

FORESTS ON THE EDGE

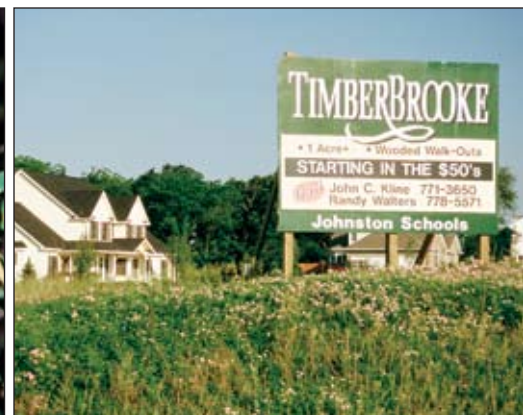
HOUSING DEVELOPMENT ON AMERICA'S PRIVATE FORESTS



USDA Forest Service



Susan Stein



U.S. Department of Agriculture
Forest Service



Pacific Northwest Research Station
General Technical Report
PNW-GTR-636
May 2005

*Susan M. Stein, Ronald E. McRoberts,
Ralph J. Alig, Mark D. Nelson, David M.
Theobald, Mike Eley, Mike Dechter, and
Mary Carr*

ABSTRACT

Stein, Susan M.; McRoberts, Ronald E.; Alig, Ralph J.; Nelson, Mark D.; Theobald, David M.; Eley, Mike; Dechter, Mike; Carr, Mary. 2005. Forests on the edge: housing development on America's private forests. Gen. Tech. Rep. PNW-GTR-636. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p.

The private working land base of America's forests is being converted to developed uses, with implications for the condition and management of affected private forests and the watersheds in which they occur. The Forests on the Edge project seeks to improve understanding of the processes and thresholds associated with increases in housing density in private forests and likely effects on the contributions of those forests to timber, wildlife, and water resources. This report, the first in a series, displays and describes housing density projections on private forests, by watershed, across the conterminous United States. An interdisciplinary team used geographic information system (GIS) techniques to identify fourth-level watersheds containing private forests that are projected to experience increased housing density by 2030. Results indicate that some 44.2 million acres (over 11 percent) of private forests—particularly in the East, where most private forests occur—are likely to see dramatic increases in housing development in the next three decades, with consequent impacts on ecological, economic, and social services. Although conversion of forest land to other uses over time is inevitable, local jurisdictions and states can target efforts to prevent or reduce conversion of the most valuable forest lands to keep private working forests resilient and productive.

Keywords: Fourth-level watershed, land use change, private forest, water quality, ecological services.

AUTHORS

Susan M. Stein is a private forest-land studies coordinator and **Mike Dechter** is a natural resource specialist, U.S. Department of Agriculture, Forest Service, Cooperative Forestry Staff, Mail Stop 1123, 1400 Independence Avenue, SW, Washington, DC 20250-1123. **Ronald E. McRoberts** is a group leader for research and analysis and **Mark D. Nelson** is a research forester, U.S. Department of Agriculture, Forest Service, North Central Research Station, 1992 Folwell Avenue, St. Paul, MN 55108. **Ralph J. Alig** is a research forester, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331. **David M. Theobald** is a research scientist, Colorado State University, Natural Resource Ecology Laboratory, Fort Collins, CO 80523-1499. **Mike Eley** is a GIS coordinator, American Farmland Trust, 1200 18th Street NW, Washington, DC 20036. **Mary Carr** is a technical publications editor, U.S. Department of Agriculture, Forest Service, CAT Publishing Arts, 1835 Black Lake Blvd. SW, Olympia, WA 98512.

Photo credits: All photos courtesy of USDA Natural Resources Conservation Service except where otherwise noted.

INTRODUCTION

America's private forests are changing. Many are located at the edges of growing towns and cities, or in prime recreation areas popular for second-home development. As more housing is built in private forests, their values and uses can be altered. Increases in housing density and associated development (such as power lines, septic and sewer systems, and shopping centers) can be linked to:

- * **Decreases in native fish and wildlife and their habitats.**
- * **Changes in forest health.**
- * **Reduced opportunities for outdoor recreation.**
- * **Poorer water quality.**
- * **Altered hydrology.**
- * **Greater loss of life and property to wildfire.**
- * **Changes in traditional uses of forests.**
- * **Decreases in the production of timber and other forest products.**

Concern about the effects of development on America's private forests has risen sharply since the 1990s, when the conversion of forest land to developed uses reached a million acres per year. Even when we consider that some agricultural lands are converted to forest each year, Forest Service researchers estimate that, by 2050, an additional 23 million acres of forest lands in net may be lost (Alig et al. 2003).

The Forests on the Edge project aims to increase public understanding of the contributions of and pressures on our private forests, and to create new tools for strategic planning. Many private forests are on the edge or interface where development pressures may affect forest attributes and management. The Forests on the Edge project seeks to improve our understanding of the processes and thresholds associated with increases in housing density in private forests and likely effects on the contributions of America's private forests to timber, wildlife, and water resources.

This report, the first in a series, displays and describes housing density projections on private forests, by watershed, across the conterminous United States (commonly called the lower 48, not including Alaska, Hawaii, and island territories, for which data were not available). Future reports will assess the contributions of private forests to timber, wildlife, and water resources; they will also provide housing density projections on a wider range of vegetation types, including the arid land vegetation found in the West.

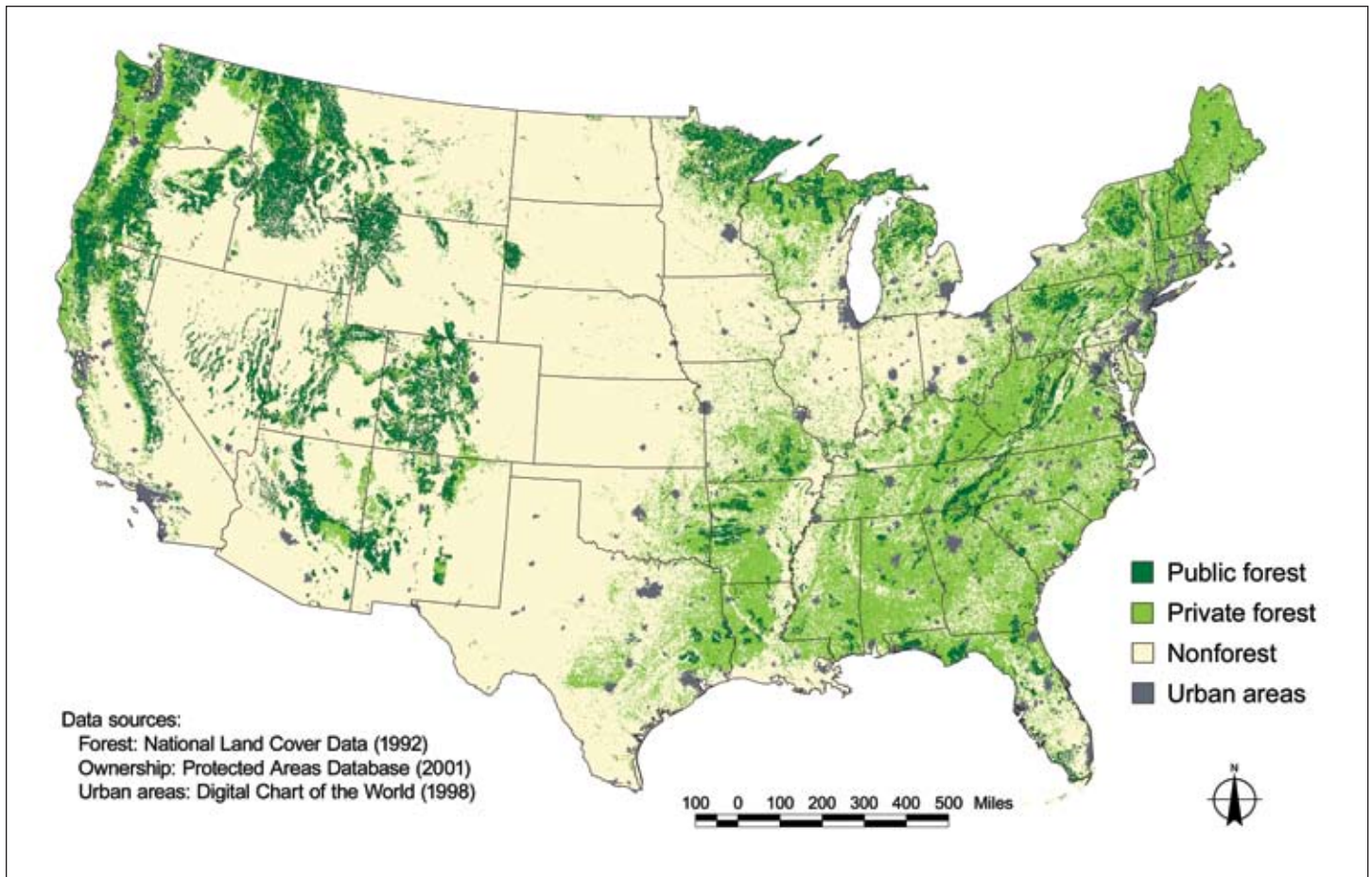


Figure 1—Location of private and public forest, nonforest, and urban areas. About three-quarters of America's private forests are in the East.

Results from this phase of the project indicate that many private forests—particularly in the East, where most private forests occur (fig. 1)—are likely to see dramatic increases in housing development in the next three decades, with consequent impacts on ecological, economic, and social services. Sustaining our forests and their benefits in the face of continuing population growth is and will be a key challenge.

What Is A “Private” Forest?

A private forest is forest land owned by individuals, families, corporations, organizations, tribes, or the forest industry.

PRIVATE FORESTS PLAY A KEY ROLE IN PROTECTING WATER QUALITY

Forests are critical to providing and protecting water. Covering nearly one-third of the Nation's land, forests supply over 50 percent of fresh-water flow in the lower 48 States. Forests protect water quality by slowing runoff, stabilizing soils, preventing erosion and floods, and filtering pollutants. According to Forest Service estimates, some 180 million people depend on forests for their drinking water¹ (Stein and Butler 2004).

¹Sedell, J. 2005. Personal communication. Station Director, Pacific Southwest Research Station, P.O. Box 245, Berkeley, CA 94701-0245.



Private forests constitute nearly 60 percent (about 430 million acres) of America's total forest land (Smith et al. 2004) and thereby provide nearly 60 percent of all waterflow originating on U.S. forests (and nearly 30 percent of all waterflow originating on land in the lower 48) in a typical year.²

²Brown, T. 2005. Personal communication. Hydrologist, Rocky Mountain Research Station, 2150 Centre Ave., Bldg. A, Suite 376, Fort Collins, CO 80526-1891.

Private forests provide many other benefits to the American public. They furnish diverse habitats for fish and wildlife, providing the key to the conservation of many species. In some regions, such as the Pacific Northwest, private forests provide a significant amount of habitat for threatened or endangered species, such as the threatened spotted owl (Holthausen et al. 1995). These habitats are important considerations for public land managers in the development and monitoring of recovery plans for such species (USDI FWS 1992). Private forests also provide

What Is A Forest?

The term "forest" has different meanings, depending on where you live or your interest in forests. For this project, we used "land that is at least 1 acre and at least 10 percent stocked by trees of any size" (Smith et al. 2004). This is the definition most commonly used by Forest Service Forest Inventory and Analysis scientists, who monitor the status of our Nation's forests each year. The source

of our data for forest cover was the National Land Cover Data compiled by the U.S. Geological Survey, which divides the country into small units (or pixels) of 323 square feet and assigns each unit to 1 of 21 vegetation categories. We selected categories that contained vegetation that was closest to our definition of forest.

A. Price, Utah Division of Forestry



Forests cover 749 million acres of the Nation's landscape. Hardwoods, conifers, and mixed species paint a diverse forest palette that ranges from sparse dry forest in the arid, interior West to lush rain forests in the Pacific Northwest, and highly productive moist forests in the South.

Tom Iraci, USDA Forest Service



the foundation for timber and other forest products businesses and accounted for 92 percent of all timber harvested in the United States in 2001 (Smith et al. 2004). Private forests in the Southern United States alone produce more timber than both private and public forests in any other country (Wear and Greis 2002a).

LONG-TERM TRENDS IN FOREST CHANGES

Although the amount of private forest land is increasing in some places in the country, the total area of private forest land has been gradually declining since the mid 20th century. From 1953 to 1997, 26 states have had a net loss in forest area. In 15 years alone (1982 to 1997), 10.3 million acres of nonfederal forest land, most of which is private, were converted to developed uses and urban areas. This is the equivalent of 680,000 acres per year. The rate of conversion jumped to 1 million acres per year during the last 5 years of this period (1992 to 1997), when 5 million acres of nonfederal forest land were permanently converted (Alig et al. 2003). Although such statistics may seem inconsequential at a national scale, we are learning that, in certain localities, housing density is increasing dramatically. Forests on the Edge is helping to identify those areas where housing development is most likely to affect our private forests.

ASSESSING HOUSING DEVELOPMENT ON PRIVATE FORESTS, 2000 TO 2030

An interdisciplinary team of specialists used geographic information system (GIS) techniques to identify watersheds across the conterminous United States containing private forests that are projected to experience increased housing density by 2030.

Watershed selection criteria—

We selected only those watersheds that had 10 percent or more forest cover **and** that had 50 percent or more of their forests in private ownership. A total of 1,026 of the Nation's 2,149 fourth-level watersheds met the selection criteria. These criteria resulted in a focus on the Eastern United States, where private forest cover is more extensive than in other parts of the country and where most forest land is in private ownership. Only the conterminous 48 States were included because data for Alaska, Hawaii, and the island territories are not adequate at this time.

Housing density projections—

Housing density projections were based on many factors, including past and current statistics on housing

density and population, road density, past growth patterns, and locations of urban areas. A more detailed description of this and other aspects of this study can be found in Stein et al. (in press).

Information sources—

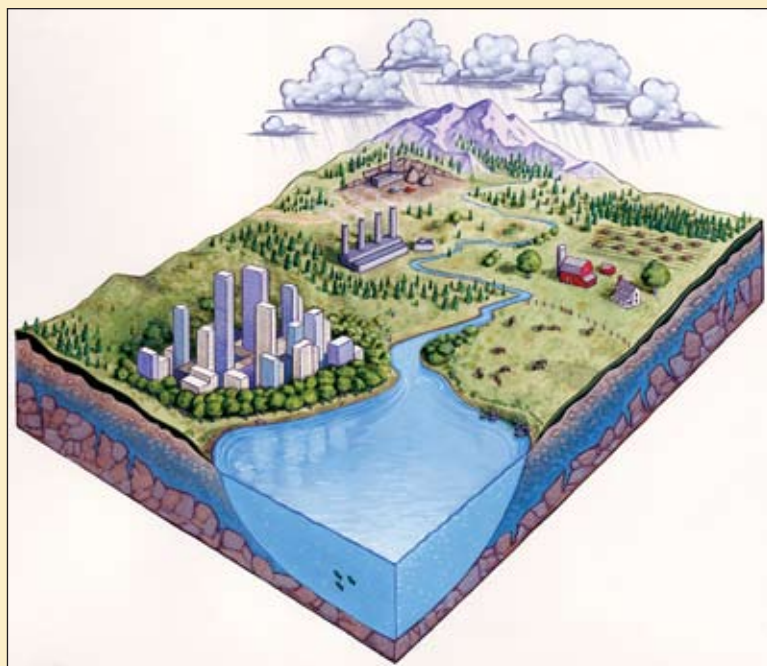
The following data layers were used in this analysis:

- Fourth-level watershed boundaries (defined by eight-digit hydrologic unit codes) (Steeves and Nebert 1994).
- Forest cover (DellaSala et al. 2001).
- Land ownership (DellaSala et al. 2001, Vogelmann et al. 2001).
- Housing density for 2000 (U.S. Census Bureau 2001). Housing density projections for 2030.³

³Theobald, D.M. [N.d.]. Sprawling in the USA? Landscape effects of urban and exurban development. Manuscript in preparation.

Watersheds Come In Different Sizes

To highlight the important connection between private forests and water, Forests on the Edge studied projected increases in housing density in private forests across watersheds. A watershed is an area of land that drains into a river, stream, or other body of water (see diagram below). To facilitate the study of watersheds of different sizes, the U.S. Geological Survey devised a system that organizes the country into watershed units. There are 2,108 watersheds in the conterminous United States at the size used for this project (referred to as "fourth-level"), which have an average of a million acres (ranging from 21,760 to about 13 million acres).



Documenting Change

A challenge for researchers is to document the net change compared to gross changes in forest area (Alig et al. 2003). Many acres converted to housing and thus **leaving** the forest land base may still have substantial tree cover and may have older trees. Many acres **entering** the forest base (by tree planting on agricultural land, for example) will not have substantial tree cover for many years, and the new forest cover may differ substantially from the forests lost in age, composition, quality, and ecological and productive value. Thus, forest conditions in a particular area can change substantially even when there is little or no net change in forest cover.

Definitions—

Private forest—For this project, included tribal, forest industry, and nonindustrial private ownerships; excluded public lands and private lands protected through conservation easements.

Rural—Private forest lands with 16 or fewer housing units per square mile. Forest lands with this housing density can generally support a diversity of economic and ecological functions commonly associated with private forests, such as management for timber, most wildlife species, and water quality.

Exurban—Private forest lands with 16 to 64 housing units per square mile. Lands with these higher housing densities can still support many wildlife species and other ecological functions, although perhaps at a reduced level. However, management for commercial timber may be less likely.

Urban—Private forest lands with 64 or more housing units per square mile. Such lands are less likely to be used for timber production or to contribute to wildlife habitat and water quality because of increased road density, infrastructure, and human population levels. Such forest patches, however, are often highly valued for their aesthetics, noise abatement properties, and positive effect on property values.

projected to have the most overwhelming impacts is the Southeast, considered the “wood basket” of the United States and an area of high biodiversity.

This finding complements the conclusions of other recent studies such as the Southern Forest Resource Assessment (Wear and Greis 2002a), which identified development as the most pertinent force of change facing forests in the South. This region has been characterized as having the highest rate of urban development in the country (Macie and Hermansen 2003). In the 1990s, urban development in the South surpassed agriculture as the leading cause of forest loss. Causes of expansion of developed area in the South include above-average population growth, above-average consumption of land per additional resident, and income growth (Alig et al. 2004).

Although most watersheds meeting our selection criteria are projected to undergo significant housing density shifts on less than 5 percent of their surface area, these shifts could have significant impacts at the local level. Twenty-six watersheds were projected to experience increased housing development on more than 20 percent of the watershed’s area. On a national level this may not be considerable; however, such a level of change could have tremendous impacts on many ecological values in these watersheds, including water quality.

The Top 15

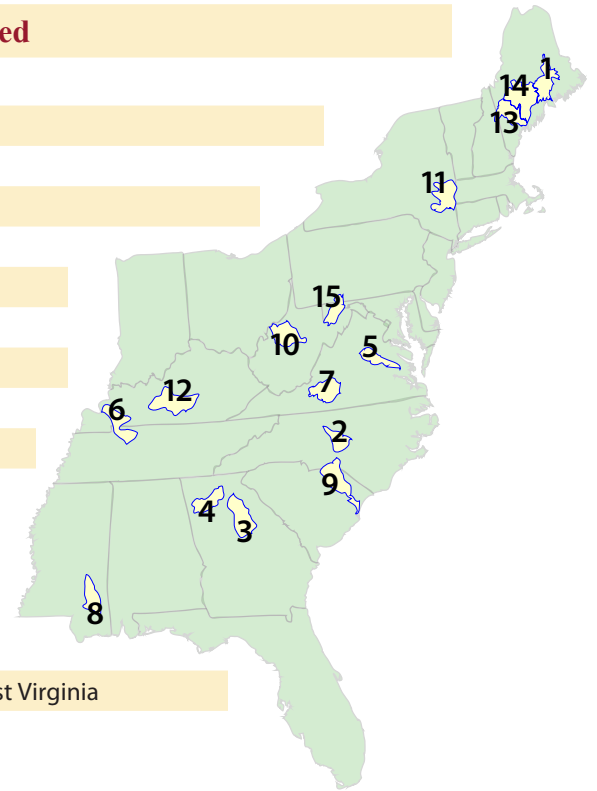
More than 15 watersheds of the 1,026 that met the selection criteria are projected to experience housing density increases on more than 200,000 acres of their surface area. The following tabulation depicts the number of acres of forest expected to shift either (a) from rural to exurban or (b) from rural or exurban to urban in each of the top 15 watersheds (all these watersheds are located in the Eastern United States):

KEY FINDINGS

Some 44.2 million acres (over 11 percent) of private forest across the conterminous United States could experience substantial increases in housing density by 2030 (fig. 2). Private forests in watersheds across the Eastern United States and in parts of California and the Pacific Northwest are projected to experience the most extensive increases. The area

The top 15 watersheds with increased housing density projected

	Watershed	Acres ⁴	State(s)
1	Lower Penobscot	310,206	Maine
2	Deep	269,817	North Carolina
3	Upper Oconee	269,003	Georgia
4	Etowah	265,961	Georgia
5	Pamunkey	262,003	Virginia
6	Lower Cumberland	259,035	Kentucky and Tennessee
7	Upper Roanoke	257,110	Virginia
8	Lower Lead	242,758	Mississippi
9	Lower Pee Dee	239,558	North and South Carolina
10	Little Kanawha	225,760	West Virginia
11	Middle Hudson	221,384	New York and Massachusetts
12	Upper Green	215,579	Kentucky
13	Lower Androscoggin	213,808	Maine and New Hampshire
14	Lower Kennebec	210,005	Maine
15	North Branch Potomac	209,187	Maryland, Pennsylvania, and West Virginia



⁴ Number of private forest acres projected to experience increase in housing density.

Two Types of Shift Across the United States

From rural or exurban to urban—

- ✱ A total of 21.7 million acres across the country are projected to shift from rural or exurban to urban by 2030.
- ✱ Two watersheds (one in Maine and one in California) are projected to experience this shift on 20 to 30 percent of their area (fig. 3).
- ✱ Thirty-eight watersheds may have a shift from nonurban to urban use levels on 10 to 20 percent of their area.
- ✱ Most affected watersheds are scattered across the Eastern United States, although some are located in the Sierra foothills of California and in northern Washington state.

From rural to exurban—

- ✱ A total of 22.5 million acres across the country are projected to shift from rural to exurban by 2030.
- ✱ Twenty-seven watersheds contain forests projected to experience this shift on more than 10 to 20 percent of their area (fig. 4).
- ✱ Hardest hit will be 12 states in the Northeast and the South.

SPECIAL CONSIDERATIONS: URBAN AREAS AND THE WEST

Because this study focuses on future change, this report does not call attention to areas that are already urbanized—for example, around many northeastern cities such as Providence, Rhode Island. In such areas, the remaining acres of private forests, important at the local level, could be under intense development pressures.

Except for certain watersheds in California and the Pacific Northwest, most Western watersheds under high development pressures are not identified in our maps because relative to the country as a whole, little private forest occurs in most of the West.

Jeff Kline, USDA Forest Service



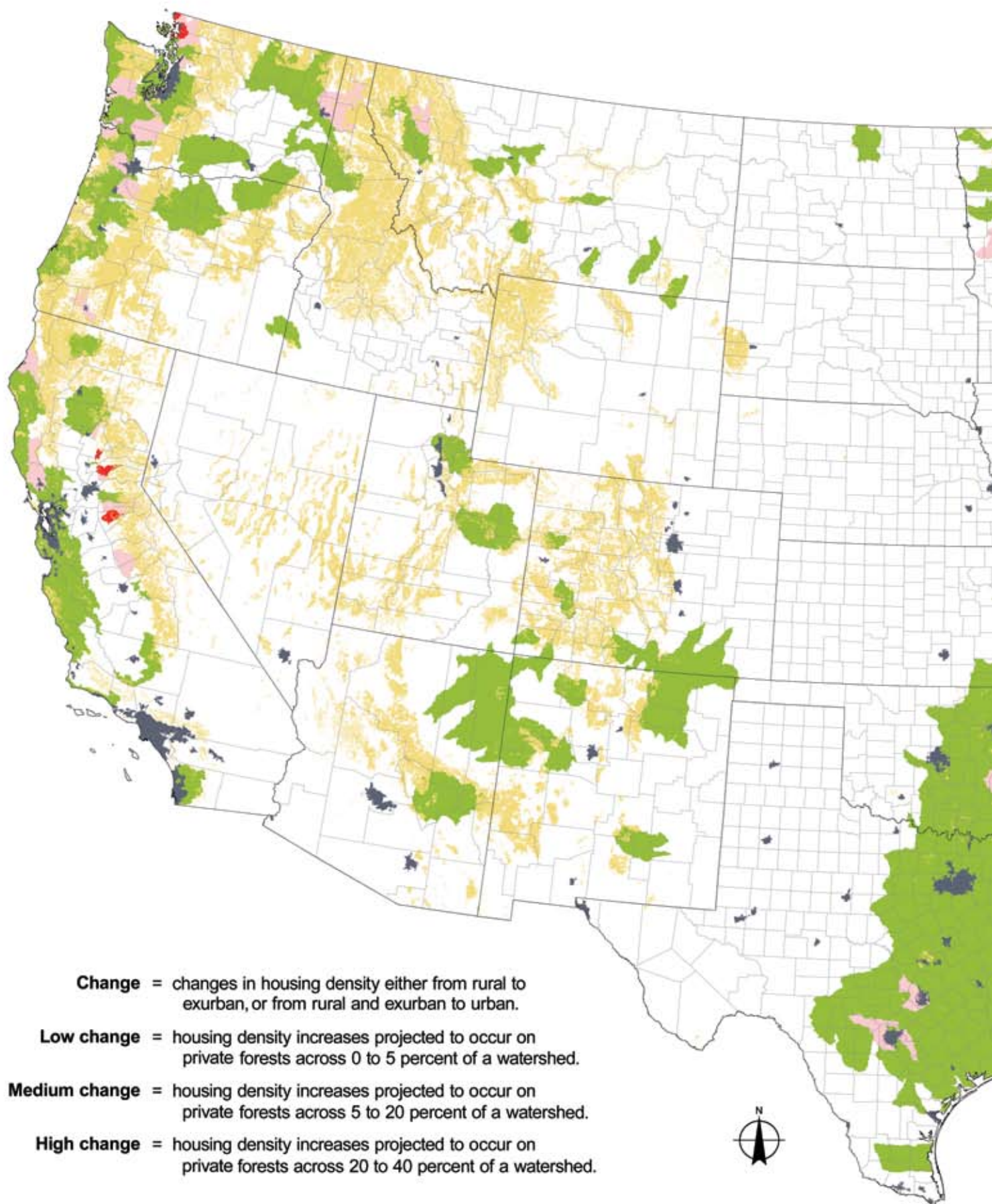
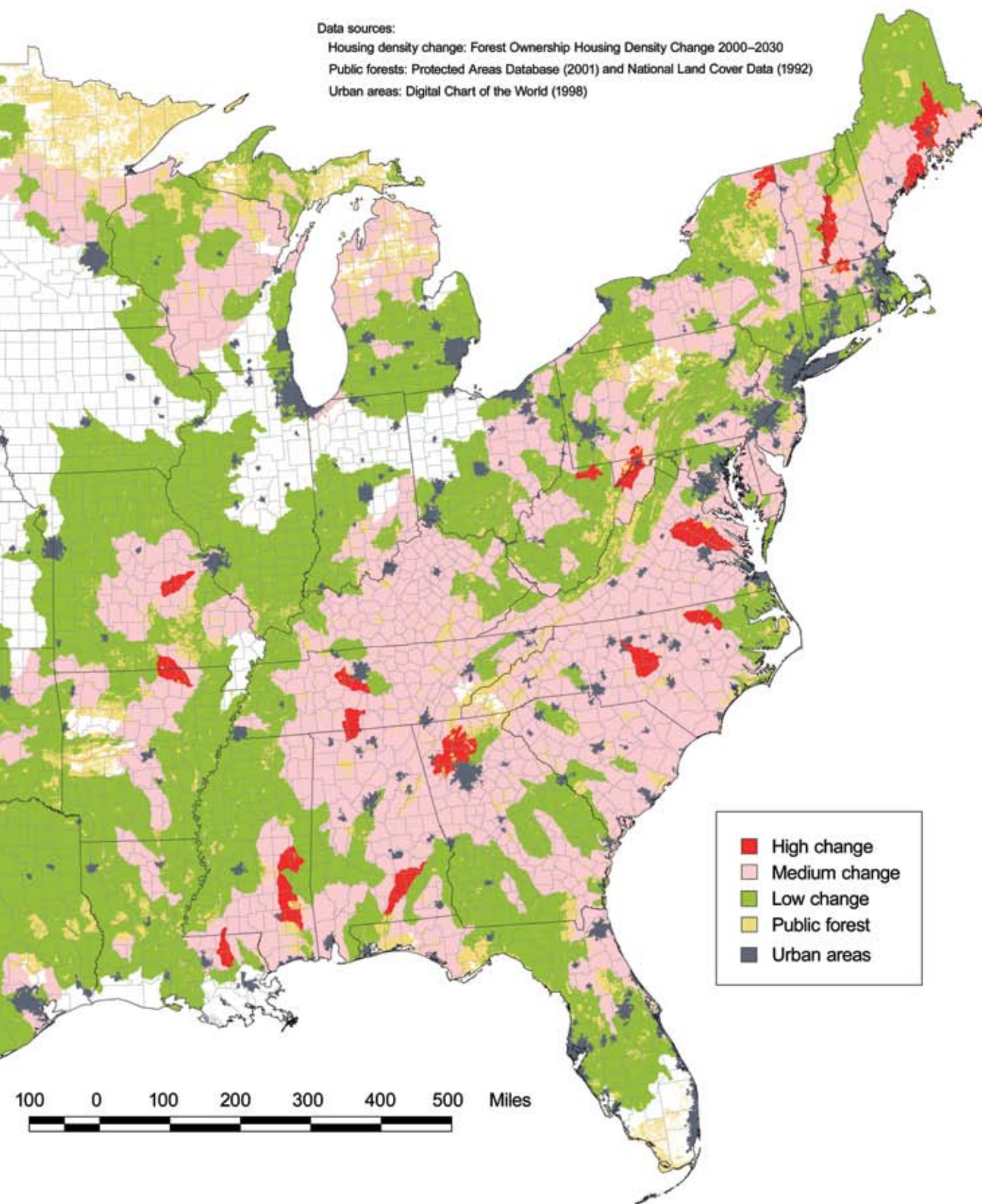


Figure 2—Watersheds in which housing density is projected to increase on private forests by 2030.



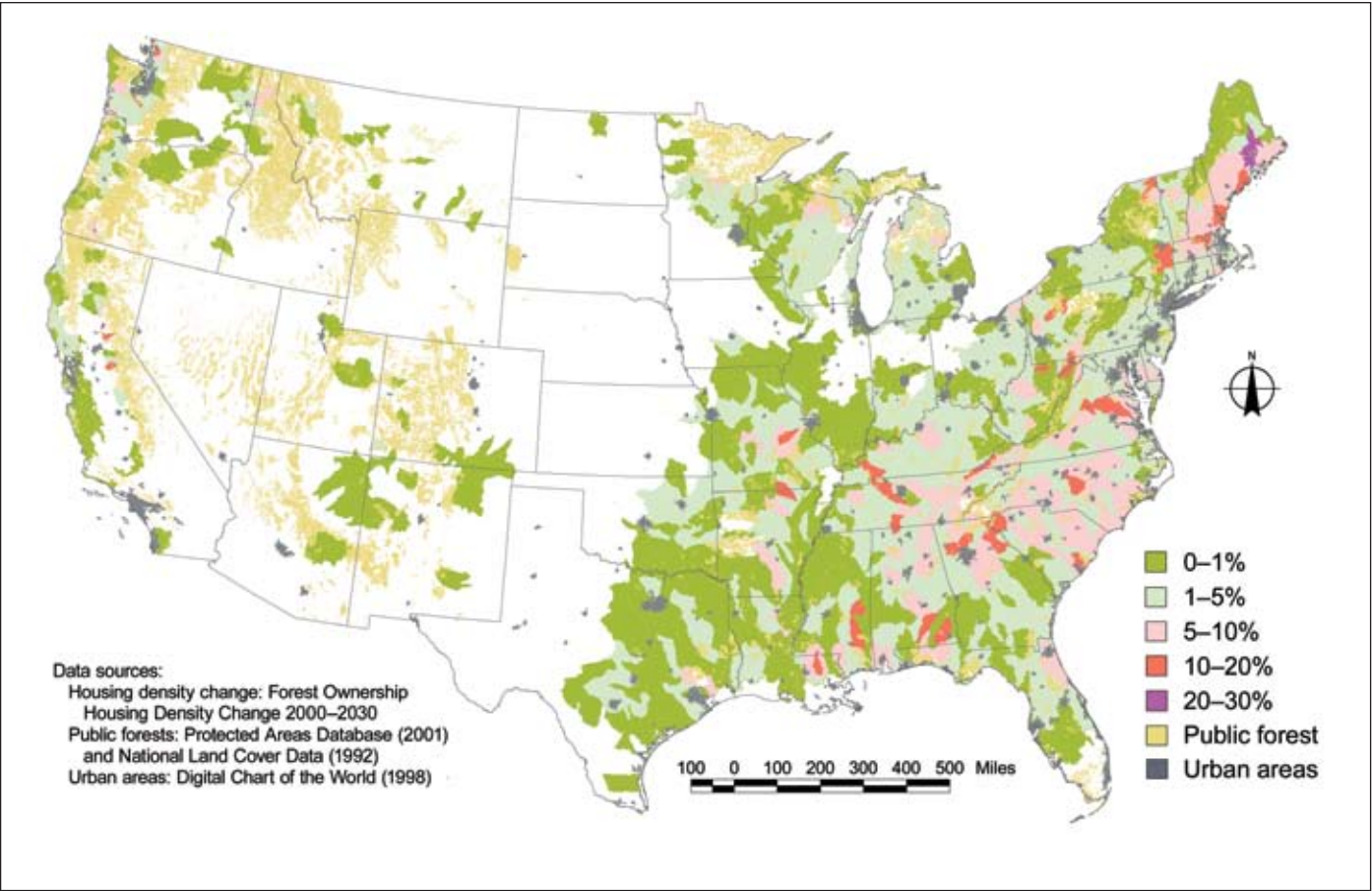


Figure 3—Percentage of watersheds with private forests that are projected to shift from rural or exurban to urban by 2030.

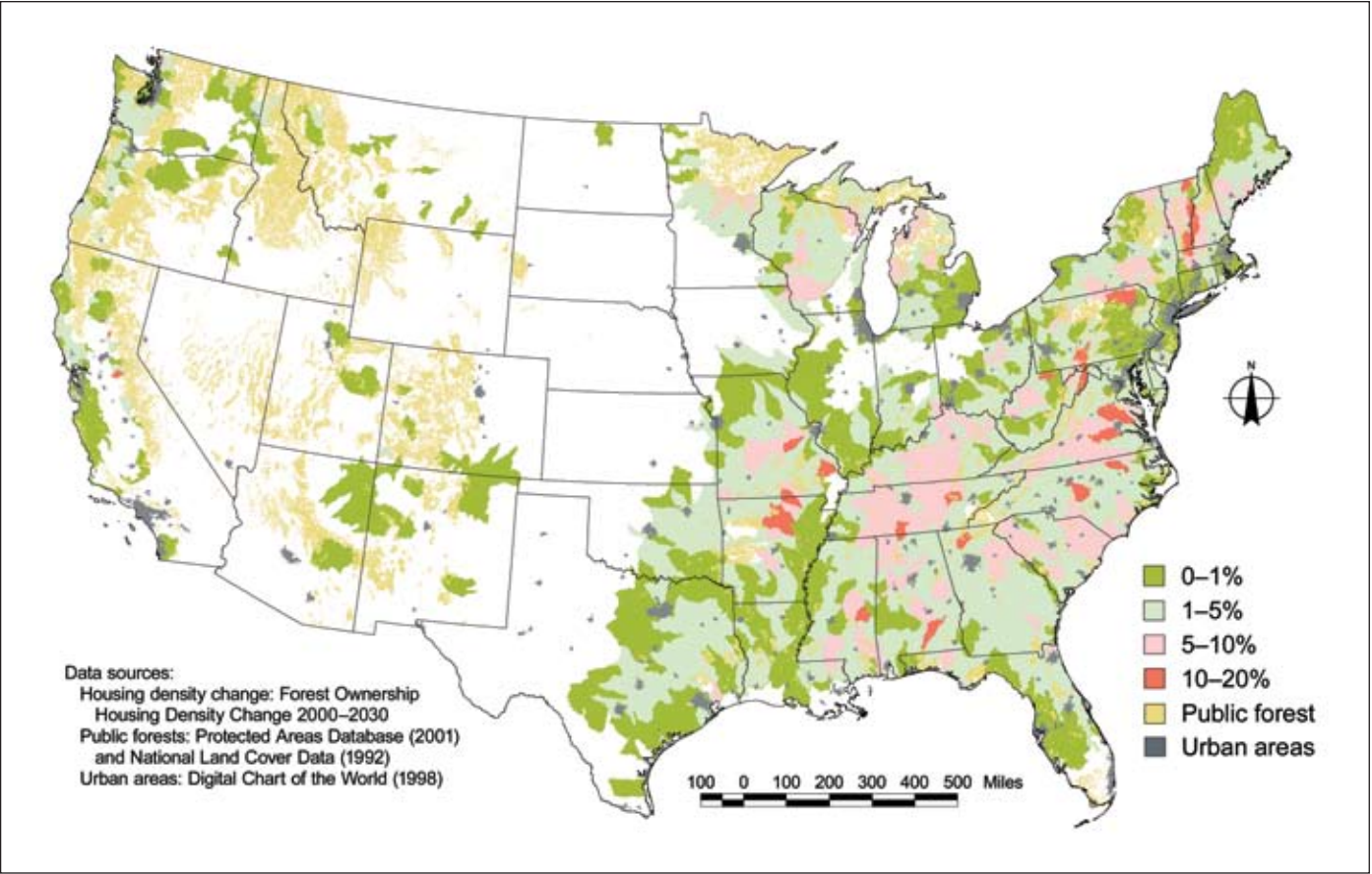


Figure 4—Percentage of watersheds with private forests that are projected to shift from rural to exurban by 2030.

Three of the fastest growing states—Utah, Nevada, and Idaho—contain only about 1.5 percent of our Nation’s private forests. The predominance of public forest land in the West may overshadow the smaller but vital parcels of private forest whose loss could be critical at the local level and should not be discounted (see sidebar below).

The next phases of Forests on the Edge will focus more on development impacts on public and private forest in the West. Important parcels of private forest in the urbanized East and in the West have already been identified by state governments through forest-land protection programs such as the Forest Service’s Forest Legacy Program and in coordination with nongovernmental land trusts.

IMPLICATIONS

The changes in housing density documented by Forests on the Edge have implications for the condition and management of affected private forests and the watersheds in which they occur. Increased housing density in forested areas and decreased parcel sizes can be associated with:

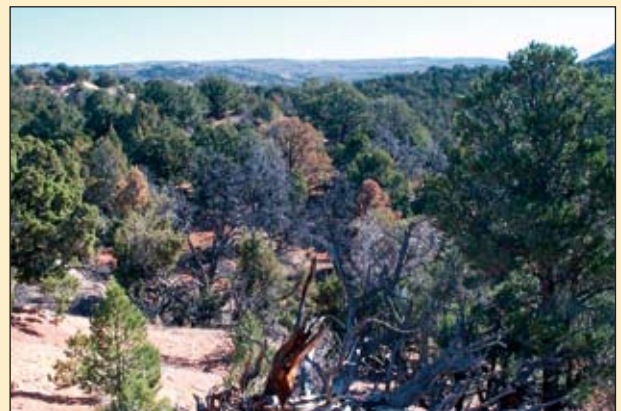
- ✱ **Decreases in native wildlife populations owing to decreased wildlife habitat quantity and quality, increased predation and mortality, and other consequences of human activity that change the relationships many wildlife species have with**

their environments (Engels and Sexton 1994; Harris 1984; Theobald et al. 1997; Vogel 1989; Wear and Greis 2002a, 2002b).

- ✱ **Alterations in forest structure and function that can derail ecological processes on which forests and forest dwellers depend, resulting in less biodiversity and more opportunities for invasions of nonnative species, insects, and diseases (Ferreira and Laurance 1997, Meekins and McCarthy 2002) (fig. 5).**
- ✱ **Long-term modifications to and reductions in water quality and aquatic diversity when forests can no longer regulate the movement of storm water across the landscape, leading to changes in streamflows, increases in sediment, reshaped stream bottoms and banks, and impacts on water quality and aquatic species such as fish and mussels (Booth and Henshaw 2001, Bryan 1972, Fisher et al. 2000, Jones and Holmes 1985, Paul and Meyer 2001).**
- ✱ **Decreases in timber production and active forest management when population densities increase (Gobster and Rickenbach 2004, Kline et al. 2004, Wear et al. 1999) (fig. 6).**

Vulnerable Forests in the West: A Mapping Challenge

Pinyon-juniper shrubland.



Photos by A. Price, Utah Division of Forestry, Fire and State Lands

Pinyon-juniper vegetation in the Southwest is an example of vegetation cover that is vulnerable to development in some areas but is not always considered forest. The land-cover layer we used for this study classified tall and dense pinyon-juniper vegetation as forest land, whereas sparse and stunted pinyon-juniper was classified as shrubland.

Inclusion of shrubland would have resulted in a map portraying more pinyon-juniper lands as forest but would have also classified all Eastern shrublands as forest, thus portraying a substantially larger area of forest land than has been reported in national inventories of forest resources. Thus, shrubland areas are not highlighted on the current map.



Figure 5—Private forest landowners in Georgia’s metropolitan counties are less likely to participate in government incentive programs for protecting soils and tree planting than are landowners in more rural counties (Harris and DeForest 1993).



Figure 6—In western Virginia, increasing human population densities have affected long-term timber management capabilities by reducing area of timberland and commercial volume of growing stock by some 40 percent from their measured values. Researchers found that the probability of forest management approaches zero at population densities of about 150 people per square mile (Wear et al. 1999).

- * **Increases in fire risk because increased housing densities in forested landscapes generate more potential for ignitions; make firefighting and fire preparedness in such areas more difficult, dangerous, and expensive; and restrict available management options for mitigating threats to forest lands (Grace and Wade 2000, Podur et al. 2002, Russel and McBride 2003).**
- * **Greater loss of life and property owing to wildfire because houses located in forested landscapes are more likely to experience threats from wildfire (Beringer 2000).**
- * **Changes in scenic quality and recreational opportunities owing to loss of open space, decreased parcel size, and fragmentation, all of which can degrade the recreational experience for hikers, campers, and mountain bikers and lead to increased likelihood of land use conflicts (Gobster and Rickenbach 2004, Patterson et al. 2003).**

✱ **Shifts in price levels and economic benefits for forest-based products—including fewer options for timber management, recreation, and other uses whose economic benefits rely on large forested areas; shifts in forest-based products from large-scale recreation to specialty products that may still be cost-effective on smaller forest tracts; and potentially increased property values associated with trees in urban areas (Ellis et al., in press; Tyrväinen 1997; Tyrväinen and Väänänen 1998; Weeks 1990) (fig. 7).**



USDA Forest Service

Figure 7—Private forest stakeholders in Wisconsin indicated in a recent survey that parcelization resulting from development makes timber production less profitable and leads to a shift from commercially valued species to less valued species (Gobster and Rickenbach 2004).

FUTURE OPTIONS

This study is but one chapter in the story of constant flux experienced by our Nation's private forest lands. Although projections of this scope and nature do not necessarily provide precise predictions of the future in all parts of the study area, they do provide an important step toward understanding those factors that could alter the conservation functions and values of private forest lands. Spatial information about land use changes resulting from this and similar studies can help scientists, resource managers, and communities plan for future growth and implement plans and policies that conserve our natural resources.

The conversion of some private forest land over time is inevitable. Although development will occur, local jurisdictions and states can plan and target efforts to prevent or reduce conversion of some of their most valuable forest lands—such as large contiguous forest tracts, forests adjacent to headwaters or riparian areas, forests with high timber or wildlife values, and forests with valuable scenic and social qualities—to keep our private working forests resilient and productive long into the future.

ACKNOWLEDGMENTS

This publication would not have been possible without the dedicated help of many people. We especially thank Larry Payne, Director of the Forest Service Cooperative Forestry staff, for his outstanding leadership on issues relating to loss of open space; Ted Beauvais, Assistant Director of Cooperative Forestry, for his excellent advice and support; Sara Comas, Cooperative Forestry, for assisting with the management of the Forests on the Edge project; and Jimmy Daukas, American Farmland Trust, for sharing his experiences on American Farmland Trust's Farming on the Edge project. We also thank the following individuals for their detailed reviews of our draft report: Dave Wear and John Greis, Forest Service Southern Research Station; Mike Foreman, Virginia Department of Forestry; Don Van Hassent, Maryland Department of Natural Resources; and Gary Lettman, Oregon Department of Forestry.

What Can We Learn From Monitoring Changes in Land Use?

Knowledge of land use changes can help people and communities adjust to shifting demands for and supplies of renewable resources from the Nation's forest and aquatic ecosystems. Monitoring those changes over time can help us:

- ✱ Understand whether we can sustain increased consumption of forest products while preserving resource stewardship options for future generations.
- ✱ Compile data that can be used to project timber harvests, wildlife habitat, and other natural resource conditions.
- ✱ Appreciate the importance of looking across the landscape and across boundaries to determine the sustainability of our activities.
- ✱ Plan for sustainable growth.

Source: Adapted from Alig et al. 2003.

METRIC EQUIVALENTS

When you know:	Multiply by:	To find:
Feet	0.3048	Meters
Acres	.405	Hectares
Square feet	.0929	Square meters
Square miles	2.59	Square kilometers

LITERATURE CITED

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

Alig, R.J.; Plantinga, A.J.; Ahn, S.; Kline, J.D. 2003. Land use changes involving forestry in the United States: 1952 to 1997, with projections to 2050—a technical document supporting the 2000 USDA Forest Service RPA assessment. Gen. Tech. Rep. PNW-GTR-587. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 92 p.

Beringer, J. 2000. Community fire safety at the urban/rural interface. *Fire Safety Journal*. 35: 1–23.

Booth, D.B.; Henshaw, P.C. 2001. Rates of channel erosion in small urban streams. In: Wigmosta, M.S.; Burges, S.J., eds. *Land use and watersheds: human influence on hydrology and geomorphology in urban and forest areas—AGU monograph series, water science and application*. Washington, DC: American Geophysical Union: 17–38. Vol. 2.

Bryan, E.H. 1972. Quality of stormwater drainage from urban land. *Water Resources Bulletin*. 8: 578–588.

DellaSala, D.A.; Staus, N.L.; Strittholt, J.R.; Hackman, A.; Iacobelli, A. 2001. An updated protected areas database [PAD] for the United States and Canada. *Natural Areas Journal*. 21(2): 124–135.

Ellis, C.D.; Lee, S-W.; Kweon, B-S. [In press]. Retail land use, neighborhood satisfaction and the urban forest: an investigation into the moderating and mediating effects of trees and shrubs. *Landscape and Urban Planning*.

Engels, T.; Sexton, C. 1994. Negative correlation of blue jays and golden-cheeked warblers near an urbanizing area. *Conservation Biology*. 8: 286–290.

Ferreira, L.V.; Laurance, W.F. 1997. Effects of forest fragmentation on mortality and damage of selected trees in Central Amazonia. *Conservation Biology*. 11(3): 797–801.

Fisher, D.S.; Steiner, J.L.; Endale, D.M.; Stuedemann, J.A.; Schomberg, H.H.; Franzluebbers, A.J.; Wilkinson, S.R. 2000. The relationship of land use practices to surface water quality in the upper Oconee Watershed of Georgia. *Forest Ecology and Management*. 128: 39–48.

Gobster, P.H.; Rickenbach, M.G. 2004. Private forestland parcelization and development in Wisconsin’s Northwoods: perceptions of resource-oriented stakeholders. *Landscape and Urban Planning*. 69(2–3): 165–182.

Grace, S.; Wade, D. 2000. Ecological and economic consequences of the 1998 Florida wildfires. Florida Department of Forestry. http://flame.fl-dof.com/joint_fire_sciences/exec_sum.pdf. (01 March 2005).

Harris, L.D. 1984. The fragmented forest: island biogeography theory and the preservation of biotic diversity. Chicago: University of Chicago Press. 211 p.

Harris, T.; DeForest, C. 1993. Policy implications of timberland loss, fragmentation, and urbanization in Georgia and the Southeast. In: Wear, D.N., ed. *Proceedings of the 1993 Southern forest economics workshop*. Durham, NC: Duke University: 70–83.

Holthausen, R.S.; Raphael, M.G.; McKelvey, K.S.; Forsman, E.D.; Starkey, E.E.; Seaman, D.E. 1995. The contribution of federal and non-federal habitat to persistence of the northern spotted owl on the Olympic Peninsula, Washington: report of the reanalysis team. Gen. Tech. Rep. PNW-GTR-352. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 68 p.

Jones, R.C.; Holmes, L.F. 1985. Effects of land use practices on water resources in Virginia. Virginia Water Resources Research Center Bulletin 144. Blacksburg, VA: Virginia Polytechnic Institute and State University. 115 p.

Kline, J.D.; Azuma, D.L.; Alig, R.J. 2004. Population growth, urban expansion, and private forestry in western Oregon. *Forest Science*. 50(1): 1–11.

Macie, E.A.; Hermansen, I.A. 2003. Human influences on forest ecosystems: the southern wildland-urban interface assessment summary report. Gen. Tech. Rep. SRS-64. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 160 p.

Meekins, J.F.; McCarthy, B.C. 2002. Effects of environmental variation on the invasive success of a nonindigenous forest herb. *Ecological Applications*. 11(5): 1336–1348.

- Patterson, M.E.; Montag, J.M.; Williams, D.R. 2003.** The urbanization of wildlife management: social science, conflict, and decision-making. *Urban Forestry and Urban Greening*. 1(3): 71–183.
- Paul, M.J.; Meyer, J.L. 2001.** Streams in the urban landscape. *Annual Review of Ecological Systems*. 32: 333–365.
- Podur, J.; Martell, D.L.; Knight, K. 2002.** Statistical quality control analysis of forest fire activity in Canada. *Canadian Journal of Forest Research*. 32(2): 195–205.
- Russel, W.H.; McBride, J.R. 2003.** Landscape scale vegetation-type conversion and fire hazard in the San Francisco Bay area open spaces. *Landscape and Urban Planning*. 64: 201–208.
- Smith, W.B.; Miles, P.D.; Vissage, J.S.; Pugh, S.A. 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. http://www.ncrs.fs.fed.us/pubs/gtr/gtr_nc241.pdf. (28 February 2005).
- Steeves, P.A.; Nebert, D.D. 1994.** Hydrologic unit maps of the conterminous United States [Database]. U.S. Geological Survey, open-file dataset “huc250k,” ed. 1. Reston, VA: U.S. Geological Survey. <http://water.usgs.gov/GIS/metadata/usgswrd/XML/huc250k.xml>. (1 March 2005).
- Stein, S.; Butler, B. 2004.** On the frontline: private forests and water resources. *Wildland Waters*. Summer. FS 790. Washington, DC: U.S. Department of Agriculture, Forest Service. 24 p. <http://www.fs.fed.us/wildlandwaters/>. (1 February 2005).
- Stein, S.; McRoberts, R.E.; Nelson, M.D.; Theobald, D.M.; Eley, M.; Dechter, M. [In press].** Forests on the edge: a GIS-based approach to projecting housing development on private forests. In: Aguirre-Bravo, C., ed., *Proceedings: monitoring science and technology symposium: unifying knowledge for sustainability in the western hemisphere*. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- Theobald, D.M.; Miller, J.R.; Hobbs, N.T. 1997.** Estimating the cumulative effects of development on wildlife habitat. *Landscape and Urban Planning*. 39: 25–36.
- Tyrväinen, L. 1997.** The amenity value of the urban forest: an application of the hedonic pricing method. *Landscape and Urban Planning*. 37(3–4): 211–222.
- Tyrväinen, L.; Väänänen, H. 1998.** The economic value of urban forest amenities: an application of the contingent valuation method. *Landscape and Urban Planning*. 43(1–3): 108–115.
- U.S. Census Bureau. 2001.** Census 2000 summary file 1 technical documentation. Washington, DC. <http://www.census.gov/prod/cen2000/doc/sf1.pdf>. 634 pp. (1 March 2005).
- U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 1992.** Final draft recovery plan for the northern spotted owl. Portland, OR. 322 p. Vol. 1.
- Vogel, W.O. 1989.** Response of deer to density and distribution of housing in Montana. *Wildlife Society Bulletin*. 17: 406–413.
- Vogelmann, J.E.; Howard, S.M.; Yang, L.; Larson, C.R.; Wylie, B.K.; VanDriel, J.N. 2001.** Completion of the 1990s national land cover data set [NLCD] for the conterminous United States. *Photogrammetric Engineering and Remote Sensing*. 67: 650–662.
- Wear, D.N.; Greis, J.G., eds. 2002a.** Southern forest resource assessment. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 635 p.
- Wear, D.N.; Greis, J.G. 2002b.** Southern forest resource assessment: summary of findings. *Journal of Forestry*. 100(7): 6–15.
- Wear, D.N.; Liu, R.; Foreman, J.M.; Sheffield, R.M. 1999.** The effects of population growth on timber management and inventories in Virginia. *Forest Ecology and Management*. 118: 107–115.
- Weeks, E.C. 1990.** Mill closures in the Pacific Northwest: the consequences of economic decline in rural industrial communities. In: Lee, R.G.; Field, D.R.; Burch, W.R., Jr., eds. *Community and forestry: continuities in the sociology of natural resources*. Boulder, CO: Westview Press: 125–140.



Mark Godfrey © 2004 The Nature Conservancy

FORESTS ON THE EDGE: PRESSURES AND OPPORTUNITIES ON AMERICA'S PRIVATE FORESTS

Phase 1 of Forests on the Edge, documented in this report, identifies forested watersheds most likely to experience housing development. Future phases will explore:

- * Private forest opportunities and threats in more detail—presenting additional data related to water quality, timberland, and wildlife values, as well as maps showing where private forests are most susceptible to development, fire, insects and diseases, and deterioration of air quality.
- * Housing density projections in the vicinity of public forests.
- * Detailed descriptions of the “top 10” watersheds of concern and of promise in the conterminous United States.

For further information on Forests on the Edge, contact:

Susan Stein
Private Forest Land Studies Coordinator
USDA Forest Service
Cooperative Forestry Staff
Mail Stop 1123
Washington, DC 20250-1123

Phone: (202) 205-0837
Fax: (202) 205-1271

sstein@fs.fed.us
<http://www.fs.fed.us/projects/fote>

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.

USDA is committed to making its information materials accessible to all USDA customers and employees.