U.S. Land-use Changes Involving Forests: Trends and Projections

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Issue of Rural Land Conversion

Land use over a landscape can be dynamic, and population growth increasingly is resulting in the conversion of forest and agricultural land to residential, commercial and industrial uses, resulting in impacts on forest and farmland habitat for a variety of wildlife species. Less forest area means less wildlife habitat, more impervious surfaces, less air and water filtration, and less area on which to sequester forest carbon to address global climate change. Land-use conversion is a primary determinant of environmental change in terrestrial ecosystems, and projections that are more than 50 million acres (20 million ha) of U.S. forest will be converted to developed uses (e.g., parking lots) over the next 50 years (Alig et al. 2004, Alig and Plantinga 2004) as the population grows by more than 120 million people. Looking beyond simple loss of area, land-use change can also lead to forest fragmentation—the transformation of a contiguous patch of forest into disjunct patches. Forest fragmentation is considered to be a primary threat to terrestrial biodiversity.

To date, more attention has been focused on biophysical aspects of land-use change and forest fragmentation than on socioeconomic and policy matters. If the country is facing the prospect of considerably more conversion of rural land and of forest fragmentation, exploration of socioeconomic and policy factors can aid in developing strategies for addressing negative effects of land-use conversion and in allowing society sufficient lead time to implement land-conservation measures. Although multidisciplinary research has strived to examine the impacts of historical landscape-level changes in wildlife habitat and other ecological conditions, managers and policymakers need enhanced ways to anticipate, describe and plan for these potential impacts.

National Trends

The U.S. Department of Agriculture's (USDA's) National Resource Inventory (NRI) (U.S. Department of Agriculture, Natural Resources

Conservation Service 2001) estimates that 5.2 percent of the nonfederal land base in the United States' 48 contiguous states has been developed, i.e., converted to urban and other developed uses such as parking lots. The approximate 5 percent of developed, nonfederal land area is at least 10 times the percentage of developed land in Canada. Total developed area is about 100 million acres (40.5 million ha) for the United States' 48 contiguous states (U.S. Department of Agriculture, Natural Resources Conservation Service 2001). The largest increases in U.S. developed area in recent decades have been in the southeastern region of the country (13 states from Virginia to Texas). Aside from the United States as a whole, this region provides more timber harvest than any other country in the world (Wear and Greis 2002). Between 1982 and 1997, the South had 7 of the 10 states with the largest average annual additions of developed area according to the USDA (U.S. Department of Agriculture, Natural Resources Conservation Service 2001). The top three—Texas, Florida and North Carolina—each added more developed area than did the country's most populous state—California.

A major source of land area data is the NRI (U.S. Department of Agriculture, Natural Resources Conservation Service2001). 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 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. Outside urban areas, the NRI also includes developed land occupied by nonfarm, rural, built-up uses, e.g., rural transportation land. The last NRI survey for the period 1992 to 1997 showed a rural land loss of 4 acres (1.6 ha) a minute or approximately 2 million acres (0.8 million ha) per year in the United States (http://www.nrcs.usda.gov/technical/nri). Within that national total is a net loss of 163,000 acres (65,965 ha) of wetland between 1992 and 1997, with conversions to developed uses (248,000 acres or 100,364 ha) representing about half of the total of 506,000 acres (204,775 ha) of converted wetland.

Although 80 percent of the U.S. population now lives in urban areas, a significant amount of low-density development has been part of the expansion in developed area. Between 1982 and 1997, the U.S. population grew by 17 percent, while urbanized area grew by 47 percent. The amount of area per person dedicated to new housing has almost doubled in the last 20 years. Since 1994, 55 percent of the total U.S. developed land has been developed as 10-or-more-acre (4-or-more-ha) housing lots and 90 percent as 1-or-more-acre (0.4-or-more-ha) lots. Eighty percent of new development has been outside existing urban areas (i.e., nonmetropolitan areas) and not used for farm housing (http://www.ers.usda.gov/briefing/landuse/urbanchapter.htm). For the South in particular, the region with a large amount of private timber harvest and substantial biodiversity, the increment in developed area for each new resident has been increasing (Alig et al. 2004), resulting in lower density development. A contributing factor there and in other regions is the decreasing number of people per household (Alig et al. 2003), due to decreasing family size, popularity of second homes, divorce rate and growing number of older adults living in single homes or alone.

Low-density development in rural areas means that development brings more people living closer to remaining forestland. Based on nationwide rural-urban continuum classes (Smith et al. 2004), 13 percent of U.S. forestland 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. forestland (Smith et al. 2004). Between 1997 and 2002, the forest area in major metropolitan areas increased by 5 percent, or more than 5 million acres (2 million ha), as U.S. developed area expanded considerably. 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.

Conversion of Forests

The long-term historical loss in U.S. 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 (Alig et al. 2003, 2004). Deforestation is the conversion of land from forest to nonforest use, and between 1982 and 1997, 22 million acres (9 million ha) were deforested on nonfederal land in the United States. The destination of about half of the converted forest acres was to urban and developed uses, with more than 10 million acres (4 million ha) of U.S. nonfederal forests converted to developed uses, according to NRI estimates. That is an area larger in size than the combined current forest area of five northeastern states (Connecticut, Delaware, Maryland, New Jersey and Rhode Island). Between 1992 and 1997, the proportion of urban and developed uses as a destination for deforested acres increased to 55 percent of the total deforestation (U.S. Department of Agriculture, Natural Resources Conservation Service 2001), with about 1 million acres (0.4 million ha) converted to developed uses per year. Some forestland is projected to be converted to agricultural uses, but opportunities also exist for substantial afforestation, including more if government farm programs are reduced (Alig et al. 1998).

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). Multiple pathways of land-use change for nonfederal forests for the contiguous 48 states between 1982 and 1997 resulted in gross area changes of about 50 million acres (20 million ha, U.S. Department of Agriculture, Natural Resources Conservation Service 2001). The gross change in forest area was 14 times as large as the net change in forest area. When forests are converted to other uses, any forest area added elsewhere does not necessarily provide the same ecosystem services because acres exiting (e.g., deforestation) or entering (e.g., afforestation) can represent quite different forest conditions. Therefore, distinctions between net and gross changes in forest area are important.

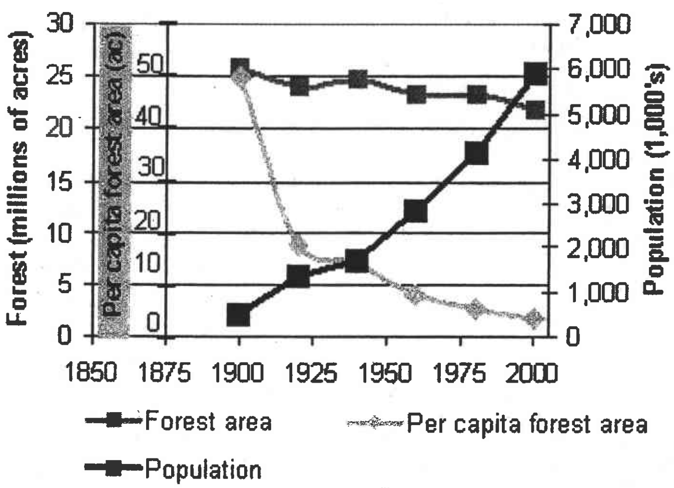
Regional Trends

Between 1990 and 2000, the population of the Pacific Northwest (Oregon and Washington) increased by 21 percent, well above the national average of 13 percent. Over the next 25 years, the region's population is projected to increase by 31 percent from its current level. Along with this increase in population comes a greater demand for land in residential, commercial and industrial uses. As in the past, the increase in urbanized land will occur at the expense of lands currently in forest, agriculture and other uses. The decline in the area of these rural lands reduces the habitat availability for a variety of wildlife species. Although some species can successfully adapt to the habitat offered by an urban environment, other populations will be adversely affected.

We next examine trends in land-use conversions and projections for western Washington, the most populous portion of the Northwest. Land-use changes occur most frequently on private land, driven by changes in population and personal income (e.g., Alig et al. 2004). Over three-quarters of the state's population live west of the crest of the Cascade Range in Washington. People, similar to wildlife, do not locate randomly on the landscape; about three-fifths of the state's population live within 10 miles (6.2 km) of coastline (including the Pacific Ocean and Sounds) (Alig and White 2007). People also migrate; between 1990 and 2000, the average annual net migration of humans into western Washington was approximately 52,000 individuals. In addition to the spatially dynamic distribution of humans, resources owned by people can vary over time and space. The highest household incomes are concentrated around the Seattle-to-Olympia corridor and around Vancouver in Clark County just north of Portland, Oregon. These areas, mostly of western Washington with larger personal incomes, have had a relatively large expansion in developed areas in recent decades.

Western Washington had a 52-percent increase in the area of urban and other developed land between 1982 and 1997, with 40 percent of that increase between 1992 and 1997 (U.S. Department of Agriculture, Natural Resources Conservation Service 2001). An area of particularly rapid development relative to effects on bird abundance and other biodiversity is the I-5 corridor, where housing density is higher than average (Alig and White 2007). Conversion of forestland to developed uses dominated either the amount converted to other uses or that converted to forests from other major land uses (Alig and White 2007). This resulted in a net loss of 313,000 acres (127,000 ha, or 4 percent) of nonfederal forest area in western Washington between 1982 and 1997. Washington has seen its population grow substantially over the last 100 years while forest area has been reduced, leading to a much smaller per-capita forest over time (Figure 1).

Figure 1. Washington population, forest area and per-capita area, 1900 to 2000 (Alig and White 2007).



Land use projections by Alig and White (2007) indicate an 8-percent loss of nonfederal forestland in western Washington between 1997 and 2027.

Seventy percent of the land that is projected to transition from forest to other uses is expected to ultimately become urban and other built-up land. Other projections of urban and developed area also indicate a substantial expansion, consistent with the continued growth in population and personal net incomes.

Looking now at the whole West, the region has grown faster than the national average, due in part to amenity-based migration. For example, a growing number of ranchettes and subdivisions has been particularly evident in the Rocky Mountain Region. In migration has included a large number of residents who choose to live in forested settings, resulting in construction of primary or secondary homes in forests or on rangelands. The Rocky Mountain Region also had the highest amount of developed area per additional person between 1992 and 1997 (U.S. Department of Agriculture, Natural Resources Conservation Service 2001, Alig et al. 2004).

Projections

Urban and developed areas are projected by econometric models to continue to grow substantially, in line with the projected U.S. population increase of more than 120 million people over the next 50 years and higher average levels of personal income (e.g., Alig and Plantinga 2004, Alig et al. 2004). Developed land will also increase in other parts of the developed world because of the global increase in population from 6 to 9 billion by 2050. U.S. developed area is projected to increase by 79 percent, raising the developed proportion of the total land base from 5.2 percent to 9.2 percent (Alig et al. 2004).

Total forestland in the United States is projected to decrease on net by approximately 23 million acres (9.3 million ha) between 1997 and 2050 (Alig et al. 2003), examined as part of periodic national assessments of forest- and rangeland ecosystems. This would be a 3-percent reduction. The main reason for the projected reduction in forestland is the conversion to urban and developed uses. Along with that, housing density on remaining forestland is projected to be substantial (Stein et al. 2005), with an increase from either rural or exurban to urban (22 million acres or 9 million ha) or from rural to exurban (22 million acres or 9 million ha). Continued development will also further fragment forests (e.g., Alig et al. 2005, Wear et al. 2004).

Natural Resource Implications for Rural Land Conversions

Land-use change can reduce wildlife habitat, can fragment wildlife habitat and can impede movement of wildlife, among other impacts (Theobald et al.

1997). Conversion of rural land to developed uses by way of deforestation includes urbanization, a leading cause of wildlife-species endangerment in the United States (Marzluff 2006) as well as in Canada (Venter et al. 2006). Conversion of forests can threaten the ability of diverse forestland-based ecosystems to provide a variety of habitats for wildlife, but can provide other goods and environmental services, such as mitigation of global climate change (Alig et al. 2002). An increasing number of structures (e.g., houses) pose increased costs of fire suppression and potential loss of substantial asset values. Long-term assessment of the condition of forests and of the relationships between forest conditions and socioeconomic factors related to deforestation is key when defining policy questions and actions needed to sustain forest-based services.

Development can eradicate or alter the quality of wildlife and fish habitat, which, in turn, can impact the presence of certain wildlife and fish species. Forest fragmentation has a multitude of effects on forest ecosystems. On the negative side, forest fragmentation is considered to be a primary threat to terrestrial biodiversity (Armsworth et al. 2004). In the United States, approximately 20 percent of resident bird species have experienced significant population declines in recent years (National Audubon Society 2002). Although there are many possible causes of these declines, one central factor is thought to be the fragmentation of forested habitat (Askins 2000). Particularly at risk are migratory songbirds, many of which nest in forests. These species are of significant conservation interest because they serve as indicators of ecosystem quality and are of considerable value to recreationists. Human health may also be impacted by forest fragmentation; Lyme disease may increase as forest edge increases, due to increased contact with wildlife as vectors. Possible positive impacts include increased tree growth of many species (if additional sunlight reaches trees that are closer to forest edges) and habitat for any wildlife species that benefit from forest fragmentation.

The intent in this section is to point out examples of the many possible impacts of forest fragmentation, recognizing that not all are negative; it depends on one's point of view. The overall or aggregate impacts of forest fragmentation depend, in part, on the social weight given to the different components of forest ecosystems. Such aggregate analysis is outside the scope of this paper but could be useful for policy analyses. Forest fragmentation is a problem for many species, especially in the eastern United States (Matthews et al. 2002). Bird densities are typically much lower in small patches of forest than in larger ones.

Fragmentation is considered a primary factor to neotropical migrant declines (Wear and Greis 2002). Neotropical migrants particularly affected by forest fragmentation (a lot nest in temperate forests) include the black-throated green warbler and the ovenbird.

A study that integrated land use, wildlife habitat and other policies was by Matthews et al. (2002). They evaluated subsidies that achieved conversion of 10 percent of the total agricultural land in each of three U.S. states (South Carolina, Maine and southern Wisconsin). Bird-density estimates were derived for 615 species with data from national breeding bird surveys. Despite considerable spatial variation in agricultural land-conversion rates and farmland-bird distribution within these states, statewide losses of farmland birds were relatively uniform between 10.8 and 12.2 percent. Increases in forest-bird populations, however, varied substantially between states: 0.3 percent in Maine, 2.5 percent in South Carolina and 21.8 percent in southern Wisconsin. Despite the prevailing wisdom as to bird-rich forests, surprisingly, a net loss in total bird populations results in all three states: -2.0 percent in Maine, -2.3 percent in South Carolina and -1.1 percent in southern Wisconsin. The loss is due to the coincidence of centers of high richness for farmland birds and low richness for forest birds with areas economically suited to conversion. Additional gains in forest species may result, however, if afforestation within the economically optimal counties is concentrated to fill in existing forest fragments presently suffering avian losses to edge predators. The results by Matthews et al. (2002) show that assessments of the biological consequences of afforestation for carbon sequestration must consider both current land cover and the distributional patterns of organisms as well as the policy's conversion goal.

An example of a wildlife and fish study in the Northwest that used land-use information was the Burnett et al. (2003) broad-scale identification of protected freshwater areas for Pacific salmon and trout in Oregon. Streamside areas adjacent to reaches with high intrinsic potential were characterized relative to land use and other attributes. Their human-development data layer was derived by interpolating structure densities (number of structures in a 13 acre [32 ha] circle around a photo point) among a grid of regularly spaced photo points from 1995 (Kline et al. 2003). Tailoring actions to the intrinsic potential of an area should enhance the efficacy and efficiency of broad-scale freshwater conservation strategies and may improve their societal support.

Globally, loss of habitat due to changing land use is a prime concern, as anthropogenic activities alter the natural world at an unprecedented rate, causing global extinction rates to rise. Venter et al. (2006) quantified the threats facing 488 species in Canada, with habitat loss the most prevalent threat (84 percent), similar to the United States. Agriculture (46 percent) and urbanization (44 percent) are the most common human activities causing habitat loss and pollution. For extant species, the number of threats per species increases with the level of endangerment. Introduced species are a much less important threat in Canada than in the United States, but the causes of endangerment are broadly similar for Canadian and globally endangered species.

Discussion and Conclusions

Concerns about reduction in forest area are long standing. Some of the earliest efforts in forest conservation were inspired by rapid loss of forests to agriculture and logging, by the desire to protect timber and water resources, and by the desire to conserve land of extraordinary beauty and uniqueness. One of the most striking and persistent ways that humans dominate Earth is by changing land use and land cover to accommodate a growing population. Urbanization and other development are increasing worldwide, with potentially important implications for biological diversity. Using the United States as an example, socioeconomic drivers of land-use change, such as population and personal income levels, have increased substantially on average since World War II and have driven marked increases in land development. Human land use is the primary force driving changes in forest ecosystem attributes. Nationwide, more than 60 percent of housing units built in the 1990s were constructed in or near wildland vegetation (Radeloff et al. 2005). More than 44 million acres (17.8 million ha) of private forest are projected to experience housing density increases, with the most heavily impacted watersheds in the East (Stein et al. 2005). Looking ahead, the U.S. population is projected to grow by more than 120 million people by 2050, with more than 50 million acres (20 million ha) projected to be deforested over the next 50 years (Alig et al. 2003).

Natural resource stewardship options are affected by the severity of conversions to developed uses. When an area is converted to urban or built-up uses, it is likely to be permanent conversion. Fragmentation due to development also affects the quality of remaining forests (e.g., Butler et al. 2004, Wear et al.

2004, Alig et al. 2005). Having more people on the forested landscape often results in loss of open space (e.g., wildlife habitat) and in concern over loss of the amenity values generally associated with open space. Growing concerns about the loss of forestland to development have also been reflected in public and private efforts to preserve forestland as open space (Kline et al. 2004). Because much of the growth is expected in areas that are relatively stressed by human-environment interactions, such as some coastal counties are, implications for landscape and urban planning include potential impacts on sensitive watersheds, riparian areas, wildlife habitat, open space and water supplies.

Impacts of human influences on North American wildlife and natural resources will continue to expand, including effects of global climate change. People will continue to be part of the problems as well as part of the solutions, so enhanced monitoring of human disturbances across landscapes and mitigation activities will be important. In the case of land-use changes, determining the extent of human settlements across developed countries presents a challenge, as definitions of "developed," "built-up," and "urban" land vary greatly (Alig and Healy 1987), particularly among nations. With a gradient of land use, human settlements vary widely in density (e.g., Alig et al. 2004), form and distribution. In North America, urban settlements, as they have been defined by the census bureaus of each nation, contain most of the population. Between 75 and 80 percent of the population of the continent is urban as defined by the census bureaus of the United States, Canada and Mexico; however, census definitions are not consistent across countries. Improved monitoring and coordination by major data collection agencies and countries would be valuable.

Land-use policies often are used to mitigate potential negative impacts of urbanization on wildlife habitat. For example, governments and private conservation groups purchase land and conservation easements preserving open space in urbanizing areas. Zoning is used to prevent land development in certain locations. To ensure that these policies are cost effective in design and implementation, managers and policymakers need information that allows them to anticipate, describe and plan for future land-development patterns and their associated impacts on wildlife. These land-use policies have developed incrementally, with the number and combination of land-use policy instruments varying dramatically across states.

Our country has a long history of natural resource policies designed to jointly pursue both economic and ecological objectives, often involving policy instruments designed to affect forest cover, such as agricultural conservation programs (e.g., Conservation Reserve Program of the Farm Bill) that have resulted in the nation's largest tree-planting efforts on a 5-year basis and that have led to additional planted forest cover. Afforestation and deforestation are part of the processes that impact forest cover and need to be analyzed alongside reforestation trends and projections. Ecological and economic consequences and ripple effects of such changes in forest cover across regions and other owner groups can be substantial. Policy impacts can be important when examining likelihood of land-use changes under alternative futures, given different possible outcomes for stressed wildlife habitats, for related impacts on regional economies and recreation, and for roles in policy to address global climate change and other natural resource issues. An opportunity exists with the renewal of the Farm Bill to increasingly integrate open space, wildlife habitat and environmental goals. Protection of wildlife habitat and other open spaces can involve interconnectedness across mixed land ownerships, as well as access questions. For example, wildlife or fish species dependent on privately owned bottomlands at certain times of the year may disappear as these private lands are developed, regardless of quality of habitat remaining on adjacent public land.

Human-induced stresses on natural systems are likely to increase in some areas, with human-related impacts possibly causing marked changes in biotic responses. Human footprints on the natural system are unprecedented, but opportunities exist to bolster the positive ones from a societal viewpoint.

Where will the future take us? Looking back to 1893, Frederick Jackson Turner called the U.S. frontier closed, with the United States evolving into an urban nation. In 1900, 34 percent of U.S. citizens lived in urban areas, By 2000, 80 percent of U.S. citizens lived in urban areas, with associated changes in the economy, culture, transportation, energy consumption and emissions, and wildlife habitat. The need to more closely examine the connections between conservation and development and how society makes choices within a context of strategic land conservation will intensify.

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