
POTENTIAL APPLICATIONS OF PREFIELD LAND USE AND CANOPY COVER DATA: EXAMPLES FROM NONFOREST AND NONSAMPLED FOREST INVENTORY PLOTS

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ABSTRACT

The Forest Inventory and Analysis (FIA) prefield workflow involves interpreting aerial imagery to determine whether each plot in a given inventory year may meet FIA's definition of forest land. The primary purpose of this determination is to minimize inventory costs by avoiding unnecessary ground surveys of plots that are obviously in nonforest areas. Since the initiation of the annual forest inventory, prefield data collection has consisted primarily of a simple visit/non-visit determination, along with a few regionally inconsistent ancillary variables. Therefore very little information was recorded for nonforest areas with trees, such as recreational developments and urban forests. Beginning in the 2012 inventory year, a nonforest land use code and a continuous tree canopy cover value will be implemented for all non-visited and non-sampled plots. The purpose of this paper is to describe the new prefield protocol and illustrate potential applications of the new variables.

INTRODUCTION

Throughout most of the nation, the Forest Inventory and Analysis Program (FIA) employs photo-interpretive techniques to identify plots in the FIA sample grid that are undoubtedly nonforest and thus do not require inclusion in the field inventory (Reams et al. 2005). The process of making these visit/non-visit determinations is referred to as FIA prefield operations, and its purpose is to reduce field costs by avoiding ground surveys of plots that are obviously nonforest. The FIA definition of forest land has both a land use and a tree cover component. Prefield photo interpreters examine each plot location on the most recent high-resolution aerial imagery and evaluate whether trees are present and whether the plot is subject to a land use that precludes it from meeting the FIA definition of forest land. Plots that are clearly and undoubtedly nonforest are removed from the field inventory and recorded as office-generated nonforest plots.

A visual assessment of the land use and tree cover of each FIA plot location is inherent to prefield visit/non-visit determinations. However, since the initiation of the annual forest inventory, prefield data collection has consisted

primarily of a simple visit/non-visit determination, along with a few regionally inconsistent ancillary variables. Nonforest land use has been recorded as a regional variable in all four FIA regions: Interior West (IW), Northern Research Station (NRS), Pacific Northwest (PNW and PNW-AK), and Southern Research Station (SRS). However, this variable is not part of the national protocol and consequently there are gaps in the national database. Very little information has been recorded for nonforest areas with trees, such as recreational developments and urban forests. Therefore the potential for prefield operations to provide additional information, such as estimates of nonforest lands with trees, has not been realized.

FIA TERMINOLOGY

FIA terminology regarding Phase 1 and Phase 2 are often confused, especially with regard to prefield operations. FIA's national sample grid is referred to as the Phase 2 (P2) grid, and prefield photo interpretation is considered part of this P2 inventory (Reams et al. 2005). In contrast, Phase 1 (P1) of the FIA inventory uses photo-interpreted point data to classify satellite imagery, produce forest/nonforest strata, and develop regional estimation statistics (see Bechtold and Patterson 2005 for details on P1 stratification). The photo-interpretive aspects of prefield operations resemble those used for FIA P1 stratification, but not all regions use P2 plot locations to develop their P1 strata. Furthermore, the land use that is recorded for P2 plots may or may not be consistent with the P1 strata.

Within the FIA P2 inventory, a certain percentage of plots is sampled each year, and the number of years required to sample all P2 plots is referred to as a cycle. For FIA regions with a five-year cycle, each inventory year is referred to as a panel and consists of 20 percent of all P2 plots (e.g., in the majority of the NRS and SRS FIA regions). For regions with a 10-year cycle, each inventory year is referred to as a subpanel and consists of 10 percent of P2 plots (IW and PNW FIA regions).

THE PREFIELD INVENTORY: NEW VARIABLES AND METHODS

Beginning with the 2012 panel, the prefield data collection will include nonforest land use and tree canopy cover variables in addition to the basic visit/non-visit determination. These variables will be populated for each P2 plot that meets one of two criteria: 1) the plot was designated as a non-visit plot, or 2) the plot was not sampled due to hazardous conditions, physical inaccessibility, or denial of access by the property owner or manager. Non-visit plots will be populated prior to field data collection for that panel, while non-sampled plots will be populated post-season. Interpreters will also record metadata for the aerial imagery used to populate land use and canopy cover; in most cases interpretations will be based on 1-m leaf-on NAIP imagery, which is collected on a 3-year return cycle (USDA Farm Service Agency 2009). Data quality will be appraised in terms of the repeatability of prefield assessments as well as prefield (i.e., office-based) vs. field assessments. The specific methods and decision criteria used to populate new variables are described below.

NONFOREST LAND USE

Prefield interpreters will record a single nonforest land use class for all non-visit and non-sampled plots, based on the land use that occurs at plot center. Land use is the apparent intent of human activity on the land, as evidenced by land cover, and consistent with the land use classification used by field crews (see list of classes in Table 1). The geometric requirements for the nonforest land use at plot center are the same as those for field-based mapping of conditions (i.e., must be at least 120 feet wide and at least 1 acre in size), and the same exceptions apply (e.g., windbreaks, rights-of-way, etc., are not subject to the minimum size requirements; see USDA 2007). If the nonforest land use at plot center does not meet these requirements, then the land use occupying the majority of the 144' circular plot area will be recorded.

PERCENT CANOPY COVER

Canopy cover is defined as the proportion of the ground surface within a given area that is covered by a vertical projection of all tree crowns minus the area of crown overlap, i.e., overlapping crowns are not double-counted (cf. Jennings et al. 1999). A plant's crown is considered a tree crown if it is an FIA tally tree species; there is no minimum size requirement on individual trees other than their ability to be seen on aerial imagery. Trees whose boles fall outside the plot area are included in canopy cover assessments if their canopies extend into the plot area.

Tree canopy cover will be assessed using dot-count methodology on all non-visited and non-sampled P2 plots

as part of the regular prefield workflow for each panel. Pilot studies have shown dot-counts to be an accurate and efficient method of assessing canopy cover relative to other methods, including image segmentation and ocular canopy assessment (Frescino et al. 2011, Goeking and Liknes 2009). The sample unit will consist of a circle with 144-foot radius around the plot center, and will completely encompass all four subplots of the field plot design. Within each circle there will be 109 systematically distributed dots. The primary axes of the dot grid will be rotated 15 degrees in a clockwise direction from true north to avoid potential alignment with linear features that may be oriented east-west or north-south, such as windbreaks or rights-of-way.

Under the 2012 protocols, prefield interpreters will not assess canopy cover at plots that are designated as visit plots and are sampled by field crews, with the exception of plots that are selected for quality assessment purposes (see below). Therefore, to ensure that the canopy cover variable is populated for all P2 plots, field crews will record canopy cover on all field-sampled plots, including plots that the field crew determines to be nonforest. Additionally, canopy cover on forested plots where trees are tallied will be modeled from stem-map data (see Toney et al. 2009).

QUALITY ASSESSMENT

Quality assessment of prefield data collection has two primary objectives: 1) to assess the relationship between field and prefield canopy cover measurements, and 2) to estimate the repeatability of photo-interpreted land use and canopy cover determinations. Samples will be drawn from each year's P2 panel to meet these objectives. To meet the first objective, a random sample of four percent of all field-visited plots in each panel, by state, will be designated for photo interpretation by a prefield interpreter. Canopy cover data collected by prefield interpreters will be compared to that collected by field crews. To meet the second objective, a second prefield interpreter will examine four percent of all non-visit plots in each year's panel and record nonforest land use, where one exists, as well as tree canopy cover. If a four percent sample equals more than 30 plots for either objective, then only 30 plots will be required for quality assessment.

INTERIOR WEST PILOT DATA: APPLICATIONS OF LAND USE AND TREE CANOPY COVER DATA

PILOT METHODS

The purpose of the Interior West pilot study was to investigate the feasibility of incorporating additional photo-interpreted variables into the prefield data collection process. Interior West FIA prefield specialists recorded land

use and ocular canopy cover data at all P2 plots in the 2009, 2010, and 2011 subpanels (Figure 1). Note that each year's sample is referred to as a subpanel, rather than a panel, because the Interior West FIA samples ten percent of all P2 plots each year and requires ten years to complete a cycle. Photo interpretations were based on the most recent 1-m NAIP imagery for each state. The subpanels for inventory years 2009-2011 consisted of 28,196 P2 plots across eight states, of which 16,503 (59 percent) were designated as non-visit plots. The high percentage of non-visit plots is due to the vast areas of rangeland without trees in the Interior West, as well as smaller percentages of plots that exist in areas with nonforest land uses such as agricultural and cultural development.

PILOT RESULTS

Quality assessment—As mentioned above, one objective of prefield quality assessment, beginning with the 2012 panel, will be to assess field versus prefield canopy cover data. The Interior West prefield pilot included both field and prefield canopy cover data for the 2009 subpanel, enabling quantitative comparison of the two metrics. Field crews recorded ground-based ocular assessments of tree canopy cover for 2,928 plots across five states, as well as transect data for 2,260 of those plots. The transect method consists of four transects on each of the four subplots in the FIA plot design. Each of these 16 transects is 25 feet long, where presence/absence of tree canopy cover is observed every foot. Prefield photo-interpreted canopy cover data exist for all of the plots where field data were collected. Correlations between prefield and field measurements were weak to moderate for both prefield versus ground-based ocular measurements ($r=0.62$) and prefield versus ground-based transects ($r=0.58$).

Ocular assessments of canopy cover using NAIP imagery have been previously shown to be highly variable among users and to overestimate canopy cover relative to less subjective methods such as dot counts and image classification (Frescino and Moisen 2011, Goeking and Liknes 2009). Therefore, the pilot data in this study are likely to be less accurate than canopy cover data collected after dot-count procedures are implemented in the 2012 subpanel. The sample applications of these data are provided below for illustrative purposes only.

Pilot Applications of Land Use Data—The most basic application of the land use data is a simple summary of the number of plots, and the corresponding number of acres represented by those plots, in each nonforest land use class. Table 1 shows the distribution of all non-visit P2 plots in the Interior West. Rangeland (land use code=20) occupies roughly 75 percent of all non-visit plots, and cropland (land use code=11) occupies about 11 percent. Each P2 plot represents slightly more than 5,900 acres

(Woudenberg et al., in press), assuming that an entire cycle has been sampled. Because we have only 30 percent of a cycle included in this pilot study, each plot represents about 19,667 acres. Multiplying the number of plots in each category by this expansion yields a conservative estimate of the total number of acres in that category.

Pilot Applications of Canopy Cover Data—When the new prefield variables are fully implemented in the 2012 inventory year, they will be collected only for non-visit and non-sampled plots. However, for the purposes of this pilot study they were collected for all P2 plots. Therefore, we can compare the frequency distribution of canopy cover at all plots within a state with the distribution of canopy cover at non-sampled plots. Figure 2 shows the distribution of canopy cover at plots that were not sampled due to either denial of access by the land owner or manager, or field crews' decisions that the plots were too hazardous to be sampled safely.

Whether plots are non-sampled due to an absence of a statewide inventory or due to the inability of the field crew to safely and legally access a plot, the assessment of canopy cover at non-sampled plots provides more information than FIA previously collected on those plots. Current FIA estimation procedures assume that non-sampled plots are randomly distributed among the Phase 1 strata, yet this assumption can increase the error of FIA's estimates, particularly in areas with low percentages of forested area (Bechtold and Scott 2005). Future work should focus on the potential incorporation of prefield canopy cover data into statistical estimators of forest area.

Pilot Applications of Combined Land Use and Canopy Cover Data—Land use and canopy cover data can be combined to provide information about the distribution of tree canopy cover among nonforest land uses, to estimate the area of tree cover in nonforest areas, and to estimate the number of plots in inventories of lands that do not meet the FIA definition of forest, such as urban forest or protective forest. Table 1 shows the mean canopy cover of each nonforest land use category. Windbreaks/shelterbelts have the highest mean canopy cover, followed in descending order by Cultural/Urban, Nonforest/chaparral, Recreation, Rights-of-Way, and Rangeland.

Although the Rangeland category averages only two percent canopy cover (Table 1), the large number of such plots and the commensurate acreage they represent indicates that trees on nonforest rangelands may account for a substantial amount of biomass and carbon in tree form. From Table 2, an entire ten-year cycle is estimated to include 2,503 Rangeland plots with canopy cover greater than ten percent. These plots likely do not meet the FIA definition of forest because the trees on the plot do not occupy more than one

acre or do not constitute a stand greater than 120 feet wide. However, these data suggest that substantial areas of the Interior West contain trees yet are too sparsely wooded to qualify as forest using traditional FIA field survey methods. Prefield data collection based on photo interpretation may be able to augment the FIA field inventory to quantify the area covered by nonforest land with trees.

Table 2 also illustrates the estimated number of plots in several other nonforest categories of interest. For example, an urban forest inventory in the eight Interior West states is likely to include about 50 plots in an entire ten-year cycle, or five plots per year. An inventory of all plots with greater than ten percent canopy cover in areas with any developed land use would consist of 110 plots per cycle (11 plots per year), while an inventory of agricultural areas would include 50 plots per cycle (five plots per year).

FUTURE APPLICATIONS OF PREFIELD INVENTORY DATA

As mentioned above, current protocols require prefield assessment of land use and tree canopy cover only at non-visit and non-sampled P2 plots. Prefield interpreters in some FIA regions will also populate the canopy cover variable for all P2 plots in the 2012 panel/subpanel, including forest plots, and this expanded dataset will serve as predictor data for the imminent update of the tree canopy cover layer in the 2011 National Land Cover Database (see Homer et al. 2004). Other potential changes to prefield workflows include the addition of a land cover classification, an updated the land use classification, and implementation of a comprehensive and nationally consistent quality assurance protocol.

CONCLUSIONS

Until recently, prefield photo-interpretation focused primarily on making visit/non-visit determinations by distinguishing potentially forested plots from obvious nonforest plots. Prefield photo interpreters examine every plot in the FIA P2 grid and are thus in a unique position to provide additional information about every plot, regardless of whether it meets the FIA definition of forest land. Tree cover in wooded areas that are not considered “forest” by FIA may contribute to biomass and carbon budgets as well as wildlife habitats in developed or sparsely wooded areas. The land use and canopy cover dataset generated within existing prefield workflows has the potential to expand FIA’s ability to inventory and monitor all lands, and not just those areas that meet the FIA definition of forest land.

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Table 1—Distribution of non-visit Phase 2 plots in each nonforest land use category for 2009, 2010, and 2011 subpanels. Area estimates are based on an expansion of 19,667 acres per plot given a sample of 30 percent of one ten-year cycle (one plot represents about 5,900 acres given a complete ten-year cycle). Mean canopy cover is averaged among plots from all three subpanels

Land Use Class	Code	Number of plots	Percentage of plots	Estimated area in Interior West (acres)	Mean canopy cover (percent)
Agricultural Land	10	581	3.58%	11,426,527	0.17
Cropland	11	1,733	10.67%	34,082,911	0.08
Pasture	12	115	0.71%	2,261,705	0.72
Idle farmland	13	225	1.39%	4,425,075	0.46
Orchard	14	2	0.01%	39,334	0.00
Windbreak/shelterbelt	17	2	0.01%	39,334	19.25
Rangeland	20	12,472	76.80%	245,286,824	2.06
Developed	30	114	0.70%	2,242,038	1.90
Cultural or urban	31	147	0.91%	2,891,049	3.22
Rights-of-way	32	142	0.87%	2,792,714	2.24
Recreation	33	11	0.07%	216,337	2.93
Mining	34	20	0.12%	393,340	1.91
Other undeveloped	40	87	0.54%	1,711,029	1.50
Naturally nonvegetated	41	506	3.12%	9,951,502	1.09
Wetland	42	78	0.48%	1,534,026	0.22
Beach	43	4	0.02%	78,668	0.00
Nonforest/chaparral	45	1	0.01%	19,667	3.00

Table 2—Total number of plots in each canopy cover class and land use category. Estimated number of plots with canopy cover greater than ten percent in one cycle is calculated as the mean annual number of plots from the 2009-2011 subpanels multiplied by ten subpanels

Land Use Class	Code	Canopy cover class					Estimated number of plots with >10% canopy cover, in one cycle
		0%	1%-5%	6%-10%	10%-20%	>20%	
Agricultural Land	10	561	25	2	2	3	17
Cropland	11	1717	33	2	1	3	13
Pasture	12	101	21		1		3
Idle farmland	13	211	16	1	2	1	10
Orchard	14	2					0
Windbreak/shelterbelt	17		2			2	7
Rangeland	20	11500	3467	798	344	407	2503
Developed	30	78	32	5	1	5	20
Cultural or urban	31	85	47	12	6	9	50
Rights-of-way	32	129	29	6	4	5	30
Recreation	33	7	4	2	1		3
Mining	34	19	1	1	2		7
Other undeveloped	40	84	35	8	1	5	20
Naturally nonvegetated	41	456	104	27	2	6	27
Wetland	42	79	5	1		1	3
Beach	43	4					0
Nonforest/chaparral	45		1				0

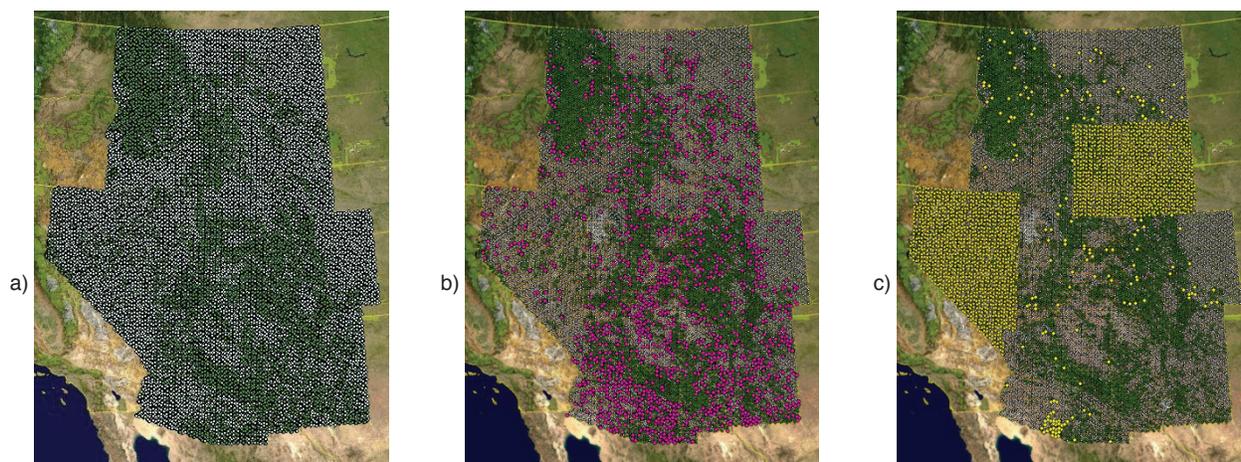


Figure 1—Maps showing plots in the Interior West FIA region in the 2009—2011 inventory years: a) Plots designated for the field inventory, from all three subplots (green dots), b) Plots that were not designated for the field inventory but include trees, from all three subpanels (magenta dots), and c) Non-sampled plots, from the 2009 subpanel only (yellow dots), i.e., plots that were designated for field sampling but no data was collected because the plot was inaccessible/hazardous or access to the property was denied.

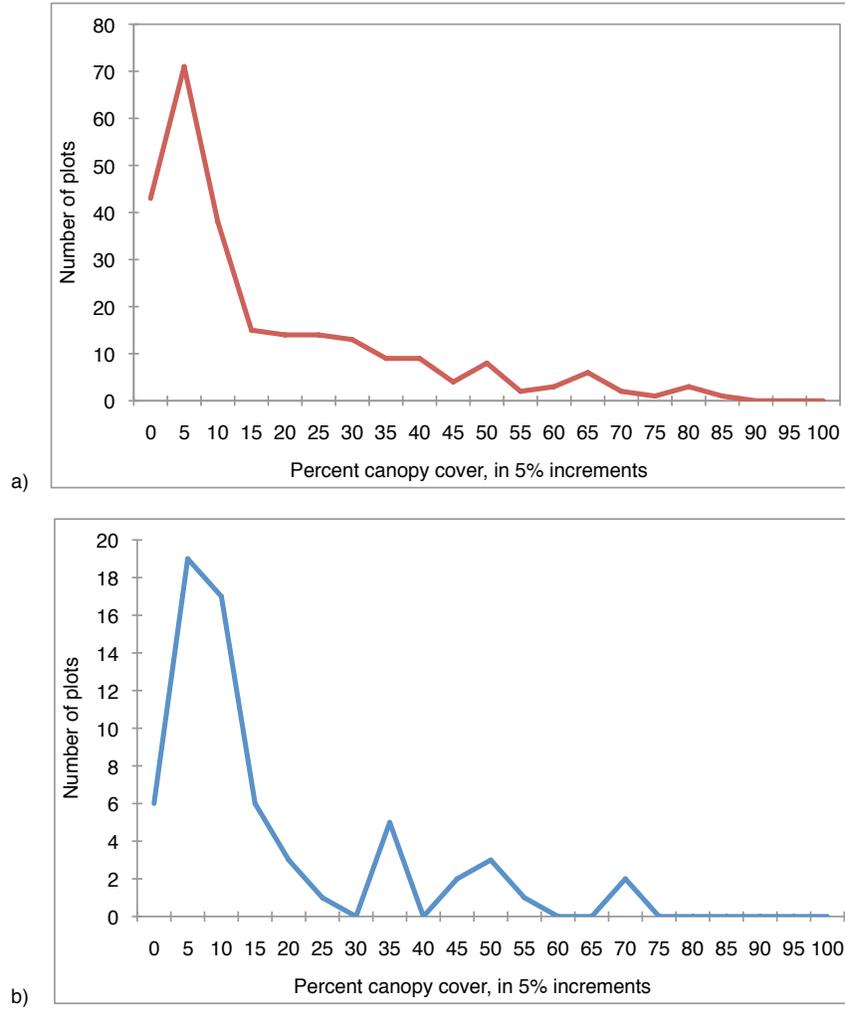


Figure 2—Histogram of tree canopy cover for P2 plots in the 2009 subpanel where a) access was denied by the land owner or manager, and b) the plot was deemed by a field crew to be hazardous and/or inaccessible due to safety concerns.