Human and Nature Interactions: A Dynamic Land Base of Many Goods and Services

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Abstract—*Availability of land is fundamental for sustainable forestry, providing the basis for the production of a wide array of goods and services (for example, biodiversity, forest carbon sequestration). This paper summarizes types of land-related data contained in major U.S. data bases, and gives examples of how such data were used in projecting changes in forest area for use in regional and national studies of forest sustainability. Forest land values are discussed, considering a variety of geographic, biological, regulatory, economic, and social situations. Forest land values provide informational signals on what amounts and types of forest land are likely and prospects for the provision of mixes of land-based goods and services. Urbanization is related to population growth and affects timberland values, forest fragmentation, forest parcelization, and ownership changes. Advances in data management and processing (for example, GIS) have allowed for advances in forest land analyses. Emerging issues include impacts of any developing markets for forest-based goods and services, such as forest carbon.*

Introduction

History contains many stories of the high regard with which man has viewed land in past times. For millennia, most wars were fought for the possession of land, and most people lived in close association with the soil, fields, and forests that sustained them. The United States has a wealth of land, with 747 million acres of forestland or more than 2.5 acres per citizen (fig. 1). With changes in society, such as growth in population and increases in consumption, human pressures on that land base are likely to increase. Monitoring such changes will be important, as will defining key policy-relevant questions that can lead to effective land use and land cover monitoring.

An example of monitoring and analysis that will be used in this paper centers on periodic U.S. natural resource assessments mandated by the national Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974, to support USDA Forest Service (2001) strategic planning and policy analyses. The RPA act requires that decadal national assessments, with mid-decade updates, include an analysis of present and anticipated uses; demand for and supply of the renewable resources of forest, range, and other associated lands; and an emphasis on pertinent supply, demand, and price relationship trends. The 2000 RPA assessment provides a broad array of information about the Nation's forests and rangelands, including the current situation and prospective area changes over the next 50 years (Alig and others 2003, 2004). Related data illustrate the dynamics of our Nation's land base, and how adjustments are likely to continue in the future. Projections of land use and forest cover changes provide inputs into a larger system of models that project timber resource conditions and harvests, wildlife habitat, and other natural resource conditions (USDA Forest Service 2001).

The 2000 RPA assessment is the most recent one and the context has broadened over time (USDA Forest Service 2001). Interest in sustainable management of the world's forest resources was heightened by the United Nations Conference on Environment and Development in 1992. Since that time, various countries have joined together to discuss and attempt to reach consensus on ways to evaluate progress toward the management of their forest resources. The United States participates in the Montreal Process, designed to use a set of criteria and indicators for the conservation and sustainable management of temperate and boreal forests. The criteria provide a common framework for describing, assessing, and evaluating a country's progress toward forest sustainability at the national level. Information from the periodic RPA Assessments can shed light on whether we can sustain both increasing consumption of forest products and forest resource conditions (Alig and Haynes 2002). Current debates about sustainability involve both physical notions of sustainability and competing socioeconomic goals for public and private land management. Land-base changes also indicate the importance of viewing "sustainability" across the entire

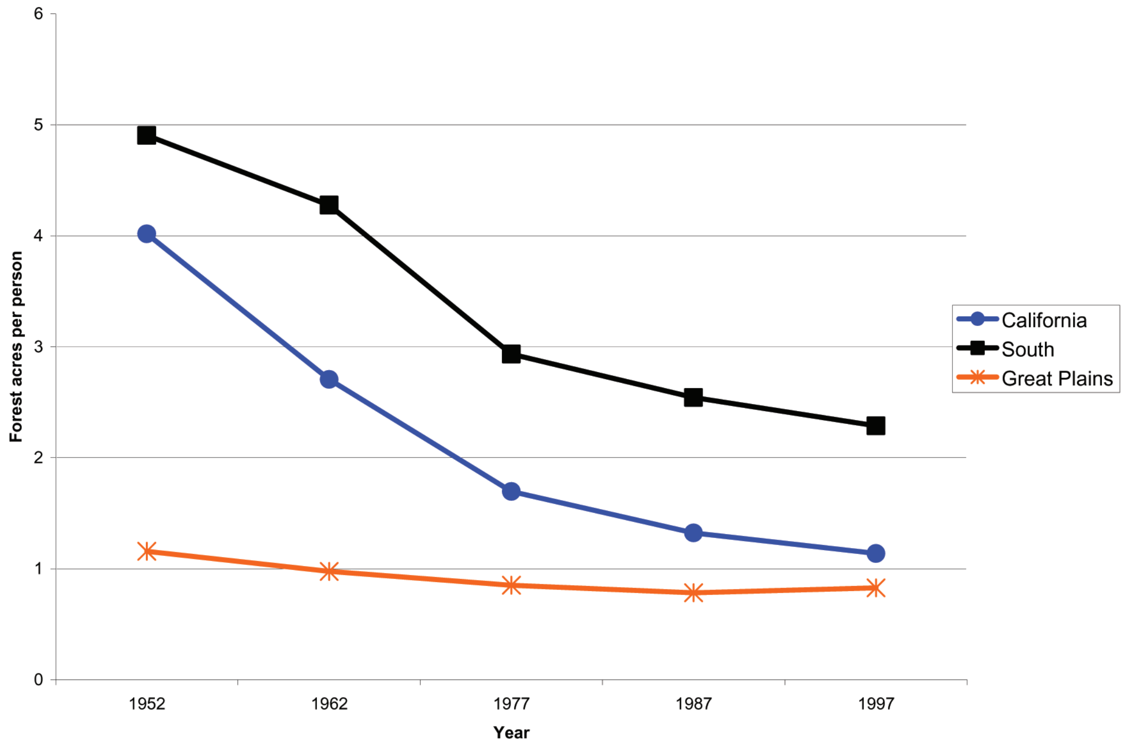

Figure 1. Change in per capita amount of forest area per resident, by selected region, 1952-1997 (acres) (Smith and others 2001).

land base and across sectors, in contrast to the current typical sector approach, as in examining "sustainable forest management" (Alig and Haynes 2002).

This synthesis paper has four parts. The first part discusses data bases used in analyzing changes in macro land use and land cover, and the methods used to project changes. The second component of the paper illustrates the utility of land value information when considering sustainability across sectors. The third part focuses on the issue of deforestation brought about by conversion to developed uses and what recent projections indicate. The fourth section of this synthesis paper discusses emerging issues regarding environmental services, such as forest carbon sequestration.

Land Use and Land Cover Changes

Over the past 25 years, renewable resource assessments have addressed demand, supply, and inventory of various renewable resources in increasingly sophisticated fashion, including simulation and optimization analyses of area changes in land uses (for example, urbanization) and land covers (for example, plantations vs. naturally regenerated forests). More than two decades ago, area projection modeling systems replaced expert opinion approaches in the national RPA assessments, as part of state of the art approaches for regional and national resources assessments. Such models reflect that key land base changes such as afforestation and deforestation are driven by quite different socio-economic factors. Projections of area changes are important for a wide range of natural resource analyses, including those for wildlife habitat, timber supply, global climate change, water, recreation, open space, and for other ecosystem services.

Land use data are collected by various agencies for a variety of purposes. Land use surveys generally differ in terms of statistical data-collection methods, scope, and a variety of other characteristics. No one land use database provides universal coverage over space and time for use in addressing all relevant land use and land cover policy questions. I next describe three primary data sources: the Forest Inventory and Analysis (FIA) data assembled to support the 2000 RPA assessment by the USDA Forest Service (Smith and others 2001); the National Resource Inventory (NRI) by the USDA National Resource Conservation Service (USDA NRCS 2001), and the Major Land Use Time Series (MLUS) by the USDA Economic Research Service (ERS) (Vesterby and Krupa 2001).

Forest Inventory and Analysis

The FIA surveys conducted by the USDA Forest Service are designed to provide objective and scientifically credible information on key forest attributes, such as forest stocks, growth, harvest, and mortality. Related data are collected by region, forest ownership category (for example, forest industry vs. nonindustrial private forests), and cover type (for example, oak-hickory), by using a sample of more than 70,000 permanent plots. The FIA inventories provide consistent forest inventory data for the Nation, back to 1952 (Smith and others 2001). Different sampling grids for the NRI and FIA surveys make the estimates from the two inventory systems statistically independent.

The FIA inventory data are gathered by using photointerpretation and ground truthing on a systematic sample of plots defined as pinpoints on the ground. These data include land use and ownership characteristics of sample plots, among other data. The land use data were used in the Kline and Alig (2001) study of land use in the west side of the Pacific Northwest.

National Resources Inventory

The NRI conducted by the USDA NRCS is designed to assess land use conditions on nonfederal lands and collects data on soil characteristics, land use, land cover, wind erosion, water erosion, and conservation practices (USDA NRCS 2001). In addition to collecting data on about 300,000 area segments and about 800,000 points within those segments, a geographic information system is used to control for total surface area, water area, and federal land. The NRI is conducted by the USDA's NRCS (2001) in cooperation with Iowa State University's Statistical Laboratory.

As a result of its statistical design, the NRI allows land use transition matrices to be developed since 1982. Land use shifts occur in both directions, a dynamic that is captured in the so-called land use transition matrices. For example, between 1982 and 1997, more than 17 million acres of nonfederal land moved out of the pasture and range category and into the forest category, while during the same period more than six million acres moved from forest to pasture and range use (USDA NRCS 2001).

Major Land Use Series

The MLUS is an inventory of land developed from a variety of land use surveys and public administrative records of land use. This long term series was developed by the USDA ERS (Vesterby and Krupa 2001). One of the most widely watched statistics by land use experts is the number of acres converted from undeveloped uses to developed, or urban, uses on an annual basis. The MLUS uses the official U.S. Census definition of urban (USDC Census Bureau 2001) and the NRI data use a definition unique to that data system, namely developed land. No technical definition of urban sprawl exists, but most definitions have elements of low-density development, geographic separation of essential places, and dependence on automobiles for travel. In response to the concerns about the growth in the use of rural land for rural residences, the USDA has added a new category to the MLUS for recent years. The FIA surveys do not provide a national estimate of urban or developed land areas.

The MLUS classifies some forested land as "special-uses" land, separate from a "forest-use" category. In particular, "special-uses" can contain forested land in federal and state parks, wilderness areas, wildlife refuges, and similar special-purpose uses. Hence, the area of MLUS "forest-use" land is lower than the FIA\RPA area of forest land (Alig and others 2003). The gap between forest land and "forest-use" land has grown over the past 60 years, with the growth of wilderness areas and other forested special-use land.

In addition, many additional sources of data exist on land use and land cover that are not used in the MLUS because they are not the most suitable for the purpose of comprehensively inventorying U.S. land. For example, the U.S. Geological Survey of the U.S. Department of the Interior maintains satellite imagery of land cover at various points in time. Many of these data sources are better suited for other specialized purposes.

Methods to Project Area Changes

Methods to project area changes for forest land and timberland differ by region of the United States. Methods vary depending on the likelihood of area changes affecting forests, the likely policy relevance of forest area changes, and the availability of time series of land use data with which to develop models of land use change. A method used increasingly in RPA Assessments and which involves use of FIA data is econometric modeling, based on statistical methods that are used to quantify relationships between land uses and hypothesized determinants. Landowners' profit maximization typically is the theoretical basis for these models, where landowners are assumed to allocate land parcels to that use generating the highest land rent or present value of future profits. Models are estimated with data describing land use decisions and profits derived from alternative land uses. Additional variables may be included to control for land-use regulations and other factors that influence land use decisions. For example, land-use policies often are used to mitigate potential negative impacts of urbanization. Econometric land use models typically are estimated with sample plot data comprised of a random sample of parcels or aggregate data such as county-level observations of land use (Ahn and others 2002, Alig 1986, Kline and Alig 1999, Kline and Alig 2001).

With the advent of satellite imagery and geographical information systems (GIS), econometric land-use models have been estimated using spatially-referenced plot or parcel-level data (Wear and Bolstad 1998, Kline and others 2001). Examples of explanatory variables in such models are rents (or proxies) for forestry, agriculture, and urban/developed uses.

An example of land use models developed using FIA data is described by Ahn and others (2002) for the South Central region. The model describes the relationship between the areas of land in different uses—private timberland, agricultural land, and urban and other land—and determinants of land use. The models were estimated by using OLS regression with pooled time series and cross-sectional data. The panel data set included 558 cross-sectional units (counties) and seven time points. Observations for the 558 counties in the South Central region were from FIA inventories conducted since the 1960s. The agricultural share of land was defined as that in cropland and pasture, and county-level observations were gathered from the Census of Agriculture for between 1964 and 1992. The share of land in urban and other uses was defined as a residual category containing uses other than forestry and agriculture (for example, suburban). The fitted models were used to project future land use in the South Central region, given assumptions about future population and net returns to land enterprises such as forestry.

Forest Land Values

Forest land values can vary by a variety of geographic, biological, regulatory, economic, and social situations. Human ties to land and the natural environment are one reason that we care about the forest land value. Forest land values help us understand the importance of forests, and to marshal land resources so that they might be used effectively and efficiently to help provide people with higher levels of living. Forest land values help us plan for better land use, to take steps for the more orderly and effective use of our land resources, and to intervene where necessary with land use zoning ordinances and other public measures to control and direct land use practices in the public interest. Forest use valuation is increasingly becoming more complicated, as is our economy, by overlays of land use zoning, environmental laws, forest practices regulation, site-specific environmental considerations, and recognition of forest resource values other than timber.

Much discussion in forest policy circles today is about forest sustainability, which seems to be part of a larger societal concern about the long-term capability of land to provide goods and services that we as a society demand. In addition to the question about the land's capability is that of land owners' responses to incentives to provide different mixes of goods and services. People vary in the values that they place on different environmental, economic, and social aspects of forests, and this affects the social valuation; this is in contrast to the private cost of providing goods and services that others may value from private forestland. An example to illustrate this is that many forestlands and open spaces (Kline and others 2004) comprise social values—ecological, scenic, recreation, and resource protection values, which are typically not reflected in market prices for land. When these social values are present, more forestland will be developed than is good for society. For open space policy, one needs to understand social values in the context of forestland market values and the economic rationale and impetus for public and private efforts to protect forestland as open space. Forest land values can reveal what it may cost to pursue different sustainability options, if land easements, purchases, or rentals are desirable. The land values reveal what people are actually willing to pay for a bundle of rights necessary to gain access to land that can provide goods and services for a certain time period.

Land prices embody information on relative valuations by different sectors of the economy. For example, valuation of land currently in forest uses in some areas is strongly influenced by trends in developed areas (Wear and Newman 2004). Land values for developed uses typically exceed those for rural uses by a substantial amount (Alig and Plantinga 2004). Agricultural values are usually second to developed uses in potential value, and they are often influenced by development potential. With rural land uses subject to increasing conversion pressure, open space concerns have heightened. The earliest significant open space preservation efforts in the U.S. involved preserving and restoring publicly owned forests and parks at national and state levels. These efforts were inspired by public concern for rapid loss of forests to agriculture and logging in the later 19th century, and the desire to protect timber and water resources, and lands of extraordinary beauty and uniqueness. Since then, public concern for land use change has evolved to recognize the contribution of open space to our day-to-day quality of life—its recreation, aesthetic, ecological, and resource protection benefits.

Changing perceptions about forestland mirror those in farmland preservation. National interest in preserving farmland arose in the 1970s from concerns about rapid loss of farmland to development, and the supposed threat to food security and agricultural viability. These concerns led to the gradual nearly nationwide implementation of local, state, and federal farmland preservation programs. More recently, recognition has grown for the environmental amenities and the social values of farmland and the role they play in motivating public support for preserving farmland. Research over the past two decades has sought to identify these land-based values and incorporate them into farmland protection policies and programs, to ensure that the public is getting what it desires from preserved farmland. Similar efforts may now be needed in forestry, to ensure that public and private open space protection efforts are tailored to provide the social values desired from forestlands.

Development of Forestland

Conversion of rural lands to urban and other built-up uses affects the mix of commodities and services produced from the global land base. In the United States, there was a 34percent increase in the amount of land devoted to urban and built-up uses between 1982 and 1997. During 1982-1997, U.S. developed area increased about 2 percent per year on average, according to the NRI (Alig and others 2004). The annual rate of conversion during the last five years of this period was more than 50percent higher than that of the previous five years. Forests, in particular, have been the largest source of land converted to developed uses in recent decades, with resulting impacts on forest cover and other ecological attributes.

The largest increases in U.S. developed area between 1982 and 1997 were in the South, a key timber supply region (USDA NRCS 2001). The South had one-third of its developed area added during those 15 years. Between 1982 and 1997, the South had seven of the ten states with the largest average annual additions of developed area according to the NRI. The top three--Texas, Florida, and North Carolina--each added more developed area than the country's most populous state, California. The increase in developed area for the South was close to 20 percent, almost four times as large as for the Great Plains, the region with both the smallest changes in developed area and population.

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

The Great Plains region has the most developed area per resident (fig. 2) across all four NRI surveys, more than one acre in 1997. However, the region varies from the rest of the country in having lost population between

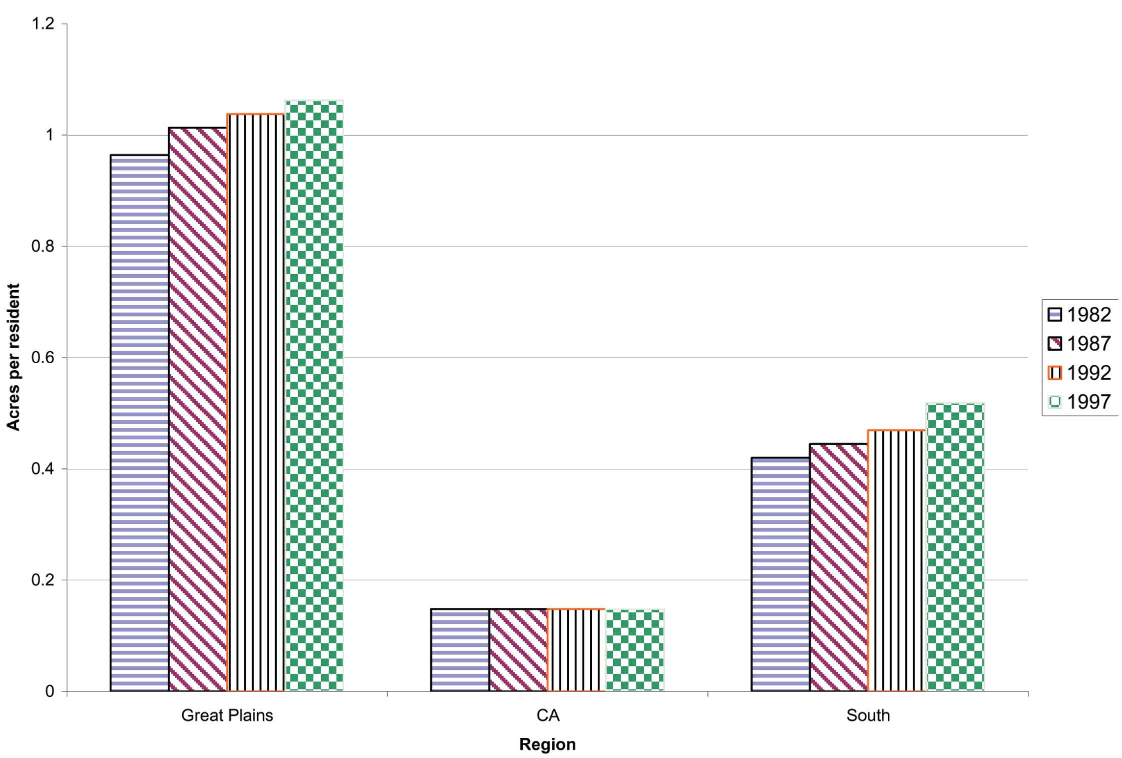

Figure 2. Total developed area per person, by U.S. selected region, 1982, 1987, 1992, and 1997 (USDA Natural Resources Conservation Service 2001).

the 1982 and 1987 NRIs, resulting in a loss in developed area. The South also has a relatively high marginal rate of land consumption, and also has had relatively large increases in population compared to the Great Plains. California, with the nation's largest population, has the lowest level of developed area per person, less than 0.2 acres per person.

Urbanization does not just result in direct conversion of forestland but can also involve forest fragmentation, forest parcelization, and ownership changes. Development pressures can also add to uncertainty about how forestland will be managed, if owners anticipate higher financial returns in an alternative use. Because forest land prices capture information regarding current as well as anticipated uses of land, land prices anticipate future development of forestland near urbanizing areas, casting a speculative shadow over timberland values (Wear and Newman 2004). With anticipated population and income growth, such dynamics could hold important implications for conditions of forestland and what environmental benefits may be sustainable.

Projections

Projections suggest continued urban expansion over the next 25 years, with the magnitude of increase varying by region (Alig and others 2004). U.S. developed area is projected to increase by 79 percent, raising the proportion of the total land base that is developed from 5.2 percent to 9.2 percent. Because much of the growth is expected in areas relatively stressed with respect to human-environment interactions, such as some coastal counties, implications for landscape and urban planning include potential impacts on sensitive watersheds, riparian areas, wildlife habitat, and water supplies. While providing additional living space and infrastructure, added development may also diminish agricultural output due to farmland loss and change ecological conditions due to conversion and fragmentation of forests and other natural landscapes. 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. forestland 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). In the South land is often suitable for multiple land uses, given relatively gentle topography and ease of access. When examining land use dynamics, the many different pathways by which land use can change warrant examining both net and gross area changes for major land uses. For example, the flow between forestland and urban and developed uses is primarily a one-way flow toward urban and developed uses, although some land classified as urban and developed (for example, corridors for electrical lines) may infrequently shift into forest or agriculture. Movement of land between forestry and agriculture in the last two decades resulted in net gains to forestry that have offset forest conversion to urban and developed uses in area terms. However, the conditions of forested acres entering and exiting the forestland base can be quite different; entering acres may be bare ground or have young trees, while exiting acres often contain large trees before conversion to developed uses.

Concern about the attributes of exiting or entering forested acres was heightened in the 1990s when the rate of development increased, with about one million acres of forests converted to developed uses per year (USDA NRCS 2001). The total or gross area shifts involving U.S. forests are relatively large compared to net estimates. Gross area changes involving U.S. forests totaled about 50 million acres between 1982 and 1997, an order of magnitude greater than the net change of 4 million acres.

Environmental Services

The linkage between land use and the environment affects many goods and services. The example of environmental services provided by the land base that I will discuss is forest carbon sequestration. Emerging issues include possible impacts of any new non-traditional markets for forest-based goods and environmental services, such as forest carbon. In discussing environmental services, I will focus on forest carbon here, while recognizing that many goods and services are potentially impacted by land base changes. Forest carbon storage has become important in international negotiations on the management of greenhouse gas emissions, because increased carbon storage can be useful in offsetting emissions of carbon from fossil fuel burning and other sources. The amount of carbon stored in forests can change through land base changes, adoption of forest management practices that allow the incorporation of more plant materials into forest soils, and changes in age structure. Carbon can also be stored in wood products.

The amount of carbon stored in trees in the East increased by 80 percent from 1950 to 1992 (Birdsey and Heath 1995). Contributing factors were tree growth on farmlands allowed to revert to forests. maturing of forests, and more fast growing plantations in the South. In the West, the addition of new forest carbon through forest growth was offset by timber harvest, resulting in little change in the overall amount stored. However, carbon storage on federal timberlands in the West may increase notably, if fires and other natural disturbances (for example, insects and disease) don't significantly reduce timber inventories.

Data sources for the forest carbon estimates are FIA field estimates of the size of trees of various species, along with statistical models of the relationships between tree stem volume and the other components of carbon storage. Carbon contained in branches, leaves, the forest floor, and soil are estimated from such surveys. Estimates by Birdsey and Heath (1995) did not include national parks and wilderness areas or slower-growing forests in non-timberland forestland, although expansion into those areas is planned.

Land use changes can be an important part of changes in forest carbon storage, but data on soil carbon are relatively scarce. Further, the influences of land management activities on soil carbon are still poorly known. Measurement protocols for forest floor litter and soil carbon were planned at the time of the Birdsey and Heath (1995) study and were to be implemented as funds became available. Given that gross land use changes are typically an order of magnitude higher than for net changes (Alig and others 2003), influences of land use shifts on soil carbon are potentially quite important. Changes in the area of any of the major land use classes relate to demographic, economic, biophysical, and policy factors (Alig 1986), so that the suite of such factors need to be considered in global climate change assessments. Projections of forest-land and timberland areas are based on projections of relevant demographic and economic factors, which are more likely to change in the future than biophysical factors. Current policies can be frozen in place in an initial conditions run or baseline, so that we can examine where the current policy trajectory (for example, no U.S. action or implementation of policy for mitigating climate change) would lead, and then examine sensitivity of projections to certain policy-related assumptions.

Risk and uncertainty considerations include changes in technology. Impacts from global warming in some cases may be partially offset by technological changes, such as genetic stock improvements to boost forest carbon sequestration efforts. Other technological changes may also allow more output from input of land, especially in regional climates favorably affected regarding crop or forest production. The net outcome can't be easily forecast. Some scenarios may arise where forest use might be better able to compete with other major rural land uses, such as agriculture (Alig and others 2002).

Future Directions

Issues for land use and land cover monitoring include consistent coverage across the entire land base. Analogous to the snapshot of land-use information by USDA's NRI, land cover modeling would benefit from periodic nationwide estimates of changes in forest cover. One source will be mapping by the National Land Cover Data mapping project (an output of the Multi-Resolution Land Characteristics Consortium), with plans for an updated version of the National Land Cover map for the year 2002. Field-based observations are also needed, to provide complementary data such as land ownership and site quality. For FIA, one challenge is to link forest resource data to socio-economic data, such as characteristics of who owns the forest land. The challenge is growing because of diverse data needed to address policy questions that arise with increased attention to ecosystem services and sustainability and activities associated with the environment, economy, and societal institutions.

Changes in ownership of forests should also be monitored, in that sales and acquisitions of forest lands continue to be active as market forces, globalization, and consolidation impact the forest sector. Forest industry is increasingly viewing its forests as strategic financial assets. Fragmentation of ownerships into several smaller ownerships is referred to as parcelization. This phenomenon can also have profound impacts on the economics of farming or forestry, even when land is not physically altered in any major way. Trends in fragmentation and parcelization warrant further study, along with monitoring of changes in population density for different classes of rural and urban land (Alig 2000). More people on the landscape include those in rural areas with attractive recreational land and aesthetic amenities, often involving forests, and related to concerns about changes in quality of life. Such demographic changes increase the size of the wildland-urban interface, whose expansion has exacerbated wildfire threats to structures and people. Overall, the U.S. had about 80 people per square mile of land in 1999 (USDC Census Bureau 2001). This compares to about 5 people per square mile in 1790, and to a world average of more than 100 persons per square mile in 1999 (United Nations 2002).

One complication in past FIA survey planning, RPA assessments, and global climate change assessments has been the lack of a unified view of future land conditions constructed at a scale that serves all of these assessment areas adequately. Attaining the ideal unification is a substantial undertaking, and this could be aided upfront by an assessment of common information needs. A modeling system that can generate land base condition projections could provide for forest ecosystems a thorough and unified description of anticipated change in the extent, structure, and condition of the nation's forests at useful regional and subregional scales. At the same time, such a system could augment economic measures, useful when investigating changes in land markets and analyzing trends in land values. Human-environment impacts can also vary across space and time, including physical fragmentation of forest cover from land-use changes that can affect natural resources in a variety of ways. For example, urbanization may cause fragmentation of wildlife habitat. A privately-owned optimal landscape can depart from a socially optimal landscape, the latter which reflects society's preferences for public goods associated with interior forest parcels. Future policy-related research can examine land use shifts for parcels in a way that is optimal from reducing forest fragmentation. However, spatial configuration considerations make this complex, in that benefits of converting (or retaining) a parcel will depend on the land uses on the neighboring parcels as well as on other parcels affected by the policy.

Future advances in land use analyses will likely also rest in part on continued improvement of spatial databases, including spatial socio-economic data, as well as improvements in spatial econometric methods to support empirical data analyses. Trade-offs must be considered when assessing the costs and benefits associated with spatial detail. Along with improved data bases, monitoring of developed area trends, associated investment in infrastructure (for example, transportation networks and nodes), and related socio-economic factors will be important in facilitating updated projections of U.S. developed area.

Given the expected U.S. population increase and changes in economic activity, a key question is how society can make positive progress toward sustainability in the face of needing more developed land to serve more people in the future. Progress toward such goals may rest on progress in a search for a more integrated approach for describing the complex interplay between human activity and the environment. To help evaluate progress, we need a useful definition of sustainability along with measurable indicators that fundamentally reflect the long-term ecological, economic, and social well being as it relates to alternative uses of land. Human demands for forests will increase with growing populations and increasing personal incomes, challenging land managers to provide for a diverse array of societal needs, including ecological, economic, and social ones. Wood use has increased by 40 percent since 1960 and is expected to rise by about 30 percent in the next four decades (USDA Forest Service 2001). In addition to substantial demand for environmental services, this may also occur alongside growing interest in spiritual values associated with forests, their sustainable use, and restoration after certain disturbances.

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