Improving Forest Inventory and Analysis Efficiency With Common Land Unit Information

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Abstract.—The Forest Service, U.S. Department of Agriculture's (USDA's) Northern Research Station Forest Inventory and Analysis program (NRS-FIA) examines inventory locations on digital aerial imagery to determine if the land use at each plot location meets the FIA definition of forest and thereby becomes a field visit site. This manual image-interpretation effort requires a significant amount of staff time yet accrues substantial financial savings. Using the same imagery currently used by NRS-FIA, the Service Center Agencies of the USDA have initiated work on a digital data set detailing agricultural areas, including a land class designation. These data are known as Common Land Units (CLUs). In this study, CLU data for the State of Minnesota were acquired from USDA's Farm Service Agency. NRS-FIA manual image-interpretation information for inventory locations was compared with the land class information in the CLU data set. Thirty-five percent of Minnesota FIA plots were identified as nonforest using the CLU data set. A little less than 1 percent of plots fell within nonforest CLU polygons yet were observed during field visits to be forested. Thus, the CLU method for identifying nonforest plots may introduce a small underestimation bias into the inventory. Because NRS-FIA plots previously observed as forested will be revisited regardless of an updated land use status, however, this bias would not occur. Thus, the CLU data set shows the potential to eliminate manual, prefield image interpretation of plots occurring within agricultural areas delineated by CLU boundaries.

Introduction

The Forest Service's Northern Research Station Forest Inventory and Analysis program (NRS-FIA) examines inventory locations on digital aerial imagery to determine if land use at plot locations meets the FIA definition of forest. If the criteria are satisfied, the location becomes a field visit site. Not visiting nonforest plots accrues substantial financial savings, particularly in States in which agriculture dominates the landscape. For example, of approximately 33,000 inventory plots image interpreted for North Dakota, South Dakota, Nebraska, and Kansas during the 5-year first annual FIA inventory, fewer than 4 percent were forested.

Ideally, land use status at plot locations is reexamined during every inventory cycle using updated imagery to detect changes that have occurred since the previous inventory. Although previously forested plots will be revisited in the subsequent cycle regardless of land use change, previously nonforested plots may change to forest land but not be identified as forested plots unless more current image products are interpreted. Omitting forested plots from field visits may result in biased estimates. This prefield effort requires a significant amount of image-interpretation time. The objective of this study was to determine to what extent image-interpretation work could be reduced by using other sources of land use information to determine whether FIA plots are forested.

Data

FIA Plots

The first annual FIA inventory in Minnesota included 16,383 plots (1999–2003). The geographic coordinates of each plot were precisely identified in one of two ways, depending

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on whether the plot was forest or nonforest. Locations for nonforest plots were obtained by transferring hardcopy photo pinpricks via Geographic Information System (GIS) software and heads-up digitizing to high-resolution, orthorectified digital aerial imagery. Locations for forested plots were recorded via a Global Positioning System receiver, and these locations were passed through a set of quality checks to ensure they were reasonably accurate.

In addition, the land use code, determined by image interpretation, was queried for each plot. Each image-interpreted land use has an associated field visit decision. For example, plots that appear to fall on or very near forest land receive a field visit while plots appearing to fall on pasture or rangeland do not. All previously forested plots are revisited, regardless of current image-interpretation results. In addition, a fraction of field-visited plots actually were determined to have nonforest land use. This land use information allowed us to compare image-interpretation–based prefield decisions (i.e., whether a plot requires a field visit) with decisions made using an alternative source of land use data.

Common Land Units

The Service Center Agencies of the U.S. Department of Agriculture (USDA), including Farm Service Agency (FSA), Natural Resources Conservation Service, and Rural Development, have initiated work on a digital data set detailing agricultural areas. These data are known as Common Land Units (CLUs) and are defined as the smallest units of land that have the following properties: a permanent contiguous boundary, common land cover and land management, a common owner, and common producer association. Areas were digitized from National Agriculture Imagery Program (NAIP) images, the same imagery currently used by NRS-FIA to make determinations of land use. CLU data for a large portion of the country have been completed, and updates will occur on a continual basis. More information on the Common Land Unit data set can be found on FSA's Web site.[3]

CLU spatial data (polygons) are readily available to USDA agencies, but CLU attribute data are restricted due to landowner privacy concerns. In this study, CLU spatial data were acquired for the State of Minnesota along with a subset of CLU attributes relating to land class designation for each CLU polygon. Land classes include Urban, Cropland, Rangeland, Forest, Water Body, Barren, Tundra, Mined Land, and Other Agricultural Land. No CLU attributes pertaining to landowner information were obtained. Figure 1 shows an example of the NAIP imagery used to create the CLU data set and CLU polygons with their associated land classes for an agricultural area in Minnesota. The CLU data set for Minnesota includes more than 1.2 million polygons.

Figure 1.—*The image at the top is a grayscale representation of a National Agriculture Imagery Program aerial image taken over an agricultural area in Minnesota. The bottom image shows the associated Common Land Unit (CLU) land classes derived from that image. The hatched polygons represent cropland, the gray polygons represent the Other Agricultural Land class, and the narrow linear white features corresponding to roadways are not attributed in CLU.*

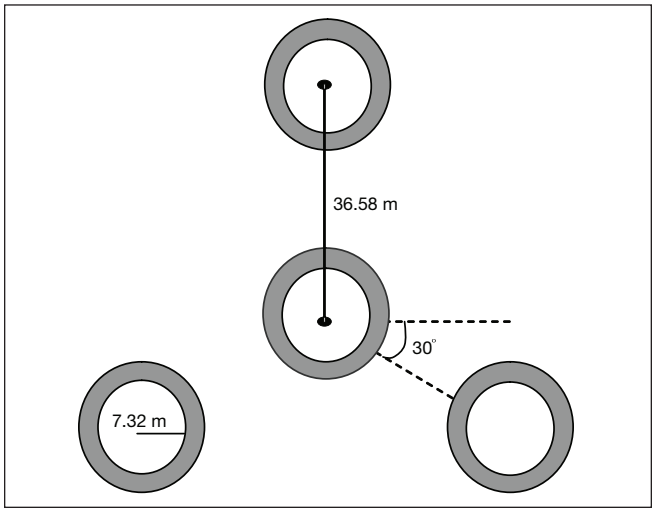
[3] http://www.fsa.usda.gov.

Methods

Using GIS software, plot coordinates (latitude, longitude—North American Datum of 1983) were reprojected to match the projection of the CLU data set (Universal Transverse Mercator, Zone 15N,—North American Datum of 1983). Polygons were constructed to represent FIA's plot design (see the inner circles in fig. 2). Next, 3-m buffers were constructed around each subplot to account for the reported uncertainty in CLU horizontal position (see the gray band surrounding each subplot in fig. 2). A subset of the CLUs was then created which included only polygons in definite nonforest land classes (i.e., polygons with missing or unknown land classes were excluded). This CLU subset was processed using standard GIS functionality to remove small "sliver" polygons.

GIS software was used to select FIA plots (subplots with buffers) that lie completely within nonforest CLU boundaries. This selected set was then labeled as nonforest. Conversely, plots that lie only partially within or completely outside nonforest CLU boundaries were not assigned a label. Because areas outside the nonforest CLU polygons can be either forest or nonforest, plots lying in these areas require additional information to make a forest/nonforest determination. FIA plots labeled as nonforest using the CLU method were then assessed in terms of the image-interpreted land use and/or the land use determined during the field visit.

Figure 2.—*Forest Inventory and Analysis plot design with 3-m buffer (outer gray circles) around each subplot (inner circles).*



Results

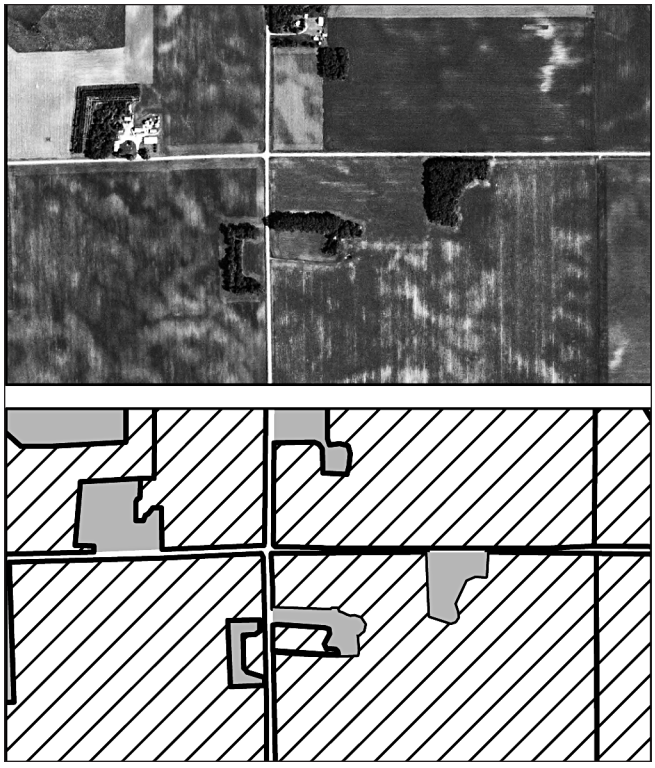
Statewide, the CLU method identified 5,741 out of 16,383 Minnesota FIA plots (35 percent) as nonforest. Of those 5,741 plots, FIA's image-interpretation method also identified 5,551 nonforest plots. A field visit was deemed necessary for the remaining 190 plots identified via image interpretation. Of those 190 plots, 67 were observed to be nonforest during the field visit. The remaining 123 plots are cases in which the CLU method would have led to forested plots being called nonforest. If a single-intensity FIA sample is assumed and each plot represents approximately 2,422 ha, these "missed" plots represent a potential underestimation of Minnesota's forest land area by 298,000 ha, or about 0.95 percent of Minnesota's 6,568,416 ha of forest land (Miles 2001).

The 123 forested FIA plots incorrectly identified by the CLU data set as nonforest are distributed across the various CLU land classes in the following manner: Urban, 1 plot; Cropland, 6 plots; Rangeland, 29 plots; Water Body, 1 plot; and Other Agricultural Lands, 86 plots. Independent image interpretation of Other Agricultural Land polygons revealed riparian trees adjacent to cropland and large tree plantings in proximity to farmsteads in this land class (see the example in figure 3). In some instances, these trees met the FIA definition of forest and therefore required a field visit.

Of the remaining 10,642 plots that the CLU method could not identify as nonforest, a field visit was not required for 5,381, as determined by FIA image interpretation. These plots can be viewed as lost opportunities for the CLU method to reduce image-interpretation work, but would not introduce bias into FIA estimates.

The CLU method shows the most potential savings to FIA in heavily agricultural counties in the southern and western regions of Minnesota. In one county, CLU data identified 89 percent of all FIA plots as nonforest. By extrapolation, the States of North Dakota, South Dakota, Nebraska, and Kansas could show similar results because of the predominance of agricultural (nonforest) land use in those States.

Figure 3.—*A National Agriculture Imagery Program image (top) showing a group of trees (just right of center) that meet the Forest Inventory and Analysis definition of forest. The image at the bottom shows the associated Common Land Unit "Other Agricultural Lands" polygons in gray, and Cropland is represented by the hatched areas.*



Conclusions

The CLU method for identifying nonforest plots has the potential to eliminate a large amount of manual image interpretation, particularly in heavily agricultural areas. Despite this potential benefit, the CLU method incorrectly identified 123 out of 16,383 forested plots as nonforest in the State of Minnesota. Although this figure represents less than 1 percent, it represents the possibility for a biased underestimation of forest land area if those plots are excluded from field visits. It should be noted that the goal of photo interpretation in the second annual inventory cycle will be to identify plots that were nonforest in the previous inventory that have become forested or partially forested. In this scenario, the 123 plots with CLU-FIA disagreement would have received a field visit despite the CLU determination because of their previous status as forested. Therefore, in a second annual inventory, the real concern is how often the CLU method misses plots that have converted from nonforest to forest land use. Additional study is required to make this determination.

As stated previously, 86 of the 123 errant nonforest determinations using the CLU method occurred in the Other Agricultural Lands class, which comprises 635,000 ha in Minnesota. Removing this class from the nonforest CLU subset would increase the number of plots that cannot be assessed using the CLU method but would also reduce the potential for underestimation of forest area in the inventory.

A recommendation for increasing the number of plots that can be identified as nonforest using the CLU data set is to supplement the analysis with road information from another source. Roads are not part of the CLU data set, and they frequently separate cropland fields in agricultural landscapes (fig. 1). Plots that either touch or straddle a road were not identified as nonforest using the method in this study, even if the areas adjacent to the road were completely nonforest. Adding roads to the CLU data set would allow the method in this study to correctly identify plots in this scenario as nonforest. In addition, a large portion of the CLU polygons have a land class of "None" or the land class is missing (more than 2.5 million ha). Updates to the CLU data set may eliminate some of these issues and could greatly improve results obtained using the method described in this study.

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