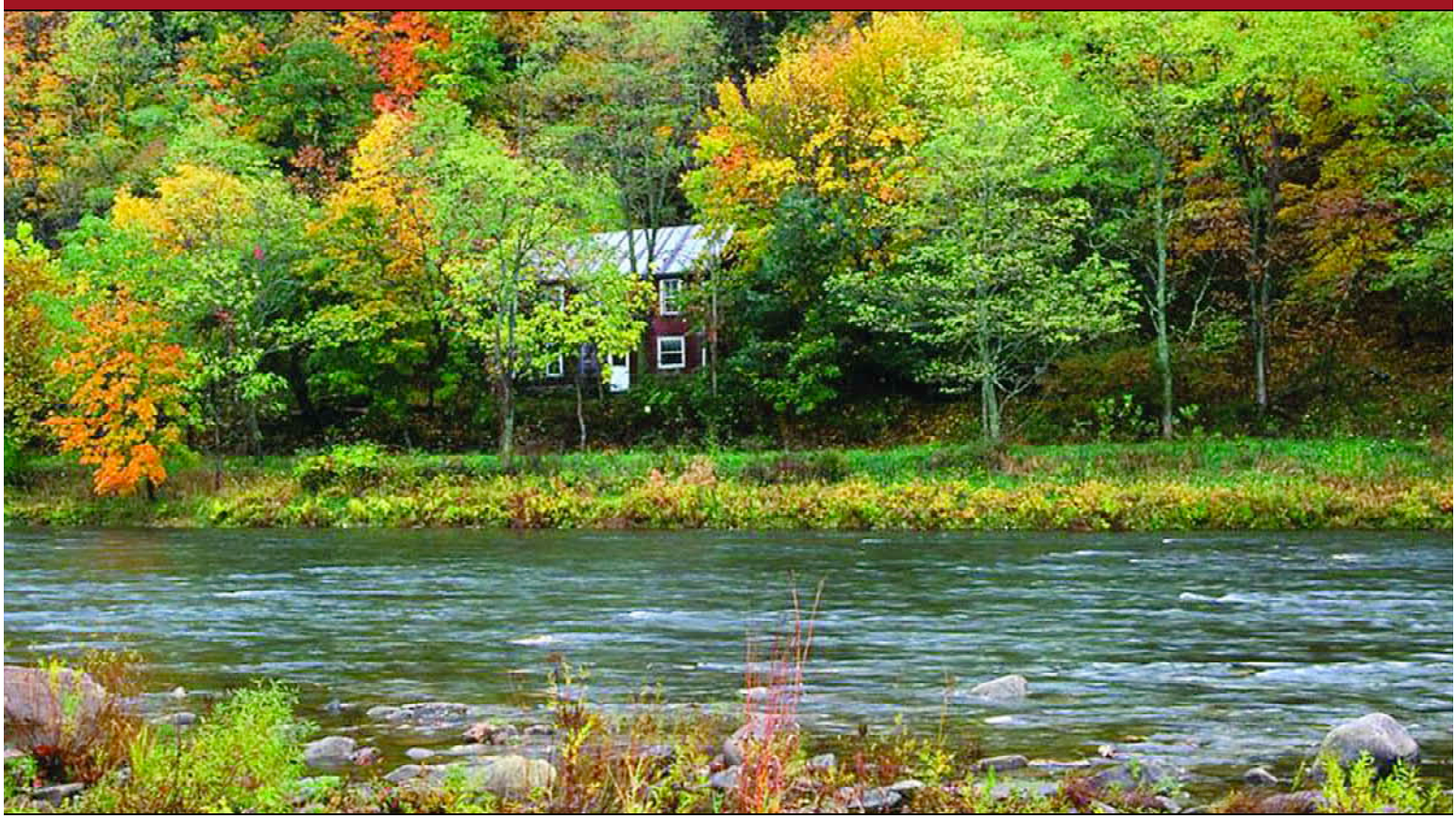
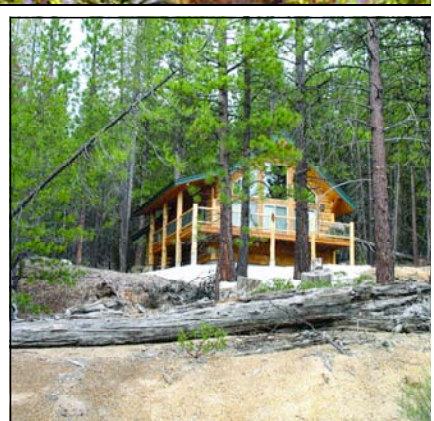
NATIONAL FORESTS ON THE EDGE

DEVELOPMENT PRESSURES ON AMERICA'S NATIONAL FORESTS AND GRASSLANDS





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Susan M. Stein, Ralph J. Alig, Eric M. White, Sara J. Comas, Mary Carr, Mike Eley, Kelly Elverum, Mike O'Donnell, David M. Theobald, Ken Cordell, Jonathan Haber, and Theodore W. Beauvais

ABSTRACT

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Many of America's national forests and grasslands—collectively called the National Forest System—face increased risks and alterations from escalating housing development on private rural lands along their boundaries. National forests and grasslands provide critical social, ecological, and economic benefits to the American public. This study projects future housing density increases on private rural lands at three distances—½, 3, and 10 miles—from the external boundaries of all national forests and grasslands across the conterminous United States. Some 21.7 million acres of rural private lands (about 8 percent of all private lands) located within 10 miles of the National Forest System boundaries are projected to undergo increases in housing density by 2030. Nine national forests are projected to experience increased housing density on at least 25 percent of adjacent private lands at one or more of the distances considered. Thirteen national forests and grasslands are each projected to have more than a half-million acres of adjacent private rural lands experience increased housing density. Such development and accompanying landscape fragmentation pose substantial challenges for the management and conservation of the ecosystem services and amenity resources of National Forest System lands, including access by the public. Research such as this can help planners, managers, and communities consider the impacts of local land use decisions.

Keywords: Land use change, national forest, housing density, road density, ecosystem services, amenity resources, amenity migration, housing development, planning.

AUTHORS

Susan M. Stein is a private forest-land studies coordinator, **Sara J. Comas** is a natural resource specialist, and **Theodore W. Beauvais** is an assistant director, U.S. Department of Agriculture, Forest Service, Cooperative Forestry Staff, Mailstop 1123, 1400 Independence Avenue, SW, Washington, DC 20250-1123. **Ralph J. Alig** is a research forester and team leader, and **Eric M. White** is a research economist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331. **Mary Carr** is a technical publications editor, U.S. Department of Agriculture, Forest Service, Publishing Arts, 1835 Black Lake Boulevard, SW, Olympia, WA 98512. **Mike Eley** is a geographic information system (GIS) coordinator, American Farmland Trust, 1200 18th Street, NW, Washington, DC 20036. **David M. Theobald** is a research scientist, Colorado State University, Natural Resource Ecology Laboratory, Fort Collins, CO 80523-1499. **Kelly Elverum** and **Mike O'Donnell** are GIS analysts, Elverum Mapping Services, 1627 Cedarwood Drive, Fort Collins, CO 80526. **Ken Cordell** is a pioneering research scientist, U.S. Department of Agriculture, Forest Service, Southern Research Station, Forestry Sciences Laboratory, 320 Green Street, Athens, GA 30602-2044. **Jonathan Haber** is a regional conservation planner, U.S. Department of Agriculture, Forest Service, Northern Region, 200 E Broadway, P.O. Box 7669, Missoula, MT 59807.

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INTRODUCTION

America's National Forest System is composed of 155 national forests and 20 national grasslands managed by the U.S. Department of Agriculture, Forest Service. Many of these forests and grasslands are facing increased risks and impacts from escalating housing development on private rural lands along their boundaries. Encompassing about 192 million acres across 44 states, Puerto Rico, and the Virgin Islands, national forests and grasslands account for 8.5 percent of the total U.S. land area and 20 percent of its forest land (USDA Forest Service 2004a) (fig. 1). Nearly a quarter of the U.S. population lives in a county that contains National Forest System land (Johnson and Stewart 2007).

National Forest System lands provide critical social, economic, and ecological benefits to the Nation, including aesthetic and spiritual values, recreation opportunities, fresh drinking water, clean air, timber and other forest products, minerals, oil and gas, livestock grazing, and abundant habitats for fish and wildlife species (see page 4 for examples). These ecosystem services and amenity resources can be altered when new houses are built on private lands within or near forest and grassland boundaries.

The population of the United States is projected to increase by at least 135 million people to approximately 420 million people by 2050 (U.S. Census Bureau 2004), resulting in substantial projected expansion in U.S. developed area (Alig and Plantinga 2004, Alig et al. 2004, Cordell and Overdevest 2001, Macie and Hermansen 2003, Nowak and Walton 2005). Counties with national forests and grasslands already are experiencing some of the highest population growth rates in the Nation as people move near public lands (Garber-Yonts 2004, Johnson and Stewart 2007, USDA Forest Service 2006a). Even **within**

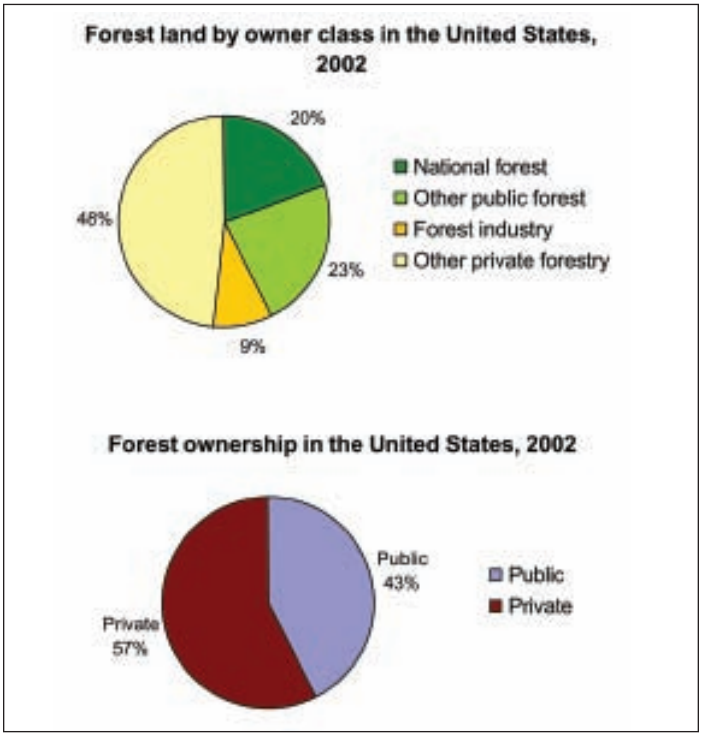


Figure 1—**Who manages America's forests?** National Forest System lands are managed by the U.S. Forest Service and account for about 20 percent of America's forested land. Some 148 million acres of National Forest System lands are forest; about 44 million acres are nonforest. Other forested lands in the country are managed by private landowners (57 percent) or by other public agencies or local governments (23 percent). Source: Smith and Darr (2004).

national forest boundaries, the number of housing units on privately held lands increased from 500,000 to 1.5 million between 1950 and 2000 (Radeloff et al. 2005a).[1]

[1] Nationwide, some 17 percent of all lands located within the boundaries of national forests or grasslands are "inholdings" held by private or other non-Forest-Service landowners (USDA Forest Service 2005b). Inholdings may be managed by other federal agencies; state, county, local, or tribal governments; private individuals; or corporate entities. Inholdings are particularly prevalent in the East, where national forests were established much later than those in the West, often to protect damaged watersheds and restore abandoned farmlands (Shands and Healy 1977); nearly half (46 percent) of the lands located within Eastern national forest boundaries are inholdings (USDA Forest Service 2006a). Western national forests generally have a more consolidated ownership pattern providing larger blocks of public land with fewer inholdings.

Although most National Forest System lands are in the West, national forests along the Appalachian Mountain chain and scattered across other Eastern and Midwestern States are within a day's drive for millions of Americans (USDA Forest Service 2005b). Private lands in the vicinity of national forests and grasslands are becoming developed at an increasing rate across the country.

A third of all federally listed threatened or endangered species currently occur on National Forest System lands or are potentially affected by national forest and grassland management (Bosch 2006). Photos courtesy of U.S. Fish and Wildlife Service.

Examples of benefits and resources associated with management objectives on National Forest System lands

National forest/grassland objective[a]	Benefits and resources
Maintain national forests for future generations (93.5)[b]	All those listed below
Protect streams and other sources of clean water (94.9)	The largest single source of fresh water in the U.S., providing 14 percent of the country's water runoff and high-quality water valued at $3.7 billion per year[c]
Provide habitat for wildlife and fish (89.2) Protect rare plant or animal species (86)	Wildlife and fish habitats for numerous species, including a third of all federally listed threatened or endangered species[d]
Manage national forest areas to leave them natural looking (86.8) Provide quiet, natural places for personal renewal (75.8)	Special areas, such as wilderness, research natural areas, national scenic areas, and national monuments
Emphasize planning and management for timber (79.1)	2 billion board feet of timber in a single year, valued at $224 million[e]
Provide recreation access, facilities, and services (74.5)	205 million recreation visits annually; 4,300 campgrounds with 122,000 camp sites; 135 alpine ski areas; 4,418 miles of wild and scenic rivers; 133,087 miles of hiking trails[f]
Provide roads, services, accommodations to support local tourism businesses (57.0)	$7.5 billion annually in direct spending in local economies resulting from recreation visits to national forests[f]

[a] Identified in Tarrant et al. (2003) as "assets."
[b] Numbers in parentheses represent the percentage of the public responding to a survey (Tarrant et al. 2003) who said they considered this management objective ("asset") important.
[c] Dissmeyer 2000, USDA Forest Service 2000b.
[d] Bosch 2006.
[e] USDA Forest Service 2005a.
[f] USDA Forest Service 2004b.

National Forests on the Edge is the second analysis conducted by the Forests on the Edge project sponsored by the Forest Service, State and Private Forestry, Cooperative Forestry staff. This report identifies national forests and grasslands across the conterminous United States most likely to be affected by increased housing density on rural private lands outside the external boundaries[2] of National Forest System lands. It also discusses how this type of development may affect national forests and grasslands; similar effects might logically be expected to confront other local, state, and federal public lands. These findings and discussions should prove useful as tools to facilitate decisionmaking about future land use options.

About Forests on the Edge

Sponsored by the U.S. Forest Service, State and Private Forestry, Cooperative Forestry staff, the Forests on the Edge project identifies areas across the country where public and private forests might change because of housing development and other factors. The project focuses on lands that currently are rural and becoming more developed. Development on rural lands is often overlooked because it may not be as visible as higher density development found closer to urban centers. The project's first report (Stein et al. 2005a) identified watersheds across the conterminous United States containing substantial amounts of private forest projected to experience increased housing densities by 2030. In total, more than 44 million acres of private forests were projected to experience increased housing density by 2030.

IDENTIFYING NATIONAL FORESTS AND GRASSLANDS ON THE EDGE

This study focuses on national forests and grasslands in the conterminous United States that might experience change owing to increased housing development on private rural lands along their boundaries. Data necessary to prepare nationally consistent housing density forecasts for lands bordering national forests in Alaska and Puerto Rico are not adequate at this time, and there are no national forests in Hawaii.

[2] "External boundary" refers to the perimeter boundaries of a national forest or grassland. In some cases, this boundary is also referred to as a "proclamation" boundary, or the outer boundary within which Congress authorized a particular national forest to be established. "Internal boundaries" are those boundaries located within the external boundaries that distinguish National Forest System lands from other lands (often referred to as inholdings). The National Forests on the Edge analysis focuses on development on private rural lands outside the national forest or grassland external boundaries.

The analysis ranks individual national forests and grasslands according to the percentage and total area of private lands (including both forest and nonforest vegetation types) adjacent to each that are now rural and are projected to experience increased housing density.

These projections of housing density increases were limited to private lands outside national forest and grassland external boundaries (fig. 2). Although private lands also may be located within the external boundaries, it was not possible to make nationwide estimates for such "internal" private lands because no nationally consistent data were available at the time of this study.

Three distances from external boundaries were chosen—0 to ½ mile, ½ to 3 miles, and 3 to 10 miles. In selecting these distances, it was assumed that changes to national forest and grassland benefits will differ depending on how close development activity is to the boundary. A literature review was conducted to identify several distances as broad indicators within which housing density increases can affect national forest functions and values. Relevant distances were found to differ widely, depending on the type of impact being studied. The distances selected for this study correspond to those routinely used by recreation managers to identify areas where visitor experiences can be affected by the sounds and sights of development.

Distances for Recreation Planning

Research-based distances form the core of the Recreation Opportunity Spectrum (ROS), which is widely used by federal agencies and a number of state agencies in recreation planning. For example, ROS remoteness criteria were used for the Forest Service's Forest and Rangeland Assessment to inventory land available for outdoor recreation at three distances from roads—0 to ½ mile, ½ to 3 miles, and beyond 3 miles (Cordell et al. 1990). Similar applications have been used by federal and state agencies to classify primitive recreation settings that lie beyond 3 miles of roads, semiprimitive settings from ½ to 3 miles from roads, and more accessible settings closer to development and within ½ mile of roads.

Terry Tollefsbol

Grizzly bears have been reported to be sensitive to road densities as low as 1 to 2 miles of road per square mile of land (Mace et al. 1996).

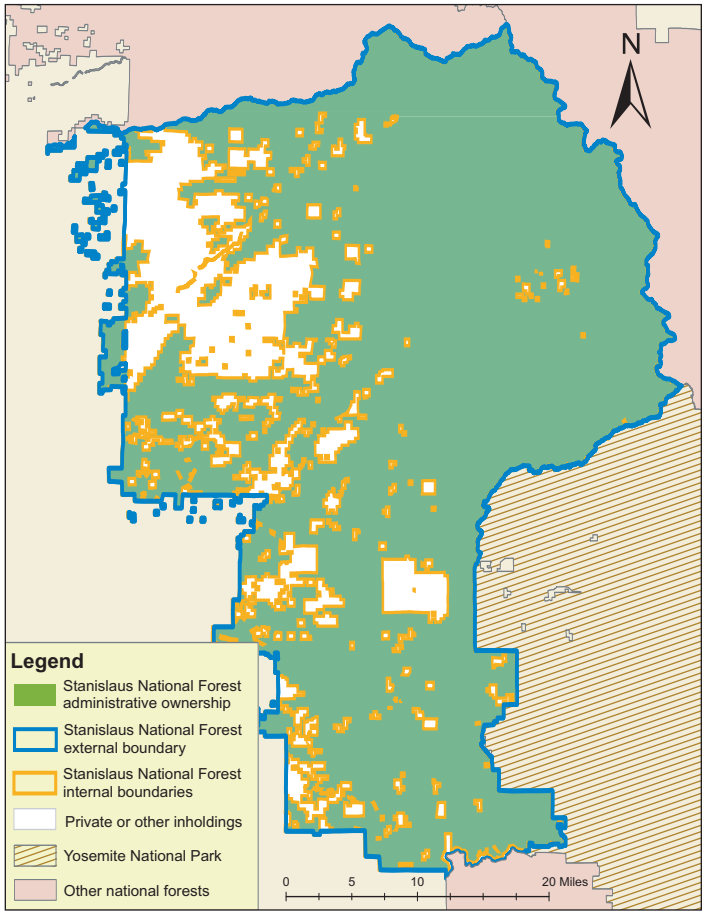


Figure 2—Internal and external boundaries for the Stanislaus National Forest, California.

How Housing Density Projections Were Made

Housing density projections in this study focus on increased housing densities on lands that are currently rural. The projections are based on past and current statistics on housing density and population, road density data, past growth patterns, proximity to urban areas, and other factors (see "Appendix" for details; see also Stein et al. 2005b, Theobald 2005). Housing density projections are based on human population estimates of 276 million for the year 2000 (U.S. Census Bureau 2001a) and 385 million for the year 2030 (NPA Data Services, Inc. 2003).

To facilitate description of estimated changes, three housing density categories were defined:[3]

- **Rural I**—Lands with 16 or fewer housing units per square mile.
- **Rural II**—Lands with 17 to 64 housing units per square mile.
- **Exurban/urban**—Lands with 65 or more housing units per square mile.

[3] These housing density categories are identical to those used in the first *Forests on the Edge* report (Stein et al. 2005a, 2005b), but the names of the categories have been changed.

Increased housing density was defined to mean increased number of housing units per unit area on lands defined here as rural I or rural II, such that the housing density would shift to a higher level category.

Because this study focuses on areas where the 2000 housing density was 64 or fewer units per square mile, housing density increases for private lands already above this housing density level are not reflected in this analysis. Similarly, many national forests surrounded by housing densities greater than 64 units per square mile also may not be highlighted in this study because they have too little surrounding rural land that would change to a higher category.

Private land refers to all lands not identified as "public" (under federal, state, or local government management).

Urban National Forests

A number of national forests and grasslands located in the conterminous United States and Puerto Rico have been designated as "urban national forests" based on their proximity to large urban centers. An urban national forest is defined as one within an hour's driving distance of a million or more people (USDA Forest Service 2003b). Owing to the presence of large urban areas, the densities of residential development around many of these urban national forests may already be higher than the rural densities that are the focus of this report, so further changes in housing densities near these urban national forests may not be represented in this study. However, these forests are likely facing many of the same management challenges as those forests where rural residential development is projected to increase.

How This Analysis Was Conducted

The analysis quantifies and displays the extent of projected increases in housing density on rural lands located near National Forest System lands throughout the conterminous United States.

Each national forest or grassland consists of numerous, often disconnected parcels (see "Appendix" for details). Three basic steps were completed to estimate increases in housing densities on private lands surrounding these parcels:

- **Step 1**—For each of the three distances, we determined the area of private land surrounding each national forest or grassland parcel that is currently under each of the three housing density categories (rural I, rural II, or exurban/urban).
- **Step 2**—For each of the three distances, we determined the area of private land now classified as rural I or rural II that is estimated to experience housing density increases between 2000 and 2030, such that the housing density would change to a higher density category.
- **Step 3**—We determined the total area and percentage of private land around each national forest and grassland estimated to experience increased housing density within each of the distances studied.

Metropolitan Design Center Image Bank, © University of Minnesota

It's a familiar and accelerating trend—new houses with large individual lots scattered across a rural landscape. Dispersed low-density housing can create disproportionately high ecological and economic impacts **per housing unit** because each rural residence occupies more land area than an urban residence (Lubowski et al. 2006, Radeloff et al. 2005b, Theobald 2005, USDA Forest Service 2006a) and because desirable home sites often lie in environmentally sensitive places such as shorelines, riparian areas, or wildlife winter ranges (Johnson and Beale 2002, USDA Forest Service 2006a).

Table 1—Percentage and area of private land at four distances from national forest and grassland boundaries nationwide projected to experience housing growth, 2000 to 2030

Distance from boundary	Amount of private rural land projected to experience housing density increase	
Miles	*Percent*[a]	*Million acres*[b]
0 to 0.5	7	1.5
0.5 to 3	7	6.2
3 to 10	8	14.1
0 to 10	8	21.7

[a] Percentage of **all** private lands (rural and nonrural) within the respective distances.

[b] Area of **rural** private lands within the respective distances.

The resulting figures give an estimate of the magnitude of land area within each distance from National Forest System lands in the conterminous United States projected to experience increased housing density. As with any national assessment, our estimates may not completely capture changes in housing density at all local levels.

KEY FINDINGS

This study estimates that between 2000 and 2030, a substantial increase in housing density will occur on more than 21.7 million acres of rural private land (8 percent of all private land) located within 10 miles of national forests and grasslands across the conterminous United States (table 1). The percentages of private land area projected to experience increases in residential development are consistent across the three distances considered—7 percent for the 0-to-½-mile and ½-to-3-mile distances and 8 percent for the 3-to-10-mile distance.

Individual national forests projected to experience the greatest increases in residential development on private lands within 10 miles of forest boundaries are located throughout the conterminous United States (fig. 3). In the East, almost all national forests are projected to experience moderate or high increases in residential development. In the West, moderate and high increases in residential development are projected around national forests located in Colorado, California, Oregon, Idaho, and Montana. We project the nine national forests most affected could see increased housing development on at least 25 percent of the private lands within one or more of the three distances studied (table 2). Three of these national forests are in the West and the other six are located in the East. Overall, the range in

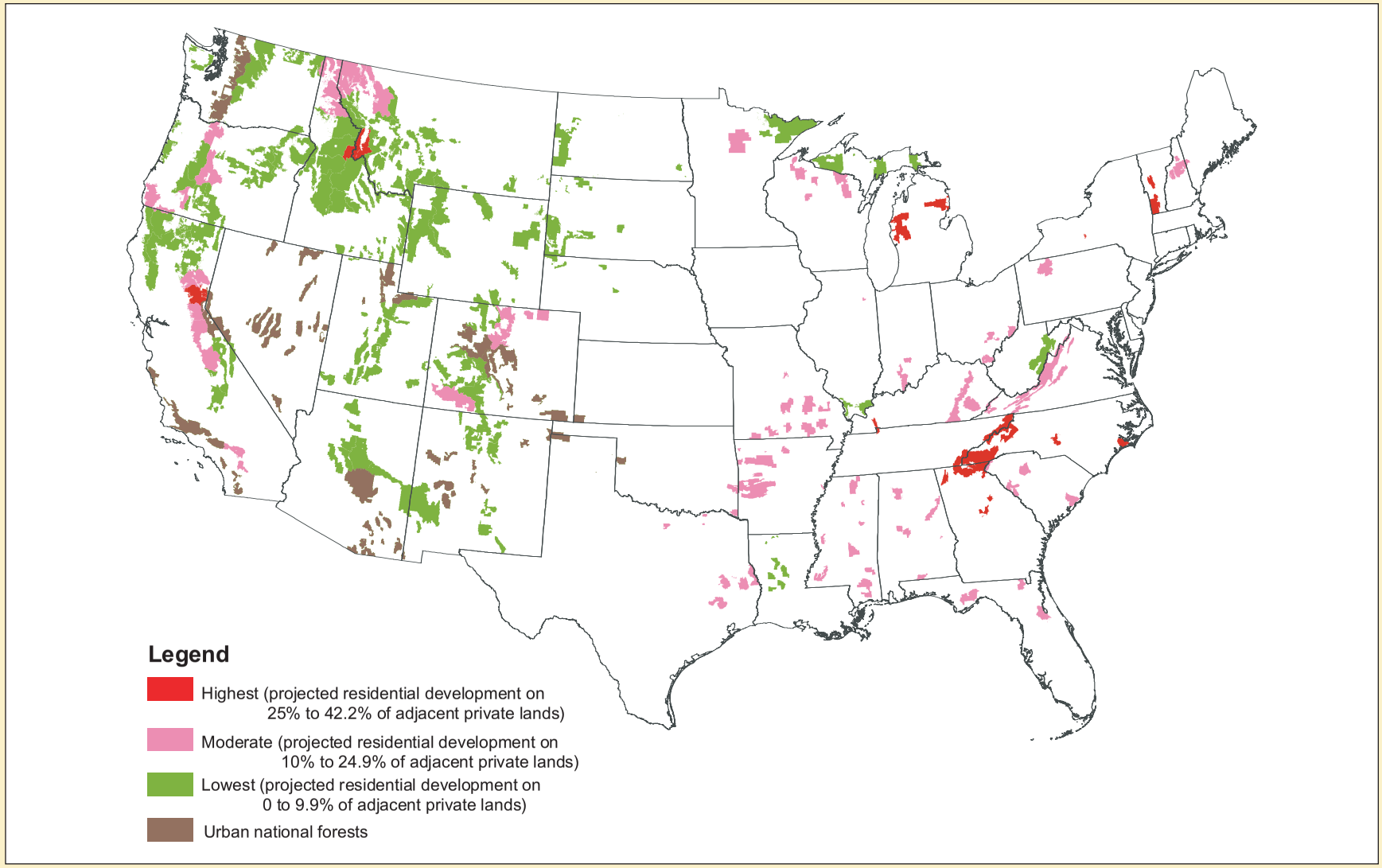


Figure 3—National Forest System lands with private lands within 10 miles projected to experience increased housing density, 2000–2030. Areas shown in brown are designated "urban national forests" (USDA Forest Service 2003b) that were not identified in this study as likely to experience significant increases in rural residential development. Housing densities near the borders of these forests may already be higher than the rural densities that are the focus of this report. Those urban national forests that do register high or moderate change in figure 3 include the Arapaho-Roosevelt, San Bernardino, Eldorado, Mount Hood, Chattahoochee-Oconee, Cherokee, and White Mountain National Forests; the National Forests of Florida; and the Midewin National Tallgrass Prairie. These urban national forests are surrounded by sufficient quantities of rural land projected to change to higher residential densities.

Table 2—National Forest System (NFS) lands with at least 25 percent of adjacent private land (at one or more distances) projected to experience housing growth by 2030

National forests and grasslands	State	Percentage[a] of adjacent private land projected to experience housing density increase[b]			
		Distance from NFS boundary (miles)			
		(0 to 0.5)	(0.5 to 3)	(3 to 10)	(0 to 10)
Western United States					
Bitterroot National Forest	Idaho, Montana	**33**	**42**	**50**	**42**
Tahoe National Forest	California	18	24	**29**	**26**
Plumas National Forest	California	**25**	24	24	24
Eastern United States					
Chattahoochee-Oconee National Forest	Georgia	**31**	**35**	**35**	**35**
Cherokee National Forest	Tennessee	**30**	**36**	**31**	**32**
National Forests in North Carolina[c]	North Carolina	**26**	**29**	**30**	**30**
Huron-Manistee National Forest	Michigan	**31**	**32**	**26**	**28**
Land Between the Lakes National Recreation Area	Kentucky, Tennessee	5	23	**31**	**28**
Green Mountain and Finger Lakes National Forests	Vermont, New York	**28**	**31**	**25**	**27**

[a] Percentage of all private lands (rural and nonrural) within the respective distances.

[b] Percentages of 25 percent or higher are highlighted red.

[c] Croatan, Uwharrie, Pisgah, and Nantahala National Forests.

percentages of housing density increases for these nine national forests is from 5 percent to 50 percent across all the distances. The Bitterroot National Forest in Idaho and Montana ranks highest in the Nation, with projected housing density increases occurring on 42 percent of the private lands within 10 miles of the forest boundary. The greatest percentage increases on the Bitterroot National Forest are projected to occur in the 3-to-10-mile category.

The percentage of adjacent private lands projected to experience housing density increases does not necessarily become higher with distance from the national forests. For example, the Cherokee National Forest and the Huron-Manistee National Forest have their highest percentages (36 and 32 percent, respectively) at the distance of ½ to 3 miles from their external boundaries, whereas the Plumas National Forest is projected to experience the highest increases in residential housing density at the 0-to-½-mile distance.

The study also ranked National Forest System lands according to the total **area** of adjacent private lands projected to experience increased housing density. Thirteen national forests or grasslands are each adjacent to more than 500 thousand rural acres projected to experience housing increases. As displayed in table 3, ten of these forests or grasslands are found in the South. This finding is not surprising given that (a) many of our southern national forests are surrounded by private lands (in part because the National Forest System lands in the South tend to be smaller, separated parcels); and (b) the South is experiencing the highest rate of urban development in the country (Alig et al. 2004, Macie and Hermansen 2003) (fig. 4). The George Washington-Jefferson National Forest in Virginia and West Virginia is projected to have the most area of increases in housing density of all national forests or grasslands, with projected changes on more than 1.4 million adjacent private rural acres. The Mark Twain National Forest in Missouri stands out among the midwestern forests with more than 1.3 million acres of adjacent rural lands projected to experience an increase in housing density.

Table 3—National Forest System lands with over 500,000 acres of adjacent rural private land (within 10 miles) projected to experience increased housing by 2030

National forest or grassland[a]	Main state	Adjacent rural private land projected to experience housing density increases
		Thousand acres
George Washington-Jefferson	Virginia	1,424
Mark Twain	Missouri	1,326
Chattahoochee-Oconee	Georgia	1,176
National Forests in North Carolina[b]	North Carolina	1,073
National Forests in Mississippi[c]	Mississippi	1,071
National Forests in Alabama[d]	Alabama	963
Huron-Manistee	Michigan	834
Francis Marion-Sumter	South Carolina	720
Ozark-St. Francis	Arkansas	702
Daniel Boone	Kentucky	650
National Forests in Texas[e]	Texas	596
Green Mountain and Finger Lakes	Vermont, New York	590
Cherokee	Tennessee	544

[a] Figures reported for individual national forests in this table should not be combined because of the potential for double counting of residential development around national forests that are close to each other.

[b] Croatan, Uwharrie, Pisgah, and Nantahala National Forests.

[c] Bienville, Chickasawhay, Delta, Desoto, Holly Springs, Homochitto, and Tombigbee National Forests.

[d] Bankhead, Conecuh, Talladega, and Tuskegee National Forests.

[e] Angelina, Davy Crockett, Sabine, and Sam Houston National Forests.

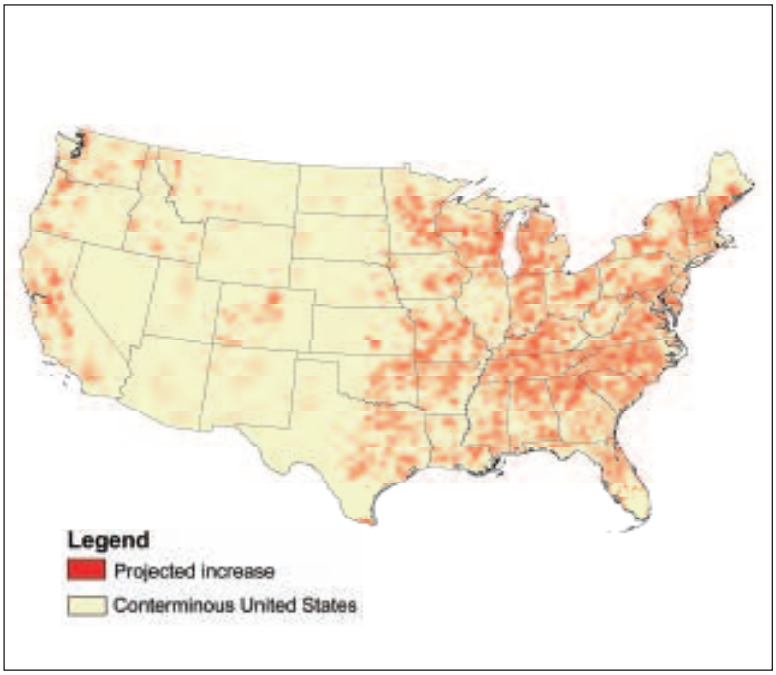


Figure 4—A broader perspective. Across the conterminous United States, approximately 1.4 billion acres of all lands are privately owned. Of these, some 153 million acres (about 10 percent) are projected to experience increased housing density in rural I and rural II areas in coming decades (regardless of their proximity to national forests or grasslands), mostly in the eastern half of the country (Theobald 2004a, 2004b). These national-level figures for all private lands may under- or overstate the situation for specific rural areas where housing development could be more or less intense.

Larry Korhnak

About the movement of people to rural areas.

National Forests on the Edge findings are consistent with recent studies on rural population change in America. Since the 1990s, there has been a substantial trend toward increased population growth in many rural counties, especially those with federal lands and abundant natural amenities (Garber-Yonts 2004; Hammer et al. 2004; Johnson 1999, 2006; Johnson and Beale 1999, 2002; Johnson and Stewart 2005, 2007; Johnson et al. 2005).

Population growth in rural ("nonmetropolitan") counties containing national forests has been consistently higher than in other rural counties over each of the past three decades (Johnson and Stewart 2007). Between 1990 and 2000, nonmetropolitan counties with more than 10 percent of the land in national forest grew by 18 percent —considerably higher than the growth rate in other nonmetropolitan counties (10.8 percent). Cordell and Overdevest (2001) further showed that population growth was particularly acute in counties near national forests in the southern Appalachians, northern New Mexico, southern California, and southeastern Idaho.

Many of the national forests and grasslands projected in this study to experience the highest levels of increased housing density near their boundaries fall within areas identified by Johnson and Beale (1999) as having had the highest recent rural population growth.

This type of lakeshore in northern Minnesota attracts second-home development, potentially affecting water quality and resulting in loss of wetland habitat.

A CLOSER LOOK: FUTURE HOUSING DEVELOPMENT AROUND FOUR NATIONAL FORESTS

Four examples from different regions illustrate how the projected 2030 housing densities (Theobald 2004b) compare to 2000 housing densities (Theobald 2004a) at the local level. Note that internal boundaries were used for these local analyses because adequate geographic information system information was available for these forests. Thus, the maps presented here (figs. 5–8), unlike our national-level maps, do include private inholdings.

On a subzero January morning, a group of elk makes its way over the snowy grassland/sagebrush winter range overlooking the Bitterroot Valley, Montana. Photo by John Vore, courtesy of Montana Department of Fish, Wildlife and Parks.

Bitterroot National Forest, Montana and Idaho

The percentage of private land projected to experience increases in housing density within 10 miles of the Bitterroot National Forest is greater than for any other national forest or grassland (table 2, fig. 5). The northernmost portion of this forest lies along either side of the Bitterroot Valley, in rapidly growing Ravalli County, Montana. One concern related to residential development within the Bitterroot Valley is its potential impact on elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) populations that seasonally inhabit the Bitterroot National Forest. Many areas of elk and mule deer winter range coincide with areas projected to experience substantial increases in the level of housing development. Increased housing density could potentially reduce the availability of winter habitat and browse, serve as impediments to habitat connectivity, and lead to increases in human/wildlife conflicts.

Stanislaus National Forest, California

The Stanislaus National Forest is located in east-central California, extending from the foothills to the crest of the Sierra Nevada. The national forest is bordered to the south by Yosemite National Park and to the east and north by the Humboldt-Toiyabe National Forest and the Eldorado National Forest, respectively. Given this pattern of federal ownership, private residential development is constrained to areas along the western boundary of the Stanislaus National Forest and along

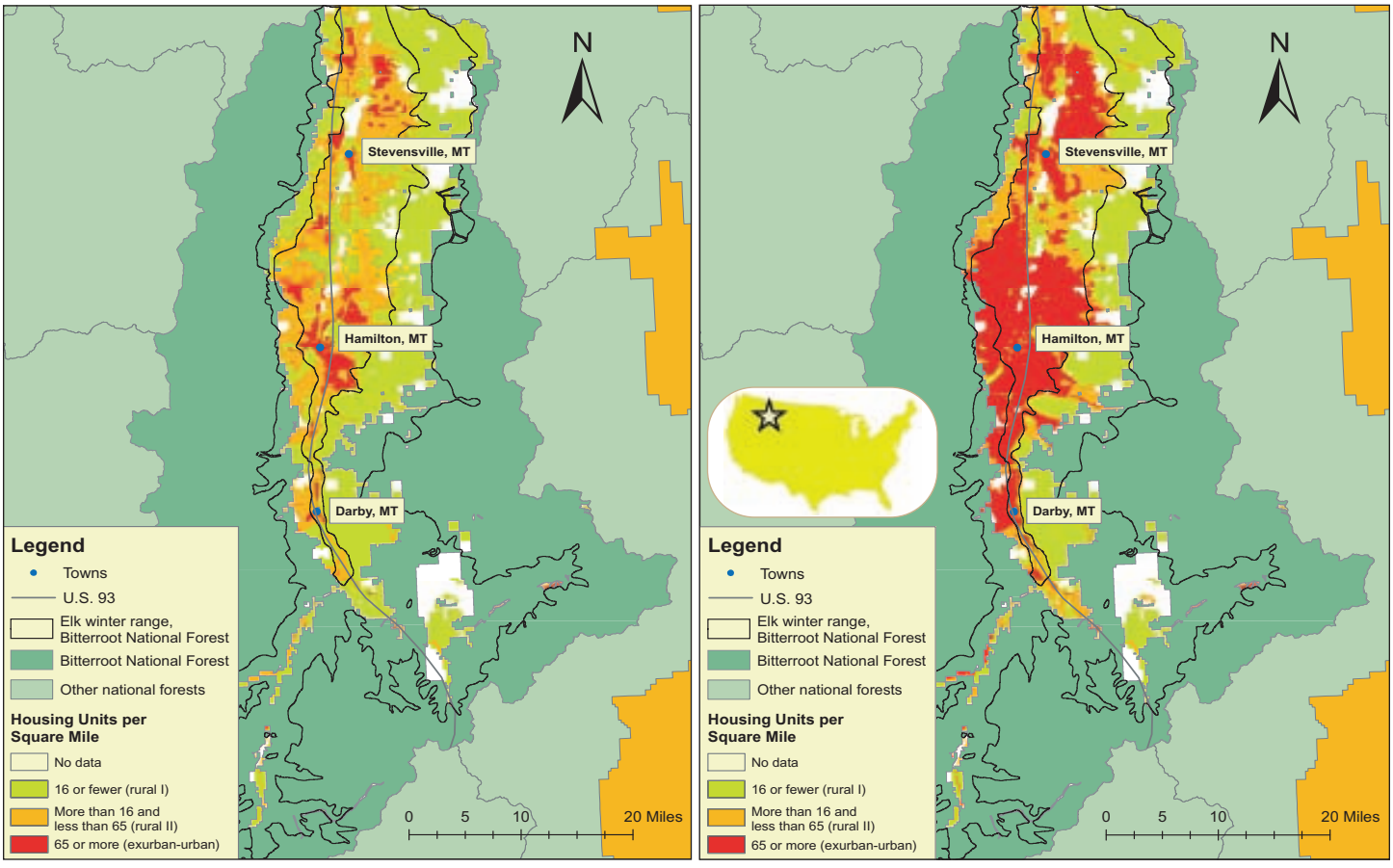


Figure 5—Housing density in the Bitterroot Valley, Montana/Idaho, 2000 and 2030. Source: Theobald 2004a, 2004b.

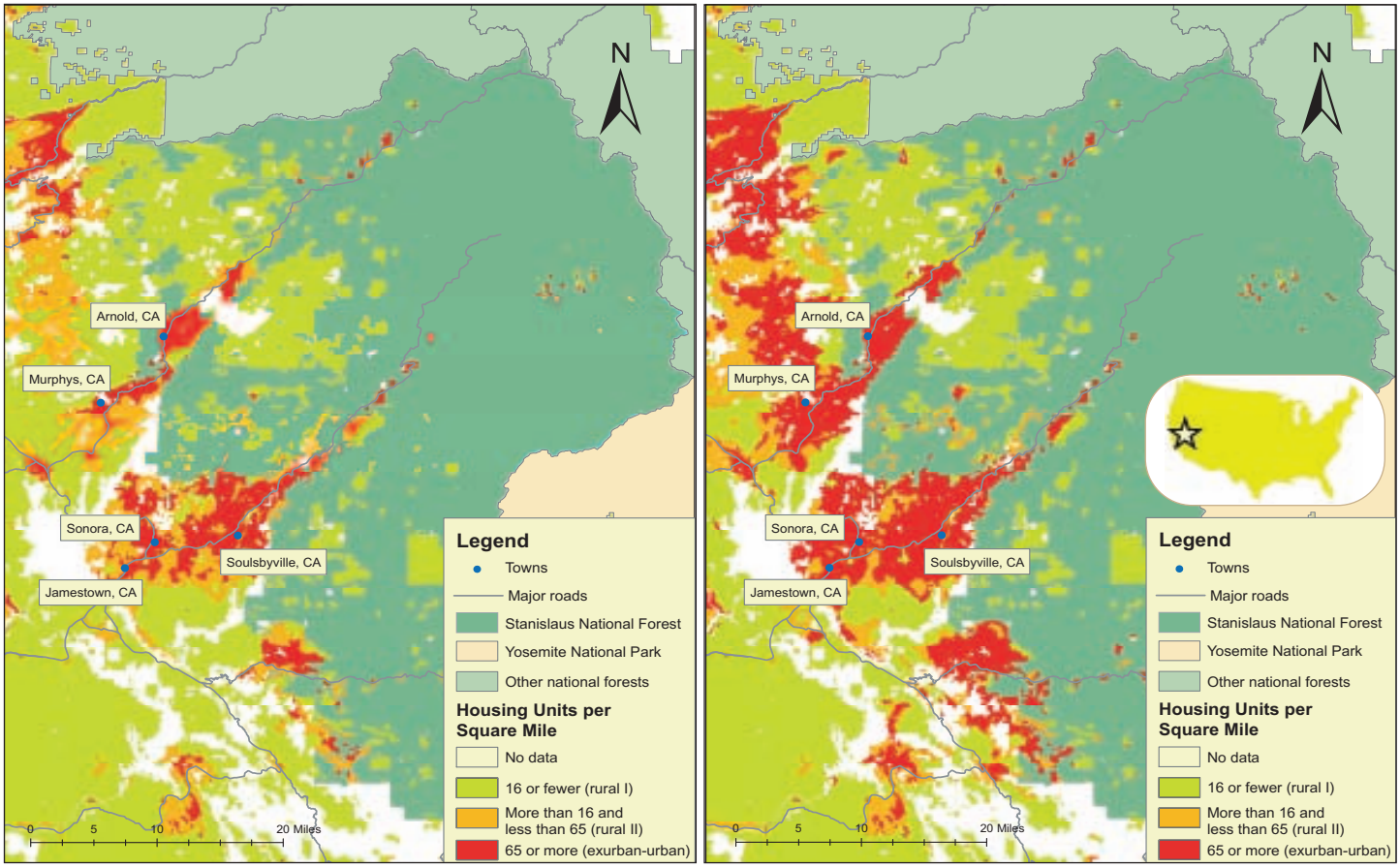


Figure 6—Housing density near the Stanislaus National Forest, 2000 and 2030. Source: Theobald 2004a, 2004b.

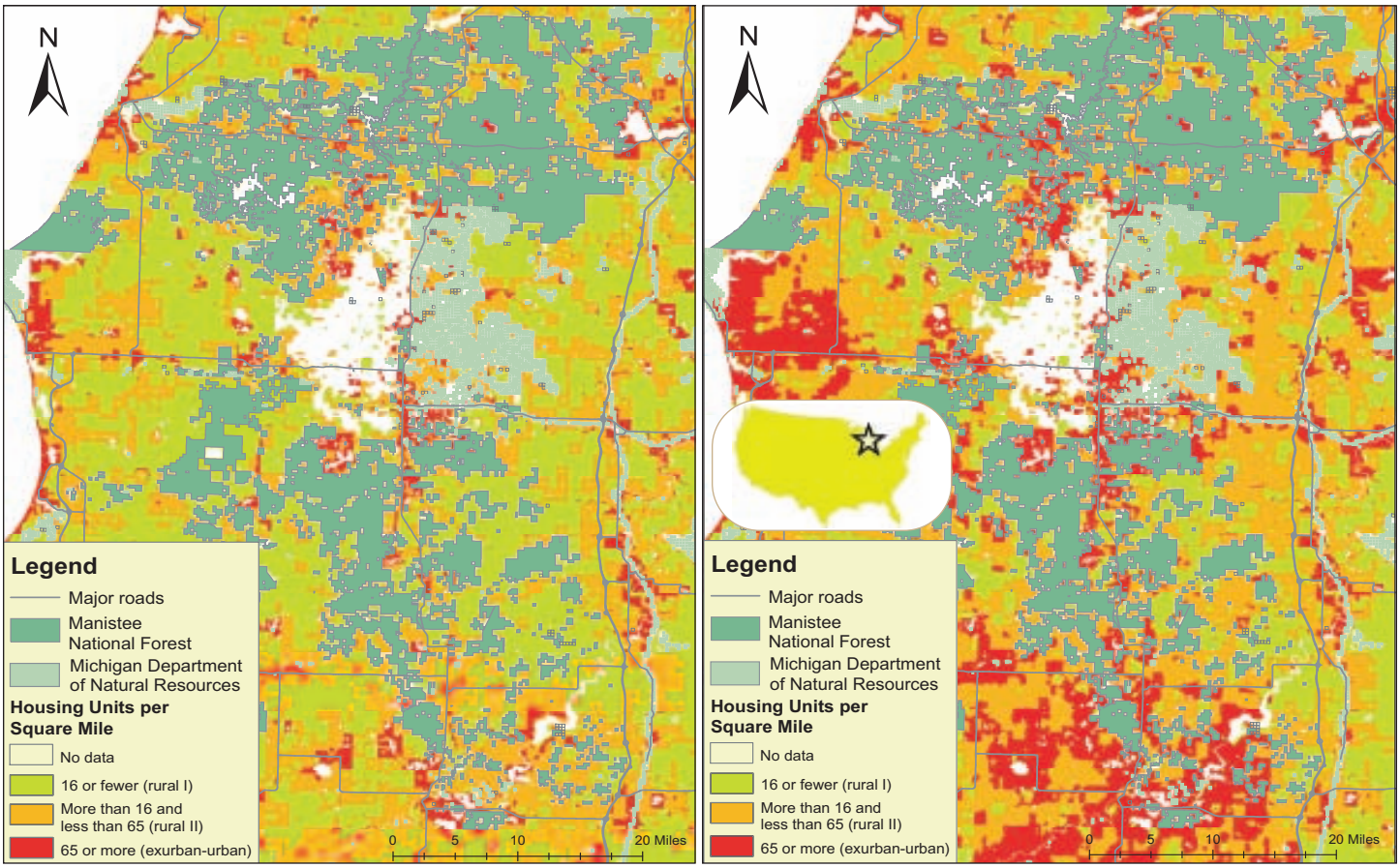


Figure 7—Housing density near the Manistee portion of the Huron-Manistee National Forest, 2000 and 2030. Source: Theobald 2004a, 2004b.

Continue

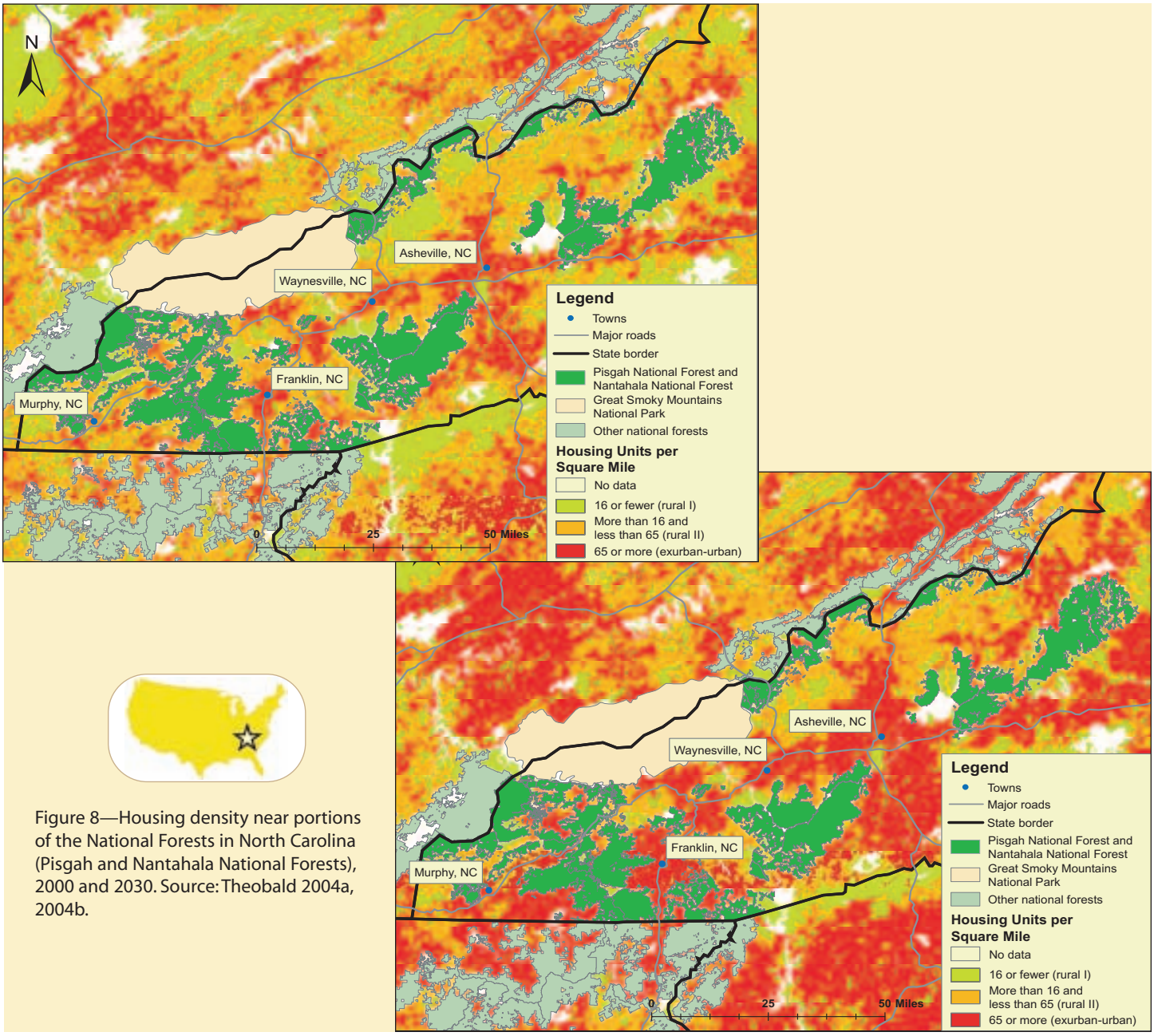


Figure 8—Housing density near portions of the National Forests in North Carolina (Pisgah and Nantahala National Forests), 2000 and 2030. Source: Theobald 2004a, 2004b.

interior travel corridors. Currently, many of the private lands immediately adjacent to the Stanislaus boundary already have housing densities greater than 64 units per square mile, in the exurban/urban category (fig. 6). Consequently, most of the projected increases in rural housing unit density would occur several miles from the national forest boundary. One exception to this general pattern is projected increases in housing density development to the exurban/urban category on currently rural lands that are adjacent to the southwestern boundary of the Stanislaus. Recreation management issues identified for this forest are likely to increase with continued development. These issues include the establishment of user-created trail systems and a decline in availability and quality of recreational opportunities (USDA Forest Service 2003a).

Huron-Manistee National Forest, Michigan

The Manistee portion of the Huron-Manistee National Forest lies in the northwestern portion of the lower peninsula of Michigan. Compared to the Bitterroot and the Stanislaus National Forests, the ownership of the Huron-Manistee National Forest (particularly within the Manistee portion) is unconsolidated, consisting of a few large blocks and many smaller blocks of noncontiguous federal lands. The result is significant intermixing of privately owned lands and federally managed lands. Currently, many areas immediately adjacent to National Forest System lands have rural I and rural II housing densities (fig. 7). However, projections of housing density for 2030 indicate substantial expansion in the extent of rural II and exurban/urban housing density in nearly all privately owned areas immediately adjacent to national forest parcels. Development-related issues

on the Huron-Manistee include user conflicts and the loss of public access (USDA Forest Service 2006c); these issues are likely to increase with additional development near the boundaries.

National Forests in North Carolina

The Nantahala and the Pisgah National Forests are both located in western North Carolina, near the Great Smoky Mountains National Park and the Blue Ridge Parkway. Both forests fall within the broader administrative unit known as the National Forests in North Carolina. The federal lands managed by these two forests are located in a number of separate blocks of noncontiguous ownership. Currently, most areas immediately beyond the boundaries of these national forests have housing densities categorized as rural II, although some areas of exurban/urban housing density do currently occur adjacent to National Forest System lands around Asheville and Franklin. Projections of 2030 housing density indicate significant increases adjacent to the national forest boundaries (table 2, fig. 8), particularly in the southern and central portions of the area. Lesser increases are projected near National Forest System land in the northeastern portion of the area considered here.

IMPLICATIONS

Increased development and accompanying landscape alteration on private rural lands adjacent to national forests and grasslands will have significant implications for the management and conservation of public land resources, ecological services and products, and social and cultural amenities (Johnson and Stewart 2007, Radeloff et al. 2005a, REO 2002). The following examples are among the specific consequences that may be associated with increased housing density on the peripheries of National Forest System lands.

Impacts on Native Fish and Wildlife Habitats and Populations

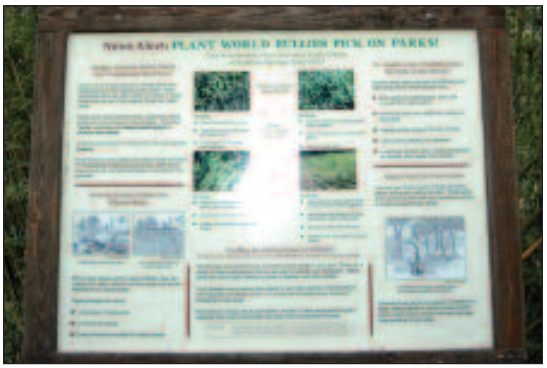
Wildlife populations on public lands—especially threatened and endangered species—can be at heightened risk from several factors associated with increased housing development on nearby private rural lands (Bass and Beamish 2006, Danielson et al. 1997, Deem et al. 2001, Ewing et al. 2005, Lepczyk et al. 2003, Manolis et al. 2002, Radeloff et al. 2005a, Riitters et al. 2002, Riley et al. 2003, Servheen 2006, Singleton et al. 2002). For example, wildlife may be excluded from usable habitats outside the national forest or grassland boundary or be otherwise affected by the fragmentation (Butler et al. 2004, Plantinga et al. 2007), degradation, or loss of those habitats. Wildlife also may suffer higher levels of mortality or displacement from increased traffic on both national forest and public roads (Jacobson 2006). They may experience disturbance or changes in behavior caused by the presence of people, roads, noise, or light; and they may be preyed upon by pets or other predators attracted to newly opened forest edges. Housing developments and associated roads may prevent wildlife from migrating or moving through areas outside forest boundaries and thus affect species that rely on a variety of ecosystems or large areas to survive. Migratory fish that spawn in National Forest System streams also can be affected by changes in water quality associated with development.

Research indicates that roads with moderate traffic volume have the highest rates of wildlife mortality, whereas roads with higher traffic volumes present the greatest barriers to wildlife movement. Traffic volumes are increasing to these critical levels on highways both on and off public lands, with large increases in areas with rapid development near national forests and other public lands (Jacobson 2006).

Impacts From Invasive Plant Species

The health of national forest and grassland ecosystems can be affected by invasive plant species, which can find new points of entry into National Forest System lands through adjacent fragmented lands, new roads, and recreation trails (Dickens et al. 2005, Holway 2005, Sieg et al. 2005, Yates et al. 2004). Invasives can compete with and replace native plants, reduce plant diversity, and cause other disruptions to ecosystem function. Diseases and insects can be introduced into wildland protected areas by nursery plants used in nearby landscaping; for example, widely used rhododendron (*Rhododendron* spp.) and camellia (*Camellia* spp.) plants can be hosts to the pathogen that causes sudden oak death in native oak (*Quercus* spp.) trees (Koch and Coulston, in press).

Remnant sagebrush stand on the west side of the Bitterroot Valley, Montana, where abundant native sagebrush communities once played host to a variety of birds, butterflies, and other wildlife both on and off the nearby Bitterroot National Forest. Today most Bitterroot sagebrush communities are gone; remaining sagebrush stands are threatened by development activity and competition from plants used for livestock forage (Daniel 2006).



Larry Korhnak

Impacts on Recreation Access and Management

Access for the general public to national forests and grasslands is a growing concern. In 1999 it was reported that about 14 percent of National Forest System land had limited public access and that managers were seeing significant reductions in access on many national forests (Peterson and Williams 1999). Housing development may lead to additional decreases in access to public lands, especially national forests, for recreation and other uses if roads on or across adjacent private lands are closed to the general public when new residents move in. Such restrictions may shift recreational use to other locations on National Forest System lands that do not have adequate infrastructure for increased recreation. Alternatively, increased housing development near National Forest System lands could lead to proliferating entry points, easier access, and increased usage of recreation services on National Forest System lands (Johnson and Stewart 2007), with accompanying challenges for effective recreation management. Unmanaged recreation has been cited by the Chief of the Forest Service as one of the top four threats to the Nation's forests (USDA Forest Service 2006b).

Anita Morzillo

Nationally, more than 50 percent of recreation use comes from those living within 30 straight-line miles of a national forest boundary (Stynes and White 2005). Public lands may become used even more heavily as nearby private lands become developed (USDA Forest Service 2006a).

Increased housing development near forest boundaries can lead to additional damage from unmanaged recreation, such as this bank erosion caused by off-highway vehicles on the Arapaho-Roosevelt National Forest.

Larry Korhnak

National forests and grasslands provide vital recreational opportunities for the American public.

Impacts on Fire Management

Potential for wildland fires is higher along the boundaries of forests where the human population has grown significantly (GAO 1999). Increased numbers of houses and people can be associated with more frequent ignitions (Cardille et al. 2001; Prestemon and Butry, in press; Radeloff et al. 2005b), especially in the Eastern United States, where nearly three-quarters of the area burned in wildland fires in federal forests from 1986 to 1996 were caused by human-related ignition sources (Prestemon and Butry, in press). Increased housing density can also be accompanied by an increase in air pollution, which has been shown to increase susceptibility of a forest to wildfire (Grulke et al., in press). A proliferation of houses increases the number of structures needing protection, complicates public land fire management and suppression, and drives up management costs (DellaSala et al. 2004, Grace and Wade 2000, Heuberger and Putz 2003, Podur et al. 2002, Radeloff et al. 2005b, Russel and McBride 2003).

Kari Greer, National Interagency Fire Center

Some 60 percent of all housing units built in the 1990s in the United States were constructed within the wildland-urban interface (Alig et al., in press, Radeloff et al. 2005b). Such houses can require intensive resources to protect them from wildland fire.

Paul Ryan, J.N. "Ding" Darling National Wildlife Refuge

A recent study of patterns of wildfire occurrence in Alabama found that most wildfires occurred in counties with population sizes between 10,000 and 63,000 or total road length (interstate highway, U.S. highway, and county road) from about 156 to 200 miles (Chen 2007).

Impacts on Water Quality and Hydrology

Water bodies and shorelines are among the sensitive areas likely to experience more environmental stress with increased human activity (Johnson and Beale 2002). Development along rivers and streams can cause excessive and unnecessary damage to banks, beds, and riparian vegetation and waterways; degrade water quality; interrupt hydrologic cycles; and affect watershed function upstream or downstream from the development activity (Schweitzer 2006). Increased housing density also creates more impervious surfaces, which lead to more runoff and increased risk of water pollution on both private and public lands (Zipperer 2002).

Developments along water courses can impact water quality and hydrology.

In the West, most fishing and hunting occurs on public lands, bringing important economic benefits to local communities (U.S. Fish and Wildlife Service and U.S. Census Bureau 2001, as cited in Sonoran Institute 2006).

Social and Economic Considerations

The presence of increased housing development near National Forest System lands can reduce open space and alter aesthetic qualities that contribute to recreation experiences (Clark and Stankey 1979). Increased human populations have been associated with an increase in crime on public lands, such as vandalism, drug activity, assaults, and illegal garbage dumping (Tynon and Chavez 2006, Whittaker 2006). Increased public access and activities on public lands could also create heightened concerns and higher costs for management of cultural resources.

Impacts on Boundary Management

Increased housing density in areas adjoining National Forest System lands can enhance the potential for encroachment, trespass, and unauthorized use and occupation of the public's land and resources. Encroachments onto national forests and grasslands can transform publicly owned environments into privately claimed backyards, lawns, flower and vegetable gardens, playgrounds, garbage dumps, and personal storage sites—potentially destroying or significantly damaging a natural environment. Among the most significant impacts on National Forest System lands from development and urbanization on adjoining private lands include illegal private road building, timber harvest, and user-created off-highway-vehicle trails on national forests and grasslands.

The Forest Service faces management challenges associated with control of property lines along the rapidly spreading wildland-urban interface. Limited funding, resources, and workforce have not kept pace with increased development on adjoining non-National Forest System lands. The Forest Service estimates that control of property lines for approximately 1 million acres of public land has been heavily compromised because of encroachment and trespass by adjoining landowners (Cunningham 2006).

Impacts on Other Federal Land Use Planning and Administration

Increased development activities on private lands in the vicinity of National Forest System boundaries can complicate resource planning on National Forest System lands and make land use planning and administration more expensive. Additional private landowners adjacent to national forests and grasslands means more neighbors with whom the Forest Service needs to coordinate in arranging access for fire management and recreation, managing ecosystems jointly across the landscape, and other management issues. Laws (such as the National Environmental Policy Act and the Endangered Species Act) and regulations (such as 36 CFR 212.55(b)) require the Forest Service and other land management

Larry Korhnak

Trash dumping on national forests and grasslands associated with increased human populations can have detrimental impacts on streams and other resources.

agencies to include the environmental effects of neighboring land uses when analyzing cumulative effects of federal actions. Travel management plans for public lands are also required to be compatible with existing conditions in nearby populated areas.

SUMMARY AND CONCLUSIONS

Increased housing development in rural areas bordering America's National Forest System lands could alter the ecological, social, and economic resources and services provided by those public lands and increase their management costs. The many natural amenities of lands located close to protected areas such as our national forests and grasslands are attracting more and more homeowners. This study estimates future housing density on rural lands at three distances from National Forest System boundaries.

Nine national forests and grasslands are projected to experience increased housing density on at least 25 percent of private lands at one or more of these distances by 2030, posing potential challenges to forest and grassland management and conservation. Thirteen national forests and grasslands are projected to experience housing density increases on over a half-million acres of rural lands within 10 miles of their boundaries. Nationwide, some 21.7 million acres of private rural lands adjacent to national forests and grasslands are projected to experience change owing to increased housing development. Much of this land is next to national forests in the Eastern United States.

The findings of *National Forests on the Edge* can help direct our attention to places where changes to National Forest System lands could be substantial. This report also helps to describe potential effects of development near National Forest System lands. Such an understanding can help scientists, resource managers, and communities anticipate potential impacts, plan for prudent growth, and implement policies that take into consideration the implications for national forests and grasslands on the edge of development while the windows of opportunity for effective conservation action remain open.

Future research to address data limitations of this effort could include:

- Compilation of nationally consistent data on private inholdings for all National Forest System lands, to enable more accurate estimates of housing density increases.
- Estimates of housing density increases on private lands that are currently at or above 65 units per square mile, because this type of increase can also affect National Forest System lands.

- Estimates of housing density increases on lands adjacent to national forests in Alaska and Puerto Rico.

Strategic, collaborative approaches are needed at local, state, regional, and national levels to help guide development in ways that reflect people's needs and values and are complementary to or consistent with the protection of resources and services on national forests and grasslands (USDA Forest Service 2006a). Current examples include:

- Keeping land in forests through such programs as the Forest Service's Forest Legacy Program.
- Concentrating growth in existing towns and clustering development away from environmentally valuable land.
- Protecting private forests with conservation easements or tax incentives.
- Coordinating among landowners to control the spread of noxious weeds or address other resource issues.

The Forest Service is committed to working in partnership with landowners, local communities, and their governments to help maintain working landscapes, conserve critical open space, and keep National Forest System lands healthy and able to sustain ecological, social, and economic benefits far into the future.

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METRIC EQUIVALENTS

When you know:	Multiply by:	To find:
Feet	0.3048	Meters
Acres	.405	Hectares
Miles	1.609	Kilometers
Square feet	.0929	Square meters
Square miles	2.59	Square kilometers

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APPENDIX

INTRODUCTION

National Forests on the Edge projected development of rural private lands within three distances of national forests and grasslands in the conterminous United States. The projections were made for private lands surrounding external forest and grassland boundaries, defined here as the outer boundary within which a national forest or grassland was established (referred to as "proclamation" boundaries for some forests). **Internal boundaries** distinguish lands actually managed by the federal government as national forests and grasslands from private lands or "inholdings" found within external boundaries. External boundaries were used for this study because there is no national-level geospatial database of private land located within national forest and grassland external boundaries.

The housing density categories used for this study are identical to those in the first *Forests on the Edge* report (Stein et al. 2005a, 2005b). However, the terms used have been changed slightly:

- **Rural I** (lands with 16 or fewer housing units per square mile).
- **Rural II** (17 to 64 housing units per square mile).
- **Exurban/urban** (65 or more housing units per square mile).
- **Private land** is defined to include all lands not classified as public by the Protected Areas Database (described further below).
- **Increase in housing density** was defined to mean shifts from rural I to rural II or from either rural category to the exurban/urban category, based on the projected increase in the number of housing units per unit area between 2000 and 2030.

Housing Density Projections

Housing density projections were based on past, current, and projected statistics on housing density and population, road density data, past growth patterns, locations of urban areas, and other factors that were used in analyses for the first *Forests on the Edge* report (Stein et al. 2005a, 2005b; Theobald 2005).

Housing density was estimated by first drawing from historical and current housing densities at a fine grain to examine spatial patterns of development. Using the historical and current housing density patterns as data inputs, a projection (simulation) model of future housing density patterns to 2030 was developed based on county-level population projections generated by NPA Data Services, Inc. (2003).

Nationwide estimates of population and housing density were computed from the U.S. Department of Commerce Census Bureau's block-group and block data for 2000 (U.S. Census Bureau 2001a). To estimate current housing density patterns, housing densities were computed by using dasymetric (density measurement) mapping techniques described in detail in previous work (Theobald 2001). Essentially, blocks were refined by using public land information and water polygons (from Census Bureau). Public land information was derived from the Protected Areas Database (PAD) (DellaSala et al. 2001), v.2—an ArcInfo polygon coverage compiled by the Conservation Biology Institute (CBI). The PAD contains boundaries of most federal and state owned/managed protected areas in the conterminous United States and Alaska, and includes county, city, and private reserves where data are available. Portions of census blocks found on public land were removed, as were portions of blocks identified as streams, rivers, ponds, lakes, and reservoirs.

Based on these refined census block geographies, the number of housing units per block, obtained from the 100 percent data from the 2000 Census Summary Tape File 1 (U.S. Census Bureau 2001b), were allocated throughout the refined blocks. The allocation of housing density is weighted to reflect the probable heterogeneity of the placement of houses that are more likely to be located near roads and less likely in portions of blocks distant (greater than about 1 km [0.62 mi]) from roads; the weighting is based on road density (computed using an 800-m [2,624-ft] radius moving neighborhood).

Road density was classified into four arbitrary categories that distinguished different levels of development: very low (0.0 to 0.25 km/km^2 [0.0 to 0.15 mi/mi^2]), low (0.25 to 1.0 km/km^2 [0.15 to 0.62 mi/mi^2]), medium (1.0 to 5.0 km/km^2 [0.62 to 3.1 mi/mi^2]), and high (greater than 5.0 km/km^2 [3.1 mi/mi^2]). Weights of 1, 2, 3, and 4 were assigned to very low to high (respectively) levels of development and were used to allocate housing density values to cells within a block. Housing density estimates for 1990 were generated from the "Year Housing Built" question from the sample data Summary File 3 data set (U.S. Census Bureau 2001c). These data are provided at the block-group level and were adjusted to ensure that the sum of units by block groups in a county equaled the counts from decadal census by using established methods (Hammer et al. 2004, Radeloff et al. 2001, Theobald 2001).

The Spatially Explicit Regional Growth Model (SERGoM) v1 (Theobald 2005) was used to model the full urban-to-rural spectrum of housing densities. It uses a supply-demand-allocation approach and assumes that future growth patterns will be similar to those found in the past decade. Four basic steps were used in SERGoM v1 to project future patterns on a decadal basis.

First, the number of new housing units in the next decade was forced to meet the demanded quantity associated with the projected county-level population. Population growth was converted to new housing units by the county-specific housing unit per population ratio for 2000. Population estimates were obtained from a demographic-econometric model (NPA Data Services 2003).

Second, a location-specific average growth rate from the previous to current time step (e.g., 1990 to 2000) was computed for each of four density classes: urban, suburban, exurban, and

rural. These growth rates were computed for each 100-m [328-ft] cell, using a moving neighborhood (radius = 1.6 km [.9936 mi]) that allows within-county heterogeneity and cross-county and state boundary growth patterns to be captured. Also, new housing units were spatially allocated based on these locally determined growth rates, which assumes that areas of future growth are likely to be near current high growth areas or "hot spots."

Third, the distribution of new housing units was adjusted according to accessibility to the nearest urban core area. That is, urbanization and conversion to urban and exurban land use typically occurs at locations that are nearer to urban core areas but that are on the fringe where land is undeveloped. Accessibility is computed in terms of minutes of travel time from urban core areas as one would travel along the main transportation network (major roads and highways). An urban core area is defined here as a contiguous cluster larger than 100 hectares (247 acres) at urban housing density. The distribution of housing density was then adjusted by creating a weight surface based on travel time from urban areas and was used to modify the location of new housing units computed in the first step.

Fourth, the new housing density was added to the current housing density, which makes the assumption that housing density does not decline over time, which is reasonable to represent patterns of expansion in suburban and exurban areas but may underrepresent areas that are in fact declining in housing density through urban decay or expansion of commercial land use into residential areas.

Analysis Procedures

A raster layer of projected changes in housing density (100 m by 100 m [328 ft by 328 ft]) was created from spatial layers of year 2000 and projected year 2030 housing densities (Theobald 2004a, 2004b, 2005). A cross-walk table was developed to translate the change categories in the raster layer to the housing density category changes considered in this report (i.e., rural I to rural II, either rural to exurban/urban).

Based on a spatial database of National Forest System lands (USDA Forest Service 2000a), buffer polygons were created for three distances from the external boundaries of individual administrative national forests: 0 to ½ mile, ½ mile to 3 miles, and 3 to 10 miles. Owing to the existence of disconnected forest parcels that are administered by the same national forest, some buffers overlapped within individual national forests. These overlapping buffers were dissolved. As a result of the shape and arrangement of the forest parcels, each national forest typically had several hundred forest buffer polygons. The buffers of adjacent national forests that overlapped one another were identified but not dissolved.

Using the projected change raster layer, the numbers of private land acres were tabulated for all forest buffer polygons for the following sets of changes: changes from rural I to rural II, from either rural to exurban/urban, and those acres not changing housing density classes. Forest-level estimates of the number of acres changing and not changing housing density classes within the three distances considered were constructed by summing the tabulated acres of each forest buffer polygon for each administrative national forest. National-level results were computed by summing across all forest buffer polygons within the distance categories, after accounting for acres in forest buffer polygons that overlapped between forests. Accounting for overlapping forest buffers between forests avoids double counting of acres in the national-level results.

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.

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Telephone	(503) 808-2592
Publication requests	(503) 808-2138
FAX	(503) 808-2130
E-mail	pnw_pnwpubs@fs.fed.us
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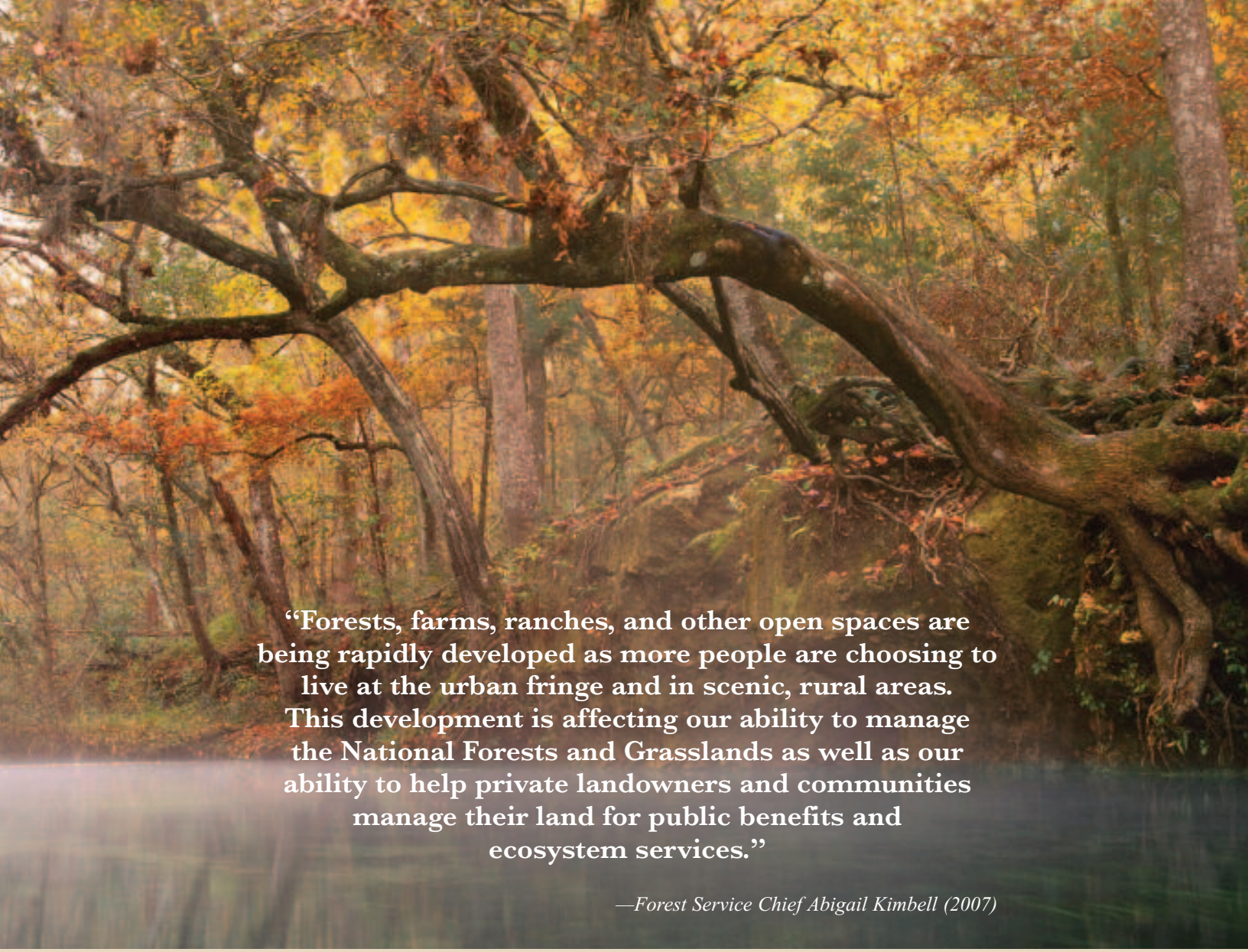

"Forests, farms, ranches, and other open spaces are being rapidly developed as more people are choosing to live at the urban fringe and in scenic, rural areas. This development is affecting our ability to manage the National Forests and Grasslands as well as our ability to help private landowners and communities manage their land for public benefits and ecosystem services."

—Forest Service Chief Abigail Kimbell (2007)

FORESTS ON THE EDGE

Forests on the Edge, a project of the U.S. Department of Agriculture, Forest Service, aims to increase public understanding of the contributions of and pressures on America's forests, and to create new tools for strategic planning. Our first report, *Forests on the Edge: Housing Development on America's Private Forests* (Stein et al. 2005a), identified private forested watersheds most likely to experience housing development. This second report identifies national forests and grasslands most likely to experience increased housing density on rural private lands along their borders.

Future studies will examine:

- Threats to private forest contributions—presenting data related to private forest benefits such as water quality, timberland, and wildlife values, as well as threats such as development, fire, insects pest and diseases; and air pollution.
- Detailed descriptions of top watersheds of concern.
- Development projections for private forest lands in Alaska, Puerto Rico, the Virgin Islands, Hawaii, and the Pacific Islands.

For further information on Forests on the Edge, contact: Susan Stein, U.S. Department of Agriculture, Forest Service, Cooperative Forestry staff, 1400 Independence Avenue, SW, Mailstop 1123, Washington, DC 20250-1123. (202) 205-0837. sstein@fs.fed.us.
http://www.fs.fed.us/openspace/fote/