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A Sensitivity Analysis of "Forests on the Edge: Housing Development on America's Private Forests"

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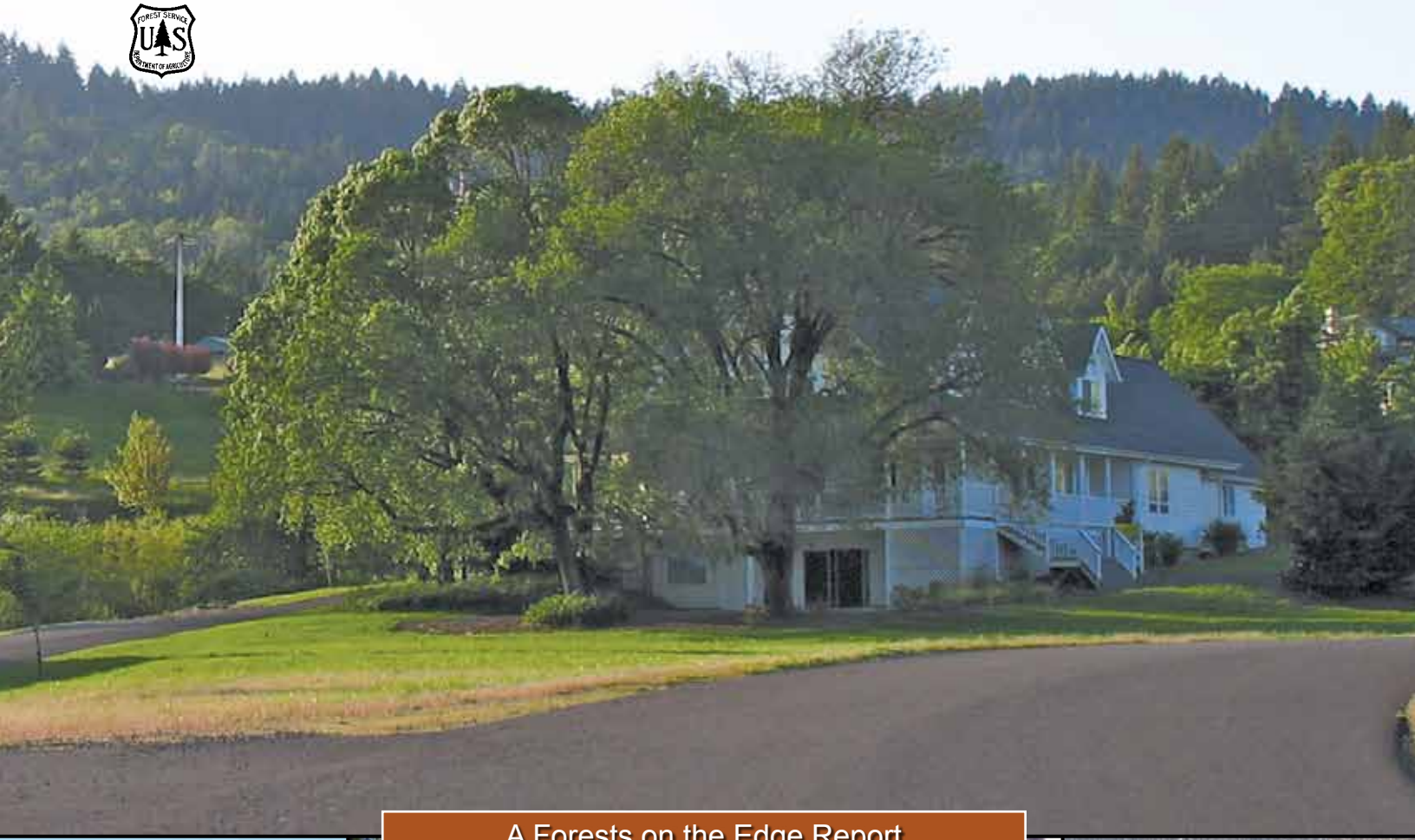
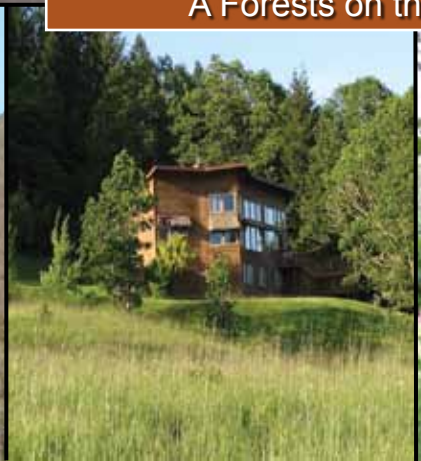
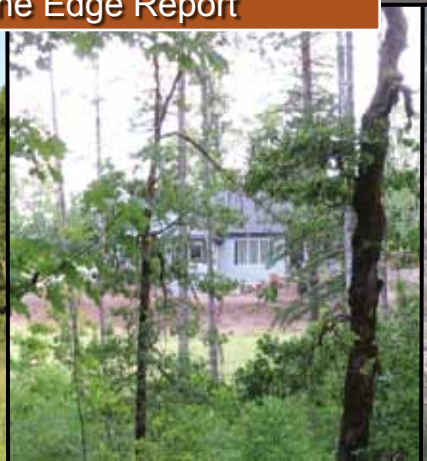


A Forests on the Edge Report





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Abstract

White, Eric M.; Alig, Ralph J.; Stein, Susan M.; Mahal, Lisa G.; Theobald, David M. 2009. A sensitivity analysis of "Forests on the Edge: Housing Development on America's Private Forests." Gen. Tech. Rep. PNW-GTR-792. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 35 p.

The original Forests on the Edge report (FOTE 1) indicated that 44.2 million acres of private forest land was projected to experience substantial increases in residential development in the coming decades. In this study, we examined the sensitivity of the FOTE 1 results to four factors: (1) use of updated private land and forest cover spatial data and a revised model of housing density change, (2) projection of residential development on woodland identified as shrub/scrub land cover, (3) inclusion of very-low-density residential development (i.e., more than 40 acres/housing unit) in the housing density change categories, and (4) inclusion of additional watersheds in the analysis by changing the screening criteria. The FOTE 1 results were found to be generally stable to the four factors. Use of updated data and a revised model had the most significant impact on the results of FOTE 1. Inclusion of shrub/scrub land cover and modification of the watershed screening criteria yielded minimal changes to the results of FOTE 1. An extensive amount (26 million acres) of very-low-density residential development was projected on private forest land, but inclusion of these acres of change did not appreciably change the FOTE results. However, given the spatial extent of projected very-low-density residential development and its potential implications for ecological processes, additional research examining this type of development and its impact on natural resources is warranted.

Keywords: Forests on the Edge, residential development, housing density, sensitivity analysis.

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Introduction

In the Forests on the Edge (FOTE) project, current and projected land use is examined in the context of public and privately owned natural resources located in rural landscapes. In the first FOTE publication (FOTE 1) (Stein et al. 2005), the authors projected residential development between 2000 and 2030 for private forestland watersheds in the contiguous 48 states. Consistent with trends in population growth, rural land development, and the spatial distribution of private forest land, significant areas of private forest in the Southern and Northeastern regions of the United States were projected to experience residential development. A number of watersheds in the Pacific Coast States were also identified as likely to experience medium or high increases in residential development. In subsequent FOTE analyses, researchers have examined projected residential development on private lands around national forests (Stein et al. 2007), completed case studies of residential development for rural areas in three regions of the country (White and Mazza 2008), and examined the benefits of and threats to private forest lands throughout the Lower 48 States. The research questions addressed in the FOTE project have expanded from that addressed in FOTE 1—quantifying expected increases in residential development on private forest land in the context of water resources—to better reflect the broader interests in examining the potential effects of residential development on public and privately owned natural resource lands. Although this sensitivity analysis is completed in regard to the results reported in FOTE 1, some of the discussion reflects the broader questions now addressed in FOTE research.

This study investigates how sensitive the results reported in FOTE 1 were to key assumptions and documents key findings.

Updated data on land ownership and forest cover and a revised model of residential development have become available in the years since the publication of the first FOTE report (Stein et al. 2005). In addition, stakeholder groups have expressed interest in modifying some aspects of the basic approach and assumptions adopted in FOTE studies. To that end, this study investigates how sensitive the results reported in FOTE 1 were to key assumptions and documents key findings.

General Approach

This sensitivity analysis focuses on the impact of the following factors on the results of the FOTE 1 research:

1. Use of updated private land and forest cover spatial data and a revised model of housing density change.

2. Projection of residential development on private shrub/scrub woodland.
3. Inclusion of very-low-density residential development (residential development with more than 40 acres per unit) in the housing density change categories.
4. Inclusion of additional hydrologic unit code (HUC) 4 watersheds[1] in the analysis by changing the screening criteria.

As in the original study, the analyses reported here were completed by creating a spatial database of projected increases in residential development between 2000 and 2030 and intersecting that with private forest and woodland resource locations. The areas of private forest and woodland projected to experience residential development were then summarized and reported by watershed. Results obtained under this sensitivity analysis were compared quantitatively and qualitatively with the results of the original FOTE analysis. The study area for this sensitivity analysis was the contiguous United States. To examine the regional impacts of the four factors, watersheds with their centroids in North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and points west were classified as the "West" and all other watersheds, including those in Texas, were classified as the "East."

The spatial analysis reported in FOTE 1 was completed by analysts not involved in the current study using previous versions of the GIS software package. To control for differences in individual programming style and software algorithms, we replicated the analysis reported in FOTE 1 and we use our replicated FOTE 1 results as the **baseline** for comparisons. Figure 2 in the FOTE 1 report (replicated in this report as fig. 1) has been widely distributed and referenced. In the analysis for each factor, we generated figures using the same classifications and breakpoints adopted in the FOTE 1 report: low change (≤ 4.9 percent of the watershed's land area projected to experience residential development), medium change (> 4.9 and ≤ 19.9 percent of the watershed's land area projected to experience residential development), and high change (>19.9 percent of the watershed's land area projected to experience residential development).

[1] "HUC 4 watersheds" represent the fourth-level hydrologic units (termed the "cataloging units") in the U.S. Geological Survey (USGS) system of hydrologic unit codes. Although highly variable, on average, HUC 4 watersheds are approximately 1 million acres.

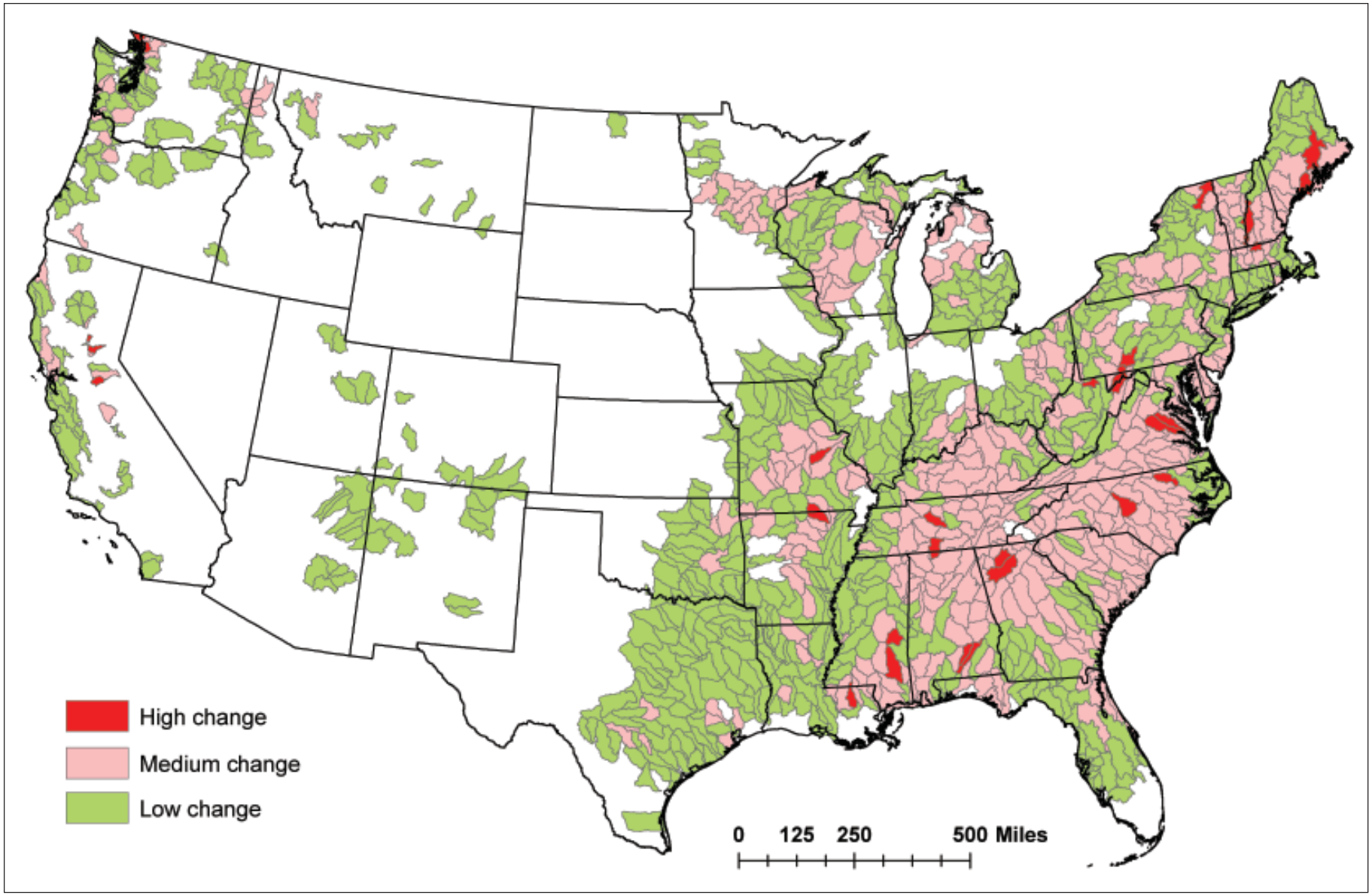

Figure 1—Watersheds in which housing density was projected to increase on private forests between 2000 and 2030 in the original Forests on the Edge report. High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area. White area represents watersheds not meeting the screening criteria and excluded from mapping (Stein et al. 2005).

Methods and Results From the First Forests on the Edge Report

The methods adopted in FOTE 1 to relate projections of housing development to rural private forest resources were described in Stein et al. (2005, 2006) and are discussed briefly in this report. Three categories of housing density are recognized in the FOTE project:

- Rural I: < 16 housing units/square mile (i.e., more than 40 acres/housing unit).
- Rural II: 16 to 64 housing units/square mile (i.e., 40 to 10 acres/housing unit).
- Exurban/urban: > 64 housing units/square mile (i.e., less than 10 acres/housing unit).

In early publications (including FOTE 1), the FOTE housing density categories were referred to as rural, exurban, and urban, respectively. The spatial data depicting current and projected future housing density used in the FOTE project are drawn from the Spatially Explicit Regional Growth Model (SERGoM) (Theobald 2005). In FOTE 1 (Stein et al. 2005), the three FOTE housing density categories were cross-walked to the 10 housing density classes contained in the output of SERGoM version 1 (v.1) (table 1). Two types of projected residential housing density change between 2000 and 2030 were recognized in FOTE 1: projected changes from rural I in 2000 to rural II in 2030 and projected changes from either rural I or rural II in 2000 to exurban/urban in 2030.

Watersheds projected to have the greatest percentages of their land areas involved in residential development on private, unprotected forest land were located primarily in the Southeastern and Northeastern United States.

Based on the land ownership and land cover data and version of SERGoM available at the time, Stein et al. (2005) reported that 44.2 million acres of rural private, unprotected forest land throughout the contiguous United States "could experience substantial increases in housing density by 2030." Of that area of projected residential development, 22.5 million acres was projected to change from rural I to rural II and 21.7 million acres was projected to change from rural I or II to exurban/urban. Watersheds projected to have the greatest percentages of their land areas involved in residential development on private, unprotected forest land were located primarily in the Southeastern and Northeastern United States, with some watersheds in the Pacific Coast States (fig. 1). The top 15 watersheds in terms of area of private, unprotected forest land projected to experience residential development were all in the Eastern States.

One component of the FOTE 1 methods that was documented in Stein et al. 2006, but only referenced in Stein et al. 2005, was the exclusion of certain SERGoM v.1 housing density classes from the calculations of housing density change between 2000 and 2030. In that modified approach, SERGoM v.1 housing

Table 1—Cross-walk between Forests on the Edge housing categories and SERGoM[a] version 1 housing density classes used in the original Forests on the Edge report (Stein et al. 2005)

Forests on the Edge housing categories	SERGoM version 1 housing density classes
Rural I	No housing units
	> 80 acres/housing unit
	50 to 80 acres/housing unit
	40 to 50 acres/housing unit
Rural II	30 to 40 acres/housing unit
	20 to 30 acres/housing unit
	10 to 20 acres/housing unit
Exurban/urban	1.7 to 10 acres/housing unit
	0.6 to 1.7 acres/housing unit
	< 0.6 acres/housing unit

[a] Spatially Explicit Regional Growth Model.

density classes adjacent to the next highest FOTE housing density category (i.e., the 40 to 50 acres/unit class for the rural I to rural II type of change and the 10 to 20 acres/unit class in the rural I or II to exurban/urban type of change) were not counted as areas of increasing housing density (table 2). The basis stated in Stein et al. (2006) for adopting that modified rule was to avoid counting marginal increases in housing density. Had that modified approach **not** been adopted, the amount of private forest land projected to experience residential development reported in FOTE 1 **would have been** 72.7 million acres. Nearly all (93 percent) of the 28.9 million acres of projected development on forest land not reported under the modified approach in FOTE 1 was in the East.

With the exception of the analysis to replicate the FOTE 1 results, thereby creating the **baseline** for comparison, the modified approach was **not** adopted in completing analysis for any of the four factors considered in this study. The **baseline** of replicated FOTE 1 results estimated for this analysis following the FOTE 1 modified approach was used in most comparisons with the four sensitivity analysis factors. When we discuss the impact of using updated data and revised model on estimates of projected residential development on forest (i.e., factor 1) we will also reference the 72.7-million-acre figure that we have reported in this section.

Table 2—Modified approach to quantifying housing density changes adopted in the first Forests on the Edge report (Stein et al. 2005)

Year 2000 SERGoM class	Year 2030 SERGoM class
Rural I to rural II increase	
Rural I categories	Rural II categories
No housing units	30 to 40 acres/housing unit
> 80 acres/housing unit	20 to 30 acres/housing unit
50 to 80 acres/housing unit	10 to 20 acres/housing unit
40 to 50 acres/housing unit[a]	
Rural I or rural II to exurban/urban increase	
Rural I and rural II categories	Exurban/urban categories
No housing units	1.7 to 10 acres/housing unit
> 80 acres/housing unit	0.6 to 1.7 acres/housing unit
50 to 80 acres/housing unit	< 0.6 acres/housing unit
40 to 50 acres/housing unit	
30 to 40 acres/housing unit	
20 to 30 acres/housing unit	
10 to 20 acres/housing unit[a]	

[a] This housing density class from the Spatially Explicit Regional Growth Model (SERGoM) was not included in the change calculation.

Sensitivity Analysis Methods

Updated Data and Revised Model

In the FOTE 1 analysis, a 100-meter-resolution (328 feet) resampled version of the 1992 National Land Cover Database (NLCD) (Vogelmann et al. 2001) and the Protected Areas Database (PAD) version 2 (DellaSala et al. 2001) were combined[2] to identify forest land that was privately owned and not protected from development (e.g., lands not under a conservation easement). Since the release of FOTE 1, the 2001 NLCD has become available (Homer et al. 2004), and the PAD has been updated[3] to include a more comprehensive set of state and locally owned lands and protected private lands. Both of these revised data sets are being used in current FOTE research activities. Four 2001 NLCD classes are currently recognized as forest land in FOTE research: 41 “deciduous forest,” 42 “evergreen forest,” 43 “mixed forest,” and 90 “woody wetlands.” Private, unprotected lands were identified using

[2] U.S. Department of Agriculture, Forest Service. 2004. Forown100m. Unpublished data set. Forest Inventory and Analysis, North Central Research Station, USDA Forest Service.

[3] Conservation Biology Institute. 2007. Protected areas database v 4.6. Unpublished data set. http://www.consbio.org. (19 February 2009).

an augmented spatial layer of land ownership[4] based on version 4.6 (see footnote 3) of the PAD.[5] As with the previous data, a 100-meter-resolution (328 feet) resampled version of the 2001 NLCD and the augmented version of the PAD were combined into a single spatial database.[6]

Two primary revisions have occurred between version 1 (used in FOTE 1) and version 3 of SERGoM. First, the model now uses the augmented version of the PAD, version 4.6 (see footnotes 3 and 4), that includes a more comprehensive set of state and local public lands and protected private lands. Second, SERGoM now incorporates a revised algorithm for spatially distributing housing units within individual census blocks that incorporates the 2001 NLCD (table 3) and, in the

SERGoM now incorporates a revised algorithm for spatially distributing housing units within individual census blocks that incorporates the 2001 NLCD and ground-water well density.

Table 3—Weights used in version 3 of SERGoM[a] for distributing housing units across National Land Cover Database (NLCD) cover classes

NLCD classes	Description	Weight
Open water and perennial ice/snow (11, 12)	No housing units on water or snowfields	0.0
Developed, open space (21)	This is typically either open space (urban parks and greens space) or roads in rural areas, so very low likelihood of housing units	0.085
Developed, low, medium and high intensity (22, 23, 24)	These cover types are where housing units most likely are located	0.55
Barren/transitional (31, 32)	Includes barren, transitional areas such as cleared or recently cleared areas, but also mines, etc.	0.115
Wildland vegetation (41, 42, 43, 51, 52, 71, 72, 73, 74)	Not likely to have high-density (urban) in these areas.	0.15
Agricultural (pasture/hay, cultivated) (61, 81, 82)	Will have some housing density, but most housing infrastructure is clustered and near roads.	0.05
Wetlands (90, 91, 92, 93, 94)	Not likely to develop in wetlands (without filling).	0.05

[a] Spatially Explicit Regional Growth Model.

[4] Theobald, D.M. 2007. Protected lands of the continental US (CUS_UPPT_100). Unpublished data set. Human Dimensions of Natural Resources and the Natural Resource Ecology Lab, Colorado State University.

[5] Slightly less than 9.5 million acres of private forest land was classified as protected—87 percent of it in the East.

[6] Mahal, L.G. 2008. Forown100cus. Unpublished data set. Forest Inventory and Analysis, Northern Research Station, USDA Forest Service.

Table 4—Housing density changes in current Forests on the Edge studies, as estimated from version 3 of the Spatially Explicit Regional Growth Model (SERGoM)

Year 2000 SERGoM class	Year 2030 SERGoM class
Rural I to rural II increase	
Rural I categories	Rural II categories
No housing units	30 to 40 acres/housing unit
> 80 acres/housing unit	20 to 30 acres/housing unit
50 to 80 acres/housing unit	10 to 20 acres/housing unit
40 to 50 acres/housing unit	
Rural I or rural II to exurban/urban increase	
Rural I and rural II categories	Exurban/urban categories
No housing units	1.7 to 10 acres/housing unit
> 80 acres/housing unit	0.6 to 1.7 acres/housing unit
50 to 80 acres/housing unit	< 0.6 acres/housing unit
40 to 50 acres/housing unit	Urban/built-up[a]
30 to 40 acres/housing unit	
20 to 30 acres/housing unit	
10 to 20 acres/housing unit	

[a] This class was added in version 3 of SERGoM and delineates commercial, industrial, and transportation land.

Western United States, ground-water well density. The remaining operational elements of SERGoM remain largely as described in Theobald (2005). The two types changes in residential housing density recognized in the FOTE project were cross-walked to the 11 housing density classes included in version 3 of SERGoM (table 4).

Residential Development on Shrub/Scrub Woodland

In the FOTE 1 analysis, five 1992 NLCD land cover classes—33 "transitional," 41 "deciduous forest," 42 "evergreen forest," 43 "mixed forest," and 91 "woody wetlands"—were treated as forest land. For both the 1992 and 2001 NLCDs, the land cover classes used to represent forest land resulted in forest area estimates similar to the national-level USDA Forest Service Forest Inventory and Analysis (FIA) estimates of forest area. However, many areas of the Western United States are dominated by woodland that does not meet the FIA definition of forest, and some portion of that woodland is likely not included in the NLCD classes used to identify forest. Although not considered forest by FIA definition, woodlands do have some characteristics consistent with forested settings. To examine the impact of exclusion of some woodland on the FOTE 1 results, we quantified projected

residential development (table 4) on private, unprotected areas of 2001 NLCD class 52 "shrub/scrub." The shrub/scrub NLCD class is described as "Areas dominated by shrubs; less than [16.5 feet] tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions" (MRLC 2007).

Here, we adopted the most liberal definition of woodland by examining projected residential development on all private, unprotected shrub/scrub acres. The same procedures for estimating projected residential development on forest land described in the previous section were duplicated using the shrub/scrub layer. The augmented PAD (see footnotes 3 and 4) was used to identify areas of the shrub/scrub land cover located on private, unprotected lands. The resulting area of shrub/scrub projected to experience residential development was summarized and reported by watershed.

Some rural residential development occurring at very low densities was not recognized in past FOTE research.

Very-Low-Density Residential Development

Residential development on rural lands has been the focus of FOTE research. However, some rural residential development occurring at very low densities was not recognized in past FOTE research. Although the total number of housing units associated with very-low-density residential development may be small, such development could affect extensive areas of the landscape by changing the patterns of traditional rural land use and visual qualities of the landscape and by modifying ecological processes.

To quantify the projected extent of very-low-density increases on private forest land, we identified areas of projected residential development among the lowest density classes of SERGoM that correspond to the rural I FOTE housing density category (table 1). Specifically, we examined projected increases in residential development among the following SERGoM density classes: no private development/more than 80 acres per housing unit (SERGoM classes 0 and 1), 50 to 80 acres per unit (SERGoM class 2), and 40 to 50 acres per unit (SERGoM class 3). Increases **among** those housing density classes would not have been recognized in previous FOTE research; increases in housing density **from** those classes to 40 acres or less per housing unit (i.e., a more dense settlement threshold than for the very-low-density classes) were recognized in the previous FOTE research. Housing classes 0 and 1 were combined in this analysis because the difference between the two in SERGoM output is somewhat artificial.

Three changes among the very-low-density classes between 2000 and 2030 were recognized in this sensitivity analysis: (1) from no private development/more than 80 acres per housing unit to the class of 50 to 80 acres per unit, (2) from no private

development/more than 80 acres per housing unit to the class of 40 to 50 acres per unit, and (3) from 50 to 80 acres per unit to the class of 40 to 50 acres per unit. The resulting layer of projected very-low-density development between 2000 and 2030 was overlain with the private, unprotected forest and shrub/scrub spatial data. The total area of projected very-low-density development on private, unprotected forest and shrub/scrub lands was then summarized and reported by watershed.

Screening Criteria for Watersheds

Screening criteria for inclusion of watersheds in FOTE 1 mapping (fig. 1) were adopted to avoid classifying watersheds with little private forest as being at high risk from projected forest-land development. In FOTE 1, only those watersheds with at least 10 percent of the watershed land area in forest cover and half of the forest cover in the watershed privately owned were included in mapping of the FOTE 1 results. In recent FOTE analyses examining the benefits of and threats to private forests, the screening criteria for mapping watersheds have been revised to at least 10 percent forest cover and containing at least 10,000 acres of private forest. To gauge the impact of the screening criteria, we quantified increases in projected residential development (table 4) on private, unprotected forest land for watersheds that (1) failed to meet the FOTE 1 screening criteria and (2) failed to meet the subsequent revised watershed screening criteria. Additionally, we compared the watersheds included or excluded by the original and revised criteria. Note that for sensitivity analysis factors 1 through 3 (see pages 1 and 2) we reported projected residential development on all watersheds regardless of whether watersheds met either screening criteria.

Results

Updated Data and Revised Model

For the contiguous United States, in all watersheds, approximately 57 million acres (15 percent) of private forest land was projected to experience increases in residential development between 2000 and 2030. Increases from rural I or II to exurban/urban housing densities account for 30.1 million acres of this projected increase and rural I to rural II increases account for the remaining 26.9 million acres. Of the forest land projected to experience either type of residential increase, 50.6 million acres (89 percent) was in the East—representing 16 percent of the eastern private, unprotected forest land. The 6.4 million acres of projected residential development on forest land in the Western States represents 9 percent of the private, unprotected

forest in the West. On average, watersheds in the Eastern States were each projected to experience residential increase on 46,000 acres of private forest land. Watersheds in the West were projected to experience, on average, residential increase on 6,000 acres of private forest land. However, the area of private forest land projected to experience residential development differed widely from watershed to watershed.

Using the revised model and updated data, we projected residential development on private forest land between 2000 and 2030 to be 57 million acres.

Using the revised model and updated data [and incorporating all the appropriate SERGoM housing density classes (table 4)], we projected residential development on private forest land between 2000 and 2030 to be 57 million acres, 13.2 million acres (30 percent) more than the **baseline** of 43.8 million acres estimated by replicating the FOTE 1 analysis.[7] However, recall that the acres of projected change reported in FOTE 1 were estimated under modified methods where not all housing density change was counted. If the modified method had **not** been adopted in FOTE 1, use of the updated data and revised model would have actually yielded a **decline** of about 15.7 million acres compared to that reported previously (57.0 million acres compared to 72.7) in the area of private forest land projected to experience substantial residential development.

Using the revised model and updated data, projected increase from rural I or II to exurban/urban was 8.7 million acres (40 percent) greater than that found in the **baseline** FOTE 1 analysis (table 5). Similarly, the revised projected increase from rural I to rural II was 4.5 million acres (20 percent) greater than that found in the **baseline** FOTE 1 analysis. On an absolute basis, the updated data and revised model yield a greater difference from the **baseline** for eastern watersheds (an additional 10.9 million acres of projected development) as compared to western watersheds (an additional 2.4 million acres of projected development). However, on a percentage basis when compared to the **baseline**, the use of updated data and revised model led to a 58 percent increase in projected forest-land development for the West and a 27 percent increase for the East.

On average, the updated data and revised model yield a projection of private forest-land area to undergo residential development that was 6,000 acres greater per watershed than that estimated in the **baseline** (table 5). This average difference of 6,000 acres represented approximately 3 percent of the 182,000 acres of private, unprotected forest land in the average watershed in the contiguous United States. However, figures differed widely across watersheds, with the minimum difference between the revised projections and the **baseline** being -195,000 acres and the

[7] The figure of 43.8 million acres of projected residential development in the replicated FOTE 1 analysis is slightly less than the figure of 44.2 million acres of projected change reported in FOTE 1 (Stein et al. 2005).

Table 5—Differences in the areas of projected residential development (2000 to 2030) between analysis using updated data and revised model and the baseline from the original Forests on the Edge report (Stein et al. 2005)[a]

	Change type		
	Rural I to rural II	**Rural I or II to exurban/urban**	**Both**
	Thousand acres		
Contiguous U.S. watersheds			
Total	4,523	8,697	13,220
Watershed average	2	4	6
Eastern watersheds			
Total	4,526	6,340	10,866
Watershed average	4	6	10
Watershed minimum	-97	-226	-195
Watershed maximum	162	211	272
Western watersheds			
Total	-3	2,357	2,354
Watershed average	0	2	2
Watershed minimum	-29	-40	-57
Watershed maximum	18	144	158

[a] See sensitivity analysis text regarding the interpretation of these changes.

maximum difference being 272,000 acres—both watersheds having the minimum and maximum difference are located in the East. On average, the use of updated data and revised model had a greater impact on an absolute basis for the eastern watersheds (an average difference of 10,000 acres per watershed) than for the western watersheds (an average difference of 2,000 acres per watershed). However, on a percentage change basis, the updated data and revised model resulted in an average difference between the revised projections and the **baseline** of 43 percent in the western watersheds and 6 percent in the eastern watersheds.

Using the updated data and revised model and limiting projections to only those watersheds meeting the screening criteria used in FOTE 1 and mapped in fig. 1, we projected 52.1 million acres of residential development on private forest land. Residential development prompting shifts from rural I or II to exurban/urban was projected on 25 million acres of private forest land and from rural I to rural II on 27.1 million acres of private forest land in the watersheds meeting the FOTE 1 screening criteria.

Mapping of the projected increases for this sensitivity analysis factor aggregated at the watershed level resulted in an image (fig. 2) that was quite similar in pattern to the image published in FOTE 1 (fig. 1). The majority of watersheds

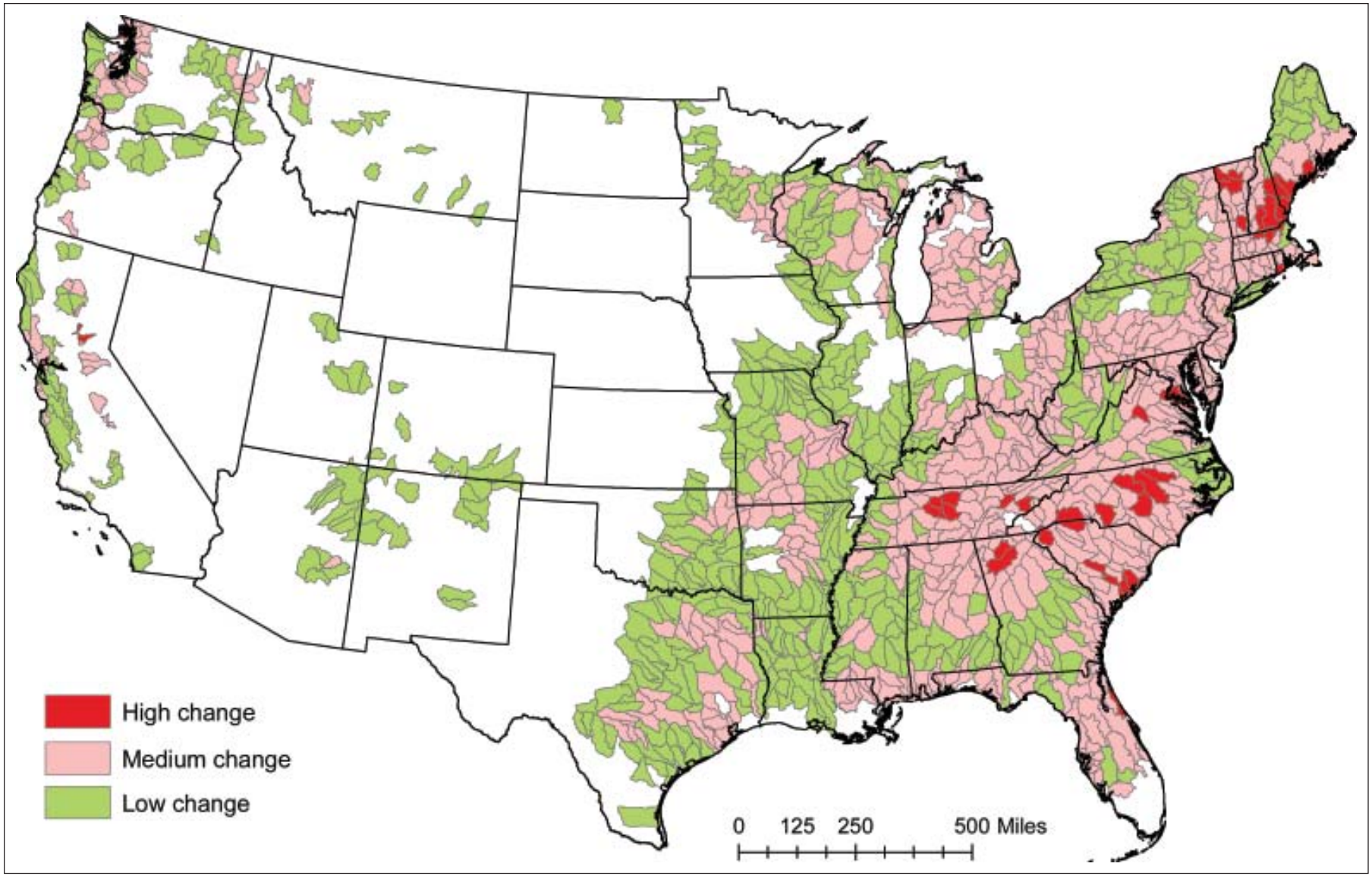

Figure 2—Watersheds in which housing density is projected to increase on private, unprotected forests between 2000 and 2030 estimated by using updated ownership and land cover data and the revised version of the Spatially Explicit Regional Growth Model. High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area. White area represents watersheds not meeting the screening criteria and excluded from mapping.

projected to experience the greatest residential development on private, unprotected forest land are still located in the Southeast and Northeast; some watersheds in the Western States are projected to have medium or high amounts of change. Approximately 68 percent (697) of the private forest-land watersheds mapped in FOTE 1 remained in the same classification (i.e., low change, medium change, and high change) using the updated data and revised model compared to their classification in FOTE 1 (table 6). However, just 7 of the 26 watersheds classified as "high change" in FOTE 1 remained classified as high change when the analysis was completed using the updated data and revised model. The majority of those watersheds moving out of the "high change" class became classified as "medium change." An additional 27 watersheds that previously were classified as "medium change" and 3 previously classified as "low change" in FOTE 1 were classified in the "high change" category when using the updated data and revised model. All but one of the watersheds moving into the "high change" category were in the East.

Residential Development on Shrub/Scrub Woodland

Based on the combined 2001 NLCD and augmented PAD, approximately 204 million acres of private, unprotected land was classified as shrub/scrub. Much shrub/scrub area was in the West, particularly in Wyoming, Arizona, New Mexico, and eastern Washington and Oregon (fig. 3). In addition, a substantial amount of private, unprotected shrub/scrub area was in western Texas, considered part of the East in this study. In the contiguous United States, in all watersheds, increases in residential development were projected on 9.6 million acres of rural private, unprotected shrub/scrub—5.8 million of those acres being in the West (table 7). Approximately 6.4 million acres of that projected increase involved residential development

Table 6—Number of watersheds by change classification for the original Forests on the Edge report (Stein et al. 2005) and for analysis using updated data and a revised model

	Updated data and revised version of SERGoM[a]			
Original report	**Low change[b]**	**Medium change[b]**	**High change[b]**	**Row sum**
Low change	420	209	3	632
Medium change	71	270	27	368
High change	5	14	7	26
Column sum	496	493	37	1,026

[a] Spatially Explicit Regional Growth Model (Theobald 2005).

[b] High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area.

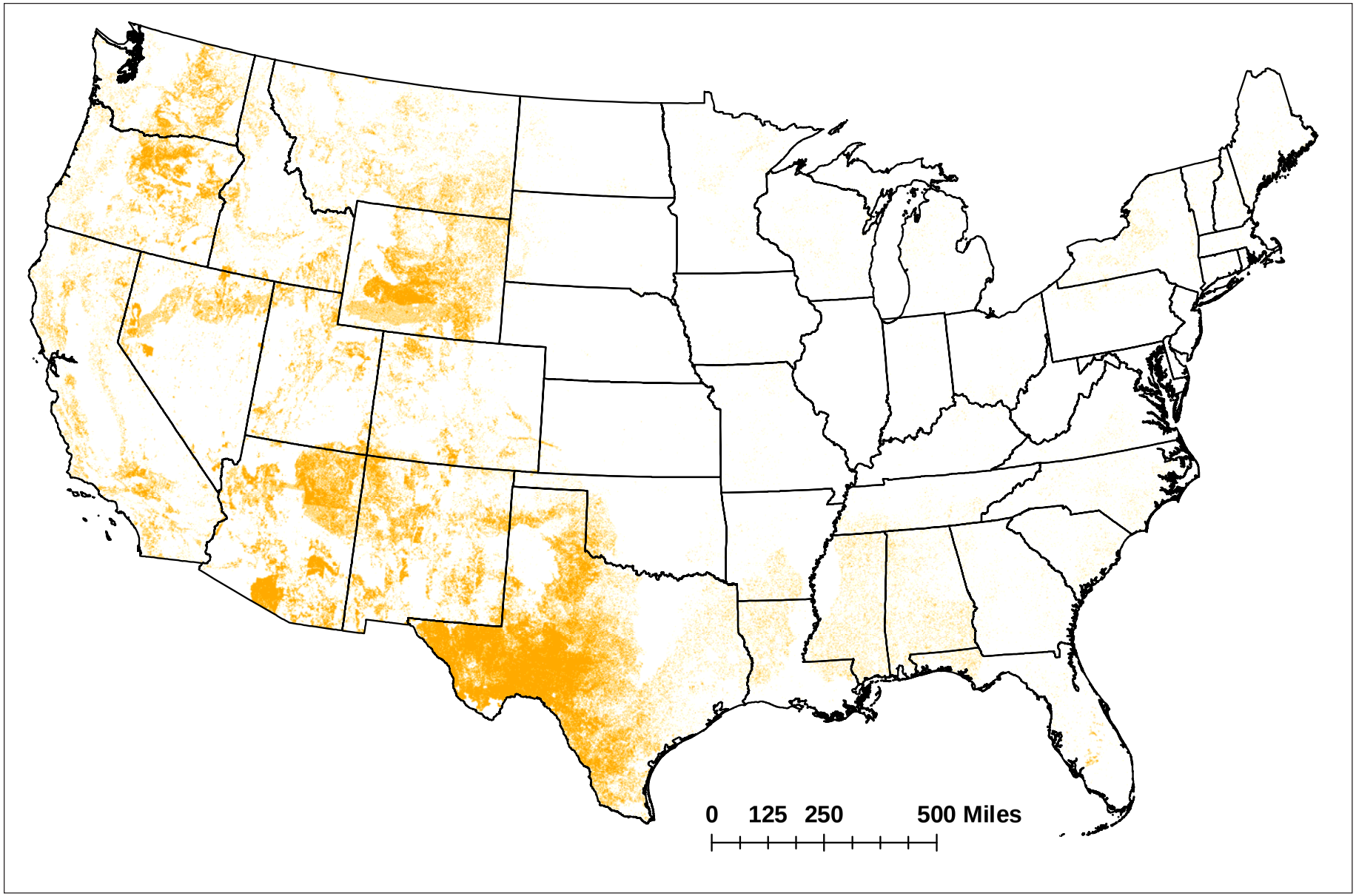

Figure 3—Privately owned, unprotected shrub/scrub land cover in the contiguous United States. Data sources: land ownership—augmented version of the Protected Areas Database (see footnotes 3 and 4); land cover—Homer et al. 2004.

Table 7—Projected residential development on private, unprotected shrub/scrub land, 2000 to 2030

	Change type		
	Rural I to rural II	Rural I or II to exurban/urban	Both
	Thousand acres		
All watersheds			
Total	3,193	6,439	9,633
Watershed average	1	3	5
Eastern watersheds			
Total	1,680	2,175	3,855
Watershed average	1	2	3
Watershed minimum	0	0	0
Watershed maximum	24	66	82
Western watersheds			
Total	1,513	4,265	5,778
Watershed average	1	4	6
Watershed minimum	0	0	0
Watershed maximum	35	153	176

Numbers may not sum across owing to rounding.

The percentage of total land area projected to undergo residential development on rural private, unprotected shrub/scrub was not extensive.

moving lands from either the rural I or II to exurban/urban densities. At the watershed level, the percentage of total land area projected to undergo residential development on rural private, unprotected shrub/scrub was not extensive, with no watershed having more than 15 percent. Based on the low, medium, and high classification scheme adopted in figure 2 of the FOTE 1 report, no watershed would be classified in the "high change" category solely owing to projected residential development on private shrub/scrub lands (fig. 4). The majority of watersheds classified into the "medium change" category owing to projected woodland development were located in southern Arizona and southern California. In a later section of this report, we examine the resulting projections of residential development for individual watersheds if projected development on forest and woodland is combined.

Counting projected development only in watersheds mapped in the FOTE 1 analysis, 4.5 million acres of rural private, unprotected shrub/scrub were projected to undergo residential development between 2000 and 2030—1.2 million acres in the East. With the FOTE 1 screening criteria, the watershed projected to have the greatest percentage of land area experiencing residential development on rural private, unprotected shrub/scrub was in central Texas and had 12 percent of watershed land area involved.

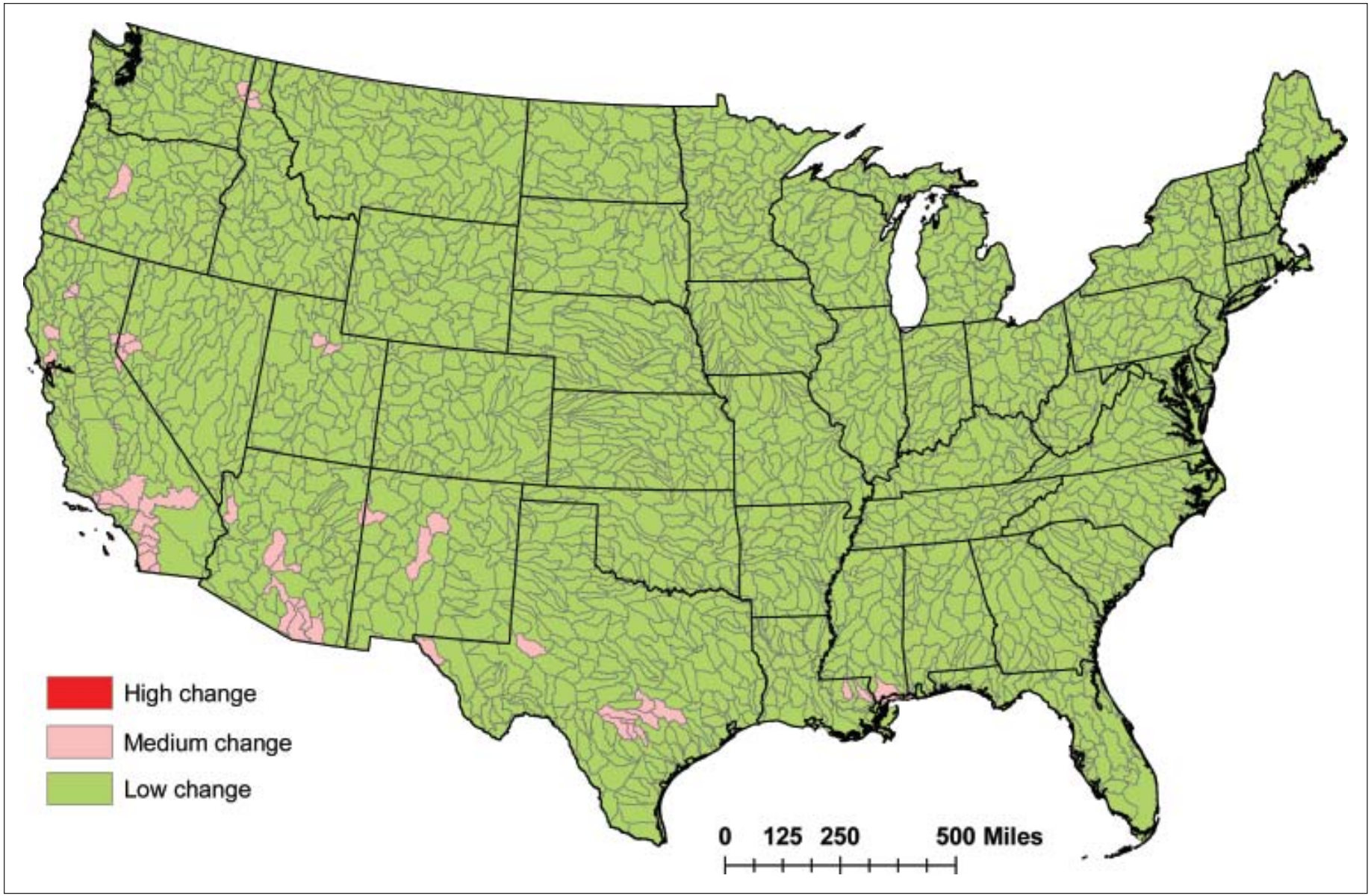

Figure 4—Watersheds in which housing density is projected to increase on private, unprotected shrub/scrub between 2000 and 2030 estimated by using updated ownership and land cover data and the revised version of the Spatially Explicit Regional Growth Model. High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area.

Very-Low-Density Residential Development

Increases in residential development among the very-low-density housing classes were projected on 26.5 million acres of private, unprotected forest land in the contiguous United States (table 8). More than 94 percent (25 million acres) of that area was in the East. Counting only projected development in the subset of watersheds meeting the screening criteria in the FOTE 1 analysis, 24.7 million acres of private, unprotected forest land was projected to experience residential development by 2030 but remain within the rural I density category. Again, the vast majority (24 million acres) of that area is in the East. On average, 3 percent of the land area of each watershed was projected to experience residential development within the rural I density category on private, unprotected forest land. In the East, the watershed projected to have the highest percentage of its land area experience private forest-land residential development within the rural I density category had 27 percent of its land area involved, in contrast to 7 percent for the most affected watershed in the West. Given the high, medium, and low classification scheme used in FOTE 1, most of the watersheds projected to have medium percentages of watershed land area experiencing very-low-density residential development on forest land are in the East (fig 5). Only four watersheds were projected to have high percentages of watershed land area experience very-low-density residential development on forest land, and all are in the East.

Table 8—Projected very-low-density residential development on private, unprotected forest land, 2000 to 2030

	Thousand acres
All watersheds	
Total	26,454
Watershed average	13
Eastern watersheds	
Total	25,062
Watershed average	23
Watershed minimum	0
Watershed maximum	256
Western watersheds	
Total	1,392
Watershed average	1
Watershed minimum	0
Watershed maximum	72

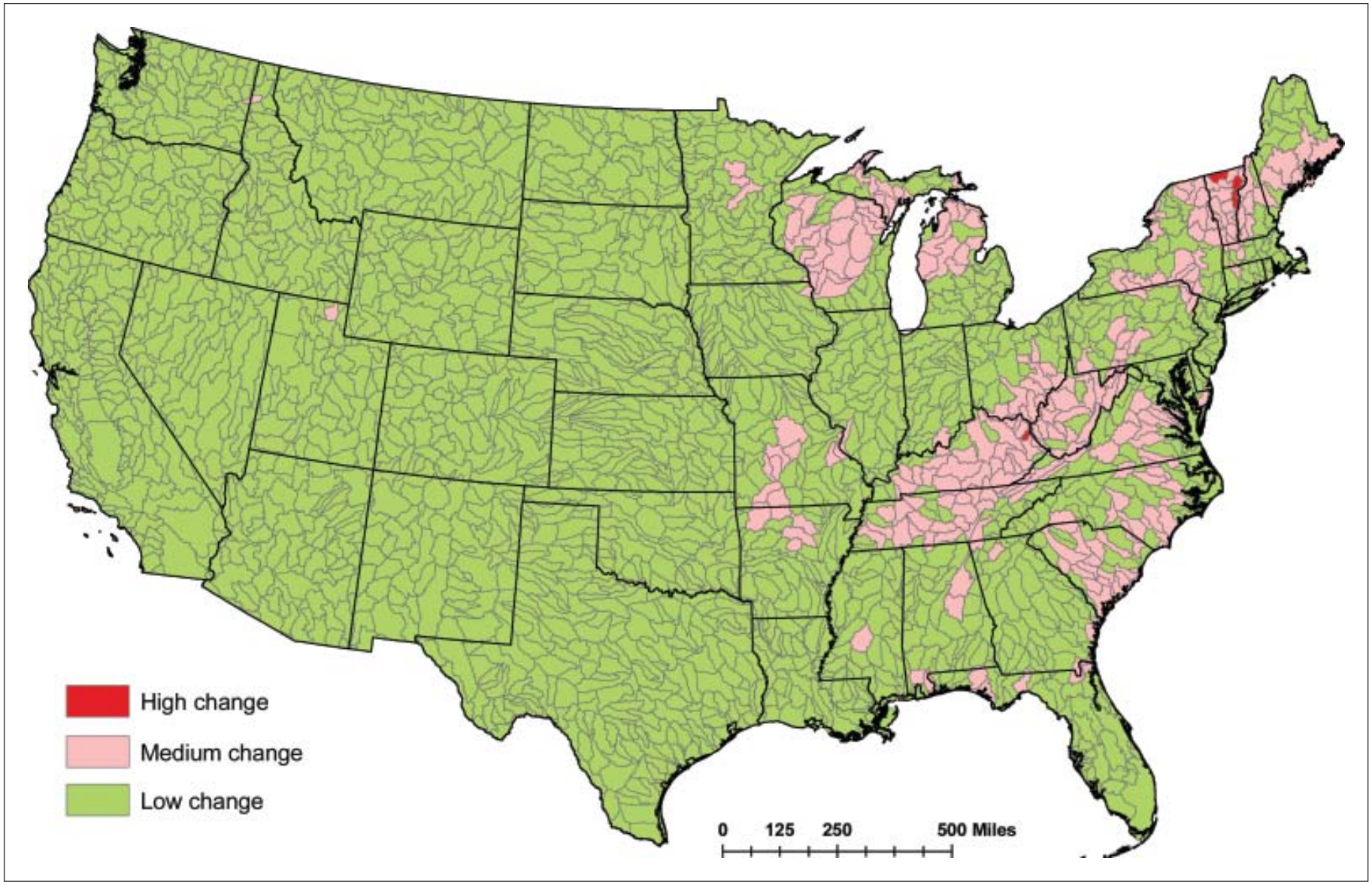

Figure 5—Watersheds in which housing is projected to increase at very low densities (i.e., more than 40 acres/housing unit) on private, unprotected forest land between 2000 and 2030 estimated by using updated ownership and land cover data and the revised version of the Spatially Explicit Regional Growth Model. High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area.

Approximately 2.8 million acres of private, unprotected shrub/scrub land were projected to experience residential development between 2000 and 2030 and remain within the rural I category. About half of those acres are in the Eastern United States—nearly all in southwest Texas. A very limited number of watersheds were projected to have a significant area of very-low-density residential development on private, unprotected shrub/scrub land (fig. 6). No watershed in the very-low-density shrub/scrub analysis was projected to fall in the "high change" category used in figure 2 of the FOTE 1 report.

Screening Criteria for Watersheds

Using the updated land cover and ownership data and changing watershed screening criteria from those in FOTE 1 to the revised criteria resulted in approximately 82-percent agreement in watersheds included in analysis (table 9). Under the revised screening criteria, 368 watersheds that did not meet the FOTE 1 criteria would now be included. Conversely, four watersheds that did meet the FOTE 1 screening criteria would now be excluded under the revised screening criteria. Those four watersheds each have less than 10,000 acres of private forest land.

Watersheds excluded from FOTE 1 accounted for 4.9 million acres of projected residential development on rural private forest lands.

The screening criteria adopted in the FOTE 1 report excluded just more than half (1,081) of the watersheds in the contiguous United States from FOTE 1 mapping.[8] Watersheds excluded from FOTE 1 accounted for 4.9 million acres of projected residential development on rural private forest lands (or approximately 9 percent of the 52 million acres of private forest land in those watersheds) based on the updated data and revised model (table 10). The number of acres projected to experience residential development on private forest land in watersheds excluded from FOTE 1 was slightly greater in the West than in the East. On average, residential development was projected for approximately 4,500 acres of forest land per watershed, although watershed-specific figures differed widely. Of the watersheds not meeting the FOTE 1 screening criteria, none had more than 14 percent of land area projected to experience residential development on rural private forest land (fig. 7); the average for excluded watersheds was 0.6 percent—1.1 percent in the East and 0.4 percent in the West.

Revised criteria for selecting watersheds resulted in the exclusion of 35 percent (741) of the watersheds in the contiguous United States (table 9). Excluded watersheds accounted for 0.9 million acres of projected residential development on rural

[8] The figure of 1,081 watersheds differs from that shown in table 9 because the 1992 NLCD and version 2 of the PAD were used in FOTE 1.

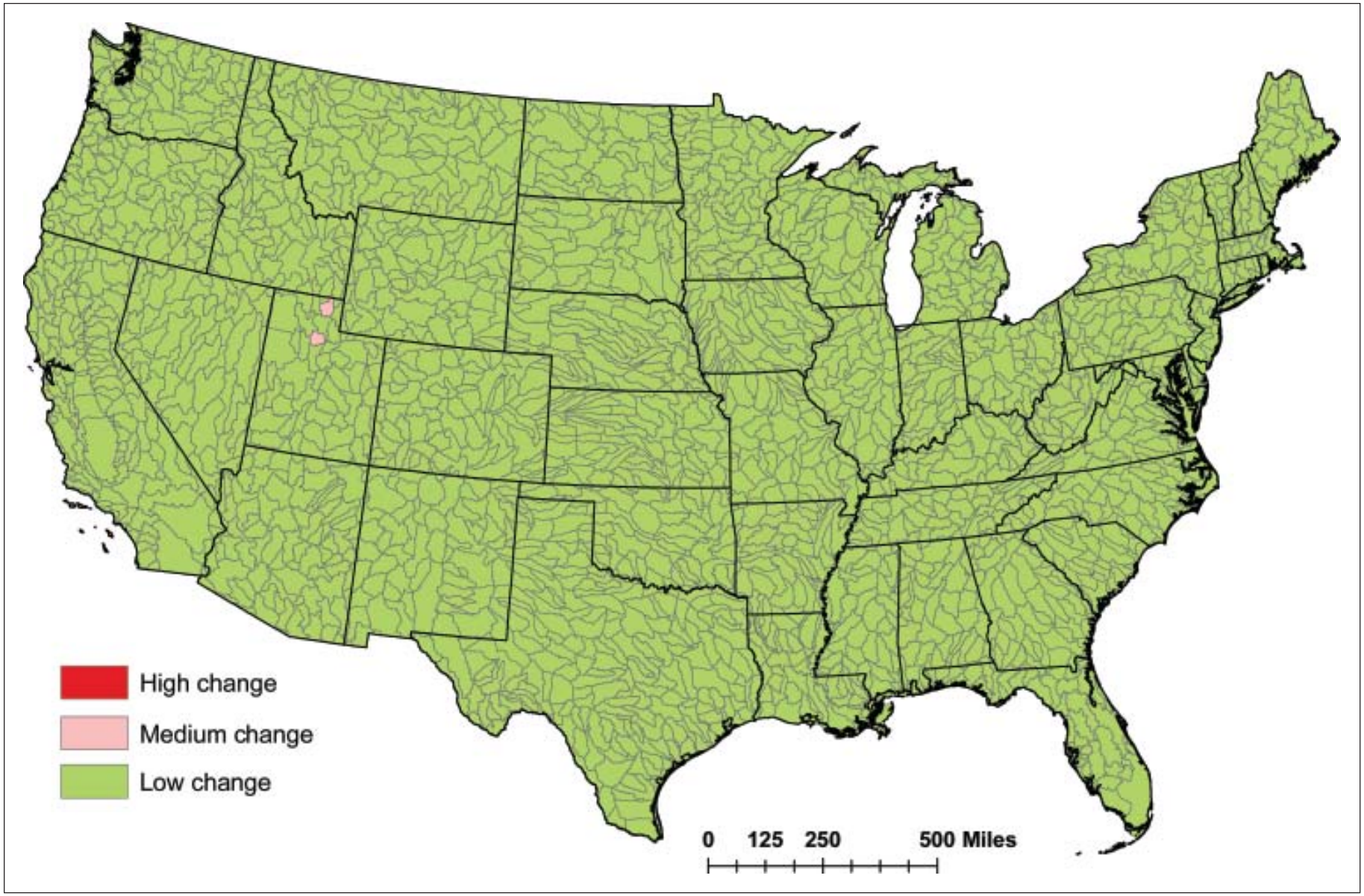

Figure 6—Watersheds in which housing is projected to increase at very low densities (i.e., more than 40 acres/housing unit) on private, unprotected shrub/scrub between 2000 and 2030. High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area.

Table 9—Comparison of watersheds excluded between the original screening criteria in the first Forests on the Edge report (Stein et al. 2005) and the revised screening criteria using updated land cover and ownership data

	Revised screening criteria		
Original screening criteria	**Excluded**	**Included**	**Row sum**
Excluded	737	368	1,105
Included	4	1,002	1,006
Column sum	741	1,370	2,111

Table 10—Projected residential development (2000 to 2030) on private, unprotected forest land associated with watersheds excluded from Forests on the Edge analysis under alternate screening criteria

	Rural I to rural II	**Rural I or II to exurban/urban**	**Both**
		Thousand acres	
Excluded watersheds, original criteria			
Western United States	774	1,914	2,688
Eastern United States	1,099	1,111	2,210
Sum	1,873	3,025	4,898
Excluded watersheds, revised criteria			
Western United States	148	209	357
Eastern United States	276	263	539
Sum	424	472	896

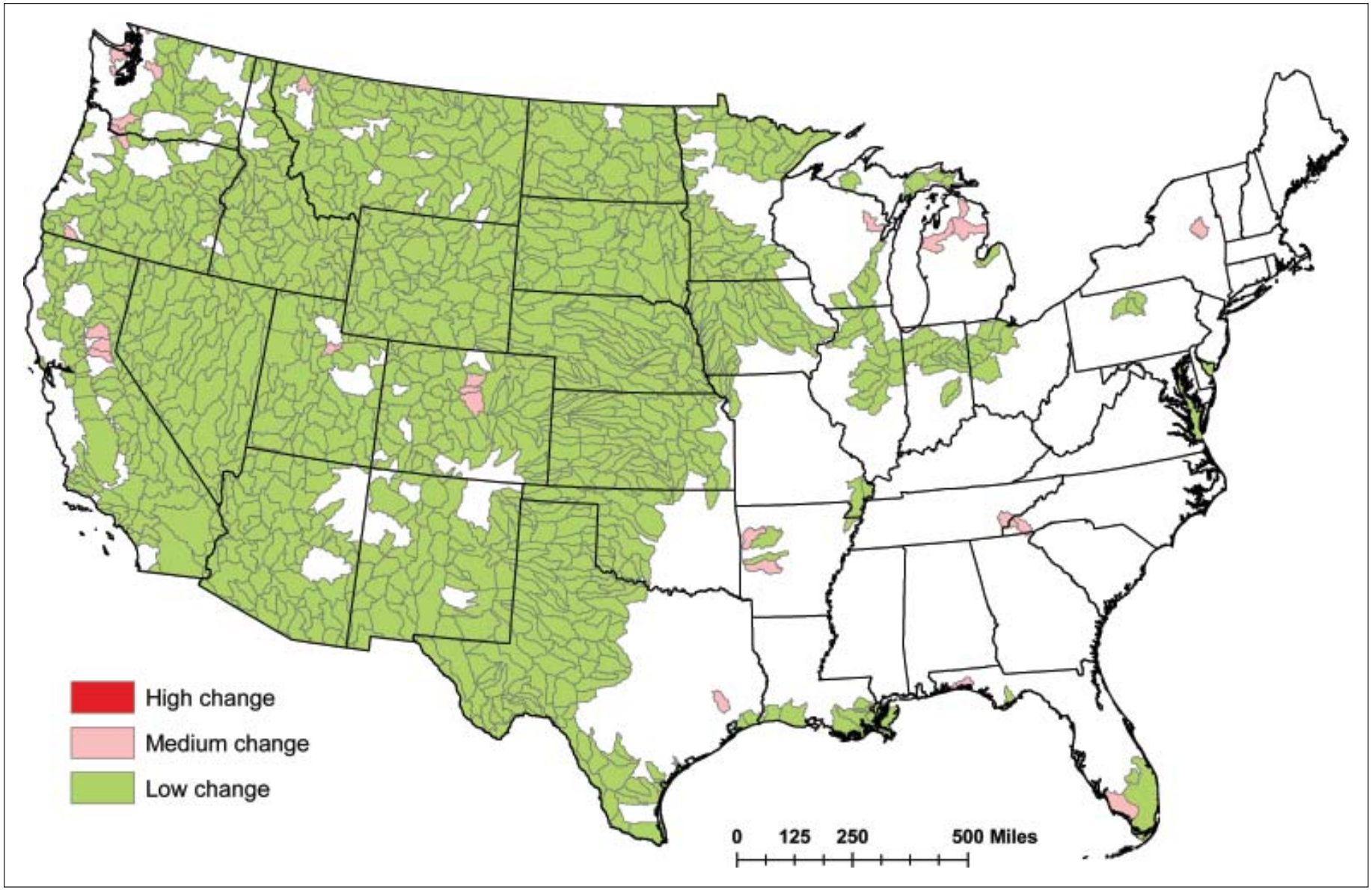

Figure 7—Projected change in housing density on private, unprotected forests for watersheds not selected for mapping in the original Forests on the Edge report (Stein et al. 2005), 2000 to 2030. High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area.

private forest lands, using the updated data and revised model (table 10). A little more than half of those acres are in eastern watersheds. On average, about 1,200 acres of residential development was projected per watershed on private, unprotected forest land in the watersheds excluded under the revised criteria. Under the revised screening criteria, no excluded watershed had more than 5 percent of its land area projected to experience residential development on private forest; the average was 0.2 percent of watershed area compared to 0.6 percent with the FOTE 1 criteria.

The FOTE 1 results are most sensitive to the use of the updated data and revised version of SERGoM.

Discussion

Updated Data and Model Revisions

The FOTE 1 results are most sensitive to the use of the updated data and revised version of SERGoM (Stein et al. 2005). The augmented version of the PAD helped to identify a more comprehensive set of state and local government lands as well as privately owned land under some form of protection from development. The revised version of SERGoM projected residential development patterns that were more concentrated around existing development and road networks compared to output from previous versions of SERGoM. All else being equal, projected development under the updated data and revised model would have led to a reduction in the acres of projected residential change on forest land from FOTE 1. However, because some increases in housing density across FOTE housing categories were not counted in FOTE 1 (table 2), the acres of forest land projected to experience residential development increased in this sensitivity analysis compared to what was reported in FOTE 1.

The absolute increase in area of projected residential development on private forest land estimated using the updated data and revised model was much greater for watersheds in the East (10.9 million acres) than in the West (2.4 million acres). However, on a percentage basis, the increase was greater in the western watersheds (58 percent versus 27 percent in the East). The pattern of absolute increase between the western and eastern watersheds is likely more related to the extent of private forest and greater population in the East than a differential impact of the updated data and revised version of SERGoM. The location of watersheds projected to have the highest percentages of their land area involved in residential development on rural private forest remained largely the same when using the revised model and updated data as that reported in FOTE 1. Given the updated data and revised model,

watersheds with the greatest percentages of watershed land area projected to undergo residential development on forest land are still primarily in the East, particularly in the Southeastern States. However, 14 (54 percent) of the individual watersheds classified as "high change" in figure 2 of FOTE 1 were classified as "medium change" using the updated data and revised model (table 6).

In the FOTE 1 report, the top 15 watersheds with the largest area of projected residential development on forest land were all in the East (Stein et al. 2005). On average, projected area of residential development on forest land in the original FOTE 1 top 15 watersheds changed by 39 percent (in absolute value terms) when using updated data and revised model, with the largest changes for the Lower Leaf (a 80-percent change) and North Branch Potomac (a 76-percent change) watersheds (table 11). Based on the updated data and revised model, the new set of top 15 watersheds with the largest areas of projected change are all still in the East (table 12). However, only three watersheds included in the FOTE 1 top 15 are included in the new top 15 list. The area of change projected for individual watersheds is

Table 11—Top 15 watersheds projected to have most change in housing density on forest land (2000 to 2030) as reported in the original Forests on the Edge report (Stein et al. 2005)

		Projected area of change		
Watershed	**State(s)**	**Original Forests on the Edge**	**Updated data/ revised model**	**Percentage change**
		Thousand acres		*Percent*
Lower Penobscot	Maine	310	135	-56.6
Deep	North Carolina	270	183	-32.1
Upper Oconee	Georgia	269	278	3.2
Etowah	Georgia	266	331	24.2
Pamunkey	Virginia	262	167	-36.1
Lower Cumberland	Kentucky, Tennessee	259	203	-21.6
Upper Roanoke	Virginia	257	155	-39.6
Lower Leaf[a]	Mississippi	243	48	-80.1
Lower Pee Dee	North Carolina, South Carolina	239	136	-43.1
Little Kanawha	West Virginia	226	56	-75.1
Middle Hudson	New York, Massachusetts	221	187	-15.5
Upper Green	Kentucky	216	141	-34.5
Lower Androscoggin	Maine, New Hampshire	214	200	-6.6
Lower Kennebec	Maine	210	308	46.7
North Branch Potomac	Maryland, Pennsylvania, West Virginia	209	49	-76.7

[a] The Lower Leaf watershed was referred to as the Lower Lead watershed in the first Forests on the Edge report (Stein et al. 2005).

Table 12—Top 15 watersheds projected to have most change in housing density on forest land (2000 to 2030) based on updated data and revised version of SERGoM[a]

Watershed	State(s)	Projected area of change		
		Original Forests on the Edge	Updated data/ revised model	Percentage change
		Thousand acres		*Percent*
Merrimack	New Hampshire, Massachusetts	144	416	188.5
Middle Chattahoochee-Lake Harding	Georgia, Alabama	129	346	168.8
Piscataqua-Salmon Falls	New Hampshire, Maine	136	345	154.1
Etowah	Georgia	266	331	24.2
Upper Neuse	North Carolina	169	323	91.4
Upper Broad	South Carolina, North Carolina	168	321	91.1
Lower St. Johns	Florida	189	314	66.4
Lower Kennebec	Maine	210	308	46.7
Upper Ocmulgee	Georgia	205	306	49.7
Saluda	South Carolina	171	295	72.3
Upper Catawba	North Carolina, South Carolina	134	280	108.6
Upper Oconee	Georgia	269	278	3.2
Saco	New Hampshire, Maine	176	260	47.5
Middle Coosa	Alabama	199	258	29.3
Lower Kentucky	Kentucky	183	244	33.5

[a] Spatially Explicit Regional Growth Model.

generally greater in the top 15 published here compared to the FOTE 1 top 15. Larger areas in table 12 compared to table 11 can be traced to the modified approach adopted in FOTE 1 (Stein et al. 2006) that excluded small increases in residential development from the change estimates (table 2).

Residential Development on Shrub/Scrub Woodland

Based on the data currently used in FOTE analyses, there are 365 million acres of private, unprotected forest in the contiguous United States and we project that 15 percent (57 million acres) will experience substantial increases in housing density on rural lands between 2000 and 2030. Comparatively, there are 204 million acres of private, unprotected shrub/scrub land in the contiguous United States, and we project that 5 percent (9.6 million acres) will experience significant increases in residential development on rural lands by 2030. No watershed in the contiguous United States had more than 15 percent of its land area projected to have development on rural private shrub/scrub, whereas 105 watersheds were projected to have more than 15 percent of their land area with development on rural private forest land.

With a greater extent of land area in shrub/scrub, it was anticipated that consideration of residential development on shrub/scrub land would lead to a more extensive area of projected residential development in the West. Alone, projected residential increase on rural private shrub/scrub did not yield widespread areas of "medium change" or any areas of "high change" in watersheds in the West (fig. 4). We combined areas of projected change for both private, unprotected forest land and shrub/scrub for individual watersheds, which yields an image of projected change (fig. 8) that is still largely similar to figure 2 of FOTE 1 (fig. 1). Nationwide, 71 (5 percent) watersheds that are classified as "low change" when considering residential development only on forest land are classified as "medium change" when counting residential development on both private, unprotected forest and shrub/scrub (table 13). Likewise, 16 (3 percent) watersheds classified as "medium change" based on forest-land residential development are classified as "high change" when combining change on private, unprotected forest and shrub/scrub lands. For the West, 12 watersheds in Utah and Wyoming classified as "low change" and one in northern Idaho/eastern Washington classified as "medium change" for projected forest-land development move up one category (to medium and high change, respectively), when considering residential development on both forest and shrub/scrub.

In this study, we adopted the most inclusive definition of woodland by treating all private, unprotected acres classified in the 2001 NLCD as shrub/scrub as potential woodland. However, it is likely that the majority of lands classified as shrub/scrub are not actually woodland. A cursory examination with satellite imagery of western landscapes where woodland could be present indicates that most of the landscapes with tree cover appear to be classified in one of the forest-land categories

Table 13—Comparison of watershed classifications between inclusion of only private, unprotected forest land versus combined private, unprotected forest and shrub/scrub lands

	Combination of private, unprotected forest and shrub/scrub lands			
Private, unprotected forest only	**Low change[a]**	**Medium change[a]**	**High change[a]**	**Row sum**
Low change	1,477	71	0	1,548
Medium change	0	510	16	526
High change	0	0	37	37
Column sum	1,477	581	53	2,111

[a] High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area.

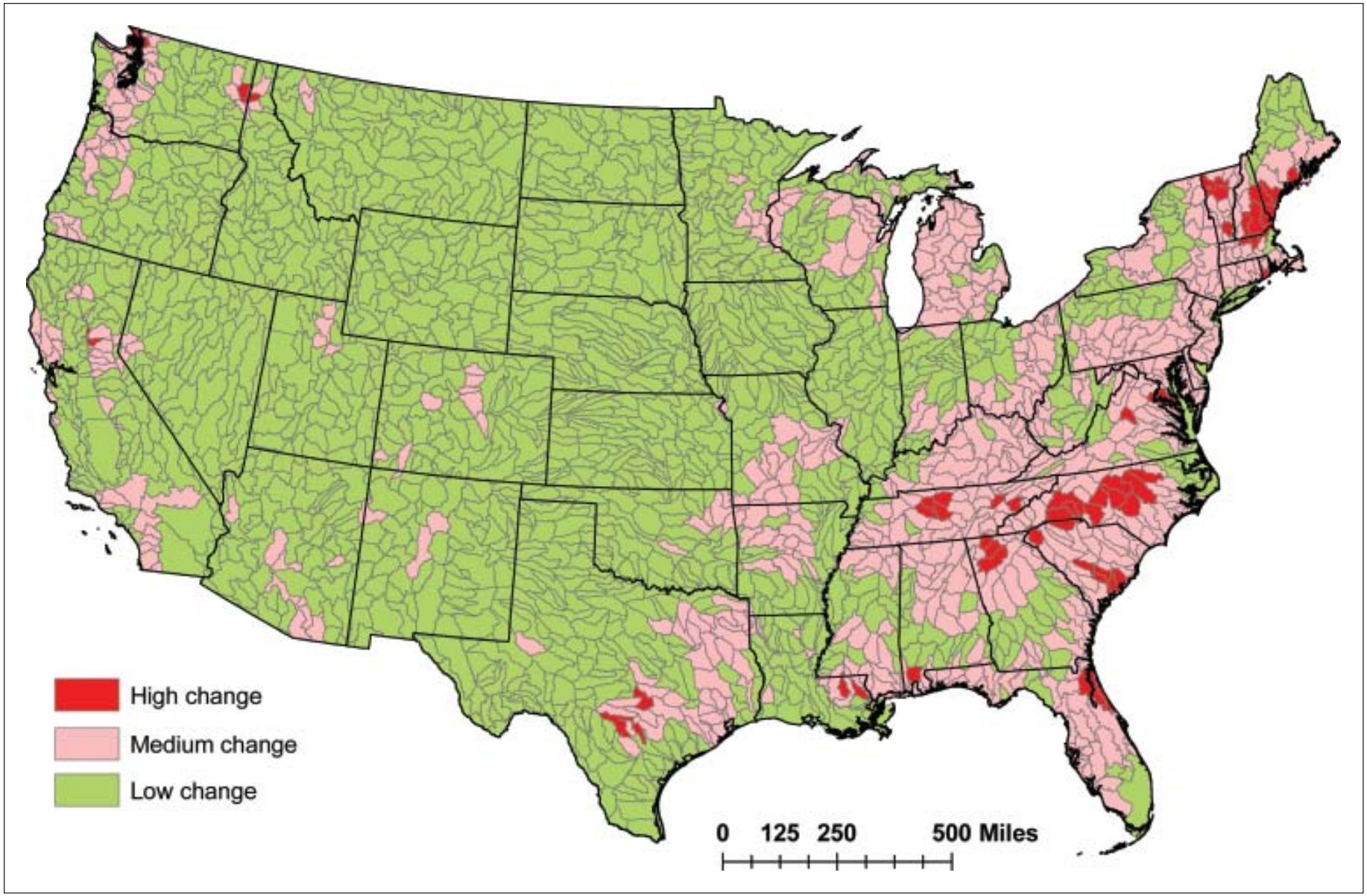

Figure 8—Watersheds in which housing density is projected to increase on private, unprotected forest and shrub/scrub between 2000 and 2030, estimated using updated ownership and land cover data and the revised version of the Spatially Explicit Regional Growth Model. High change: > 19.9 percent of watershed land area, medium change: > 4.9 and ≤ 19.9 percent of watershed land area, low change: ≤ 4.9 percent of watershed land area.

of the NLCD, and the shrub/scrub NLCD classification typically encompasses landscapes covered in small herbaceous vegetation (fig. 9). However, more comprehensive examination is required.

Very-Low-Density Residential Development

A large area of private, unprotected forest land was projected to be involved in very-low-density housing development by 2030 (26.5 million acres). Although the number of housing units involved in this very-low-density development is relatively small, this development likely has significant impacts on ecological processes. The East accounts for nearly all of the projected increases in very-low-density

Although the number of housing units involved in this very-low-density development is relatively small, this development likely has significant impacts on ecological processes.

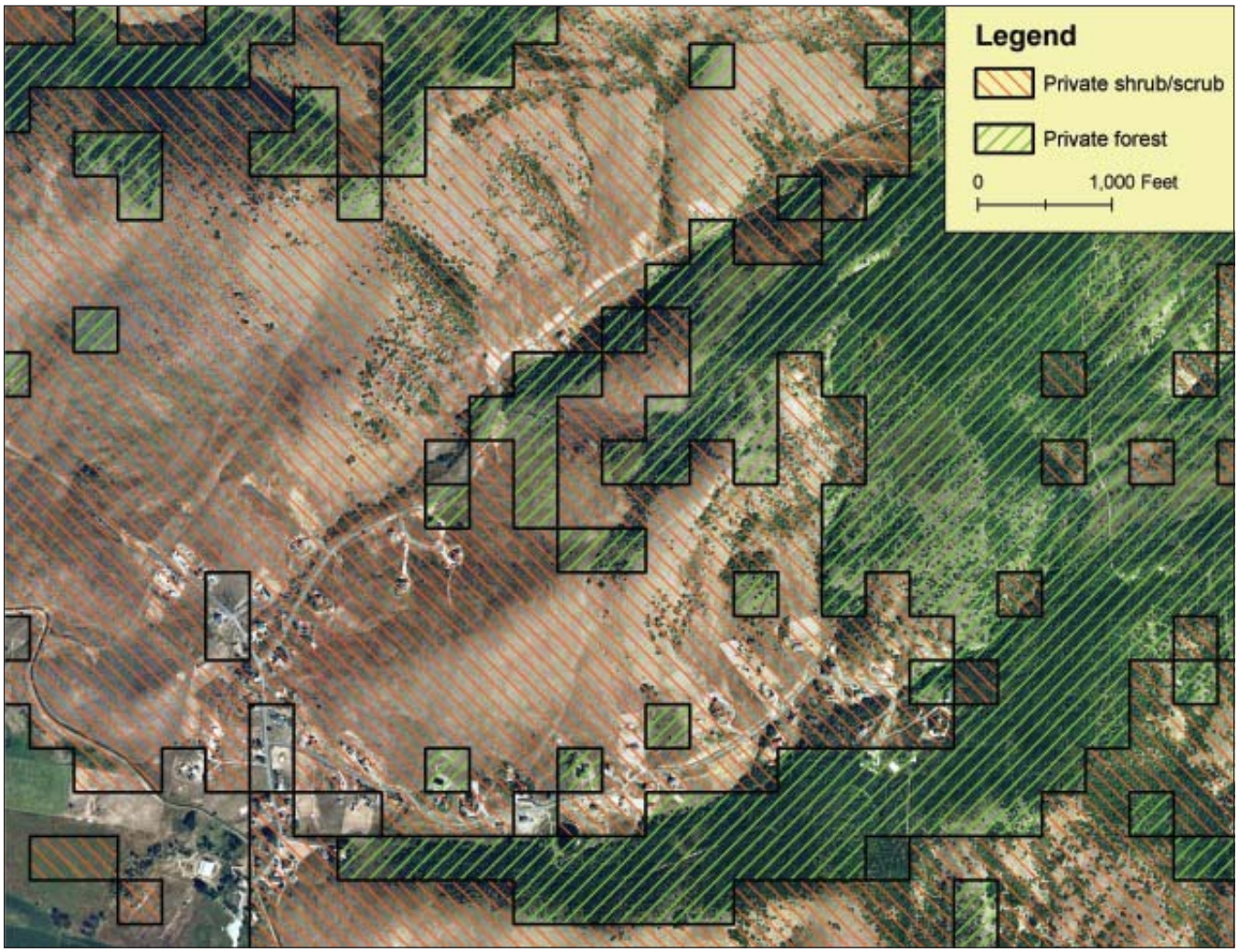

Figure 9—Example of forest and shrub/scrub land cover classification in the 100-meter-resolution (38 feet) resampled version of the 2001 National Land Cover Database used in this analysis, Weber County, Utah.

residential development on private forest land. More than half of the projected increase in very-low-density development in the Eastern States is from the class of more than 80 acres per housing unit to the class of 50 to 80 acres per housing unit. The Eastern States with the greatest extents of their land area projected to be involved in very-low-density development on private forest land are Kentucky (2.0 million acres), Wisconsin (1.8 million acres), Tennessee (1.8 million acres), Missouri (1.2 million acres), West Virginia (1.1 million acres), and Vermont (0.9 million acres).

Approximately 1.4 million acres of very-low-density residential development is projected on private forest land in the Western States. Oklahoma (0.24 million acres), Oregon (0.22 million acres), Utah (0.17 million acres), and Colorado (0.11 million acres) have the greatest amounts of land area projected to be affected. Nearly 900,000 acres of private forest land in the West is projected to change from having almost no housing development (greater than 80 acres per housing unit or no housing units) to having housing densities of between 50 and 80 acres per housing unit between 2000 and 2030.

The majority of projected residential development within the rural I category was in the Eastern United States. This pattern is counter to a common perception that very-low-density residential development is primarily a western issue. A potential explanation for this disparity is that very-low-density residential development in the western landscape may be more visually apparent and have greater implications for the social structure of local communities than the same development in the Eastern States (see Sell and Zube 1986 and Zube and Sell 1986 for helpful discussions of human perceptions of rural change). Residential development in landscapes with few other housing units and sparse vegetation (both conditions that exist in many areas of the West) may be more visually apparent than in landscapes without these characteristics. Additionally, very-low-density development that brings new residents (many of whom may be inmigrants from other regions of the United States or urban areas) might affect the social culture of rural communities that were previously associated primarily with traditional rural production, such as agriculture and forestry. Further, in generally starting from a more undeveloped landscape, early increments of change may seem more dramatic or rapid in the West compared to the East where development has been entrenched in many areas for a relatively long time. The higher percentage of public land in the West may also force development into narrow areas or other confined landscapes; as a result, development may be more concentrated in some areas of private ownership although low for the entire area.

Screening Criteria for Watersheds

Original and revised screening criteria for watershed selection yield fairly consistent sets of watersheds for inclusion in FOTE analyses. However, the revised criteria did allow a greater number of watersheds to be included in FOTE analyses and reduced the amount of projected private forest-land residential development that was not mapped. The original screening criteria excluded approximately 5 million acres of projected residential development from the FOTE 1 mapping; the revised screening criteria excluded only 900,000 acres of residential development from mapping. In aggregate, the original screening criteria excluded more western watersheds (821 watersheds and 2.7 million acres of projected residential development on private forest land) compared to eastern watersheds (260 watersheds and 2.2 million acres of projected residential development). The revised screening criteria exclude 531 watersheds from consideration in the West and 210 from consideration in the East. However, the area of projected residential development on private forest in watersheds excluded by the revised criteria is greater in the Eastern States than in the Western States (540,000 versus 355,000 acres). Although the projected development not mapped as a result of the screening criteria appears high, at the watershed level, the screening criteria had minimal impact. On average, watersheds excluded from mapping in FOTE 1 had 0.6 percent of their land areas projected to experience residential development on private forest land, compared to 0.2 percent under the revised screening criteria. No watershed excluded under the original screening criteria had more than 14 percent of its land area projected to have development on forest land.

Factors Influencing Rural Residential Development

Models of land use typically rely on past behavior and land use patterns to inform expectations about future land use, and the housing density model used in FOTE research is no exception. A number of factors may lead to changes in human behavior that result in future development patterns that differ from our current expectations. Factors such as decreases in real incomes and tightening of credit markets, increasing energy costs and higher commuting costs, and changes in preferences may reduce the demand for residential development in forested areas in the coming decades. Additionally, changes in the demand for traditional or nontraditional production from forests (e.g., cellulosic ethanol) may make it more costly to purchase land in forested areas—thereby slowing residential development on forest land. Changes in rates of residential development on forested lands may occur

uniformly across the country or, more likely, differ by region. Although there is currently uncertainty about future housing markets, residential development in rural landscapes in the United States has been ongoing for decades, and with the population of the United States expected to increase by at least another 130 million people by 2050, resource managers should expect and plan for continued development pressure on many of the Nation's private forests.

Results from FOTE 1 are relatively stable to changes in the assumptions used in the analysis.

Conclusions

Results from FOTE 1 are relatively stable to changes in the assumptions used in the analysis. The FOTE 1 results were most sensitive to the use of updated data and a revised version of the spatial housing density model (SERGoM) (Theobald 2005) used in the analysis. Under those changes, the area of projected residential development increased by 13 million acres over that reported in FOTE 1—a 30-percent increase. However, because not all acres of projected residential development on private forest land were reported in FOTE 1 owing to the exclusion of marginal increases in residential housing density, this comparison is somewhat misleading. If the FOTE 1 analysis had included those marginal housing density increases, that research would have projected 72.7 million acres of residential development on private forest land—15.7 million acres more than that estimated using the updated data and revised model. The top 15 watersheds with the largest areas of developed private forest land that are projected using updated data and the revised model differ appreciably from those identified in FOTE 1. Despite the differences cited above, the regional distribution of watersheds projected to have the greatest percentages of their watershed land areas experience private forest-land development is quite similar between the results using the updated data and revised version of SERGoM and those reported in FOTE 1.

Inclusion of private woodland had relatively minimal impact on the results of FOTE 1, increasing the total area involved in residential development by 4.6 million acres. It is unclear, however, how many of those acres of projected residential development are actually on woodland. Opportunities for future research include using other information (e.g., LANDFIRE vegetation data, digital elevation models, ecoregion maps) to identify the subset of the shrub/scrub NLCD land cover that is most likely to represent woodland and including that subset in future FOTE analyses. However, the addition of a subset of the private, unprotected shrub/scrub layer would likely have very little, if any, impact on the FOTE results, given the limited impacts we found when including **all** the private, unprotected shrub/scrub land cover. Impacts on FOTE results aside, the resource implications and effects on

rural communities resulting from development on shrub/scrub lands are important and worth considering.

Approximately 26 million acres of very-low-density housing development (i.e., more than 40 acres/housing unit) are projected on private forest land. Nearly all of that area is in the East, and inclusion of residential change in the very-low-density range would not have changed the spatial pattern of the FOTE 1 results, East versus West. Future research to examine projected very-low-density residential development and the impact of that development on forest and other open spaces is warranted. Although fewer acres are projected to experience very-low-density residential development in the West compared to the East, development in the West may be more visually predominant given differences in topography, vegetation, and current levels of development. Given the amount of projected very-low-density development and the unique implications of this type of development for ecological processes, resource management, and rural communities, research addressing this development is likely best completed via a comprehensive stand-alone FOTE study rather than by adding a category to the current FOTE housing categories.

The screening criteria adopted in FOTE 1 did exclude from mapping a greater number of watersheds in the Western States than in the Eastern States. However, the watershed-level impact of the screening criteria was relatively limited. At the extreme, an excluded western watershed was projected to have 11 percent of its land area experience residential development on private, unprotected forest land. On average, 0.4 percent of the land areas of excluded western watersheds were projected to experience residential development on private forest land. The revised screening criteria included a number of previously excluded watersheds and resulted in fewer acres of projected residential development on forest land not mapped. Ultimately, FOTE researchers should consider the utility of initially starting with all watersheds and then later use screening criteria to focus on particular policy or resource management questions.

There are several opportunities for future studies that surfaced as a result of the research reported here. First, the output of SERGoM allows for examination of past changes in residential development, and these data may be useful to gauge model accuracy and past patterns of residential development on natural resource lands. Second, the watershed unit of analysis was chosen in the context of the research question posed in FOTE 1, which related to water quality and availability. Given that the research questions addressed in the FOTE program have broadened, there are now opportunities to examine alternate analysis units. Third, as the spatial data

available to identify protected lands become more comprehensive, there are opportunities to update projections of forest-land conversion as well as to further examine the interplay between protected land designation and residential development on adjacent lands. Fourth, in the context of divestiture of forest land from forest industry to private investment entities and of public land sales from states, opportunities exist to improve our understanding of and ability to project residential development on forest-land parcels located far from existing development.

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Metric Equivalents

When you know:	Multiply by:	To get:
Feet	0.305	Meters
Acres	.405	Hectares
Square miles	2.59	Square kilometers

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