Forest Land-Use Change in the Conterminous United States

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Abstract.—Information on status and trends in both land use and land cover are needed to assess the Nation's land resources. The U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) program collects annual inventory data on forest land as well as other land use and cover classes. FIA also produces other sources of data and information on land resources. We present an example application of using FIA data to estimate status and change in forest land area, and we introduce the FIA Land Resources Explorer, an online interactive web application. The flagship product in the application is the Land Resources Dashboard, which provides a variety of tabular estimates, maps, and figures pertaining to land resources.

INTRODUCTION

Tracking both the spatial arrangement and changes through time of forest land and other land uses and land covers is essential for monitoring land resource conditions and trends (Nelson et al. 2020). Land cover describes conditions at a given time (Burley 1961, Osborne 1942), and land use describes the social and economic intent for which land is utilized (Coulston et al. 2014, Lund 2002). The area in forest land use is a key sustainability indicator under the Montréal Process (Nelson et al. 2015), and it is the primary measurable factor that addresses jurisdictional and corporate zero net deforestation commitments. While estimates based on land cover maps (e.g., National Land Cover Database) have suggested net losses in United States forest cover area over the past few decades, estimates of forest land produced by the U.S. Department of Agriculture (USDA), Forest Service, Forest Inventory and Analysis (FIA) program show net gains between 1987 and 2012 (rates of change have leveled off since then) (Oswalt et al. 2019). We present an example application of FIA data used to estimate status and change in forest land area, and we introduce the FIA Land Resources Explorer.

METHODS

FIA employs a probability-based sample design; permanent, fixed-radius, remeasured cluster-plots; and corresponding statistical estimators for producing unbiased estimates for a variety of attributes for forest land and other land uses, land covers, and land change, which are managed in multiple tables of the FIA Database (Burrill et al. 2021). FIA's definition of forest land includes elements of both land use and land cover.[2] Detailed forest composition and structure information, as well as land use and land cover, is recorded for each FIA plot containing forest land. Most nonforest plots are not field measured, but all nonforest plots are assessed for land use and land cover attributes using remotely sensed imagery and image-interpretation methods. FIA's data and tools can be used to produce design-unbiased estimates of status and change, and

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[2] FIA defines forest land as land at least 10-percent canopy cover by trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10-percent canopy cover with trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre and 120 feet wide measured stem-to-stem from the outer-most edge. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide. This is the domestic reporting definition which is different from the definition used in international reporting (which includes a minimum tree canopy height criteria).

their associated estimates of variance, within and between all land classes. Change estimates are made possible by the remeasurement of conditions at permanent sample locations. Fewer than half of the states experienced more than 1 percent net gain or net loss since the previous measurement. Average plot remeasurement periods (REMPER) differed among states and FIA regions, ranging in years from 5.7 in the Northern region, 6.5 in the Southern region, 9.6 in the Rocky Mountain region, and 9.9 in the Pacific Northwest region. Average REMPER in the Northern and Southern regions has been increasing as many states transitioned from 5- to 7-year measurement cycles. Statistical tests of difference in land change can also be produced (Westfall et al. 2013). We provide an example of statistical tests of change ($p = < 0.05$) in forest land area, which were conducted on 47 of the conterminous United States (CONUS) for which remeasurement data are available during the most recent 5- to 10-year span.

RESULTS

FIA Data and Estimates

A large majority of FIA's sample plots experienced no permanent change in nonforest or forest, and fewer than 2 percent of plots transitioned to or from forest between recent and previous measurements (Fig. 1). Plots with persisting forest or nonforest were prevalent; plots with forest loss or forest gain were sparsely distributed throughout much of CONUS, with a few denser clusters of change in northeastern California, central Oregon, western Texas, along the forest/nonforest tension zone transecting Minnesota and Wisconsin, and in other scattered local areas (Fig. 1). The combined 47-state region showed a net loss of about 1 percent of previous forest land use area, a statistically significant difference. For individual states, 21 had statistically significant loss, 14 had nonsignificant loss, 7 had significant gain, and 5 had nonsignificant gain.

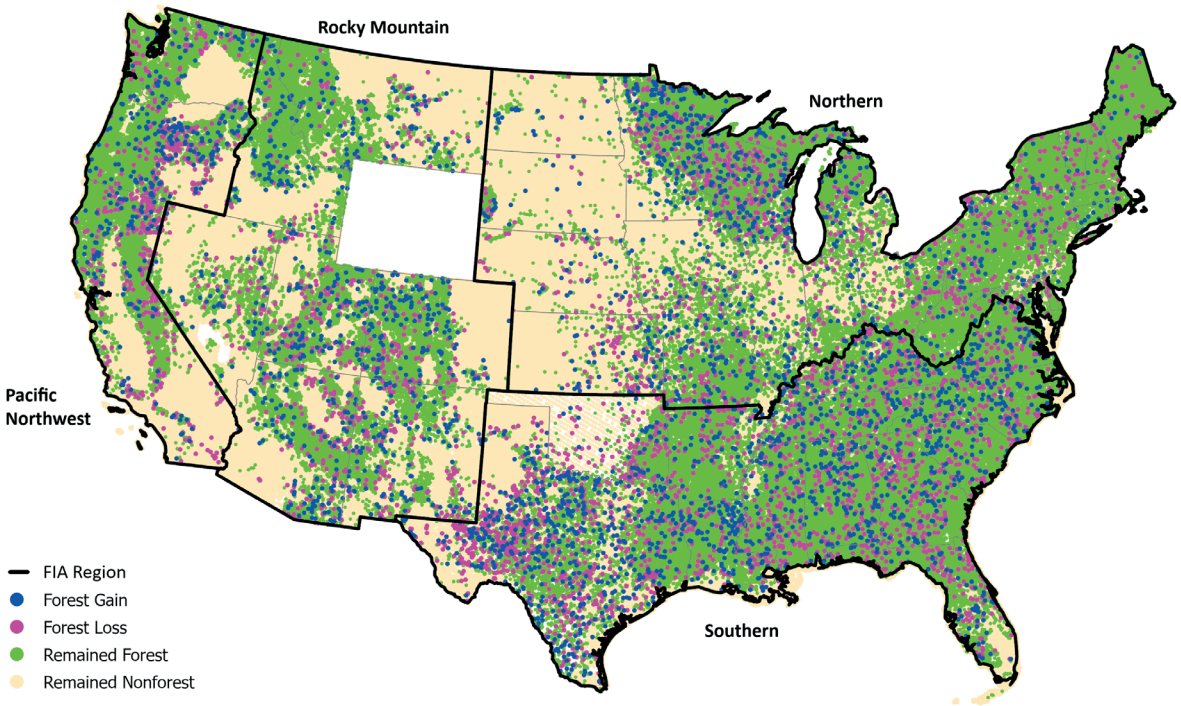

Figure 1.—Forest gain and forest loss of at least 25 percent and persisting forest and nonforest with less than 25 percent change between current (~2019) and previous measurements in the conterminous United States. Approximate locations of remeasured FIA plots show per-plot status. At the time of map creation, Wyoming (large white rectangle) had insufficient remeasurements for assessing change, and western Oklahoma had sparser remeasurement data than eastern Oklahoma. Bold lines delineate FIA regions: Northern, Southern, Rocky Mountain, and Pacific Northwest.

FIA Land Resources Explorer

The FIA program produces additional land change information beyond the FIA-based estimates described in the preceding paragraph. In partnership with the Forest Service Geospatial Technology Applications Center (GTAC), FIA has assessed land use, land cover, and agent of change for all states in the FIA Northern region and selected states in other regions using image-based change estimation (ICE), an approach based on photointerpretation of digital imagery from the National Agriculture Imagery Program (NAIP) at FIA plot locations (Megown et al. 2015, Webb et al. 2012). FIA and partners also developed and produced the Landscape Change Monitoring System (LCMS), which produces per-pixel predictions of land use, cover, and change from the Landsat Time Series. A new tool, the FIA Land Resources Explorer, provides comprehensive access to this variety of land resources information.

The Explorer is an interactive, user-friendly suite of tools for viewing land area estimates and maps from multiple information sources. It presents information on land use, land cover, and change as directed by the 2014 Farm Bill (updated in 2018, P.L. 115–334), which can be used to support land management decisions. The flagship tool in the Explorer is the FIA Land Resources Dashboard (Fig. 2), produced by a collaborative team from FIA and GTAC. Users can view estimates for states, FIA survey units, and counties based on the latest available data, which are updated monthly. Although the dashboard presents only land use estimates at this time, future versions are planned to include land-use change, land cover, and land-cover change.

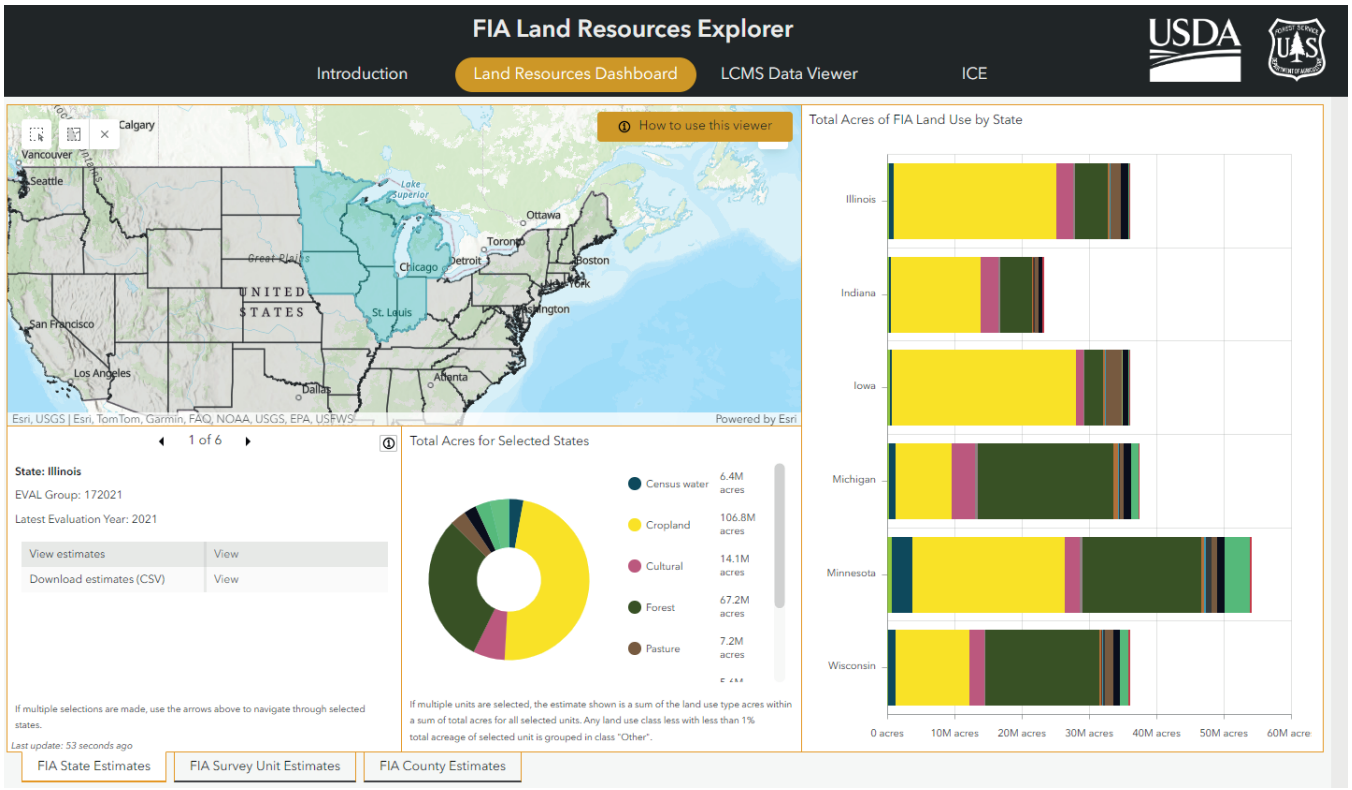

Figure 2.—FIA Land Resources Explorer Land Resources Dashboard. Example of current land use area estimates within each of six upper midwestern states (Minnesota, Wisconsin, Michigan, Indiana, Illinois, and Iowa).

SUMMARY

Small net changes in forest land area can obscure larger, offsetting gross gains and gross losses. Definitional and other operational changes further confound comparisons of change estimates, highlighting the need for additional national consistency efforts. Remeasurement periods differ among states and within states during the same period, prompting a need to report more comparable change estimates on an average annual basis. The continued development of user-friendly tools such as the FIA Land Resources Explorer can help to demystify not only estimates of current land use and land cover, but also changes over time.

REFERENCES

Burley, T.M. 1961. **Land use or land utilization?** The Professional Geographer. 13(6): 18–20.

Burrill, E.A.; DiTommaso, A.M.; Turner, J.A.; Pugh, S.A.; Christensen, G.A.; Perry, C.J.; Conkling, B.L. 2021. **The Forest Inventory and Analysis Database: database description and user guide version 9.0.1 for phase 2.** Internal report. On file with: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis, 201 14th St., Washington, DC 20250.

Coulston, J.W.; Reams, G.A.; Wear, D.N.; Brewer, C.K. 2014. **An analysis of forest land use, forest land cover and change at policy-relevant scales.** Forestry. 87: 267–276. https://doi.org/10.1093/forestry/cpt056.

Lund, H.G. 2002. **When is a forest not a forest?** Journal of Forestry. 100(8): 21–28. https://doi.org/10.1093/jof/100.8.21.

Megown, K.; Lister, A.; Patterson, P.; Frescino, T.; Jacobs, D.; Webb, J.; Daniels, N.; Finco, M. 2015. **Image-based change estimation (ICE): monitoring land use, land cover and agent of change information for all lands.** In: Stanton, S.M.; Christensen, G.A., comps. Pushing boundaries: new directions in inventory techniques and applications: Forest Inventory and Analysis (FIA) symposium 2015. Gen. Tech. Rep. PNW-HTR-931. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 218.

Nelson, M.D.; Riitters, K.H.; Coulston, J.W.; Domke, G.M.; Greenfield, E.J.; Langner, L.L.; Nowak, D.J.; O'Dea, C.B.; Oswalt, S.N.; Reeves, M.C.; Wear, D.N. 2020. **Defining the United States land base: a technical document supporting the USDA Forest Service 2020 RPA Assessment.** Gen. Tech. Rep. NRS-191. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 70 p. https://doi.org/10.2737/NRS-GTR-191.

Nelson, M.D.; Robertson, G.; Riitters, K.H. 2015. **Conserving forest biological diversity: how the Montreal Process helps achieve sustainability.** The Wildlife Professional. 9(2): 44–48.

Osborne, J.G. 1942. **Sampling errors of systematic and random surveys of cover-type areas.** Journal of the American Statistical Association. 37(218): 256–264.

Oswalt, S.N.; Smith, W.B.; Miles, P.D.; Pugh, S.A., coords. 2019. **Forest resources of the United States, 2017: a technical document supporting the Forest Service 2020 RPA Assessment.** Gen. Tech. Rep. WO-97. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 223 p. https://doi.org/10.2737/WO-GTR-97.

Webb, J.; Brewer, C.K.; Daniels, N.; Maderia, C.; Hamilton, R.; Finco, M.; Megown, K.A.; Lister, A.J. 2012. **Image-based change estimation for land cover and land use monitoring.** In: Morin, R.S.; Liknes, G.C., comps. Moving from status to trends: Forest Inventory and Analysis (FIA) symposium 2012. Gen. Tech. Rep. NRS-P-105. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 46–53.

Westfall, J.A.; Pugh, S.A.; Coulston, J.W. 2013. **Conducting tests for statistically significant differences using forest inventory data.** Res. Pap. NRS-22. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 10 p. https://doi.org/10.2737/NRS-RP-22.

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