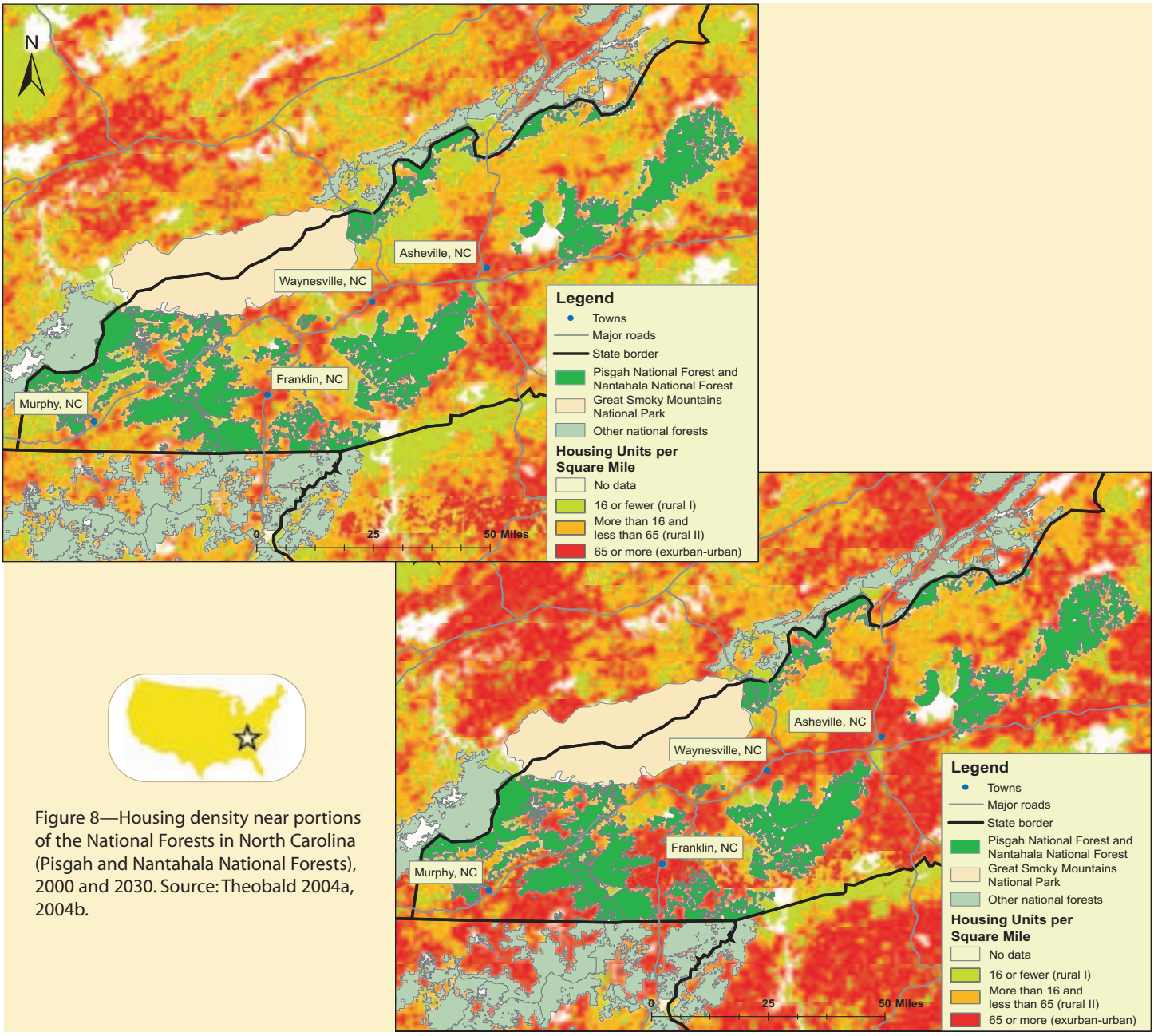


Figure 8—Housing density near portions of the National Forests in North Carolina (Pisgah and Nantahala National Forests), 2000 and 2030. Source: Theobald 2004a, 2004b.

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

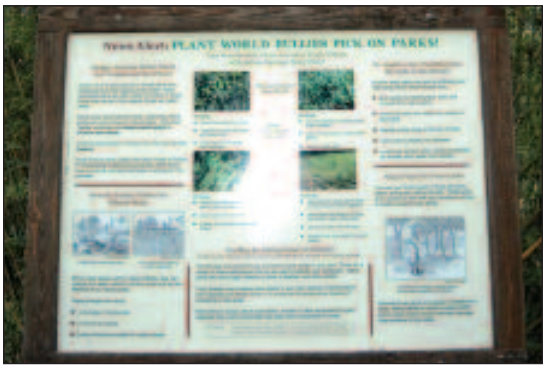
Wildlife populations on public lands—especially threatened and endangered species—can be at heightened risk from several factors associated with increased housing development on nearby private rural lands (Bass and Beamish 2006, Danielson et al. 1997, Deem et al. 2001, Ewing et al. 2005, Lepczyk et al. 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

REFERENCES

Alig, R.; Kline, J.; Lichtenstein, M. 2004. Determinants of developed area, with projections to 2025. Landscape and Urban Planning. 69: 219–234.

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

Alig, R.J.; Stewart, S.; Nowak, D.; Wear, D.; Stein, S. [In press]. Conversions of forest lands: trends, determinants, and policy considerations. In: Pye, J.M.; Rauscher, H.M.; Sands, Y.; Lee, D.C.; Beatty, J.S., eds. Advances in threat assessment and their application to forest and rangeland management. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Bass, F.; Beamish, R. 2006. Can nation's parks survive the pressure? Part 1 of 2-part series, 06/19/2006. Missoula, MT: Associated Press. http://www.msnbc.msn.com. (19 June 2006).

Bosch, M. 2006. Personal communication. National Endangered Species program leader, USDA Forest Service, Washington Office, Sidney R. Yates Federal Building, 201 14th Street, SW, Washington, DC 20250.

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

Cardille, J.A.; Ventura, S.J.; Turner, M.G. 2001. Environmental and social factors influencing wildfires in the upper Midwest, Unites States. Ecological Applications. 11: 111–127.

Chen, X. 2007. Spatial pattern of wildfires in Alabama, USA. International Journal of Environmental Studies. 64(2): 229–242.

Clark, R.N.; Stankey, G.H. 1979. The recreation opportunity spectrum: a framework for planning, management, and research. Gen. Tech. Rep. GTR-98. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 32 p.

Cordell, H.K.; Bergstrom, J.C.; Hartmann, L.A.; English, D.B.K. 1990. An analysis of the outdoor recreation situation in the United States. Gen. Tech. Rep. RM-189. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 112 p.

Cordell, H.K.; Overdevest, C. 2001. Footprints on the land: implications of population and economic growth for this country's natural lands. In: Cordell, H.K.; Overdevest, C., eds. Footprints on the land: an assessment of demographic trends and the future of natural resources in the United States. Champaign, IL: Sagamore Publishing: 229–284.

Cunningham, R. 2006. Personal communication. Supervisory biological scientist, USDA Forest Service, Washington Office, 201 14th Street SW, Washington, DC 20024.

Daniel, R. 2006. Sage advice: fragmented and declining, valley's sagebrush habitat offers beauty and diversity. Hamilton, MT: Ravalli Republic. May 31. http://www.ravallirepublic.com/articles/2006/05/31/outdoors/75-outdoors.txt. (29 August 2006).

Danielson, W.R.; Degaff, R.M.; Fuller, T.K. 1997. Rural and suburban forest edges: effects on egg predators and nest predation rates. Landscape and Urban Planning. 38: 25–36.

Deem, S.L.; Karesh, W.B.; Weisman, W. 2001. Putting theory into practice: wildlife health in conservation. Conservation Biology. 15(5): 1224–1233.

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

DellaSala, D.A.; Williams, J.E.; Williams, C.D.; Franklin, J.F. 2004. Beyond smoke and mirrors: a synthesis of fire policy and science. Conservation Biology. 18: 976–986.

Dickens, S.M.; Gerhardt, F.; Collinge, S.K. 2005. Recreational portage trails as corridors facilitating non-native plant invasions of the Boundary Waters Canoe Area wilderness (U.S.A.). Conservation Biology. 19: 1653–1657.

Dissmeyer, G.E., ed. 2000. Drinking water from forests and grasslands: a synthesis of the scientific literature. Gen. Tech. Rep. SRS–39. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 246 p.

Ewing, R.; Kostyack, J.; Chen, D.; Stein, B.; Ernst, M. 2005. Endangered by sprawl: how runaway development threatens America's wildlife. Washington, DC: National Wildlife Federation, Smart Growth America, and NatureServe. 54 p.

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

General Accounting Office [GAO]. 1999. Western national forests: a cohesive strategy is needed to address catastrophic wildfire threats. GAO/RCED-99-65. Washington, DC. 60 p.

Grace, S.; Wade, D. 2000. Ecological and economic consequences of the 1998 Florida wildfires. [Poster]. In: U.S. Geological Survey and wildland fire workshop. Tallahassee, FL: Florida Department of Agriculture and Consumer Services, Division of Forestry. http://firescience.cr.usgs.gov/html/abs_poster2000.html. (13 September 2006).

Grulke, N.E.; Minnich, R.A.; Paine, T.; Dunn, A.; Chavez, D. [In press]. Air pollution increases forest susceptibility to wildfires in southern California. In: Pye, J.M.; Rauscher, H.M.; Sands, Y.; Lee, D.C.; Beatty, J.S., eds. Advances in threat assessment and their application to forest and rangeland management. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Hammer, R.B.; Stewart, S.I.; Winkler, R.; Radeloff, V.C.; Voss, P.R. 2004. Characterizing spatial and temporal residential density patterns across the U.S. Midwest, 1940–1990. Landscape and Urban Planning. 69(2–3): 183–199.

Heuberger, K.A.; Putz, F.E. 2003. Fire in the suburbs: ecological impacts of prescribed fire in small remnants of longleaf pine (*Pinus palustris* Sandhill). Restoration Ecology. 11(1): 72–81.

Holway, D.A. 2005. Edge effects of an invasive species across a natural ecological boundary. Biological Conservation. 121: 561–567.

Jacobson, S. 2006. The increasing threat of highway-caused wildlife mortality and barrier impacts on U.S. public lands. [Poster]. In: Advances in threat assessment and their application to forest and rangeland management. Boulder, CO.

Johnson, K.M. 1999. The rural rebound. Washington, DC: Population Reference Bureau. Reports on America. 1(3). 20 p.

Johnson, K.M. 2006. Demographic trends in rural and small town America. Durham, NH: University of New Hampshire, Carsey Institute. 35 p.

Johnson, K.M.; Beale, C. 1999. The continuing population rebound in non-metro America. Rural Development Perspectives. 13(3): 2–10.

Johnson, K.M.; Beale, C. 2002. Nonmetro recreation counties: their identification and rapid growth. Rural America. 17(4): 12–19.

Johnson, K.M.; Stewart, S. 2005. Recreation, amenity migration and urban proximity. In: Green, G.P.; Deller, S.C.; Marcouiller, D.W., eds. Amenities and rural development: theory, methods and public policy. Northampton, MA: Edward Elgar: 177–196.

Johnson, K.M.; Stewart, S. 2007. Demographic trends in national forest, recreational, retirement and amenity areas. In: Kruger, L.; Mazza, R.; Lawrence, K. eds. Proceedings —recreation research and management workshop. Gen. Tech. Rep. PNW-GTR-698. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 187-199.

Johnson, K.M.; Voss, P.R.; Hammer, R.B.; Fuguitt, G.V.; McNiven, S. 2005. Temporal and spatial variation in age-specific net migration in the United States. Demography. 42(4): 791–812.

Kimbell, A. 2007 (27 March). Open space conservation strategy. Letter from Forest Service Chief to Regional Foresters, Station Directors, Area Director, International Institute for Tropical Forestry Director, Deputy Chiefs, and WO staff. On file with: USDA Forest Service, Office of the Chief, Sidney R. Yates Federal Building, 201 14th Street, SW, Washington, DC 20250.

Koch, F.H.; Coulston, J.W. [In press]. Modeling current climate conditions for forest pest risk assessment. In: Pye, J.M.; Rauscher, H.M.; Sands, Y.; Lee, D.C.; Beatty, J.S., eds. Advances in threat assessment and their application to forest and rangeland management. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Lepczyk, C.A.; Mertig, A.; Liu, J. 2003. Landowners and cat predation across rural-to-urban landscapes. Biological Conservation. 115: 191–201.

Lubowski, R.N.; Vesterby, M.; Bucholtz, S.; Baez, A.; Roberts, M.J. 2006. Major land uses in the United States, 2002. Economic Information Bull. 14. Washington, DC: U.S. Department of Agriculture, Economic Research Service. 54 p.

Mace, R.D.; Waller, J.S.; Manley, T.L.; Lyon, L.J.; Zuuring, H. 1996. Relationships among grizzly bears, roads, and habitat in the Swan Mountains, Montana. Journal of Applied Ecology. 33: 1395–1404.

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.

Manolis, J.C.; Andersen, D.E.; Cuthbert, F.J. 2002. Edge effect on nesting success of ground nesting birds near regenerating clearcuts in a forest-dominated landscape. The Auk. 119(4): 955–970.

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

NPA Data Services, Inc. 2003. County population projections —key indicators of county growth, 1970–2024, extended to 2030. Arlington, VA.

Peterson, G.L.; Williams, J.M. 1999. Access to national forest land. In: Cordell, H.K.; Betz, C.J.; Bowker, J.M.; English, D.B.K.; Johnson, C.Y.; Mov, S.H.; Bergstron, J.C.; Teasley, R.J.; Tarrant, M.J., eds. Outdoor recreation in American life: a national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing: 42–45.

Plantinga, A.; Alig, R.; Eichman, H.; Lewis, D. 2007. Linking land-use projections and forest fragmentation analysis. Res. Pap. PNW-RP-570. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 41 p.

Podur, J.; Martell, D.L.; Knight, K. 2002. Statistical quality control analysis of forest fire activity in Canada. Canadian Journal of Forest Research. 32: 195–205.

Prestemon, J.P.; Butry, D.T. [In press]. Wildland arson: a research assessment. In: Pye, J.M.; Rauscher, H.M.; Sands, Y.; Lee, D.C.; Beatty, J.S., eds. Advances in threat assessment and their application to forest and rangeland management. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Radeloff, V.C.; Hammer, R.B.; Stewart, S. 2005a. Rural and suburban sprawl in the U.S. Midwest from 1940 to 2000 and its relation to forest fragmentation. Conservation Biology. 19(3): 793–805.

Radeloff, V.C.; Hammer, R.B.; Stewart, S.; Fried, J.S.; Holcomb, S.S.; McKeefry, J.F. 2005b. The wildland-urban interface in the United States. Ecological Applications. 15(3): 799–805.

Radeloff, V.C.; Hammer, R.B.; Voss, P.R.; Hagen, A.E.; Field, D.R.; Mladenoff, D.J. 2001. Human demographic trends and landscape level forest management in the northwest Wisconsin Pine Barrens. Forest Science. 47(2): 229–241.

Regional Ecosystem Office [REO]. 2002. Interagency regional monitoring, overview: Northwest Forest Plan. 12 p. www.reo.gov/monitoring. (24 August 2006).

Riitters, K.H.; Wickham, J.D.; O'Neill, R.V.; Jones, K.B.; Smith, E.R.; Coulston, J.W.; Wade, T.G.; Smith, J.H. 2002. Fragmentation of continental United States forests. Ecosystems. 5: 815–822.

Riley, S.P.D.; Sauvajot, R.M.; York, E.C.; Kamradt, D.A.; Bromley, C.; Fuller, T.K.; Wayne, R.K. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. Conservation Biology. 17: 566–576.

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.

Schweitzer, B. 2006 (8 March). Letter from Office of the Governor, State of Montana, to directors of Montana Department of Environmental Quality, Department of Natural Resources and Conservation, and Department of Fish, Wildlife, and Parks. On file with: Office of the Governor, Montana State Capitol Bldg., P.O. Box 200801, Helena, MT 59620-0801.

Servheen, C. 2006 (July 25). The future for sensitive wildlife in Missoula County. Letter to the editor from Christopher Servheen, U.S. Fish and Wildlife Service and the College of Forestry and Conservation, University of Montana. Missoula, MT: Missoulian.

Shands, W.E.; Healy, R.G. 1977. The lands nobody wanted. Washington, DC: Conservation Foundation. 282 p.

Sieg, C.H.; Flather, C.H.; Barastatis, N.; Fowler, J.F.; Hof, J.; Kartesz, J.T.; Knowles, M.S.; Mitchell, J. 2005. Exotic plant richness as an indicator of ecosystem health: an update to support the 2005 RPA assessment. Unpublished draft. On file with: Carolyn Sieg, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 2500 S Pine Knoll, Flagstaff, AZ 86001-6381.

Singleton, P.H.; Gaines, W.L.; Lehmkuhl, J.F. 2002. Landscape permeability for large carnivores in Washington: a GIS weighted-distance and least-cost corridor assessment. Res. Pap. PNW-RP-549. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 89 p.

Smith, W.B.; Darr, D. 2004. U.S. forest resource facts and historical trends. FS-801. Washington, DC: U.S. Department of Agriculture, Forest Service. 37 p.

Sonoran Institute. 2006. Backcountry bounty: hunters, anglers and prosperity in the American West. Tucson, AZ. 18 p.

Stein, S.; McRoberts, R.E.; Alig, R.J.; Nelson, M.D.; Theobald, D.M.; Eley, M.; Dechter, M.; Carr, M. 2005a. 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.

Stein, S.; McRoberts, R.E.; Nelson, M.D.; Theobald, D.M.; Eley, M.; Dechter, M. 2005b. Forests on the edge: a GIS-based approach to projecting housing development on private forests. [CD-ROM]. In: Aguirre-Bravo, C.; Pellicane, P.J.; Burns, D.P.; Draggan, S., eds. Proceedings: monitoring science and technology symposium: unifying knowledge for sustainability in the Western Hemisphere. RMRS-P-37CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Stynes, D.J.; White, E. 2005. Spending profiles of national forest visitors, NVUM four-year report. 44 p. www.fs.fed.us/recreation/programs/nvum/NVUM4YrSpending.pdf. (24 August 2006).

Tarrant, M.A.; Cordell, H.K.; Green, G.T. 2003. PVF: a scale to measure public values of forests. Journal of Forestry. 101(6): 24–30.

Theobald, D.M. 2001. Land use dynamics beyond the American urban fringe. Geographical Review. 91: 544–564.

Theobald, D.M. 2004a. bhc2000 v.1. Environmental Systems Research Institute (ESRI) raster digital data. On file with: David M. Theobald, Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO 80526.

Theobald, D.M. 2004b. bhc2030 v.1. Environmental Systems Research Institute (ESRI) raster digital data. On file with: David M. Theobald, Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO 80526.

Theobald, D.M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society. 10(1): 32. http://www.ecologyandsociety.org/vol10/iss1/. (13 September 2006).

Tynon, J.F.; Chavez, D.J. 2006. Crime in national forests: a call for research. Journal of Forestry. 104(3): 154–157.

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2000a. Environmental Systems Research Institute (ESRI) shapefile. Geospatial Service and Technology Center. http://roadless.fs.fed.us/documents/feis/data/gis/coverages/nfsland_us_dd.zip. (06 April 2007).

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2000b. Water and the Forest Service. FS-660. Washington, DC: Policy and Analysis Section. 40 p.

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2003a. Final environmental impact statement—interface recreation trails. Calaveras County, CA: Calaveras Ranger District. 195 p.

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2003b. Urban national forests: special places for millions of people. On file with: Cooperative Forestry, 1400 Independence Ave. SW, Washington, DC 20250. 71 p.

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2004a. Find national forests and grasslands. [Interactive map]. http://www.fs.fed.us/recreation/map/finder.shtml. (28 August 2006).

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2004b. National forest visitor use monitoring program—national project results—January 2000 through September 2003. 12 p. http://www.fs.fed.us/recreation/programs/nvum/national_report_final_draft.pdf. (03 August 2006).

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2005a. FY 1905–2005 annual national sold and harvest summary. Washington, DC: Forest Management. 2 p.

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2005b. Land area report. 2005. http://www.fs.fed.us/land/staff/lar/LAR05/index.html. (13 September 2006).

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2006a. Cooperating across boundaries: partnerships to conserve open space in rural America. Washington, DC. 51 p.

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2006b. Four threats to the health of our nation's forests and grasslands. http://www.fs.fed.us/projects/four-threats/. (05 April 2007).

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 2006c. Huron-Manistee National Forests—final environmental impact statement to accompany the 2006 land and resource management plan. Cadillac, MI. 366 p.

U.S. Department of Commerce, Census Bureau [U.S. Census Bureau]. 2001a. Census 2000 Summary file 1, technical documentation. Washington, DC.

U.S. Department of Commerce, Census Bureau [U.S. Census Bureau]. 2001b. Census 2000 Summary file 1. Washington, DC.

U.S. Department of Commerce, Census Bureau [U.S. Census Bureau]. 2001c. Summary file 3, dataset. Washington, DC.

U.S. Department of Commerce, Census Bureau [U.S. Census Bureau]. 2004. U.S. interim projections by age, sex, race, and Hispanic origin. www.census.gov/ipc/www/usinterimproj/. (03 April 2007).

Whittaker, M. 2006 (26 July). Rangers take on urban woes in wide open spaces. New York: New York Times.

Yates, E.D.; Levia, D.F., Jr.; Williams, C.L. 2004. Recruitment of three non-native invasive plants into a fragmented forest in southern Illinois. Forest Ecology and Management. 190: 119–130.

Yoder, J.K. 2002. Damage abatement and compensation programs as incentives for wildlife management on private land. In: Clark, L.; Hone, J.; Shivik, J.A.; Watkins, R.A.; Vercauteren, K.C.; Yoder, J.K., eds. Human conflicts with wildlife: economic considerations—proceedings of the third NWRC special symposium. Fort Collins, CO: National Wildlife Research Center: 17–28.

Zipperer, W.C. 2002. Urban influences on forests. In: Human influences on forest ecosystems: the southern wildland-urban interface assessment. Gen. Tech. Rep. SRS-55. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 73–91.

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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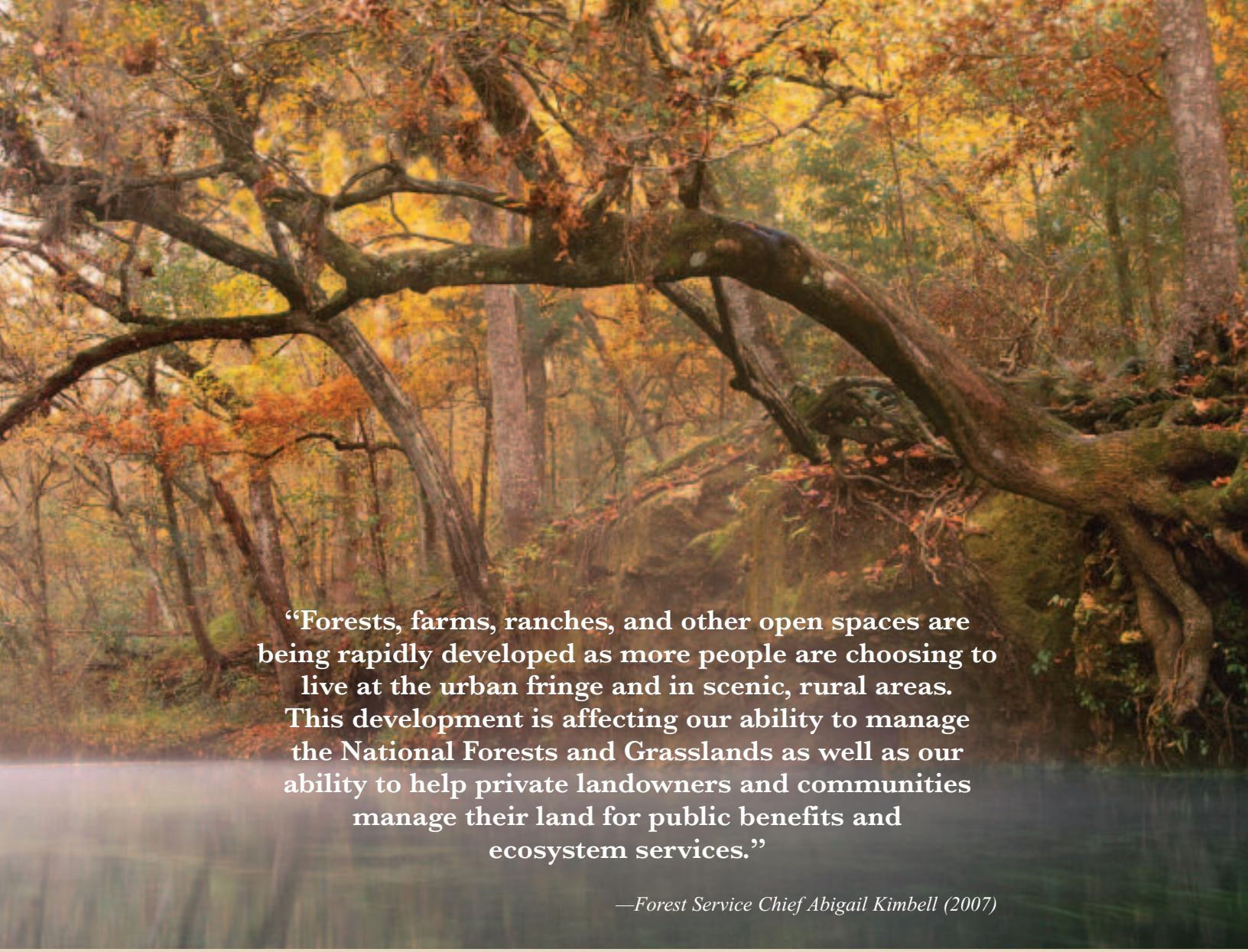

"Forests, farms, ranches, and other open spaces are being rapidly developed as more people are choosing to live at the urban fringe and in scenic, rural areas. This development is affecting our ability to manage the National Forests and Grasslands as well as our ability to help private landowners and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