Available online at www.sciencedirect.com

SCIENCE DIRECT

Landscape and Urban Planning 69 (2004) 219–234

LANDSCAPE AND URBAN PLANNING

This article is also available online at:
www.elsevier.com/locate/landurbplan

Urbanization on the US landscape: looking ahead in the 21st century

Ralph J. Alig[a,*], Jeffrey D. Kline[a], Mark Lichtenstein[b]

[a] *USDA Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331, USA*
[b] *Training Support Division–Natural Resources Branch, US Army Environmental Center, 5179 Hoadley Road, Aberdeen Proving Ground, MD 21010, USA*

Accepted 30 July 2003

Abstract

Conversion of rural lands to urban and other built-up uses affects the mix of commodities and services produced from the global land base. In the United States, there was a 34% increase in the amount of land devoted to urban and built-up uses between 1982 and 1997. This increase came predominantly from the conversion of croplands and forestland, with the largest increases in developed area happening in the southern region of the country. In an analysis of drivers influencing developed land uses in the US, we found results that were consistent with hypothesized relationships, including significant increases in development as a result of increases in population density and personal income. From these results, we projected changes in potential future urbanization and development by 2025 given estimated increases in population and real personal income. The projections suggest continued urban expansion over the next 25 years, with the magnitude of increase varying by region. US developed area is projected to increase by 79%, raising the proportion of the total land base that is developed from 5.2 to 9.2%. Because much of the growth is expected in areas relatively stressed with respect to human–environment interactions, such as some coastal counties, implications for landscape and urban planning include potential impacts on sensitive watersheds, riparian areas, wildlife habitat, and water supplies.
Published by Elsevier B.V.

Keywords: Land use economics; Land allocation; Landscape planning; Urbanization trends and projections

1. Introduction

Conversion of rural lands to urban and other built-up uses affects the mix of commodities and services produced from the world's land base. Further conversions to such developed uses are likely to be substantial, as the world's population is projected to increase by more than one-third over the next 30 years, adding 2 billion people (United Nations, 2002). Almost all expected growth in the world's population is concentrated in urban areas. While providing additional living space and infrastructure, added development may also diminish agricultural output due to farmland loss and change ecological conditions due to conversion and fragmentation of forests and other natural landscapes.

In this paper, we examine urbanization trends and drivers for the United States, a country that has added more than 50 million people between 1980 and 2000, about a 24% increase (USDC Census Bureau, 2001). While this growth in population is substantial, during roughly the same time period the amount of US land devoted to urban and built-up uses grew by more

* Corresponding author. Tel.: +1-541-750-7267; fax: +1-541-750-7329.
E-mail address: ralig@fs.fed.us (R.J. Alig).

0169-2046/$20.00 Published by Elsevier B.V.
doi:10.1016/j.landurbplan.2003.07.004

than 34% (USDA Natural Resources Conservation Service, 2001). This increase in developed land has come predominantly from the conversion of croplands and forestland. Forests, in particular, have been the largest source of land converted to developed uses in recent decades, with resulting impacts on forest cover and other ecological attributes. From a societal viewpoint, rapid increases in developed area have not gone unnoticed by the US public. Urban sprawl tied with crime as the leading local concern of Americans in a late-1990s poll by the Pew Center (2000). In 1999 approximately 1000 measures were introduced in state legislatures to change planning laws and to make development in the US more orderly and conserving.

With respect to projecting developed area, Alig and Healy (1987) provided projections of changes in US developed area from 1982 to 2000 based on an earlier analysis of developed land area. However, that earlier study was based on only one cross section of nationwide land use data available at the time. Although the associated projections indicated a significant future increase in developed area, external demographic and macroeconomic projections did not anticipate the above-average growth in the 1990s, a growth that was also accompanied by an accelerated rate of development. With the benefit of new data on population and development that are now available, the current study updates those projections by incorporating additional time-series data and updated external macroeconomic and demographic projections.

In this paper, we examine historical trends for developed land area in the US over the past 20 years. Based on historical data on urban area and associated demographic (e.g., population) and socio-economic factors (e.g., personal income), we estimate models of urban land area. We use the models to generate 25-year projections of potential future urbanization and development, based on a projected 35% increase in the US population (NPA Data Services, 2001). We then discuss implications of projected increases in urban area and regional variations in urbanization.

2. Trends in developed areas

Examining historical trends can provide helpful guidance in identifying key factors that are likely to influence urbanization and other changes in developed area in future years. The discussion of historical trends across time and space in this section provides a foundation for subsequent empirical investigation of key determinants of changes in developed area.

When looking at the changes in US developed area over time, two major data sources both show a steady increase in recent decades. Estimates by the US Census Bureau extend farthest back in time, and show a 130% increase in census-defined urban area between 1960 and 2000. Census urban area is comprised of all territory units in urbanized areas and in places of more than 2500 persons outside of urbanized areas. The Census measure of urbanization labels as built-up some land that is still to some extent available for rural productive uses, thereby probably erring on the side of overgenerous inclusion. Although the term "paved over" has frequently been used to describe urban land, only a small fraction of the land so classified is literally paved.

The other data source, which appears more useful in our study than Census urban data, is the National Resource Inventory (NRI) (USDA Natural Resources Conservation Service, 2001). The NRI estimate of developed area increased 34% between 1982 and 1997. Between 1982 and 1997, developed area as a percentage of the total land area in the 48 contiguous states increased from 3.9 to 5.2%. One important feature of the NRI data classification, in contrast to the Census urban data, is the attempt to exclude areas devoted to agricultural crops, forestry, or similar purposes when they are within a parcel or contiguous area that is otherwise built-up. Outside urban areas, the NRI also includes developed land occupied by nonfarm rural built-up uses (e.g., rural transportation land), which are not included in the Census urban category.

The NRI was conducted every 5 years between 1982 and 1997, leading to four estimates across time. NRI data are widely used and sampling details (e.g., measurement error) can be obtained from the USDA Natural Resources Conservation Service's web site: http://www.nrcs.usda.gov/technical/NRI/. For the NRI, the intent is to identify developed land that has been permanently removed from the rural land base. Therefore, the developed land category includes: (1) large tracts of urban and built-up land; (2) small tracts of built-up land (less than four ha in size); and (3) land outside of these built-up areas that is in roads, railroads, and associated rights-of-way (USDA

Natural Resources Conservation Service, 2001). Overall, NRI "urban and built-up areas" are defined as land uses "consisting of residential, industrial, commercial, and institutional land" as well as several public infrastructure land use categories, such as railroads, landfills, and sewerage treatment plants, among others. Within NRI inventories of "urban and built-up areas," highways and other transportation facilities are included if they are surrounded by urban areas. Land use definitions from the four NRI inventories conducted in 1982, 1987, 1992, and 1997 remain consistent from one inventory to the next, and can be used to examine the expansion of developed land uses through time. For the purposes of our analysis, we call urban and built-up land and rural transportation land defined by the NRI simply "developed land".

Most of the US developed area has been added since World War II (USDC Census Bureau, 2001; USDA Natural Resources Conservation Service, 2001). Further, the amount of US development accelerated in the 1990s. During 1982–1997, US developed area increased about 2% per year on average, according to the NRI. The annual rate of conversion during the last 5 years of this period was more than 50% higher than that of the previous 5 years.

Regionally, the largest increases in US developed area between 1982 and 1997 were in the south (Fig. 1), according to the NRI (USDA Natural Resources Conservation Service, 2001). The south contains ten states as listed in Table 1, and had one-third of its developed area added during those 15 years. Between 1982 and 1997, the south had seven of the ten states with the largest average annual additions of developed area according to the NRI. The top three—Texas, Florida, and North Carolina—each added more developed area than the country's most populous state, California.

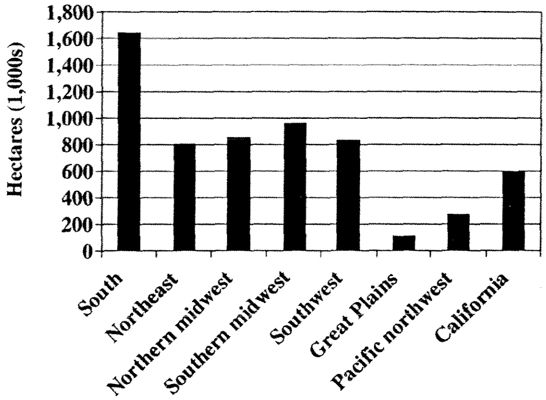

Fig. 1. Change in developed area in the United States, by region, 1982–1997 (million ha) (USDA Natural Resources Conservation Service, 2001).

As a subregion within the south, the southeast (Florida, Georgia, North Carolina, South Carolina, and Virginia) in 1997 had more than 10% of its land

Table 1
Definitions of explanatory variables tested in the urbanization model

Variable	Definition
POPULATION DENSITY	Population (1000s) per square kilometer in county (Bureau of Economic Analysis)
PER CAPITA INCOME	Per capita income (US$ 1000s) in county (Bureau of Economic Analysis)
METROPOLITAN	Variable equals 1 if county is defined as metropolitan by the US Bureau of Census; 0 otherwise
AGRICULTURAL PRODUCTS VALUE	The gross market value before taxes and production expenses of agricultural products sold in the county (US$ 1000s) divided by land in farms (US Bureau of Census)
SPATIAL LAG	Weighted average proportion of land in urban uses in surrounding adjacent counties
HOUSEHOLD SIZE	Average number of persons per household in the county
NORTHEAST	Variable equals 1 if county is located in CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, or VT; 0 otherwise
SOUTH	Variable equals 1 if county is located in AL, FL, GA, KY, MS, NC, SC, TN, VA, WV; 0 otherwise
NORTHERN MIDWEST	Variable equals 1 if county is located in IA, IL, IN, MI, MN, MO, OH, WI; 0 otherwise
SOUTHERN MIDWEST	Variable equals 1 if county is located in AR, KS, LA, OK, TX; 0 otherwise
GREAT PLAINS	Variable equals 1 if county is located in MT, ND, NE, SD, WY; 0 otherwise
SOUTHWEST	Variable equals 1 if county is located in AZ, CO, NM, NV, UT; 0 otherwise
PACIFIC NORTHWEST	Variable equals 1 if county is located in ID, OR, WA; 0 otherwise
CALIFORNIA	Variable equals 1 if county is located in CA; 0 otherwise

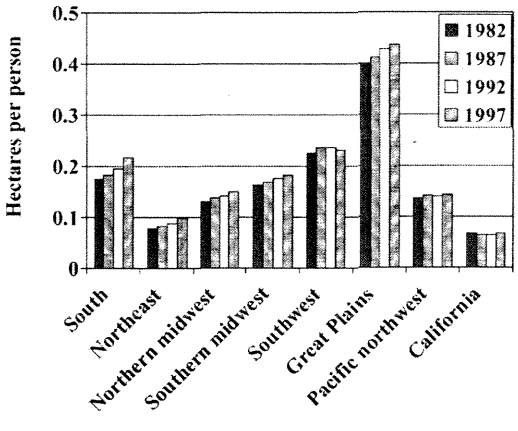

Fig. 2. Total developed area per person, by US region, 1982, 1987, 1992, and 1997 (USDA Natural Resources Conservation Service, 2001).

in developed use. This is similar to the northeast, with both the northeast and the southeast approaching 12% of their total land area as developed. The north (northeast and northern Midwest regions combined) had about one-third of the total addition to developed area. The western regions—Great Plains, Southwest, California, and Pacific Northwest—accounted for less than one-fifth of the total addition.

The Great Plains and the Southwest show relatively high marginal rates of developed area per additional resident. The Great Plains has the most developed area per resident (Fig. 2) across all four NRI surveys. However, it varies from the rest of the country in having lost population between the 1982 and 1987 NRIs, resulting in a loss in developed land area. The Southwest has the second highest level of developed area per person. The south also has a relatively high marginal rate of land consumption, and in addition has had relatively large increases in population compared to the Southwest and Great Plains (Fig. 3). Regional differences for the south were also noted in studies by Alig and Healy (1987) and Reynolds (2001).

Regional differences in urbanization rates are further illustrated by examining trends for three cities within these different regions. In the Pacific Northwest region, for example, while the population of Portland, Oregon (Portland–Vancouver Metro Area) grew by 32% in the 1990s (USDC Census Bureau, 2001), its land area classified as urban increased by only 22%, resulting in a population density increase of 8% in a state with a relatively potent land use law (Kline and Alig, 1999). In contrast, in the south region, Charlotte, North Carolina's population grew by 33%, but its urban area increased by 44%. The more than proportional increase in urban area was due to city population density decreasing by 5%. Finally, in the northeast is the case of Pittsburgh, Pennsylvania, where population declined 5% and urban area increased by 1%, resulting in an overall population density decline of 6%.

As these examples illustrate, significant regional differences can arise not just from total population growth, but also in how that population is distributed across space. While western regions had higher population growth rates, the south has added the most

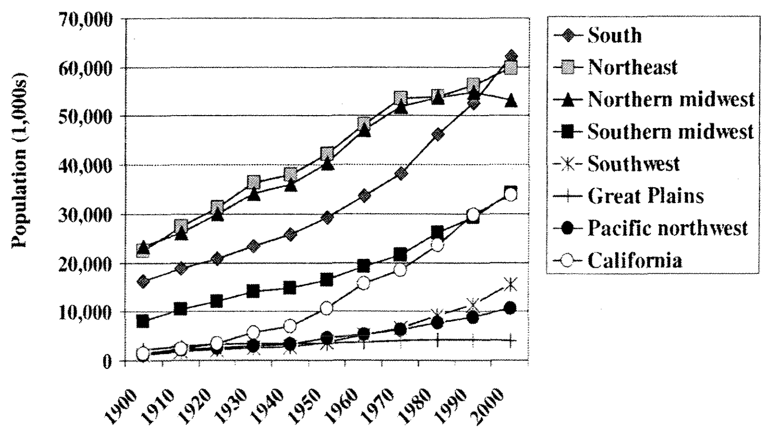

Fig. 3. US population by region, 1900–2000 (USDC Census Bureau, 2001).

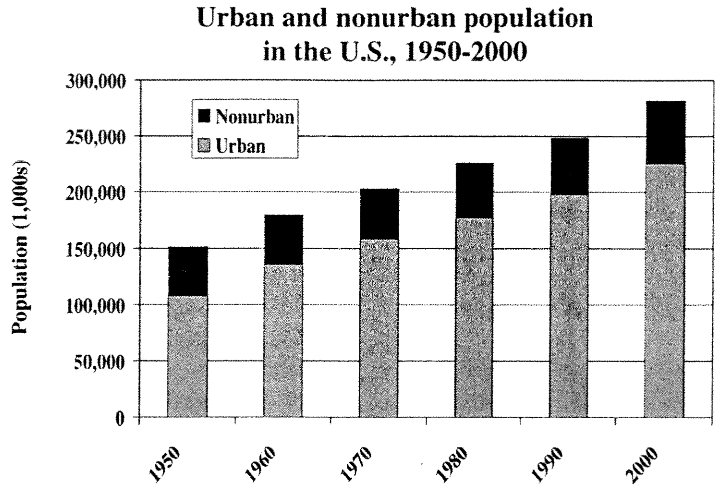

Fig. 4. US population by urban and nonurban components, 1950–1998 (USDC Census Bureau, 2001).

developed area. The south has a larger total population and on average adds more developed area per additional resident.

Key determinants of such changes in developed area have been studied at different scales of inquiry, but with relatively few statistical models at the national scale in the widely available literature. Alig and Healy (1987) estimated regression relationships between urban land area and explanatory variables such as population and personal income for 1970–1980 using Census data, and for 1982 using the first NRI survey of land use. The most important determinants of built-up area were population and personal income variables. The urban proportion of the US population steadily increased from 1950 to 1998, with about 80% of the population now living in urban areas (Fig. 4). In addition to a growing US population, personal income levels on average have also increased substantially since World War II, in constant dollar terms (USDC Census Bureau, 2001). Margo (1992) reported that personal income growth contributed to US suburban growth. In some cases income growth has increased demand for larger houses and lots. Over that same historical period, area of US urban and built-up land has also steadily increased.

Studies at a regional scale include Coughlin et al.'s (1977) examination of urbanized land area for 41 counties in the eastern US in 1970 as related to population density and housing density. Vesterby and Heimlich (1991) also examined a subset of US counties, focusing on those counties that grew by at least 25,000 persons and 25% between 1970 and 1980. Land consumption rates were compared to an earlier study of fast-growth counties, showing that there was little change in marginal rates of urban land consumption between 1960 and the early-1980s. The rate of population growth for larger cities increased on average in the 1990s compared to the 1980s. For cities with 1990 populations above 100,000, the median population growth rate in the 1990s was 9%, more than double the median growth rate of the 1980s (Glaeser and Shapiro, 2001).

Changes in regional urban land areas have also been analyzed when developing regional land use projection models in support of the USDA Forest Service's (2001) Resources Planning Act Assessments. For example, in an early study, Alig (1986) estimated econometric models of six major land uses in the southeast US for 1949–1984, which contained urban population and personal income as key determinants in explaining the proportion of land devoted to urban and related uses. Follow-up studies were conducted for the south central US (Ahn et al., 2002), Pacific Northwest (Kline and Alig, 2001), Lake States (Mauldin et al., 1999) and Maine (Plantinga et al., 1999). Consistent key determinants for the urban area component in these studies are generally population measures and personal income.

Examination of past trends and associated studies point to several core facts to guide our statistical investigation of key determinants of the more than doubling of US developed area since 1950. First, post-World War II increases in developed area were associated with relatively large increases in population and personal income. From 1950 to 2000, the US population increased by 86%, from 151 to 281 million people. Average family income (in constant dollars) increased by more than 150% during this historical period, giving individuals more income to spend. US per capita disposable income in 1998 was US$ 22,353, which represents more than a 10% increase, in real terms, during the 1990s, when we observed acceleration in the rate of expansion of developed area. Regionally, during the past 40 years the largest population growth in the US has been in the south, although western regions have had a higher percentage increase in population. One factor in population growth for both regions has been the climate, as warm, dry places grew since World War II (Glaeser and Shapiro, 2001).

3. Modeling urban land

Land rent maximization is the theoretical basis for several decades of econometric modeling to support development of projection models of land use changes. Barlowe (1978) defines land rent as residual economic surplus, or the total revenue less the total cost. The initial formulation of the concept of land rent is attributable to Ricardo in the 19th century. Ricardo indicated that land rent is a function of soil fertility or climate. Later von Thunen extended Ricardo's theory by adding location and transportation costs components to the model (Barlowe, 1978). Modern land use theory has been built on the earlier contributions of Ricardo and von Thunen, and can be summarized as follows: given a fixed land base, relative land rents are the key determinants of the allocation of land among competing uses. A landowner is assumed to choose to develop land when the present value of the future stream of net returns generated by land in a developed use rises above the present value representing a rural land use or alternative rural land uses, with all other factors or things remaining the same. For example, increased population growth would increase demands for land in residential, commercial, and industrial uses, and thereby increase the value of land in a developed use relative to rural land uses.

In testing the land rent theory in the case of urban and other built-up land, economic and demographic variables are used as proxies for rents from built-up land. Our basic approach in this study is to estimate the relation between the area of land in urban and other built-up uses and the economic and demographic factors influencing such land use decisions. We examined factors related to urbanization and development using regression models describing the proportion of land in urban and built-up uses throughout the US. Given projections of the land use determinants, the fitted models are used in a subsequent section to generate projections of urban and built-up land to 2025.

Developed area data for analysis come from the four NRI data sets from 1982 to 1997 described previously (USDA Natural Resources Conservation Service, 2001). Other data are from the USDC Census Bureau (2001) and US Bureau of Economic Analysis, among other sources. We use county-level developed land areas from the NRI inventories covering the 48 contiguous states to compute the proportion of land in developed uses present within each county at each NRI inventory year. The dependent variable used in our regression analysis is a logit transformation of the county-level proportion of land in developed uses, computed as

$$\mathrm{logit}(\mathrm{Developed}_m) = \ln\left[\frac{P(\mathrm{Developed}_m)}{1 - P(\mathrm{Developed}_m)}\right]$$

where "ln" is the natural logarithm and $P(\mathrm{Developed}_m)$ is the proportion of land in developed uses in each county m computed using NRI data. The logit transformation was used as a dependent variable in the regression equation, where x is a set of independent explanatory variables describing factors in each county m hypothesized to affect the urbanization or development of land, and β is a set of estimated regression coefficients:

$$\mathrm{logit}(\mathrm{Developed}_m) = \beta x_m$$

Actual explanatory variables tested in the regression model included population density to account for the impact that population growth has on the expansion of urban areas. We included per capita incomes to account for the likelihood that urban land is a superior good, so that per capita land consumption rises with real personal income. Even with constant tastes and preferences, a larger population base with higher income levels will add up to greater consumption and demands for developed space.

Agricultural income is included to test the hypothesis that urban land consumption is inversely related to opportunity costs of foregone agricultural production. Urban fringe residents in areas of high value agricultural production would tend to economize on land by adopting more compact settlement patterns or smaller lots.

A variable describing existing metropolitan areas defined by the US Census Bureau is included to account for the likelihood that existing urban areas likely attract new development. Metropolitan counties satisfy at least one of three criteria: (1) contain a city or town with a population of 50,000 or more; (2) are Census Bureau defined urbanized areas with a county population of 100,000 or more; or (3) are counties with close economic and social ties to other metropolitan counties. For the whole US, more than one-quarter of counties are currently classified as metropolitan. That compares with less than one-tenth 50 years ago (USDC Census Bureau, 2001).

We also tested a spatial lag variable (*SPATIAL LAG*) computed as the weighted average proportion of land in urban uses in surrounding adjacent counties. In particular, the spatial lag accounts for potential spatial autocorrelation that can arise from our use of spatial land use data. Spatial autocorrelation can result from omitted spatial variables that influence county or region-wide land use changes, such as topography, and spatial behavioral relationships, such as county, state, or regional land use policies (Nelson and Hellerstein, 1997). Inclusion of the spatial lag variable in preliminary tests resulted in a statistically significant positive coefficient. However, the spatial lag variable also was found to be highly correlated with the population density, income, and metropolitan area variables included in the model, based on Pearson correlation coefficients. For this reason, the spatial lag variable was omitted from final models so that information could be obtained regarding those other variables. As a result, potential spatial autocorrelation in the estimated models remains untreated, which is consistent with most existing published area-base type land use models (Plantinga et al., 1999).

We also tested household size as an explanatory variable. Household size has been decreasing over time, but it did not appear as a variable in the final model. An aging population has the effect of decreasing family size and increasing the number of homes per person. In the past, each additional household consumed about 0.4 ha of land. The average number of persons per US household has been falling, from 3.14 persons per household in 1970 to 2.63 in 1990 (USDC Census Bureau, 2001). However, cross-sectional variation appears to have overwhelmed changes across time in our data series and the variable was dropped from consideration in the model.

One other research question is whether significant regional variations exist regarding the consumption of land for developed uses. We tested regional dummy variables to account for regional differences in urbanization rates, using the south as the reference region.The regression equation estimated is

$$
\begin{aligned}
&\text{Logit(Developed)}\\
&\quad = \beta_0 + \beta_1(\text{POPULATION DENSITY})\\
&\qquad + \beta_2(\text{PER CAPITA INCOME})\\
&\qquad + \beta_3(\text{AGRIC. PRODUCTS VALUE})\\
&\qquad + \beta_4(\text{METROPOLITAN}) + \beta_5(\text{NORTHEAST})\\
&\qquad + \beta_6(\text{NORTHERN MIDWEST})\\
&\qquad + \beta_7(\text{SOUTHERN MIDWEST})\\
&\qquad + \beta_8(\text{GREAT PLAINS}) + \beta_9(\text{SOUTHWEST})\\
&\qquad + \beta_{10}(\text{PACIFIC NORTHWEST})\\
&\qquad + \beta_{11}(\text{CALIFORNIA}).
\end{aligned}
$$

Specific explanatory variables are described in Table 1, where β_0 is an intercept term, and the β_1 though β_{11} are regression coefficients to be estimated. Two versions of the regression equation were estimated. The first version is based on ordinary least squares, while the second uses generalized least squares to estimate a random effects model (Greene, 1998) that accounts for potential cross-correlation among multiple time-series observations of developed land within individual counties.

4. Results

4.1. Regression results

The main findings are consistent with hypothesized relationships. Results of the regression models are presented in Table 2. The ordinary least squares regression model is highly significant, with an adjusted $R^2 = 0.60$ ($F = 1.614$, d.f. $= 11$, $P < 0.001$). The generalized least squares model also had an adjusted $R^2 = 0.60$, but is found to be superior based on a Lagrange Multiplier test (LM $= 16.223$, d.f. $= 1$, $P < 0.001$). All estimated coefficients generally are found to be statistically significant at a high level of confidence ($P < 0.0001$) and with the expected signs.

The estimated coefficient for the *POPULATION DENSITY* variable suggests that population density has a positive impact on the proportion of land in urban uses. The variable *PER CAPITA INCOME* is also positive and consistent with increased consumption of land for urban uses as personal incomes rise. The variable *METROPOLITAN* is positive and suggests increased expansion of urban land uses in areas located within metropolitan areas as defined by the US Census Bureau.

The other income-related variable, *AGRICULTURAL PRODUCTS VALUE*, has a negative coefficient in the ordinary least squares model, but is positive in the generalized least squares model. A negative coefficient likely would reflect the equilibrating tendencies in land markets, where higher values for agricultural production would tend to reduce the consumption of land for nonagricultural uses. However, a positive coefficient may reflect the tendency for high value agricultural land in many parts of the US to be located in relatively close proximity to existing urban areas. In fact, we did find that *POPULATION DENSITY* and *AGRICULTURAL PRODUCTS VALUE* were relatively highly correlated, based on a Pearson's correlation coefficient of $r = 0.74$. This is consistent with the hypothesis that high per hectare agricultural values are found in more urban settings.

The statistical significance of the regional dummy variables suggests that regional differences exist in the consumption of land for developed uses. The negative coefficients for all regional dummy variables are consistent with historically higher rates of land consumption per additional person in the south, which is the reference region in the regression models.

4.2. Projections of developed area

We used the estimated regression model coefficients to project developed land area to 2025 for the US. Projected estimates of developed area can then be factored into the many long-range projections of future supply and demand for agricultural crops, animal products, forest products, recreation land, wildlife habitat, water use, and other landscape and environmental measures (see for example, USDA Forest Service, 2001). An

Table 2
Estimated coefficients of the urbanization models

Variable	Ordinary least squares		Generalized least squares	
	Estimated coefficient	t-statistic	Estimated coefficient	t-statistic
Intercept	−3.787	−141.19	−3.621	−160.02
POPULATION DENSITY	0.563	18.94	1.738	79.86
PER CAPITA INCOME	0.055	35.83	0.043	349.75
METROPOLITAN	0.681	45.82	0.538	19.94
AGRICULTURAL PRODUCTS	−0.020	−9.33	0.005	25.63
NORTHEAST	0.004	0.06	−0.198	−4.26
NORTHERN MIDWEST	−0.200	−12.42	0.185	−5.89
SOUTHERN MIDWEST	−0.637	−37.41	−0.606	−18.00
GREAT PLAINS	−1.332	−61.35	−1.285	−30.10
SOUTHWEST	−1.646	−58.74	−1.595	−29.24
PACIFIC NORTHWEST	−1.272	−41.26	−1.268	−20.24
CALIFORNIA	−0.991	−22.91	−1.205	−14.19
Model statistics	Adjusted $R^2 = 0.60$, $F = 1.614$ (d.f. $= 11$, $P < 0.001$), $N = 11967$		Adjusted $R^2 = 0.60$, LM $= 16223$ (d.f. $= 1$, $P < 0.001$), $N = 11967$	

abundance of land is seen by some as one hallmark of the US, and projections of developed area can aid decision-making as a forward-looking process in addressing whether adequate rural land will be available to support valued environmental goods and services in the future.

Our projections of developed area involved computing projected future proportions of developed land within counties, based on projected values of population density and other explanatory variables. The proportions were then multiplied by each county's respective land area to estimate the total area of urban land through 2025.

Population density projections are based on county-level projected population growth through 2025 (NPA Data Services, 2001). Projected increases in population through 2025 are 13% in the northeast, 49% in the south, 20% in the northern Midwest, 45% in the southern Midwest, 25% in the Great Plains, 80% in the southwest, 54% in the northwest, and 44% in California. Projected increases in per capita income (in constant dollars) within individual counties average 72% nationwide.

The NRI-defined area of developed land is projected to increase from 39.5 million ha in 1997 to 70.5 million ha in 2025 (Table 3). Projected developed land areas suggest significant urban expansion over the next quarter century, with the magnitude of increase varying by region. By region, developed land areas are projected to increase by 73% in the northeast, 75% in the south, 80% in the northern Midwest, 81% in the southern Midwest, 71% in the Great Plains, 86% in the southwest, 82% in the northwest, and 98% in California, for a nationwide increase of 79%. The south is projected to continue to have the most developed area, reaching nearly 19 million ha by 2025.

The percentage of the total US surface area in the 48 contiguous states occupied by developed or built-up uses is projected to increase from 5.2% in 1997 to 9.2% by 2025. The projected developed and built-up area of 70.5 million ha in 2025 represents an area equal to 38% of the current US cropland base, or 23% of the current US forestland base (Smith et al., 2001).

We also performed sensitivity analyses by altering projected trends in population density and personal income growth (Table 3). Assumptions about the future are a major influence on projections and we can gain some insights on the relative importance of different assumptions or study limitations by altering key assumptions and assessing the effect on projections. To help guide the sensitivity analyses, we assessed the relative influence of explanatory variables in our model. We computed elasticities that represented the estimated change in the proportion of developed land given a ten percent change in each explanatory variable. Three elasticities for nondummy variables computed at the mean are: population density, 0.0004; per capita income, 0.0036; and agricultural products, 0.0000. For example, at the means, a 10% increase in personal income in the model would increase the

Table 3
Actual and projected hectares[a] (1000s) of developed land in 2025, by region

Region	1997[b]	2025[c]	Low[d] 2025	High[e] 2025
Northeast	5900	10197	7817	13026
South	10696	18688	14248	24049
Northern Midwest	8669	15619	11692	20584
Southern Midwest	6259	11323	8448	14997
Great Plains	1956	3353	2560	4395
Southwest	2161	4019	2942	5598
Pacific Northwest	1636	2976	2207	3998
California	2208	4366	3133	5946
US total	39485	70541	53047	92494
Percentage of continental US area developed	5.2	9.2	6.9	12.1

[a] Projected using coefficients from generalized least squares model (Table 2).
[b] Developed area for continental US (USDA Natural Resources Conservation Service, 2001).
[c] Based on population and per capita income growth projected by NPA Data Services (2001).
[d] Based on 50% less population and per capita income growth projected by NPA Data Services (2001).
[e] Based on 50% more population and per capita income growth projected by NPA Data Services (2001).

predicted proportion of developed land from 0.0456 to 0.0492. The elasticities suggest that population density and per capita income have the larger relative influences, although note that a single point estimate should be viewed cautiously because of the nonlinear nature of the logistic function. That is, the elasticity will vary, depending where on the function the values are computed.

In our sensitivity analysis, if population density and personal incomes grow 50% less than projected, the percentage of the total US surface area in the 48 contiguous states occupied by developed or built-up uses is projected to increase to 6.9% (rather than the base 9.2%) by 2025. If population and personal incomes grow 50% more than projected, the percentage of the total US surface area in the 48 contiguous states occupied by developed or built-up uses is projected to increase to 12.1%.

5. Discussion

Regression results are consistent with hypothesized relationships between developed area and socioeconomic factors driving the development of land. The results also are largely consistent with findings in earlier studies. In particular, positive coefficients for the population density and personal income variables in a national scale study are consistent with findings by Alig and Healy (1987). Based on the regression model developed using 1982–1997 NRI data, the positive coefficients for population density and personal income result in a projected increase of 79% in US developed area by 2025. Projected development rates vary by region, with a range of 71–98% and with the south continuing to have the most developed area.

Land values for developed uses typically exceed those for rural uses by a substantial amount and while agricultural values are usually second to developed uses in potential value, they are often influenced by development potential. Our negative coefficient in the ordinary least squares model for the variable representing agricultural products value is consistent with Brueckner and Fansler's (1983) findings that agricultural rent had a negative impact on urban land consumption in 40 urbanized areas. However, the positive coefficient in the generalized least squares model suggests that the agricultural products values variable could be correlated with other topographic and geographic factors also influencing developed land area. Limitations in data with which to describe agricultural land rents have led some investigators to suggest that, generally speaking, developed uses are so dominant over agricultural uses in land markets that agricultural income has no measurable influence on consumption of land for developed uses. Ideally, the agricultural land rent-related variables should represent net agricultural profits or land rents per hectare, but data with which to construct such variables are not available across all counties in the US.

The role of agricultural income in such a model is complicated as well by the fact that many agricultural producers have benefited financially through land markets from the encroachment of urban growth. The market price of land can be decomposed into different sources of value, such as its current use in agricultural production and its expected use in alternative enterprises. In many areas adjacent to urban centers, the influence from the expectation of urban development on the value of the land is greater than its actual, current use in farm or forestry production. For example, more than 15% of US farmland is considered to have urban development significantly influence its market value. For those urban-influenced hectares, urban development pressures account for two-thirds of their market value (Barnard, 2000). For many landowners, this urbanizing influence can materially increase their net worth, and allow them to borrow more and perhaps expand their agricultural operations, or to sell their land and realize capital gains.

Some producers view urban sprawl as a business opportunity, providing an adjacent market that allows them to stay in farm production. They can shift their commodity mix to satisfy the nearby market demand for perishable fruits and vegetables, as well as other fresh commodities. Other producers have adjusted by catering to the demand by local residents for farm visits. In 2000, 28% of respondents indicated that a motivation for their sightseeing trip was to visit a farm or agricultural setting (calculations based on USDA Forest Service, 2000–2002). These include visits to purchase farm products or visits to learn about farming and enjoy the view on the farm. Pumpkin patches and U-pick operations are common in many urban areas.

In addition, adjacent urban development can mean that farm operator household members have off-farm job opportunities. The average US farm household earns more income off the farm than on the farm (Ahearn et al., 1993). Off-farm opportunities in nearby urban areas have been a key to the survivability of many US farms.

The statistically significant negative dummy variable coefficients for all regions relative to the south reference case are consistent with the findings by Alig and Healy (1987) regarding the south. The present study examined changes using four NRI data measurement points, while the Alig and Healy (1987) study analyzed data from the 1982 NRI. Since the 1982 NRI, the south has continued the trend of having more built-up land per capita than the US average. The south had the largest percent change in developed area among regions from 1992 to 1997 (USDA Natural Resources Conservation Service, 2001).

The increase in developed area for the south was close to 20%, almost four times as large as for the Great Plains, the region with the smallest percent change. The Great Plains' lower rate of consumption of land for developed uses is related to relative population changes. With respect to landscape planning, falling populations in some Great Plains counties has led to proposals to create in such places a "Buffalo Commons" or large ecological or wildlife refugees (Popper and Popper, 1994).

Several factors contribute to expansion of developed area in the south: (1) above average population growth in part due to climatic factors, including attraction of immigrants (Glaeser and Shapiro, 2001); (2) above average marginal consumption rates of land per additional resident (USDA Natural Resources Conservation Service, 2001); and (3) income growth. Expansion of developed area and urban sprawl in the south has been described as a major issue for future natural resource management, especially for the region's forests (Seelye, 2001; Wear and Greis, 2002).

The south is a region where land is often suitable for multiple land uses, given relatively gentle topography and ease of access. When examining land use dynamics, the many different pathways by which land use can change warrant examining both net and gross area changes for major land uses. For example, the flow between forestland and urban and developed uses is primarily a one-way flow toward urban and developed uses, although some land classified as urban and developed (e.g., corridors for electrical lines) may infrequently shift into forest or agriculture. Movement of land between forestry and agriculture in the last two decades has resulted in net gains to forestry that have offset forest conversion to urban and developed uses in *area* terms. However, forest conditions of hectares entering and exiting the forestland base are likely to have been quite different; entering hectares may be bare ground or have young trees, while exiting hectares often contain large trees before conversion to developed uses.

Concern about the attributes of exiting or entering forested hectares was heightened in the 1990s when the rate of development increased, with 0.4 million ha of forests converted to developed uses per year. Over the entire land base, the total or gross area shifts involving forests are relatively large compared to net estimates. Increased rate of development may mean more indirect pressure for conversion of forests, where forests are converted to replace agricultural land that has been developed. When all conversions of land into and out of forest are included, the net area of nonfederal forests increased by about 1.6 million ha in the contiguous 48 states between 1982 and 1997, according to NRI estimates. However, gross area changes involving forests totaled about 20 million ha between 1982 and 1997, an order of magnitude greater than the amount of net changes.

We performed sensitivity analyses involving major assumptions underlying our projections—future growth in population density and personal income—to address uncertainty because we are dealing with an open system and with the unknowable future. Complexities include using relationships derived from past trends to project future patterns in conjunction with using assumed future values for key explanatory variables. Projections can help to narrow the range of possible futures that decision makers need to focus on, but regardless of the sophistication of the underlying models, the possibility of unpredictable events remains. Efforts to reduce uncertainty can reveal previously undisclosed complexities, and availability of additional data and research may warrant periodic redoing of certain long-term projections. This study updated the Alig and Healy (1987) study, which had access to only one cross section of NRI land use data available in the mid-1980s. The earlier external demographic and macroeconomic projections also underestimated what actually transpired and did not anticipate above-average US economic growth in the 1990s, accompanied by an accelerated rate of development over a broad geography.

With respect to broad-scale geography, our projections of developed area indicate that most of the US will remain undeveloped. However, undeveloped land may be scarce in certain areas, including where urban sprawl is a concern. Development is often concentrated close to interstate highways and in coastal areas, where more than half of the US population resides (USDC National Oceanic and Atmospheric Administration, 1999). Coastal counties are among the most heavily developed areas in the nation, with the coastal areas of California as examples in that state. The significance of the METROPOLITAN variable in our model suggests that new development is likely to occur close to older development. As population grows, and as coastal areas accommodate ever-increasing residential, commercial, and industrial uses, land and water resources are expected to diminish in both quality and quantity (USDC National Oceanic and Atmospheric Administration, 1999). With respect to temporal changes, our projections are intended as long term, which may mask shorter-term fluctuations in underlying population changes and settlement patterns. A historical example of such shorter-term shifts is that the decadal pattern of nonmetropolitan population rebound in the early-1990s was followed by slower growth in the second half of the decade. The nonmetropolitan US as a whole had net in-movement of people from metropolitan areas and a significant population rebound, in contrast with the 1980s (USDA Economic Research Service, 2002).

The relationship between population and developed area involves components that may be of interest to policy makers. First, developed area per person increased between the 1982 and 1997 NRI surveys. This suggests that the country is not economizing on its use of land for living and playing. This has raised concerns about urban sprawl, further bolstered by the acceleration in development in the 1990s. Second, our use of aggregate numbers masks large variation across space. For example, developed land as a percentage of a state's land base has a wide range, from less than one percent in states such as Wyoming, to more than 25% for New Jersey. Thus, our study was designed to provide broad-scale indicators of developed land, and possible variation across more local areas, such as states or counties, should be borne in mind.

6. Conclusions

Our regression results are consistent with hypothesized relationships, and population density and personal income levels are the primary determinants of developed area in the US. Developed land in 1997 represented about 5.2% of the land base in the contiguous 48 states, and this is projected to almost double by 2025 based on our regression model. Projected development rates vary by region, with the largest projected increase in the south.

Further increases in developed area will have significant implications for landscape and urban planning. Entire conferences or symposia (e.g., American Farmland Trust, 1999; DeCoster and Sampson, 2000) have been devoted to exploring the range of impacts of land development. The land use and environment linkage affects many goods and services and selected aspects are covered in periodic national resource assessments (e.g., USDA Forest Service, 2001), regional resource assessments (e.g., Kline et al., 2001), and other studies (e.g., Kahn, 2000).

Such human–environment impacts will include direct and indirect effects, and can also vary across space and time. Direct impacts include conversion of the rural land base for forestry and agriculture, likely leading to a smaller overall rural land base in the future. For example, US forest area is projected to be about three percent smaller by 2050, primarily due to conversions to urban and developed uses (Alig et al., 2002). This translates into less wildlife habitat and outdoor recreation area.

Indirect effects include forests and agricultural lands that can be physically fragmented. Fragmentation can affect natural resources in a variety of ways, with adverse impacts often cited, such as fragmentation of green space or wildlife habitat for certain species. If fragmentation rates increase faster than population growth, this can have a "bow wave effect" (DeCoster, 2000), which extends far in front of expanding development. It can lead to higher land prices, social and regulatory pressures that affect rural land uses, and changes in incentives to manage rural land.

Fragmentation of ownerships into several smaller ownerships is referred to as parcelization. This phenomenon can also have profound impacts on the economics of farming or forestry, even when land is not physically altered in any major way (Healy and Short, 1981; see also Gobster and Rickenbach, this issue). Trends over time in fragmentation and parcelization warrant further study, along with monitoring of changes in population density for different classes of rural and urban land (Alig, 2000). More people on the landscape include those in rural areas with attractive recreational land and aesthetic amenities, often involving forests. Such demographic changes increase the size of the wildland–urban interface, whose expansion has exacerbated wildfire threats to structures and people. Overall, on average, the US had about 30 people/km^2 of land in 1999 (USDC Census Bureau, 2001). This compares to about 2 people/km^2 in 1790. Although the US has had a large increase in population density, the US had a lower population density than the world average of 40 persons/km^2 in 1999 (United Nations, 2002). However, population density continues to vary notably within the US, warranting monitoring of trends in suburbanization and regional migration (e.g., from the northern "Rust Belt" to the southern "Sun Belt").

Continued spread of built-up uses over the rural landscape has other important indirect impacts. Cumulative effects of expanding developed land may include loss of farmland and forestland to a degree that availability of working farms and forests or green space may become an issue (Kline and Wichelns, 1996). Expectations of neighboring landowners about the future use of their land may also be influenced, generally reflected in higher asking prices. Property taxes may also rise, reflecting the new, higher land values. Composition of land ownership may also change, with an increasing proportion of landowners being primarily nonfarmers, although the land may still be used for farming, often on a rental basis.

Although in the face of encroaching urbanization some individual agricultural producers may be better off when they sell their land to developers, the checkerboard pattern of developed land and farm and forest production can have a variety of negative impacts on producers who choose to stay (Alig and Ahearn, 2003; Alig et al., 2003). Impacts include complaints by new residents about the noise and pollution associated with farm and forestry production, loss of local farm infrastructure such as input suppliers, and the difficulty in expanding for those producers who would like to purchase nearby parcels of land. For those who want to stay in agriculture or forest production, low profit margins do not allow producers to compete with developers for additional land as land prices are bid up by residential and other types of development encroachment. All of these impacts can easily translate into higher production costs.

Social consequences of landscape changes can affect both rural and urban interests. For urban planning, implications of growth in urban populations and developed area can include increased traffic congestion, conversion of open space, increased commuting times, residential energy consumption (e.g., Kahn, 2000), and concerns about changes in quality of life. Changes in quality of life may improve in some cases with increased housing opportunities. Those involved in landscape and urban planning will also recognize that significant expansion of developed land is often an inadvertent byproduct of policies that were designed for other purposes. Related future research could investigate how natural amenities, such as climate (e.g., Kahn, 2000), topography, and presence of bodies of water correlate with changes in settlement patterns and nonmetropolitan population. An increasing population of retirees has augmented out-migration from central cities and suburbs to rural areas that offer aesthetic amenities. In such cases, natural amenities may be more important determinants of development than nearness to metropolitan centers or type of local economy (McGranahan, 1999; see also Hammer et al., this issue).

Future research needs also include further investigation of the potential impacts of greater numbers of people occupying the US landscape and the resulting impacts on quality of life as well as on goods and services from terrestrial and aquatic ecosystems. Population increases can lead to more fragmentation and parcelization of terrestrial ecosystems. An example of related research is examining the relationship between timber management activities of forest owners and density of development (Kline et al., 2004). Integrating urbanization into landscape-level ecological assessments is receiving increased attention (Kline et al., 2001).

Additional data collection and data enhancements permitted us to expand our investigation at a broad scale of developed area trends compared to an earlier study (Alig and Healy, 1987). Since the earlier study, availability of geo-referenced data sets has expanded. Future advances in land use analyses will likely also rest in part on continued improvement of spatial databases, including spatial socio-economic data, as well as improvements in spatial econometric methods to support empirical data analyses. One current shortcoming is the quality and spatial scale of available data. Trade-offs must be considered when assessing the costs and benefits associated with spatial detail in landscape and urban planning. Along with improved data bases, monitoring of developed area trends, associated investment in infrastructure (e.g., transportation networks and nodes), and related socio-economic factors will be important in facilitating updated projections of developed area in the US.

Knowledge of the drivers behind land use change is useful for informing policy discussions concerning society and the environment. One important characteristic of policy formation is that it is concerned with the future. Policy makers must anticipate future conditions and estimate the effects that proposed policies are likely to produce. Value in charting the future includes providing ideas to policy makers of the future allocation of the US land base between urban and rural uses. Given the expected US population increase and changes in economic activity, a key question is how can society make positive progress toward sustainability in the face of needing more developed land to serve more people in the future. Progress toward such goals may rest on progress in a search for a more integrated approach for describing the complex interplay between human activity and the environment. To help evaluate progress, we need a useful definition of sustainability along with measurable indicators that fundamentally reflect the long-term ecological, economic, and social well being as it relates to alternative uses of land.

Acknowledgements

We appreciate the assistance of NRI data analysts in the Washington Office of the USDA Natural Resources Conservation Service. We acknowledge funding support from the USDA Forest Service's Pacific Northwest Research Station and Strategic Planning and Resource Assessment office, and EPA's Office of Atmospheric Programs, Sequestration Branch in Washington, DC.

References

Ahearn, M., Perry, J., El-Osta, H., 1993. The Economic Well-being of Farm Operator Households. AER No. 666, US Department of Agriculture, Economic Research Service, Washington, DC.

Ahn, S., Plantinga, A., Alig, R., 2002. Determinants and projections of land use for the South Central United States. Sov. J. Appl. For. 26 (2), 78–84.

Alig, R., 1986. Econometric analysis of forest acreage trends in the Southeast. For. Sci. 32 (1), 119–134.

Alig, R., 2000. Where do we go from here? Preliminary scoping of research needs. In: Sampson, N., DeCoster, L. (Eds.), Proceedings of the Forest Fragmentation 2000. Annapolis, MD, 17–20 September 2000. American Forests, Washington, DC, p. 371.

Alig, R., Ahearn, M., 2003. Effects of policy and technological change on land use. In: Boyle, K., Plantinga, A. (Eds.), The Economics of Land Use Change. Ashgate Publishing, Burlington, VT, in press (Chapter 5).

Alig, R., Healy, R., 1987. Urban and built-up land area changes in the United States: an empirical investigation of determinants. Land Econ. 63 (3), 215–226.

Alig, R., Mills, J., Butler, B., 2002. Private timberlands: growing demands, shrinking land base. J. For. 100 (2), 32–37.

Alig, R., Platinga, A., Ahn, S., Kline, J., 2003. Land use changes involving forestry in the United States: 1952 to 1997, with projections to 2050. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-587. Portland, Oregon.

American Farmland Trust, 1999. Proceedings, Keep America Growing: Balancing Working Lands and Development, June 6–9, 1999, Philadelphia, PA. American Farmland Trust, Washington, DC.

Barlowe, R., 1978. Land Resource Economics, third ed. Prentice-Hall, Englewood Cliffs, NJ.

Barnard, C., 2000. Urbanization Affects a Large Share of Farmland. US Department of Agriculture, Economic Research Service, RCAT, Washington, DC.

Brueckner, J., Fansler, D., 1983. The economics of urban sprawl: theory and evidence on the spatial sizes of cities. Rev. Econ. Stat. 50, 479–482.

Coughlin, R., et al., 1977. Saving the Garden: The Preservation of Farmland and Other Environmentally Valuable Land. Regional Science Research Institute, Philadelphia, PA.

DeCoster, L., 2000. Summary of the Forest Fragmentation 2000 Conference. In: DeCoster, L., Sampson, N. (Eds.), Proceedings of the Forest Fragmentation 2000. Annapolis, MD, 17–20 September 2000. Sampson Group, Inc., Alexandria, VA, pp. 2–12.

DeCoster, L., Sampson, N. (Eds.), 2000. In: Proceedings of the Forest Fragmentation 2000. Annapolis, MD, 17–20 September 2000, Sampson Group, Inc., Alexandria, VA.
Glaeser, E., Shapiro, J., 2001. City Growth and the 2000 Census: Which Places Grew and Why. Center on Urban and Metropolitan Policy, The Brookings Institution, Washington, DC.
Gobster, P.H., Rickenbach, M.G., 2004. Stakeholder perceptions of private forestland parcelization and development: landscape change in Wisconsin's Northwoods. Landsc. Urban Plann. 69, 165–182.
Greene, W.H., 1998. LIMDEP Version 7.0: User's Manual, revised ed. Econometric Software, Inc., Plainview, NY.
Hammer, R.B., Stewart, S.I., Winkler, R.L., Radeloff, V.C., Voss, P.R., 2004. Characterizing dynamic spatial and temporal residential density patterns from 1940 to 1990 across the North Central United States. Landsc. Urban Plann. 69, 183–199.
Healy, R., Short, J., 1981. The Market for Rural Land: Trends, Issues, and Problems. The Conservation Foundation, Washington, DC.
Kahn, M., 2000. The environmental impact of suburbanization. J. Policy Anal. Mgmt. 19 (4), 569–586.
Kline, J., Alig, R., 1999. Does land use planning slow the conversion of forest and farm lands? Growth Change 30 (1), 3–22.
Kline, J., Alig, R., 2001. A Spatial Model of Land Use for Western Oregon and Western Washington. Research Paper PNW-RP-528, US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.
Kline, J., Moses, A., Alig, R., 2001. Integrating urbanization into landscape-level ecological assessments. Ecosystems 4, 3–18.
Kline, J., Wichelns, D., 1996. Public preferences regarding goals of farmland preservation programs. Land Econ. 72 (4), 538–549.
Kline, J.D., Azuma, D.L., Alig, R.J., 2004. Population growth, urban expansion and private forestry in Western Oregon. Forest Science 50(1).
Margo, R., 1992. Explaining the postwar suburbanization of the population in the United States: the role of income. J. Urban Econ. 21 (2), 183–199.
Mauldin, T., Plantinga, A., Alig, R., 1999. Land Use in the Lake States Region: An Analysis of Past Trends and Projections of Future Changes. Research Paper PNW-RP-519, US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.
McGranahan, D., 1999. Natural Amenities Drive Rural Population Change. FRED Report No. 781, US Department of Agriculture, Economic Research Service, Washington, DC.
Nelson, G., Hellerstein, D., 1997. Do roads cause deforestation? Using satellite images in econometric analysis of land use. Am. J. Agric. Econ. 79, 80–88.
NPA Data Services, Inc., 2001. National Economic Projections, Series E. NPA Data Services, Inc., Arlington, VA. URL: http://www.npadata.com.
Pew Center, 2000. Sprawl Now Joins Crime as Top Concern. URL: http://www.pewcenter.org/about/pr_ST2000.html.
Plantinga, A., Mauldin, T., Alig, R., 1999. Land Use in Maine: Determinants of Past Trends and Projections of Future Changes. Research Paper PNW-RP-511, US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.
Popper, F., Popper, D., 1994. Forum: Great Plains: checkered past, hopeful future. Appl. Res. Public Policy Winter, 89–120.
Reynolds, J., 2001. Land use change and competition in the South. J. Agric. Appl. Econ. 33 (2), 271–281.
Seelye, K., 2001. Sprawl Seen to Hurt South's Forests. New York Times, late ed. Final, Section A, 27 November 2001, p. 10.
Smith, W., Vissage, J., Sheffield, R., Darr, D., 2001. Forest Resources of the United States, 1997. Gen. Tech. Rep. NC-219, US Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN.
United Nations, 2002. World Urbanization Prospects. Economic and Social Affairs Working Paper 173, United Nations, Population Division, New York.
US Department of Agriculture, Economic Research Service, 2002. Rural Population and Migration. URL: http://www.ers.usda.gov/Briefing/Population.
US Department of Agriculture, Forest Service, 2000–2002. National Survey on Recreation and the Environment (NSRE): 2000–2002. The Interagency National Survey Consortium, Coordinated by the USDA Forest Service, Recreation, Wilderness, and Demographics Trends Research Group, Athens, GA and the Human Dimensions Research Lab, University of Tennessee, Knoxville, TN.
US Department of Agriculture, Forest Service, 2001. 1997 Resources Planning Act (RPA) Assessment. US Department of Agriculture, Forest Service, Washington, DC.
US Department of Agriculture, Natural Resources Conservation Service, 2001. Summary Report: 1997 National Resources Inventory (revised December 2001). US Department of Agriculture, Natural Resource Conservation Service, Washington, DC.
US Department of Commerce, Census Bureau, 2001. Statistical Abstract of the United States, 2001. Table 1046. URLs: http://www.census.gov/prod/www/statistical-abstract-us.html; http://www.census.gov/prod/2002pubs/01statab/stat-ab01.html.
US Department of Commerce, National Oceanic and Atmospheric Administration, 1999. In: Proceedings of the Trends and Future Challenges for US National Ocean and Coastal policy. Washington, DC, 22 January 1999. National Oceanic and Atmospheric Administration, National Ocean Service, Washington, DC.
Vesterby, M., Heimlich, R., 1991. Land use and demographic change: results from fast-growth counties. Land Econ. 67 (3), 279–291.
Wear, D., Greis, J., 2002. Southern forest resource assessment: summary of findings. J. For. 100 (7), 6–14.

Ralph J. Alig is a team leader of the Land Use and Land Cover Dynamics Research Unit (http://www.fsl.orst.edu/lulcd/) with the USDA Forest Service's Pacific Northwest Research Station in Corvallis, OR, USA. He has a PhD in land use economics from Oregon State University and has researched landscape, regional, and

national land use economics for more than 25 years. He has developed macro land use and forest cover models and coordinated the national land use and land cover projections for the Forest Service's decadal Resources Planning Act Assessments. He also was a co-developer of a national land use model for the agricultural and forestry sectors.

Jeffrey D. Kline has worked with land use policy and land conservation for 20 years in both government agencies and nonprofit organizations. He received his master's degree in resource administration and management from the University of New Hampshire in 1988, and his PhD in environmental and natural resource economics from the University of Rhode Island in 1996. Currently, he is a research forester with the USDA Forest Service's Pacific Northwest Research Station in Corvallis, OR, USA, where he examines the impacts of population growth and urbanization on forests and forest management.

Mark Lichtenstein received his master's degree in forest economics from Oregon State University in 2001, and his BS in forest management form Oregon State University in 1999. Currently, he is an economist with a private firm and developing management plans for forests on military lands.