SOCIO-ECONOMIC CAUSES AND CONSEQUENCES OF FUTURE ENVIRONMENTAL CHANGES WORKSHOP

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November 16, 2005

EPA Region 9 Building

75 Hawthorne Street 1st Floor Conference Room San Francisco, CA

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U.S. Environmental Protection Agency
Socio-Economic Causes and Consequences of Future Environmental Changes Workshop

November 16, 2005
EPA Region 9
75 Hawthorne Street
1St Floor Conference Room
San Francisco, CA

8:45-9:15	**Registration**	
9:15 -9:30	**Introductory Remarks – Tom Huetteman, Deputy Assistant Regional Administrator, USEPA Pacific Southwest Region 9**	
9:30-11:30	**Session I:**	**Trends in Housing, Land Use, and Land Cover Change** Session Moderator: Jan Baxter, US EPA, Region 9, Senior Science Policy Advisor
	9:30 – 10:00	Determinants of Land Use Conversion on the Southern Cumberland Plateau **Robert Gottfried (presenter)**, Jonathan Evans, David Haskell, and Douglass Williams, University of the South
	10:00– 10:30	Integrating Economic and Physical Data to Forecast Land Use Change and Environmental Consequences for California's Coastal Watersheds Kathleen Lohse, David Newburn, and **Adina Merenlender (presenter)**, University of California at Berkeley
	10:30 – 10:45	**Break**
	10:45 – 11:00	Discussant: Steve Newbold, US EPA, National Center for Environmental Economics
	11:00 – 11:15	Discussant: Heidi Albers, Oregon State University
	11:15 – 11:30	Questions and Discussions
11:30 – 12:30	**Lunch**	
12:30 –2:30	**Session II:**	**The Economic and Demographic Drivers of Aquaculture and Greenhouse Gas Emissions Growth** Session Moderator: Bobbye Smith, U.S. EPA Region 9
	12:30 – 1:00	Future Growth of the U.S. Aquaculture Industry and Associated Environmental Quality Issues **Di Jin (presenter)**, Porter Hoagland, and Hauke Kite Powell, Woods Hole Oceanographic Institution

	1:00 – 1:30	Households, Consumption, and Energy Use: The Role of Demographic Change in Future U.S. Greenhouse Gas Emissions Brian O'Neill, Brown University, **Michael Dalton (presenter)**, California State University – Monterey Bay, John Pitkin, Alexia Prskawetz, Max Planck Institute for Demographic Research
	1:30 – 1:45	Discussant: Tim Eichenberg, The Ocean Conservancy
	1:45 – 2:00	Discussant: Charles Kolstad, University of California at Santa Barbara
	2:00 – 2:30	Questions and Discussion
2:30 – 2:45	**Break**	
2:45 - 4:55	**Session III:**	**New Research: Land Use, Transportation, and Air Quality** Session Moderator: Kathleen Dadey, US EPA, Region 9, Co-chair of the Regional Science Council
	2:45 - 3:10	Transforming Office Parks Into Transit Villages: Pleasanton's Hacienda Business Park **Steve Raney (presenter)**, Cities21
	3:10 – 3:35	Methodology for Assessing the Effects of Technological and Economic Changes on the Location, Timing and Ambient Air Quality Impacts of Power Sector Emissions Joseph Ellis and **Benjamin Hobbs (presenter)**, Johns Hopkins University, Dallas Burtaw and Karen Palmer, Resources for the Future
	3:35 - 4:00	Integrating Land Use, Transportation and Air Quality Modeling **Paul Waddell (presenter)**, University of Washington
	4:00- 4:25	Regional Development, Population Trend, and Technology Change Impacts on Future Air Pollution Emissions in the San Joaquin Valley Michael Kleeman, Deb Niemeier, **Susan Handy (presenter)**, Jay Lund, Song Bai, Sangho Choo, Julie Ogilvie, Shengyi Gao, University of California at Davis
	4:25 – 4:55	Questions and Discussion
4:55 – 5:00	**Wrap-Up and Closing Comments**	

Determinants of Land Conversion On The Southern Cumberland Plateau

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Introduction

Within the Southeast, where forest issues are politically volatile, the Cumberland Plateau of southeastern Tennessee has attracted regional and national attention as a major hotspot for forestry-related, landscape-level change. The Plateau, the western portion of the Appalachian mountains, extends from northeastern Alabama to southwest Virginia, ranging in altitude from 2,000 to 4,145 feet. Part of the Allegheny Plateau, it continues north to the Mohawk Valley of New York.

As discussed below, the seven counties of the southern Tennessee Cumberland Plateau, our study area, have experienced a loss of about 20% of its native forest canopy from 1981 to 2003, with the rate of loss accelerating over time. This period also experienced a severe outbreak of the southern pine beetle and divestiture of substantial timberland holdings.

The removal of the native forest to permit other uses may have significant ecological implications. The Cumberland Plateau in Tennessee contains some of the largest remaining tracts of privately owned, contiguous temperate deciduous forest in North America. From a conservation biology standpoint this area has received special attention because of the extremely rich animal and plant diversity associated with these remaining tracts of native hardwood forest habitat (Clements and Wofford, 1991; Martin *et al*., 1993; Evans, 1996). Native forests on the Cumberland Plateau consist predominately of a mixture of oak (Quercus spp.) and hickory (Carya spp.) species, along with other hardwood species. These forest tracts represent migratory songbird habitat and serve as the headwaters to some of the most biologically diverse, freshwater stream systems found in the world (Ricketts *et al*. 1999).

The Cumberland Plateau also has some of the highest predicted herpifaunal diversity of anywhere in the state and one of the most diverse communities of woody plants in the eastern United States (Durham 1995; Ricketts *et al*. 1999). The hard mast (acorns) associated with the mature oak canopy of the plateau forest serves as a keystone resource within the food web of this ecosystem. The availability of this oak mast resource

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directly or indirectly affects the survivorship of hundreds of animal species inhabiting the forest (McShea and Healy 2002).[1] Because of the rapid forest change and the ecological importance of the native hardwood forests, the Tennessee Nature Conservancy has launched a major effort to maintain forest cover in the northern and southern portions of Tennessee's Cumberland Plateau. The National Resources Defense Council also has focused recently on the Plateau and pine conversion there, declaring it a "biogem," along with the Everglades, the Tongass National Forest, and the Yellowstone/Greater Rockies.

This paper constitutes part of a U.S.E.P.A.-funded project under the STAR program to develop a GIS simulation model of land use change and associated water quality and avifaunal diversity changes on a seven-county portion of the surface (i.e., excluding the slopes) of the southern Tennessee Plateau. We present here initial results of the building and location of homes on parcels of ten acres or more for the period 1981-2003, as well as a discussion of preliminary insights into the drivers of land cover change over this time period. As such our study represents one of only a few that use parcel level data to examine land conversion in a rural context, as opposed to the urban fringe. However, the nature of the available data and of the study area make this study even more interesting. The bluffs that characterize the edges of the Plateau comprise unique amenities that command a high premium. Our GIS data allow us to examine their impact on land use conversion. Using land cover data we also can examine the impact that a parcel's land cover, and land cover in the surrounding area, has on the probability a home will be built. Accordingly, we can examine the extent to which pine conversion and conversion to grassy cover affect landowners who use their land primarily for recreation and residence, homeowners who may value environmental amenities greatly. We also can explore changes in land cover due to homebuilding and timber company divestitures. This paper focuses on homebuilding and changes in land use/land cover (LULC) for the period 1981 to 2003.

The paper proceeds as follows. After a brief review of the literature, the paper develops a theoretical framework for land use change. It then describes the case study area and the data available. The subsequent sections discuss the results of 1) the logit

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[1] This preceding sentences are largely taken from Evans, Pelkey and Haskell (2002).

analysis of homebuilding, and 2) a preliminary examination of the causes of land cover change. The last section provides some concluding thoughts.

Review of the literature

The growth of landscape ecology and conservation biology has highlighted the importance that the pattern of land cover (determined by humans' use of the land), has on ecological processes. Therefore, ecological models rely on land use/land cover (LULC) patterns. This dependence has spawned the development of models of LULC change at the regional, or landscape, level (for a good discussion see Bockstael and Irwin, 2000).

Noneconomists have developed spatially explicit models of landscape change, sometimes incorporating economic variables such as distance to roads, population, and distance to towns into the analysis. However, these models fail to make explicit the underlying socioeconomic processes causing the landscape to change (Bockstael and Irwin, 2000).

On the other hand, economists have worked on spatial issues a great deal, examining the underlying processes of change in LULC.[2] Although economists make explicit their behavioral assumptions and analysis underlying LULC change, the lack of data (or the expense of collecting it) at the appropriate spatial scale for supporting ecological models has, in part, forced them to operate at larger scales (Baker, 1989; Bockstael and Irwin, 2000; Miller and Platinga, 1999). Most spatial models of land use change track changes in the distribution of land area among one or more variables. Typically they specify changes in the share of land uses at some aggregate level, such as the county (see Alig, 1986; Alig and Healy, 1987; Hardie and Parks, 1997; Hardie, *et al*., 2000; Miller and Platinga, 1999; Parks, 1987; Platinga,1996; Stavins and Jaffe, 1990; White and Fleming, 1980; Wu and Segerson, 1995). While more spatially explicit, these models do not provide information on actual locations or configurations of land use. Baker concludes,

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[2] For good discussions of the theory of land use, see Alonso (1964) and Randall and Castle (1985**.** See Baker (1989) Parks and Alig (1988), and Bockstael and Irwin (2000) for discussions and typologies subsequent models of land use.

> The most important present limit to the development of better models of landscape change may be a lack of knowledge of how and why the landscape changes, and how to incorporate such knowledge in useful models, rather than a lack of technology to develop and operate models of landscape change (p. 127).

Among the four approaches he suggests to address this lack of knowledge he includes multivariate analyses of possible exogenous and endogenous contributions to empirically-derived rates of landscape change. Acknowledging that multivariate analyses have their own limits, he suggests that modeling itself may offer an alternative route to the identification of key variables.

There exists a small literature of economic models and their applications at a finer scale of resolution. Cropper, Puri and Griffiths (2001) analyze parcel level data using bivariate logit to determine the location of deforestation and its rate, utilizing soil quality, impedance-weighted distance to the nearest market, distance to a road, population density, and locational dummy variables. Turner, Wear and Flamm (1996) examine land cover transitions of cells of a grid superimposed upon the landscape in two watersheds using multinomial logit. Transition probabilities vary according to slope, elevation, distance to roads and markets, and population density. They find differences in transition probabilities over time, perhaps caused by omitted variables such as timber or agricultural prices. Nelson and Hellerstein (1997) use cross-section data from satellite imagery to examine land use as a function of slope, soil quality, aspect, and access to roads and to villages. Landis (1995) and Landis and Zhang (1998) utilize a multinomial logit model to estimate the probability of land use change for the San Francisco Bay and Sacramento areas based upon site and community characteristics. They use these results, in turn, to calculate land use transition probabilities. As Bockstael and Irwin (2000) point out, this model does not directly explain land prices and uses cells rather than land parcels, the actual decision making unit, as the scale of analysis.

For purposes of our research Bockstael (1996) and Costanza *et al.* (1996) provide, perhaps, the most useful attempt at disaggregated modeling of land conversion. They examine residential conversion in the Patuxent watershed, near Washington, D.C. by first estimating the value of land in alternative uses by using the hedonic approach. They then estimate the probability of a parcel's being converted as a function of its value in alternative uses and its costs of conversion. As Bockstael points out, one drawback of this model is that it does not provide an economic explanation for the level of land use change, only its location. Geogehegan, Wainger and Bockstael (1997) develop a model in which the coefficients of some explanatory variables vary over space. They find, for instance, that the value of an additional unit of access to roads and lot size varies according to the distance from the central business district. Bockstael and Irwin (2000) rightly point out that the above spatially disaggregated models require huge datasets that typically are unavailable.

Subsequent work by their research team utilizes a hazard model to examine land use change. Irwin and Bockstael (2001, 2002) model land use change in both time and space by examining optimal timing decisions. The former paper incorporates actor interaction effects whereby residential land parcels exert a negative effect on one another, leading to fragmented land development patterns. The latter paper examines the relative magnitude and directions of these effects, and the effect of policies intended to cluster development and promote open space. Whereas these models permit an analysis of land use change over time in terms of optimal timing, they do not address the external driving forces behind land use changes over time – changes in interest rates, population, income, etc. – that are of prime interest for the research described below.

Based upon our analysis of Tennessee's Forest Greenbelt Program, experience, and theoretical intuition, landowner and buyer characteristics should play important roles in determining land use patterns over time (see Gottfried, 1998, 1999; Brockett and Gebhard, 1999; Brockett, Gottfried and Evans, 2001; Williams, *et al*., 2001). Bockstael and Irwin (2000) point out that agent-interaction models of urban land use patterns are driven by interactions between spatially distributed agents. These interactions may occur through market forces, nonpecuniary externalities from land uses or economic activities (such as social interactions) that affect the agents' utility or profits. The spatial distribution of current agents over the landscape, and their interactions, affect future location decisions, making their spatial distribution endogenous. This leads to a complex urban spatial structure that “is characterized by multiple equilibria, path dependence, and what Arthur (1989) terms ‘historical chance’” (p. 29).

Our research will add to the sparse economics literature of land use change at the parcel level. It will build on the work of Bockstael *et al*. by utilizing a model that explicitly incorporates the impact of exogenous economic variables on land use change over time, while including owner characteristics and interactions between parcels. In this way we not only contribute to the small number of models at this scale, but also contribute to the few studies examining land use change over time and the driving forces behind it. Most parcel level studies of land use change focus on areas experiencing urban pressures. This study examines a very rural area where pressures stem largely from changes in resource use and relatively light residential development. As such, it may shed light on change in other rural areas throughout the South.

Theoretical Framework

The probability that a given parcel will convert to some other use, j, depends upon five factors: 1) The relative value of land in use j compared to those of other uses (assumed to be given – the region is a price-taker in the land market). These are the bid prices prospective buyers for different uses on average would be offering. 2) The probability that the land owner will encounter a prospective buyer for use j. 3) The probability that that buyer, if not representing the highest-valued land use, will not face competition from another buyer desiring the land for a higher-valued use. 4) The probability that the value for use j will exceed the owner’s reservation price (comprised of the use value of the land plus the owner’s present value of intangible benefits, the reservation premium). 5) The cost of conversion to use j.

The relative values of the parcel in different uses will depend, in part, upon the suitability of that parcel for these uses as determined by the parcel characteristics as well as exogenous economic variables such as population growth and interest rates. The probability of conversion depends positively on the difference between the value of the land in the alternative use j and the current use i. The values in different uses capture the expected net benefits that prospective buyers anticipate from use j. Note that the value of the land may differ from price. The former represents the value land would have if it were in a particular use, the market for which may not as yet be present in an area.

1) $V_{tj} - V_{ti} = f(e_{jt}, c, N_{jt}) – g(e_{it}, c, N_{it})$

where V_{tj} = value of parcel in alternative use j at time t
V_{ij} = value of parcel in current use i at time t
e_t = exogenous economic variables at time t
c = parcel characteristics
N_t = land use in time t of nearby parcels

Landowners may change land use themselves without first selling to someone who then changes its use. To simplify modeling, when landowners themselves consider changing land use, the model treats this as an encounter with a buyer for that prospective land use. The probability of an encounter of a landowner with a prospective buyer who would convert to another land use j depends upon relative land values, parcel characteristics (including land use/land cover), area land use, and owner characteristics. The higher the value of land in a given use, the more incentive buyers have to seek parcels they can use for that purpose. They, of course, will seek parcels having characteristics most suitable for that use. Finally, particularly when the prospective land use is relatively new to the area, information on that use and/or the suitability of the parcels in the region for that use, may be scarce. Therefore, landowners close to an industrial pine plantation, for instance, may be more likely to consider converting their land to pine, or buyers may be more inclined to think that neighboring parcels might prove suitable for pine given the presence of a nearby plantation. Similarly, for residential development the initial residential development in an area may provide the idea to other developers that this area is suitable for development – it may signal the presence of a market that before they were unaware of. Agglomeration effects may also work so that real estate agents more likely will come to an area where other agents are at work – prospective clients may find it easier to deal in an area where there are many agents than a few. Accordingly, prospective buyers for these uses may be more present where there already has been such activity in the area. Positive and negative externalities associated with the uses of nearby parcels will affect the attractiveness of the parcel a given use. Finally, owner characteristics will affect the probability of their being aware of other land use options.

2) $E_{tj} = h(V_{tj}, V_{ij}, c, N_t, O_t)$,

where E_{tj} = probability that a landowner encounters a prospective buyer for land use j at time t

O_t = owner characteristics at time t

The probability that a particular buyer representing a given land use will offer the highest of competing prices will depend, of course, on the value of the land for different uses and the probabilities of encounters between the owner and prospective buyers for other land uses E_k through E_m..

3) $S_{tj} = p(V_{tk},\ldots, V_{tm}, E_{tk},\ldots, E_{tm})$,

where S_{tj} = probability that the bid price, or value, offered by a buyer for use j will be the highest price offered the landowner at time t.

The probability that the bid price for use j will exceed the owner’s reservation price depends upon value of a parcel for use j, the value of the land in its current use, and the owner’s reservation premium, which varies according to owner characteristics.

4) $G_{tj} = r(V_j, V_i, RP_t(O_t))$,

where G_{tj} = probability that bid price for use j is greater than the owner’s reservation price t at time t

RP_t = reservation premium, a function of owner characteristics

O_t = owner characteristics

Finally, the cost of converting the land to use j will depend upon the cost of inputs to the conversion process, the characteristics of the parcel itself, and the opportunity cost of changing from the current land use.

5) $T_{tij} = s(I_{tj}, c, V_{ti})$,

where T_{ij} = cost of converting land to use j from use i
I_t = cost of inputs to conversion process t time t

Given the above, the following function, therefore, determines the probability, Ctij, that a given parcel will change to some alternate use j from use i at time t.

6a) $C_{tij} = m(V_{ti}, V_{tj}, E_{tj}, S_{tj}, G_{tj}, T_{tj})$

or

6b) $C_{tij} = m(e_t, c, N, O_t, I_t)$.

The Case Study Area

The study area comprises 616,000 acres of the top of the Cumberland Plateau in southeastern Tennessee (see Figure 1). As such it includes part or all of seven counties: Franklin, Marion, Grundy, Sequatchie, Warren, Van Buren, and Bledsoe.

Data developed by the Sewanee Landscape Laboratory for the Small Area Assessment Forestry Demonstration Project of the Southern Forest Resource Assessment (Evans *et al*. 2002) and for the current project found that from 1981 to 2003 intact native forest canopy declined in the southern Cumberland Plateau by about 19% (approximately 90,000 acres). This conversion tended to be concentrated in certain areas. During the same time pine plantations increased by 100% (35,000 to 70,000 acres) and agriculture/residential (grass/shrub land cover) by 50% (77,000 to 115,000). Figure 2 shows that the acres of native forest lost per year has increased steadily over the period, while the increase in acres of pine has increased at a decreasing rate from 1990 to 2003. Most significant, perhaps, is the marked increase in the rate of increase of agriculture/residential from 2000 to 20003.

Figure 3 shows that up to the 1997-2000 period native forest tended to convert to pine rather than agriculture/residential (ag/res). However, in that period the situation changed dramatically as conversion to ag/res far outstripped pine conversion. The decline in the annual rate of pine conversion, as well as rising rates of conversion of pine to ag/res, may result from the disastrous southern pine beetle epidemic that started around 2000.

Over the period 1981-2001 the rate of land sales increased dramatically starting in 1986 (Figure 4). The rate of home also construction increased steadily through 1999, with several counties experiencing downturns in the last four years. It is interesting to note that Van Buren County, which experienced a large divestiture of Huber land starting in 1998, experienced a large increase in the annual rate of home construction recently compared to other counties. The real price per acre of tracts from 10 to 200 acres has increased since 1984, whereas larger parcels have increased in price since about 1986 (Figure 5).

These changes have occurred in an area characterized by a skewed land distribution. Considering only parcels over ten acres, in the year 2000 the largest 1% of landowners owned 49% of the Plateau surface. Similarly, fifty-six percent of the Plateau surface was owned by owners holding 1000 acres or more. Timber companies held twenty percent of the Plateau surface while other businesses held an additional eighteen percent. Owners with mailing addresses outside of the county where the parcel was located or of a neighboring county (absentees) owned 51% of the land. However, the business-oriented owners tended to hold larger parcels. Business-oriented owners held only 13% of land in parcels from 10 to 500 acres compared to 63% of land in parcels 500 acres or more. Individuals, however, owned 83% of land in small parcels compared to 22% of the land in large parcels. Similarly, owners from outside of the area held 70% of the land in parcels over 500 acres compared to only 30% of the land in parcels under 500 acres.

Within the study area this landownership pattern has changed dramatically since 2000. Of the ten largest landowners in the study area, all but four (a timber company, a developer, the State of Tennessee and The University of the South) have sold their lands. Van Buren County represents the most extreme case of skewed land distribution and divestiture. Prior to 1997 two timber companies owned about 90% of the County, which lies almost totally on the top of the Plateau. Since 2000 one of these firms divested itself of all of its Plateau land, generally selling to developers or individuals.[3] There are relatively few public lands in the study area.

The study area resembles much of Appalachia, with its relatively high levels of unemployment and poverty, and low levels of education. Towns tend to be small and small in number, and with a few exceptions, relatively stable in population. County populations, however, generally have grown, with inmigration exceeding outmigration since 1983-84. Migrants tend to come from other counties in Tennessee, with large numbers also coming from the South and Midwest. Exactly how many migrants settle on the Plateau is more difficult to determine. Van Buren and Grundy counties, which are almost totally on the Plateau, may provide some more insight. Grundy County only regained the population it had had in 1980 by 1995. Inmigration to Grundy has trended upward since 1991-92, the majority of migrants coming from neighboring counties and Hamilton County (Chattanooga). Van Buren's population has remained a relatively constant 5,000 (Moore, Pickron and Tucker 2000). Yet, anecdotal evidence continues to point to an influx of people, often second home owners and retirees, coming to these areas for its natural amenities. Realtors relate that many lot sizes for retiree/second homes tend to be large, often 20 to 100 acres. Of course, once land has been divided into lots and held by people desiring green space for their home, this change may prove largely irreversible, making it difficult for others to buy the land for pine plantations, for instance.

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[3] Bowater, the other timber company and the largest landowner on the Plateau, has announced it will sell much or all of its Tennessee landholdings. This may mean that shortly almost all of the land in Van Buren will have changed hands since 1997, and that only three of the original ten largest landowners in 2000 will remain as of 2005.

Description of Data

Developing a micro-level land use transition model for this region requires spatially explicit parcel level characteristics data, parcel level data on LULC over time, information on landowners and potential buyers, and regional economic data. We possess all this information to varying degrees. Tennessee has a centralized county revenue system whereby almost all property tax records are standardized and coordinated by the State, thereby providing a standardized, intercounty compatible tax database. We have obtained from the State the December 1999, 2000, 2001, and 2002 and early 2004 tax assessor data for all our counties. We have digitized all parcels of ten acres or more in the study area to create tax map GIS coverages for 2000 or 2001, depending upon the county. Because these tax maps were drawn by hand at each court house, they introduce some spatial error. We have linked the 2000 assessor data to the 4,792 parcels of ten acres or more as of 2000/2001, creating a GIS coverage that permits spatial analysis of any data contained in the property tax database, such as parcels owned by out-of-state individuals or businesses or parcels with structures worth more than a given dollar amount. Consequently, towards the end of our study period we have detailed parcel level spatial and economic information. Unfortunately, the state maintains no historical data so that we lack comparable data for earlier years. Consequently, as the year of home construction and land cover changes diverges from 2000/2001 both the parcel boundaries and associated tax data become less accurate.

Finally, we have GIS coverages for 1981, 1990, 1997, 2000 and 2003 of land cover in pine plantations, native hardwood, and “other” (grassy/shrub cover, such as lawns or pasture). These relatively spatially accurate coverages do not always align perfectly with the hand-drawn parcel boundaries, thereby introducing error in the land cover of each parcel. The tax data indicate the number and type of residential structures on a parcel and their year of construction. However, they do not give the location of the structure. Therefore, when a house is built we only know the area within which it was built, but not its precise location on the ground.

Of the 851 houses built during 1980-2003, 794 represent the first houses built on a parcel. Of these, 609 represent the case where only one house was built on the parcel when the first house was built and 174 represent cases where two homes were built on previously undeveloped land. This paper will focus on the building of one or more houses on previously undeveloped land.

This raises the question of what "residential land use" means in a rural context. Much land development in the case study area consists of selling tracts of 10 to 100 acres for recreation land or hobby farms/forests. Many of these parcels ultimately may have a home built upon them. Because the towns on the Plateau tend to be relatively low density and relatively stable, most of the active development tends to occur on these medium size parcels. As seen below, the land market for parcels from ten up to ninety acres appears to differ from that for parcels ninety acres and greater. Building a home may or may not change the land cover to a significant degree. The following section discusses a logit analysis of homebuilding. It then explores possible determinants of changes in land cover.

Analysis of Changes in Land Use/Land Cover

Residential Development of Undeveloped Land

Table 1 summarizes the variables used in the logit analysis along with their expected signs. Our dependent variable for the logit analysis is a dummy variable (hbuilt) taking the value of 1 if one or more homes are built on previously undeveloped land during the year. We follow previous research and include both site characteristics, neighborhood characteristics, and amenity variables. Site characteristics variables include bluff frontage, access to public water, sewer, natural gas, and electricity, location on a paved road, distance to a city and to a major road, and size of parcel. The effect of these location variables is unclear because of the tradeoff between convenience and privacy. One would expect smaller parcels to have a greater probability of home construction.

Land cover of a parcel should affect its attractiveness for housing vis-à-vis other uses. Thus, land cover may be viewed from the perspective either of aesthetic amenities or productivity. For example, native forest may have more aesthetic value to landowners than a pine forest, while grassy land used for grazing cattle may have more productive value than a hardwood forest. The relative effects of these land cover variables are ambiguous as they depend upon the preferences of landowners. We would expect native forest and grass/shrub to have more aesthetic value than pine, and therefore to have a positive sign, whereas grass may have more productive value relative to the other land covers and therefore have a negative sign. However, in the latter case greater cleared area also lowers the cost of home construction, causing the percentage of a parcel in grass/shrub to have an ambiguous expected sign.

The neighborhood, of course, should affect the likelihood of building a house on a parcel. The more attractive it is the greater the probability of a home being built on a parcel. This may be captured, in part, by the average value of homes on nearby parcels. Because of the rapid changes in land cover occurring on the Plateau, we are particularly interested in understanding how changes in land cover affect residents and landowners. Land cover in the area surrounding a parcel should affect its attractiveness for home construction. Two sets of buffer variables capture the effect of neighboring land cover. The first measures the percentage of a 0.1 km buffer around a parcel in native forest, pine, and grass/shrub (two other land covers that have been combined, reservoirs and “mixed pine”, serve as the default). The second variable consists of a 1 km buffer. Thus, the former captures land use immediately surrounding the parcel whereas the latter captures land use in a larger area. One might expect that having forest nearby makes a parcel more attractive for homes whereas having a pine plantation makes it less attractive. Grass/shrub nearby provides scenic, rural vistas, and therefore has a positive expected sign. Protected areas similarly may provide positive amenities to homebuilders. Consequently, parcels adjacent to a protected area should experience a greater probability of building. Finally, a larger number of homes in the vicinity and a close proximity of a neighboring home provide the information that residential land use is a possibility for a parcel as well as provide amenities in terms of having neighbors.

Ownership also should affect homebuilding. Timber companies should be less likely to build on their land. Business owners include firms who either develop land or may be prone to selling to developers. For years prior to 1999-2001 parcels owned by business in 1999-2001 less likely will experience homebuilding inasmuch these owners no longer would hold the land if it had been built on previously. However, post 1999-2001 such parcels more likely will be developed than others.

Finally, external economic drivers should affect the probability of building of a home. Declines in mortgage rates, population growth in the southeastern US, lower home construction costs, lower unemployment rates (as an income proxy) and rises in the stock market (wealth) all should affect homebuilding positively.

Results

Table 2 shows the results of the logit analysis utilizing the 0.1km buffers for land use around a parcel. Analysis using the 1km buffer yields very similar results. Preliminary work showed that parcels greater than ninety acres tended to behave differently from those less than ninety. Consequently, all dependent variables were interacted with a dummy for parcels greater than or equal to ninety acres. Similarly, the period from 1997 onward appeared to show different characteristics than the earlier period, so all independent variables were interacted with a dummy for the period for 1997 to 2003. Interaction terms that did not add significantly to the model were removed.[4]

The model performed largely as expected. Consider parcel characteristics. Homes appeared more often on parcels of less than ninety acres than on larger parcels. Parcels with bluff frontage, water, gas, and electricity all had a greater probability of construction. Parcels with sewer had an even greater probability after 1996 whereas larger parcels with electricity were more likely to experience construction than smaller. The reason for the latter is unclear. Distance from a city and a major road, as well as location on an unpaved road increased probability, probably reflecting a desire for privacy. For large parcels distance from a major road decreased the probability of home construction. Bluff frontage increased the likelihood of construction for small parcels but decreased it for large. The latter may be due some interaction between large parcels on

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[4] Some care needs to be exercised in interpreting the coefficients. These present the marginal effect of a one unit increase in the variable on the probability of a house being built. In the case of an interaction term its coefficient must be added with that of the regular variable in order to obtain its effect on probability; i.e., its coefficient shows the marginal contribution to probability relative to the regular variable. So, for SEWER1997, for instance, its impact on probability is given by summing its coefficient with that for SEWER.

bluffs and the types of owners who hold them. For instance, during this period CSX Corporation owned a large tract with miles of bluff but did not use it to build homes. Note the negative sign for BUSOWNER, even after 1996 (though the businesses were more likely to build in the second period than in the first). Large parcels with larger percentages of native forest had lower probabilities, especially in the second period. In the earlier period small parcels with pine had larger probabilities whereas in the later period they had smaller probabilities. Larger parcels experienced declines in probability as pine increased, particularly in the second period. Larger percentages of grass/shrub cover increased home construction for small parcels in the period before 1997 but decreased it after that. For larger parcels more grass/shrub decreased probability, especially so in the second period. Pine decreased probability more than native forest or grass.

With respect to neighborhood characteristics only the buffer for grass/shrub resulted significant. The more grass/shrub (relative to mixed pine/hardwood) adjoining the parcel the less likely a home will be built. Evidently grass/shrub presents a disamenity. The average value of homes in the area, number of nearby houses, and distance to the nearest parcel with a house all had significant coefficients with the expected sign. However, the latter variable had less of an impact on large parcels. This may result from the development of large tracts, which tend to be further from developed areas than small tracts. Location next to a protected area seems to have no impact on homebuilding.

As expected, parcels owned by timber companies as of 2000/2001 showed lower probabilities, as did parcels owned by businesses. However, the latter effect declined for the second period. The latter may result from the purchase of former timber lands by development businesses starting in 1997. Because some “business” lands as of 2000 actually were timber company lands prior to 1997, such parcels would be more likely to be developed in the second period.

The county dummy variable coefficients show the likelihood of development compared to Bledsoe County.

Finally, the time series variables were insignificant with the exception of the Wilshire index. The latter probably reflects the impact on wealth of the large run-up in the stock market during the 1990’s and its subsequent decline. Though the other variables resulted insignificant they all have their expected signs.

Table 3 summarizes the above results.

Changes in Land Use/Land Cover

The question remains as to the impact that homebuilding has on land cover. Changes in land use may or may not be reflected in changes of land cover. When owners convert part or all of their parcel to a grassy/shrub cover, that cover may be used for pasture, a golf course, or a lawn. As of the current state of our data, we cannot distinguish between these uses. Similarly, when a landowner builds a house, they may nestle the house in the forest, or may clear some or all of their land for lawn. An owner changing the use of his native forest holding from hardwood production to recreation or low density housing may change land cover very little.

One might expect that the influx of new permanent and second homeowners would constitute a prime cause of change of native forest to grass. However, this may not be the case. Analysis of all new homes on parcels under 100 acres (for 1980 to 2000) reveals that all these parcels contained native forest, the average being 20 acres. The majority also had some grass, with the average grass per parcel being about 10 acres. Therefore, these wooded parcels often presented already cleared areas where, conceivably, home construction could proceed without clearing. When home construction caused a change in LULC for at least some of the parcel, in the great majority of cases native forest changed to only one other LULC. These “pure” conversions (about 20% of the home construction from 1980-90 and 1990-2000) usually entailed clearing native forest for grass/shrub. The remainder went to “logged,” which ultimately would result either in pine or grass. The average clearing size for grass was 9 and 13 acres respectively for each of the two periods. Only four pure conversions of native forest as the result of homebuilding occurred during 1997-2000 and these resulted in no conversion to grass/shrub. The relatively small numbers of conversions from native forest to grass/shrub, and the small sizes of these conversions, suggests that in all likelihood homebuilding did not represent the prime driver of the large changes of native forest to grasss/shrub that the Plateau has experienced. Of course, the yet-to-be-performed analysis for the period 2000-2003 may reveal otherwise.

Surprisingly, most of the increase in grassy/shrub cover may result from growth of agriculture, in particular for pasture or hay production. A large proportion of the growth in grass/shrub in the most recent period has occurred on former timber lands in Van Buren County that were sold to one land developer that, in turn, has sold to individuals and other developers. Informal interviews with county officials, buyers of the developers' land, and the developer itself indicate that many local landowners had been waiting for years to expand their pastures or their hay operations. When the timber company divested, they bought substantial acreage, often in tracts of one thousand or more acres. Approximately 2,000 head of cattle have been added to the county herd since about 2000 (Swoape, 2005). In Grundy County, the county experiencing the next largest amount of conversion to grass/shrub anecdotal evidence suggests that perhaps three to four hundred acres have been cleared in the last two to three years for cattle production due to the high cattle prices (Kimbro, 2005).

A similar process has occurred on a large tract at the opposite end of the study area. The same company as in Van Buren County sold its timber rights to this tract to another timber company and then sold the land to an individual from Florida who, in turn, sold the now harvested land to a local developer. That developer, in turn, is selling the land off in tracts from ten to hundreds of acres, largely to Floridians. However, some nearby landowners also have bought hundreds of acres of this large tract for horse pasture. The Floridians evidently seek solitude. Accordingly to the developer they are unlikely to clear much of their land. Other individuals indicate that many immigrants to this part of the study area clear at least some of their land when they build. The question remains, however, whether this acreage represents a significant portion of the conversion the data reveal.

Part of the conversion to grass/shrub also may result from changed corporate strategy as the result of the pine beetle epidemic. The developer that bought the Huber lands in Van Buren County claims to have cleared no land itself. As much of the divestiture in Van Buren County occurred around the time of the pine beetle, it is possible that clearing occurred originally with the intention to establish a pine plantation(s) but that the owners decided against that after the hardwood harvest. This cleared land then became available for pasture. It has proven difficult to establish who actually cleared that land. It appears that divestiture created the opportunity for agricultural expansion as well as homebuilding. Thus, divestiture, particularly in concert with the pine beetle, may have promoted conversion of native forest to grass at least indirectly.

We intend to apply the theoretical framework developed above to a multinomial probit analysis of changes in LULC. Most studies of change in LULC have divided the landscape into cells and analyzed the conversion of cells. We had intended to study LULC conversion at the scale of the parcel as a more logical unit of decisionmaking than a cell. However, because many parcels contain various management units with different LULC's, we have decided to analyze the conversion of these subparcel units over time, allowing for a finer degree of resolution than a parcel level analysis and for a more behaviorally appropriate analysis than a cell level approach.

Given the fact that the tax parcel boundaries and the LULC do not line up precisely we have encountered many subparcel polygons that result from the process of intersecting of these two datasets. They represent spurious management units and, as such, need to be eliminated from the analysis. We currently are engaged in that task. This also may necessitate recalculation of various spatial variables for these polygons. After that has been completed we then will engage in the probit analysis.

Conclusions

The region's changes in land use trends since 1996 towards clearing native forest for grass/shrub cover as opposed to pine, and the massive divestitures that have started in 1997, appear to be reflected, at least indirectly, in the logit analysis of homebuilding. Certainly the model shows that variables often behave differently after 1996 in ways that appear to reflect the above. For instance, parcels surrounded by larger amounts of grass/shrub appear to have experienced more homebuilding in the first period than those with smaller amounts of grass, but experienced the opposite in the second period when increased conversion to grass was occurring. The behavior of the landowner variables suggest that divestiture may have affected the likelihood of homebuilding, as would be expected.[5] The model generally behaved as expected.

While data problems have precluded a probit analysis of changes in land use/land cover, analysis of the data along with anecdotal evidence suggest that much of the change of native forest cover to grass/shrub may result more from agricultural conversion than from homebuilding. Subsequent probit analysis should enable us to test this hypothesis.

REFERENCES CITED

Alig, R. J. 1986. Econometric Analysis of the Factors Influencing Forest Acreage Trends in the Southeast. *Forest Science* 32(1): 119-134.

Alig, R. J. and R. G. Healy. 1987. Urban and Built-Up Land Area Changes in the United States: An Empirical Investigation of Determinants. *Land Economics* 63(3): 215-226.

Arthur, W. G. 1989. Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *Economic Journal* 99: 116-31.

Baker, W. L.1989. A Review of Models of Landscape Change. *Landscape Ecology* 2(2): 111-133.

Bockstael, N. E. 1996. Modeling Economics and Ecology: the Importance of a Spatial Perspective. *American Journal of Agricultural Economics* 78(5): 1168-80.

Bockstael, N. E. and E. G. Irwin. 2000. “Economics and the Land Use-Environment Link.” In T. Tietenberg and H. Folmer, eds. *The International Yearbook of Environmental and Resource Economics 2000/2001*. Northampton, MA: Edward Elgar.

Clements, R. and E. Wofford. 1991. The Vascular Flora of Wolf Cove, Franklin County, TN. *Castanea* 56:268-286.

Costanza R, Wainger L, Bockstael N. 1996. Integrating spatially explicit ecological and economic models: theory and applications in the Patuxent River watershed, Maryland. In: Costanza R, Segura O, Martinez-Alier J, eds. *Getting Down to Earth: Practical Applications of Ecological Economics*. Washington, DC: IslandPress, pp. 249-84.

Cropper, M., J. Puri, and C. Griffiths. 2001. Predicting the Location of Deforestation. *Land Economics* 77(2): 172-86.

Evans, J.P. 1996. Forward. In: *Managing Natural Resources: A Planning Guide for Franklin County*. Edited by D. Durham. Tennessee Conservation League.

Evans, J. P., N. Pelkey and D. Haskell. 2002. *An Assessment of Forest Change on the Cumberland Plateau in Southern Tennessee*. Small Area Assessment Forestry Demonstration Project for the Southern Forest Resource Assessment. Final Report

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[5] Attempts to include variables to capture divestiture failed. STATA would eliminate any such variable from the analysis inasmuch as it completely determined failure.

submitted to the U. S. Environmental Protection Agency and The U.S. Fish and Wildlife Service. Sewanee Landscape Analysis Laboratory, The University of the South, Sewanee, TN. March.

Durham, D., ed. 1996. Managing Natural Resources: A Planning Guide for Franklin County. Tennessee Conservation League Publication.

Geoghegan, J., Wainger, L., Bockstael, N. 1997. Spatial Landscape Indices in a Hedonic Framework: an Ecological Economics Analysis Using GIS. *Ecological Economics* 23: 251-264.

Gottfried, R.1988. The Effect of Recreation Communities on Local Land Prices: The Case of Beech Mountain. *American Economist* 22(1).

Hardie, I. and P. Parks. 1997. Land Use with Heterogeneous Quality: An Application of an Area Base Model. *American Journal of Agricultural Economics* 77: 299-310.

Hardie, I., P. Parks, P. Gottlieb, and D. Wear. 2000. Responsiveness of Rural and Urban Land Uses to Land Rent Determinants in the U.S. South. *Land Economics* 76(4): 659-73.

Irwin, E. G. and N. E. Bockstael. 2001. Interacting Agents, Spatial Externalities, and the Endogenous Evolution of Residential Land Use Pattern. *Journal of Economic Geography*. Forthcoming.

_____. 2002. Managing Urban Sprawl: The Effects of Land Use Externalities. Paper presented at the Lincoln Institute for Land Policy workshop on “Analysis of Urban Land Markets and the Impact of Market Regulation,” Cambridge, MA, July 10-12.

Irwin, E. G. and N. E. Bockstael. 2001.The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Vales. *American Journal of Agricultural Economics* 83(3): 698ff.

Kimbro, C. 2005. Personal communication. University of Tennessee Agricultural Extension Agent, Grundy County.

Landis, J. 1995. Imagining Land Use Futures: Applying the California Urban Futures Model. *Journal of the American Planning Association* 61(4): 438-57.

Landis, J. and M. Zhang. 1998. The Second Generation of the California Urban Futures Model. Part 2: Specification and Calibration Results of the Land-Use Change Submodel. *Environment and Planning B: Planning and Design* 25: 795-824.

Martin, W., S. Boyce, and A. Echternacht. 1993. *Biodiversity of the Southeastern United States: Upland Terrestrial Communities*. NY: Wiley and Sons.

McShea, W. J. and W. M. Healy.2002. *Oak Forest Ecosystems*. Baltimore, MD: Johns Hopkins University Press.

Miller, D. J. and A. J. Platinga. 1999. Modeling Land Use Decisions with Aggregate Data. *American Journal of Agricultural Economics* (81): 180-94.

Moore, L., N. Pickron, and M. Tucker. 2000. *Demographic Analysis of Bledsoe, Franklin, Grundy, Marion, Sequatchie, Van Buren and Warren Counties: 1980 to 1997*.Unpublished report. Sewanee Landscape Laboratory.

Nelson, G. A. and Daniel Hellerstein. 1997. Do Roads Cause Deforesation? Using Satellite Images in Econometric Analysis of Land Use. *American Journal of Agricultural Economics* 79: 80-88.

Parks, P. J. 1987. *The Influence of Economic and Demographic Factors on Forest Land Use Decisions in North Carolina.* Report of the Southeastern Center for Forest Economics Research.

Parks, P. J. and R. J. Alig.1988. Land Base Models for Forest Resource Supply Analysis: A Critical Review. *Canadian Journal of Forest Research* 18: 965-973.

Ricketts, T. H., E. Dinerstein, D. Olson, C. J. Loucks, W. Eichbaum, D. Della Sala, K. Kavanagh, P. Hedao, P. Hurley, K. Carney, R. Abell, and S. Walters. 1999. *Terrestrial Ecoregions of North America*. Washington, DC: Island Press, Washington.

Stavins, R. N. and A. B. Jaffe. 1990. Unintended Impacts of Public Investments on Private Decisions: The Depletion of Forested Wetlands. *American Economic Review* 80(3): 337-52.

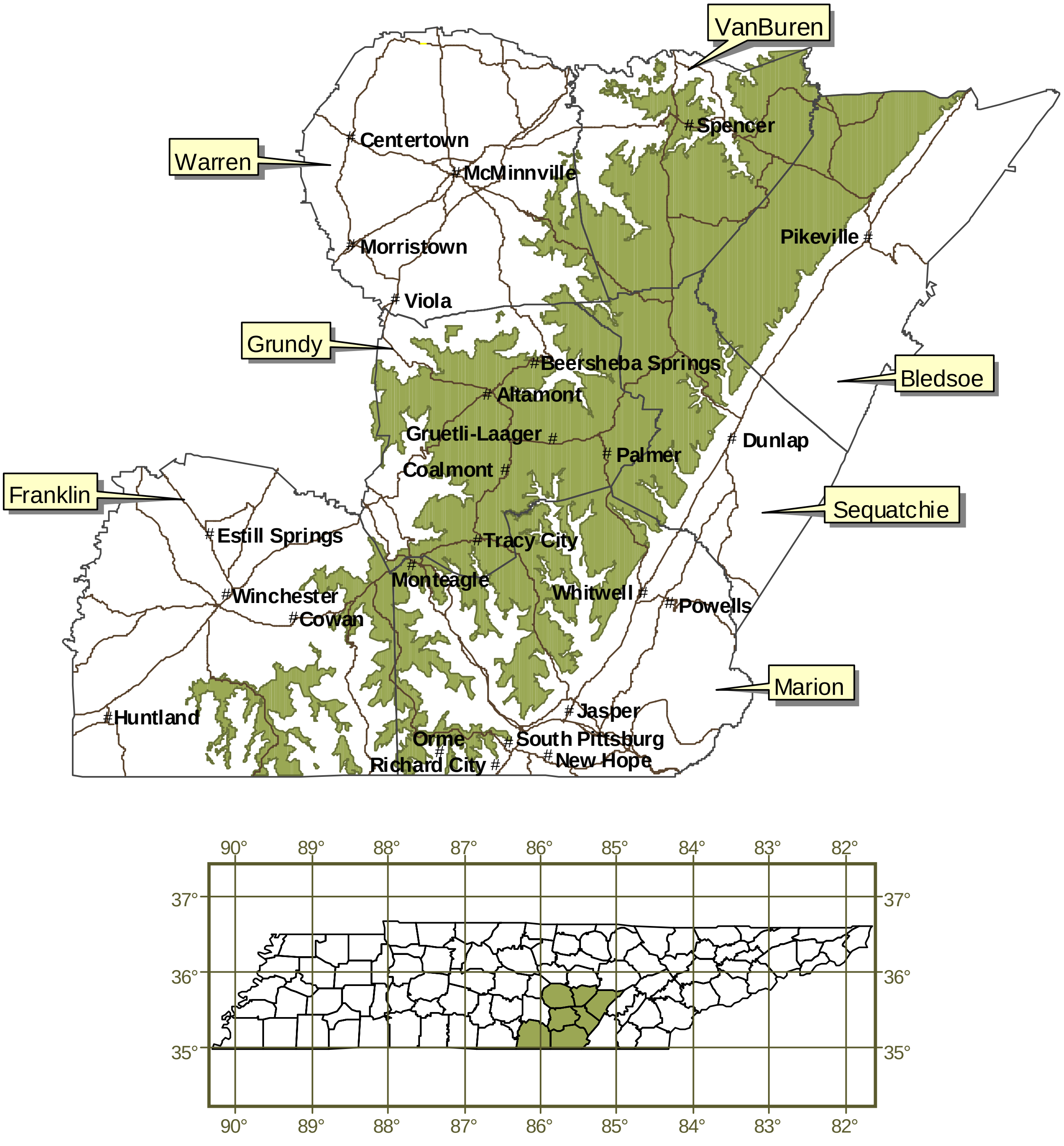
Swoape, S. 2005. Personal communication. University of Tennessee Agricultural Extension Agent, Van Buren County.

Turner, M., D. Wear, and R. Flamm. 1996. Land Ownership and Land-Cover Change in the Southern Appalachian Highlands and the Olympic Peninsula. *Ecological Applications* 6(4): 1150-72.

White, F. and F. Fleming. 1980. An Analysis of Competing Land Uses. *Southern Journal of Agricultural Economics* 12: 99-103.

Wu, J. and K. Segerson. 1995. The Impact of Policies and Land Characteristics on Potential Groundwater Pollution in Wisconsin. *American Journal of Agricultural Economics* 77: 1033-47.

Figure 1


VanBuren
Warren
Grundy
Franklin
Bledsoe
Sequatchie
Marion
Spencer
Centertown
McMinnville
Morristown
Viola
Pikeville
Beersheba Springs
Altamont
Gruetli-Laager
Palmer
Dunlap
Coalmont
Estill Springs
Tracy City
Monteagle
Winchester
Cowan
Whitwell
Powells
Huntland
Jasper
Orme
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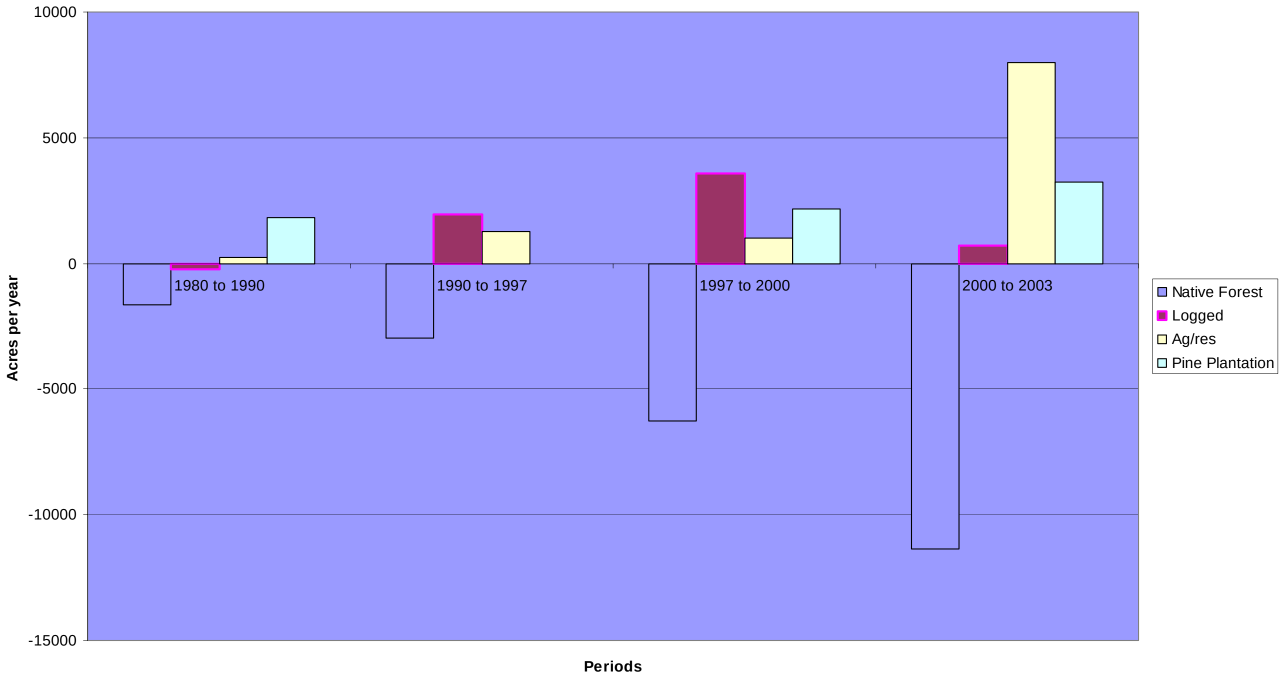

Figure 2. Annual Rate of Land Cover Change by Period

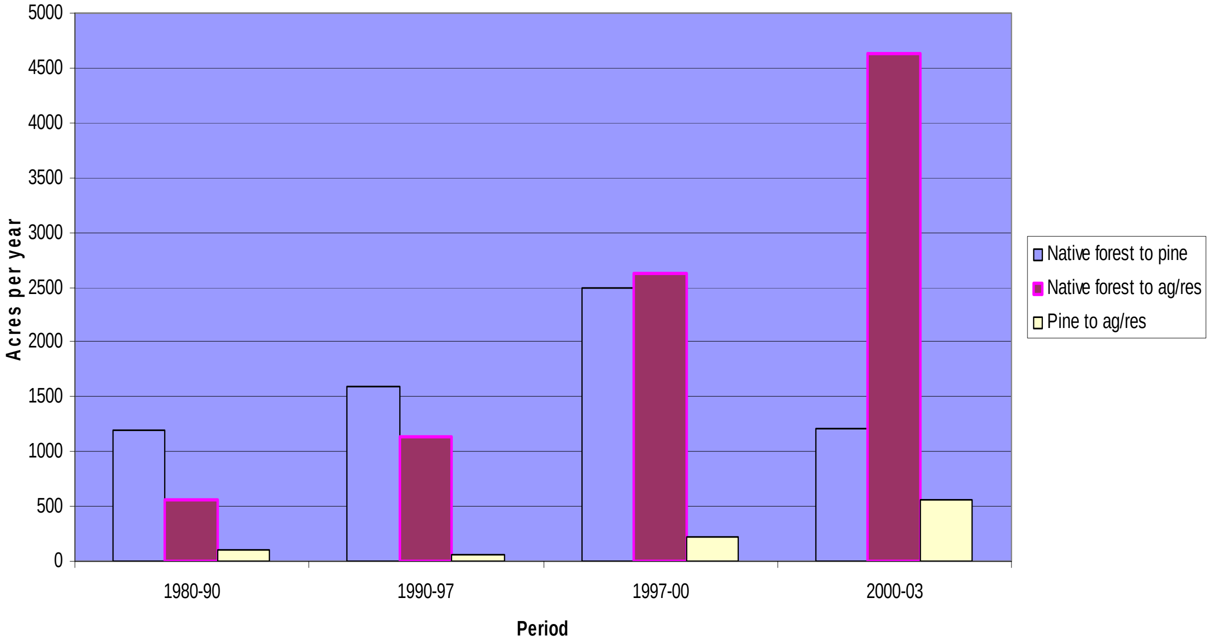

Figure 3. Annual Rates of Land Cover Conversion

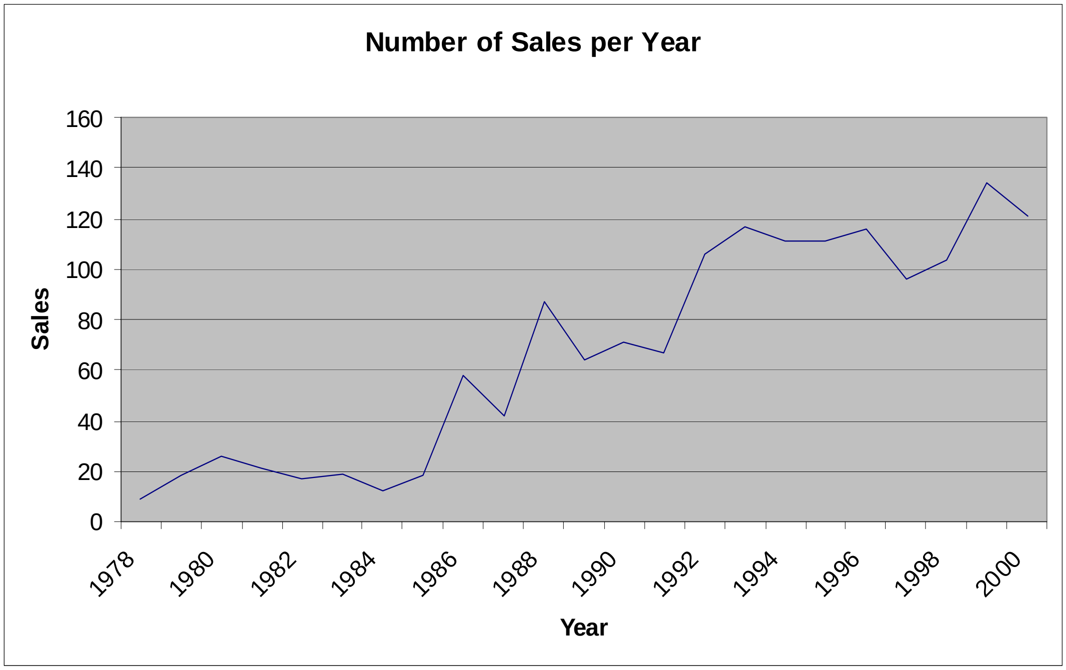

Figure 4. Land Sales per Year

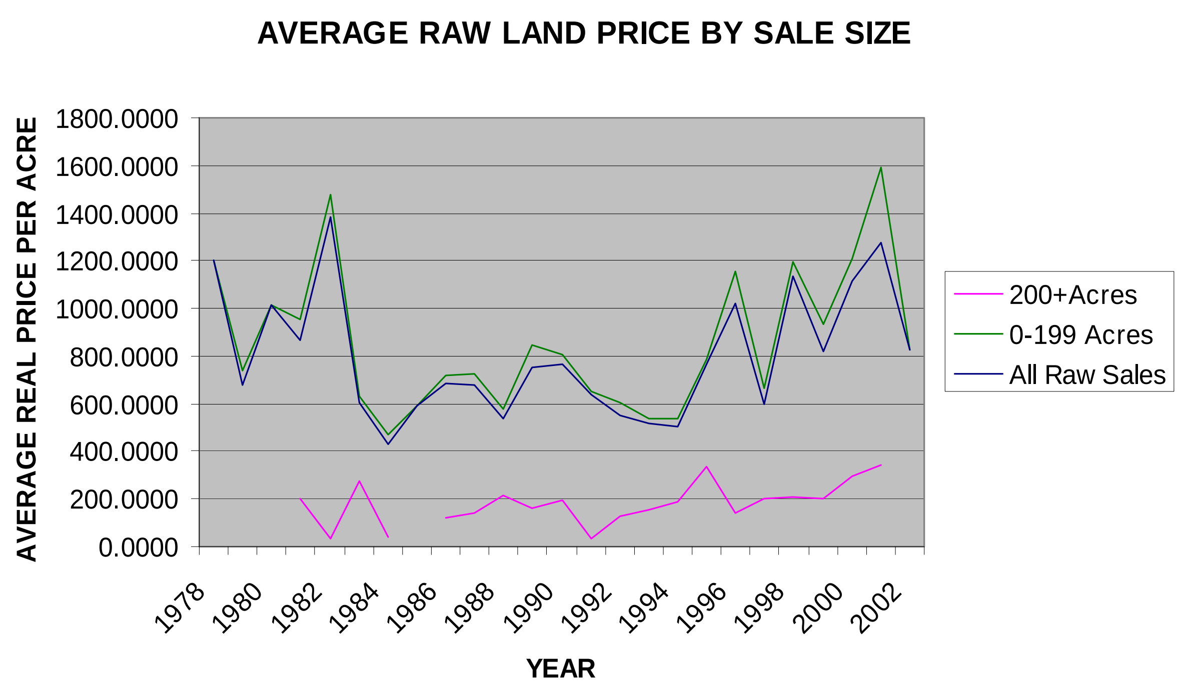

Figure 5. Trends in Price Per Acre of Raw Land

Table 1. Variables for the Logit Model

Variable	Description	Expected Sign
HBUILT	House built on parcel during the year	Na
“COUNTY”	Dummy for counties	?
BUFFER%MR	Percent of land within a radius of 0.1 or 1km in mixed pine or reservoir	?
BUFFER%PINE	Percent of land within a radius of 0.1 or 1km in pine plantation	-
BUFFER%AR	Percent of land within a radius of 0.1 or 1km in agriculture or residential (grassy/shrub)	+
BLUFF_FRONTAGE	Parcel located on bluff (0,1)	+
SIZELT90	Size of parcel less than 90 acres (0,1)	+
PERC_NF	% of parcel in native forest	?
PERC_PP	Percentage of parcel in pine plantation	-
PERC_OT	Percentage of parcel in grass/shrub	?
PAVED	Parcel on a paved road	?
NEIGHB_AVG	Average value of houses on parcels within 1km of a parcel	+
WATER	Parcel has public water (0,1)	+
SEWER	Parcel has public sewer (0,1)	+
GAS	Parcel has natural gas (0,1)	+
ELEC	Parcel has electricity (0,1)	+
NEARBY_HOUSES	Number of houses on parcels within 1km	+
DISTWHOLES	Distance to nearest parcel with a house, counting areas with parcels <10 acres as having houses	-
LNDISTCITY	Log of distance to nearest city (meters)	?
ADJ_PROT_AREA	Parcel adjacent to a protect area (0,1)	+
DIST_ROAD	Straight line distance to nearest major road (meters)	?
BUSOWNER	Parcel owner is a business (0,1)	+
TIMBEROWNER	Parcel owner is a timber company (0,1)	-
MORTGAGE_RATE	Mortgage rate on a home	-
POP_SE_CHANGE	Change in population in SE United States	+
MS_CONST_COST	Marshall Swift Construction Cost Index (deflated by CPI)	-
WILSHIRE	Wilshire stock index	+
UNEMPLOYRATE_TN	Unemployment rate in Tennessee	-
Interaction terms	*GE90: parcels 90 acres or more *1997: for period 1997 or later	

Table 2. Logit Results for Homebuilding Model

Marginal effects from logit Number of obs = 83603
chi2(47) = 677.17
Prob > chi2 = 0.0000
Log Likelihood = -3715.3375 Pseudo R2 = 0.0804

Dependent Variable: HBUILT

Independent Variables	Coef.	Std. Err.	P>z
Franklin County	-0.00022	0.000876	0.80
Grundy County	-0.00058	0.000639	0.36
Marion County	-0.00104	0.000758	0.17
Sequatchie County	0.001231	0.000715	0.09
Van Buren	-0.00111	0.000663	0.09
Warren County	-0.00074	0.0013	0.57
Marion1997	-0.00496	0.001225	0.00
Warren1997	-0.00503	0.002882	0.08
BUFFER%FOR, 0.1km	-0.00237	0.002749	0.39
BUFFER%PINE, 0.1km	-0.00465	0.00425	0.27
BUFFER%GRASS, 0.1km	-0.00662	0.003002	0.03
BLUFF_FRONTAGE	0.001431	0.000604	0.02
BLUFF_FRONTAGEGE90	-0.00345	0.001332	0.01
SIZELT90	-1.8E-05	9.81E-06	0.07
PERC_NF	0.002506	0.0018	0.16
PERC_NF1997	-0.00534	0.001705	0.00
PERC_NFGE90	-0.0046	0.001185	0.00
PERC_PP	0.006388	0.004348	0.14
PERC_PP1997	-0.02865	0.011432	0.01
PERC_PPGE90	-0.03883	0.015888	0.02
PERC_OT	0.007696	0.002035	0.00
PERC_OT1997	-0.00871	0.001871	0.00
PERC_OTGE90	-0.00854	0.008816	0.33
PAVED	-0.00087	0.000399	0.03
NEIGHB_AVG	1.33E-08	6.90E-09	0.05
WATER	0.000974	0.000421	0.02
SEWER	0.00085	0.000933	0.36
SEWER1997	0.006597	0.001352	0.00
GAS	0.002662	0.001148	0.02
ELEC	0.00327	0.00048	0.00
ELECGE90	0.001785	0.000834	0.03
NEARBY_HOUSES	0.000159	3.01E-05	0.00
DISTWHOLES	-4.18E-06	1.01E-06	0.00
DISTWHOLESGE90	3.97E-06	1.07E-06	0.00
LNDISTCITY	8.41E-05	5.21E-05	0.11
ADJ_PROT_AREA	-0.00139	0.001061	0.19
DIST_ROAD	1.54E-06	4.93E-07	0.00
DIST_ROADGE90	-5.64E-06	1.93E-06	0.00
TIMBEROWNER	-0.00858	0.004016	0.03
BUSOWNER	-0.00502	0.001635	0.00
BUSOWNER1997	0.004498	0.002103	0.03
MORTGAGE_RATE	-5.2E-05	0.000125	0.68
POP_SE_	2.82E-09	4.30E-09	0.51
MS_CONST_COST	-0.0019	0.007755	0.81
WILSHIRE	3.82E-07	1.31E-07	0.00
WILSHIRE1997	3.47E-07	1.72E-07	0.04
UNEMPLOYRATE_TN	-0.00014	0.000179	0.44
CONSTANT	-0.02558	0.005769	0.00

Table 3. Factors Affecting Probability of Home Construction

Significant variables with positive effect

BUFFER%MR, 0.1km (relative to native forest)
BLUFF_FRONTAGE, SMALL PARCELS
SIZELT90
PERC_AR>PERC_AR1997 (relative to native forest)
NEIGHB_AVG
WATER
SEWER, after 1997
GAS
ELEC, particularly after 1997
NEARBY_HOUSES
LNDISTCITY
DIST_ROAD, small parcels
WILSHIRE

Significant variables with negative effect

BUFFER%AR, 0.1km >BUFFER%PP, 0.1KM (relative to native forest)
BLUFF_FRONTAGE, LARGE PARCELS
PERC_PP1997
PERC_PP, LARGE PARCELS
PAVED
DISTWHOLES for small parcels
DIST_ROAD, large parcels
TIMBEROWNER (less likely than business owner)
BUSOWNER, particularly before 1997

Forecasting Land Use Change and Environmental Consequences for California's Coastal Watersheds

Kathleen Lohse, David Newburn, and **Adina Merenlender (presenter)**, University of California at Berkeley

Abstract

Land-use change has received less attention than other threats to natural systems and in particular, exurban development is poorly understood despite the fact that it is the fastest growing type of land use in the United States. In this study, land use and cover information was integrated with watershed variables at two different scales resulting in new insights regarding the importance of addressing the environmental impacts of exurban development. The results from a coarse scale examination of the relationship between land cover and in stream habitat demonstrate that the proportion of agriculture and urban development at a watershed scale can be useful for predicting downstream embeddedness (amount of fine sediment in fish spawning gravels). Findings from our study indicate, for the first time, that urban and exurban development patterns have differential impacts on streams, suggesting that it is no longer appropriate to aggregate these land use types in risk assessment and forecast models. Improved parcel-level land use change models were used to estimate the expected changes to land cover due to land use change and how these changes may impact future stream conditions. This approach provides thresholds of different types of land use change beyond which stream habitat is likely to be impacted from increased sediment, which in turn can influence anadromous fish population recovery.

Introduction

Land-use change has received less attention than other threats to natural systems such as global climate change and air and water pollution. This is true despite the fact that land-use change is the primary driver of habitat loss and ecosystem degradation and greatly exacerbates most of the other threats to the environment (Harte 2001). Land-use change has multiple socio-economic drivers and complex biophysical outcomes that generally elude our ability to provide a technical fix for the problems generated. In general our approach has been to address the process and pattern of past land-use change, forecast future land-use change, and determine the risk of these changes to the environment to help plan for a more sustainable future.

In particular, the characteristics associated with and processes that lead to exurban development are poorly understood despite the fact that this is now the fastest growing type of land use in the United States (Theobald 2001). This lower density development is different than the dense suburban development that commonly occurred from 1960 to 1990. Exurban development results in an unorganized scattering of homes on large parcels of land (1 unit/4-16 ha or 10-40 acres) along rural roads that do not have street lights, which rely on private water wells and individual sewage systems (Theobald 2001).

The increased rate of exurban development, along with the larger land area required to support it, means that ten times the amount of land in the United States was converted to low-density development as compared to urban densities (at least 1+ unit/4 ha or 10 acres) in 2000 (Theobald 2001). Estimates based on night-time satellite imagery suggest that 37 percent of the U.S. population now lives in exurban areas that account for 14 percent of the land area. Purely urban areas including traditional dense suburban development account for only 1.7 percent of the land area and house 55 percent of the population. In contrast, rural areas (84 percent of the land area) contain only 8 percent of the population (Sutton et al. 2005). Here we demonstrate the importance of addressing this type of develop when exploring land use change and its impacts to the environment in coastal California watershed.

Land-use is thought to be a primary cause of sediment production and delivery to streams but predicting in-stream sediment levels based on patterns of land use within a watershed have not been well-developed (Nilsson et al. 2003). It has been suggested that building empirical relationships between land use and observed sediment fluxes or concentrations may be a useful approach (Nilsson et al. 2003). In particular, sedimentation has been identified as a primary agent degrading freshwater ecosystems and limiting the persistence and recovery of salmonid populations along the Pacific coast of the United States because high levels of fine sediment (< 2 mm diameter) in spawning gravels are correlated with low survival of salmonid eggs and alevins (Kondolf 2000).

Exploring the relationship between land use, excluding and including exurban development, and environmental impacts is an important first step. For this study, we did this by examining the relationship between land cover and the condition of down stream habitat using land use/cover data at two different resolutions – TM Satellite data and parcel level county data. Satellite imagery is commonly used to determine land use, yet can not resolve low density residential development. Once relationships between land use and impacts to stream habitat are established we then used parcel-level land use change models to forecast the consequences of likely future change on down stream habitat.

Methods

Study Region

The Russian River basin is located in Sonoma and Mendocino Counties in northern California (Figure 1). The 3,850 km^2 basin is underlain primarily by the Jurassic-Cretaceous-age Franciscan Formation and experiences a Mediterranean climate with cool, wet winters and hot, dry summers, with mean annual rainfall ranging from 69 to 216 cm. Natural vegetation consists mostly of mixed-hardwood forests, oak savannas, and grassland with conifer-dominated forests occurring near the coast and intermittently on north-facing slopes throughout the basin. Primary land uses include vineyards, timber harvest, urban, and residential development. Currently, there are high rates of land-use change on the hillslopes with conversions from natural vegetation to vineyard (Merenlender 2000) and suburban and exurban development (Merenlender et al. 2005).

Analysis

We developed statistical models to explore the relationship between upland land use and stream habitat at two different resolutions. The first was done using satellite data for land cover classes and the second used land cover types designated by Sonoma County at the parcel level. In both cases, we draw on existing habitat data at the reach scale from field surveys by the California Department of Fish and Game. Specifically, we used embeddedness scores as the dependent variable. Between 1997 and 2000 field crews recorded the concentration or level of fine sediment within gravel and cobble substrate, termed "embeddedness," at each potential spawning site on a four-level, ordinal scale, from one (very low levels of fine sediment) to four (very high levels of fine sediment). Through dynamic segmentation and calibration, we spatially linked reach-scale data to a drainage network within the GIS.

We delineated approximately 150 watersheds in the Russian River basin and extracted watershed and land use change metrics that were potentially important in determining in-stream and watershed scale responses. For the coarse scale analysis we used land classifications based on LANDSAT TM imagery to determine the proportion of watersheds covered in different land uses (e.g. urban, agriculture, forest). We then examined the statistical relationships between land use /land cover and embeddedness. Furthermore, we examined the scale of influence of land use cover within watersheds as well as across watersheds.

To examine the impacts of rural residential development and couple empirical regression stream habitat models with the land use change models, we developed new statistical models based on the land cover as designated by parcel level data and tax assessor data rather than LANDSAT imagery data. Developing parcel-level land use maps also allowed us to capture individual decision-making processes and to measure the effects of different residential densities (low, medium, and high). For this scale of analysis, we selected watersheds with stream gradients less than 0.03, to evaluate depositional stream reaches most likely impacted by sediment. Based on these criteria, we selected 64 watersheds (surveyed from 1994-1997) for model development and 41 watersheds (surveyed from 1998-2002) as a validation set. Watersheds ranged in size from from 500 to 18,165 ha,

We developed multiple ordinal logistic regression models to examine the relative contribution of land use at the parcel level on embeddedness. Multiple ordinal logistic regression applies maximum likelihood estimates (MLE) after transforming the dependent variable into a logit value, the natural logarithm of odds of the dependent occurring or not occurring;
$\log (P_i/1-P_i) = B_i + B_1X_1 + B_2X_2 + B_3X_3$ where i = 1, 2, and 3 rank response (response-1). Much like ordinary least squares regression models, multiple ordinal logistic models can be used to determine the percent of the variance in the dependent variable explained by the independent and rank the relative importance. Unlike OLS, logistic regression models do not assume linearity of relationships and do not require normally distributed data. Rather, logistic functions model a threshold response, in this case, the probability

of reduction in substrate quality associated with increases in different land use, periods of land use or cumulative land use.

Model performance was evaluated based on usefulness (strength of the relationship, pseudo-R^2), accuracy (percent of correctly predicted maximum likelihood estimators), and significance (model chi-square or deviance). Restricted chi-square tests were employed to test the importance of the explanatory variables and their additivity.

The spatially explicit land-use change model used for the final application of this research was constructed using parcel-level data (Bell and Irwin 2002). The model is conditioned on the initial land-use state, taken as "developable" parcels in 1990. This excludes those lands protected in parks and reserves and parcels already converted to residential, vineyard or other high-intensity land uses prior to 1990 based on existing land-use maps. Land-use conversion is defined as transitions from developable parcels in 1990 to either a residential type or vineyard use during the period 1990-2000. The conversion decision is considered irreversible due to the substantial up-front fixed costs. The classes of residential densities used are in Table 1. Because Suburban and Exurban were highly correlated ($r^2 = 0.68$), we aggregated these two classes. The land use change models were calibrated separately for each of the major land uses since the likelihood of development for each land use type depended on different factors.

Table 1: Housing density land use classification (adapted from Theobald 2003).

Housing density class	Acres/structure	Housing density (structures/acre)	Residential land use
Very High	0.25	≥ 4	Urban
High	0.25-1	≥1	Urban
Medium	>1-5	<1 and ≥ 0.2	Suburban
Low	>5-40	<0.2 and ≥ 0.025	Exurban
Very Low	>40	<0.025	Rural

Given the three possible land-use outcomes over the period 1990-2000, a multinomial logit model was employed to explain land-use transitions as a function of parcel site and neighborhood characteristics. The Sonoma County Tax Assessor's Office database provides the land-use data source, which was linked to the digital parcel map within a GIS. Parcel boundaries permitted the overlay and extraction with GIS layers to obtain many site and neighborhood characteristics on land quality, accessibility to urban centers, public water and sewer services, zoning and neighboring land use. For example, average percent slope and elevation in meters was calculated for each parcel. Growing-degree days, summed over the April to October vineyard growing season, serves as a proxy for microclimate. A dummy variable was used to represent whether a given parcel is situated within the 100-year floodplain. An optimal routing algorithm within the GIS was used to calculate the minimum travel time in minutes between each parcel and San Francisco along the road network, utilizing weighted travel speeds of 55 mph on major highways and 25 mph on county roads.

Logit parameters are potentially biased in the presence of spatially autocorrelated errors. We estimated logit on random stratified bootstrapped samples taken from the full data set. These samples did not have sample-selection bias and had less spatial autocorrelation than the full sample, because the parcels were farther apart. This bootstrapped subsampling technique did not have noticeably different parameter estimates or prediction errors as compared to standard logit estimation.

Finally, we forecasted substrate quality and its uncertainty based on the average land use change for 2010. Estimated coefficients from the multinomial logistic regression are employed to predict the relative probability of land-use change, since the site characteristics for all parcels are known within the GIS. For this prediction phase, explanatory variables for percentages of neighboring land uses are updated from 1990 to 2000. The model output is the relative probability of future residential and vineyard development for each of the 16,773 developable parcels.

These models were used to convert the current land cover types for each parcel to their estimated future type of land cover. Land cover conversions for 2002-2010 were estimated using a Markov decision process, where transitions were considered stochastic with decisions partly informed by site specific characteristics. Monte carlo simulation methods were repeated 1000 times to obtain the average area converted to exurban, urban, and vineyard development. Then we were able to calculate the percent of the different land uses in each watershed (% of total watershed area) for the past (1990), recent (1997), current (2002) and future (2010) time periods.

Results

Results from our first set of analyses, using land cover designations from satellite imagery, showed a strong relationship between embeddedness and proportion of watersheds in urban and agricultural land use. The power of the empirical regression model depended on the size of the watershed. Generally, the watershed scale was the best predictor of embeddedness compared to other local or drainage network scales of influence (Opperman et al. 2005).

The parcel level models again demonstrated that agricultural land in the watershed is a significant predictor of embeddedness, but they also reveal the importance of even low density housing on stream condition. Preliminary results show that low-medium residential housing and agriculture have a strong impact on the concentration of fine sediment in streams. During the land use transition period from 1990 to 1997, 92% of parcels developed for housing were converted to the urban housing class. In contrast, 77% of the acreage developed for housing was converted to exurban housing (60% as exurban and 17% as suburban). These results demonstrate the importance of addressing exurban development in examining land use across these watersheds. Simple logistic regression models of recent development (1997) revealed significant and negative nonlinear effects of different land uses on substrate quality (Figure 2). While urban has the most adverse impact on embeddedness, this is followed by exurban development and then vineyards.

The strongest multiple ordinal logistic regression model to explain embeddedness combines past development of exurban housing with expansion of urban and vineyard during the recent growth period from 1990-1997. The combined land use model predicted the maximum likelihood estimator for embeddedness with 80% accuracy and fell within 95% confidence intervals for watersheds surveyed from 1998- 2002 (when one outlier stream with channelized banks was removed).

Estimation results for this land-use change model indicate that conversion to vineyard use is more likely on areas with lower slope and higher growing-degree days (warmer microclimate). Steeper slopes raise expected vineyard establishment costs and lower grape yields, while cooler coastal microclimates are less likely to allow grapes to reach maturity. Vineyards are also more likely in areas designated for “land intensive agriculture” or “diverse agriculture” under the 1989 General Plan. These zoning designations correspond to the prime agricultural areas within the County, and future residential development is highly restricted.

Residential conversion is more likely in areas zoned for rural or urban residential, the baseline zoning category in table 1, and more likely on parcels zoned for smaller minimum lot sizes. The importance of zoning for residential conversion is clear since higher density zoning increases rents per acre associated with residential uses. Areas with access to urban services are estimated to be more likely to be developed for residential use, whereas residential conversion is less likely on steeper slopes and within the 100-year floodplain. Residential use was expected to have higher likelihood in the southern region of Sonoma County; however, the estimate coefficient for travel time to San Francisco is positive. The percentage of neighboring 1990 urban development increases the likelihood of residential conversion, whereas the percentage of protected open space did not appear to significantly affect residential conversion.

Forecasts for 2010 stream conditions resulted in different estimated embeddedness levels for each watershed and with the level and type of development (Figure 3). Various development scenarios can be run to evaluate high and low growth options.

Discussion

This research shows that increased sediment from urban, exurban, and agricultural areas and associated roads may be one cause of stream habitat degradation that could potentially influence salmonid abundance and recovery. This landscape-scale analysis emphasizes the overarching importance of large-scale land-use patterns on environmental condition. In areas where rural residential development is pervasive it is critical to be able to measure the extent of this type of development – a land use type that is not detectable using many of the readily available methods of assessing land cover/use based on remote sensing.

Understanding the influence of upland land use on stream habitat that influences salmonid survivorship is important to consider for restoration strategies. Much attention and resources have been spent on piece-meal stream restoration and sediment control efforts at the local scale (e.g., bank stabilization). This research indicates that the benefits of localized restoration efforts may be overwhelmed by ongoing land use at larger scales. To improve salmon habitat conditions, restoration efforts should emphasize protecting riparian corridors throughout entire watersheds and promoting programs or policies that ameliorate the influence of urban development, roads and agricultural land use.

One of the major advancements of this work is the calibration of LUC models to distinguish among different levels of residential density. Findings from our study indicate that urban and exurban development patterns have differential impacts on streams. Zoning that allows for low density residential development may have adverse impacts at the larger watershed scale possibly due to heavily used unpaved road networks and development of steep hillsides.

In our study area it would not be appropriate to aggregate all types of residential development into a single land use type in risk assessment and forecast models. Rather we need to move towards considering human development along a continuum (Theobald 2004). We further suggest that parcel level data may be the fundamental unit of land use change analysis because it represents the economic decision unit for land owners and resolves issues of geographical scale and boundary issues that have long hampered the progress in ecological forecasting scale (Nilsson 2003). Such data will help to overcome the challenges of coupling ecological and economic forecast models that operate at different spatial and temporal scales, and help us move towards a more sustainable future.

The models developed during this research project were also used to improve targeting for land conservation (Newburn et al. 2006). This approach incorporates threat and cost into the selection criteria for prioritizing land conservation and also has application to evaluating outcomes of private land conservation tools such as conservation easements (Merenlender 2004). To implement the ideas developed from this research we work closely with the Sonoma County Agricultural Preservation and Open Space District and the Sonoma County Water Agency.

Literature Cited

Bell, K., and E. Irwin. 2002 Spatially Explicit Micro-Level Modeling of Land-use Change at the Rural-Urban Interface. Agricultural Economics 27:217-232.

Harte, J. 2001. Land use, biodiversity, and ecosystem integrity: the challenge of preserving earths' life support system. Ecology Law Quarterly 27: 929-965.

Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Trans. Am. Fish. Soc., 129: 262-281.

Merenlender, A. M., Brooks, C., Shabazian, D., gao, S., and R. Johnston. 2005. Forecasting exurban development to evaluate the influence of land-use policies on wildland and farmland conservation. Journal of Conservation Planning 1(1):64-88.

Merenlender, A. M., Huntsinger, L., Guthey, G., and S. K. Fairfax. 2004. Land trusts and conservation easements: Who is conserving what for whom? Conservation Biology 18(1):65-75.

Merenlender, A. M. 2000. Mapping vineyard expansion provides information on agriculture and the environment. California Agriculture 54(3):7-12.

Newburn, D., Berck, P., and A. M. Merenlender 2006 Habitat and Open Space At Risk of Land-Use Conversion: Targeting Strategies for Land Conservation American Journal of Agricultural Economics 88(1):28-42

Nilsson, C., J. , Pizzuto, E., Moglen, G. E., Palmer, M. A., Stanley, E. H., Bockstael, N. E. & Thompson, L. C. (2003) Ecosystems **6,** 659-674.

Opperman, J. J, Lohse, K., Brooks, C., Kelly, N. M., and Merenlender, A. M. 2005. Influence of land use on fine sediment in salmonid spawning gravels within the Russian River basin, California. Canadian Journal of Fisheries and Aquatic Science 62:2740-2751

Sutton, P., T. J. Cova, and C. D. Elvidge. 2005. Mapping "exurbia" in the conterminous United States using nighttime satellite imagery. Geocarto. In press.

Theobald, D. M. 2001. Land-use dynamics beyond the American urban fringes. Geographical Review 91: 544-564.

Theobald, D. M. 2003. Targeting conservation action through assessment of protection and exurban threats. Conservation Biology **17,** 1624-1637.

Theobald, D. M. 2004 Placing exurban land-use change in a human modification framework. Frontiers in Ecology and the Environment **2,** 139-144.

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Figure 1. Location of the Russian River basin in California.

Figure 2.
Along the x axis is the percent of exurban, urban, and vineyard land use types and the y axis represents the probability of the ranked embeddedness score. These odinal logistic regression models results show nonlinear effects of increasing land use on embeddedness. Increases in land use in the watershed reduced the odds of low embeddedness occurring.

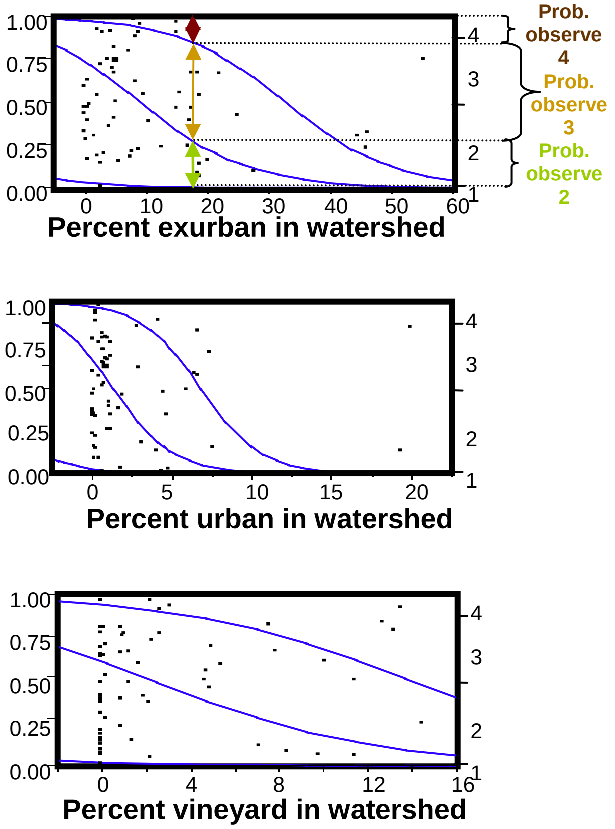
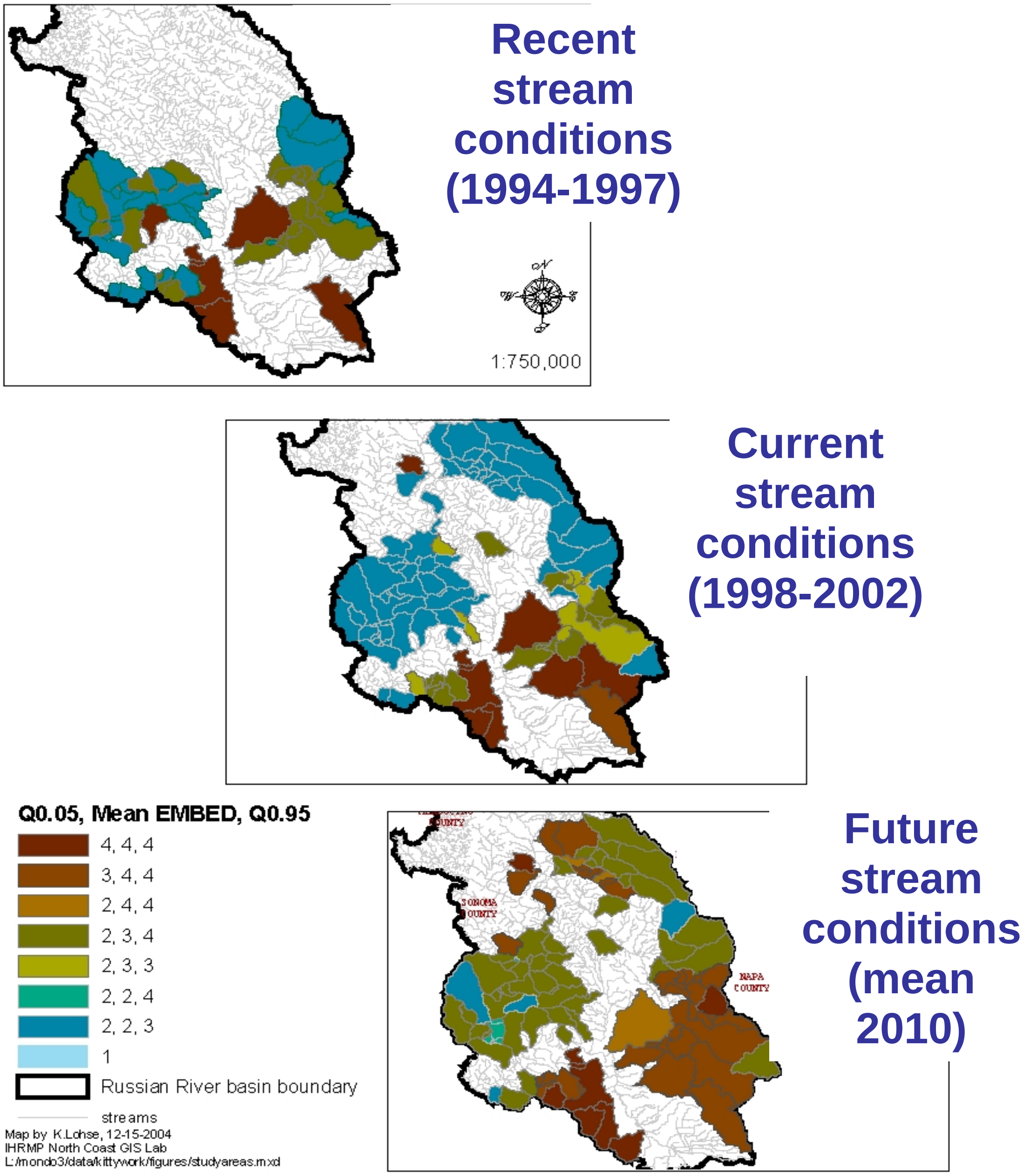


Figure 3. : Predicted patterns of embeddedness based on minimum, average, and maximum levels of land use in the build and test watersheds. Maximum levels of development were based on the mean and 2 standard errors predicted from Monte Carlo Simulations. Minimum levels of development were based on 25% of the average development scenario.



Map by K.Lohse, 12-15-2004
IHRMP North Coast GIS Lab
L:/mondo3/data/kittywork/figures/studyareas.mxd

Modeling land use change:
discussion of Gottfried et al. and Merenlender et al.

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Based on a discussion presented at the EPA workshop, "Socio-Economic Causes and Consequences of Future Environmental Changes"

U.S. EPA Region 9
San Francisco, CA

17 November 2005

Introduction

This note discusses two reports presented at the EPA workshop, “Socio-Economic Causes and Consequences of Future Environmental Changes,” held 17 November 2005 in San Francisco, CA: “Determinants of land conversion on the southern Cumberland Plateau,” presented by Gottfried, and “Forecasting land use change and environmental consequences for California’s coastal watersheds,” presented by Merenlender and Newburn.

Models for forecasting land use changes can be useful for environmental policy evaluation in at least two ways. First, they can be used to characterize the changing baseline (no-policy) conditions against which proposed policies should be compared. Second, they can aid in the geographical targeting of habitat protection efforts. Although the research projects discussed in this note are not yet completed (which perhaps can account for some of the questions I raise below), it is clear that these projects are tackling a range of interesting and important questions about the drivers of land use change and that they have the potential to make contributions along both dimensions indicated above.

I will address several issues specific to each paper in turn, and then raise a few policy (and other) questions and offer some recommendations that may be relevant for both sets of authors.

Gottfried et al.

The overall goals of the larger research program lead by Gottfried are to develop a spatial socioeconomic model of land use/land cover (LULC) change for the Southern Cumberland Plateau, integrate the LULC change model with bird, amphibian, and water quality landscape models, and to use the integrated models to evaluate potential environmental impacts of, and policy responses to, likely socioeconomic events or trends.[1] The report presented at the workshop focused on one component of this larger research agenda, the determinants of homebuilding in the Cumberland Plateau.

The report begins with a review of the economic literature on land use change that neatly sets the stage for a presentation of the current work. Next the authors develop a “theoretical model of land use change,” which comes in the form of a series of stylized equations and accompanying prose descriptions of the process of land use change through the emergence of markets for new land uses and the search by individuals for the purchase of parcels and their conversion. However, it is not clear that the stylized equations add much of substance to the narrative description of the theorized process of land use change. The authors could consider either (1) tightening up this section by removing the stylized equations (distinctions could still be made in narrative form between the different components of the land use change process that currently are highlighted by the equations), or (2) expanding this section to make better use of the equations by way of a more explicit linkage to work done by previous researchers and the authors’ own intentions for operationalizing the framework. Have

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[1] http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/5436

previous researchers focused on just one or a few of the separate processes identified by each stylized equation? Have previous researchers combined certain processes where they might be better treated separately? Will the authors attempt to model each of these processes independently? If so, how will they be combined in the end? And so forth.

While it is difficult to place some of the preliminary results into the context of the larger research project, at least one result is particularly suggestive. In the logit model of homebuilding a dummy variable for years after 1996 is found to be statistically significant. If I understand the authors' interpretation correctly, this is taken as evidence of a large scale structural change in the market owing to massive divestitures of pine plantations by the few large landowners in the area, which in turn may have been partly influenced by the southern pine beetle outbreak around this time. Earlier in the report the authors discussed the importance of changes in large scale economic (or in this case ecological) conditions as drivers of land use change, and their interpretation of the logit modeling results seems consistent with that idea. In this case an essentially unpredictable ecological change at a scale much larger than the study area, the pine beetle outbreak, led to decisions by a small handful of individuals in (or out of?) the study area, owners of pine plantations, which finally led to the changes in land use the authors are interested in forecasting.

This raises questions about the kinds of explanatory variables that should be included in the model, the appropriate scale at which to measure them, and the potential accuracy of long run forecasts of land use change. If much land use change is due to largely unpredictable shifts in macro-economic or ecological conditions, then how much confidence can we have in the quantitative predictions of models that exclude such factors? Can we rely on the idea that such unpredictable structural changes will likely affect both the baseline and policy cases in a similar manner so our policy evaluations, which rely on differences between baseline and policy conditions, should still be reliable? These questions are not taken up by the authors in this report, but their results begin to suggest future research along these lines.

The report concludes with a brief description of plans to "apply the theoretical framework developed above to a multinomial probit analysis of changes in LULC." The authors can be forgiven for restricting the present report to the preliminary results currently available and plans for future work. However, a more detailed description of how the theoretical model, which isolated a series of causal processes that combine to determine the rate of land use change, will be operationalized with a single statistical model would be useful.

Merenlender et al.

The overall objective of the larger research program led by Merenlender is to "examine the environmental consequences of land use change for California coastal watersheds that impact anadromous fish," and the specific goals are to develop land use change models, forecast land cover changes, and predict the effects of those changes on stream conditions and salmon populations.[2] The report presented at the workshop contains preliminary results from one

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[2] http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/5627/report/0

component of this larger research program: an empirical model of the effects of watershed land use conditions on the quality of stream habitat. (Two other models also were mentioned in the report: a model of land use change, and a simulation exercise that used the land use change model and the watershed embeddedness model together to forecast future stream conditions. However, the main focus of the report was on estimating the relationship between land use conditions and stream habitat quality.)

The report used a regression model to characterize the effects of various land use types – specifically agriculture, urban, and exurban lands – on embeddedness in downstream river reaches at various spatial scales. The fit of the regression model was highest when the explanatory variables were measured at the watershed scale, and the effects of each land use type were found to be substantially different. It appears that the amount of urban and vineyard acres in a watershed increases embeddedness at a higher rate than exurban acres, but this ordering was not completely clear from the graphs presented in the report. A table of regression results and an expanded prose interpretation of the results would be helpful here.

It also was not immediately clear what the per household effect on embeddedness was for urban and exurban land uses. Strong claims were made about the importance of distinguishing between urban and exurban land uses, so an expanded discussion of their differential effects on embeddedness would strengthen the report. In particular, even though urban areas appear to have a larger impact per acre, they could have a smaller impact per household if the difference in the average housing density between the two land use types is large enough. This could have a bearing on recommendations one would draw from these results for zoning restrictions or other similar land use policies.

Some general policy questions and recommendations

Several policy questions and recommendations apply more or less equally to both reports. First, a general issue that both research teams should be able to address is how land use protection efforts should be targeted geographically. An agency interested in spending funds on land protection generally will confront a continuum of expensive land in immediate danger of conversion to inexpensive land that may not be converted for a long time to come, if ever. The nature of the tradeoff here is obvious – with a limited budget one could purchase a small amount of land that very likely would be converted otherwise, or one could buy more land that may not be in need of protection.

Recently, the Merenlender research team has published an essay on this topic in *Conservation Biology* (Newburn et al. 2005). It should be possible to say something concrete in specific cases if the empirical relationship between the probability of conversion and land values is known. Just such a modeling exercise is one of the goals of both of these research projects.

As a simplified first cut at addressing this question, consider using either probit or logit regression to estimate a model of land conversion probabilities as a function of land values (plus whatever other explanatory variables are thought to be important). For example, a logit model with just two land use states, undeveloped or developed, would be:

$$P_i = \frac{e^{a+bV_i}}{1+e^{a+bV_i}}$$

where P_i is the probability that parcel *i* will be converted from an undeveloped state to a developed state (over some time period of interest), V_i is the assessed value of parcel *i* (i.e., the price it should fetch if sold on the land market), and *a* and *b* are parameters to be estimated.

Now consider a land protection agency who wants to maximize the amount of land left in an undeveloped state. This gives the following optimization problem:

$$\underset{x_i}{Max} \quad I - \sum_{i=1}^{I} P_i \left(1 - x_i\right)$$

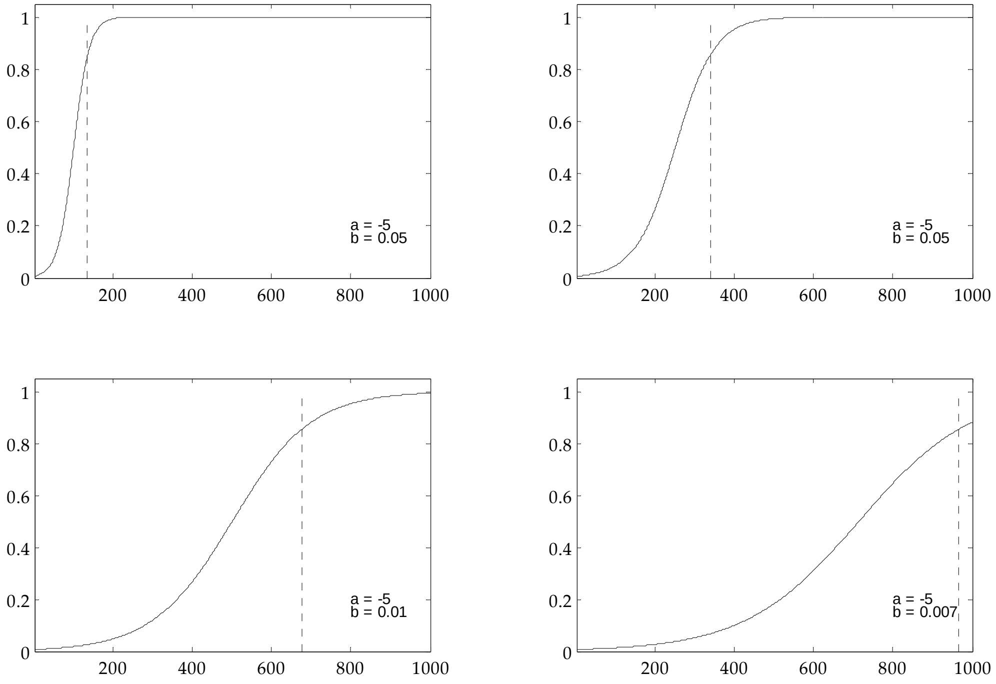
subject to:

$$B \geq \sum_{i=1}^{I} x_i V_i$$

where x_i is 1 if parcel *i* is purchased and 0 otherwise, *I* is the total number of parcels (all land parcels are the same size in this example), and *B* is the amount of funds available for purchasing land. The expression to be maximized is the expected area of land left in an undeveloped state, and the land protection agency is constrained by a limited budget. Posed this way this is a classic knapsack problem, the solution of which is to choose parcels in decreasing order of their benefit-to-cost ratios (Dantzig 1957). Since the objective is to maximize the total expected area of undeveloped land, the benefits are P_i and the costs are V_i.

With the *P(V)* function estimated using the logit model, it is straightforward to find the value of *V* that maximizes the expression for the benefit cost ratio, $R(\equiv P/V)$. A few examples are shown in the graphs on the following page.

The solutions (found numerically by identifying where $\partial R/\partial V$ switches from positive to negative as *V* increases) are at the shoulder of the S-curve that describes the probability of conversion as a function of land values (identified by the vertical dashed lines in the graphs). This suggests that more land will be left undeveloped if the land protection agency targets parcels for purchase that are somewhat less than 100% certain to be developed otherwise, but not too much less. The optimal probabilities for targeting in the four examples below are between 80-85%. Also note that a corner solution is possible (not shown in the graphs). If the probability of conversion even for the most valuable parcels is low enough, the agency should target the highest valued parcels for purchase.



This model is overly simplified in several ways (I have been particularly vague about the dynamic aspects of the problem and the time horizon), but I believe it points to the potential practical utility of the research being conducted by both Gottfried and Merenlender. It would be instructive to work out this problem in particular case studies using empirical results that should emerge from both of these research projects.[3]

Another suggestion for both authors is to review the behavioral rationale given for the standard multinomial logit model of site choice in the recreation demand literature (e.g., Haab and McConnel 2002, especially Ch 8 and App B). The behavioral and informational assumptions there are clearly spelled out: there is maximizing behavior assumed on the part of the recreators, some variables are assumed unknown to the researcher but known to the recreators, and so forth. There may be a close analogy to be made with the land use change case: a parcel is either left in its current use or converted to another use in any given time period depending on which has the highest expected NPV, similar to a recreator choosing to stay at home or to visit a particular recreation site on any give choice occasion depending on which will deliver the greatest utility. This might help to forge a tighter link between the behavioral economic model and the statistical model used to analyze the land use change data.

Other considerations also may be important when choosing between a reduced form and a structural modeling approach to land use change. For example, a naive application of a

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[3] In a forthcoming article, Newburn et al. (2006) use a dynamic programming approach to address this issue in a much more rigorous way than the simple model sketched here.

hedonic property value model for forecasting land use changes typically would assume that the cross sectional data used to estimate the model represented a market equilibrium. What are the implications if the data were collected when the market was going through a major adjustment? What if the market is always adjusting? With time series data on land use conditions and macro-economic conditions, research in this area has the potential to estimate dynamic models of property values and land use changes. This would allow researchers to address such questions as: How long does a differential between expected PV and conversion costs persist; in other words, how long does it take for land markets to achieve equilibrium? Do observed conditions approximate an equilibrium conditional on, say, last year's macro economic conditions? Or do these larger scale drivers change so rapidly and unpredictably relative to the speed of adjustments in the land market that observed prices are always adjusting? What implications would this have for policy evaluation? Under what conditions will using a static hedonic property model that assumes the market is in equilibrium when it actually is in the process of adjustment lead to biased forecasts of land use changes?

Finally, it would helpful to know what types of policies the authors imagine their research informing, both in general and specific terms. Does the analyst just get qualitative lessons in the form of rules of thumb, or does the analyst get generally applicable numerical models that can be applied in many other settings if the appropriate data are collected? Can the models be used to evaluate zoning changes, water withdrawal restrictions, within-watershed land use changes including riparian buffers or set-backs, on farm best management practices, etc? What "instructions for use" would the authors give to policy makers or analysts for applying their models and results? Answers to these questions are rarely spelled out in scholarly articles, which means that professional policy analysts that want to use the results of research such as this often must fill in some large gaps as best they can. In my experience, this seems to be a major source of much uncertainty in the final policy analysis.

References

Dantzig, G.B. 1957. Discrete-variable extremum problems. *Operations Research* 5(2):266-277.

Haab, T.C., and K.E. McConnell. 2002. Valuing Environmental and Natural Resources: The Econometrics of Non-market Valuation. Northampton, MA: Edward Elgar.

Newburn, D., Berck, P, and A.M. Merenlender. 2006. Habitat and open space at risk of land-use conversion: targeting strategies for land conservation. *American Journal of Agricultural Economics* 88(1):28-42.

Newburn, D., Reed, S., Berck, P, and A. Merenlender. 2005. Economics and land-use change in prioritizing private land conservation. *Conservation Biology* 19(5):1411-1420.

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Session I Discussant

Comments on:
Gottfried's "Determinants of Land Use Conversion on the Southern Cumberland Plateau" and Merenlender's "Integrating Economic and Physical Data to Forecast Land Use Change and Environmental Consequences for California's Coastal Watersheds"

Thank you for giving me the opportunity to be here and to read these papers. I work on similar issues but using different techniques and reading these papers was a good chance for me to think about things differently, which is always a useful exercise. I will make a few general comments, then some specific comments on each paper, and then return to a few more general comments for this literature.

General Comments:

Both papers do two things that are important and helpful.

First, both papers use parcels as the unit of analysis. They have both argued that using parcels is a good thing and I am confirming that point. Often these data do not exist and we are forced to use other units of analysis and then do some hand-waving to interpret results. But, with the parcel as the unit of analysis we have a direct correspondence between the unit over which people make decisions and the unit of analysis, and that improves the discussion of policy and causality.

Second, most of the literature that uses this kind of analysis and these types of data sets focus on either urban or tropical settings, and today's papers focus instead on non-urban areas of the US. I am convinced, for the following reasons, that land use patterns away from cities but still in the US are important and understudied:

- Land in those areas provides ecosystem services (even though outside of protected areas) that are potentially quite important. In fact, I would hazard a guess that a large fraction of the ecosystem services of importance to the US are generated outside of urban areas, such as biodiversity protection, watershed protection, and recreation opportunities. In urban areas, some land certainly provides ecosystem services and benefits but those benefits may accrue largely to the local people, such as through view and dog parks. So, much of the land that generates ecosystem services is out of urban areas.
- In biodiversity protection, for example, both policy and ecological literatures emphasize the importance of biodiversity outside of protected areas and often on private land. The question of how to create incentives and policies to promote ecosystem service provision on private land has become large, and some programs such as CREP try to do that. But, without studies like the ones presented this morning, we have little information about land use and land cover change decisions on private land away from urban areas and so have little information about the potential response to policies aimed there.

- Should we expect land use patterns in these areas to be influenced by the same things as in urban areas and/or to respond to policy in the same way? If not, policy that is developed based on analysis of urban areas will not improve land use patterns in rural areas. These studies provide useful information about how land decisions in non-urban settings differ from those in urban settings.

Some Specific Comments on Adina Merenlender's paper:

In addition to the emphasis on non-urban location, I really like the development of a framework that seeks to link land use patterns to a conservation outcome/ecosystem service (here sediment that decreases spawning sites for salmonid populations). To further that sort of interdisciplinary connection, I suggest that the authors look at the watershed models that examine salmon populations as a function of water temperature and of riparian land use (such as those by Junjie Wu and others).

The paper focuses on the watershed as a whole rather than looking only at the riparian portions of the watershed, and I agree that that focus is important. Still, the riparian land use is particularly important in protecting rivers from sediment and from temperature and I imagine that it wouldn't be difficult, with such a great data set, to develop some riparian measures in addition to the watershed measures to examine their relative importance. Also, although many policies do aim at local scale improvements such as bank stabilization, as stated in the paper, millions of dollars are spent annually on implementing policies at the watershed level to protect salmonid species in Oregon alone.

The analysis here does not simply put forward averages but instead uses the probabilities of land use transitions to form the basis for generating 1000 possible future land use patterns (incorporating stochasticity based on those transition probabilities) and then analyzes the characteristics of that range or distribution of possible outcomes. I like that approach very much because it allows for more of a landscape style analysis rather than a per-parcel analysis. (It reminds me of work by Dave Lewis and Andrew Plantinga.) Ecosystem services are generated at a landscape scale and so moving from parcels – where the decisions are made – to the landscape generated by those individual decisions can be a particularly useful way of linking disaggregated decisions to the provision of ecosystem services. This mode of analysis also provides an opportunity to look at the spatial configuration of land use and the role of particular patterns on ecosystem outcomes and that opportunity has not yet been fully realized in the work presented thus far. I encourage the authors to think more in that direction.

Today's presentation discussed the role of zoning more than the paper did. I did have a concern in the paper that zoning decisions are made as a function of things like productivity and desirability of land uses and so there is some endogeneity there. But, in the presentation, the authors seem to be thinking about those aspects of zoning in an appropriate way.

Specific Comments on Gottfried's paper

The paper develops a model of the land market that I assume is meant to address characteristics of the land market in rural areas that are different from those in an urban area. I would like to see more discussion of those differences, perhaps linking to models of incomplete and thin markets as discussed in the development economics literature.

I would also like to know more about both the owner characteristics and about neighborhood characteristics. For example, why don't current owners convert to more highly valued uses? Why have they waited to expand pasture land? And does the amount of a particular land use, say horse stables, in the area alter the value of that land use (localized supply effects)?

As a new Oregonian, I would be remiss to not inquire about the issues of timber land in this region. First, are there links to the national phenomenon of diverse forest products companies selling off forest land to focus only on producing paper/wood goods as opposed to also producing timber? This research may be able to contribute to the discussion of that national trend. Second, the paper refers to a company with a mill located not too far away and that company's need to "feed" that mill. The mill's presence is potentially very important in driving the market – and the land use of pine versus hardwood. The mill needs raw wood every year – does that fact inform land management in the area and can that type of issue be teased out of these data? In Oregon, mills have closed down all across the state (due in part to restrictions on harvesting on federal land) and dramatically altered the location of timber production. That fact leads me to believe that some analysis about feeding that mill could prove important.

I would also like to see more detail or more use of the data in determining the divisions made here: lots under 90 acres versus larger; and pre/post 1999-2001. How can you use the data to test for differences across sizes and times rather than subdividing prior to analysis?

General Comments

Both papers find that open space is not significant in residential conversion. As someone who studies open space, who makes my own location decisions as a function of open space, and who sees developers incorporating open space into their decisions, this lack of significance bothers me. Is my research of no value? But maybe this result is exactly why we need analyses of non-urban settings: perhaps open space works very differently in less densely populated areas where people get many of those benefits from their own multi-acre sized lots. This lack of significance on open space, then, underscores the importance of doing research that distinguishes between land use decisions made in urban settings (where open space is typically quite important) and those made in non-urban settings, both through models and through empirical testing of those models.

The one thing that is missing from these papers and from most of this literature is a spatially-explicit behavioral model. I remember discussing "economies of configuration" with Professor Gottfried about ten years ago. Ecologists have been describing the importance of configuration for ecosystem services for at least that long. But economists have not yet done a good job of examining how disaggregated decisions by landowners add up to different configurations of land cover. This literature relies on proximity measures to a large degree and has not developed behavioral models of spatial configuration. Because many ecosystem services are a function of configuration of land uses, we need to understand how behavior leads to configuration.

Overall, both papers represent the tip of the iceberg in terms of what these projects will generate and contribute. Both research projects, in their use of parcels and in their focus on non-urban areas, take important steps toward understanding land use patterns in those settings and provide a foundation for exploring the links between policy, decisions, and ecosystem services or outcomes. And I applaud them for this work.

Summary of the Q&A Discussion Following Session I

Mark Johnson, (EPA Region 10)
Directing his question to Dr. Gottfried, Mr. Johnson noted that in his introductory remarks Dr. Gottfried had referred to “water quality proxies” but then hadn’t specified what those dependent variables were.

Dr. Robert Gottfried, (University of the South)
Dr. Gottfried responded, “Initially we were going to work with macro-invertebrates in the streams,” but he acknowledged that the data was difficult to collect and they didn’t have enough samples to connect land-use changes with that variable. Although he still feels “that would be a good way to go,” he stated that for now they are left with the “crude” proxy of “data about landowner types and what sorts of buffers have been maintained along riparian zones.” He said that he would “love to have a real sediment model operating, but that’s going to have to be down the road somewhere.”

Joseph Mihelarakis, (California Department of Transportation)
Mr. Mihelarakis wondered what was the motivating factor for Bowater’s divestiture of all their acreage, which comprised a significant portion of the area covered by Dr. Gottfried’s study. He added that he “didn’t get the connection between the demand for paper, which seems to be rising, and the lowering demand for pine in the region.”

Dr. Robert Gottfried
In response, Dr. Gottfried explained, “If I understand it correctly, newsprint demand is going down because of the internet and so forth, so there is that element.” He added that Bowater’s initial establishment of pine plantations was due, in part, to the insurance companies’ requirement that a paper mill have a secure supply of inputs. In other words, they needed a captive source of timber. He went on to explain that “these days with the amazing amount of pine that’s grown in the Southeast, they no longer have to have their own captive source” to demonstrate that they have a secure source of inputs. Consequently, Bowater and other paper companies are choosing “rather than have a long-term return off of land that’s rather low” to sell the land and put the money in other investments that offer a quick return—and to go ahead and buy pine on the market.

Dr. Gottfried wondered whether in the long run these paper companies are “in a sense shooting themselves in the foot” by selling off their internal production control capacities and totally relying on the market for their supply.

Pierre duVair, (California Energy Commission)
Mr. duVair addressed Drs. Merenlender and Newburn on “the causal relationships between land use change and degree of embeddedness or sedimentation,” saying he was “curious about the potential ability to distinguish between natural versus anthropogenic sources of sedimentation.” For instance, he wondered about the ability to “understand the relationship of construction and stormwater runoff versus climate change and variability and how that might influence natural erosion.”

Dr. Adina Merenlender, (University of California at Berkeley)
Dr. Merenlender began by re-emphasizing “how much variation there is in the embeddedness” and she related how they tried to at least tackle some of the data outliers and understand what was going on there. She said the research team, which was charged with studying land-use and forecasting land-use changes and hopefully making some predictions based on those forecasts, was strengthened by the addition of a geologist who was able to help present and analyze other possibilities. She added that, “Unfortunately, the historic timber harvest plan databases are rather limited, but we *were* able to get some idea of where the California Department of Forestry and Fire Protection had mapped timber harvest plans and we also looked at different geologies and found that it did not enhance the model in any way.” She quickly added that the models used “are not 100% predictive”—they are generally happy to get 70-80% explanatory power out of them—“so, there is a lot about the system that we cannot explain by the simple variables that we try to plug in.” She agreed that there is a lot going on regarding the general morphology and geology and other aspects that are studied on a more site-specific scale.

Addressing targeting, Dr. Merenlender emphasized the importance of looking at priorities for acquisition over time. She noted that “as you allocate your budget for conservation, when one thinks about threat and acquiring sites that *are* threatened, it’s important to think about acquiring those sooner, as threat progresses and changes the patterns on the landscape, than to acquire the next set of threatened resources.” She cited the current situation along the Pacific coast where coastal forests with their redwoods and other flora receive a lot of exposure and advocacy despite the fact that the hardwood rangelands are actually more threatened to development, near term. She closed by reiterating that it’s important to allocate local budgets more in tune with addressing identified near-term resource threats as opposed to long-term threats. She also proposed more focus on wildland configurations and explorations of the types of relationships that clearly show the impacts of protective changes that are made so there can be an effective measurement and assessment of progress.

END OF SESSION I Q&A