Conversions of Forest Land: Trends, Determinants, Projections, and Policy Considerations

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Abstract

Forest land conversion leads to ecological effects (e.g., changes in water quality and wildlife habitat) and socioeconomic effects (e.g., expanding urban-forest interface, reduced long-term timber production possibilities and loss of open space). Socioeconomic drivers of land use change such as population totals and personal income levels have increased substantially since World War II. Human land use is the primary force driving changes in forest ecosystem attributes. Land use changes affecting forests since 1990 have been heavily concentrated in the South. Nationwide, more than 60 percent of housing units built in the 1990s were constructed in or near wildland vegetation. More than 44 million acres of private forest are projected to experience housing density increases between 2000 and 2030, with the majority of the most heavily impacted watersheds in the East. The United States population is projected to grow by more than 120 million people by 2050, and deforestation associated with this growth is projected to exceed 50 million acres. Fragmentation of remaining forests is also projected and expected to be concentrated in distinct subregions; in the South, these include urbanizing areas and areas close to interstate highway corridors. As urban lands expand into surrounding areas, retaining trees can have significant benefits. Current benefits of urban vegetation on environmental quality nationally are on the order of several billion dollars per year.

Keywords: Deforestation, development, fragmentation, land-use change, population growth.

Forest Land Conversion and Recent Trends

Forests cover about one-third of the United States and range from wildland forests to urban forests. These diverse ecosystems provide a variety of habitats for wildlife; help to cleanse the air and water; supply timber, fuelwood, and other harvested products; serve as places for recreation; help to mitigate the effects of global climate change; and provide other essential goods and environmental services.

Forests are vulnerable to conversion to other land uses. An increasing number of houses and other buildings in and near forests portend growing costs and complications in fire suppression and potential loss of many values derived from forests. Long-term assessment of the condition of forests and of the relationships between forest conditions and socioeconomic factors is the key to defining policy questions and actions needed to sustain forest-based services.

In this synthesis, we survey recent trends, determinants, and projections of forest land conversion in the United States. Examples with more detailed treatments, supporting tables, and figures are available in Alig and others (2003, 2004, 2010) and Alig and Ahearn (2006). Forest land conversion is a persistent issue for managers and policymakers; for example, a recent position statement concerning loss of forest land by the Society of American Foresters (2004) lists ecological effects (e.g., effects on water quality and wildlife habitat) and socioeconomic effects (e.g., expansion of the urban-forest interface, reduction of forest recreation opportunities, reduction of long-term timber production possibilities, and loss of open space) as important implications of forest loss. We examine how socioeconomic drivers of land-use change, such as population totals and personal income levels, have increased substantially since the Second World War and led to changes in forest ecosystem attributes. We summarize determinants of land-use changes, focusing on the societal and private tradeoffs of retaining land in forests. Our projections reflect population

Table 1—Databases used in studies of different types of land base changes

Land base change	Coverage	Databases
Deforestation	48 contiguous States; 1982 to 1997, with national updates for 2001 and 2003	USDA NRCS 2001
Afforestation	Annual tree planting by State, 1980 to 1998; periodic estimates of reversions to forests	USDA Forest Service Tree planting reports; periodic and annual FIA surveys
Forest fragmentation	1992, with another in progress	National land cover database
Forest parcelization	Periodic owner surveys	National forest landowner survey
Structure additions to forests	Decadal national census; special studies	USDC Census Bureau; Oregon structure counts (contact: Dept. of Forestry)
Urban forest changes	National	USDC Census Bureau

growth that spurs demand for land for developed uses at the same time that demands for some forest products and other forest benefits are increasing. Risk and policy considerations necessitate that creating effective policy in this area will require careful deliberation concerning private and social viewpoints. For example, some forest benefits (such as wildlife habitat and other ecosystem services) can most effectively be produced at scales greater than the individual private parcel scale and because market imperfections can cause some social forest benefits to be undersupplied when this is the case (Kline and others 2004a).

Five categories of significant changes affecting forest area are:

- Afforestation
- Deforestation
- Forest fragmentation
- Forest parcelization
- Increased numbers of structures, such as houses, on forest land

This analysis does not address changes in forest cover type. For an example of a national analysis on this topic, see Alig and Butler (2004). Examination of intensification of land management is illustrated by the 2001 RPA Timber Assessment (Haynes 2003).

Table 1 lists supporting major databases, and Table 2 lists examples of studies that have examined land base dynamics in the United States. In the United States, millions of acres of land shift uses each year (USDA NRCS 2001) reflecting billions of choices made by individuals, corporations, nongovernmental organizations, and governments. Next, we look at recent trends in those five categories of changes in the land base. Examining historical trends provides guidance for identifying key factors that are likely to influence forest land condition and associated natural resources in future years. Discussion of historical trends is a foundation for considering projected changes.

Forest Area Changes in Total

From 1953 to 1997, a majority (26) of States had a loss in forest area according to periodic surveys by the USDA Forest Service, e.g., Smith and others (2004). Nine States had net losses of at least 1 million acres each, ranging up to 6.3 million acres. In descending order of net loss amount, the States are Texas, Florida, California, Oklahoma, Louisiana, Washington, Alaska, Missouri, and Minnesota. Seven States had net gains of more than 1 million acres, ranging up to 4.1 million acres. In descending order of net gain amount, the States are New York, Ohio, Pennsylvania, West Virginia, Mississippi, Alabama, and Kentucky. The only regions with net gain in forest area were the North, where a relatively large amount of pastureland reverted naturally to forest, and the Intermountain Region, where a large number of acres were reclassified from pasture or rangeland to forest over time.

Note that much of the shift from pastureland or rangeland to forest use is due to reclassification over time.

Table 2—Example studies of determinants of land base changes involving forest land

Land base change	Data	Studies	Bases
Deforestation	Econometric	Alig and Healy 1987, Alig and others 2004, Kline and Alig 2001, Hardie and others 2000	USDA NRCS 2001; FIA surveys
Afforestation	Econometric	Lee and others 1992, Kline and others 2002	USDAForest Service tree planting reports
Forest fragmentation	Econometric and statistical	Butler and others 2004, Wear and others 2004, Alig and others 2005	National land cover database
Forest parcelization	Statistical	Butler and Leatherberry 2004	National forest landowner survey
Structure additions to forests	Statistical	Hammer and others 2004, Radeloff and others 2005, Stewart and others 2003	USDC Census Bureau changes
Urban forest changes	Statistical	Nowak and Walton 2005	USDC Census Bureau

As trees grow, they expand to reach the 10-percent canopy cover used to define forest land, which changes the pastureland classification to forest use. Even though now classified as forest, the land may still be used for grazing. Shifts between grazing land and forest uses are common, and although they are technically considered as shifts into and out of agriculture, they really represent multiple, overlapping uses.

Deforestation

The long-term loss in United States forest area since the early 1950s has been due to a combination of factors, but, in more recent decades, has been primarily due to conversion to urban and developed uses. Deforestation is conversion from forest to nonforest use, and between 1982 and 1997, 23 million acres were deforested on non-Federal land in the United States. Here we concentrate on private lands and secondarily on other non-Federal lands, for which more data are available (e.g., USDA NRCS 2001). The destination of about half of the converted forest acres was to urban and developed uses (Figure 1). Between 1982 and 1997, more than 10 million acres of non-Federal forests were converted to developed uses, an area larger than the combined current forest area of five Northeastern States (Connecticut, Delaware, Maryland, New Jersey, and Rhode Island). In the most recent data remeasurement period (1992–97), the proportion of deforestation due to urban and developed increased to 55 percent (USDA NRCS 2001).

Net changes (area into forest minus area out of forest) are typically much smaller than total or gross changes (area into forest plus area out of forest). Gross change in area of non-Federal forests in the contiguous 48 States between 1982 and 1997 totaled about 50 million acres (USDA NRCS 2001). The gross change in forest area was 14 times as large as the net change in forest area.

Conversion to Developed Uses—
Development spans a broad range of population density associated with settlement patterns, and definitions of development can depend on the data source and the purpose for which the data are analyzed. Two major data sources both show a steady increase in developed uses over recent decades. Estimates from the U.S. Census Bureau extend furthest back in time and show a 130-percent increase in census-defined urban area between 1960 and 2000. Census urban area comprises all territory units in urbanized areas and in places of more than 2,500 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 (Alig and Healy 1987). Although the term "paved over" has frequently been used to describe

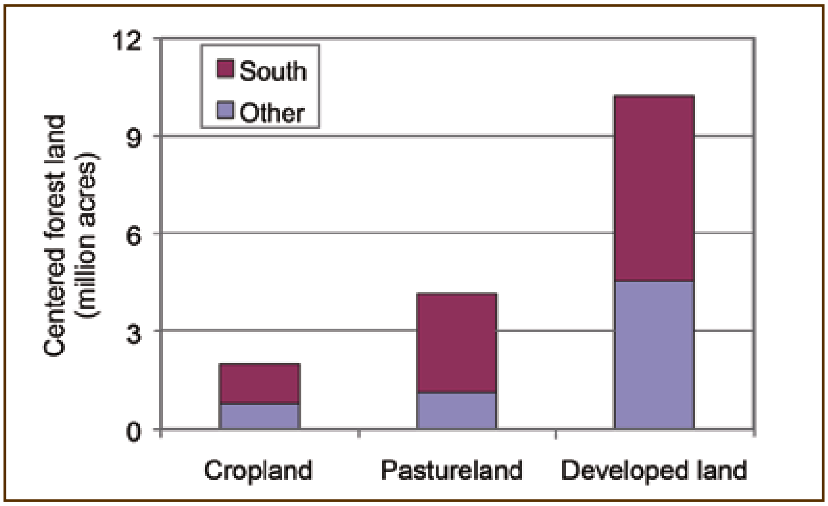

Figure 1—Conversion of nonfederal forest land by destination, and South vs. non-South, 1982-97 (USDA NRCS 2001) (note does not include rangeland and other miscellaneous uses).

urban land, only a small fraction of the land so classified is literally paved.

The other major data source is the National Resource Inventory (NRI) (USDA NRCS 2001), and it covers a shorter period (1982-97). The NRI estimate of U.S. developed area increased 34 percent between 1982 and 1997, with an acceleration in the 1990s that was more than 50 percent higher than that of the previous 5 years of measurement. Between 1982 and 1997, developed area as a percentage of the total land area in the 48 contiguous States increased from 3.9 percent to 5.2 percent. Forests were the largest individual source of developed land.

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. Including transportation infrastructure can be important in that new roads open land to development, alter the environment (e.g., facilitate invasion of certain species), can create congestion, and can degrade the quality of life. Changes in rural land use have historically been and remain connected with changes in motor vehicle use, technology, and policy.

A significant amount of low-density development has been part of the expansion in developed area. Rural America is home to a fifth of the Nation's people, and rural residential lots tend to be larger than housing lots in urban areas. One factor in the relatively greater increase in rural residential land use is that it is generally land extensive compared with the land-intensive residential use in urban areas. Rural residential lots, although fewer in number than urban lots, tend to be larger, averaging nearly 3 acres per household, compared with less than a half-acre per household in urban residential areas (USDA ERS 2006). Forty-four million acres, 60 percent of all rural residential lands, are in the largest lot-size category, over 10 acres. Rural land in this category is 3 1/2 times the area of urban land in this category. The wide acreage disparity between rural and urban large-lot categories is likely attributable to relative land values—lower land prices in rural areas make large lots more affordable (USDA ERS 2006).

The low-density housing development in rural areas means more people living closer to remaining forest land. A measure added in recent periodic Forest Inventory and Analysis (FIA) surveys conducted by the USDA Forest Service has been the identification of forest lands by rural-urban continuum class. Based on nationwide rural-urban continuum classes (Smith and others 2004), 13 percent of United States forest land now is located in major metropolitan counties, and 17 percent in intermediate and small metropolitan counties and large towns, together making up 30 percent of all U.S. forest land (Smith and others 2004, p. 47). Between 1997 and 2002, the forest area in major metropolitan areas increased by 5 percent, or more than 5 million acres, as the United States developed area expanded considerably. Consider that for the whole United States, more than one-quarter of counties are currently classified as metropolitan. That compares with less than one-tenth 50 years ago.

Amount of urban land per additional person is higher for non-metropolitan counties. Many Americans prefer to live in less-congested areas and will commute additional minutes or hours to realize their goals, taking advantage of the United States' excellent road system. Moreover, an increasing population of retirees has augmented out-migration from central cities and suburbs to rural areas that offer aesthetic amenities. Natural amenities may be a more important determinant of county-level inmigration than nearness to metropolitan centers or type of local economy (McGranahan 1999).

South

The largest increases in U.S. developed area between 1982 and 1997 were in the South, a key timber supply region (USDA NRCS 2001). There, the amount of land in urban and other developed uses increased more than 50 percent since the 1960s. The South had one-third of its developed area added during those 15 years, equal to about half of the U.S. total of developed area added during that period. Between 1982 and 1997, the South had 7 of the 10 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 did the country's most populous State, California. Over a more recent period, 1992–97, 6 of the 10 States that lost the most cropland, forests, and other open spaces to urban development were in the South. These six southern States in descending order of amount converted were Texas, Georgia, Florida, North Carolina, Tennessee, and South Carolina (USDA NRCS 2001).

In the Southeast, the concentration of development has been in the area of the urban Piedmont Crescent, extending from Richmond to Atlanta. Within this area are the Interstate 85 and Interstate 40 corridors, the backbone of job growth in the Southeast. Many of the smaller cities are adjacent to larger urban areas, resulting in population concentrations in larger metropolitan areas. The urban areas of the Piedmont are likewise expected to witness the fastest growth, whereas the mountains and the Coastal Plain will experience most of their growth in nonmetropolitan areas.

Several factors contribute to expansion of developed area in the South:

1. Above average county population growth due in part to climatic factors and attractiveness to immigrants (Glaeser and Shapiro 2001).
2. Above average marginal consumption of land per additional resident.
3. Income growth.

The Southern Forest Resource Assessment (Wear and Greis 2002) identified urbanization as one of the primary threats to forests in the region.

North

Areas of urban and developed uses steadily increased in the North since 1982. Between 1992 and 1997, the area of urban and developed area in the Northeast increased from 10.4 to 11.9 percent of the land base. Corresponding increases in the North Central subregion were from 6.7 to 7.3 percent.

The North had about one-third of the total addition to U.S. developed area between 1982 and 1997. The North had 3 of the 10 States with the largest average annual additions of developed area according to the NRI.

West

The West—Great Plains, Southwest, California, and Pacific Northwest—accounted for less than one-fifth of the total national addition to NRI developed area between 1982 and 1997. However, recent growth in the region has been above the national average. A growing number of "ranchettes" and large-lot subdivisions characterize housing growth in the Rocky Mountain region, resulting in the highest amount of developed area per additional person between 1992 and 1997 (Alig and others 2004, USDA NRCS 2001).

The largest percentage of change for a major land use in the contiguous three Pacific Coast States (California, Oregon, and Washington) was the 262-percent increase in urban area between 1960 and 1997 (Alig and others 2003). Urban area as a percentage of total land varies notably by State: 5.9 percent for California, 3.2 percent for Washington, and 1.0 percent for Oregon (Vesterby and Krupa 2001). The State of Washington illustrates the importance of migration for regional population growth and the concentration of growth in coastal areas (Alig and White 2007). Between 1990 and 2000, net migration to western Washington was 180 percent of the national increase (births minus deaths). Approximately 3.5 million people (59 percent of Washington State residents) live within 10 miles of coastline (including the Pacific Ocean and sounds).

Conversion to Agriculture

More than 8 million acres of forest land were converted to agricultural uses between 1982 and 1997 (USDA NRCS 2001). About half of the converted land has gone to pasture use, with the remainder fairly evenly split between crop use and rangeland. Forest land contributed 55 percent of the land that shifted into agriculture from 1982 to 1997, as land continued to be converted from less intensive uses, like forest, to agricultural uses, like cropland and pasture.

As with the conversions of forest land to developed uses, the majority of forest to agricultural conversions was in the Eastern United States and concentrated in the South. The South had the majority of forest land involved in either conversion to agriculture or gained from agriculture. In the South, land is often suitable for multiple land uses, given relatively gentle topography and ease of access.

On net, forestry gained 14.4 million acres from agriculture between 1982 and 1997. Of total land shifting out of agriculture, 22.7 million acres (46 percent) shifted into forest use, with about 17 million acres being former pastureland. Much of the shift from pastureland to forest use is due to reclassification over time. Factors associated with afforestation can differ by region and over time (in the North, for example, some land formerly used for dairy operations has reverted to forest cover). Most of the afforestation across the Nation—forestation either by human or natural forces of non-forest land—has been of a passive nature, e.g., reclassification as forest cover increased primarily through natural succession. However, tree planting has played a role especially in the South where 25 million acres of pine plantations have been established since 1952, (Alig and Butler 2004) mostly on land formerly in pasture and range use.

Forest Fragmentation

Land use change can lead to forest fragmentation—the transformation of a contiguous patch of forest into disjunct patches. Forest fragmentation is widely considered to be a primary threat to terrestrial biodiversity (Armsworth and others 2004), and recent analysis of the fragmentation of continental U.S. forests indicates that it is so pervasive that edge effects potentially influence ecological processes on a majority of forested lands (Riitters and others 2002).

Definitions of forest fragmentation differ and are influenced by the questions or policy issues of interest. One major distinction is between treating fragmentation as a process and treating it as a pattern (e.g., Alig and others 2000). Here we discuss forest fragmentation as a pattern. Fragmented forests may occur naturally across the landscape (as in the Great Basin, NV), or this pattern may be a result of human activities, resulting in edge, core or interior habitat, and interspersion changes (Butler and others 2004). Forest fragmentation can be quantified spatially using various indices of landscape structure, with different metrics for different scales of analysis and measurements of interest. Although many fragmentation statistics are available, none provide a definitive indicator of landscape fragmentation, only a means for comparing the characteristics and relative degree of fragmentation across landscapes or periods. Numerous biophysical studies have provided snapshots of forest fragmentation, primarily for the East (Table 1).

Forest Parcelization

Forest parcelization is the subdivision of forest tracts into smaller ownerships. This phenomenon can have profound impacts on the economics of forestry and lead to reduced forest management, even when land is not physically altered. Land ownership can influence forest land management and investment practices. In addition, per unit costs of forest management practices will increase if economies of scale are lost.

Many of the forest-related increases in population density have been on nonindustrial private forest (NIPF) lands, the ownership class most subject historically to land use changes (e.g., Smith and others 2004). Because NIPF owners are aging and have descendants who live farther from the forest and for whom timber management is not a primary objective, dealing with real estate appreciation may be more central to family succession planning now than it was in the past. Critical wildlife habitat is often provided by NIPF ownership, as in the Pacific Northwest, where lowlands and riparian areas critical to threatened and endangered species are primarily in NIPF ownership (Bettinger and Alig 1996). Family forests are a large component of the NIPF ownership class; the number of family forest owners increased from 9.3 million in 1993 to 10.3 million in 2003, and these owners now control 42 percent of the Nation's forest land (Butler and Leatherberry 2004).

Recent shifts in the ownership of the most intensively managed forests in the United States could lead to a substantial increase in parcelization. In the sales of large forest properties, there often is a spinoff for real estate development purposes (highest and best use), and overall, the amount of large industrial forest ownership has been reduced materially in a relatively short time. A large share of the forests long held by consolidated forest products companies has recently been sold to institutional investors. Many of these transactions have occurred in the South. Institutional investors currently hold about 8 percent of the investable U.S. timberland (Wilent 2004). By the end of 2003, the top 10 timberland investment organizations (TIMOs) managed about 9 million acres of U.S.timberland, and some analysts predicted that TIMOs and other investor groups (e.g., Real Estate Investment Trusts, or REITs) will purchase another 10 to 15 million acres in the next decade (Wilent 2004).

Two main types of investment models are pursued by TIMOs: separate accounts and closed-end funds. Whereas separate accounts tend to be managed for the long term, closed-end accounts are typically held for a more limited period of 10 to 15 years before being sold. One estimate is that one-half of all TIMO investments are of the closed-end type (SAF 2004). In terms of forest fragmentation and conversion, it is the closed-end accounts that may exacerbate rates of deforestation. When TIMOs sell land, they pursue the highest value they can receive, which will most likely be for development and real estate. Currently, sales and acquisitions of forest industry (FI) lands continue to be active as market forces, globalization, and consolidation impact the forest sector.

The emergence of timberland holding firms with timber production objectives but no link to processing facilities has created some difficulties in this traditional taxonomy. Lacking processing facilities, these firms would be grouped in the NIPF class. Yet their timber management behavior is more closely akin to that of the integrated firms in FI. Shifts from traditional integrated FI ownership to the TIMO/REIT class were extremely rapid in the late 1990s and early 2000s, and it is likely that the future will see still further decline in traditional, integrated FI ownership.

With a substantial amount of prime U.S. timberland shifting from being a personal or industrial asset to being a financial one, more frequent turnover in forest ownership may be part of a new era in forest ownership. This warrants increased attention in data collection and land base monitoring because such changes have implications for a broad range of forest-based ecosystem goods and services owing to the influence of changing forest ownership patterns on forest conversion, fragmentation, and parcelization.

Increased Numbers of Buildings and People on Forest Land

A significant proportion of forest land undergoing development each year is used for dispersed residential development in fringe suburbs and smaller cities, commonly known as sprawl. Sprawl is characterized by low-density residential and commercial settlements, and increases in housing density on or adjacent to forests can result in changes to the forest's quality and function and changes in forest investment (e.g., Kline and others 2004b). Forest lands are very popular as residential building sites; forests provide homeowners with shade, screening from neighbors,

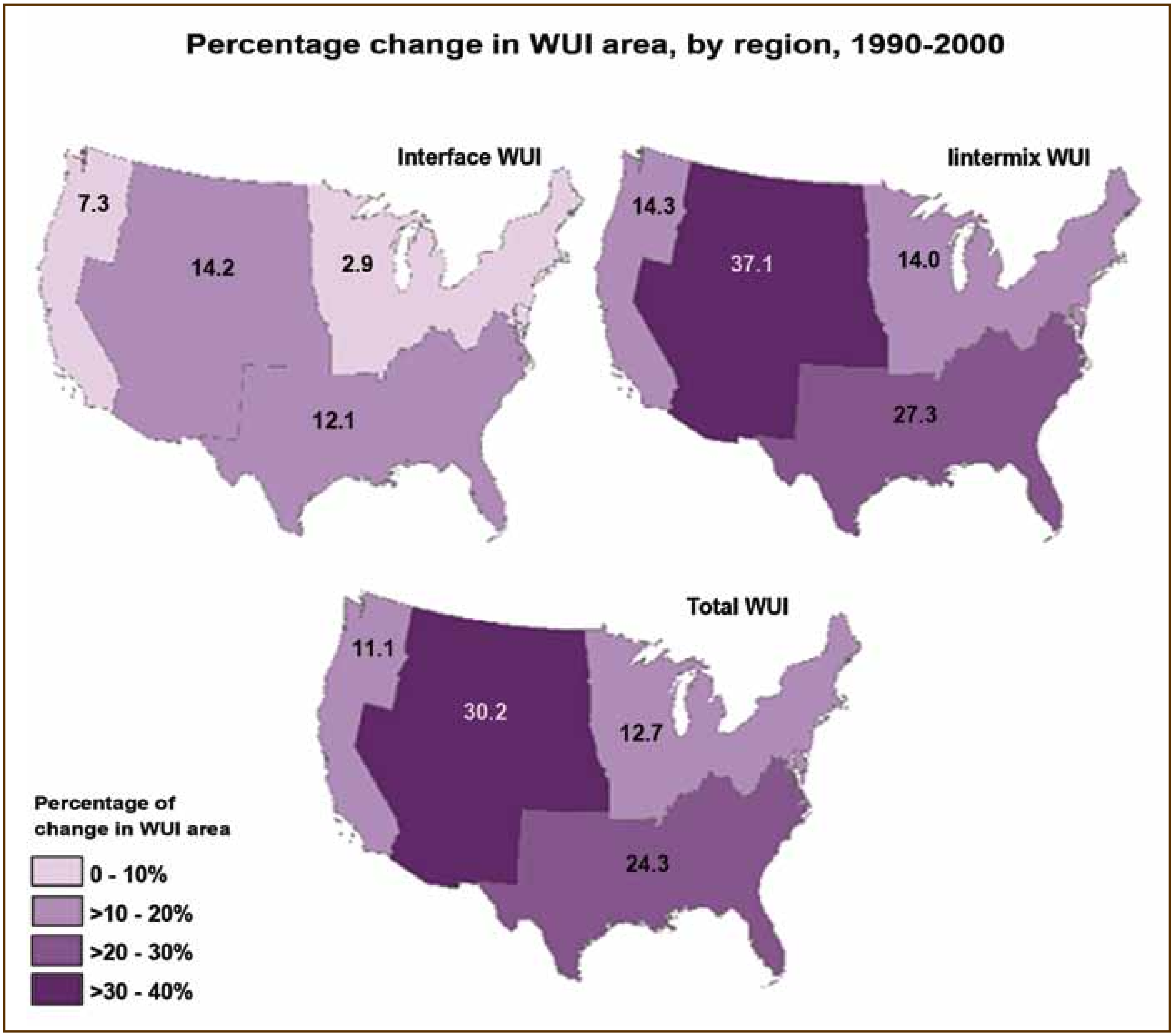

Figure 2—Wildland-urban interface in the United States and percentage change in area by region, 1990-2000.

scenic views, wildlife and bird watching opportunities, and often, easy access to forest-based recreation opportunities. New communication and transportation technologies reduce the isolation of remote locations and make possible long-distance commuting and a wide variety of remote work arrangements. These developments effectively reduce the costs associated with living far from cities and towns. Many areas of the United States are experiencing residential growth in the forests and pressure to develop remaining forests.

The colocation of houses and forests (as well as other wildlands) is captured in the national map of the Wildland Urban Interface (WUI), which was created to aid analysis of the national wildland fire situation (Figure 2). The WUI definition that guided creation of this map and analysis is found in the Federal Register (USDA and USDI 2001) and specifies minimum housing density of 1 structure per 40 acres (or 6.17 structures per km^2) and either co-location with, or close proximity to, wildland vegetation. National Land Cover Data and Census Bureau housing data are used together to determine where these conditions exist. Two main types of WUI—intermix and interface—are identified. Intermix exists where housing and wildland vegetation (at least 50 percent of all pixels in the census block are forests, grasslands, or shrublands) coincide. Areas that meet the housing density minimum but where the wildland vegetation is less dense are considered interface if they are within 1.5 miles of extensive wildland vegetation (defined as an area larger than 5 km^2 or 1,235 acres with >75 percent wildland vegetation). Together, the intermix and interface make up the WUI (Radeloff and others 2005).

In areas where forest conditions, weather, and climate make wildfire possible, the WUI is a zone where the threat of loss from wildfire is high, because fires can be carried into this zone where they will threaten homes and lives. Consequently, the WUI has high priority for wildfire hazard reduction treatments. The WUI is also the area where wildland fire outreach programs focus their attention. Resource managers and their outreach partners work with communities and property owners to mitigate wildfire hazards and to plan for evacuation and other emergency measures in the event of wildfire.

Across the United States, the 1990s were a period of rapid housing growth, with a net gain of 13.5 million housing units, a rate of 13 percent growth. The WUI was clearly a preferred setting for new housing; overall WUI growth was 22 percent, and intermix growth was 37 percent. The growth patterns for the United States were consistent across the regions, with growth slower in the non-WUI and faster in the intermix WUI (Figure 2). Most of this WUI housing growth took place in areas already designated as WUI in 1990. The growth in WUI area owing to new neighborhoods reaching the housing density minimum for WUI was just 1.5 percent nationally, though it expanded much more in the South and North than in the West.

Across the United States as a whole, the distribution of housing units across the high-, medium-, and low-density interface categories changed little over the decade. Growth in the intermix WUI occurred at high, medium, and low densities, with biggest gains in medium-density intermix. This finding is consistent with adding housing units to existing WUI areas (since existing WUI already had at least low-density housing in 1990) at a greater rate than adding new areas to the WUI. However, in the West, housing growth was strongest in high-density intermix.

In the South, housing increased by 18 percent, almost as much as it increased in the Rocky Mountain region and presented an even greater contrast between non-WUI housing growth (9 percent) and WUI housing growth (29 percent). Over 3 million housing units were added to the WUI during this decade, and the WUI expanded to cover 17.1 percent of the land area, a greater share than in any other region.

Housing grew more slowly in the North than in any other region at just 9 percent. However, the intermix WUI gained nearly 1.2 million new housing units, an increase of 21 percent over the decade. The area of the WUI also expanded; by 2000, over 15 percent of the North was WUI.

Housing increased by 23 percent in the Rocky Mountain region more than in any other region. Once again, WUI housing growth was even stronger (37 percent), whereas intermix WUI housing grew by 75 percent. Although the 2000 WUI makes up just 1.4 percent of this region's land area, it contains 45.7 percent of the housing units.

Housing growth in the West Coast region was 12 percent overall, with over 1 million new WUI housing units, an 18-percent increase in the number of WUI homes. WUI area also expanded from 5.8 to 6.5 percent of the three-State area. Of the 16.1 million housing units in this region, over a quarter (4.5 million) are located in the interface WUI.

Analyzing housing growth within the WUI classification provides insight about more than the location and density characteristics of recent change; it also indicates the impact of this growth on forests, grasslands, and other wildland vegetation. More than 60 percent of housing units built in the 1990s were constructed in or near wildland vegetation. Although the fire management community originated the WUI concept as an approximation of where values are at risk from wildland fire, the WUI zone is significant for a broader range of ecosystem services. Clean water, timber, recreation, and other services and outputs from undeveloped land are at risk when development encroaches, and encroachment was significant during the 1990s.

Trees in Urban and Developed Areas

The extent of urban forest has grown appreciably in recent decades. As urban lands expand into surrounding areas, natural resources are often affected or displaced. Between 1990 and 2000, most urban expansion in the United States was on forested or agricultural land (Nowak and others 2005). Urban areas in the United States, as defined in the 2000 census, contain approximately 3.8 billion trees with an average tree canopy cover of 27 percent (Nowak and others 2001). The impact of current urban vegetation on environmental quality nationally is on the order of several billion dollars per year (e.g., Nowak and Crane 2002, Nowak and others 2006).

Urbanization concentrates people, materials, and energy into relatively small geographical areas to facilitate the functioning of an urban society. Urbanization often degrades local and regional environmental quality as natural landscapes are replaced with anthropogenic materials. Byproducts of urbanization (e.g., heat, combustion, and chemical emissions) affect the health of local and regional landscapes, as well as the health of people who visit or reside in and near urban areas. Urban vegetation, through its natural functioning, can improve environmental quality and human health in and around urban areas, with benefits including improvements in air and water quality, building energy conservation, cooler air temperatures, and reduction in ultraviolet radiation.

Forest-Land Dynamics

Five types of land base changes (afforestation, deforestation, forest fragmentation, forest parcelization, and increased number of buildings and people on forest land) have significantly altered U.S. forests over the last half century. Although net changes in total forest area are relatively small from a national perspective, many more forest acres are actually involved in land use changes as the gross amount of change is more than 10 times the net amount. Small net changes in forest cover do not necessarily equate to small net changes/losses in services provided by forests. The gross changes reflect the combined outcome of the five types of land-base changes, which often result in spatial rearrangement of land uses and land covers. The South, which now provides more timber harvest than any other region of the country, in particular, has seen many forest-related land-use changes resulting from population growth and economic activity. In addition to deforestation, substantial forest ownership changes in the South include the shifting of prime timberland from a personal or industrial asset to a financial one. Further, many remaining forest acres are affected by addition of houses on them or nearby. For some forests that are converted to urban uses, there are opportunities to manage urban trees to reduce some of the adverse environmental and health effects associated with urbanization. The South also has a relatively large number of afforestation opportunities, including land suitable for biofuels production as part of global change mitigation strategies.

Determinants

Based on land use theory, empirical testing utilizes real world data to quantify model parameters and test for consistency with underlying hypothesized behavioral relationships. Empirical models can be used to predict how land use will change in response to changes in economic conditions and policies. A method increasingly reported in the literature is econometric modeling, which is based on statistical methods that are used to quantify relationships between land uses and hypothesized determinants such as landowners' profit from land management. Determinants to be tested are drawn from the interaction of biophysical, ecological, and socioeconomic processes and forces, often operating at a variety of scales. For example, market forces tend to operate at much larger scales than biophysical processes commonly studied at micro levels such as stands or reaches of a stream. Most econometric models of land use developed to date have been regional in nature, although Lubowski (2002) recently developed a national land use model.

Econometric land use models typically are estimated with sample plot data for a random sample of parcels or aggregate data such as county-level observations of land use (e.g., Ahn and others 2002, Alig 1986, Hardie and Parks 1997, Kline and Alig 1999, Kline and Alig 2001, Lubowski and others 2006, Parks and Murray 1994, Plantinga 1996, Wear and others 1996). With the advent of satellite imagery

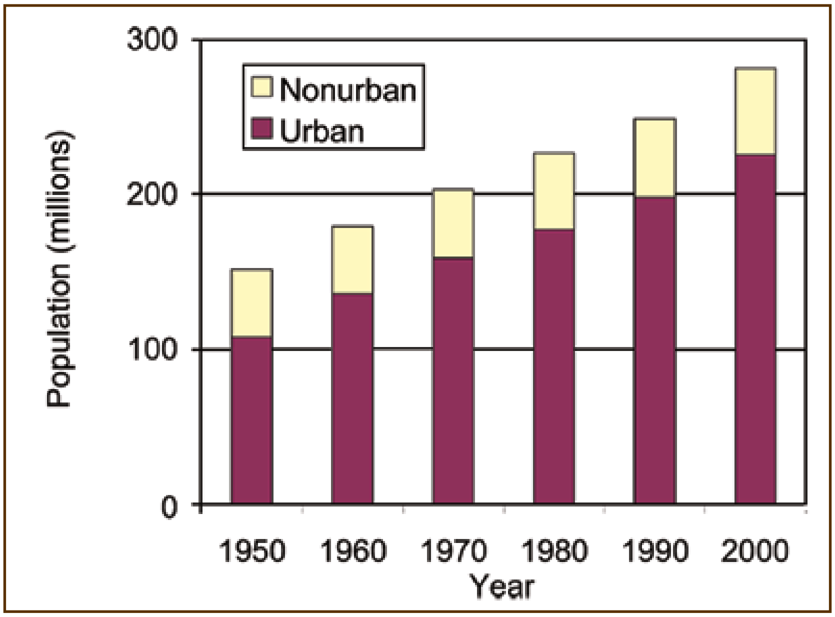

Figure 3–United States population by urban and nonurban components, 1950 to 2000.

and geographical information systems (GIS), econometric land-use models have been estimated using spatially referenced plot or parcel-level data (e.g., Bockstael 1996, Irwin and Geoghegan 2001, Kline and Alig 2001, Wear and Bolstad 1998). Examples of explanatory variables in such models are rents (or its proxies) for forestry, agriculture, and urban/developed uses.

Findings from econometric studies indicate that drivers of deforestation differ notably from those of afforestation and reforestation activities. Major determinants for deforestation associated with conversion to urban and developed uses in the United States are population totals and personal income levels. The rate and extent of urbanization are typically governed by such determinants, which shift demand toward urban and developed uses. Revealed behavior by landowners indicates that values for developed uses (e.g., residential uses) are generally higher than those for rural uses (e.g., forestry and agriculture) (Alig and Plantinga 2004, Alig and others 2004). Within the rural land base, relative land rents for forestry and agriculture affect deforestation (i.e., forest converted to agriculture), afforestation, and reforestation decisions. A number of econometric studies offer insights about determinants of afforestation (e.g., Plantinga 1996) and reforestation activities (e.g., Alig and others 1990, Lee and others 1992, and Kline and others 2002), including tests of government subsidies. For example, Lubowski (2002) found that rising government subsidies for agricultural crops restrained an increase in forest area in the Mississippi Delta area by 10 percent from 1982 to 1997.

Population

A key determinant in land use change is population growth, which affects the demand for land. But, population growth has potentially contradictory effects on forest land conversion; it can increase demand for land for residential use, while also increasing demand for (and thus, price of) wood products. Rising prices for wood products will tend to increase the relative rents associated with keeping land in forest rather than converting it to residential use.

Figure 3 shows population growth for the United States since 1950. The population has increased almost fourfold since 1900. The distribution of population has also changed over time. For example, decentralization of population relative to city centers has involved a downward trend in the percentage of U.S. population within 3 miles of city centers. Around 1900, about 80 percent of the population lived within 3 miles of those centers; now less than 30 percent of the population does so. However, the proportion of people who live in more broadly categorized “urban areas” has steadily increased since 1950 and is now about 80 percent. The largest increases in population between 1980 and 2000 have been in metropolitan edges (Heimlich and Anderson 2001). At the same time, the populations of some non-metropolitan counties adjacent to metropolitan ones have increased as well.

The location of population is important in connection with vulnerability of communities and assets (e.g., houses). More than half of the U.S. population lives in coastal areas (within 50 miles of a coast), part of a growing trend. This has implications for vulnerabilities to extreme weather events, such as last year's hurricanes on the Gulf Coast. More broadly, coastal ecosystems are increasingly being stressed by factors that include lowland development in States such as Florida and Texas.

The Census Bureau projects that the Nation's population will increase by more than 120 million by 2050—more than a 40-percent increase over the 2000 population size. The two major components driving the United States population growth are fertility (births) and net immigration. Almost one-third of the current population growth is caused by net immigration. Net immigration remains constant at 880,000 per year, whereas the Census Bureau recognizes that there is considerable uncertainty about the future flow of migrants. By 2050, the Nation's population is projected to be 82 million people larger than it would have been without growth through migration. In fact, about 86 percent of the U.S. population growth during the year 2050 may be due to the effects of post-1992 net immigration.

Population redistribution (i.e., regional growth and decline within the United States) is due in part to amenity migration. The National Forests of the United States have rich scenic and recreational resources that have induced amenity growth in nearby rural areas of the country over the past three decades (Garber-Yonts 2004). The 2000 U.S. Census showed that national forest (NF) counties (counties where >10 percent of land area is national forest, n = 454) had higher population growth rates than other counties. This is true especially in those NF counties that were nonmetropolitan (n = 386), where the 1990 growth rate was 18.1 percent versus 10.3 percent in nonmetropolitan, non-NF counties. Migration accounted for most growth across all NF counties, even metropolitan ones, despite the much stronger role of natural increase (i.e., more births than deaths) in metropolitan county growth generally.

Personal Income

Average family income (in real or inflation-adjusted dollars) increased by more than 150 percent from 1950 to 2000, giving individuals more income to spend. The U.S. per capita disposable income in 1998 was $22,353, which represents more than a 10-percent increase, in real terms, during the 1990s alone.

Further increases in personal income are projected, but not at the level of increase in the 1990s (USDA Forest Service 2001). Even with constant tastes and preferences, a larger population base with higher income levels will result in greater consumption and demands for developed space. For example, consumers may demand more shopping space, as between 1990 and 2000 when the United States shopping area increased by 27 percent and number of shopping centers by 24 percent (USDC Census Bureau 2001).

Incomes From Rural Land Uses

More than 90 percent of land use changes on non-Federal lands in recent decades have been among rural land uses (USDA NRCS 2001): forests, crops, pasture, or range. Where climate and physiography permit, these rural uses can compete for the same land. For example, a reduced supply of agricultural land due to urbanization can result in "replacement" conversion of forest land to agricultural uses (Alig and Healy 1987). Market forces often result in shifts in the use of rural lands between agricultural production and forest production. Increasingly global markets are also affected by technological improvements, and, since World War II, increases in cropland yields per acre have generally been larger than corresponding increases in forestry yields. Enhanced productivity has the effect of concentrating agricultural uses on a smaller land base and easing demands for conversion of forests to agriculture.

Net income from forestry enterprises is affected by prices for products including timber. Over the 50 years from 1952 to 2002, real prices of softwood lumber, hardwood lumber, and paper rose (at compound rates of 0.8 percent, 0.4 percent, and 0.3 percent, respectively), whereas prices of softwood plywood, oriented strand board (OSB) (since 1976), and paperboard fell (Haynes and others 2007). Recent timber market projections for the USFS Resources Planning Act (RPA) Assessment (Haynes and others 2007) indicate that prices for some forest products will increase over time but at a slower rate. Prices of softwood lumber, hardwood lumber, and OSB are projected to rise slowly (at compound rates of 0.2 percent, 0.3 percent, and 0.1 percent, respectively), and prices of softwood plywood, paper, and paperboard are projected to remain stable or fall. Slow product price growth is reflected in many categories of timber prices (which determine returns to landowners). Sawtimber stumpage prices in the South and interior West are expected to decline slowly after 2010, while those in the PNW and North are expected to rise at about 0.2 percent and 0.8 percent per year. Southern hardwood pulpwood prices rise in the projection as hardwood inventories contract. Southern softwood pulpwood prices oscillate in response to the changing fiber mix, ending the projection near recent levels.

On the agricultural side, real prices have declined for major agricultural crops grown on land also suitable for forestry. Toward the end of the 20th century, farmers and ranchers were increasingly caught in a cost-price squeeze. The ratio of the Prices Received Index to the Prices Paid Index fluctuated considerably over the past hundred years (Ahearn and Alig 2006, USDA NASS 2006). Commodity prices spiked upward during both World Wars and plunged during the Great Depression. Prices again shot upward during the early 1970s, spurred on by sharply increased world demand. Technological improvements in agriculture, such as in yields per acre, have generally outpaced those in forestry. Although this has resulted in an increase in the use of land for agricultural cropland in some areas, the increase in aggregate crop yields and downward pressure on agricultural market prices resulted in land saving for farmers and a net switch from agriculture to forestry at the national scale.

The outlook for agricultural income often involves substantial uncertainty in land use studies because of the cyclical nature of the agricultural economy, effects of government programs, and technological developments (e.g., genetically modified materials) (Alig and Ahearn 2006, Alig and others 2003). Emergency aid provided to farmers through legislation in 1998 through 2001 suggests that the direction of the current policy transition remains uncertain. Under the Federal Agricultural Improvement and Reform Act of 1996, the Federal Government is moving further away from direct involvement in farm commodity markets. However, threats of droughts and other elements that inject volatility in agricultural and forestry production have prompted some annual adjustments in the government intervention plans. With lower agricultural prices than in the mid-1990s, the 2002 farm bill was debated during a period when agricultural prices were low. The debate showed that there was some interest in changing the thrust of the 1996 farm bill by introducing new countercyclical policies. Policy shifts in this area could affect the dynamics of the link between land use patterns and market prices.

Projections

Projections from different studies (e.g., Resources Planning Act Assessments) are summarized next and compared where appropriate. Land use projections are generally prepared by obtaining projections of the independent variables and then simulating the impacts of projected conditions on future land uses (Table 3). Projections can be implemented to contrast the potential effects of policy or market changes with historical usage (counterfactual simulations, e.g., Lubowski and others 2006) or to project future land uses over a range of scenarios (e.g., Alig and others 2003). Projection exercises have indicated that future land uses are especially sensitive to changes in population density, income, and agricultural and timber prices and production costs.

Developed Uses

Urban and developed areas are projected to continue to grow substantially in line with the projected population increase of more than 120 million people over the next 50 years (Alig and others 2004). This will be part of a global increase in population, as the world's population is projected to grow from 6 to 9 billion by 2050. The U.S. developed area is projected to increase by 79 percent, raising the proportion of the total land base that is developed

Table 3—Sources of land use projections, by region (note: no large-scale forest parcelization projections were located)

Land base change	Approach	Studies	Projected amount in U.S.
Deforestation	Econometric and mathematical optimization	Alig and Healy 1987, Alig and others 2004, FASOM (Alig and others 2002) Alig and Plantinga 2004	More than 50 million acres deforested by 2050, mostly for developed uses
Afforestation	Econometric and mathematical optimization	Lee and others 1992, Kline and others 2002, FASOM (Alig and others 1998, 2002), Alig and others 2003, Alig and Plantinga 2004	About 20 million acres converted from agriculture to forest by 2050 (FASOM)
Forest fragmentation	Econometric	Wear and others 2004	South projected to lose about 2 million acres of interior forest by 2020
Structure additions to forests	Statistical	Stien and others 2005	44 million acres of private forest with substantial increase in housing density by 2030
Urban forest changes	Statistical	Nowak and Walton 2005	29 million acres of forest to be urbanized by 2050

from 5.2 percent to 9.2 percent. Projections based upon Census Bureau data indicate similar substantial increases in urban area. Urban land in the United States is projected to increase from 3.1 percent in 2000 to 8.1 percent in 2050, an area of about 97 million acres, which is larger than the state of Montana. Most of the urban growth is projected to occur around the more heavily urbanized areas, with significant expansion in the East and along the west coast.

Population and income pressures on land uses are not uniform across the Nation. For example, population has shifted from the North to the South and the West in recent decades. Because much of the growth is expected in sensitive areas already burdened by anthropogenic impacts, such as some coastal counties, implications for landscape and urban planning include potential impacts on sensitive watersheds, riparian areas, wildlife habitat, and water supplies. Although providing additional living space and infrastructure, added development may also diminish agricultural output by reducing farmland and changing ecological conditions by converting and fragmenting forests and other natural landscapes. The projected developed and built-up area of about 175 million acres in 2025 represents an area equal to 38 percent of the current U.S. cropland base, or 23 percent of the current U.S. forest land base. In line with recent historical trends, the South is projected to continue to have the most developed area through 2025 (Alig and others 2004).

Forest Land

Total forest land area in the United States is projected to decrease on net by approximately 23 million acres, or 3 percent between 1997 and 2050 (Alig and others 2003). Projections of forest land area are related to those above for the other major land uses. The main reason for the projected reduction in forest land area is conversion to urban and developed uses associated with the projected increases in population and income discussed earlier.

The projected reduction in forest land is consistent with earlier studies (e.g., USDA Forest Service 1988). The notable reductions in the South are generally consistent with the regional assessment of the southern forest resource situation, indicating that urbanization, among all forces of change, will have the most direct, immediate, and permanent effects on the extent, condition, and health of forests in the South (Wear and Greis 2002). Projections estimate that tens of millions of acres of forests in the region will be lost to urbanization from 1992 to 2040. The 13 States in the South are projected to have an overall net decline of only 2 percent in forest area because some farmland will be converted to forests. Timberland area is projected to increase in the South-Central region, where much land is suitable for use in either agriculture or forestry, as a consequence of conversion of agricultural land to forest. Such conversion is to be expected if it is assumed that real prices for agricultural commodities fall and agricultural subsidies and related programs are reduced.

The largest forest area losses in the South are projected for the Southeast. Forest land at the periphery of urban areas is likely to be developed. For example, in Georgia about 5.6 million acres of forests may be converted to developed uses by 2010. It is conservatively estimated that as much as 26 percent of the timber-growing stock measured in the 1997 Georgia inventory could be affected (Wear and Newman 2004).

Projections for other regions of the country largely follow recent historical trends (Alig and others 2003). Most of the losses are projected to be on NIPF lands.

Comparison of Land Use Projections—
We compared land use projections from models by Lubowski and others (2006) and Hardie and others (2000). We use these models to project land uses in the Southeastern United States to the year 2020. Using two separate models allows us to examine potential differences based on modeling structure. The Lubowski and others model estimates transitions or changes in land uses, whereas the Hardie and others model estimates the equilibrium land use shares in each period. Both models summarize land uses at the county level and are based on measures of land uses from the National Resource Inventory (NRI). The 1997 NRI survey serves as the base year for projections.

Projections for the South as a whole show a significant continuation of urbanization and are consistent with the Nowak and others (2006) projections and separate projections by Alig and others (2004). Urban area in the South is projected to increase under all scenarios.

Year 2020 forest land area projected by the model of Lubowski and others is similar to those generated by the model of Hardie and others under a high timber price scenario. The Hardie and others model projects that forest land area in the South could fall as much as 20 million acres under a low timber price scenario. Econometric land use models are generally effective tools for projecting forest area; but an important consideration is whether there are any changes in the underlying structural relationships over the historical or projection periods, analyzed using statistical methods to test for changes (e.g., significant policy environment alteration) in model parameters over time (Ahn and others 2000).

Projections of Forest Fragmentation—
Relatively few studies have projected forest fragmentation, especially at larger scales. One example of a broader scale study is in Wear and others (2004) where changes are forecast in interior forest for each county in the South, a region where recent trends include significant land use change. Wear and others, who based forest fragmentation projections on population density forecasts to the year 2020, assumed that relative returns to agricultural and timber production would remain at current levels. Under this scenario, the South as a whole is forecast to lose 747 000 ha (1.85 million acres), or about 2.12 percent of interior forest cover.

These changes are not constant across the region. Among ecological sections, the Southern Appalachian Piedmont would lose the greatest area of interior forest cover (173 166 ha or 427,903 acres). The gulf prairies and marshes in Texas, which have very little interior forest, would lose the greatest proportion of interior forest (56.7 percent) (Wear and others 2004). The second and fourth greatest reductions are projected for the eastern and western Florida coastal lowlands, respectively. Aggregation to the ecological province level indicates that the Outer Coastal Plain would experience the greatest reduction in interior forest. All ecological sections with losses forecast at greater than 2 percent are located either on the Atlantic and Gulf Coastal Plain or in the upland areas of North Carolina, Virginia, Tennessee, and Kentucky.

The distribution of forecast losses of forest interior between urban and rural counties was examined further. Urban counties were defined as those attached to metropolitan statistical areas (MSAs) by the Office of Management and Budget, and rural counties were defined as the remainder. The MSA counties contain 492 690 ha (1,217,463 acres) or 66 percent of the total forecast loss of 747 744 ha (1,847,716 acres). (Heavily impacted MSAs are concentrated in Florida. The Tampa-St. Petersburg-Clearwater MSA is forecast to lose 34.5 percent of its interior forest, and 7 of the 10 MSAs with the highest percentage losses are found in Florida. Columbia (South Carolina), Atlanta (Georgia), and Raleigh-Durham-Chapel Hill (North Carolina) round out the top 10.

Housing Density—

Projections of housing density increases on forest land were made in the Forests on the Edge study discussed in "Forest land Conversion and Recent Trends." This project has ranked watersheds across the conterminous United States according to the percentage of each watershed that contains private forest projected to experience increased housing density (Stein and others 2005, Theobald 2005). Three housing density thresholds were identified: rural (no more than 15 units for every square mile); urban (at least 64 units per square mile); and ex-urban (16 to 63 units per square mile). Areas identified as having a substantial increase (44 million acres in total) were those where housing was projected to increase from either rural or ex-urban to urban (22 million acres) or from rural to ex-urban (22 million acres). Watersheds included in the assessment had at least 10 percent forest cover with a minimum of half private land.

Note that for the WUI research, projections of WUI growth, 2010 to 2030, will be made by Northern Research Station scientists and collaborators as soon as the housing density projections on which they are built have been completed. The WUI projections will assume that vegetative cover will remain constant through 2030.

Most watersheds projected to experience the greatest amount of change were located in the East, although some were located in the Great Lakes area, California, and the Pacific Northwest. The greatest change will be in 12 States in the Northeast and South (Stein and others 2005). A study in progress is identifying watersheds where private forests contribute most to water quality, timber, interior forest, and at-risk species habitat and determines where these contributions may be most affected by factors such as housing increases, fire, air pollution, insect pests, and disease. As discussed in a case study at this conference, private forested watersheds most affected are generally found in the East and along the West Coast (Stein and others, this volume). Stresses on forest environmental conditions can be compounded if more people live on the remaining forest land as the U.S. population density continues to increase. The United States had about 80 people per square mile of land in 1999 (USDC Census Bureau 2001) in comparison to about 5 people per square mile in 1790.

Risk and Policy Considerations

A broad complement of research studies is consistent in projecting continued development of forests or increases in the housing density of remaining forests in the future, or both. Key assumptions in such studies include projected increases in population and income, which are generally viewed as more likely to approximate future conditions over the next five decades. In contrast, other assumptions are viewed as having larger bands of possible outcomes, and examples of such assumptions are future changes in the agricultural sector, technological changes, changes in forest practice regulations, and global climate change. The relative sensitivity of projected land use changes to such assumptions has been tested in a number of studies (e.g., Alig and others 2003, Haynes 2003, USDA Forest Service 1988).

It appears that tens of millions of acres of forest are at risk of being converted to nonforest and that many more acres remaining in forest cover will have houses and other structures added over the next several decades. To the extent that this loss of forest land may have detrimental impacts on the social values derived from forests, it seems reasonable to ask how changes in policy might affect this outcome. We next discuss several types of policies that could have some influence on the future of forests in the United States.

Government Policies

Government policies that can contribute to development include Federal/State expansion of highways, income tax subsidy for home ownership, and extension of public utilities. Policy responses to any perceived problem can involve local, regional, State, and national responses. An example of local influence is zoning and development impact fees. Regional responses may include regional governance or tax sharing. State policies include urban growth boundary approaches as in Oregon. Conservation easements have been increasing in popularity as a tool for encouraging the protection of forests and other lands. Landowners receive tax benefits or are paid a lump sum in exchange for restricting the type and amount of development and other uses that may take place on their property. Easement restrictions are identified in a legal agreement signed by the landowner and a conservation recipient (usually a public agency or land trust). To qualify for tax benefits, an easement must be perpetual, with future owners bound by the same restrictions.

National Level—

At a national level, the USDA (1983) is an example of a Federal agency with a major land use responsibility. Departmental policy is to promote land use objectives responsive to current and long-term economic, social, and environmental needs. This policy recognizes the rights and responsibilities of State and local governments for regulating the uses of land under their jurisdiction. It also reflects the department's responsibility to:

1. Assure that the United States retains a farm, range, and forest land base sufficient to produce adequate supplies, at reasonable production costs, of high-quality food, fiber, wood, and other agricultural products that may be needed.
2 Assist individual landholders and State and local governments in defining and meeting needs for growth and development in such ways that the most productive farm, range, and forest lands are protected from unwarranted conversion to other uses.
3. Assure appropriate levels of environmental quality.

Contemporary land use policies as a whole are multiobjective in nature, as is evident in the policy directive of USDA (1983). Implementation of multiobjective policies is laden with tensions. For example, although the USDA policy directive was written nearly two decades ago, major challenges still exist in attaining a balance that satisfies USDA's many constituents. One challenge involves a major contemporary focus of land use policies—the management of the direction of development. Urban sprawl has been cited as one of the leading concerns of Americans (Pew Center 2000). According to the Pew report, approximately 1,000 measures aimed at changing planning laws and at making United States development more orderly and conserving were introduced in State legislatures in the late 1990s. Concerns about sprawl originate from both the disamenities associated with increased congestion as well as the loss of productive land for agriculture and forestry uses. Although the recent and current situation in agriculture is one of surpluses and depressed markets, agriculture is historically cyclical in the long run. With a rapidly growing world population, food and fiber demand is likely to increase in the future. There has not been sufficient confidence that the current land market is capable of appropriately discounting the future value of farmland to account for this eventuality. Long-term loss of prime agricultural land and forest land to urban uses arises in part because lands that are highly suitable for agriculture or forestry and for urban expansion are often one and the same—gently sloped, fertile valleys, and flood plains. Urban conversion is generally one way; the land is usually irretrievably lost for less intensive use within typical planning horizons.

State and Local Levels—

State and local governments use a variety of tools to protect farm and forest lands as productive resource bases. These tools include agricultural zoning, differential farm tax assessments, right to farm laws, agricultural districts, purchase of development rights, transfer of development rights, comprehensive land use planning, and urban growth boundaries.

At a State level, Oregon has a statewide land use policy involving urban growth boundaries (e.g., Kline and Alig 1999). For example, Portland, Oregon, in the 1990s had

30 percent of new housing as infill and redevelopment. Boulder, Colorado, has an urban containment policy. The city restricts new development, and the majority of the workforce lives outside city limits.

Two USDA programs, the Farmland Protection Program for agricultural lands and the Forest Legacy Program for forest lands, complement State and local government programs that purchase development rights. The purchase of development rights gives government agencies the option of conserving open space for future use in farm or forest production without government acquisition. The land will not necessarily be required to stay in a current farm or forestry use, but under a program that purchases development rights, a landowner will not be allowed to develop the parcel. Because the cost of cultivating undeveloped land is considerably less than the expense associated with reversing development, purchasing development rights is viewed as an investment in food and forestry security for future generations. Conservation easements and other partial interests in land have also been increasingly used to accomplish particular natural resource protection goals such as maintaining open space that provides scenic beauty and wildlife habitat.

Most land use protection programs are designed to conserve urban open space. Few are focused directly on working forests. Managed by the USDA Forest Service in partnership with State governments, the Forest Legacy Program is designed to encourage the protection of privately owned forest land and promote sustainable forestry practices by purchasing development rights, including conservation easements. Legacy parcels continue to produce forest commodities and noncommodity ecological values such as healthy riparian areas and fish and wildlife, as well as scenic, aesthetic, cultural, and recreational resources, on landscapes otherwise likely to be shifted to nonforest use. As of 2006, the program has protected 1.15 million acres in 33 States. Interest in the program has grown, with 46 States and Territories now enrolled in the program, up from 24, 5 years ago, and with over $200 million in requests each year. In 2006, Federal appropriations for the program were $56 million, with 91 percent of this money directed to conservation projects. Conservation easements in general have been increasing in popularity as a tool for encouraging the protection of forests and other lands, and are also used by NGOs, such as the Pacific Forest Trust. Landowners receive tax benefits or are paid a lump sum in exchange for signing a legal document that restricts the use of their land. These restrictions might include development as well as certain other forms of land use.

Risk, Hazard, and Land Use Change

The focus of this conference is primarily on threats to ecosystems, and we discuss the role of land use change and housing growth in creating and amplifying threats to ecosystems. A related issue worth exploring is the relationship between human settlement patterns and vulnerabilities to natural disasters. Natural disasters have many varied consequences, including damage to ecosystems and human communities. Recent trends in land use and housing growth not only create stresses on natural ecosystems, they also increase society's vulnerability to natural hazards.

Housing growth is perhaps the single most important factor behind increasing economic losses from natural disasters. The threat posed by most natural disasters has not changed significantly over time. Wildland fire is an exception, to some extent; many ecologists argue that forest management policies contribute directly and indirectly to increasing the severity of wildland fires. Global climate change has also been indicted in recent catastrophic weather events, and although scientific opinion is mixed regarding its role in current patterns, scientists agree that there is potential for significant change in the future. However, in the short run, i.e., over the past 50 years, the likelihood of natural hazards has been relatively stable, but losses in the United States have increased because our vulnerability to these hazards has increased. More houses and more wealth concentrated in regions of the country facing significant hazard levels describe the trend in the United States over the past 50 years (Cutter and Emrich 2005, De Souza 2004, van der Vink and others 1998).

Regional patterns of growth and decline in the United States have shifted population and property value to more vulnerable areas (van der Vink and others 1998). By 1970, population and housing growth had shifted away from the cities of the Northeastern United States and into two regions facing considerable natural hazards: the Southeast, with its exposure to hurricanes from both the Atlantic and the Gulf; and the West where a wide range of hazards are present. Colorado and California stand out as States where population and housing growth have been substantial (California earlier in the period, Colorado later) and both face the threat of catastrophic wildland fires. In California, earthquakes and landslides are also major threats to heavily populated cities. Coastal Oregon and Washington are exposed to tsunami risks; Southwestern States (Arizona, and later in the period, New Mexico and Nevada) have grown tremendously and have active fire regimes.

Selective urban deconcentration, which has been the overarching pattern of settlement change in the late 20th century (Johnson and others 2005), has brought growth to many rural communities and to suburbs more distant from the urban core. This change from the centuries-long urban concentration pattern contributes to vulnerability in two ways. First, isolated communities and especially unincorporated areas have less infrastructure (e.g., roads and water supply systems) and fewer resources for providing protection services (e.g., police and fire protection). Rapid growth exacerbates the difficulties of providing adequate infrastructure. Second, wildland fire is a meaningful threat to homes in the wildland urban interface, which is typically found around the outer edges of metropolitan areas and throughout the countryside, the same areas where housing growth has been most dramatic.

United States society's response to natural disasters has been more oriented to reaction than to planning. When losses to human communities are substantial, the outcome is often new policy, reallocation of public spending, and regulation. To take an example familiar to the resource management community, the Healthy Forests Restoration Act can be seen as a policy response to the bad fire seasons of 2000 and 2002. With human community vulnerability and loss comes the prospect of more changes such as these. To date, few incentives or policies have addressed the root cause—the development of new housing units without regard to landscape patterns, ecological processes, or hazard exposure.

Research to Improve Analyses of Risk of Forest Land Conversion: Expected Benefits and Costs

Improved analyses of threats from conversions of forest land require additional data and research pertaining to:

1. Expected benefits and costs regarding likelihood of land use conversion for a particular unit of land.
2. Environmental impacts, losses in commodity production, and other costs that may arise if a unit of land is developed, such as increased costs for fire suppression with houses in the wildland-urban interface.
3. Estimates of opportunity costs of retaining forest land, such as land values, to provide a sense of what it may cost to transfer development rights, implement a conservation easement, or undertake some other policy action.

Here we point to several studies as examples where improved information is being pursued, with a more detailed discussion outside the scope of this paper.

At a national scale, the RPA Assessments have examined costs and benefits associated with land conversion for several decades (e.g., Alig and others 2003, Nowak and Walton 2005, USDA Forest Service 1989). With a growing wildland-urban interface, other national studies have focused on housing growth (e.g., Stein and others 2005, Stewart and others 2003). Other national studies have focused on global climate change and relationships to land use and land cover changes (e.g., Alig and others 2002). At a regional scale, two studies for the South illustrate the changing nature of the informational requirements and analytical approaches: the study of the South's "fourth forest" (USDA Forest Service 1988) and the *Southern Forest Resource Assessment* (Wear and Greis 2002).

Forest conditions have received increasing attention in recent years, with bioregional assessments implemented to examine conditions at an ecoregional rather than a jurisdictional level: e.g., the Southern Appalachian Assessment (USDA Forest Service 1996), the Southern Forest Resource Assessment (Wear and Greis 2002), and the Coastal

Landscape Analysis and Modeling Study (Kline and others 2003). One part of improving such resource-centric studies is better tracking of ecological structures that are changing in response to human population growth and economic developments at broad scales across a region (Wear and others 2004). The identification of specific conservation targets within these broad areas would require additional work at a finer scale. Nevertheless, the methods described by Wear and others (2004) could provide a mechanism for defining conservation priorities for the region at a broad scale. Forecasts of interior forest change can be viewed as a risk measure indicating where human activities are more likely to change ecosystem structure, similar to the risk indicators developed at a much finer scale by Theobald (2003). This forecast provides a first step in setting priorities: defining where the structure is likely to change and where it is likely to be relatively stable. Wear and others (2004) identified four ecological sections of the South where 5 percent or more of existing interior forest is forecast to be lost by 2020, but they also identified 16 ecological sections, or about half of the sections in the Southeastern United States, where less than 1.5 percent would be lost. Areas that are found to be essentially stable could be excluded from further detailed analysis, allowing analysts to focus their efforts on that portion of the landscape that is more likely to change without some intervention.

A second step in defining conservation priorities involves examining the ecological condition of the broad areas with relatively high threat levels. Indicators such as numbers of imperiled species highlight where ongoing change may have the most impact on biodiversity. Although a detailed assessment of ecological scarcity is beyond the scope of this paper, the Southern Forest Resource Assessment (Wear and Greis 2002) illustrates the approach. For lands that are urbanized, a tool developed to assess urban forests structure and functions is the Urban Forest Effects (UFORE) model (Nowak and Crane 2000; www.itreetools.org).

Different types of land base changes can result in different forest ecosystem conditions because acres exiting (e.g., through deforestation) or entering (e.g., through afforestation) the forest land base can represent quite different forest conditions. This change becomes even more important when there is a relative acceleration in one type, as in deforestation, as occurred in the 1990s, when about 1 million acres of forests were converted to developed uses per year (USDA NRCS 2001).

With a projected increase of more than 120 million people in the United States over the next 50 years, the different projections of additional developed land area and housing growth all point to significant increases that represent threats of forest conversion. Demand for wood products is expected to keep growing, driven by the same population increases and economic development that affect demands for other major land uses. Given dynamics of the changing population and social values, some forest conversion can adversely impact provision of public goods by forests, such as the environmental service of storing terrestrial carbon to mitigate climate change, which falls outside private decisionmaking. Measuring and evaluating multiple forest benefits associated with public goods can be difficult owing to a general lack of information describing forest outputs and their values. This lack of information is especially true when it comes to valuing benefits accruing from ecosystem services, a set of values clearly needed to fully value open space and other ecosystems services provided by private forests. Efforts to better align commercial uses of forests with conservation objectives have led to increased interest in what is being called sustainable forestry, although there are similar efforts tied to other major competing interests in the land, such as sustainable agriculture or sustainable communities. Land use will continue to change as private decisionmakers and society examine options to adjust to changing demands for and supplies of renewable resources (e.g., biofuels for energy security and to address climate change) (e.g., White 2010) and ecosystem services from the Nation's forest and aquatic ecosystems. Sustainability analyses will be enhanced if both land use and land investment options are examined. Analyses should be explicit as to timing of tradeoffs and market-level impacts, to help promote enhanced integrated macro analyses of land base changes using a balanced mixture of spatially explicit data and other information.

References

Ahearn, M.; Alig, R. 2006. A discussion of recent land-use trends. In: Economics of rural land-use change. Burlington, VT: Ashgate Press: 11–26. Chapter 2.

Ahn, S.; Plantinga, A.J.; Alig, R.J. 2000. Predicting future forest land area: a comparison of econometric approaches. Forest Science. 46(3): 363–376.

Ahn, S.; Plantinga, A.; Alig, R. 2002. Determinants and projections of land use for the South Central United States. Southern Journal of Applied Forestry. 26(2): 78–84.

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

Alig, R.; Adams, D.; McCarl, B. 1998. Impacts of land exchanges between the forest and agricultural sectors. Journal of Agriculture and Applied Economics. 90(5): 3137.

Alig, R.; Adams, D.; McCarl, B. 2002. Projecting impacts of global change on the U.S. forest and agricultural sectors and carbon budgets. Forest Ecology and Management. 169: 3–14.

Alig, R.; Ahearn, M. 2006. Effects of policy and technological change on land use. In: Economics of rural land-use change. Burlington, VT: Ashgate Press: 27–40. Chapter 3.

Alig, R.; Butler, B. 2004. Area changes for forest cover types in the United States, 1952 to 1997, with projections to 2050. Gen. Tech. Rep. PNW-613. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 106 p.

Alig, R.; Butler, B.; Swenson, J. 2000. Fragmentation and national trends in private forestlands: preliminary findings from the RPA Assessment. In: Sampson, N.; DeCoster, L., eds. Proceedings, Forest Fragmentation 2000. Washington, DC: American Forests: 34–47.

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

Alig, R.; Kline, J.; Lichtenstein, M. 2004. Urbanization on the U.S. landscape: looking ahead in the 21st century. Landscape and Urban Planning. 69(2-3): 219–234.

Alig, R.; Lee, K., Moulton, R. 1990. Likelihood of timber management or nonindustrial private forests: evidence from research studies. Gen. Tech. Rep. SE-60. Asherville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 17 p.

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

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

Alig, R.; Plantinga, A.; Ahn, S.; Kline, J. 2003. Land use changes involving forestry for the United States: recent trends and projections. Gen. Tech. Rep. PNW-GTR-587. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 92 p.

Alig, R.; Plantinga, A.J.; Haim, D.; Todd, M. 2010. Area changes in U.S. forests and other major land uses, 1982 to 2002, with projections to 2062. Gen. Tech. Rep. PNW-GTR-815. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 98 p.

Alig, R.; White, E. 2007. Projections of forestland and developed land areas in western Washington. Western Journal of Forestry. 22(1): 29–35.

Armsworth, P.R.; Kendall, B.E.; Davis, F.W. 2004. An introduction to biodiversity concepts for environmental economists. Resource and Energy Economics. 26: 115–136.

Bettinger, P.; Alig, R.J. 1996. Timber availability on non-Federal land in western Washington: implications based on physical characteristics of the timberland base. Forest Products Journal. 46(9): 1–16.

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

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

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

Cutter, S.L.; Emrich, C. 2005. Are natural hazards and disaster losses in the U.S. increasing? Eos, Transactions of the American Geophysical Union. 86(41): 381–396.

De Souza, R. 2004. In harm's way: hurricanes, population trends, and environmental change. Population Reference Bureau. http://www.prb.org/Template.cfm?Section=PRB&template=/ContentManagement/ContentDisplay.cfm&ContentID=11713. [Date accessed: June 7, 2006].

Garber-Yonts, B. 2004. The economics of amenities and migration in the Pacific Northwest: review of selected literature with implications for national forest management. Gen. Tech. Rep. PNW-GTR-617. Portland, OR: U.S. Department of Agriculture, Forest Service Pacific Northwest Research Station. 48 p.

Glaeser, E.; Shapiro, J. 2001. City growth and the 2000 census: which places grew and why. Washington, DC: Center on Urban and Metropolitan Policy, The Brookings Institution. [Number of pages unknown].

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

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

Hardie, I.W.; Parks. P.J. 1997. Land use in a region with heterogeneous land quality: an application of an area base model. American Journal of Agricultural Economics. 73: 300–310.

Haynes, R., coord. 2003. An analysis of the timber situation in the United States: 1952 to 2050. Gen. Tech. Rep. PNW-GTR-560. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 254 p.

Haynes, R.; Adams, D.M.; Alig, R.J. [and others]. 2007. The 2005 RPA timber assessment update. Gen. Tech. Rep. PNW-GTR-699. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 212 p.

Heimlich, R.; Anderson, W. 2001. Development at the urban fringe and beyond: impacts on agriculture and rural land. Ag. Econ. Rep. No. 803. Washington, DC: U.S. Department of Agriculture, Economic Research Service. [Number of pages unknown].

Irwin, E.; Geoghegan, J. 2001. Theory, data, methods: developing spatially-explicit economic models of land use change. Journal of Agriculture Ecosystems and Environment. 85(1-3): 7–24.

Johnson, K.M.; Nucci, A.; Long, L. 2005. Population trends in metropolitan and nonmetropolitan America: selective deconcentration and the rural rebound. Population Research and Policy Review. 24: 527–542.

Kline, J.; Alig, R. 1999. Does land use planning slow the conversion of forest and farm lands? Growth and Change. 30: 3–22.

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

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

Kline, J.; Butler, B.; Alig, R. 2002. Tree planting in the South: What does the future hold? Southern Journal of Applied Forestry. 26(2): 85–92.

Kline, J.D.; Azuma, D.L.; Alig, R.J. 2004b. Population growth, urban expansion, and private forestry in western Oregon. Forest Science. 50(1): 33–43.

Kline, J.D.; Azuma, D.L.; Moses, A. 2003. Modeling the spatially dynamic distribution of humans in the Oregon (U.S.A.) coast range. Landscape Ecology. 18(4): 347–361.

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

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

Lubowski, R.N.; Plantinga, A.J.; Stavins, R.N. 2006. Land-use change and carbon sinks: econometric estimation of the carbon sequestration supply function. Journal of Environmental Economics and Management. 51(2): 135–152.

McGranahan, D. 1999. Natural amenities drive rural population change. FRED Rep. No. 781. Washington, DC: U.S. Department of Agriculture, Economic Research Service. [Number of pages unknown].

Nowak, D.J.; Crane, D.E. 2000. The urban forest effects (UFORE) model: quantifying urban forest structure and functions. In: Hansen, M.; Burk, T., eds. Proceedings of the IUFRO conference: Integrated tools for natural resources inventories in the 21st century. Gen. Tech. Rep. NC-212. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 714–720.

Nowak, D.J.; Crane, D.E. 2002. Carbon storage and sequestration by urban trees in the U.S.A. Environmental Pollution. 116(3): 381–389.

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

Nowak, D.J.; Noble, M.H.; Sisinni, S.M.; Dwyer, J.F. 2001. Assessing the U.S. urban forest resource. Journal of Forestry. 99(3): 37–42.

Nowak, D.J.; Walton, J.T. 2005. Projected urban growth and its estimated impact on the U.S. forest resource (2000–2050). Journal of Forestry. 103(8): 383–389.

Nowak, D.J.; Walton, J.T.; Dwyer, J.F. [and others]. 2005. The increasing influence of urban environments on U.S. forest management. Journal of Forestry. 103(8): 377–382.

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

Pew Center. 2000. Sprawl now joins crime as top concern. http://www.pewcenter.org/about/pr_ST2000.html. [Date accessed unknown].

Plantinga, A.J. 1996. The effect of agricultural policies on land use and environmental quality. American Journal of Agricultural Economics. 78(4): 1082–1091.

Radeloff, V.C.; Hammer, R.B.; Stewart, S.I. [and others]. 2005. The wildland urban interface in the United States. Ecological Applications. 15: 799–805.

Riitters, K.H.; Wickham, J.D.; O'Neill, R.V. [and others]. 2002. Fragmentation of continental United States forests. Ecosystems. 5: 815–822.

Smith, W.; Miles, P.; Vissage, J.; Pugh, S. 2004. Forest resources of the United States, 2002. Gen. Tech. Rep. NC-241. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 137 p.

Society of American Foresters (SAF). 2004. Loss of forest land: a position statement of the Society of American Foresters. http://www.safnet.org/policyandpress/psst/loss of forestland.cfm. [Date of access unknown].

Stein, S.; McRoberts, R.E.; Nelson, M.D. [and others]. 2005. Forests on the edge: housing development on America's private forests. Gen. Tech. Rep. PNW-636. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 15 p.

Stein, S.M.; Hatfield, M.; McRoberts, R.E. [and others]. 2010. Threats to private forest lands in the U.S.A: A Forests on the Edge study. In: Pye, John M.; Rauscher, H. Michael; Sands, Yasmeen; Lee, Danny C.; and Beatty, Jerome S., tech. eds. Advances in threat assessment and their application to forest and rangeland management. Gen. Tech. Rep. PNW-GTR-802. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest and Southern Research Stations: 133–144. Vol. 1.

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

Theobald, D.M. 2003. Targeting conservation action through assessment of protection and ex-urban threats. Conservation Biology. 17(6): 1624–1637.

Theobald, D.M. 2005. Landscape patterns of ex-urban growth in the U.S.A. from 1980 to 2020. Ecology and Society. 10(1): 32. [online] URL: http://www.ecologyandsociety.org/vol110/iss1/art32/. [Date accessed unknown].

U.S. Department of Agriculture (USDA). 1983. Land use policy. USDA Environmental Compliance Land Use Policy Departmental Regulation, 9500–3, March 22, 1983. Washington, D.C.

U.S. Department of Agriculture, Economic Research Service (ERS). 2006. Rural residential land use: tracking its growth. http://www.ers.usda.gov/publications/agoutlook/aug2002/ao293e.pdf [Date accessed: July 12, 2006].

U.S. Department of Agriculture, Forest Service. 1988. The South's fourth forest: alternatives for the future. For. Resour. Rep. 24. Washington, DC. 512 p.

U.S. Department of Agriculture, Forest Service. 1989. RPA assessment of the forest and rangeland situation in the United States, 1989. For. Resour. Rep. 26. Washington, DC. 72 p.

U.S. Department of Agriculture, Forest Service. 1996. The Southern Appalachian assessment social/cultural/economic technical report. Atlanta, GA: Southern Region. 219 p.

U.S. Department of Agriculture, Forest Service. 2001. 1997 Resourses Planning Act (RPA) assessment. Washington, DC. [Number of pages unknown].

U.S. Department of Agriculture, National Agricultural Statistical Service (USDA NASS). 2006. Trends in U.S. agriculture. USDA-NASS: Price Index Ratio - Received to Paid: 1910–1997. http://www.usda.gov/nass/pubs/trends/agprices.htm [Date accessed: June 14, 2006].

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). 2001. Summary report: 1997 National Resources Inventory (revised December 2001). Washington, DC.

U.S. Department of Commerce, Census Bureau, 2001. Statistical abstract of the United States, 2001. Table 1046. http://www.census.gov/prod/www/statistical-abstract-us.html. [Date accessed unknown]. www.census.gov/prod/2002pubs/01statab/stat-ab01.html. [Date accessed unknown].

U.S. Department of Agriculture; U.S. Department of the Interior (USDI. 2001). Urban wildland interface communities within vicinity of Federal lands that are at high risk from wildfire. Federal Register. 66(3): 751–777.

van der Vink, G.; Allen, R.M.; Chapin, J. [and others]. 1998. Why the United States is becoming more vulnerable to natural disasters. Eos, Transactions of the American Geophysical Union. 79(44): 533, 537.

Vesterby, M.; Krupa. K. 2001. Major uses of land in the United States, 1997. Bull. No. 973. Washington, DC: U.S. Department of Agriculture, Economic Research Service. [Number of pages unknown].

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

Wear, D.; Greis, J. 2002. Southern forest resource assessment: summary of findings. Journal of Forestry. 100(7): 6–14.

Wear, D.; Newman, D. 2004. The speculative shadow over timberland values in the U.S. South. Journal of Forestry. 102(8): 25–31.

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

Wear, D.N.; Turner, M.G.; Flamm, R.O. 1996. Ecosystem management with multiple owners: landscape dynamics in a southern Appalachian watershed. Ecological Applications. 6(4): 1173–1188.

White, E.M. 2010. Woody biomass for bioenergy and biofuels in the United States—a briefing paper. Gen. Tech. Rep. PNW-GTR-825. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p.

Wilent, S. 2004. Investors increase timberland holdings. The Forestry Source. 9(12): 1, 3–4.

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