a version of the analytical experiment employed by Stavins and Jaffe (1990) in their analysis of the factors affecting changes in U.S. wetlands, I explore the importance of the different profit variables in driving the national-level changes among the major land uses from 1987 to 1997. I first simulate the total amount of land transitioning between the six land-use categories (crops, pasture, forest, urban, CRP and range) using my estimated parameters for the 1987-92 and 1992-97 periods and the actual values of all the profit variables during these two periods.[55] This simulation with the historical variables (the "factual simulation") provides a basis for comparison with a series of five simulated counterfactual scenarios. In each counterfactual scenario, I hold constant one of the profit variables (profits for crops, pasture, forests, urban, and range) at its value for the 1982-87 transition while allowing all the other profit variables to take their actual historical values.[56] The difference in the simulated land-use changes between the counterfactual and factual simulations represents an estimate of the influence of the changes in the given profit variable on changes in land use.

The simulations exploit the changes in profit variables between the 1978-82, 1982-87, and 1988-92 periods. The values of the profit variables in the different periods are listed with the descriptive statistics in Table 2. Between the 1978-82 to 1988-92 periods, there were total real increases of $26 (44%) in annual per acre crop profits, $11 (185%) in annual per acre forest profits, and $1,173 (35%) in annual per acre urban profits. During this period, we

[55] In my model, I assume that landowners use the lagged values of net returns over the previous five years in forming expectations over future land-use profits. Thus, my factual simulations use the average real land-use returns from 1983 to 1987 and from 1988 to 1992 to compute the probabilities for 1987-92 and 1992-97 respectively. The counterfactual simulations in which the profits to one of the land uses remain unchanged assume that the profits to this particular use remain at the values from 1978-82, which were used in estimating the parameters for the 1982-87 transition. I do not consider the factors affecting changes over the 1982-87 period because, under the chosen historical simulation strategy, this would require average profit data from 1973 to 1978 which was unavailable for all the land-use choices.

[56] This point estimate in forest profits lies within the range of other econometric estimates in the literature. In particular, based upon estimates from a study of land-use change in the Mississippi Delta region, Newell and Stavins (2000) develop a marginal cost curve for carbon sequestration in the U.S. They estimate that 1.0 million acres and 1.6 million acres could be forested at average costs of $15.10 and $20.25 per acre, respectively. In an econometric study of crop area change, Parks and Hardie (1995) estimate an increase of 9 million forest acres at an average cost of $49/acre.

observe total real declines of $3 (20%) in annual per acre pasture profits and of $0.80 (almost 1%) in annual per acre range profits.

I use the estimated parameters, the profit variables corresponding to my simulation scenario, and the NRI data on the land quality data for each plot to estimate individual plot-level transition probabilities for the 1987-92 and 1992-97 periods for each of the NRI plots that remain privately owned from 1987 to 1997. Depending on the use of the plot in 1987, I multiply the plot-level 1987-92 transition probabilities for that starting use times the acreage in that use given by the NRI sampling weights assigned to each plot. In this way, I simulate the amount of land transitioning from each use to every other use from 1987 to 1992. After simulating the 1987 to 1992 changes, the simulated amount of land in each use in 1992 is multiplied by the corresponding plot-level transition probability for the 1992-97 period to simulate the changes through 1997.[57] Summing together the simulated plot-level acreages yields the estimates of the total land in each use for the forty-eight contiguous U.S. states.

5.2 SIMULATION RESULTS: CHANGES IN FOREST AREA

The conditional logit and nested logit specifications yield simulation results that are qualitatively similar in most cases for all of the different land uses considered. Although he simulation results provide information on the effects of changing profits on the transitions among all of the different land uses, I present the results for changes in forest areas as an example of the potential policy applications of my modeling approach.

5.2.1 Effects of Changes in Different Land-Use Returns

To begin, the factual simulation for increases in forest area from 1987 to 1992 are in line with the actual rise according to the NRI. According to the NRI, total privately owned forests in the contiguous forty-eight states increased slightly by about 2.1 million acres (about 0.5%) between 1987 and 1997, excluding forest areas that moved into federal ownerships during this period. The major part of this increase was due to rising commercial timberland

57 As discussed earlier, given that land virtually never transitions out of urban uses, I did not estimate parameters for the transition from urban to other uses. In the simulations, I assume that land in urban uses remains in urban use with 100% probability. In terms of the CRP, I simulate land leaving the program during the 1992-97 period when the CRP contracts first began to expire. I compute transition probabilities to all uses for plots starting in the CRP using parameters estimated with observations of plots that started in CRP during the 1992-97 period and which first entered the CRP during the 1982-87 period. In this way, I restrict my attention to only those plots which potentially became eligible for leaving the CRP upon expiration of the minimal ten-year contracts. The estimated coefficients were positive on all the profit variables and significant for the profits for crops and forests.

acreage (Vesterby and Krupa 2001). In the factual simulation, forest areas rise by around 1.8 to 2.1 million acres from 1987 to 1997. The great bulk of this simulated increase (74 to 80%) was driven by the increase in forest profits.

The simulation results suggest that the $11 increase in annual per acre forest profits from the 1978-82 to the 1988-92 periods accounted for a net increase in forest area of about 1.5 million acres. Apart from forest profits, urban profits were the most important of my economic variables driving forest area change during this period. The simulated increase in forest acreage with no rise urban profits from 1987-97 would have been 589 to 742 thousand acres or 32 to 25% above the factually simulated increase. Rising crop returns exerted a significant though lesser impact, restraining the increase in forest areas by 19 to 24%.

The simulation results suggest that the effect of pasture profits is ambiguous ranging from -1% to 16% under the conditional and nested logit specifications, respectively. The nested logit results imply that forest areas would have been larger if pasture profits had not declined from 1987 to 1997. This anomalous result is obtained due to the negative elasticity on the probability of choosing pasture with respect to pasture profits for the 1992-97 period (Table 5.2). This elasticity is not significantly different from zero and contrasts with positive and significant elasticities obtained for the 1982-87 and 1987-92 periods. This suggests that the role of pasture profits in affecting forest areas was likely to have been negative and perhaps closer to zero as the conditional logit model indicates.

5.2.2 Transitions through which Land-Use Returns Affect Forest Area Change

Understanding the effects of the different profit variables on particular forest transitions, rather than on the net forest change, is important for evaluating the resulting environmental impacts. As a result, I separately examine the effects of the different profit variables on each of the transition to and from forests (Tables 7.1 and 7.2). This reveals that the simulated increase in forest areas as a result of forest profits encouraging all transitions *to* forests was 51 to 60% while the increase obtained from restraining all transitions *from* forests was 23 to 20%. Together these two potential channels of effects account for the 74 to 80% increase in forest areas attributable to the rise in the estimated per acre forest profits.

More particularly, the effect of forest profits was most intense on the transitions from crops to forests, accounting for 15 to 20% of the increase in this type of changes (not considering the CRP to forest transition as the acreages involved are relatively trivial). In contrast, rising forest profits accounted for about 10% of the increase in range to forest transitions and only 1 to 2% of the increase in pasture to forest changes. In terms of conversion from forests, conversions to urban areas involved the greatest acreage and rising forest profits played a small role in restraining these conversions (by about 2 to 4%). In contrast, the impact of urban profits overpowered these effects, increasing conversions to urban uses by 10 to 20%.

It seems reasonable that forest profits played a stronger role in encouraging conversions to forests, rather than in increasing the retention of existing forest areas. Most existing private forests are owned by non-industrial owners who may be motivated to hold forests for recreational and other non-timber benefits; forest industry accounted for less than 19% of all privately owned forests in the U.S. in 1997 (USDA FS 2001). As a result, the average forest owner is likely to be less responsive to timber profits compared to the commercial owners who might be responsible for new forest plantings. The fact that the major part of the increase in forest areas between 1987 and 1997 was in commercial timberlands supports the view that decisions to convert new lands forests are undertaken by more commercially minded landowners with a different profile than the average owner of existing forest lands.

Although rising forest profits had a relatively small effect on pasture to forest conversions relative to forest establishment on crop and range areas, pasture lands provided the greatest source of new forest areas from 1987 to 1997. The relative unimportance of forest profits in driving transitions from pasture suggests that the conversion of pasture to forests was perhaps the result of natural regeneration on abandoned pasture lands rather than commercially-minded forest establishment decisions. Anderson and Magleby (1997) cite natural regeneration of abandoned farms as a major factor driving the loss of grassland areas in the U.S. The fact that I do not obtain a larger effect of falling pasture profits on pasture to forest transitions combined with the anomalous direction of the pasture elasticity discussed above might also be a reflection of the relatively poor quality of the available data on pasture returns.

Total acreage in crop to forest transitions was less than half of the acreage in pasture to forest transitions. Nevertheless, not only did forest profits have a greater impact on encouraging crop to forest transitions but the total amount of land shifting into forests from corps as a result of forest profits was greater than the total amount shifting from pasture to forests as a result of forest profit changes. The impact of forest profits on cropland accounted for 26 to 33% of the increase in forest areas from 1987 to 1997 as opposed to 4 to 10% from the impact of forests on pasture.

Observed increases in forest returns reduced forest to urban decisions by just 2 to 4%. These results suggest that efforts to restrain urban "sprawl" or to prevent forest area loss by increasing forest profits are likely to have limited effectiveness. Once urban development becomes feasible, development returns are so much higher than the returns to other land uses that observed changes in non-urban returns are of insufficient magnitude to make any difference. This is consistent with findings that use value assessments and other preferential tax policies, used in all U.S. states as a policy to encourage the retention of cropland, have minimal effects in restraining urban development choices (USDA ERS 2000).

5.3 Policy Implications

My estimation of a Markov matrix of land-use transition probabilities permits an examination of the ecological and carbon sequestration consequences of the gross rather than net land-use changes that could be induced by incentive-based policies. The simulation results indicate that rising profits for forestry induce the shifts of land from alternate rural uses, principally crops, into forest areas and have a lesser effect on increasing the retention of lands already in a forested state. While crop areas were the most sensitive to forest profits, low quality croplands were the most likely to convert to forests, as discussed in Section 4.2.1 and shown in Table 4.1. This suggests that incentive-based programs that raise returns to holding forests to promote carbon sequestration could have added benefits in terms of retiring cropland on poor quality soils in support of the goals of the CRP. Moreover, such policies will likely be more effective in encouraging forest establishment than in preventing forest conversion to other uses and thus will tend to initiate the process of carbon sequestration rather than prevent the release of carbon from forest conversions. These results confirm previous findings of lower carbon sequestration costs in the United States through policies aimed at encouraging afforestation rather than at discouraging deforestation (Newell and Stavins 2000; Plantinga and Ahn 2002). In terms of wildlife habitat, this asymmetry in costs suggests that policies that raise the benefits of forest ownership are more likely to promote the growth of new forest areas, potentially commercial timber plantations, rather than maintaining areas of mature forests.

The historical simulations of forest areas suggest that the effect of a near doubling of forest profits between 1978-82 and 1987-92 was largely responsible for inducing an increase in forest areas after 1987. Nevertheless, the overall increase in forest areas and the portion of this increase attributable to the increase in forest profits are extremely small as a percentage of the total forest area in the nation (only 0.5% and 0.4% respectively). Given the relative limited size of the changes in profits observed historically, out-of-sample simulations are necessary to understand the impacts of larger scale profit changes or to estimate the potential costs of inducing large-scale changes in forest areas or other land-use categories through economic incentive-based policies.

The estimated parameters can be used to simulate changes in land use for a wide range of possible economic and policy scenarios involving out-of sample changes in the profits to land-use returns from crops, pasture, forest, urban and range uses. In one possible application, my estimated parameters provide a starting point for a related research project estimating a marginal cost function for carbon sequestration through forestry in the United States (Lubowski, Plantinga, and Stavins 2001). Knowledge of the carbon sequestration supply function is necessary for assessing the cost-effectiveness of carbon sequestration policies relative to other strategies for abating greenhouse gas concentrations. To construct the supply function, the first step is to establish a baseline land-use scenario against which to measure changes in land use induced by afforestation policies. We then model the afforestation policy as increases in the return to forestry and compute land-use transition probabilities under alternative levels of the afforestation incentives. These constructed transition probabilities are used to simulate land-use changes. Using transition probabilities at the NRI plot-level permits simulation of the different effects of incentives on lands of different qualities and simulation of the resulting changes in the distribution of land quality within different land-use categories. Given the importance of land quality in determining transition probabilities, this capability of the model will be potentially important for understanding the marginal impacts of different incentive levels.

Simulating the effects of incentive-based policies at the national level introduces the additional issue of the endogeneity of land-use profits. For example, conversion of agricultural land to forest decreases the supply of agricultural commodities and increases the future supply of timber, both of which affect the net returns to agriculture and forestry. While plausible at a state or regional level, price exogeneity cannot be justified at a national level, and we have developed a model of agricultural commodity and timber markets to endogenize prices in our simulations. We use a partial equilibrium model of agricultural commodity and timber markets, based on estimated input price elasticities culled from the literature, to incorporate endogenous price effects into the policy simulations. After simulating land-use changes under different incentive levels, the final step is to measure the policy-induced changes in land use relative to the baseline and translate land-use changes into changes in terrestrial carbon storage. The carbon sequestration supply function is then derived by arraying per unit afforestation incentives against total carbon sequestration. A similar approach can be used for examining different environmental effects of forest area changes as well as changes in a variety of different land uses and their environmental implications under alternative economic and policy scenarios that affect the returns to the alternative land-use choices.

6. CONCLUDING COMMENTS

This paper presents the first econometric analysis of a comprehensive set of land-use transitions in the forty-eight contiguous United States. I use the nationwide survey of plot-level land-use and land quality information from the NRI and assemble data on county-level per acre profits to alternative land uses. With this information, I exploit cross-sectional variation among land plots in different uses to estimate the parameters of a set of first-order Markov transition probabilities for three different transition periods (1982-87, 1987-92, and 1992-97). I consider six different uses (crops, pasture, forest, urban, range, and the Conservation Reserve Program) and conduct the first analysis with a consistent framework for estimating the responsiveness to the economic returns of both urban and non-urban uses.

Estimated parameters, transition probabilities, and elasticities indicate the role of economic profits in spurring land use transitions and important effects of land quality on the different transition probabilities. Estimated elasticities suggest that conversions from crops and from pasture are responsive to the profits from a greater set of alternative uses than conversions from forests and range. Forest lands tend to be responsive to both crop and urban development profits while range lands appear responsive to urban values alone.

Historical simulations provide insights for understanding how changes in economic returns will continue to affect nationwide land-use changes in the future. Historical simulations for the period from 1987 to 1997 identify rising timber profits as the major factor encouraging the increase in forest areas and identify rising urban profits as an important factor restraining forest area expansion. Results disaggregated by transitions suggest that forest profits have a higher impact on transitions *to* rather than *from* forest lands. These results suggest that economic-incentive based policies raising forestry profits are likely to have a greater effect in inducing forest establishment as opposed to retention. At the same time, rising urban values are likely to be significant drivers of future forest declines.

Historical simulations provide an understanding of the effects of historical changes in land-use profits on different land-use transitions. Nevertheless, given the limited size of historical changes in land-use profits, out-of-sample simulations are required to understand the possible impacts from more dramatic economic and policy scenarios. This paper develops an empirical framework and presents a set of estimated parameters that provide a basis for nationwide out-of-sample simulations to address a wide range of land-use policy issues. A related project involves using the estimated parameters from this analysis to construct a marginal cost function for carbon sequestration from afforestation and reduced deforestation in the contiguous forty-eight U.S. states. A similar methodology can be used to examine nationwide transitions between all the major land uses under different projected scenarios for crop prices, agricultural subsidies, timber prices, grazing fees, and urban values. Additional applications include evaluation of the marginal costs of urban development taxes to preserve open space and of other incentive-based policies to internalize the environmental impacts of land-use transitions on soil erosion, water pollution, and wildlife habitat.

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Table 1.1

Changes in Major Non-Federal Land Uses between 1982 and 1987 in the Lower Forty-Eight States from National Resources Inventory (NRI) [1] (in thousands of acres)

	Land Use in 1987						
Land Use in 1982	**Cropland**	**Pastureland**	**Forest Land**	**Urban Land**	**Rangeland**	**CRP [2]**	**1982 Total**
Cropland	388,802 93.28%	10,708 2.57%	1,763 0.42%	1,720 0.41%	1,017 0.24%	12,783 3.07%	416,793 100%
Pastureland	8,253 6.24%	116,371 87.97%	5,197 3.93%	984 0.74%	872 0.66%	608 0.46%	132,285 100%
Forest Land	940 0.24%	1,607 0.40%	394,059 98.64%	2,440 0.61%	400 0.66%	51 0.01%	399,498 100%
Urban Land	0 0%	0 0%	0 0%	51,580 100%	0 0%	0 0%	51,580 100%
Rangeland	3,565 0.86%	1,490 0.36%	675 0.16%	848 0.21%	406,346 98.33%	326 0.08%	413,251 100%
1987 Total	401,560 28.41%	130,176 9.21%	401,695 28.42%	57,573 4.07%	408,636 28.91%	13,768 0.97%	1,413,408 100%

[1] Percentages are of 1982 totals (far right column). Totals include only lands which remained non-federal and in the six listed uses between 1982 and 1987. Read the table horizontally to see how land that was under a particular land use in 1982 (row heading) was subsequently allocated in terms of land use in 1987 (column heading). Read the table vertically to see how land that that was in a particular land use in 1987 (column heading) was previously allocated in terms of land use in 1982 (row heading).
[2] Note that there is no corresponding row entry for the Conservation Reserve Program (CRP) as this federal program was established in 1985.

Table 1.2

Changes in Major Non-Federal Land Uses between 1987 and 1992
in the Lower Forty-Eight States
from National Resources Inventory (NRI)[1]
(in thousands of acres)

	Land Use in 1992						
Land Use in 1987	**Cropland**	**Pastureland**	**Forest Land**	**Urban Land**	**Rangeland**	**CRP**	**1987 Total**
Cropland	369,953 92.35%	7,853 1.96%	1,207 0.30%	1,862 0.46%	990 0.25%	18,749 4.68%	400,615 100%
Pastureland	6,340 4.88%	116,777 92.32%	3,638 2.80%	1,308 1.01%	453 0.35%	1,302 3.83%	129,819 100%
Forest Land	484 0.13%	989 0.25%	396,113 98.72%	2,920 0.73%	702 0.18%	52 0.01%	401,262 100%
Urban Land	0 0%	0 0%	0 0%	57,728 100%	0 0%	0 0%	57,729 100%
Rangeland	2,257 0.55%	865 0.21%	913 0.22%	986 0.24%	402,414 98.74%	124 0.03%	407,558 100%
CRP	13 0.10%	0 0%	0 0%	0 0%	0 0%	13,787 99.9%	13,801 100%
1992 Total	379,049 26.87%	126,485 8.97%	401,872 28.49%	64,805 4.59%	404,560 28.68%	34,014 2.41%	1,410,785 100%

[1] Percentages are of 1987 totals (far right column). Totals include only lands which remained non-federal and in the six listed uses between 1987 and 1992. Read the table horizontally to see how land that was under a particular land use in 1987 (row heading) was subsequently allocated in terms of land use in 1992 (column heading). Read the table vertically to see how land that that was in a particular land use in 1992 (column heading) was previously allocated in terms of land use in 1987 (row heading).

Table 1.3

Changes in Major Non-Federal Land Uses between 1992 and 1997
in the Lower Forty-Eight States
from National Resources Inventory (NRI)[1]
(in thousands of acres)

	Land Use in 1997						
Land Use in 1992	**Cropland**	**Pastureland**	**Forest Land**	**Urban Land**	**Rangeland**	**CRP**	**1992 Total**
Cropland	360,349	9,289	1,886	2,754	1,522	2,049	377,849
	95.37%	2.46%	0.50%	0.73%	0.40%	0.54%	100%
Pastureland	8,952	107,250	6,143	1,879	1,561	110	125,894
	7.11%	85.19%	4.88%	1.49%	1.24%	0.09%	100%
Forest Land	736	1,883	393,224	4,526	1,163	23	401,556
	0.18%	0.47%	97.93%	1.13%	0.29%	0.01%	100%
Urban Land	2	0	2	65,015	0	0	65,020
	0%	0%	0%	0%	100%	0%	100%
Rangeland	1,963	694	1,587	1,150	399,663	21	405,078
	0.48%	0.17%	0.39%	0.28%	98.66%	0.01%	100%
CRP	2,238	809	184	7	297	30,465	34,001
	6.58%	2.38%	0.54%	0.02%	0.87%	89.60%	100%
1997 Total	374,239	119,926	403,026	75,331	404,207	32,668	1,409,398
	26.55%	8.51%	28.60%	5.34%	28.68%	2.32%	100%

[1] Percentages are of 1992 totals (far right column). Totals include only lands which remained non-federal and in the six listed uses between 1992 and 1997. Read the table horizontally to see how land that was under a particular land use in 1992 (row heading) was subsequently allocated in terms of land use in 1997 (column heading). Read the table vertically to see how land that that was in a particular land use in 1997 (column heading) was previously allocated in terms of land use in 1992 (row heading).

Table 2
Descriptive Statistics of the Variables

Plot-Level Variables[1]	Number of Plots	Mean	Median	Standard Deviation	Minimum	Maximum
Plot in Land Capability Class (LCC) 1 or 2	803,303	0.26	0	0.43	0	1
Plot in Land Capability Class (LCC) 3 or 4	803,303	0.33	0	0.47	0	1
Plot in Land Capability Class (LCC) 5 or 6	803,303	0.21	0	0.41	0	1
Plot in Land Capability Class (LCC) 7 or 8	803,303	0.20	0	0.40	0	1
NRI Sampling Weight (acres/plot)	803,303	1,765	1,300	2,239.9	100	192,200

County-Level Variables (Values in US$ 1990) [2]	Number of Counties	Mean	Standard Deviation	Median	Minimum	Maximum
Annual crop profit/acre (1978-1982) [3]	3,014	58.4	38.4	55.3	-604.1	495.8
Annual crop profit/acre (1982-1987)	3,014	74.3	45.2	70.8	-510.9	368.6
Annual crop profit/acre (1988-1992)	3,014	84.3	47.9	79.1	-98.1	546.6
Annual pasture profit/acre (1978-1982)	3,014	16.1	11.4	14.9	-179.2	200.8
Annual pasture profit/acre (1982-1987)	3,014	8.1	8.3	6.2	-189.5	75.3
Annual pasture profit/acre (1988-1992)	3,014	12.8	9.2	12.0	-125.4	159.7
Annual forest profit/acre (1978-1982)	3,014	6.0	6.9	3.8	-5.3	41.4
Annual forest profit/acre (1982-1987)	3,014	9.0	10.5	6.6	-0.8	83.1
Annual forest profit/acre (1988-1992)	3,014	17.1	19.9	13.0	-0.7	151.1
Annual urban profit/acre (1978-1982)	3,014	3,302.2	3,120.3	2,766.8	181.4	21,309.6
Annual urban profit/acre (1982-1987)	3,014	4,651.7	5,591.7	3,348.3	199.3	38,492.8
Annual urban profit/acre (1988-1992)	3,014	4,475.3	4,418.5	3,636.3	254.3	29,584.9
Annual range profit/acre (1978-1982) [4]	3,014	11.1	10.1	8.8	0	78.4
Annual range profit/acre (1982-1987)	3,014	10.3	8.9	8.1	0	65.0
Annual range profit/acre (1988-1992)	3,014	10.3	9.3	8.1	0	68.6

[1] Aggregates of the plot-level land-use choices that are the dependent variables are shown in Tables 1.1-1.4.
[2] Values are averages over each five year period of weighted annual county-level returns where weights are based on the county acreage in each land use. Values are expressed in 1990 dollars, deflated using the producer price index for all commodities from the Bureau of Labor Statistics. The Appendix contains details on the construction of the different net returns measures.
[3] LCC is a rating of the suitability of soils for crop production based on twelve characteristics. Higher values indicate worse land quality for crops.
[4] All crop profit estimates include county-level estimates of direct government payments per acre (not including the Conservation Reserve Program).
[5] Minimum range profits are zero as I assume there are no management costs to the landowner for range production as discussed in the Appendix.

Table 3.1 Maximum Likelihood Estimation Results for Land-Use Choice Model: Starting Use is Crops

Variable (alternative/nest equation where variable enters listed in parentheses)	Alternative Specifications and Transition Periods					
	Conditional Logit			Nested Logit[1]		
	1982-1987	1987-1992	1992-1997	1982-1987	1987-1992	1992-1997
Net crop profit (crop)	0.00452***	0.00784***	0.00349***	0.00484***	0.00869***	0.00589***
	(0.00027)	(0.00028)	(0.00037)	(0.00028)	(0.00030)	(0.00052)
Crop profit X LCC=3 and 4 (crop)[2]	0.00079**	-0.00195***	-0.00118**	0.00072*	-0.00222***	-0.00335***
	(0.00040)†††	(0.00037) †††	(0.00050) †††	(0.00042) †††	(0.00041) †††	(0.00069) †††
Crop profit X LCC=5 and 6 (crop)	-0.00504***	-0.00571***	-0.00514***	-0.00477***	-0.00653***	-0.00602***
	(0.00081)	(0.00066) †††	(0.00069) †††	(0.00086)	(0.00071) †††	(0.00098)
Crop profit X LCC=7 and 8 (crop)	-0.0024**	-0.00335***	-0.00181	-0.00207*	-0.00335***	-0.00397*
	(0.00102) ††	(0.00103) †††	(0.00155)	(0.00114) ††	(0.00114) †††	(0.00218)
Net pasture profit (pasture)	-0.00232	0.01114***	0.01039***	-0.00202	0.01247***	0.0143***
	(0.0017)	(0.00288)	(0.00231)	(0.0017)	(0.00288)	(0.00235)
Pasture profit X LCC=3 and 4 (pasture)	0.00584***	-0.0025	0.00352	0.00575**	-0.00274	0.0004
	(0.00223) ††	(0.00387) †††	(0.00304) †††	(0.00223) †††	(0.00388) †††	(0.0031) †††
Pasture profit X LCC=5 and 6 (pasture)	-0.01192**	-0.02262***	-0.01196**	-0.01172**	-0.02388***	-0.01274**
	(0.00498) †††	(0.00733) †	(0.00554)	(0.00500) †††	(0.00737)	(0.00566)
Pasture profit X LCC=7 and 8 (pasture)	-0.0237***	-0.01925*	-0.01688*	-0.02245***	-0.01865*	-0.02035**
	(0.00738) †††	(0.00996)	(0.00877)	(0.00734) †††	(0.00997)	(0.00905)
Net forest profit (forest)	0.11916***	0.04517***	0.02301***	0.71608***	0.40656***	0.07324***
	(0.00412)	(0.00316)	(0.00147)	(0.05072)	(0.04122)	(0.01147)
Forest profit X LCC=3 and 4 (forest)	-0.00421	-0.00463	-0.00524**	-0.19317***	-0.21973***	-0.04317***
	(0.00567) †††	(0.00458) †††	(0.00228) †††	(0.04407) †††	(0.04424) †††	(0.01213) †††
Forest profit X LCC=5 and 6 (forest)	-0.00399	-0.00066	-0.00691	-0.13055**	-0.27228***	-0.04934***
	(0.01154) †††	(0.00755) †††	(0.00435) †††	(0.06411) †††	(0.04966) †††	(0.01547) ††
Forest profit X LCC=7 and 8 (forest)	-0.00645	0.00919	-0.00834	-0.03412	-0.20966**	-0.07225***
	(0.02611) †††	(0.01918) †††	(0.0108)	(0.1049) †††	(0.07850) †††	(0.01890)
Net development profit (urban)	0.00023***	0.00012***	0.00017***	-0.00128	0.00048	0.00021
	(0.00001)	(0.00001)	(0.00001)	(0.0017)	(0.00049)	(0.00041)
Urban profit X LCC=3 and 4 (urban)	0.000002	-0.000002	-0.00002*	-0.00001	0.000003	-0.00002
	(0.00002) †††	(0.00001) †††	(0.00001) †††	(0.00011)	(0.00004)	(0.00003)
Urban profit X LCC=5 and 6 (urban)	-0.00006	0.000004	0.0000007	0.00032	0.00004	0.00001
	(0.00005) †††	(0.00002) †††	(0.00002) †††	(0.00054)	(0.00009)	(0.00004)
Urban profit X LCC=7 and 8 (urban)	-0.00008	-0.00003	-0.00008**	0.00045	-	-
	(0.00006) †††	(0.00002) †††	(0.00004) ††	(0.00067)	-	-
Net range profit (range)	0.03589***	0.02652***	0.03864***	0.09612***	0.05959***	0.06749***
	(0.00500)	(0.00634)	(0.00398)	(0.01304)	(0.01335)	(0.00818)
Range profit X LCC=3 and 4 (range)	-0.01279**	0.00773	-0.01126**	0.01488	-0.0057	-0.01193
	(0.00619) †††	(0.00757) †††	(0.00514) †††	(0.01666) †††	(0.01634) †††	(0.01015) †††
Range profit X LCC=5 and 6 (range)	-0.01558*	-0.0102	-0.03054***	-0.01001	-0.01114	-0.03291*
	(0.00841) †††	(0.01007) ††	(0.00887)	(0.02258) †††	(0.02268) ††	(0.01712) ††
Range profit X LCC=7 and 8 (range)	-0.05871***	-0.05094*	-0.03512**	-0.08468	-0.10848**	-0.02634
	(0.02232)	(0.02959)	(0.01404)	(0.05194)	(0.04891)	(0.02754)
Pasture constant (pasture)	-3.68903***	-3.67934***	-3.86469***	-3.67645***	-3.63465***	-3.72457***
	(0.03619)	(0.03767)	(0.04649)	(0.03618)	(0.03827)	(0.05044)
Dummy for LCC=3 and 4 (pasture)	0.40741***	0.43331***	0.39866***	0.40386***	0.41466***	0.26637***
	(0.04756) †††	(0.04868) †††	(0.05921) †††	(0.04764) †††	(0.04933) †††	(0.06420) †††
Dummy for LCC=5 and 6 (pasture)	0.83402***	1.03784***	0.91158***	0.84258***	0.9944***	0.84842***
	(0.08837) †††	(0.08077) †††	(0.09401) †††	(0.08896) †††	(0.08184) †††	(0.09969) †††
Dummy for LCC=7 and 8 (pasture)	1.64069***	1.59897***	1.1542***	1.6352***	1.58682***	1.02751***
	(0.12294) †††	(0.11947) †††	(0.17103) †††	(0.12284) †††	(0.12085) †††	(0.18990) †††
Forest constant (forest)	-6.04101***	-5.65921***	-5.41937***	-0.18084	-0.98205***	0.60253***
	(0.06349)	(0.06656)	(0.05996)	(0.23078)	(0.26712)	(0.16469)

Dummy for LCC=3 and 4 (forest)	0.48303***	0.1654*	0.16164*	-0.37794	0.4631	-0.43519**
	(0.08529) †††	(0.09258) †††	(0.08436) †††	(0.26963) †††	(0.30841) †††	(0.21247)
Dummy for LCC=5 and 6 (forest)	0.93027***	0.94748***	0.73422***	-0.65596*	0.16047	-0.75513**
	(0.14281) †††	(0.14134) †††	(0.13613) †††	(0.35701) †††	(0.38899) †††	(0.30177)
Dummy for LCC=7 and 8 (forest)	1.6933***	1.26857***	1.38466***	-1.32482**	-0.59211	-0.77721
	(0.23095) †††	(0.26921) †††	(0.26168) †††	(0.53167) †††	(0.63946) ††	(0.39354)
Urban constant (urban)	-5.54106***	-5.03681***	-4.97839***	-5.68165***	-5.47606***	-5.17288***
	(0.05532)	(0.05071)	(0.05191)	(0.06376)	(0.06714)	(0.06344)
Dummy for LCC=3 and 4 (urban)	-0.20466**	-0.218***	-0.19729**	-0.23403***	-0.12974*	-0.16421**
	(0.08709) †††	(0.07616) †††	(0.07678) †††	(0.08578) †††	(0.07359) †††	(0.07127) †††
Dummy for LCC=5 and 6 (urban)	-0.52478**	-0.55495***	-0.49113***	-0.4159*	-0.34544*	-0.22915
	(0.23506) †††	(0.18948) †††	(0.16903) †††	(0.23378) †††	(0.18741) †††	(0.16719) †††
Dummy for LCC=7 and 8 (urban)	0.36781	0.32082	0.28444	0.39082	-	-
	(0.33848) †††	(0.29348) †††	(0.3096) †††	(0.33655) †††	-	-
Range constant (range)	-7.15585***	-6.52501***	-6.34293***	-	-	-
	(0.12564)	(0.11866)	(0.09566)	-	-	-
Dummy for LCC=3 and 4 (range)	1.52355***	0.81639***	1.01737***	-	-	-
	(0.14569) †††	(0.14450) †††	(0.11765) †††	-	-	-
Dummy for LCC=5 and 6 (range)	2.3135***	2.28567***	1.93753***	-	-	-
	(0.18719) †††	(0.17369) †††	(0.16106) †††	-	-	-
Dummy for LCC=7 and 8 (range)	3.49459***	2.7192***	2.91655***	-	-	-
	(0.23949) †††	(0.27949) †††	(0.22262) †††	-	-	-
CRP constant (CRP)	-4.21858***	-3.00526***	-5.42648***	-4.20069***	-2.9499***	-5.23155***
	(0.03026)	(0.02545)	(0.05976)	(0.03048)	(0.02666)	(0.06594)
Dummy for LCC=3 and 4 (CRP)	1.5865***	0.80537***	0.82035***	1.58081***	0.78407***	0.64262***
	(0.03610) †††	(0.03211) †††	(0.07460) †††	(0.03649) †††	(0.03343) †††	(0.08225) †††
Dummy for LCC=5 and 6 (CRP)	1.64673***	1.03025***	0.77239***	1.65731***	0.97664***	0.69119***
	(0.06011) †††	(0.05440) †††	(0.12852) †††	(0.06162) †††	(0.05650) †††	(0.13736) †††
Dummy for LCC=7 and 8 (CRP)	1.47071***	1.03556***	0.8077***	1.48311***	1.02625***	0.63254**
	(0.10950) †††	(0.09780) †††	(0.27624) †††	(0.11113) †††	(0.10035) †††	(0.29888) †††
Nonfarm constant (nonfarm)	-	-	-	-5.89245***	-5.67519***	-5.50741***
	-	-	-	(0.06909)	(0.07309)	(0.10948)
Dummy for LCC=3 and 4 (nonfarm)	-	-	-	0.86453***	0.6221***	0.65739
	-	-	-	(0.07145) †††	(0.06614) †††	(0.07485) †††
Dummy for LCC=5 and 6 (nonfarm)	-	-	-	1.59388***	1.81347***	1.60288***
	-	-	-	(0.10611) †††	(0.09092) †††	(0.11919) †††
Dummy for LCC=7 and 8 (nonfarm)	-	-	-	2.34264***	1.98809***	2.232***
	-	-	-	(0.15224) †††	(0.15355) †††	(0.15266) †††
Inclusive value parameter (farm)	-	-	-	0.46849***	0.23***	0.20334**
	-	-	-	(0.10964)	(0.06761)	(0.09378)
Inclusive value parameter (nonfarm)	-	-	-	0.1497***	0.09121***	0.27819***
	-	-	-	(0.01017)	(0.01214)	(0.04866)
Inclusive value parameter (urban)	-	-	-	-0.17457	0.24807	0.78027
	-	-	-	(0.23139)	(0.25111)	(1.53511)
Number of observations	262,315	248,905	227,424	262,315	248,905	227,424
Log likelihood value	-79,994	-86,756	-55,227	-79,746	-86,591	-55,197
Log likelihood value (constant only model)	-470,005	-445,978	-407,489	-470,005	-445,978	-407,489
McFadden's likelihood ratio index	0.8298	0.8055	0.8645	0.8303	0.8058	0.8645

Notes: Standard errors are in parentheses. Dashes (-) indicate that no coefficient was estimated.
*, **, and *** denote significance at 10%, 5%, and 1% levels respectively.
† ,†††, and ††† denote significance at 10%, 5%, and 1% levels respectively of the sum of the coefficient on a variable interacted with an LCC dummy and the coefficient on the corresponding variable (or constant) with no interactions.
[1] The nested model includes three nests: farm (crops, pasture, CRP), nonfarm (forest, range) and urban (urban). For 1987-92 and 1992-97, data did not permit estimation of coefficients on the dummy for LCC equals 7 or 8 in the urban equation for the nested model.
[2] This notation is for an interaction with the dummy variable for the Land Capability Class (LCC) for the plot. LCC values range from 1 to 8 with higher values indicating worse land quality for crops.

Table 3.2 Maximum Likelihood Estimation Results for Land-Use Choice Model: Starting Use is Pasture

Variable (alternative/nest equation where variable enters listed in parentheses)	Alternative Specifications and Transition Periods					
	Conditional Logit			Nested Logit[1]		
	1982-1987	1987-1992	1992-1997	1982-1987	1987-1992	1992-1997
Net crop profit (crop)	0.00833***	0.00673***	0.00617***	0.0084***	0.00694***	0.00639***
	(0.00056)	(0.00056)	(0.00038)	(0.00056)	(0.00057)	(0.00035)
Crop profit X LCC=3 and 4 (crop)[2]	-0.0015**	-0.00014	-0.0004	-0.00138**	0.00014	-0.0006
	(0.00068) †††	(0.00069) †††	(0.00048) †††	(0.00068) †††	(0.0007) †††	(0.00045) †††
Crop profit X LCC=5 and 6 (crop)	-0.00187	0.00004	-0.00185**	-0.00187	0.00011	-0.00178**
	(0.00122) †††	(0.00116) †††	(0.00076) †††	(0.00122) †††	(0.00117) †††	(0.00071) †††
Crop profit X LCC=7 and 8 (crop)	-0.00303**	-0.00054	-0.00438***	-0.00316**	-0.00172	-0.00433***
	(0.00124) †††	(0.00142) †††	(0.00092) ††	(0.00125)	(0.00147) †††	(0.00083) †††
Net pasture profit (pasture)	0.0131***	-0.01***	-0.01345***	0.01567***	-0.00362	-0.00654***
	(0.00168)	(0.00256)	(0.00204)	(0.00192)	(0.00331)	(0.00163)
Pasture profit X LCC=3 and 4 (pasture)	0.00818***	0.0194***	0.01233***	0.011***	0.02264***	0.00478***
	(0.00220) †††	(0.00324) †††	(0.00256)	(0.00260) †††	(0.00431) †††	(0.00178) ††
Pasture profit X LCC=5 and 6 (pasture)	-0.00578*	0.01944***	0.00233	-0.00249	0.02557***	0.00186
	(0.00321) †††	(0.00535) ††	(0.00379) †††	(0.00444) †††	(0.00843) †††	(0.00178) †††
Pasture profit X LCC=7 and 8 (pasture)	-0.00063	0.02253***	0.01833***	-0.00045	-0.0177	0.00828***
	(0.00453) †††	(0.00677) ††	(0.00513)	(0.007) ††	(0.0112) ††	(0.00272)
Net forest profit (forest)	0.03917***	0.00839	0.00361*	0.66339***	0.4111***	0.06641***
	(0.00597)	(0.00529)	(0.00219)	(0.09156)	(0.11365)	(0.01731)
Forest profit X LCC=3 and 4 (forest)	-0.00807	0.01529***	-0.00273	-0.27564***	-0.38232***	-0.08943***
	(0.00736) †††	(0.00578) †††	(0.00275)	(0.09886) †††	(0.11298) †	(0.01808) †††
Forest profit X LCC=5 and 6 (forest)	-0.00444	-0.00803	-0.00197	0.01578	0.18423	-0.08563***
	(0.00858) †††	(0.00803)	(0.00324)	(0.11219) †††	(0.14109) †††	(0.01841) †††
Forest profit X LCC=7 and 8 (forest)	-0.0157	-0.01033	0.00233	-0.03732	-0.38555***	-0.07907***
	(0.01273) ††	(0.01155)	(0.00452)	(0.19932) †††	(0.13055)	(0.02802)
Net development profit (urban)	0.00031***	0.00017***	0.00021***	-0.00082	0.00109	0.00021***
	(0.00003)	(0.00002)	(0.00001)	(0.00123)	(0.00313)	(0.00001)
Urban profit X LCC=3 and 4 (urban)	-0.00002	-0.00001	-0.00003*	0.00007	-0.00015	-0.00005***
	(0.00004) †††	(0.00002) †††	(0.00002) †††	(0.00015)	(0.00044)	(0.00002) †††
Urban profit X LCC=5 and 6 (urban)	-0.00006	0.00001	-0.00003	0.00012	0.00002	-0.00003
	(0.00006) †††	(0.00003) †††	(0.00003) †††	(0.00025)	(0.00021)	(0.00003) †††
Urban profit X LCC=7 and 8 (urban)	0.00014**	0.0001**	0.00004	-0.00041	0.0006	0.00004
	(0.00006)	(0.00004) †††	(0.00005) †††	(0.00063)	(0.00173)	(0.00005) †††
Net range profit (range)	0.03378***	0.05513***	0.0606***	0.0948***	0.11127***	0.0601***
	(0.00551)	(0.00825)	(0.00365)	(0.01263)	(0.01639)	(0.00519)
Range profit X LCC=3 and 4 (range)	-0.00146	-0.03135***	-0.01553***	-0.00075	-0.05692***	0.02422***
	(0.0062) †††	(0.01001) †††	(0.00446) †††	(0.01431) †††	(0.01806) †††	(0.00715) †††
Range profit X LCC=5 and 6 (range)	-0.00138	-0.01572	-0.01601***	-0.02986*	-0.03332	0.00403
	(0.00734) †††	(0.01108) †††	(0.00604) †††	(0.01564) †††	(0.02069) †††	(0.0091) †††
Range profit X LCC=7 and 8 (range)	-0.00364	-0.04376**	-0.02025**	-0.07617***	-0.1119***	-0.00809
	(0.01244) †††	(0.02040)	(0.00903) †††	(0.01747)	(0.02282)	(0.01246) †††
Pasture constant (pasture)	2.35795***	3.1598***	2.84947***	2.32064***	3.11716***	2.75946***
	(0.04527)	(0.05133)	(0.04516)	(0.04701)	(0.05263)	(0.04540)
Dummy for LCC=3 and 4(pasture)	0.21198***	0.07717	0.09372	0.18054***	0.07473	0.18981***
	(0.05637) †††	(0.0632) †††	(0.05733) †††	(0.05885) †††	(0.06478) †††	(0.05441) †††
Dummy for LCC=5 and 6 (pasture)	1.05921***	0.63872***	0.7397***	1.0189***	0.6135***	0.76056***
	(0.09269) †††	(0.10394) †††	(0.09139) †††	(0.10122) †††	(0.10863) †††	(0.08275) †††
Dummy for LCC=7 and 8 (pasture)	1.30896***	0.96661***	0.44661***	1.31424***	1.20661***	0.59594***
	(0.12033) †††	(0.14800) †††	(0.11405) †††	(0.13277) †††	(0.16263) †††	(0.10927) †††
Forest constant (forest)	-0.97448***	-0.78651***	-0.36976***	1.29993***	2.17995***	1.81266***
	(0.06173)	(0.07714)	(0.05861)	(0.26494)	(0.46472)	(0.23355)

Dummy for LCC=3 and 4 (forest)	0.44299***	0.33216***	0.29099***	0.0579	0.13693	0.83407***
	(0.07553) †††	(0.09257) †††	(0.07347) †	(0.30007) †††	(0.48713) †††	(0.26662) †††
Dummy for LCC=5 and 6 (forest)	1.59693***	1.42064***	1.1294***	-0.53304*	-1.69449***	0.71296**
	(0.10336) †††	(0.12917) †††	(0.10356) †††	(0.3226) †††	(0.54417) †	(0.29208) †††
Dummy for LCC=7 and 8 (forest)	2.37168***	2.33686***	1.45306***	0.79183	0.67429	1.35659***
	(0.13280) †††	(0.17449) †††	(0.13014) †††	(0.53375) †††	(0.66059) †††	(0.44123) †††
Urban constant (urban)	-2.61871***	-1.61646***	-1.7141***	-4.04631***	-5.70283***	-1.71136***
	(0.11033)	(0.09073)	(0.08014)	(0.23373)	(0.45280)	(0.07916)
Dummy for LCC=3 and 4 (urban)	0.14041	0.11425	0.18896*	-0.01123	-0.16743	0.21492**
	(0.13856) †††	(0.1135) †††	(0.10107) †††	(0.13392) †††	(0.10435) †††	(0.10026) †††
Dummy for LCC=5 and 6 (urban)	0.63097***	0.16357	0.34118**	0.12989	-0.8009***	0.36848**
	(0.20483) †††	(0.18327) †††	(0.15713) †††	(0.20584) †††	(0.18935) †††	(0.15362) †††
Dummy for LCC=7 and 8 (urban)	0.86854***	0.32912	0.2271	0.23091	-1.05063***	0.25306
	(0.25277) †††	(0.25917) †††	(0.21725) †††	(0.25143) †††	(0.26743)?	(0.21478) †††
Range constant (range)	-3.43496***	-4.05478***	-2.89582***	-	-	-
	(0.16066)	(0.26212)	(0.12681)	-	-	-
Dummy for LCC=3 and 4 (range)	1.15081***	1.53394***	0.99583***	-	-	-
	(0.17980) †††	(0.29057) †††	(0.14734) †††	-	-	-
Dummy for LCC=5 and 6 (range)	2.06554***	2.41053***	1.62036***	-	-	-
	(0.20906) †††	(0.32018) †††	(0.18454) †††	-	-	-
Dummy for LCC=7 and 8 (range)	1.10703***	2.46098***	1.15995***	-	-	-
	(0.35949) †††	(0.41883) †††	(0.25529) †††	-	-	-
CRP constant (CRP)	-2.68798***	-1.9238***	-4.94866***	-2.68508***	-1.91152***	-4.9446***
	(0.10513)	(0.09922)	(0.34372)	(0.10512)	(0.09925)	(0.34398)
Dummy for LCC=3 and 4 (CRP)	0.43578***	0.23101*	1.25798***	0.44057***	0.24693	1.25516***
	(0.12757) †††	(0.1228) †††	(0.37621) †††	(0.12758) †††	(0.12298) †††	(0.37626) †††
Dummy for LCC=5 and 6 (CRP)	0.78498***	0.61532***	0.48133	0.78613***	0.61804***	0.47583
	(0.18263) †††	(0.17750) †††	(0.61075) †††	(0.18262) †††	(0.17765) †††	(0.61329) †††
Dummy for LCC=7 and 8 (CRP)	0.09728	0.53851*	1.05065	0.0915	0.49079*	1.07303
	(0.35961) †††	(0.28035) †††	(0.65512) †††	(0.35978) †††	(0.28193) †††	(0.65524) †††
Nonfarm constant (nonfarm)	-	-	-	-2.26952***	-4.67606***	5.36278***
	-	-	-	(0.21892)	(0.44811)	(1.87350)
Dummy for LCC=3 and 4 (nonfarm)	-	-	-	0.38666***	0.17782**	0.78922***
	-	-	-	(0.05562) †††	(0.07160) †††	(0.21733) †††
Dummy for LCC=5 and 6 (nonfarm)	-	-	-	1.15416***	0.45235***	2.56842***
	-	-	-	(0.09373) †††	(0.12697) †††	(0.55242) †††
Dummy for LCC=7 and 8 (nonfarm)	-	-	-	1.56886***	0.82185***	2.63412***
	-	-	-	(0.12014) ††	(0.17129) †††	(0.54711) †††
Inclusive value parameter (farm)	-	-	-	0.45789***	-0.2938**	2.99133***
	-	-	-	(0.07941)	(0.14088)	(0.67358)
Inclusive value parameter (nonfarm)	-	-	-	0.03031***	-0.00969	0.02803
	-	-	-	(0.00609)	(0.01003)	(0.03037)
Inclusive value parameter (urban)	-	-	-	-0.3589	0.15517	-
	-	-	-	(0.53633)	(0.4439)	-
Number of observations	88,588	83,161	77,707	88,588	83,161	77,707
Log likelihood value	-44,738	-35,266	-44,447	-44,446	-35,183	-44,379
Log likelihood value (constant only model)	-158,728	-149,005	-139,232	-158,728	-149,004	-139,232
McFadden's likelihood ratio index	0.7181	0.7633	0.6808	0.7200	0.7639	0.6813

Notes: Standard errors are in parentheses. Dashes (-) indicate that no coefficient was estimated.
*, **, and *** denote significance at 10%, 5%, and 1% levels respectively.
† ,†††, and ††† denote significance at 10%, 5%, and 1% levels respectively of the sum of the coefficient on a variable interacted with an LCC dummy and the coefficient on the corresponding variable (or constant) with no interactions.
[1] For 1982-87 and 1987-92, the nested model includes three nests: farm (crops, pasture, CRP), nonfarm (forest, range) and urban (urban). For 1992-97, the model includes only two nests: farm (crops, pasture, CRP, urban), and nonfarm (forest, range).
[2] This notation is for an interaction with the dummy variable for the Land Capability Class (LCC) for the plot. LCC values range from 1 to 8 with higher values indicating worse land quality for crops.

Table 3.3 Maximum Likelihood Estimation Results for Land-Use Choice Model: Starting Use is Forest

Variable (alternative/nest equation where variable enters listed in parentheses)	Alternative Specifications and Transition Periods					
	Conditional Logit [1]			Nested Logit [2]		
	1982-1987	1987-1992	1992-1997	1982-1987	1987-1992	1992-1997
Net crop profit (crop)	0.00827***	0.00514***	0.00315***	0.02342***	0.01568***	0.00325***
	(0.00125)	(0.00152)	(0.00086)	(0.00287)	(0.00129)	(0.00110)
Crop profit X LCC=3 and 4 (crop) [3]	-0.00591***	0.00346*	0.00245**	-0.02032***	-0.00402***	0.00163
	(0.00165) †††	(0.00208) †††	(0.00108) †††	(0.00321) ††	(0.00147) †††	(0.00134) †††
Crop profit X LCC=5 and 6 (crop)	0.00122	0.00781***	0.00433***	-0.00728*	-0.01022***	0.00456***
	(0.00214)	(0.00242) †††	(0.00130) †††	(0.00394) †††	(0.00193) †††	(0.00174) †††
Crop profit X LCC=7 and 8 (crop)	-0.00577**	-0.00097	-0.00074	-0.02478***	-0.01798***	-0.00022
	(0.00272)	(0.00298)	(0.00162) †	(0.00337)	(0.00193)	(0.00183) ††
Net pasture profit (pasture)	0.01859***	0.00447	0.01195	0.02314***	0.00417	0.00963
	(0.00469)	(0.01242)	(0.00779)	(0.00805)	(0.01383)	(0.00945)
Pasture profit X LCC=3 and 4 (pasture)	-0.00361	0.01263	-0.00244	0.00229	0.00791	-0.00781
	(0.00567) †††	(0.01377) †††	(0.00929) †	(0.01001) †††	(0.01527) ††	(0.01145)
Pasture profit X LCC=5 and 6 (pasture)	-0.01272**	-0.02422	-0.01283	-0.00257	-0.01864	-0.01083
	(0.00626)	(0.01735)	(0.01091)	(0.01227) ††	(0.01834)	(0.01403)
Pasture profit X LCC=7 and 8 (pasture)	-0.01611**	0.00334	-0.01505	-0.02875**	0.01493	-0.01812
	(0.00722)	(0.01694)	(0.01029)	(0.01406)	(0.01822)	(0.01278)
Net forest profit (forest)	-0.01548***	-0.00614	0.00195	-0.1014***	-0.03984	-0.00574
	(0.00582)	(0.00465)	(0.00246)	(0.03606)	(0.02795)	(0.00837)
Forest profit X LCC=3 and 4 (forest)	0.01651**	0.00787	0.00135	0.12185***	0.0349	0.00729
	(0.00696)	(0.00556)	(0.00282) ††	(0.04059)	(0.03055)	(0.00746)
Forest profit X LCC=5 and 6 (forest)	0.02714***	0.0222***	0.00128	0.17711***	0.10168***	0.00872
	(0.00769) ††	(0.00598) †††	(0.0028) ††	(0.04248) †††	(0.03130) †††	(0.0079) ††
Forest profit X LCC=7 and 8 (forest)	0.01806**	0.03464***	0.00203	0.16109***	0.17555***	0.00885
	(0.00872)	(0.00740) †††	(0.003) ††	(0.04399) ††	(0.03197) †††	(0.00965) †
Net development profit (urban)	0.0004***	0.00023***	0.00024***	0.00257	0.00032***	0.0005***
	(0.00003)	(0.00002)	(0.00002)	(0.01502)	(0.00004)	(0.00005)
Urban profit X LCC=3 and 4 (urban)	-0.00024***	-0.00012***	-0.00011***	0.00041	-0.00015***	0.00003
	(0.00003) †††	(0.00002) †††	(0.00002) †††	(0.00245)	(0.00003) †††	(0.00006) †††
Urban profit X LCC=5 and 6 (urban)	-0.00029***	-0.00014***	-0.00013***	-0.00047	-0.0002***	0.00003
	(0.00004) †††	(0.00002) †††	(0.00002) †††	(0.00284)	(0.00004) †††	(0.00007) †††
Urban profit X LCC=7 and 8 (urban)	-0.00033***	-0.00016***	-0.00015***	-	-0.00023***	-0.00007
	(0.00003) †††	(0.00002) †††	(0.00002) †††	-	(0.00004) †††	(0.00007) †††
Net range profit (range)	0.04896*	-0.04416	0.05438***	0.04707	-0.75709	0.04692
	(0.02709)	(0.25428)	(0.01415)	(0.03128)	(0.49498)	(0.04765)
Range profit X LCC=3 and 4 (range)	-0.00063	0.0858	0.00033	0.00235	0.75516	0.00693
	(0.02835) †††	(0.25449) †††	(0.015) †††	(0.03232) †††	(0.49481)	(0.04669) †††
Range profit X LCC=5 and 6 (range)	-0.0054	0.05754	-0.03269**	0.00072	0.78065	-0.02503
	(0.02792) †††	(0.25442) †††	(0.01576) †††	(0.03194) †††	(0.49527) †††	(0.049) †††
Range profit X LCC=7 and 8 (range)	-0.02742	0.05831	-0.03756**	-0.02431	0.77285	-0.02942
	(0.02837) †	(0.25437)	(0.01508) †††	(0.03232) †††	(0.49511) ††	(0.04693) †††
Pasture constant (pasture)	0.07741	-0.1944	0.41667**	0.97214***	1.3023***	0.46441**
	(0.15168)	(0.2217)	(0.17246)	(0.21320)	(0.19890)	(0.19350)
Dummy for LCC=3 and 4 (pasture)	0.04036	1.53771***	0.84368***	-0.9678***	0.61607***	0.82623***
	(0.18441)	(0.28169) †††	(0.21764) †††	(0.25438)	(0.21253) †††	(0.24220) †††
Dummy for LCC=5 and 6 (pasture)	1.35144***	2.2961***	1.2951***	0.60689*	-0.27203	1.26123***
	(0.24005) †††	(0.35285) †††	(0.26518) †††	(0.32938) †††	(0.22808) †††	(0.29666) †††
Dummy for LCC=7 and 8 (pasture)	1.92109***	2.18191***	1.75564***	0.42729	-0.78189***	1.94274***
	(0.29626) †††	(0.38412) †††	(0.28331) †††	(0.28292) †††	(0.23811) †††	(0.30950) †††
Forest constant (forest)	5.49762***	5.92627***	5.50659***	10.43296***	6.83537***	8.22128***
	(0.11572)	(0.15630)	(0.12285)	(0.86813)	(0.33515)	(1.79220)

Dummy for LCC=3 and 4 (forest)	0.07522	1.10418***	0.86845***	-2.75651***	0.09016	-1.44152
	(0.14045) †††	(0.21960) †††	(0.16270) †††	(0.89577) †††	(0.37047) †††	(1.75534) †††
Dummy for LCC=5 and 6 (forest)	1.67582***	2.17998***	1.9088***	-3.77038***	-1.05124***	-2.28799
	(0.20090) †††	(0.29262) †††	(0.20822) †††	(0.88165) †††	(0.36506) †††	(1.81251) †††
Dummy for LCC=7 and 8 (forest)	2.61027***	2.29422***	2.14862***	-3.93418***	-1.75362***	-2.82631
	(0.26023) †††	(0.32850) †††	(0.23948) †††	(0.88019) †††	(0.36472) †††	(1.79007) †††
Urban constant (urban)[4]	-0.03196	0.81239***	0.85826***	0.43819***	2.23333***	0.33474**
	(0.14334)	(0.17083)	(0.13473)	(0.14047)	(0.14349)	(0.16977)
Dummy for LCC=3 and 4 (urban)	0.48469***	1.38307***	1.11324***	-0.56733***	0.30077**	0.7506***
	(0.17083) †††	(0.23287) †††	(0.17436) †††	(0.11440)	(0.14284) †††	(0.21359) †††
Dummy for LCC=5 and 6 (urban)	1.66433***	1.97256***	1.54857***	0.17113	-0.5753***	1.25313***
	(0.22821) †††	(0.30562) †††	(0.22084) †††	(0.14791) †††	(0.13856) †††	(0.26478) †††
Dummy for LCC=7 and 8 (urban)	2.64893***	2.13235***	1.75615***	-	-0.63875***	1.73182***
	(0.27993) †††	(0.33916) †††	(0.25006) †††	-	(0.14011) †††	(0.29337) †††
Range constant (range)	-4.20543***	-5.1343**	-2.79869***	-	-	-
	(0.72158)	(2.10304)	(0.39968)	-	-	-
Dummy for LCC=3 and 4 (range)	1.97679***	4.34539**	2.38972***	-	-	-
	(0.75033) †††	(2.11871) †††	(0.42971) †††	-	-	-
Dummy for LCC=5 and 6 (range)	4.45036***	7.24565***	4.26835***	-	-	-
	(0.75150) †††	(2.11974) †††	(0.44289) †††	-	-	-
Dummy for LCC=7 and 8 (range)	5.59801***	7.68711***	5.09773***	-	-	-
	(0.76720) †††	(2.12409) †††	(0.45360) †††	-	-	-
CRP constant (CRP)	-2.64719***	-1.56349***	-3.29577***	-1.686***	-1.14754***	-3.2543***
	(0.34618)	(0.28710)	(0.44354)	(0.36655)	(0.23851)	(0.44181)
Dummy for LCC=3 and 4 (CRP)	-0.44037	-0.24243	0.39888	-1.36931***	0.09436	0.35013
	(0.45206) †††	(0.44924) †††	(0.60812) †††	(0.46941) †††	(0.36283) †††	(0.59929) †††
Dummy for LCC=5 and 6 (CRP)	0.47406	-0.42205	-	-0.13832	-	-
	(0.57391)	(0.75318) †††	-	(0.59845) †††	-	-
Dummy for LCC=7 and 8 (CRP)	1.01585	-0.71616	0.45675	-0.65416	-2.18877***	0.68123
	(0.63547) †††	(0.882) †††	(0.89062) †††	(0.60957) †††	(0.72795) †††	(0.86154) †††
Nonfarm constant (nonfarm)	-	-	-	3.89803***	5.84067***	-7.40502
	-	-	-	(0.55948)	(0.32622)	(12.6313)
Dummy for LCC=3 and 4 (nonfarm)	-	-	-	0.07135	-	2.07614***
	-	-	-	(0.17932) †††	-	(0.57563)
Dummy for LCC=5 and 6 (nonfarm)	-	-	-	1.38321***	-	3.98641**
	-	-	-	(0.21570) †††	-	(1.74416)
Dummy for LCC=7 and 8 (nonfarm)	-	-	-	1.48733***	-	4.84773*
	-	-	-	(0.20397) †††	-	(2.78583)
Inclusive value parameter (farm)	-	-	-	0.3655***	0.64874***	0.16199***
	-	-	-	(0.07598)	(0.08456)	(0.02777)
Inclusive value parameter (nonfarm)	-	-	-	0.1318**	0.07686**	1.39091
	-	-	-	(0.05379)	(0.0386)	(1.83614)
Inclusive value parameter (urban)	-	-	-	0.0556	-	-
	-	-	-	(0.32429)	-	-
Number of observations	247,556	242,322	233,454	247,556	242,322	233,454
Log likelihood value	-21,434	-19,648	-28,407	-21,493	-19,665	-28,256
Log likelihood value (constant only model)	-443,561	-434,183	-418,293	-443,561	-434,183	-418,293
McFadden's likelihood ratio index	0.9517	0.9547	0.9321	0.9515	0.9547	0.9324

Notes: Standard errors are in parentheses. Dashes (-) indicate that no coefficient was estimated. *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. † ,†††, and ††† denote significance at 10%, 5%, and 1% levels respectively of the sum of the coefficient on a variable interacted with an LCC dummy and the coefficient on the corresponding variable (or constant) with no interactions.

[1] For 1992-97, data did not permit estimation of coefficient on the dummy for LCC equals 5 or 6 in the CRP equation.

[2] For 1982-87, the nested model includes three nests: farm (crops, pasture, CRP), nonfarm (forest, range) and urban (urban). For 1987-92 and

[3] This notation is for an interaction with the dummy variable for the Land Capability Class (LCC) for the plot.

Table 3.4 Maximum Likelihood Estimation Results for Land-Use Choice Model: Starting Use is Range

Variable (alternative/nest equation where variable enters listed in parentheses)	Alternative Specifications and Transition Periods					
	Conditional Logit			Nested Logit[1]		
	1982-1987	1987-1992	1992-1997	1982-1987	1987-1992	1992-1997
Net crop profit (crop)	0.00535	0.00417	0.00803	-0.00489	0.00647	0.02451***
	(0.00344)	(0.00301)	(0.00489)	(0.00428)	(0.00404)	(0.00779)
Crop profit X LCC=3 and 4 (crop)[2]	-0.00713*	-0.00228	-0.00384	0.00666	-0.00394	-0.0182**
	(0.00372)	(0.00318) †	(0.00504) †††	(0.00483)	(0.00415) †	(0.00693) †††
Crop profit X LCC=5 and 6 (crop)	-0.00234	-0.00067	-0.01165**	0.01346**	-0.00115	-0.02756***
	(0.00419)	(0.00383)	(0.00534) †	(0.00575) ††	(0.00479) †	(0.00789)
Crop profit X LCC=7 and 8 (crop)	-0.00138	0.00701	-0.00624	0.02054***	0.00707	-0.02514***
	(0.00469)	(0.00357) †††	(0.00539)	(0.00587) †††	(0.00465) †††	(0.00714)
Net pasture profit (pasture)	0.03399**	-0.0983*	0.07808***	0.08357***	-0.11318*	0.1008***
	(0.01471)	(0.05913)	(0.02798)	(0.01958)	(0.06065)	(0.03607)
Pasture profit X LCC=3 and 4 (pasture)	-0.01725	0.13684**	-0.02588	-0.0393	0.15476**	-0.03838
	(0.01516) †††	(0.05967) †††	(0.0289) †††	(0.01968) †††	(0.06135) †††	(0.03538) †††
Pasture profit X LCC=5 and 6 (pasture)	-0.03887**	0.02165	-0.06603**	-0.04671**	0.05688	-0.0825**
	(0.01573)	(0.06588) †††	(0.03009)	(0.01986) †††	(0.06678) †††	(0.03682)
Pasture profit X LCC=7 and 8 (pasture)	-0.05639***	0.09597	-0.06606**	-0.08621***	0.10053	-0.08788**
	(0.01940) †	(0.06403)	(0.03096)	(0.02116)	(0.065)	(0.03890)
Net forest profit (forest)	-0.21801	0.03864	-0.01497	-0.39229	-0.00494	-0.01809
	(0.21713)	(0.07097)	(0.11439)	(0.24314)	(0.13504)	(0.11805)
Forest profit X LCC=3 and 4 (forest)	0.31154	-0.01164	0.03763	0.48931	0.03167	0.03962
	(0.21756) †††	(0.07209) ††	(0.11445) †††	(0.24385) †††	(0.1358) †	(0.11811) †††
Forest profit X LCC=5 and 6 (forest)	0.285	-0.035	0.0307	0.45956*	0.01128	0.03392
	(0.21738) †††	(0.07269)	(0.11442) †††	(0.24339) †††	(0.13585)	(0.11808) †††
Forest profit X LCC=7 and 8 (forest)	0.29082	-0.03298	0.03274	0.46495*	0.00615	0.03585
	(0.21765) †††	(0.07168)	(0.11441) †††	(0.24368) †††	(0.13548)	(0.11807) †††
Net development profit (urban)	0.00024***	0.00009**	0.00016***	0.00063	0.00008	0.00364
	(0.00005)	(0.00004)	(0.00003)	(0.00126)	(0.00007)	(0.00221)
Urban profit X LCC=3 and 4 (urban)	-0.00004	0.00004	-0.00001	-0.00004	0.00007	0.00006*
	(0.00005) †††	(0.00005) †††	(0.00003) †††	(0.00012)	(0.00007) †††	(0.00041) †
Urban profit X LCC=5 and 6 (urban)	-0.000004	0.00004	-0.00001	0.00006	0.00008	-0.00013
	(0.00005) †††	(0.00005) †††	(0.00004) †††	(0.00016)	(0.00007) †††	(0.00053) †
Urban profit X LCC=7 and 8 (urban)	-0.00005	0.00002	-0.00002	-	0.00006	-
	(0.00005) †††	(0.00005) †††	(0.00003) †††	-	(0.00007) †††	-
Net range profit (range)	0.0004	-0.01512**	-0.00663	-0.03722*	-0.02411	-0.00388
	(0.00527)	(0.00713)	(0.00788)	(0.02106)	(0.012)	(0.00504)
Range profit X LCC=3 and 4 (range)	-0.01948***	-0.02185***	-0.03305***	-0.0132	-0.03095**	-0.02174**
	(0.00610)	(0.00797) †††	(0.00870) †††	(0.019) †††	(0.01236) †††	(0.00832) †††
Range profit X LCC=5 and 6 (range)	-0.00846	-0.00492	0.00912	0.02711	0.00017	0.00278
	(0.00631)	(0.00878) †††	(0.00947)	(0.02182) †††	(0.0134) †††	(0.00658)
Range profit X LCC=7 and 8 (range)	-0.02934***	-0.00462	-0.00376	-0.01714	-0.00217	-0.00453
	(0.00803)	(0.01034) †††	(0.01042)	(0.02205) †††	(0.01411) †††	(0.007) †
Pasture constant (pasture)	-1.49855***	-0.69023*	-1.73556***	-2.67727***	-0.53966	-1.18039**
	(0.31982)	(0.35729)	(0.50743)	(0.38990)	(0.38367)	(0.55263)
Dummy for LCC=3 and 4 (pasture)	0.1979	-0.43853	0.29631	1.04991**	-0.5761	-0.27807
	(0.34153) †††	(0.38253) †††	(0.53936) †††	(0.40968) †††	(0.40548) †††	(0.58678) †††
Dummy for LCC=5 and 6 (pasture)	0.86003**	0.44063	-0.06099	1.59853***	0.27928	-0.66361
	(0.37223) †††	(0.44913)	(0.58682) †††	(0.43482) †††	(0.4681)	(0.63302) †††
Dummy for LCC=7 and 8 (pasture)	1.24719***	0.34649	0.54313	2.97408***	0.42295	-0.31919
	(0.45716)	(0.52409)	(0.63871) †††	(0.49075)	(0.54547)	(0.65092) †††
Forest constant (forest)	-2.21184***	-2.04339***	-2.28248***	-6.13464***	-6.40946***	-6.84094***
	(0.42542)	(0.38236)	(0.84844)	(0.50278)	(0.49537)	(0.82754)

Dummy for LCC=3 and 4 (forest)	-0.53306	0.25994	1.11574	-1.37171**	-0.68528	0.51605
	(0.45788) †††	(0.41353) †††	(0.86156) †††	(0.51577) †††	(0.52681) †††	(0.84288) †††
Dummy for LCC=5 and 6 (forest)	1.16382**	1.5906***	1.90107**	-0.36707	-0.42239	0.97251
	(0.45813) †††	(0.43941) †††	(0.86713) ††	(0.52298) †††	(0.5204) †††	(0.83437) †††
Dummy for LCC=7 and 8 (forest)	1.76511***	3.57867***	3.46139***	-1.39444**	0.40492	1.36511
	(0.49175) †	(0.44577) †††	(0.87969) †††	(0.53590) †††	(0.50677) †††	(0.83173) †††
Urban constant (urban)[4]	-2.88779***	-2.19348***	-1.19617***	-2.4385***	-2.08542***	-0.37989**
	(0.33589)	(0.34480)	(0.33977)	(0.22185)	(0.36913)	(0.18448)
Dummy for LCC=3 and 4 (urban)	0.10898	0.63601*	-0.03176	-1.08922***	0.46224	-0.94482***
	(0.37744) †††	(0.36991) †††	(0.37048) †††	(0.26106) †††	(0.40035) †††	(0.23455) †††
Dummy for LCC=5 and 6 (urban)	0.99479**	1.35493***	-0.26348	-0.71427**	1.21915***	-1.0596***
	(0.39527) †††	(0.41036) †††	(0.40383) †††	(0.27684) †††	(0.43937) †††	(0.27996) †††
Dummy for LCC=7 and 8 (urban)	2.66973***	2.70739***	1.35193***	-	2.54422***	-
	(0.41212)	(0.42818) †††	(0.42265)	-	(0.45927)	-
Range constant (range)	3.46972***	4.2288***	4.61528***	-	-	-
	(0.15520)	(0.19581)	(0.27432)	-	-	-
Dummy for LCC=3 and 4 (range)	0.70826***	0.76223***	0.77984***	-	-	-
	(0.17382) †††	(0.21520) †††	(0.29605) †††	-	-	-
Dummy for LCC=5 and 6 (range)	1.95463***	2.07796***	0.83185***	-	-	-
	(0.20440) †††	(0.26540) †††	(0.32272) †††	-	-	-
Dummy for LCC=7 and 8 (range)	3.30431****	3.2683***	2.0546***	-	-	-
	(0.25222) †††	(0.28867) †††	(0.35867) †††	-	-	-
CRP constant (CRP)	-5.80862***	-3.9846***	-3.63501***	-6.25107***	-3.91734***	-2.74154***
	(1.43566)	(0.76292)	(0.86830)	(1.45098)	(0.77796)	(0.86251)
Dummy for LCC=3 and 4 (CRP)	3.53918**	1.31394*	-1.17554	4.11583***	1.27667	-1.95663*
	(1.44248) †††	(0.79283) †††	(1.13017) †††	(1.45895) †††	(0.80726) †††	(1.11459) †††
Dummy for LCC=5 and 6 (CRP)	3.64486**	1.29314	-1.03173	4.29081***	1.29286	-1.8307
	(1.45522) †††	(0.87269) †††	(1.18116) †††	(1.47302) †††	(0.89009) †††	(1.16039) †††
Dummy for LCC=7 and 8 (CRP)	3.81136**	2.14137**	-0.22756	5.173***	2.12589**	-1.41958
	(1.48715) †††	(0.92417) †††	(1.2772) †††	(1.50003) ††	(0.94783) †††	(1.25101) †††
Nonfarm constant (nonfarm)	-	-	-	3.18356***	4.14154***	5.02663***
	-	-	-	(0.15002)	(0.18965)	(0.23080)
Dummy for LCC=3 and 4 (nonfarm)	-	-	-	0.17617	0.64149***	0.30252
	-	-	-	(0.16849) †††	(0.20372) †††	(0.24666) †††
Dummy for LCC=5 and 6 (nonfarm)	-	-	-	0.91713***	1.89429***	0.48307*
	-	-	-	(0.18463) †††	(0.24053) †††	(0.28915) †††
Dummy for LCC=7 and 8 (nonfarm)	-	-	-	1.6227***	2.85441***	1.27306***
	-	-	-	(0.22916) †††	(0.29150) †††	(0.23639) †††
Inclusive value parameter (farm)	-	-	-	-0.84377***	0.69433***	0.67051***
	-	-	-	(0.20327)	(0.13835)	(0.18025)
Inclusive value parameter (nonfarm)	-	-	-	0.28796***	0.63616***	1.63957***
	-	-	-	(0.09099)	(0.13429)	(0.55045)
Inclusive value parameter (urban)	-	-	-	0.34362	-	0.04156*
	-	-	-	(0.68881)	-	(0.02504)
Number of observations	126,452	122,255	119,190	126,452	122,255	119,190
Log likelihood value	-12,621	-9,712	-10,059	-12,589	-9,708	-10,061
Log likelihood value (constant only model)	-226,572	-219,052	-213,560	-226,572	-219,052	-213,560
McFadden's likelihood ratio index	0.9443	0.9557	0.9529	0.9444	0.9557	0.9529

Notes: Standard errors are in parentheses. Dashes (-) indicate that no coefficient was estimated.
*, **, and *** denote significance at 10%, 5%, and 1% levels respectively.
† ,††, and ††† denote significance at 10%, 5%, and 1% levels respectively of the sum of the coefficient on a variable interacted with an LCC dummy and the coefficient on the corresponding variable (or constant) with no interactions.
[1] For 1982-87 and 1987-92, the nested model includes three nests: farm (crops, pasture, CRP), nonfarm (forest, range) and urban (urban). For 1992-97, the model includes only two nests: farm (crops, pasture, CRP, urban), and nonfarm (forest, range). For 1982-87 and 1992-97, data did not permit estimation of coefficients on the dummy for LCC equals 7 or 8 in the urban equation for the nested model.
[2] This notation is for an interaction with the dummy variable for the Land Capability Class (LCC) for the plot.

Table 4.1 Land-Use Transition Probabilities at the Means by Different Land Qualities: Starting Use is Crops

Land Capability Class (higher values indicate worse land quality)	Probabilities by Land-Use Transition and Period[1]								
	Crops to Crops Transition			Crops to Pasture Transition			Crops to Forest Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
All LCCs	0.9458**	0.9304**	0.9577**	0.0224**	0.0194**	0.0228**	0.0034**	0.0028**	0.0047**
	(0.0020)	(0.0011)	(0.0010)	(0.0005)	(0.0004)	(0.0006)	(0.0002)	(0.0002)	(0.0002)
LCC 1 and 2	0.9645**	0.9535**	0.9673**	0.0173**	0.0140**	0.0169**	0.0027**	0.0022**	0.0039**
	(0.0020)	(0.0006)	(0.0008)	(0.0004)	(0.0003)	(0.0004)	(0.0002)	(0.0001)	(0.0002)
LCC 3 and 4	0.9127**	0.8983**	0.9462**	0.0273**	0.0249**	0.0293**	0.0035**	0.0031**	0.0051**
	(0.0019)	(0.0012)	(0.0012)	(0.0005)	(0.0005)	(0.0006)	(0.0002)	(0.0002)	(0.0002)
LCC 5 and 6	0.8709**	0.8277**	0.9063**	0.0420**	0.0473**	0.0525**	0.0077**	0.0073**	0.0110**
	(0.0035)	(0.0039)	(0.0045)	(0.0019)	(0.0020)	(0.0023)	(0.0009)	(0.0009)	(0.0011)
LCC 7 and 8	0.8528**	0.8215**	0.8926**	0.0641**	0.0689**	0.0477**	0.0177**	0.0102**	0.0164**
	(0.0078)	(0.0084)	(0.0091)	(0.0052)	(0.0053)	(0.0046)	(0.0030)	(0.0022)	(0.0028)

Land Capability Class (higher values indicate worse land quality)	Probabilities by Land-Use Transition and Period[1]								
	Crops to Urban Transition			Crops to CRP Transition			Crops to Range Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
All LCCs	0.0038**	0.0043**	0.0067**	0.0229**	0.0411**	0.0048**	0.0017**	0.0020**	0.0032**
	(0.0004)	(0.0001)	(0.0002)	(0.0004)	(0.0007)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
LCC 1 and 2	0.0042**	0.0044**	0.0070**	0.0106**	0.0248**	0.0030**	0.0007**	0.0011**	0.0018**
	(0.0004)	(0.0002)	(0.0002)	(0.0003)	(0.0004)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
LCC 3 and 4	0.0034**	0.0042**	0.0064**	0.0494**	0.0663**	0.0079**	0.0036**	0.0031**	0.0052**
	(0.0005)	(0.0002)	(0.0003)	(0.0007)	(0.0008)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
LCC 5 and 6	0.0029**	0.0036**	0.0066**	0.0682**	0.1006**	0.0098**	0.0082**	0.0135**	0.0139**
	(0.0006)	(0.0006)	(0.0008)	(0.0023)	(0.0029)	(0.0010)	(0.0010)	(0.0011)	(0.0012)
LCC 7 and 8	0.0060**	0.0052**	0.0091**	0.0485**	0.0824**	0.0077**	0.0109**	0.0118**	0.0265**
	(0.0021)	(0.0002)	(0.0004)	(0.0043)	(0.0057)	(0.0019)	(0.0028)	(0.0024)	(0.0035)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Probability values are evaluated at the means of the data for the specified land quality class using the estimated parameters from the nested logit model in Table 3.1. Standard errors are estimated using the Delta Method.

[1] These are the probabilities of the indicated land-use transition given that the starting use is crops. 100% probability is normalized to 1.

Table 4.2 Land-Use Transition Probabilities at the Means by Different Land Qualities: Starting Use is Pasture

Land Capability Class (higher values indicate worse land quality)	Probabilities by Land-Use Transition and Period[1]								
	Pasture to Crops Transition			Pasture to Pasture Transition			Pasture to Forest Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
All LCCs	0.0604**	0.0442**	0.0598**	0.8890**	0.9140**	0.8193**	0.0068**	0.0101**	0.0514*
	(0.0026)	(0.0018)	(0.0016)	(0.0231)	(0.0158)	(0.0235)	(0.0008)	(0.0011)	(0.0220)
LCC 1 and 2	0.0944**	0.0614**	0.0833**	0.8511**	0.8943**	0.7846**	0.0052**	0.0075**	0.0455**
	(0.0034)	(0.0020)	(0.0016)	(0.0251)	(0.0166)	(0.0062)	(0.0006)	(0.0007)	(0.0036)
LCC 3 and 4	0.0641**	0.0479**	0.0634**	0.8862**	0.9085**	0.8179**	0.0058**	0.0088**	0.0456*
	(0.0020)	(0.0014)	(0.0016)	(0.0223)	(0.0163)	(0.0198)	(0.0007)	(0.0010)	(0.0180)
LCC 5 and 6	0.0353**	0.0285**	0.0364**	0.9169**	0.9332**	0.8512**	0.0105**	0.0149**	0.0626
	(0.0017)	(0.0015)	(0.0030)	(0.0181)	(0.0128)	(0.0689)	(0.0013)	(0.0017)	(0.0713)
LCC 7 and 8	0.0243**	0.0187**	0.0324**	0.9211**	0.9375**	0.8218**	0.0153**	0.0232**	0.0966
	(0.0022)	(0.0019)	(0.0034)	(0.0302)	(0.0143)	(0.0920)	(0.0020)	(0.0033)	(0.0954)

Land Capability Class (higher values indicate worse land quality)	Probabilities by Land-Use Transition and Period								
	Pasture to Urban Transition			Pasture to CRP Transition			Pasture to Range Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
All LCCs	0.0389	0.0253**	0.0591**	0.0043**	0.0057**	0.0006**	0.0006**	0.0007	0.0098*
	(0.0433)	(0.0030)	(0.0019)	(0.0003)	(0.0003)	(0.0001)	(0.0002)	(0.0004)	(0.0045)
LCC 1 and 2	0.0447	0.0305**	0.0797**	0.0044**	0.0060**	0.0004**	0.0003**	0.0002*	0.0065**
	(0.0361)	(0.0024)	(0.0018)	(0.0004)	(0.0005)	(0.0001)	(0.0001)	(0.0001)	(0.0008)
LCC 3 and 4	0.0380	0.0275**	0.0603**	0.0049**	0.0060**	0.0011**	0.0009**	0.0014**	0.0117*
	(0.0327)	(0.0032)	(0.0016)	(0.0004)	(0.0004)	(0.0002)	(0.0001)	(0.0002)	(0.0046)
LCC 5 and 6	0.0324	0.0176**	0.0375**	0.0040**	0.0052**	0.0003	0.0009**	0.0006**	0.0120
	(0.1051)	(0.0036)	(0.0034)	(0.0005)	(0.0006)	(0.0002)	(0.0002)	(0.0002)	(0.0136)
LCC 7 and 8	0.0374	0.0160**	0.0416**	0.0015**	0.0035**	0.0006	0.0002*	0.0011**	0.0071
	(0.3708)	(0.0041)	(0.0058)	(0.0005)	(0.0008)	(0.0003)	(0.0001)	(0.0003)	(0.0071)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Probability values are evaluated at the means of the data for the specified land quality class using the estimated parameters from the nested logit model in Table 3.2. Standard errors are estimated using the Delta Method.

[1] These are the probabilities of the indicated land-use transition given that the starting use is pasture. 100% probability is normalized to 1.

Table 4.3 Land-Use Choice Probabilities at the Means by Different Land Qualities: Starting Use is Forest

Land Capability Class (higher values indicate worse land quality)	Probabilities by Land-Use Transition and Period[1]								
	Forest to Crops Transition			Forest to Pasture Transition			Forest to Forest Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
All LCCs	0.0016	0.0022	0.0024	0.0038	0.0054	0.0087	0.9884**	0.9891**	0.9817*
	(0.0174)	(0.0027)	(0.0682)	(0.0430)	(0.0067)	(0.2488)	(0.0071)	(0.0068)	(0.4053)
LCC 1 and 2	0.0046	0.0039	0.0062	0.0059	0.0059	0.0087	0.9790**	0.9871**	0.9734
	(0.2547)	(0.0048)	(0.7675)	(1.6049)	(0.0072)	(0.8758)	(0.0106)	(0.0087)	(0.7635)
LCC 3 and 4	0.0041	0.0024	0.0041	0.0051	0.0098	0.0109	0.9825**	0.9846**	0.9745
	(0.0965)	(0.0022)	(0.1171)	(0.1201)	(0.0093)	(0.3108)	(0.0106)	(0.0109)	(0.5795)
LCC 5 and 6	0.0008	0.0020	0.0019	0.0033	0.0038	0.0063	0.9903**	0.9897**	0.9851**
	(0.0024)	(0.0016)	(0.0469)	(0.0097)	(0.0030)	(0.1553)	(0.0049)	(0.0053)	(0.3003)
LCC 7 and 8	0.0007	0.0016	0.0010	0.0026	0.0035	0.0082	0.9917**	0.9902**	0.9838**
	(0.0019)	(0.0013)	(0.0252)	(0.0076)	(0.0028)	(0.2079)	(0.0049)	(0.0049)	(0.2888)

Land Capability Class (higher values indicate worse land quality)	Probabilities by Land-Use Transition and Period								
	Forest to Urban Transition			Forest to CRP Transition			Forest to Range Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
All LCCs	0.0054	0.0022	0.0049	0.0001	0.0003	0.0001	0.0007**	0.0008	0.0022
	(0.0042)	(0.0028)	(0.1417)	(0.0013)	(0.0003)	(0.0026)	(0.0002)	(0.0028)	(0.0014)
LCC 1 and 2	0.0102	0.0026	0.0111	0.0003	0.0005	0.0002	0.0001	0.0000	0.0004
	(0.6797)	(0.0032)	(0.9451)	(0.0851)	(0.0006)	(0.2343)	(0.0000)	(0.0000)	(0.0002)
LCC 3 and 4	0.0075	0.0018	0.0086	0.0002	0.0005	0.0002	0.0006**	0.0010**	0.0017
	(0.0045)	(0.0017)	(0.2447)	(0.0040)	(0.0004)	(0.0046)	(0.0001)	(0.0001)	(0.0010)
LCC 5 and 6	0.0044	0.0020	0.0037	0.0001	0.0005	0.0000	0.0011**	0.0019**	0.0028**
	(0.0029)	(0.0016)	(0.0918)	(0.0002)	(0.0004)	(0.0011)	(0.0001)	(0.0002)	(0.0009)
LCC 7 and 8	0.0037**	0.0023	0.0023	0.0001	0.0001	0.0001	0.0013**	0.0023**	0.0047**
	(0.0005)	(0.0019)	(0.0576)	(0.0002)	(0.0001)	(0.0016)	(0.0001)	(0.0002)	(0.0013)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Probability values are evaluated at the means of the data for the specified land quality class using the estimated parameters from the nested logit model in Table 3.3. Standard errors are estimated using the Delta Method.
[1] These are the probabilities of the indicated land-use transition given that the starting use is forest. 100% probability is normalized to 1.

Table 4.4 Land-Use Choice Probabilities at the Means by Different Land Qualities: Starting Use is Range

Land Capability Class (higher values indicate worse land quality)	Probabilities by Land-Use Transition and Period[1]								
	Range to Crops Transition			Range to Pasture Transition			Range to Forest Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
All LCCs	0.0054**	0.0027**	0.0037	0.0029**	0.0010	0.0011	0.0013**	0.0020**	0.0035
	(0.0016)	(0.0009)	(0.0356)	(0.0010)	(0.0007)	(0.0102)	(0.0004)	(0.0006)	(0.0520)
LCC 1 or 2	0.0334**	0.0140**	0.0125**	0.0101**	0.0034**	0.0044**	0.0020**	0.0024**	0.0010
	(0.0062)	(0.0030)	(0.0023)	(0.0021)	(0.0010)	(0.0012)	(0.0006)	(0.0007)	(0.0005)
LCC 3 or 4	0.0185**	0.0072*	0.0092	0.0071**	0.0028*	0.0031	0.0013**	0.0018**	0.0029
	(0.0035)	(0.0031)	(0.0533)	(0.0014)	(0.0013)	(0.0180)	(0.0002)	(0.0002)	(0.0439)
LCC 5 or 6	0.0052**	0.0021*	0.0033	0.0027**	0.0007	0.0008	0.0019**	0.0014*	0.0032
	(0.0011)	(0.0010)	(0.0148)	(0.0006)	(0.0004)	(0.0037)	(0.0002)	(0.0007)	(0.0148)
LCC 7 or 8	0.0017**	0.0016	0.0018	0.0011**	0.0006	0.0005	0.0009**	0.0030**	0.0050
	(0.0004)	(0.0008)	(0.1026)	(0.0003)	(0.0003)	(0.0293)	(0.0001)	(0.0003)	(0.3818)

Land Capability Class (higher values indicate worse land quality)	Probabilities by Land-Use Transition and Period								
	Range to Urban Transition			Range to CRP Transition			Range to Range Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
All LCCs	0.0016*	0.0028*	0.0022*	0.0006*	0.0002*	0.0000	0.9882**	0.9914**	0.9895
	(0.0006)	(0.0012)	(0.0009)	(0.0002)	(0.0001)	(0.0004)	(0.0128)	(0.0038)	(1.0355)
LCC 1 and 2	0.0058**	0.0121**	0.0062**	0.0001	0.0002	0.0003	0.9486**	0.9679**	0.9756**
	(0.0012)	(0.0026)	(0.0013)	(0.0001)	(0.0002)	(0.0002)	(0.0189)	(0.0103)	(0.2588)
LCC 3 and 4	0.0019*	0.0098*	0.0032*	0.0020**	0.0005*	0.0001	0.9692**	0.9779**	0.9816
	(0.0008)	(0.0041)	(0.0015)	(0.0005)	(0.0002)	(0.0004)	(0.0146)	(0.0111)	(1.0928)
LCC 5 and 6	0.0013*	0.0025*	0.0014*	0.0005**	0.0001	0.0000	0.9885**	0.9932**	0.9912
	(0.0005)	(0.0012)	(0.0006)	(0.0001)	(0.0001)	(0.0002)	(0.0082)	(0.0036)	(4.6151)
LCC 7 and 8	0.0015*	0.0012	0.0022*	0.0003*	0.0001	0.0000	0.9945**	0.9936**	0.9904
	(0.0006)	(0.0006)	(0.0009)	(0.0001)	(0.0001)	(0.0017)	(0.0152)	(0.0026)	(1.0699)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Probability values are evaluated at the means of the data for the specified land quality class using the estimated parameters from the nested logit model in Table 3.4. Standard errors are estimated using the Delta Method.

[1] These are the probabilities of the indicated land-use transition given that the starting use is range. 100% probability is normalized to 1.

Table 5.1 Land-Use Choice Elasticities at the Means for Nested Logit Specification: Starting Use is Crops

	Land-Use Transition and Period								
	Crops to Crops Transition			Crops to Pasture Transition			Crops to Forest Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Probability[1]									
	0.9458**	0.9304**	0.9577**	0.0224**	0.0194**	0.0228**	0.0034**	0.0028**	0.0047**
	(0.0020)	(0.0011)	(0.0010)	(0.0005)	(0.0004)	(0.0006)	(0.0002)	(0.0002)	(0.0002)
Elasticity[2]									
Crop profit	0.0143**	0.0348**	0.0110**	-0.2726**	-0.5176**	-0.3447**	-0.1271**	-0.1182**	-0.0693
	(0.0008)	(0.0011)	(0.0012)	(0.0156)	(0.0217)	(0.0432)	(0.0293)	(0.0406)	(0.0446)
Pasture profit	0.0001	-0.0016**	-0.0043**	-0.0048	0.0822**	0.1828**	0.0001	-0.0004**	-0.0009*
	(0.0006)	(0.0005)	(0.0008)	(0.0272)	(0.0235)	(0.0312)	(0.0001)	(0.0001)	(0.0004)
Forest profit	-0.0010	-0.0004	-0.0007	-0.0010	-0.0004	-0.0007	0.8763**	0.7489**	0.3101**
	(0.0239)	(0.0166)	(0.0225)	(0.0239)	(0.0166)	(0.0225)	(0.0522)	(0.0723)	(0.0433)
Urban profit	-0.0015	-0.0011	-0.0023	-0.0015	-0.0011	-0.0023	-0.0015	-0.0011	-0.0023
	(0.5321)	(0.2521)	(0.6977)	(0.5321)	(0.2521)	(0.6977)	(0.5321)	(0.2521)	(0.6977)
Range profit	-0.0002	-0.0001	-0.0005	-0.0002	-0.0001	-0.0005	-0.2674**	-0.1823**	-0.1540**
	(0.0060)	(0.0044)	(0.0079)	(0.0060)	(0.0044)	(0.0079)	(0.0352)	(0.0441)	(0.0269)

	Land-Use Transition and Period								
	Crops to Urban Transition			Crops to Range Transition			Crops to CRP Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Probability[1]									
	0.0038**	0.0043**	0.0067**	0.0017**	0.0020**	0.0032**	0.0229**	0.0411**	0.0048**
	(0.0004)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0004)	(0.0007)	(0.0002)
Elasticity[2]									
Crop profit	-0.1271**	-0.1182**	-0.0693	-0.1271**	-0.1182**	-0.0693	-0.2726**	-0.5176**	-0.3447**
	(0.0293)	(0.0406)	(0.0446)	(0.0293)	(0.0406)	(0.0446)	(0.0156)	(0.0217)	(0.0432)
Pasture profit	0.0001	-0.0004**	-0.0009*	0.0001	-0.0004**	-0.0009*	0.0001	-0.0016**	-0.0043**
	(0.0001)	(0.0001)	(0.0004)	(0.0001)	(0.0001)	(0.0004)	(0.0006)	(0.0005)	(0.0008)
Forest profit	-0.0010	-0.0004	-0.0007	-1.1551**	-0.8338**	-0.2375**	-0.0010	-0.0004	-0.0007
	(0.0239)	(0.0166)	(0.0225)	(0.1488)	(0.1770)	(0.0791)	(0.0239)	(0.0166)	(0.0225)
Urban profit	0.3952**	0.2482**	0.3418**	-0.0015	-0.0011	-0.0023	-0.0015	-0.0011	-0.0023
	(0.0236)	(0.0133)	(0.0159)	(0.5321)	(0.2521)	(0.6977)	(0.5321)	(0.2521)	(0.6977)
Range profit	-0.0002	-0.0001	-0.0005	0.6793**	0.2944**	0.3765**	-0.0002	-0.0001	-0.0005
	(0.0060)	(0.0044)	(0.0079)	(0.0870)	(0.0703)	(0.0477)	(0.0060)	(0.0044)	(0.0079)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Probability and elasticity values are evaluated at the means of the data for all land quality classes. Standard errors are estimated using the Delta Method.

[1] This is the probability of choosing the indicated land use given that the land parcel was in crops at the start of the indicated transition period. 100% probability is normalized to 1.

[2] This is the percentage change in the probability of choosing the indicated use for a 1% change in the indicated profit variable. Bold text indicates own-profit elasticities (elasticities of choosing a particular use with respect to the profits to that use).

Table 5.2 Land-Use Choice Elasticities at the Means for Nested Logit Specification: Starting Use is Pasture

	Land-Use Transition and Period								
	Pasture to Crops Transition			Pasture to Pasture Transition			Pasture to Forest Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Probability[1]									
	0.0604**	0.0442**	0.0598**	0.8890**	0.9140**	0.8193**	0.0068**	0.0101**	0.0514*
	(0.0026)	(0.0018)	(0.0016)	(0.0231)	(0.0158)	(0.0235)	(0.0008)	(0.0011)	(0.0220)
Elasticity[2]									
Crop profit	**0.2991****	**0.3799****	**0.3413****	-0.0198**	-0.0185**	-0.0187**	-0.0088**	0.0052*	-0.0644
	(0.0232)	**(0.0308)**	**(0.0218)**	(0.0020)	(0.0019)	(0.0014)	(0.0018)	(0.0025)	(0.0188)
Pasture profit	-0.3047**	-0.0829**	0.0297*	**0.0292****	**0.0036****	**-0.0119**	-0.1359**	0.0232**	0.1020*
	(0.0289)	(0.0257)	(0.0135)	**(0.0036)**	**(0.0012)**	**(0.0081)**	(0.0181)	(0.0039)	(0.0535)
Forest profit	-0.0004	0.0001	0.0000	-0.0004	0.0001	0.0000	**0.2227****	**0.0784**	**0.0049**
	(0.0116)	(0.0074)	(0.0278)	(0.0116)	(0.0074)	(0.0278)	**(0.0303)**	**(0.0555)**	**(0.0267)**
Urban profit	-0.0174	-0.0077	-0.0254	-0.0174	-0.0077	-0.0254	-0.0174	-0.0077	-0.0005
	(0.6905)	(0.8916)	(0.0236)	(0.6905)	(0.8916)	(0.0236)	(0.6905)	(0.8916)	(0.0209)
Range profit	0.0000	0.0000	-0.0002	0.0000	0.0000	-0.0002	-0.0717**	-0.0493**	-0.1258
	(0.0003)	(0.0001)	(0.0044)	(0.0003)	(0.0001)	(0.0044)	(0.0108)	(0.0116)	(0.0686)

	Land-Use Transition and Period								
	Pasture to Urban Transition			Pasture to Range Transition			Pasture to CRP Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Probability[1]									
	0.0389	0.0253**	0.0591**	0.0006**	0.0007	0.0098*	0.0043**	0.0057**	0.0006**
	(0.0433)	(0.0030)	(0.0019)	(0.0002)	(0.0004)	(0.0045)	(0.0003)	(0.0003)	(0.0001)
Elasticity[2]									
Crop profit	-0.0088**	0.0052*	-0.0187**	-0.0088**	0.0052*	-0.0644**	-0.0198**	-0.0185**	-0.0187**
	(0.0018)	(0.0025)	(0.0014)	(0.0018)	(0.0025)	(0.0188)	(0.0020)	(0.0019)	(0.0014)
Pasture profit	-0.1359**	0.0232**	0.1020	-0.1359**	0.0232**	0.1020	-0.3047**	-0.0829**	0.0297*
	(0.0181)	(0.0039)	(0.0535)	(0.0181)	(0.0039)	(0.0535)	(0.0289)	(0.0257)	(0.0135)
Forest profit	-0.0004	0.0001	0.0000	-1.8439**	-1.3290	-0.0219	-0.0004	0.0001	0.0000
	(0.0116)	(0.0074)	(0.0278)	(0.3757)	(0.7634)	(0.4647)	(0.0116)	(0.0074)	(0.0278)
Urban profit	**0.4303****	**0.2959****	**0.3306****	-0.0174	-0.0077	-0.0005	-0.0174	-0.0077	-0.0254
	(0.0516)	**(0.0271)**	**(0.0259)**	(0.6905)	(0.8916)	(0.0209)	(0.6905)	(0.8916)	(0.0236)
Range profit	0.0000	0.0000	-0.0002	**0.8509****	**0.7056****	**1.0421****	0.0000	0.0000	-0.0002
	(0.0003)	(0.0001)	(0.0044)	**(0.1279)**	**(0.1666)**	**(0.0496)**	(0.0003)	(0.0001)	(0.0044)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Probability and elasticity values are evaluated at the means of the data for all land quality classes. Standard errors are estimated using the Delta Method.

[1] This is the probability of choosing the indicated land use given that the land parcel was in pasture at the start of the indicated transition period. 100% probability is normalized to 1.

[2] This is the percentage change in the probability of choosing the indicated use for a 1% change in the indicated profit variable. Bold text indicates own-profit elasticities (elasticities of choosing a particular use with respect to the profits to that use).

Table 5.3 Land-Use Choice Elasticities at the Means for Nested Logit Specification: Starting Use is Forest

	Land-Use Transition and Period								
	Forest to Crops Transition			Forest to Pasture Transition			Forest to Forest Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Probability[1]									
	0.0016	0.0022	0.0024	0.0038	0.0054	0.0087	0.9884**	0.9891**	0.9817*
	(0.0174)	(0.0027)	(0.0682)	(0.0430)	(0.0067)	(0.2488)	(0.0071)	(0.0068)	(0.4053)
Elasticity[2]									
Crop profit	**0.2104****	**0.2797****	**0.2946****	-0.0460	-0.0232	-0.0418**	-0.0001	-0.0004	-0.0001
	(0.0656)	**(0.0543)**	**(0.0644)**	(0.0373)	(0.0179)	(0.0113)	(0.0157)	(0.0140)	(0.0032)
Pasture profit	-0.0835	-0.0095	0.0062	**0.1047**	**0.0396**	**-0.0075**	-0.0003	-0.0002	0.0000
	(0.0526)	(0.0224)	(0.0536)	**(0.0577)**	**(0.0910)**	**(0.0591)**	(0.0292)	(0.0399)	(0.0109)
Forest profit	-0.0256	-0.0352*	-0.0356	-0.0256	-0.0352*	-0.0356	**0.0004**	**0.0007**	**0.0006**
	(0.0323)	(0.0135)	(0.1245)	(0.0323)	(0.0135)	(0.1245)	**(0.0009)**	**(0.0009)**	**(0.0547)**
Urban profit	-0.0013	-0.0254	-0.2756**	-0.0013	-0.0254	-0.2756**	-0.0013	-0.0005	-0.0009
	(1.3581)	(0.0236)	(0.0514)	(1.3581)	(0.0236)	(0.0514)	(1.3581)	(0.0209)	(0.0252)
Range profit	0.0000*	0.0000	-0.0007	0.0000*	0.0000	-0.0007	-0.0002	0.0005	-0.0005
	(0.0000)	(0.0002)	(0.0009)	(0.0000)	(0.0002)	(0.0009)	(0.0015)	(0.0347)	(0.0013)

	Land-Use Transition and Period								
	Forest to Urban Transition			Forest to Range Transition			Forest to CRP Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Probability[1]									
	0.0054	0.0022	0.0049	0.0007**	0.0008	0.0022	0.0001	0.0003	0.0001
	(0.0042)	(0.0028)	(0.1417)	(0.0002)	(0.0028)	(0.0014)	(0.0013)	(0.0003)	(0.0026)
Elasticity[2]									
Crop profit	-0.0001	-0.0232	-0.0418**	-0.0001	-0.0004	-0.0001	-0.0460	-0.0232	-0.0418**
	(0.0157)	(0.0179)	(0.0113)	(0.0157)	(0.0140)	(0.0032)	(0.0373)	(0.0179)	(0.0113)
Pasture profit	-0.0003	-0.0095	0.0062	-0.0003	-0.0002	0.0000	-0.0835	-0.0095	0.0062
	(0.0292)	(0.0224)	(0.0536)	(0.0292)	(0.0399)	(0.0109)	(0.0526)	(0.0224)	(0.0536)
Forest profit	-0.0256	-0.0352*	-0.0356	-0.1965	-0.4622	-0.0254	-0.0256	-0.0352*	-0.0356
	(0.0323)	(0.0135)	(0.1245)	(0.2151)	(0.2511)	(0.1969)	(0.0323)	(0.0135)	(0.1245)
Urban profit	**0.2313****	**0.2986****	**0.7920****	-0.0013	-0.0005	-0.0009	-0.0013	-0.0254	-0.2756**
	(0.0203)	**(0.0754)**	**(0.0576)**	(1.3581)	(0.0209)	(0.0252)	(1.3581)	(0.0236)	(0.0514)
Range profit	0.0000*	0.0000	-0.0007	**0.2852**	**-0.5639**	**0.2316**	0.0000*	0.0000	-0.0007
	(0.0000)	(0.0002)	(0.0009)	**(0.2197)**	**(3.4581)**	**(0.3305)**	(0.0000)	(0.0002)	(0.0009)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Probability and elasticity values are evaluated at the means of the data for all land quality classes. Standard errors are estimated using the Delta Method.

[1] This is the probability of choosing the indicated land use given that the land parcel was in forest at the start of the indicated transition period. 100% probability is normalized to 1.

[2] This is the percentage change in the probability of choosing the indicated use for a 1% change in the indicated profit variable. Bold text indicates own-profit elasticities (elasticities of choosing a particular use with respect to the profits to that use).

Table 5.4 Land-Use Choice Elasticities at the Means for Nested Logit Specification: Starting Use is Range

	Land-Use Transition and Period								
	Range to Crops Transition			Range to Pasture Transition			Range to Forest Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Probability[1]									
	0.0054**	0.0027**	0.0037	0.0029**	0.0010	0.0011	0.0013**	0.0020**	0.0035
	(0.0016)	(0.0009)	(0.0356)	(0.0010)	(0.0007)	(0.0102)	(0.0004)	(0.0006)	(0.0520)
Elasticity[2]									
Crop profit	**-0.0415**	**0.3491**	**0.0655**	-0.4016*	-0.0497	-0.0226	0.0016	-0.0007	-0.0002
	(0.0458)	**(0.1776)**	**(0.2290)**	(0.1861)	(0.0409)	(0.3565)	(0.0851)	(0.0708)	(0.3307)
Pasture profit	-0.3342	0.0074	-0.0315	**0.2200**	**-0.1539**	**0.3986**	0.0014	0.0001	-0.0003
	(0.5111)	(0.0240)	(0.0922)	**(0.1715)**	**(0.5331)**	**(0.4169)**	(0.2430)	(0.0199)	(0.1472)
Forest profit	0.0000	0.0000**	-0.0007	0.0000	0.0000**	-0.0007	**0.0839**	**0.0291**	**0.1268**
	(0.0001)	(0.0000)	(0.0118)	(0.0001)	(0.0000)	(0.0118)	**(0.3601)**	**(0.4225)**	**(0.9058)**
Urban profit	-0.0009	-0.0607	-0.0009	-0.0009	-0.0607	-0.0009	-0.0009	-0.0009	-0.0009
	(1.0967)	(0.0362)	(0.2568)	(1.0967)	(0.0362)	(0.2568)	(1.0967)	(0.0711)	(0.2568)
Range profit	0.1184**	0.2127**	0.1679	0.1184**	0.2127**	0.1679	0.4143	0.3351**	0.1019
	(0.0379)	(0.0332)	(0.9715)	(0.0379)	(0.0332)	(0.9715)	(0.2335)	(0.1233)	(0.9724)

	Land-Use Transition and Period								
	Range to Urban Transition			Range to Range Transition			Range to CRP Transition		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Probability[1]									
	0.0016*	0.0028*	0.0022*	0.9882**	0.9914**	0.9895	0.0006*	0.0002*	0.0000
	(0.0006)	(0.0012)	(0.0009)	(0.0128)	(0.0038)	(14.8355)	(0.0002)	(0.0001)	(0.0004)
Elasticity[2]									
Crop profit	0.0016	-0.0497	-0.0002	0.0016	-0.0007	-0.0002	-0.4016*	-0.0497	-0.0226
	(0.0851)	(0.0409)	(0.3307)	(0.0851)	(0.0708)	(0.3307)	(0.1861)	(0.0409)	(0.3565)
Pasture profit	0.0014	0.0074	-0.0003	0.0014	0.0001	-0.0003	-0.3342	0.0074	-0.0315
	(0.2430)	(0.0240)	(0.1472)	(0.2430)	(0.0199)	(0.1472)	(0.5111)	(0.0240)	(0.0922)
Forest profit	0.0000	0.0000**	-0.0007	-0.0001	-0.0001	-0.0004	0.0000	0.0000**	-0.0007
	(0.0001)	(0.0000)	(0.0118)	(0.0003)	(0.0008)	(0.0122)	(0.0001)	(0.0000)	(0.0118)
Urban profit	**0.5558****	**0.3983***	**0.4190****	-0.0009	-0.0009	-0.0009	-0.0009	-0.0607	-0.0009
	(0.0486)	**(0.1790)**	**(0.0310)**	(1.0967)	(0.0711)	(0.2568)	(1.0967)	(0.0362)	(0.2568)
Range profit	0.1184**	0.2127**	0.1679	**-0.0018**	**-0.0022**	**-0.0015**	0.1184**	0.2127**	0.1679
	(0.0379)	(0.0332)	(0.9715)	**(0.0059)**	**(0.0018)**	**(0.9712)**	(0.0379)	(0.0332)	(0.9715)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Probability and elasticity values are evaluated at the means of the data for all land quality classes. Standard errors are estimated using the Delta Method.

[1] This is the probability of choosing the indicated land use given that the land parcel was in range at the start of the indicated transition period. 100% probability is normalized to 1.

[2] This is the percentage change in the probability of choosing the indicated use for a 1% change in the indicated profit variable. Bold text indicates own-profit elasticities (elasticities of choosing a particular use with respect to the profits to that use).

Table 6 Simulated Change in 48 State Forest Acreage Under Alternative Scenarios: 1987 to 1997

Simulation Scenario[1]	Change in Forest Acreage (thousands of acres)		Percentage of Factually Simulated Change		Percentage of Factual Acreage Change Attributable to Variable Held Constant[2]	
	Alternative Specifications[3]					
	Condit'l Logit	Nested Logit	Condit'l Logit	Nested Logit	Condit'l Logit	Nested Logit
(1) Factual Simulation[3]	2,110.3	1,819.5	100.0%	100.0%	0.0%	0.0%
(2) No Change in Any Returns[4]	1,810.0	1,524.6	85.8%	83.8%	-14.2%	-16.2%
(3) No Change in Crop Returns	2,624.7	2,163.9	124.4%	118.9%	24.4%	18.9%
(4) No Change in Pasture Returns	2,085.4	2,104.1	98.8%	115.6%	-1.2%	15.6%
(5) No Change in Forest Returns	555.7	365.6	26.3%	20.1%	-73.7%	-79.9%
(6) No Change in Urban Returns	2,851.8	2,408.2	135.1%	132.4%	35.1%	32.4%
(7) No Change in Range Returns	2,130.4	1,775.2	101.0%	97.6%	1.0%	-2.4%

[1] Simulations are based on coefficient estimates for the 1987-1992 and 1992-1997 transition periods reported in Tables 3.1-3.4.
[2] The difference between the counterfactual and factual simulation divided by the factual simulation. Positive (negative) values thus indicate that the forest acreage *increase* was smaller (greater) in the factual versus counterfactual simulation due to the historical change in the variable under consideration.
[3] Conditional Logit (Condt'l Logit) and Nested Logit specifications.
[4] The factual simulation (1) is based on the historical values of all variables used in the estimation.
[5] Counterfactual simulations 2-7 hold the returns for the specified use constant at the average of 1978 to 1982 annual values (the value used in estimating the coefficients for the 1982-1987 transition period).

Table 7.1 Simulated Changes in Land Areas Shifting *to* Forest by Transition and Alternative Scenarios: 1987 to 1997

Land-Use Transition and Simulation Scenario [1]	Change in Acreage in this Transition (thousands of acres)		Percentage of Factually Simulated Change		Percentage of Acreage Change in this Transition Attributable to Variable Held Constant[2]		Percentage of Total Forest Acreage Change Attributable to Variable's Effect on Transition[3]	
	Alternative Specifications[4]							
Crops to Forest Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation[5]	3,653.6	3,454.9	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns[6]	3,343.5	2,868.1	91.5%	83.0%	-8.5%	-17.0%	-14.7%	-32.3%
(3) No Change in Crop Returns	3,906.8	3,565.9	106.9%	103.2%	6.9%	3.2%	12.0%	6.1%
(4) No Change in Pasture Returns	3,679.4	3,497.6	100.7%	101.2%	0.7%	1.2%	1.2%	2.3%
(5) No Change in Forest Returns	3,096.2	2,757.2	84.7%	79.8%	-15.3%	-20.2%	-26.4%	-38.3%
(6) No Change in Urban Returns	3,663.9	3,464.5	100.3%	100.3%	0.3%	0.3%	0.5%	0.5%
(7) No Change in Range Returns	3,652.9	3,420.8	100.0%	99.0%	0.0%	-1.0%	0.0%	-1.9%
Pasture to Forest Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation	9,087.1	9,030.3	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns	8,957.6	9,354.5	98.6%	103.6%	-1.4%	3.6%	-6.1%	17.8%
(3) No Change in Crop Returns	9,171.0	9,199.2	100.9%	101.9%	0.9%	1.9%	4.0%	9.3%
(4) No Change in Pasture Returns	9,079.2	9,290.8	99.9%	102.9%	-0.1%	2.9%	-0.4%	14.3%
(5) No Change in Forest Returns	8,865.3	8,938.8	97.6%	99.0%	-2.4%	-1.0%	-10.5%	-5.0%
(6) No Change in Urban Returns	9,110.8	9,073.9	100.3%	100.5%	0.3%	0.5%	1.1%	2.4%
(7) No Change in Range Returns	9,081.6	8,989.1	99.9	99.5%	-0.1%	-0.5%	-0.3%	-2.3%
CRP to Forest Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation	81.5	78.7	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns	48.2	31.0	59.1%	39.4%	-40.9%	-60.6%	-1.6%	-2.6%
(3) No Change in Crop Returns	83.2	78.7	102.0%	100.0%	2.0%	0.0%	0.1%	0.0%
(4) No Change in Pasture Returns	81.2	78.7	99.6%	100.0%	-0.4%	0.0%	-0.0%	0.0%
(5) No Change in Forest Returns	47.4	31.6	58.2%	40.1%	-41.8%	-59.9%	-1.6%	-2.6%
(6) No Change in Urban Returns	81.5	78.7	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(7) No Change in Range Returns	81.5	78.2	100.0%	99.3%	0.0%	-0.7%	0.0%	0.0%
Range to Forest Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation	2,519.4	2,495.6	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns	2,301.7	2,294.0	91.4%	91.9%	-8.6%	-8.1%	-10.3%	-11.1%
(3) No Change in Crop Returns	2,519.5	2,495.9	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(4) No Change in Pasture Returns	2,525.7	2,499.8	100.2%	100.2%	0.2%	0.2%	0.3%	0.2%
(5) No Change in Forest Returns	2,259.9	2,245.1	89.7%	90.0%	-10.3%	-10.0%	-12.3%	-13.8%
(6) No Change in Urban Returns	2,522.6	2,499.2	100.1%	100.1%	0.1%	0.1%	0.1%	0.2%
(7) No Change in Range Returns	2,553.9	2,537.1	101.4%	101.7%	1.4%	1.7%	1.6%	2.3%

[1] Simulations are based on coefficient estimates for the 1987-1992 and 1992-1997 transition periods reported in Tables 3.1-3.4.
[2] The difference between the counterfactual and the factual simulation divided by the factual simulation. Positive (negative) values thus indicate that an acreage *increase* was smaller (greater) in the factual versus counterfactual simulation due to the historical change in the variable under consideration.
[3] The difference between the counterfactual and factual simulation divided by the factual simulation of total forest acreage change in Table 6.
[4] McFadden's Conditional Logit (MCL) and Nested Logit (NL) specifications.
[5] The factual simulation (1) is based on the historical values of all variables used in the estimation.
[6] Counterfactual simulations 2-7 hold the returns for the specified use constant at the average of 1978 to 1982 annual values (the value used in estimating the coefficients for the 1982-1987 transition period).

Table 7.2 Simulated Change in Land Areas Shifting *from* Forest by Transition and Alternative Scenarios: 1987 to 1997

Land-Use Transition and Simulation Scenario[1]	Change in Acreage in this Transition (thousands of acres)		Percentage of Factually Simulated Change		Percentage of Acreage Change in this Transition Attributable to Variable Held Constant		Percentage of Total Forest Acreage Change Attributable to Variable's Effect on this Transition	
	Alternative Specifications							
Forest to Crop Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation	1,244.9	2,190.5	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns	1,085.2	1,987.1	87.2%	90.7%	-12.8%	-9.3%	-7.6%	-11.2%
(3) No Change in Crop Returns	1,057.1	1,933.6	84.9%	88.3%	-15.1%	-11.7%	-8.9%	-14.1%
(4) No Change in Pasture Returns	1,247.7	2,183.8	100.2%	99.7%	0.2%	-0.3%	0.1%	-0.4%
(5) No Change in Forest Returns	1,271.1	2,204.1	102.1%	100.6%	2.1%	0.6%	1.2%	0.7%
(6) No Change in Urban Returns	1,248.0	2,242.7	100.2%	102.4%	0.2%	2.4%	0.1%	2.9%
(7) No Change in Range Returns	1,245.0	2,190.5	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Forest to Pasture Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation	2,698.9	5,191.4	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns	2,848.4	5,601.0	105.5%	107.9%	5.5%	7.9%	7.1%	22.5%
(3) No Change in Crop Returns	2,706.9	5,314.3	100.3%	102.4%	0.3%	2.4%	0.4%	6.8%
(4) No Change in Pasture Returns	2,745.1	5,229.2	101.7%	100.7%	1.7%	0.7%	2.2%	2.1%
(5) No Change in Forest Returns	2,784.1	5,267.8	103.2%	101.5%	3.2%	1.5%	4.0%	4.2%
(6) No Change in Urban Returns	2,706.2	5,348.7	100.3%	103.0%	0.3%	3.0%	0.3%	8.6%
(7) No Change in Range Returns	2,698.8	5,191.3	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Forest to Urban Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation	7,365.9	3,731.6	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns	6,885.7	3,094.6	93.5%	82.9%	-6.5%	-17.1%	-22.8%	-35.0%
(3) No Change in Crop Returns	7,368.8	3,793.9	100.0%	101.7%	0.0%	1.7%	0.1%	3.4%
(4) No Change in Pasture Returns	7,365.6	3,723.5	100.0%	99.8%	0.0%	-0.2%	0.0%	-0.4%
(5) No Change in Forest Returns	7,649.2	3,816.0	103.8%	102.3%	3.8%	2.3%	13.4%	4.6%
(6) No Change in Urban Returns	6,649.2	2,987.9	90.3%	80.1%	-9.7%	-19.9%	-34.0%	-40.9%
(7) No Change in Range Returns	7,365.8	3,731.5	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Forest to CRP Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation	70.7	167.8	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns	73.5	175.8	104.0%	104.8%	4.0%	4.8%	0.1%	0.4%
(3) No Change in Crop Returns	72.1	174.2	102.0%	103.8%	2.0%	3.8%	0.1%	0.4%
(4) No Change in Pasture Returns	70.7	167.0	100.0%	99.5%	-0.0%	-0.5%	0.0%	0.0%
(5) No Change in Forest Returns	72.0	169.4	101.8%	101.0%	1.8%	1.0%	0.1%	0.1%
(6) No Change in Urban Returns	70.8	168.4	100.2%	100.4%	0.2%	0.4%	0.0%	0.0%
(7) No Change in Range Returns	70.7	167.8	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Forest to Range Transition	MCL	NL	MCL	NL	MCL	NL	MCL	NL
(1) Factual Simulation	1,850.8	1,958.8	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(2) No Change in Any Returns	1,948.3	2,164.6	105.3%	110.5%	5.3%	10.5%	4.6%	11.3%
(3) No Change in Crop Returns	1,851.0	1,960.0	100.0%	100.1%	0.0%	0.1%	0.0%	0.1%
(4) No Change in Pasture Returns	1,851.0	1,959.3	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
(5) No Change in Forest Returns	1,936.7	2,149.7	104.6%	109.7%	4.6%	9.7%	4.1%	10.5%
(6) No Change in Urban Returns	1,852.7	1,960.4	100.1%	100.1%	0.1%	0.1%	0.1%	0.1%
(7) No Change in Range Returns	1,859.1	1,969.0	100.5%	100.5%	0.5%	0.5%	0.4%	0.6%

[1] See explanatory notes at bottom of Table 7.1.

DATA APPENDIX

A.1 Land Use and Land Characteristics

I use plot-level data on land-use decisions and land quality from the Natural Resources Inventory (NRI) conducted by the USDA Natural Resources Conservation Service in cooperation with the Iowa State University Statistical Laboratory. The NRI is a panel survey of land use, land cover, soil characteristics, erosion, and conservation practices conducted at five year intervals from 1982 to 1997 on a sample of non-federal lands across the United States. [58]

The NRI survey covers the entire United States except for Alaska and Washington, DC. I consider only the forty-eight contiguous states, dropping Hawaii and the Caribbean. I focus on plots which are privately-owned in adjacent time periods, excluding federal, state, county, municipal and Indian and individual trust lands, because profit-maximization is unlikely to be a reasonable approximation of the decision-making criteria for these ownership groups.[59] I limit my analysis to private lands so as to focus on the types of lands which are likely to respond to economic incentives.

I further limit my focus to lands that can be classified as either crops, pasture, forests, range, urban/built-up, or in the Conservation Reserve Program. I exclude lands under rural roads and transportation as these land uses are likely to change through a different decision-making process than profit maximization by private landowners. I also exclude streams and water bodies, marshlands, and "barren lands" such as sand dunes, permanent snow fields, and bare rock. Finally, I exclude additional private lands which the NRI classifies under "miscellaneous/minor" uses and which cannot be assigned to any of my four land-use categories. With these adjustments, the land base for my analysis comprises approximately 1.4 billion acres, representing about 66% of the total land area and about 94% of the privately-owned land area in the contiguous forty-eight states.

A.2 Land-Use Returns

I calculate annual county-level per acre net returns for each year from 1978 to 1997 for five different land uses (crops, pasture, forestry, range and urban uses) and then construct five-year

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[58] The NRI uses a random, stratified two-stage sampling scheme, and each NRI "plot" is a point observation which is assigned a particular acreage weight depending on the sampling features of that area. Each NRI plot can be identified to the level of the county (as well as to constituent hydrological units) (Nusser and Goebel 1997; Fuller 1999).

[59] Private lands cover approximately 1.3 billion acres between 1982 and 1997, representing about 70% of the total land area of the contiguous forty-eight states.

average measures of these returns. Below, I further describe my methods and data for measuring each of these sets of returns.

A.2.1 Crops

To measure the returns from land in crops, I compute an annual county-level weighted average of the net returns per acre from different varieties of crops from 1978 to 1997 plus the value of direct government payments per acre (excluding payments to the Conservation Reserve Program). The weights are the proportion that the planted acreage of a particular crop represented of the total county's crop acreage in a given year, using acreage information from the National Agricultural Statistics Service (NASS) of the USDA. I consider the following major crop types tracked by NASS: wheat (winter wheat, durum wheat, and other spring wheat are treated separately), rye, rice, corn, oats, barley, sorghum, cotton, sugarcane, sugar beets, tobacco, flaxseed, peanuts, soybeans, sunflowers, all dry edible beans, hay (alfalfa hay and all other hay are treated separately), and potatoes.

To calculate gross per acre returns for each crop in each year, I multiply state-level market-year-average (MYA) prices from the USDA's Economic Research Service (ERS) by the average county-level yields.[60] These yields are derived by dividing the annual production of that crop by the planted acreage for each county obtained from NASS. In computing net returns, I use annual ERS data on total crop costs and returns at the level of multi-state crop production regions for eleven major crops (barley, corn, cotton, oats, rice, sorghum, soybeans, sugar beets, sugarcane, tobacco, and wheat). For hay, peanuts, and "other small grains," I use state-level data on total costs and returns from the Census of Agriculture from 1982, 1987, 1992 and 1997. I calculate the percentage that production costs represent of the total returns from a particular crop at the state or regional level.[61] Multiplying the county-level returns for that crop by one minus this percentage then yields the net

[60] Market-year-average prices are computed by weighing monthly prices by the amount of the crop marketed that month. Missing years in the state price series were imputed by extrapolation using the average trend of either a more inclusive commodity group for that state (such as "all wheat" instead of "winter wheat") or else the average of the trends for a particular crop from all bordering states. When possible, trends were computed and applied using a five-year average price as the baseline. Extrapolation procedures were similar for the forest and pasture prices below.

[61] I use the measures of cash (as opposed to economic) costs and returns, including direct government payments when those are reported. The cash costs include expenditures on seed; fertilizer, lime and gypsum; chemicals; custom operations; fuel, lube and electricity; repairs; hired labor; other variable cash expenses; general farm overhead; taxes and insurance; and interest.

returns from that crop.[62] Estimates for all direct government payments per acre (excluding the Conservation Reserve Program) were obtained for major crop categories at the state-level from the Census of Agriculture. I estimated county-level average per acre direct government payments by weighting the state-level payments by the county's acreage of the different crop types.

A.2.2 Pasture and Range

To estimate annual net returns to land under pasture, I use the county-level average of annual pasture yields for different soil types from the National Cooperative Soil Survey (NCSS). I weight these yields for the different soil types for which data is provided according to NRI information on the acreage in each soil type in each county. NCSS estimated yields do not vary over time and are based on "engineering" estimates of the productive capacity of different soil types. Yields for irrigated and irrigated lands were weighted at the county-level based on proportions of irrigated and non-irrigated pasture lands obtained from the NRI. These county-level pasture yields were converted from "animal units" to tons of forage using the conversion factor for average pasture quality from Atkinson and Petritz (2001) and multiplied by state price for "other hay" from the ERS. I assumed that pasture management costs were equivalent to state-level costs for hay production obtained from the Census of Agriculture.

To estimate range profits, I also use the county-level average of range forage yields for different soil types from the National Cooperative Soil Survey (NCSS), weighted with NRI data on soil type acreages. Using the conversion for the amount of forage required to sustain a standard "animal unit" (a one thousand pound beef cow), I multiply the forage yield times state-level per head grazing rates for private lands from the ERS database on cash rents. To the extent that there are any costs of range management, I assume these costs are borne by the tenant and thus already captured in the grazing rates.

[62] NASS does not provide county acreage and production data for six states (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont). For these states, I use an alternative method for calculating crop returns using data from the Census of Agriculture conducted in 1982, 1987, 1992, and 1997. I use total county-level cash returns from agricultural sales (minus sales of livestock and poultry) divided by the total acreage in crops in the county. I compute net returns using the Census data on the share that production costs represent of all agricultural sales in the county, including livestock and poultry, as crop costs are not separately reported.

A.2.3 Forestry

I compute annualized forestry returns using a weighted county-level measure of the net present value of sawtimber revenues from different forest types. I employ state-level stumpage prices for different timber species gathered from a variety of state and federal agencies and private data reporting services.[63] Whenever possible, I use state-level stumpage prices reported for private landowners obtained from state agencies or private data sources.[64] When prices from private sales are not available, I employ stumpage prices from "cut and sold reports" for state forest timber sales or, otherwise, US Forest Service timber sales.[65]

I match my forest prices with regional merchantable timber yield estimates for different forest types developed by Richard Birdsey of the USDA Forest Service.[66] In order to match individual species prices (such as hard maple, soft maple, beech, yellow birch) with more aggregate forest types (such as maple-beech-birch), I weigh prices using state-level sawtimber production volumes from the Forest Inventory Analysis (FIA) Timber Product Output database for 1996. Using the Birdsey yields and these annual weighted prices, I then calculated the net present value of an infinite stream of forestry revenues for each forest type based on an optimal rotation age determined with the standard Faustmann formula. I assume a discount rate of 5%.

In computing the net present value measures, I assume that the forest starts at year zero in an already planted state; initial planting costs vary depending on the previous use and are considered as part of conversion costs. However, I include an estimate of replanting costs at the end of the first

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63 When sources report prices only at a sub-state level, I compute a weighted state-level price for each timber type using acreages of the relevant forest types in the price reporting regions.

64 Stumpage prices are the prices for the timber in a standing tree and in theory will differ from delivered log prices (at the mill) by the amount of logging and transport costs. In the case of Indiana, as stumpage prices were unavailable, I compute "pseudo" stumpage prices, using delivered log prices, weighted by the average quality mix, and subtracting estimates of logging and hauling costs provided by Bill Hoover at Purdue University. For California and Eastern Washington, I use the stumpage price values reported by the state tax authorities for assessing timber tax rates.

65 I employ "cut" prices which are the prices actually paid when stands are harvested rather than the "sold" prices paid for timber to be harvested in the future. Cut prices have the disadvantage of being volume weighted composites rather than species-specific but provide a more precise measure of the stumpage value for a variety of reasons (Haynes 1988). I use stumpage prices from state forest sales for Idaho, Montana, and Oregon and data from US Forest Service sales in Colorado, Wyoming, Nevada, Utah, Arizona, New Mexico, and South Dakota. There remain seven states for which no stumpage price data is available: Delaware, Iowa, Kansas, Maryland, Nebraska, New Jersey, and North Dakota. I assign stumpage prices to these areas using prices for relevant timber species from neighboring states.

66 I use yields for medium quality sites (site index 60 through 78). I convert volumes from cubic feet to board feet using regional conversion factors, differentiated by hardwoods and softwoods, from Haynes (1990). To make prices comparable across the nation, I convert prices to the international 1/4 inch log rule (a system for estimating the number of board feet in a log). If a particular data source reports a log rule conversion factor, I use that factor for the reported prices. Otherwise, I use the log rule conversions for Pennsylvania from Finley and Rickenbach (1996) as these are the most consistent with other sources.

rotation in the calculation of the net present value and the optimal rotation length. I use regional estimates of planting costs plus annual management costs from Moulton and Richards (1990). Management costs are assumed to keep up with inflation while planting costs vary over time according to a cost index developed from data for the South from Dubois, McNabb and Straka (1999).[67] Finally, to construct county-level returns, I weigh the state-level net present value measures for each forest group using county acreages from the FIA.[68]

A.2.4 Urban Use

I proxy the returns from developing a parcel of land in a county with the price of an acre of land used to build a single-family home. No county-level data exists on lot prices for developed land (the value of the land without a house). However, I construct a county-level annual measure of developed lot prices by taking county-level data on single-family home prices, which include both the value of the house and of the land, and backing out the price of the underlying land.

I obtain median county-level prices for single family homes for 1980 and 1990 from the decennial Census of Population and Housing Public Use Microdata Samples (PUMS 5% sample), which provide owner estimates of the price of single family-homes at the level of county groups and subgroups. I consider only the value of single-family houses built within the five years preceding each census to ensure that the prices reflect the characteristics of the houses being built in 1980 and 1990. Using 1980 and 1990 as base years, I extrapolate yearly data for each year between 1980 and 1999 using the Office of Federal Housing Enterprise Oversight (OFHEO) House Price Index. Based upon repeat home sales data, this index tracks quarterly changes in the price of a single-family home for each U.S. state. While this data only provides the state average home price trend, I capture some of the county-level differences in annual home price changes by scaling the state trend up or down for each county to fit the change in home prices between 1980 and 1990 from the census.

To back out the underlying land price, I multiply my annual estimate of the median single-family home price in each county by an estimate of the median share that the value of the lot represents in the total price of a single-family home. I compute this "lot share" from data in the

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[67] My planting cost index is based on average seedling densities and on a weighted average of tree planting (hand and machine) and site preparation costs (mechanical and chemical) for an acre in the South.

[68] Forest type compositions are likely to be highly correlated over time and I use weights based on a single FIA survey. When possible, I use the latest survey conducted prior to 1982, the date of the first NRI observation. For counties for which the FIA reports no data or zero forest areas, I assume the mean state-level forestry return for that year.

annual Characteristics of New Housing Reports (C-25 series) from Census Bureau and the U.S. Department of Housing and Urban Development. Based upon surveys of developers, these reports provide estimates of the price per square foot of single family homes sold (the price of the house plus the land) as well as an estimate of the price per square foot of the house excluding the value of the lot. This data thus permits the calculation of the lot share for single-family homes sold each year. The data from the C-25 reports from 1978-1995 is only at the level of the four main census regions. However, I scale these regional estimates to the level of metro and non-metro areas within each of the nine census divisions using the Survey of Construction (SOC) micro-data, available from 1995-1999.

Combining the home price and lot share data thus yields a measure of median lot prices for single-family homes in each county for each year from 1980 to 1999 (estimates going back to 1978 are obtained using the regional home price data from the Census of Construction reports). To obtain a per acre measure of developed lot values, I divide the estimated median lot prices in each county by an estimate of lot sizes derived from the C-25 reports (making the assumption of constant returns to scale in land). The C-25 reports from 1978-1995 only provide data on lot sizes at the national level but these are scaled to the level of metro and non-metro areas within each of the nine census divisions using the SOC micro-data.