CHAPTER 6.

National Update of Forest Fragmentation Indicators, 2001—2011

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INTRODUCTION

This chapter summarizes temporal trends in forest fragmentation for the conterminous United States from 2001 to 2011. As distinguished from forest loss per se, forest fragmentation refers broadly to the subdivision of the remaining forest into smaller parcels, the creation of more forest edge per unit of forest area, and the increased distance between the remaining forest parcels. The processes of forest disturbance and recovery, both natural and anthropogenic, together determine the trends of forest fragmentation geographically and over time. The impacts of forest fragmentation on ecological goods and services naturally vary according to the particular circumstances of forest change, such as the natural forest condition in a given area, the particular drivers and patterns of forest change, and the specific ecological process or attribute of interest. The goal of national monitoring of forest fragmentation is to provide a consistent characterization of the status and trends of forest spatial patterns in a way that can potentially address a large number of specific concerns about a variety of ecological goods and services. For these and other reasons, the primary indicator for national monitoring is multiscale forest area density, and the primary data source is the National Land Cover Database (NLCD). The 2010 Forest Health Monitoring (FHM) national report (Potter and Conkling 2013) included a national analysis of forest fragmentation (Riitters 2013) based on the 2001 NLCD. This chapter updates the status and trends of forest fragmentation using the 2006 and 2011 NLCD.

METHODS

National Land Cover Maps

The data set included the NLCD land cover maps for the conterminous United States (CONUS) in the years 2001, 2006, and 2011 (Fry and others 2011, Homer and others 2004, Jin and others 2013, Xian and others 2009). To ensure consistency over time, the most recent NLCD editions (U.S. Geological Survey 2014a, 2014b, 2014c) of each year were used (because the 2001 and 2006 NLCD were updated when the 2011 NLCD was released). The NLCD maps identify 16 land cover classes at a spatial resolution of 0.09 ha/pixel (i.e., each pixel is 30 m by 30 m). For this analysis, the 16 NLCD land cover classes were combined into two generalized classes called forest (the NLCD deciduous, evergreen, mixed forest, and woody wetlands classes) and nonforest (all other NLCD classes). No attempt was made to identify the specific nonforest NLCD classes that were associated with the status and trends of forest fragmentation. Ocean area adjacent to land was included in the analysis but data summaries were limited to the boundaries of detailed county maps (ESRI 2005). Although this analysis did not incorporate information about NLCD classification accuracy, the overall per-pixel classification accuracy of forest versus nonforest in the NLCD is approximately 90 percent (Wickham and others 2010, 2013). The estimates of forest area and change from NLCD land cover maps differ from Forest Inventory and Analysis (FIA) forest area statistics (e.g., Oswalt and others 2014) primarily because of differences in the definition of forest (Coulston

and others 2014). For example, forest is defined as a land use by FIA whereas the NLCD defines forest as a land cover.

Fragmentation Model

National maps of forest fragmentation were derived for each of the three NLCD years by using the same techniques (Riitters and others 2002) that were used in earlier Forest Health Monitoring reports (e.g., Riitters 2013, Riitters and Coulston 2013). Those reports provide additional details and illustrations of the fragmentation model. Briefly, the fragmentation status of individual forest pixels was evaluated by measuring the forest area density (FAD) in a surrounding neighborhood and repeating that measurement for five neighborhood sizes. FAD is defined as the proportion of all pixels within a fixed-area neighborhood that are forest pixels, and the five neighborhood sizes were 4.41 ha (7 pixels by 7 pixels), 15.21 ha (13 by 13), 65.61 ha (27 by 27), 590.49 ha (81 by 81), and 5314.41 ha (243 by 243). Neighborhood size is hereafter referred to as "landscape size" and the values are rounded to three significant digits. Five neighborhood sizes were used because fragmentation naturally is scale dependent, because the effects of fragmentation may be scale dependent, and because knowledge of fragmentation as manifested at different scales is required to inform resource management as practiced at those different scales. The five selected neighborhood sizes span several orders of magnitude of measurement scale, and the smallest three sizes correspond roughly to familiar sizes in English measurement units (approximately 10 acres, 40 acres, and 160 acres). For a given year, each forest pixel was assigned a value of FAD for each landscape size by centering the neighborhoods on its location. Thus, five FAD measurements were made for each extant forest pixel for each of the three years. For a given landscape size, the forest pixels were grouped into fragmentation categories based on their FAD values (table 6.1).

In comparison to an assessment of the status of forest fragmentation at a single time, an assessment of trends of forest fragmentation over time has to account for changes in the underlying "population" of forest pixels over time (Riitters and Wickham 2012). Clearly, the loss of a forest pixel will reduce the total area of extant forest in a given fragmentation category. Similarly, the gain of a forest pixel will increase the total area in a given fragmentation category, but in this case the specific fragmentation category depends on which landscape gained the forest pixel. For example, forest area added to a forest-dominated landscape is unlikely to be classified in the rare fragmentation category. Furthermore, for a forest pixel that persists over time, its FAD values and hence fragmentation category may change according to the gains and losses of other forest pixels in its neighborhood. Thus, the patterns of forest losses and gains in relation to the extant forest pattern can have both direct and indirect effects on the fragmentation status of the extant forest area at a given time.

For data summaries, FIA regions (fig. 6.1) were selected for consistency and comparability with other Forest Service national resource assessments. For each region, the proportion

Table 6.1—The conversion of forest area density (FAD) measurements to fragmentation categories

Forest area density (FAD)	Fragmentation category[a]
FAD = 1.0	Intact
0.9 ≤ FAD < 1.0	Interior
0.6 ≤ FAD < 0.9	Dominant
0.4 ≤ FAD < 0.6	Transitional
0.1 ≤ FAD < 0.4	Patchy
0.0 < FAD < 0.1	Rare

[a]Riitters (2013).

of total forest cover in each fragmentation category was calculated for each year. This enables analysis of trends in forest fragmentation by region, but does not reflect changes in total forest area over time. To place regional results in context, a separate summary of total forest area changes over time was also compiled for each region.

For comparisons with other national assessments (USDA Forest Service 2011, 2012), a second "cumulative" model was applied to the multiscale FAD data. In the cumulative model, a given forest pixel was labeled as "intact forest" if its associated FAD equaled 1.0, as "interior forest" if FAD ≥ 0.9, and as "dominant forest" if FAD ≥ 0.6. The model is "cumulative" because a forest pixel that met the "intact" criterion also qualified as "interior" and "dominant" and one that met the "interior" criterion also qualified as "dominant." The results for the cumulative model were summarized nationally, for each of the three years, for each of five landscape sizes, by calculating the percentages of forest pixels that met the three cumulative criteria for intact, interior, and dominant forest.

RESULTS AND DISCUSSON

Net Change of Total Forest Area

In 2001, there were 2.353 million ha of forest in the conterminous United States. Total forest area decreased to 2.323 million ha in 2006 and 2.284 million ha in 2011. The total decrease from 2001 to 2011 was 69 640 ha, representing a net loss of 3.0 percent of total forest area during that period. In comparison, net regional losses from 2001 to 2011 varied from 1.0 to 5.5 percent (fig. 6.2). Most (71 percent) of the net loss of forest area was in the two southern

Figure 6.1—Forest Inventory and Analysis regions. Note: Alaska, Hawai'i, and Puerto Rico were not included in this study.

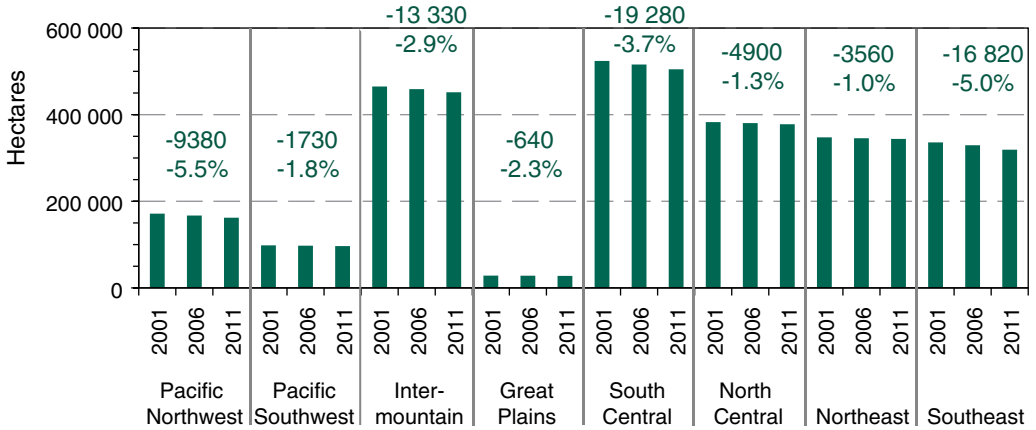

Figure 6.2—Total forest cover in 2001, 2006, and 2011, by FIA region. The net change from 2001 to 2011 is indicated for each region in hectares (top number) and percent (bottom number).

regions (36 100 ha) and the Intermountain region (13 330 ha). The largest percentage net losses were in the Pacific Northwest and Southeast regions, and the lowest percentage net losses were in the two northern regions.

Changes in Forest Fragmentation

The percentages of total forest area in each of the six fragmentation categories, nationally and by region, are shown in figure 6.3 for three of the five landscape sizes. In the following discussion, the six fragmentation categories are interpreted as a gradient of fragmentation from low fragmentation (intact category) to high fragmentation (rare category). The results for the Great Plains region are quite different from other regions because that region contains much less forest cover overall, because many of the native forest types in that region are naturally fragmented, and because a relatively larger proportion of total forest cover in that region occurs as urban tree cover.

The general trends of fragmentation category area in relation to landscape size were described in a previous FHM national report (Riitters 2013). Briefly, because forest cover tends to be more spatially correlated at a local scale than regional scale, it is easier to achieve a high FAD threshold in smaller landscapes than in larger landscapes. As a result, larger landscapes have more fragmentation than do smaller landscapes. For example, with increasing landscape size there is an increase in the total of the rare

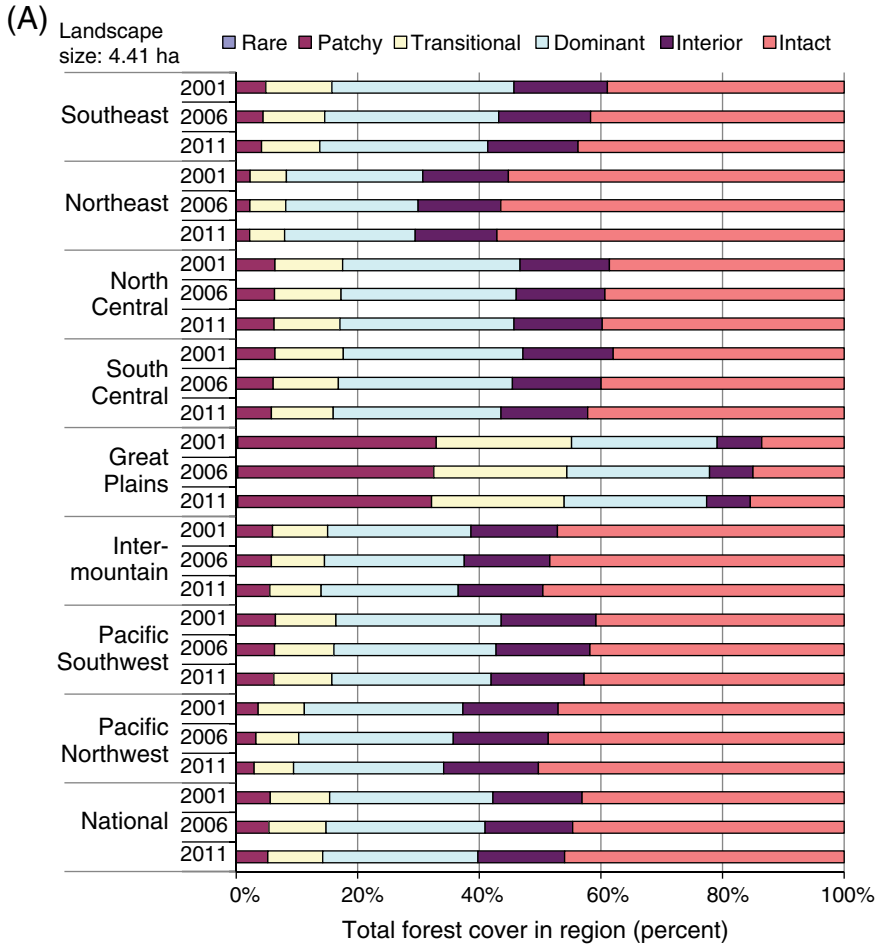

Figure 6.3—The percentage of total forest area in each of six fragmentation categories, for three landscape sizes, nationally and by region. (A) 4.41-ha landscape size; (B) 65.6-ha landscape size; (C) 590-ha landscape size.
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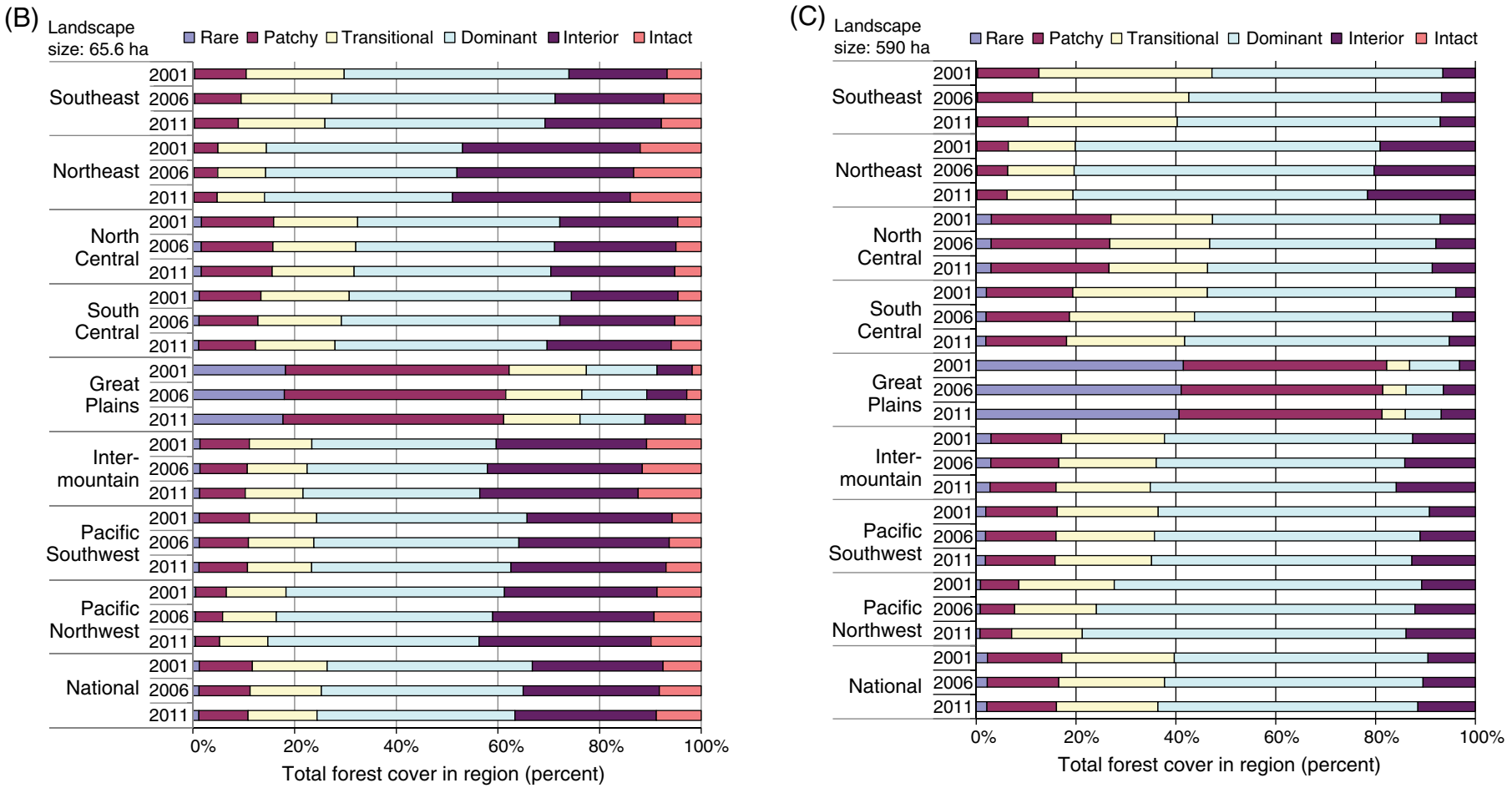


Figure 6.3 (continued)—The percentage of total forest area in each of six fragmentation categories, for three landscape sizes, nationally and by region. (B) 65.6-ha landscape size; (C) 590-ha landscape size.

plus patchy categories and a decrease in the intact plus interior categories. At the same time, however, the total of the transitional plus dominant categories increases much more than the rare plus patchy categories with increasing landscape size because forest cover still continues to dominate large landscapes even if it is more fragmented.

The temporal results indicate a net decrease in the percentage of relatively unfragmented forest cover (interior plus intact categories) in all regions and during both time periods (2001 to 2006 and 2006 to 2011). That decrease was translated to net increases in the percentage of relatively fragmented forest cover (rare plus patchy categories) in most, but not all, regions and time periods. To simplify the temporal trend information and clarify regional comparisons of fragmentation, the net changes in the area within each fragmentation category for a landscape size of 65.6 ha were expressed as annual percent change[3] from 2001 to 2011, by region (fig. 6.4). This presentation format clarifies that all regions exhibited a net loss of interior and intact forest, and that all regions except the Great Plains region exhibited a net gain of rare, patchy, and transitional forest. The Eastern United States had more

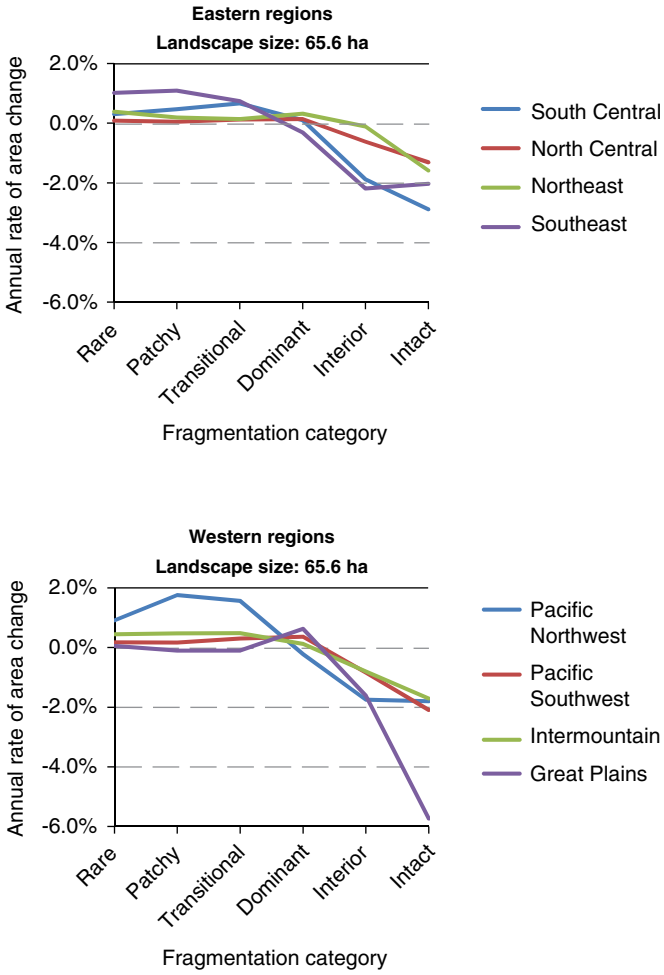


Figure 6.4—Annualized percentage of change in the area in each of six fragmentation categories, by region, from 2001 to 2011.

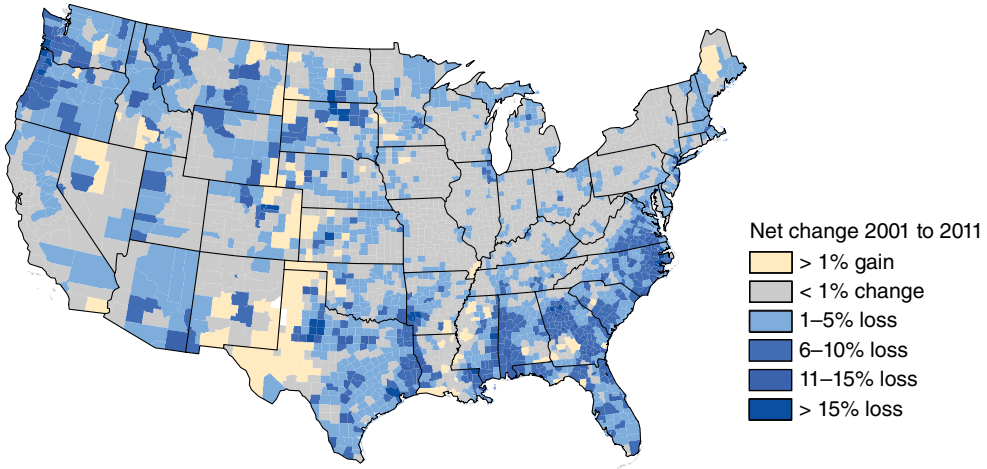
[3] $annual\ percent\ change = 100 * \left(\left(\frac{area\ in\ 2011}{area\ in\ 2001} \right)^{\frac{1}{10}} - 1 \right)$

fragmentation in the two southern regions than in the two northern regions. In the West, the Pacific Northwest tended to have higher fragmentation rates than the Pacific Southwest and Intermountain regions. (The percentage change results for the Great Plains region are not really comparable to the other results because of the small amount of intact area in that region in 2001.)

The national geography of forest cover change and fragmentation is further illustrated by a county-level comparison of the net percentage changes in total forest area (fig. 6.5A) and interior plus intact forest area (fig. 6.5B) from 2001 to 2011. To prepare fig. 6.5A, the total area of forest cover in each county was calculated using the 2001 and 2011 NLCD forest maps, and the difference was expressed as percentage change from the base year 2001. To prepare fig. 6.5B, the total area of intact plus interior forest in a 65.6-ha landscape was calculated for 2001 and 2011, and the difference was expressed as a percentage change from the base year of 2001. The inset map identifies forest-dominated counties containing more than 50 percent of forest cover. To interpret the maps, note that the same legend applies to both maps, and that darker blue colors indicate larger percentage losses. Most of the forest-dominated counties exhibited a net loss of total forest cover, and the rate of loss of interior plus intact forest exceeded the rate of loss of total forest cover. This result is consistent with and extends to 2011 the results for the 2001 to 2006 time period reported by Riitters and Wickham (2012). From 2001 to 2011, there was a widespread shift of the extant forest to a more fragmented condition, including places with relatively small changes in total forest cover.

The "cumulative" fragmentation model highlights changes in landscapes with lower levels of fragmentation. From 2001 to 2011, there was an increase in fragmentation of the extant forest across all landscape sizes for all three cumulative fragmentation categories (fig. 6.6). Since forested places tend to be clustered in proximity to one another, forest is usually the dominant land cover in these areas. Thus, for landscapes up to 5310 ha, at least 60 percent of forest land is in forest-dominated landscapes (fig 6.6; "Dominant forest"). However, since blocks of forest land are usually fragmented by inclusions of nonforest land, the percentage of forest land that is relatively unfragmented decreases rapidly as landscape size increases from 4.41 ha to 5310 ha (fig. 6.6; "Interior forest"). Fragmentation is so extensive that only 8 percent of forest land occurs in 65.6 ha landscapes that are completely forested (fig. 6.6; "Intact forest").

(A) Total forest cover area



(B) Intact plus interior forest cover area

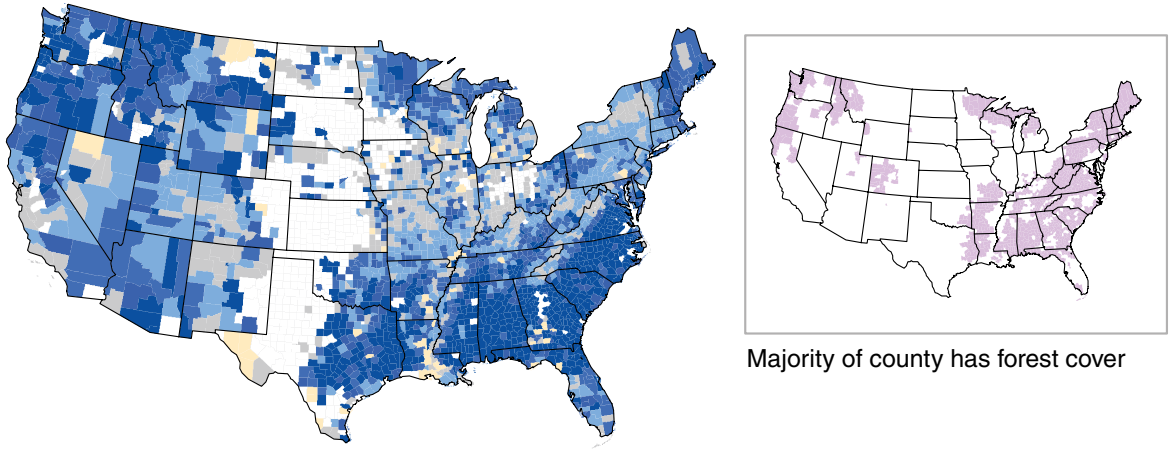


Figure 6.5—(A) The net change in total forest cover in a county from 2001 to 2011, expressed as a percentage of the total forest area in 2001. (B) The net change in intact plus interior forest cover in a county from 2001 to 2011, when analyzed at 65.6-ha scale, expressed as a percentage of the total intact plus interior forest cover in 2001. Counties without color are the 3 counties that had no forest cover in 2001 and the 498 counties that had no intact plus interior forest cover in 2001. The inset map identifies counties where more than 50 percent of total area had forest cover in 2001.

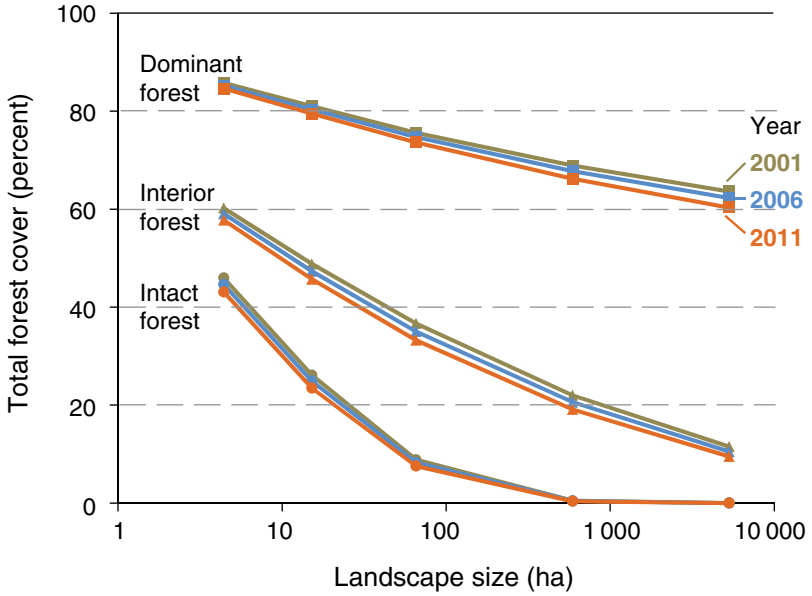


Figure 6.6—National summary of forest cover fragmentation using the cumulative classification model (see text for explanation). The chart shows the percentage of forest cover in the conterminous United States that is considered intact (completely forested landscape), interior (greater than 90 percent forested), or dominant (greater than 60 percent forested) and how those proportions change with increasing landscape size. In the cumulative model, intact is a subset of interior, which is a subset of dominant, which is a subset of total forest cover area. Green, blue, and orange symbols indicate conditions in 2001, 2006, and 2011, respectively.

SUMMARY

Analysis of national land cover maps for the years 2001, 2006, and 2011 showed that decreases in total forest cover underestimated forest fragmentation for several criteria used to define fragmentation and across several orders of magnitude of measurement scale. Although forest tends to be the dominant land cover type where forest occurs, fragmentation is pervasive and increasing over time, even in regions exhibiting relatively small changes in total forest cover area. In addition to regional differences in the change of total forest cover, there is important regional variation in the area and rate of change of relatively unfragmented forest. It is important to continue monitoring the status and trends of forest fragmentation in a consistent way nationally, and the next update to this analysis will be conducted upon the release of the 2016 national land cover map.

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