

COMPARING MINNESOTA LAND COVER/USE AREA ESTIMATES USING NRI AND FIA DATA

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ABSTRACT.—Areas for land cover/use categories on non-Federal land in Minnesota were estimated from Forest Inventory and Analysis (FIA) data and National Resources Inventory (NRI) data. Six common land cover/use categories were defined, and the NRI and FIA land cover/use categories were assigned to them. Area estimates for these categories were calculated from the FIA and NRI data and compared. Differences were found between FIA and NRI area estimates for all land cover/use categories.

The Forest Service (FS) and Natural Resources Conservation Service (NRCS) are both agencies within the United States Department of Agriculture (USDA), and each conducts a national inventory. The FS Forest Inventory and Analysis (FIA) program conducts surveys of all land in the United States to monitor the status, trends, and health of our Nation's forests. The NRCS conducts the National Resources Inventory (NRI) on all non-Federal land to monitor the status, condition, and trends of our Nation's soil, water, and related resources. These national inventories often overlap in types of estimates produced and geographic areas over which the estimates are made. Yet, resource area estimates produced by the two agencies do not always agree. A demonstration project in north central Oregon examined FIA and NRI area estimates by constructing a common sampling frame for the two inventories (Goebel and others 1998). In this study we used the existing FIA and NRI sampling designs with FIA data from the 1977 and 1990 periodic inventories and the 1999 annual inventory and the 1997 NRI data for the years 1982, 1987, 1992, and 1997 to explore estimation differences in Minnesota. The objectives of this study were to 1) define common land cover/use categories, 2) crosswalk NRI and FIA land cover/use categories, and 3) compare land cover/use area estimates obtained from FIA and NRI data.

LAND COVER/USE CATEGORIES

The Forest Inventory and Analysis (FIA) and National Resources Inventory (NRI) programs differ in many of their land cover/use classifications. Because these classifications are generally not one-to-one matches, we chose to combine land cover/use into six major classifications for area estimate comparison: forest land, cropland/pastureland, other rural land, developed land, small water areas, and Census water (table 1). Although the categories used in this paper have been generalized, assignment problems still arise because of differences in definitions between the two inventories.

The first land cover/use category, forest land, is defined by FIA as land that is currently at least 10 percent stocked with live trees of any size that are expected to reach a height of at least 12 feet at maturity or land that has been at least 10 percent stocked in the past and not currently developed for nonforest use. Forest land is not subject to nonforest uses that prevent normal tree regeneration and succession such as regular mowing or intensive grazing. To qualify as FIA forest land, the area must be at least 1 acre in size and have a minimum width of 120 feet (FIA Field Methods for Phase 2 Measurements, 2001, <http://fia.fs.fed.us/library.htm#Manuals>). The NRI defines forest land as land that is at least 10 percent stocked by trees of any size that will be at least 4 m (13 ft) tall at maturity. Also included in forest land is land bearing evidence of natural regeneration of tree cover (cutover forest or abandoned farmland) and not currently developed for nonforest use. The minimum area for classification of NRI forest land is 1 acre, and the area must be at least 100 feet wide (1997 NRI Data Collection Instructions, http://www.nrcs.usda.gov/technical/NRI/1997/data_gathering.html). Although similar in many ways, there are several differences between FIA and NRI forest

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Table 1.—FIA and NRI non-Federal land cover/use categories combined for the six general categories: forest land, cropland/pastureland, other rural land, developed land, Census water, and non-census water

Combined category	FIA Code	Description	NRI Code	Description
Forest land	20	Timberland	341	Forest, grazed
	21	Pastured timberland	342	Forest, not grazed
	22	Plantations		
	40	Unproductive forest land		
	41, 45	Reserved forest land		
	57	Wide windbreaks		
	59	Wooded pasture		
Cropland/pastureland	51	Cropland with trees (orchards)	1-6	Horticulture crops
	52	Pasture with trees	11-20	Row crops
	54	Idle farmland with trees	21-116	Close grown crops
	61	Cropland without trees	141-143	Hayland
	62	Pasture without trees	170-180	Other cropland
	64	Idle farmland without trees	211-213 410	Pasture CRP
Other rural land	46	Christmas tree plantations	400	Farmsteads
	50	Reserved non-forest with trees	401	Other land in farms
	53	Wooded strip	611, 612	Salt flats, bare rock
	56	Narrow windbreaks	614, 615	Beaches and dunes
	58	Shelterbelt	616	Mixed barren land
	65	Marsh without trees	617, 618	Mud flats, river wash
	66	Other farmland and farmsteads	620	Other barren land
	69	Reserved non-forest without trees	640 650	Marshland All other land
Developed land	67	Urban and other areas without trees	613 619	Mines, quarries, etc. Oil wasteland
	68	Rights-of-way	700	Large urban
	71	Urban forest land	730	Small urban
	72	Urban and other with trees	810	Interstate highway
			820	Paved federal or state highways
			830	Other paved roads
			840	Gravel road
			850	Dirt road
			860	Railroad
		870	Other (private) roads	
Census water	90	Census water (<i>> 660 ft wide or > 40 ac</i>)	921-924	Census waterbody (<i>> 40 ac</i>)
			913	Perennial stream (<i>>660 ft wide</i>)
Non-census water	80	Non-census water (<i>120-660 ft wide or 1-40 ac</i>)	901	Waterbody (<i>2-40 ac</i>)
	89	Reserved non-census water (<i>120-660 ft wide or 1-40 ac</i>)	902	Waterbody (<i>< 2 ac</i>)
			911	Perennial stream (<i>< 66 ft wide</i>)
			912	Perennial stream (<i>66-660 ft wide</i>)

land definitions. FIA requires a minimum forest area width of 120 feet, while NRI requires a minimum width of only 100 feet. Both NRI and FIA require a minimum stocking of 10 percent, but interpretations differ. The 10-percent stocking requirement is generally adhered to by FIA, but it has been modified to include several western woodland types where stocking cannot be determined, and the condition has (or has had in the past) at least 5 percent canopy cover by trees of any size. In the Oregon project, FIA used an operational definition for designating an area of 10-percent stocked forest as having a 10-percent cover (Goebel and others 1998). The NRI interprets 10 percent stocked, when viewed from a vertical direction, as a canopy cover of 25 percent or greater. The FIA interprets 10 percent stocked, in terms of basal area per acre and/or number of trees per acre, as a comparison of the degree of occupancy of land by live trees compared to the growth potential of the land. FIA has a wide range of forest subcategories, while NRI has two: grazed and not grazed.

Within the forest land category, we also compared area estimates of forest type. The NRI and FIA both use forest type categories defined by the Society of American Foresters (SAF). The 1997 NRI database includes forest cover type data that we compared with those in the FIA inventories. Because FIA does not recognize the oak-pine forest type in Minnesota, the NRI data in the oak-pine forest type (representing approximately 80.3 thousand acres) were reassigned to the red-white-jack pine forest type.

The second land cover/use category, cropland/pastureland, includes a wide range of NRI land cover/use categories and a more limited group from FIA. This cropland/pastureland category includes orchards and other horticultural crops, cultivated cropland, noncultivated cropland, pastureland, and Conservation Reserve Program (CRP) land. The third land cover/use category, other rural land, includes farmsteads, Christmas tree plantations, wooded strips and windbreaks not large enough to meet the forest definition, barren land, and marshland. Developed land is the fourth land cover/use category. The NRI includes forested land less than 10 acres in size within urban and built-up areas as urban. Although normally considered forest land, the FIA urban forest land use code (71) is included in the developed land category so that this grouping would include areas of similar land types. The NRI categories for mines, quarries, gravel pits, and borrow pits (613) and for oil wasteland (619) are included with developed land since these would be categorized by FIA as urban and other (67, 72). Although

the NRI estimates that approximately 180,000 acres of Minnesota are in the first category (613), none are in the oil wasteland category. Both FIA and NRI use the U.S. Bureau of Census definitions for large (census) water, the fifth land cover/use category. Note that Census water is not included in Federal land ownership. In both inventories, the small (non-census) water category—the sixth land cover/use category—includes smaller streams and bodies of water.

The land cover/use categories for this study were compared on non-Federal land. No land cover/use data were collected for NRI points that fell on federally owned land. FIA plots that are field-visited have an ownership category recorded from which Federal ownership can be determined. A land cover/use, but not ownership, is recorded for non-forested FIA plots that are not field-visited. Because of these inventory differences, we determined that 1) land cover/use comparisons for FIA and NRI data must be made within the non-Federal land ownership, and 2) FIA data must first be separated into Federal and non-Federal groupings. For FIA plots having a recorded ownership class, the FIA ownership was used. For FIA plots with no recorded ownership, the geostatistical estimation data for the 1997 NRI (Nusser and others 1999) provided the GIS layer used in this study to determine if the FIA plots were located on Federal or non-Federal land.

FEDERAL GIS LAYER

The geostatistical estimation data for the 1997 NRI were used as a GIS layer in this study to assign Federal and non-Federal ownership to FIA plots with no recorded ownership. The NRI constructed this data set to provide geostatistical information on total surface area, surface area of Federal land, and area in large water bodies and large streams for each sub-county area, referred to as a HUCCO. The area intersected by the boundaries of a county and four-digit hydrologic unit area (see <http://www.nhq.nrcs.usda.gov/land/meta/m2143.html>) forms a HUCCO. The NRI uses this data set in the estimation process to develop area expansion factors for its point data.

To construct the geostatistical data layer, Census TIGER digital line files from 1995 were obtained from the U.S. Bureau of the Census (see www.census.gov/ftp/pub/geo/www/tiger/). These files represent 1:100,000 scale maps that delineate county boundaries, water bodies and streams, roads, and other land features. The 1998 release of a digital layer for Federal lands, updated to 1996 conditions and at a scale of 1:2,000,000, was obtained from the U.S. Geological Survey (USGS). When

TIGER information on Federal land was consistent with the USGS data, Federal boundaries were extracted from the TIGER data. Otherwise, Federal boundaries were extracted from the USGS layer. The National Oceanic and Atmospheric Administration (NOAA) shoreline was modified to exclude water areas extending beyond the shoreline of the U.S. coast for counties bordering the oceans and Great Lakes and to include islands belonging to the coastal counties. The shoreline modification was used to match NRI land definitions and is often referred to as the Lawson shoreline (Nusser and others 1999).

DATA

FIA data from the 1977 and 1990 periodic inventories and the 1999 annual inventory were used in the analysis. The periodic FIA inventories were historically conducted on a State-by-State basis at approximate intervals ranging from 6 to 8 years in the South and 11 to 18 years elsewhere (Gillespie 1999). The Agricultural Research, Extension, and Education Reform Act of 1998 directed the FIA program to conduct an annual inventory; FIA has begun to implement that inventory at an approximate rate of 20 percent per year in the East. The 1999 FIA data are taken from the first year of annual data collected in Minnesota and have subsequently fewer observations (1,821 plots) than the 1977 and 1990 data with 35,964 and 43,955 plots, respectively (McRoberts 1999, Brand and others 2000). Note that the 1977 and 1990 FIA inventories in Minnesota contained three times the number of plots in the base program (referred to as triple intensity), while the 1999 inventory contains 20 percent of the plots in the base program.

This study includes 1997 NRI data for the years 1982, 1987, 1992, and 1997, with 24,426 observations. The NRI has also begun a continuous inventory (with partial implementation in 2000 and full implementation in 2001) in which observations on 20 to 25 percent of the sampling units will be collected annually on sets of core and rotational sampling units. Neither the NRI continuous inventory data nor the FIA annual inventory data from 2000 and 2001 were available for inclusion in this paper.

DESIGN AND ESTIMATION

The sampling design for FIA is double sampling for stratification, conducted in two phases (Hansen and others

1992; Schreuder and others 1993 on page 188; http://www.srsfia1.fia.srs.fs.fed.us/statistics_band/stat_documents.htm). All FIA estimates and sampling errors provided here are based on stratified random sampling estimators with stratification after the selection of the sample (poststratification) presented in Cochran (1977 on pages 134-135) with finite population correction ignored. The sampling design of the NRI surveys is a stratified two-stage area sample (Nusser and Goebel 1997, Goebel 1998, Nusser and others 1998, Fuller 1999, Fuller and others 2001). The NRI area estimates and standard errors are obtained with stratified cluster sampling estimation techniques based on Cochran (1977 on pages 288-289).

RESULTS

Estimates of totals and standard errors for areas of non-Federal land in each of the land cover/use categories in table 1 were made for the NRI and FIA data using the statistical estimation procedures specified in the prior section. The results are given for the NRI and FIA data in tables 2 and 3, respectively. The NRI uses the U.S. Bureau of Census data for State total area, Federal land, and Census water as control data in the assignments of weights and therefore no standard errors are included for these categories. Similarly, no standard errors are reported for Census water and total area in table 3 of FIA estimates. The total area for Minnesota in tables 2 and 3 differs slightly. The FIA uses the 1970, 1980, and 1990 U.S. Census data values for their 1977, 1990, and 1999 inventories, respectively. The NRI database updates total land area for past inventories to that of the current inventory so that trends over time may be compared. Therefore, NRI totals for the years 1982-1997 in the 1997 database are based on the 1990 U.S. Census figures. The NRI definition for land included in shoreline, as mentioned in the section entitled Federal GIS Layer, causes slight deviation from the U.S. Census figure. Area estimates of non-Federal forest land by forest type categories are given in table 4.

Although the inventories are conducted at different dates, the NRI estimates of area in non-Federal forest land in Minnesota are all greater than those of FIA by nearly 2 million acres (tables 2 and 3). The NRI estimates of non-Federal forest area over the years from 1982 to 1997 show an increase of between 133.2 and 403.2 thousand acres (based on 95 percent confidence intervals for change), with an increase of between 170.9 and 359.1 thousand acres between 1992 and 1997.

Table 2.—NRI area estimates for land cover/use categories in Minnesota. Standard errors for estimates are in parentheses.

	1982 NRI	1987 NRI	1992 NRI	1997 NRI	1982-1997 change
	- - - - - Thousand acres - - - - -				
Nonfederal	47,953.5	47,932.1	47,936.2	47,936.3	
Forest land	15,980.1 (230.6)	15,903.2 (232.8)	15,983.3 (233.3)	16,248.3 (231.3)	268.2 (68.9)
Crop/pastureland	26,897.3 (243.6)	26,780.7 (235.3)	26,579.8 (232.9)	26,392.0 (234.1)	-505.3 (69.7)
Other rural land	2,780.6 (106.9)	2,822.6 (109.6)	2,842.7 (111.2)	2,536.4 (103.5)	-244.2 (44.0)
Developed land	1,901.0 (60.9)	2,028.7 (62.4)	2,131.4 (64.2)	2,365.1 (69.0)	464.1 (37.7)
Non-census water	394.9 (16.8)	396.8 (16.9)	399.1 (17.2)	394.5 (17.1)	-0.4 (7.5)
Federal land	3,326.3	3,342.3	3,336.3	3,336.3	
Census water	2,729.7	2,735.6	2,737.3	2,737.3	
Total	54,009.9	54,009.9	54,009.9	54,009.9	

Because the NRI sampling locations do not change between inventories, the NRI is a trending database and paired comparisons make it possible to place standard errors on the estimates of change. The FIA inventories indicate a slight decline in non-Federal forest land between 1977 and 1990 by approximately 0.3 million acres, but an overlap of the 95 percent confidence intervals for the estimates from the 1990 and 1999 inventories indicate there is no difference in estimates of non-Federal forest land. The NRI estimates a loss of between 368.7 and 641.9 thousand acres of non-Federal cropland/pastureland in Minnesota between 1982 and 1997, with between 201.7 and 433.3 thousand acres of that loss occurring between 1982 and 1992. The 1977 and 1990 FIA estimates of the area of non-Federal land in the cropland/pastureland show an approximate 476-thousand acre decrease. The FIA area estimates for non-Federal land in the other rural

land and developed land categories are higher than to those of NRI. Both the NRI and FIA area estimates of developed land increase over time.

DISCUSSION

Differences in definitions for land cover/use categories by the NRI and FIA may contribute to differences in estimates of area for the six categories of non-Federal land. Area estimates of non-Federal forest land by the NRI are greater than those of FIA. Both the FIA and NRI use forest land definitions of 10 percent stocking and a minimum size of 1 acre. However, the FIA requires strips of forest land to be at least 120 feet in width, while the NRI requires only a 100-foot width. A 10-percent stocking level is interpreted by the NRI as 25 percent

Table 3.—FIA area estimates for land cover/use categories in Minnesota. Standard errors for estimates are in parentheses.

	1977 FIA	1990 FIA	1999 FIA
	- - - - - Thousand acres - - - - -		
Nonfederal	47,766.9	47,392.4	47,638.5
Forest land	14,102.5 (54.2)	13,843.7 (51.4)	13,556.8 (294.5)
Cropland/pastureland	27,307.7 (75.4)	26,831.7 (71.6)	27,122.5 (416.6)
Other rural land	3,775.1 (28.0)	3,958.7 (27.5)	3,681.3 (153.5)
Developed land	2,343.9 (22.1)	2,450.9 (21.6)	2,886.7 (135.9)
Non-census water	237.7 (7.0)	307.4 (7.7)	391.2 (50.0)
Federal land	3,212.7 (25.9)	3,516.5 (25.9)	3,286.7 (145.0)
Census water	3,058.7	3,107.1	3,107.1
Total	54,038.3	54,016.0	54,032.2

cover, as viewed from above. This interpretation may include areas of forest land that have less than 10 percent stocking. Table 4 provides a breakdown of estimated non-Federal forest land area into forest types. The estimated acres of non-stocked forest land by the NRI are much lower than those of the 1990 and 1999 FIA. Although the inventories were conducted for different years, the NRI area estimates for the red-white-jack pine forest type are nearly double those of the FIA, while the FIA area estimates of maple-beech-birch and non-stocked are more than twice those of NRI.

Data collection procedures may also contribute to the differences in estimates. In 1982, all NRI points were field-visited with aerial photograph (scale 1:7900) in hand. In the 1992 NRI, about 25 percent nationally were field-checked, while in 1997 a smaller percentage were field-checked. All 1977 Minnesota FIA Phase 2 plots that were forested or possibly forested, based on Phase 1 stratification, were field-visited. For the 1990 Minnesota FIA inventory, aerial photos (1:15,840) of all 1977 ground plots were examined (Miles and others 1995). The photos were used to classify the 1977 ground plots as either disturbed or undisturbed forested plots and for part of the State, verification of the photointerpretation for undisturbed forest plots was done

from fixed wing aircraft. All disturbed forest plots and one-third of undisturbed forest plots were field-visited, and models were used to update the remaining undisturbed forest plots. A smaller percentage of non-forested FIA Phase 2 plots were field-visited and remote sensing (e.g., aerial photos) was instead used to assign the plots to land use categories.

CONCLUSIONS

The sampling methods and definitions used by the FIA and NRI inventory programs may contribute to differences in area estimates for the various land cover/use categories outlined in this paper. Both agencies use definitions that rely on a combination of land cover and land use. While land cover classifications are based strictly on the current cover observed on the land, land use is more convoluted. Classifications based on land use are interpretations of how the land is used. The forest land definition, for example, includes land that is forested now or has been forested in the past but that has not been converted to any other use. With the expanding use of remote sensing by both agencies, common definitions based on land cover would provide a venue for closer agreement of area estimates in those classes. Continuing with the forest land

Table 4.—Area estimates of non-Federal forest land in Minnesota by forest type. Standard errors for estimates are in parentheses.

	1977 FIA		1990 FIA		1997 NRI		1999 FIA	
	<i>(Thousand acres)</i>		<i>(Thousand acres)</i>		<i>(Thousand acres)</i>		<i>(Thousand acres)</i>	
White-red-jack pine	584.2	(11.0)	696.3	(11.5)	1,273.2	(137.0)	620.2	(63.0)
Spruce-fir	2,447.2	(22.6)	3,443.4	(25.6)	3,897.4	(182.9)	2,546.5	(127.7)
Oak-hickory	922.2	(13.9)	1,160.1	(14.9)	1,765.4	(85.7)	1,460.7	(96.7)
Elm-ash-cottonwood	922.3	(13.9)	1,291.9	(15.7)	1,923.4	(112.3)	1,355.5	(93.1)
Maple-beech-birch	1,063.4	(14.9)	1,303.9	(15.8)	593.4	(56.2)	1,214.7	(88.2)
Aspen-birch	5,766.2	(34.7)	5,572.0	(32.6)	6,672.6	(247.6)	5,813.5	(192.9)
Non-stocked	2,105.2 ^a	(20.9)	376.1	(8.5)	122.9	(29.5)	270.7	(41.6)
Total	13,810.7	(53.6)	13,843.7	(51.4)	16,248.3	(231.3)	13,281.7	(291.5)

^a Note that the 1977 FIA estimate for area of nonstocked forest land is based on a definition of nonstocked forest land that caused many more plots to be classified as nonstocked in 1977 than the definition that is currently used by FIA. In 1977 a plot was classified as nonstocked if it did not have sufficient stocking in live growing-stock trees (trees of commercial species that have or potentially have a merchantable saw log in them). The new definition of nonstocked excludes only dead trees; it does not exclude noncommercial species or cull trees that do not contain a saw log or potential saw log.

example, forest land that is clearcut may initially be assigned to a land cover class of grass, followed by shrubland as regeneration occurs, and finally forest land as the trees mature. The land use definitions may be retained as additional types of classifications by each of the agencies to meet their needs, while the land cover definitions would provide the common classifications.

A common digital base map with Federal boundaries and Census water superimposed on other political boundaries could provide a common county-level data set for use by both agencies. The geospatial GIS layer, constructed for use by the NRI and used in this study, may be the first iteration of this type of data layer.

Further work needs to include investigation into why the FIA and NRI estimates are seemingly different. It may be an issue of ownership; misclassification of plots as Federal or non-Federal may have led to differences. Closer inspection of differences should be investigated geospatially, by land cover/ use category, and other factors to better understand where the differences lie and how to reconcile those differences.

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