Fifteen-Year Changes in the Landscape Context of FIA Forest Land in the Conterminous United States

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Abstract.—We assessed historical changes in the landscape context of forest (circa 2016) that occurred between 2001 and 2016. We quantified three measures of context—forest cover fragmentation, anthropogenic interface, and forest edge typology—within a 15.2 ha neighborhood centered on representative forest inventory plot locations in the conterminous United States. Net change of interface area was attributable mainly to privately owned land in the East, amounting to a 4.9 percent decrease of forest area in the agriculture interface and a 3.7 percent increase of area in the developed interface. Overall, net loss of interior forest area was due primarily to losses on Federal land in the West and corporate land in the East. Consistent with the dynamics of interface classes and interior forest area, edge typology revealed an overall increase in forest cover adjacent to developed and shrub/grass covers and a decrease in forest adjacent to agricultural cover.

INTRODUCTION

The forest area of the conterminous United States (CONUS) occurs in a variety of landscape settings ranging from primarily urban or agricultural areas to remote wilderness areas. Forest threats often depend on these landscape settings (i.e., the spatial context), and novel threats to the extant forest area can emerge when the surrounding landscape changes because of human activities. For example, the risk of exotic plant invasion on U.S. Department of Agriculture (USDA), Forest Service, Forest Inventory and Analysis program (FIA) plots in the East is related to disturbance and propagule pressure from nearby roads and other development (Riitters et al. 2017), and the expansion of developed area near a forested location is expected to increase such risk at that location. Similarly, interior forest is required to support many species (e.g., Fischer and Lindenmayer 2007), and the types of vegetation, land uses, or land covers at the edges of forest affect a variety of edge-sensitive ecological processes (e.g., Murcia 1995).

We investigated CONUS landscape changes from 2001 to 2016 in support of the 2020 USDA Forest Service Resources Planning Act (RPA) Assessment. An earlier contribution summarized forest cover fragmentation trends and patterns (Riitters and Robertson 2021), while overall changes in landscape context were addressed by Riitters et al. (2020). Here, we report a third aspect of landscape change supporting the 2020 assessment: the integration of landscape data based on land cover maps with estimation of forest areas using FIA plot-level data to evaluate changes in landscape context near land defined as forest land by FIA circa 2016.

METHODS

Landscape Context Data

Our description of landscape context generally follows the framework used in earlier RPA assessments, wherein context is measured using the National Land Cover Database (NLCD) (e.g., Riitters 2011, USDA Forest Service 2016). We consider three aspects of landscape context: forest cover fragmentation, anthropogenic interface, and forest edge typology. Within a 15.2 ha neighborhood (hereafter, "neighborhood") centered on each FIA plot location, we measured those three aspects of context using the 2001 and 2016 NLCD maps (Homer et al. 2020). The NLCD 2016 classifies land cover into 16 (Level II) classes with a spatial resolution of 0.09 ha per pixel. We combined the 16 classes into the following groupings: forest, developed, agriculture, shrub & grass, water, and barren based on current (NLCD 2021) Level I classes

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provided at the Multi-Resolution Land Characteristics Consortium website. Importantly, the "forest" class included the NLCD "woody wetlands" class, and herbaceous wetlands were assigned to the "water" class. To assess fragmentation, we assigned interior status (yes or no) to a given plot location if the neighborhood contained at least 90 percent forest cover. To assess anthropogenic interfaces, we measured the proportions of agriculture and developed land cover in the surrounding neighborhood and assigned plots to the "agriculture" or "developed" interface classes if the proportion of either of the corresponding land cover classes occupied at least 10 percent of the neighborhood. The "both" interface class corresponds to locations where agriculture and developed classes each occupy 10 percent simultaneously; in the "neither" class, there is less than 10 percent of either agriculture of developed classes. To assess forest edge typology, we tabulated the adjacency (pixel-level co-occurrence) of the six land cover types and examined the adjacencies containing forest within the neighborhood. Thus, the types of forest adjacencies were forest to forest, forest to developed, forest to agriculture, forest to shrub & grass, forest to water, and forest to barren. For each plot, the frequency of each type of forest adjacency was expressed as the proportion of total forest adjacencies in the neighborhood.

Forest Inventory Plot Data

A total of 137,911 forest and nonforest FIA plots from the 2016 inventory period for each state in CONUS were used in the analysis. We used condition class information (Burrill et al. 2018) for stratification and population estimation (Bechtold et al. 2005), but all condition classes on a given plot were attributed with the same set of landscape context descriptors in that neighborhood. We used the proprietary ownership data and the exact plot locations. For analysis, we excluded 17 forest types that occupied less than 405 km^2 each, eight exotic forest types, and the "unassigned" forest type, which includes nonstocked forest land. The resulting sample represented 96 percent (2.7 million km^2) of total FIA forest area in 2016.

Analysis Methods

For each plot, we identified the geographic region (East or West), ownership (Federal, State and local, corporate, and noncorporate), and the expansion factors needed for population-level area estimates. For interior forest status and interface classes, the estimate of forest area in each landscape context was simply the sum of the expansion factors for the condition classes that had that context. A different procedure was followed to evaluate forest edge typology because both the total number and potential types of forest adjacencies necessarily depend on the amount of forest cover in a neighborhood, which varies among plots. We calculated weighted mean proportions when aggregating the plot-level proportions to a stratum level using the expansion factors as weights (Riitters et al. 2012). All of these procedures were applied to both the 2001 and 2016 measurements of landscape context, and the historical change of landscape context from 2001 to 2016 for the circa 2016 forest area was simply the difference of the stratum area (or proportions) between those years.

RESULTS

Interior Forest Cover Status

Over the CONUS, the share of circa 2016 forest area assigned a status of "interior" decreased from 42.8 percent in 2001 to 40.4 percent in 2016. The gross gain in interior forest area over that time was 112.9 thousand km^2, while the gross loss was 177.2 thousand km^2, resulting in a net loss of 64.3 thousand km^2. Figure 1 illustrates three main points: (1) most of the total gross change (gain and loss) was on privately owned land in the East (188.8 thousand km^2); (2) most of the net loss occurred on Federal land in the West (27.1 thousand km^2) and corporate land in the East (14.2 thousand km^2); and (3) for all ownerships, net percentage change was larger in the West than in the East.

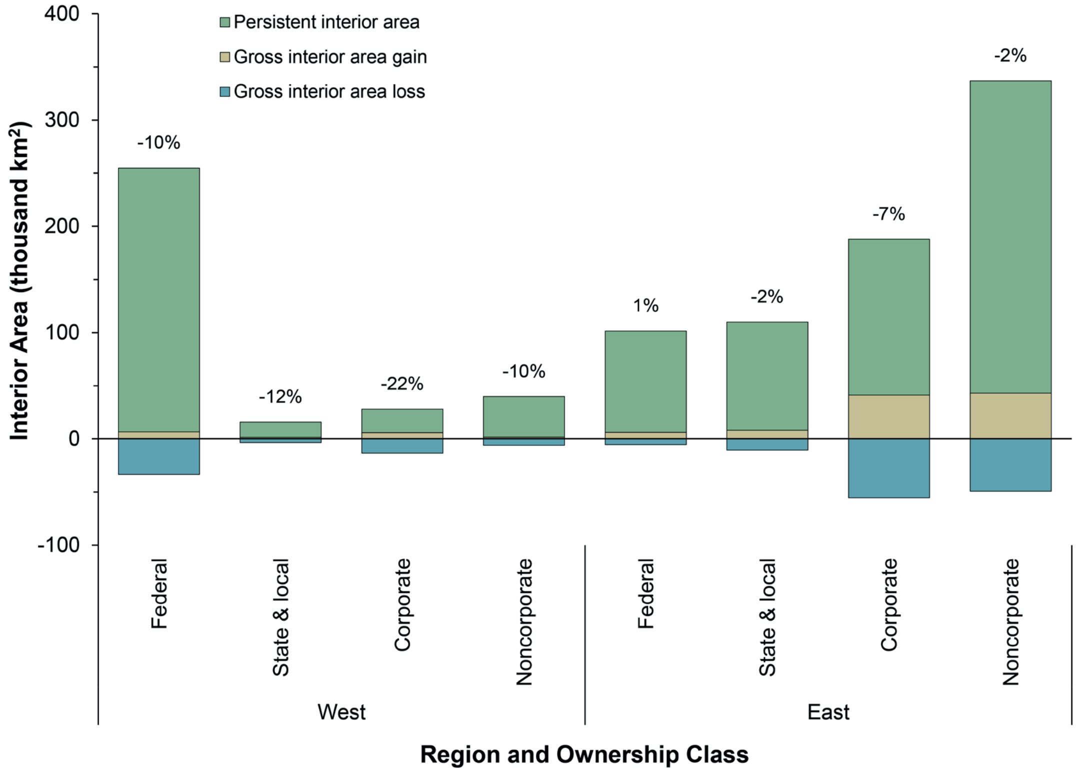

Figure 1.—Change of interior forest area from 2001 to 2016 in the conterminous United States by region and ownership class. The net percent changes are shown above the bars. The East region includes the states in the Northern and Southern FIA units. The West region includes states in the Pacific Northwest and Rocky Mountain FIA units.

Interface Classes

In both 2001 and 2016, privately owned land in the East contained most of the forest area in the agriculture interface (approximately 93 percent) and most of the forest area in the developed interface (approximately 70 percent). Between 2001 and 2016 and driven principally by changes in the East, the share of CONUS forest area in the agriculture interface decreased from 15.9 percent to 15.1 percent, while the share in the developed interface increased from 11.4 percent to 11.8 percent. These changes are consistent with the regional trends of pasture (agriculture) reversion to forest, and of forest conversion to urban land that have been demonstrated in other studies (e.g., Nelson et al. 2020). Those interacting patterns of land use conversions are reflected in the patterns of landscape context changes from 2001 to 2016 (Fig. 2).

Forest Edge Typology

The analysis of changes in forest adjacencies with other forest, agriculture, developed, or shrub & grass (Fig. 3) reflected the stories of landscape change based on interior forest and interface area change. In the West, and consistent with interior forest loss in primarily non-interface landscapes (which include the shrub & grass class), there was a decrease in forest to forest adjacencies, and the largest increases were in forest to shrub & grass adjacencies. A similar change occurred for the eastern corporate forest area only; in other eastern ownerships, there was a decrease in forest to agriculture adjacencies and increases in forest to shrub & grass and forest to developed adjacencies. There was little change in forest adjacencies with water and barren in all regions and ownerships.

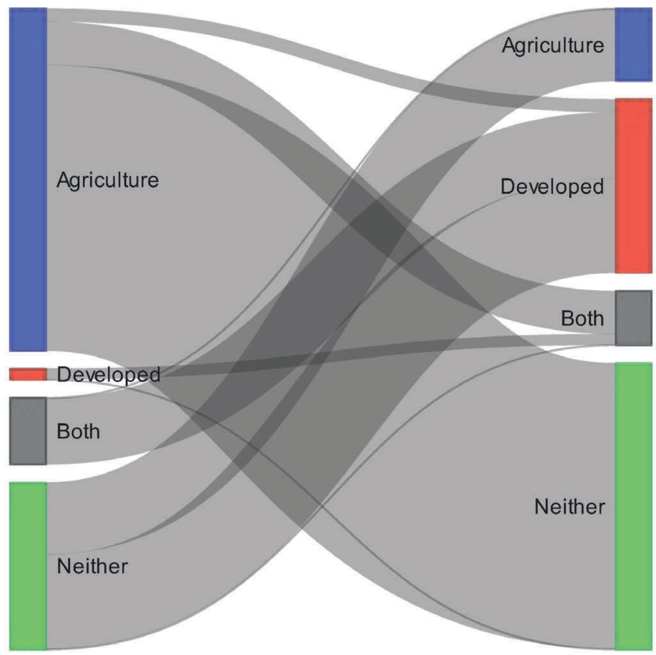

Figure 2.—Flow of area from an interface class in 2001 (left) to an interface class in 2016 (right) for forest area exhibiting a change of interface class in the conterminous United States. The height of a bar is proportional to area in the given year, and the width of a flow is proportional to the area of the flow.

Figure 3.—Change in percentage of forest edge typology from 2001 to 2016 in the conterminous United States by adjacency type, region, and ownership class. Forest to water and forest to barren adjacency types showed little change and are therefore not shown. The East region includes the states in the Northern and Southern FIA units. The West region includes states in the Pacific Northwest and Rocky Mountain FIA units.

DISCUSSION AND CONCLUSION

Although net change statistics are informative, they do not adequately convey the extent or importance of landscape context changes. Considering interior forest, for example (Fig. 1), the total area of gross change (both gain and loss) was 4.5 times larger than the area of net change and was an area equivalent to 25 percent of the original interior area. Gross loss of interior area alone was 16 percent of the original area of interior forest. Some ecological processes or ecosystem services could be substantially affected by that gross change. For example, from the perspective of an obligate interior forest species, the spatial rearrangement of interior forest area, with substantial losses of interior forest in some places, could be more important than the magnitude of net area change. Loss of interior forest anywhere likely means that organisms or populations would need to migrate to new locations, if possible, to stay within interior forest. Furthermore, the 11 percent of the interior forest area that was "new" in 2016 could provide habitat of different conditions, such as earlier successional stages than the existing forest, and thus support a different assemblage of species than in the prior period.

Similarly, considering changes in interface classes (Fig. 2), approximately half of forest area that moved into the developed interface class came from formerly non-interface landscapes (the "neither" category), while the replacement of the lost non-interface landscape area came almost exclusively from formerly agriculture interface landscapes. From the perspective of sustaining forest in non-interface landscapes, a key question is whether or for how long agriculture reversion can continue to replace forest that transitioned into developed interface area as urbanization continues to encroach upon forest land.

Transitions within natural vegetated landscapes are largely considered less permanent than transitions from natural land covers to agriculture or developed land covers. Still, natural transitions represented the largest increases in edge typology metrics (i.e., forest to shrub & grass; Fig. 3) across all ownership classes in the West and East, and perhaps also in interface classes (e.g., shrub & grass interfaces are grouped with the non-interface class; Fig. 2). In the productive eastern landscapes, a 15-year period is enough for land to move from forest to shrub & grass to forest again. Elsewhere, these transitions can take much longer than the duration of this analysis. Additionally, these neighborhood land cover transitions could have occurred at any point in the 15-year window and thus capture change over an aggregate of that time. The three context measures used here can be applied to shorter or longer temporal windows for additional perspectives.

Overall, our estimates of landscape change are likely conservative because we excluded the nonstocked forest condition class from our analysis, a condition that is often associated with a recent disturbance. Although the estimate of total CONUS forest area has been relatively stable for several decades (Oswalt et al. 2019), our work demonstrates that the landscape context of much of that area has changed substantially during that time.

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