Comparison of U.S. Forest Land Area Estimates From Forest Inventory and Analysis, National Resources Inventory, and Four Satellite Image-Derived Land Cover Data Sets

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Abstract.—Our objective was to test one application of remote sensing technology for complementing forest resource assessments by comparing a variety of existing satellite image-derived land cover maps with national inventory-derived estimates of United States forest land area. National Resources Inventory (NRI) 1997 estimates of non-Federal forest land area differed by 7.5 percent from estimates based primarily on Forest Inventory and Analysis data reported in the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) draft 2002 forest resource assessment. The NRI estimates differed only 2.2 percent from non-Federal land area, with the NRI estimate slightly smaller than the RPA estimate. Comparisons of statewide forest land area estimates derived from these two inventories with four satellite image-derived maps reveal area-weighted root mean square deviations ranging from 2.5 to 41.0 percent across the conterminous United States. In general, estimates of non-Federal forest land area from RPA and NRI were more closely related to each other than to image-derived estimates. The Forest Cover Types map and the National Land Cover Data set produced image-derived estimates that were most similar to the RPA estimate of forest land area across all land ownerships.

For more than half a century, global forest resource assessments (FRAs) have been conducted by the Forest Resources Assessment Programme of the Food and Agriculture Organization (FAO) of the United Nations to "provide information on the state of forest resources worldwide on a continuing basis." These FRAs are based primarily on national forest inventory information provided by countries, supplemented by state-of-the-art technology. The global FRA of 2000 (Food and Agriculture Organization of the United Nations 2001) identified a need to complement future inventories of forest parameters through remote sensing technology. Zawila-Niedziecki (2000) edited a compilation of works on this effort, presented at an International Union of Forest Research Organizations conference on remote sensing and forest monitoring. Our study sought to test one application of remote sensing technology for complementing FRAs by comparing estimates of forest land area from a variety of existing satellite image-derived land cover maps with national inventory-derived estimates of U.S. forest land area.

The Forest Inventory and Analysis (FIA) program of the U.S. Department of Agriculture (USDA) Forest Service (http://fia.fs.fed.us) conducts detailed surveys of the Nation's forests across all ownerships. The USDA Natural Resources Conservation Service (NRCS) monitors land use, status, condition, and trends of the Nation's soils, water, and related natural resources on non-Federal lands through its National Resources Inventory (NRI) (http://www.nrcs.usda.gov/technical/NRI). Differences in sampling designs and definitions of land cover/use categories contribute to differences in estimates of forest land and other common land cover/use categories between these two inventories (Lessard *et al.* 2003). Czaplewski *et al*. (2002) reported that NRI statewide estimates of forest area can differ by more than 30 percent from FIA estimates, although these large relative differences occur only in a few sparsely forested states where forest land area is small.

Satellite image-derived land cover data and related geospatial data layers provide an alternative source of information from which forest land area estimates can be calculated and compared

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with inventory estimates. Conversely, field-based inventory data provide a reference for assessing the accuracy of satellite image-derived data. For example, Owens (2001) reported that lowland conifer, pines, and nonforest groups had the largest differences with respect to area when comparing FIA plot-based and Landsat Thematic Mapper (TM) image-based estimates in Michigan's Upper Peninsula. She reported difficulty in creating a common legend between FIA forest types and forest type classes in a TM image-based map, and reported that differences in spatial resolution between FIA and TM maps led to differences in area estimates (Owens 2001).

Häme *et al*. (2001), Päivinen *et al*. (2001), Kennedy and Bertolo (2002), and Schuck *et al*. (2003) compared pan-European forest area estimates derived from forest inventory and satellite image-derived sources. For some European countries, forest land area estimates derived from Advanced Very High Resolution Radiometer (AVHRR) satellite imagery and official statistics were within ± 5 percent. For other European countries, area-weighted root mean square errors (RMSE) of estimates derived from AVHRR imagery and forest inventory statistics were tens of percent (Päivinen *et al*. 2001, Schuck *et al*. 2003). Thus, satellite image-derived estimates of forest land area appear relatively comparable across large geographic areas such as the European Union, but differences in these estimates vary among regions and tend to increase within smaller geographic regions.

In our study we explored the efficacy of satellite image-derived maps for estimating forest land area in the United States by comparing estimates obtained from FIA, NRI, and four satellite image-derived data sets: 1991 Forest Cover Types, 1992–93 Land Cover Characteristics, 2001 Vegetation Continuous Fields, and the 1992 National Land Cover Data set. We address differences among FIA and NRI estimates by incorporating ancillary geospatial data. Comparisons are made for the entire United States, the conterminous United States (CONUS), and for individual States.

Data and Methods

Land Ownership

Polygons in the Conservation Biology Institute's Protected Areas Database (PAD) 2001 (DellaSala *et al*. 2001) that delineate boundaries of Federal ownership were recoded into a single Federal lands class. Areas within detailed State boundaries not delineated in PAD as Federal lands or surface water were assumed to have non-Federal ownership. PAD Federal lands were used as a geospatial filter when comparing satellite image-derived estimates with NRI and FIA estimates of non-Federal forest land area.

Inventory Estimates

Forest and Rangeland Renewable Resources Planning Act of 1974

Estimates used in this study come from the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), P.L. 93-378, 99 Stat. 4765 (USDA Forest Service) FRA 2002 Draft Tables on U.S. forest resources, with source dates ranging between 1983–2000 and an average of 1994 (http://ncrs2.fs.fed.us/4801/fiadb/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf). RPA data were derived from FIA data, except for portions of some western States where National Forest System (NFS) lands were inventoried independently (Smith *et al.* 2001, USDA Forest Service 2003). Each of the five regions in the national FIA program report estimates of forest land area for their respective States. These estimates are obtained by multiplying total area inventoried by the mean proportion forest land estimated from forest inventory plot observations. National FIA precision standards "are designed to meet statistical guidelines for accuracy within one standard deviation at the 67 percent level for each State: ± 3–5 percent per million acres of timberland, ± 5–10 percent per million acres of all other forest land" (Smith *et al.* 2001). Because natural variability among plots and budgetary constraints limit the sufficiency of sample sizes, national FIA precision standards may not be achieved using estimation techniques based on simple random sampling. A technique known as stratified estimation (post-sampling stratification) is used to reduce uncertainty of FIA estimates (Cochran 1977, Hansen 2001). Sampling errors used in this study were obtained from a compilation of published statewide FIA reports (Hansen unpublished report) or by updating published data from previous inventories using formula 3 in Hansen (2001). FIA sampling errors for Alaska and Hawaii were estimated based on a conservative assumption that their forest land area estimates meet the FIA national precision standard (likely an underestimate of sampling error) because no FIA sampling errors were available for these two States.

FIA defines forest land as "timberland," "reserved forest land," or "other forest land," including some pastured land with trees, forest plantations, and unproductive forest land. This definition of forest land also requires 10-percent minimum stocking level or, for several western woodland types where stocking cannot be determined, 5-percent canopy cover; minimum area of 0.405 ha (1 acre); and a minimum continuous canopy width of 36.58 m (120 feet) (USDA Forest Service 2003).

National Resources Inventory

NRI is a statistical survey designed to help gauge natural resource status, conditions, and trends on non-Federal land in the United States and is carried out under the authority of a number of legislative acts including the Rural Development Act of 1972, the Soil and Water Resources Conservation Act of 1977, the Federal Agriculture Improvement and Reform Act of 1996, and the Farm Security and Rural Investment Act of 2002. Although NRI data are currently collected on an annual basis, NRI inventories were conducted every 5 years from 1977 through 1997. For this project, statewide NRI estimates of non-Federal forest land were obtained from the NRI 1997 inventory. The 1997 NRI database was chosen because of the temporal similarity to the 2002 RPA's mean data source date of 1994. Although future NRI inventories will also include Alaska, no 1997 NRI data were collected for that State; Alaska is therefore excluded from NRI statewide estimates. The NRI is a longitudinal sample survey based on scientific statistical principles and procedures. The NRI is designed as a stratified cluster sample. Estimates and standard errors of the estimates are calculated using standard statistical procedures (Cochran 1977, Fuller *et al*. 1986, Särndal *et al.* 1992).

The NRI land cover/use definition of forest land is similar to that of FIA in minimum size (0.405 ha or 1 acre) and stocking (10 percent) requirements. Although both require a minimum area of 1 acre, NRI specifies a minimum width of 100 feet, while FIA specifies a minimum width of 120 feet. In some areas of the west, FIA interprets the 10-percent stocking requirement to be equivalent to 5-percent canopy cover, but the stocking definition used by FIA most often is calculated from field measurements of basal area and number of trees per unit area. NRI interprets 10-percent stocking to be equivalent to 25-percent canopy cover when viewed from a vertical direction. Also included in both FIA and NRI forest land definitions are lands not currently developed for nonforest use that bear evidence of natural regeneration of tree cover (for example, cutover forest or abandoned farmland).

Satellite Image-Derived Estimates

This study used four satellite image-derived maps to estimate forest land area. Statewide estimates of forest land area for each of these image sources was obtained by overlaying a detailed State boundary geospatial dataset (ESRI® Data & Maps 2002) using ArcGIS® software (ESRI).

Forest Cover Types

Forest Cover types (FC) data were produced by the Forest Service and the United States Geological Survey (USGS) and are distributed on the National Atlas Web site (http://www.nationalatlas.gov/fortypem.html). Sometimes referred to as the "RPA map" because of its inclusion in the 1997 RPA report (Smith *et al.* 2001), FC is a thematic classification of 25 forest cover types derived from 1991 AVHRR imagery at 1-km spatial resolution (Zhu and Evans 1994). When estimating forest land area, we included all 25 forest types and excluded four nonforest classes (ocean fill, non-U.S. land, U.S. nonforest, and lakes) from the 29 available classes.

Land Cover Characteristics

Land Cover characteristics (LC) data were produced by USGS and are distributed on the National Atlas website (http://www.nationalatlas.gov/landcvm.html) as a map of 25 land cover classes at 1-km spatial resolution (Loveland *et al.* 2000).This data set was created using AVHRR imagery from 1992–93. When estimating forest land area, we excluded 20 nonforest classes and included 5 forest classes: Deciduous Broadleaf Forest, Deciduous Needleleaf Forest, Evergreen Broadleaf Forest, Evergreen Needleleaf Forest, and Mixed Forest.

Vegetation Continuous Fields

Vegetation Continuous Fields (VCF) data provide per-pixel tree cover estimates as percent tree canopy cover data and are derived from 2001 Moderate Resolution Imaging Spectroradiometer (MODIS) imagery at 500-m spatial resolution. VCF data are produced and distributed by the Global Land Cover Facility at

the University of Maryland (http://modis.umiacs.umd.edu/vcf.htm). Hansen *et al.* (2002) reported that a VCF minimum percent tree canopy cover threshold of 35 percent produced a map of CONUS forest land similar in forest land area to a 1992 Forest Service estimate (Powell *et al.* 1993). We calculated two independent VCF percent tree cover thresholds that produce national estimates of forest land area equivalent to NRI 1997 estimates of non-Federal forest land in the United States (excluding Alaska) and RPA draft 2002 estimates for all 50 states, across all land ownerships. Statewide estimates of forest land area were obtained from image pixels having VCF percent tree canopy values greater than or equal to national thresholds corresponding to NRI and RPA estimates.

National Land Cover Data Set

The circa 1992 National Land Cover Data set (NLCD) is a 30-m spatial resolution national land cover data set produced and distributed by the USGS EROS Data Center (EDC), available at http://landcover.usgs.gov/natllandcover.asp, using early 1990s Landsat Thematic Mapper imagery and other sources of digital data. The classification system used for NLCD provides a consistent hierarchical approach to defining 21 classes of land cover across CONUS (Vogelmann *et al.* 2001). For estimating forest land area we examined eight combinations of up to six NLCD classes: transitional (33)[4], deciduous forest (41), evergreen forest (42), mixed forest (43), shrubland (51), and woody wetland (91). Table 1 provides definitions for each combination of NLCD

Table 1.—*CONUS estimates of forest land area (thousand acres) and proportion of CONUS in forest land for non-Federal lands (both NRI and RPA) and for lands of all ownerships (RPA only) derived from NRI, RPA, lower (95low) and upper (95up) limits of NRI and RPA 95-percent confidence intervals, FC, LC, VCF25, VCF36, and combinations of NLCD 1992 classes: 41, 42, and 43 (NLCD3); 33, 41, 42, and 43 (NLCD4a); 41, 42, 43, and 51 (NLCD4b); 41, 42, 43, and 91 (NLCD4c); 33, 41, 42, 43, and 51 (NLCD5a); 33, 41, 42, 43, and 91 (NLCD5b); 41, 42, 43, 51, and 91 (NLCD5c); 33, 41, 42, 43, 51, and 91 (NLCD6); and all 21 classes combined (NLCD21).**

	Non-Federal lands		All land ownerships	
Estimate	**Thousand acres**	**Proportion**	**Thousand acres**	**Proportion**
NRI	404,680	0.271	–	–
NRI95low	391,655	0.262	–	–
NRI95up	417,704	0.279	–	–
RPA	437,315	0.292	620,306	0.321
RPA95low	432,205	0.289	613,819	0.318
RPA95up	442,425	0.296	626,793	0.325
FC	451,091	0.302	631,897	0.329
LC	473,881	0.317	**620,503**	**0.323**
VCF36	**407,699**	**0.273**	–	–
VCF25	–	–	**623,413**	**0.325**
NLCD3	–	–	562,986	0.292
NLCD4a	–	–	575,248	0.298
NLCD4b	–	–	912,741	0.473
NLCD4c	–	–	**617,539**	**0.320**
NLCD5a	–	–	925,003	0.479
NLCD5b	–	–	629,801	0.326
NLCD5c	–	–	967,294	0.501
NLCD6	–	–	979,556	0.507
NLCD21	–	–	1,930,619	1.000

*Values in **bold** type indicate that for pair-wise comparisons, one estimate of CONUS forest land area falls within the 95 percent Confidence Interval of the NRI estimate (for non-Federal land) or the RPA estimate (for all land ownerships).

[4] The correct numerical designation for the transitional class is 33; its designation as 31 in Vogelmann *et al.* (2001) is attributed to a manuscript error (Vogelmann, EROS Data Center, U.S. Geological Survey, personal communication, 10 October 2001).

classes. NLCD forest land area estimates are compared with other estimates across all ownerships, but not with estimates of non-Federal forest land as with the other three satellite image-derived estimates.

Comparisons

RPA/NRI Comparisons

Using statewide sampling errors described above for the two inventory estimates, three separate sets of 95-percent confidence intervals were computed for RPA estimates of forest land area across all ownerships, RPA estimates of non-Federal forest land area, and NRI estimates of non-Federal forest land area. Nonoverlapping confidence intervals for RPA and NRI estimates of non-Federal forest land were interpreted as indicating the plot-based estimates were significantly different.

No estimate of uncertainty (e.g., confidence interval) was available for the image-based estimates. Differences in estimates of forest land area between image- and plot-based estimates are reported as significantly different if image-based estimates fell outside the 95-percent confidence intervals for RPA (across all land ownerships) and NRI (non-Federal lands). Using PAD, Federal lands were excluded from satellite image-based maps when comparing image and NRI estimates of non-Federal forest land area.

Root Mean Square Deviation

In this paper we use area-weighted root mean square deviation (RMSD) rather than RMSE (as was cited from previous studies) for comparing differences in pairs of statewide forest land area estimates derived from plot- or image-based sources:

$$RMSD_{rs} = \sqrt{\sum_i \frac{a_i}{A}\left(\hat{p}_{ir} - \hat{p}_{is}\right)^2} \qquad (1)$$

where a_i is the area of the ith state, A is the total area (sum of a_i s for all states), and $\hat{p}_{ir}$ and $\hat{p}_{is}$ denote the estimated proportion of forest land area in the ith state obtained from two (r, s) of the six sources compared in this study (Häme *et al.* 2001). Values for a_i's, $\hat{p}_{ir}$'s, and $\hat{p}_{is}$'s pertain either to non-Federal lands only or to all land ownerships (depending on estimate pairs), but are consistent in each pair.

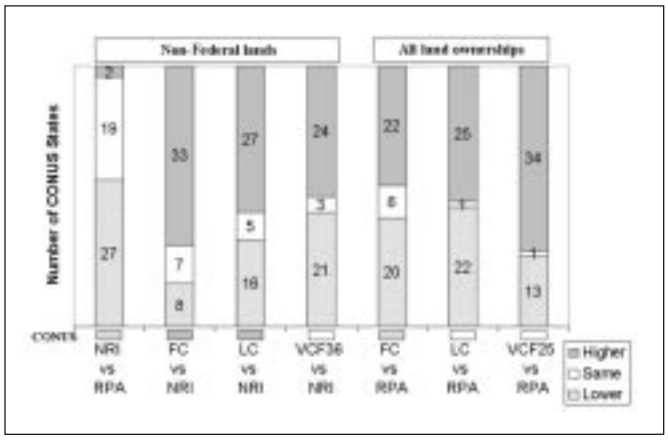
Results

We observed a 2.8-percent difference between 1997 U.S. Census Bureau statistics and 2001 PAD-derived non-Federal land area for the Nation (1.8-percent difference when excluding Alaska). Likewise, statewide 2001 PAD estimates of non-Federal land area generally were within a few percent of 1997 Census Bureau statistics, with notable exceptions for Wyoming (24 percent), Alaska (15 percent), and Idaho (11 percent). (Appendix A; appendixes are not included in this manuscript due to space constraints but are available from the senior author.) An RMSD of 2.5 percent (2.3 percent when excluding Alaska) was observed when comparing PAD to Census Bureau estimates of U.S. non-Federal land.

RPA and NRI estimates of non-Federal forest land area differ by 7.5 percent (NRI-RPA/RPA) across CONUS and as much as 54 percent for individual statewide comparisons (Appendix B). Relative to non-Federal land area (NRI-RPA/non-Federal), the CONUS difference is only 2.2 percent and the maximum statewide difference is 12 percent. The NRI estimate (± 95 percent confidence interval) of CONUS non-Federal forest land area (404.7 ± 13.0 million acres) was significantly less than the RPA estimate (437.3 ± 5.1 million acres) (Appendix B). Statewide NRI estimates were significantly less than RPA estimates in 27 States, similar in 19 States, and significantly greater in 2 of 48 CONUS States (Appendix B, fig. 1). The RMSD for NRI versus RPA forest land area estimates was 3.9 percent (table 2).

Minimum VCF tree canopy cover thresholds of 36 percent (VCF36) and 25 percent (VCF25) resulted in national estimates of forest land area within 95-percent confidence intervals of NRI estimates for CONUS non-Federal lands (404.7 ± 13.0 million acres) (Appendix B) and RPA estimates for the entire United States across all ownerships (748.9 ± 7.2 million acres) (Appendix C). VCF thresholds resulting in statewide estimates of forest land area equivalent to RPA statewide estimates (all ownerships) ranged from 2 percent in Arizona, Nevada, New Mexico, and Utah to more than 55 percent in Connecticut, Massachusetts, and Rhode Island, with six states (Alaska, Illinois, Indiana, Iowa, Ohio, and Oklahoma) having thresholds within 5 percent of RPA's nationwide VCF threshold (25 percent) (Appendix C).

Figure 1.—*Comparison of statewide estimates of forest land area within the conterminous United States (CONUS), excluding Alaska and Hawaii. Bar areas and numerals portray the number of States in each pair-wise comparison where the first estimate is higher, the same as, or lower than the 95-percent confidence interval of the second estimate. Rectangular bars below the x-axis illustrate CONUS-wide comparisons, using the same scheme as described for statewide comparisons.*



Of the three estimates of CONUS non-Federal forest land derived from image products, both FC and LC were significantly higher than NRI while VCF36 was not significantly different than NRI (Appendix B, fig. 1). Based on RMSD, FC appears more similar to both NRI (5.0 percent RMSD) and RPA (2.9 percent RMSD) than do three other image-derived estimates of non-Federal forest land percent (table 2, Appendix B). Slightly larger RMSD values were observed when comparing non-Federal forest land percent estimates based on VCF36 to NRI (6.0 percent) and RPA (7.3 percent) (table 2, Appendix B).

For CONUS estimates across all land ownerships, NLCD3 and NLCD4a (table 1) were significantly lower; FC, NLCD4b, NLCD5a, NLCD5b, NLCD5c, and NLCD6 were significantly higher; and LC, VCF25, and NLCD4c did not differ significantly from the RPA estimate of forest land area (table 1, fig. 1, Appendix C, Appendix D). Of these three estimates, NLCD4c had the smallest RMSD (5.8 percent) (table 1) for CONUS while VCF25 resulted in the smallest RMSD for the entire United States (9.9 percent), relative to RPA estimates. Compared to the RPA estimate across all ownerships, however, FC had the lowest RMSD of all image-derived estimates (2.5 percent) (table 1, table 2).

Table 2.—*Area-weighted RMSD (percent) for pair-wise comparisons of forest land area estimates for CONUS non-Federal lands (above diagonal, italics font) and for CONUS lands across all ownership (below diagonal, regular font).**

Comparison	RPA	NRI	FC	LC	VCF25	VCF36
RPA	…..	*3.9*	*2.9*	*13.2*	–	*7.3*
NRI	–	…..	*5.0*	*14.2*	–	***6.0***
FC	2.5	–	…..	*14.0*	–	*7.6*
LC	**12.2**	–	13.1	…..	–	*13.1*
VCF25	**10.7**	–	10.6	12.0	…..	–
NLCD3	7.0	–	8.3	12.9	13.0	…..
NLCD4a	6.4	–	7.7	12.4	12.1	–
NLCD4b	32.2	–	32.4	38.6	41.0	–
NLCD4c	**5.8**	–	6.3	12.4	8.3	–
NLCD5a	32.2	–	32.4	38.5	40.8	–
NLCD5b	6.2	–	6.5	12.6	7.3	–
NLCD5c	31.4	–	31.4	37.7	39.3	–
NLCD6	31.5	–	31.5	37.7	39.2	–

*Values in **bold** type indicate that for pair-wise comparisons, one estimate of CONUS forest land area falls within the 95-percent Confidence Interval of the other estimate in that pair.

Discussion

Because of its similarity with the 1997 Census Federal land area statistics, PAD was deemed suitable for use as a geospatial filter to exclude Federal land in image-derived analyses for national estimates and for most statewide estimates of non-Federal forest land area. Differences in shoreline definitions and census vintage between ESRI® Data & Maps (2002) State boundary delineations; census statistics; and NRI statistics may result in slight differences in statewide total land area estimates. This study does not address possible effects of these differences on estimates of statewide forest land area.

In general, estimates of non-Federal forest land area from the two inventory sources were more closely related to each other than to the image-derived estimates. The notable exception was the closer agreement between FC and RPA than between NRI and RPA. The relatively small differences between NRI and FIA may be the result of differences in sampling intensity, year of photography, definitions of forest land cover/use, or inventory conventions on range and pasturelands. Greatest differences occurred in the arid western states, which is also where the most rangeland occurs, often with substantial patches of woody canopy).

VCF Estimates

The VCF36 threshold that produced estimates comparable with the NRI 1997 CONUS estimate of non-Federal forest land is nearly identical to the 35 percent-threshold reported by Hansen *et al.* (2002) as being equivalent to a 1992 CONUS Forest Service estimate of forest land area across all ownerships. It is different, however, from the 25-percent threshold we observed for the RPA 2002 nationwide estimate of forest land across all ownerships. No single VCF threshold appears suitable for all national inventories.

By identifying VCF percent tree canopy thresholds specific to inventory, geographic area, land ownership, and date, we obtained VCF-derived estimates of forest land area that fell within 95-percent confidence intervals of NRI and RPA forest land area estimates. For most States, it is inappropriate to extract statewide estimates of forest land area using maps created with a nationwide VCF threshold. The vast majority of VCF-derived statewide estimates were significantly larger or smaller than their corresponding inventory-based estimates, and RMSD values were approximately 6 and 11 percent for comparisons of NRI:VCF36 (non-Federal lands) and RPA:VCF25 (all land ownerships), respectively.

The VCF data set includes continuous estimates of percent tree, percent herbaceous, and percent bare cover, allowing for user-defined thresholds, varying by inventory, land ownership, and geographic extent. Although not analyzed in this study, a similar product (forest density, derived from 1-km AVHRR) also is available as a companion to the FC data (Zhu 1994). Improvements to VCF-derived estimates of forest land area would be expected by determining thresholds in smaller geographic areas; stratifying areas by forest types, type groups, or life forms; or by calibrating per-pixel continuous estimates of land cover to match inventory-based estimates.

NLCD Estimates

All eight NLCD combinations used in this study included three "pure" forest classes (deciduous forest, evergreen forest, and mixed forest) and seven of the eight combinations included one, two, or three additional NLCD classes (transitional, shrubland, and woody wetland). Area estimates derived from NLCD varied widely with class combinations. Estimates from NLCD combinations that included shrubland were about 50 percent larger than RPA estimates of CONUS forest land area across all ownerships and had RMSD values of 31–32 percent. In contrast, NLCD combinations that excluded shrubland resulted in estimates similar to RPA estimates, with RMSD values of about 6–7 percent. In particular, the NLCD4c four-class combination (deciduous forest, evergreen forest, mixed forest, and woody wetland) had the lowest RMSD (5.8 percent) of any NLCD-derived estimate of CONUS forest land area across all ownerships and was the only NLCD-derived estimate to fall in the 95-percent confidence interval surrounding the RPA estimate. NLCD5b included one additional class (transitional), had an RMSD value (6.2 percent) slightly larger than NLCD4c, and produced an estimate of forest land area only slightly larger than the RPA 95 percent upper confidence interval. The apparent superiority of NLCD over some of the other satellite image-derived estimates may result from its finer spatial resolution (30 m versus 500–1000 m) combined with its temporal similarity (~1992) to the mean date of RPA data collection (~1994). Although NLCD estimates

were not calculated for non-Federal lands, such a calculation might be useful for comparison with NRI estimates of non-Federal forest land and other land cover classes.

Forest Cover Types Estimates

Compared with RPA estimates across all land ownerships, the FC-derived estimates had the lowest RMSD of any image-derived estimate, even though the CONUS estimate from FC was significantly larger than the RPA estimate of CONUS forest land area. It is not surprising that FC performed well, despite its coarser spatial resolution (1-km pixel size), because the "Forest Cover Types" used in the FC classification were defined to be consistent with RPA definitions.

Conclusions

Five conclusions may be drawn from the results of this study. First, inventory-derived estimates of non-Federal forest land area from draft 2002 RPA data and 1997 NRI data were closer to each other than to image-derived estimates, with the exception of the Forest Cover Types map. Second, compared to both RPA and NRI, estimates of forest land area derived from FC resulted in the smallest image-derived RMSD, both for non-Federal lands and for all land ownerships. Third, a combination of four land cover classes (deciduous forest, evergreen forest, mixed forest, and woody wetland) from the 1992 National Land Cover Data set resulted in an estimate of CONUS forest land that was similar to the RPA estimate and had an acceptably low RMSD. Addition of "transitional" class resulted in a slightly larger estimate, and also may account for differences between forest land use (e.g., RPA) and forest land cover (e.g., NLCD) by including forest clearcuts and other areas of forest regeneration not usually recognized by satellite imagery as forest cover. Fourth, thresholds of VCF percent tree canopy data can be selected that produce estimates comparable with plot-based estimates at either State or national levels. A single threshold based on nationwide or CONUS-wide plot-based estimates, however, is inappropriate for obtaining estimates within smaller geographic areas, e.g., States. Finally, multiple satellite image-derived land cover maps with a variety of characteristics (date of imagery, classification scheme, spatial resolution, etc.) show potential for complementing U.S. forest resource assessments.

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