ON FIA VARIABLES FOR ECOLOGICAL USE[1]

David C. Chojnacky[2]

Abstract—The Forest Inventory and Analysis (FIA) program collects or calculates over 300 variables for its national network of permanent forest plots. However, considerable ecological analysis can be done with only a few key variables. Two examples—Mexican spotted owl habitat in New Mexico and down deadwood in Maine—are used to illustrate the potential of FIA data for ecological use. These examples illustrate the importance of the variables (1) diameter at breast height, (2) tree species, and (3) live/dead/cut tree status for compiling estimates and confidence intervals within FIA's sample design. Priority variables are suggested for constructing an ecological database with FIA data.

INTRODUCTION

The Forest Inventory and Analysis (FIA) program collects or calculates over 300 variables for its national network of permanent forest plots (FIA 2001). Many of these variables are collected specifically to assess the U.S. timber supply. However, ecological analysis of forest structure is also possible with these data.

The FIA variables can be classified into two broad groups of "attribute" and "category" variables (Chojnacky 1996). Attribute variables are generally continuous variables based upon direct field measurements (or functions of direct measurements). Examples include diameter at breast height (dbh), tree age, height, volume, biomass, and so forth. Category variables are generally discrete classifications of observed phenomena or social/political groupings. Examples include county, vegetation class, geographic location, tree species, forest type, land uses, and many other observations of forest structure and use impacts.

Of the two variable types, the continuous attribute variables are most flexible because these can usually be summarized in raw form, combined with other variables in calculations, used in models to produce estimates, and fit theory for confidence interval computation within FIA's double sampling for stratification design (Chojnacky 1998). On the other hand, discrete categorical variables are generally not compiled as statistical endpoints. More often, categorical variables classify summations of attribute variables or classify forest area.

The difference between "attribute" and "category" can be fuzzy for some calculated variables that are functions of both variable types, but the point of distinction hinges on the end product. A variable can be considered an "attribute" if it is possible to total it in some meaningful manner and estimate a variance within FIA's sample design. This definition can be tricky for a variable such as percent understory cover because a "total cover" estimate is not meaningful, but a ratio estimator for total cover divided by total area (for any size area) is a nice attribute variable with a variance (Chojnacky 1998, p. 13).

Categorical variables are not necessarily undesirable, but they are somewhat limited and often difficult to define for multiple uses. For example, forest type (Hansen and others 1992) and habitat type (Pfister and others 1977) are two categorical variables for plot-level vegetation description. Forest-type classifies from a timber stocking perspective, and habitat-type classifies from a climax vegetation perspective, but neither necessarily gives an accurate description of present tree cover by species, and they do not collapse uniformly in some hierarchical fashion. Ability to logically collapse categorical variables is crucial because FIA data applications inevitably have too few plots for some category, which requires category grouping.

An example of a well-defined, flexible, categorical variable is taxonomic tree species. Species distinction is supported by a wealth of information, including taxonomic nomenclature, genetics, growth rates and forms, specific gravity, shade tolerance, nutrient requirements, and so forth. Species has been traditionally used by FIA to tally regional timber statistics on volume or numbers of trees, but FIA defers to forest-type all plot-level forest classifications because of the problem of multiple species per plot. However, this is likely more a matter of traditional convenience from earlier days of limited computing power than of practical necessity. For example, the continuous variable, basal area, could easily be ranked according to predominate species or species group to obtain a flexible plot classifications tailored to many different needs (Chojnacky and Woudenberg 1994).

This paper illustrates, by example, ecological analyses done with only a few variables. Estimates are based on attribute (continuous) variables but also use categorical (discrete) variables that can be easily and meaningfully regrouped. The two ecological examples include Mexican spotted owl habitat calculated for a national forest in New Mexico and down deadwood estimated for Maine.

METHODS

The data for both examples were previously analyzed in other studies. For the owl example, habitat data were

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[2] Research Forester, USDA Forest Service, 201 14th Street, SW, Yates Building, Washington, DC 20250.

compiled for a test on using FIA data to monitor Mexican spotted owl habitat as defined by a recovery plan for the owl's "threatened" status (Chojnacky and Dick 2000). Included were 464 FIA plots spanning 1.3 million ha of forest and wilderness in New Mexico's Gila National Forest from the 1994 inventory. FIA attribute variables used were dbh, tree height, and number of trees per plot. FIA category variables included tree species, live/dead tree status, tree dominance class, forest type, and habitat type. The latter three variables were needed for an elaborate "forest cover" algorithm defined by the recovery plan. (Forest cover probably could have been defined more simply, but the previous study had to be done in compliance to recovery plan guidelines.) Also used were several sample design variables for field plots sizes, phase 1 and phase 2 samples sizes, and stratum identifications and areas. These were needed to compute confidence intervals and expand the estimates to forest totals.

Data for the down deadwood (DDW; also called coarse wood debris) example were compiled from 1,842 plots that were re-measured in Maine's 1995 inventory (Chojnacky and Heath [In preparation]). Down deadwood data are not currently available in the FIA database but they were collected in Maine from transects overlaid on FIA plots. Down deadwood is important for assessing carbon stocks for global warming concerns, habitat for numerous organisms, nutrient cycling, and soil movement (fig. 1). The purpose of the deadwood study was to predict DDW from other routinely collected FIA variables. Results showed a subsampling scheme and simple model as reasonable. For this approach, dbh and DDW were the only attribute variables used. FIA category variables included tree species, live/dead/cut tree status, ownership, stand size class, and forest type. Because Maine's 32 forest types were unmanageable for simple compilation, predominate basal area by species was used to collapse the forest types into six groups. Also used were the sample design variables for sample sizes and stratum areas.

Figure 1—Down deadwood or coarse woody debris found in eastern hardwood forest.

RESULTS AND DISCUSSION

Mexican Spotted Owl

An actual amount of Mexican spotted owl habitat was not calculated from the FIA data. Instead, area was calculated for a plausible habitat scenario defined from the bird's habitat needs (Chojnacky and Dick 2000). The main purpose of the scenario was to assess the FIA sample intensity for detecting change. Results of the 95 percent confidence intervals for mixed-conifer and ponderosa pine forest cover ranged from ±20 to ±35 percent (fig. 2). The small amount of pine-oak was more variable at ±50 to ±73 percent.

The results for the Gila National Forest were encouraging because the planned use of the method was for combining several national forests into recovery units, which would increase sample size and further reduce confidence intervals. The habitat scenario needs testing against actual owl demographic data, but there seems sufficient power in the FIA data to monitor modest changes in habitat area.

The FIA variables needed to monitor owl habitat included dbh, height, tree species, live/dead tree status, and several other plot-level and tree classifications for computing forest cover. The list could be shortened to the first four variables if forest cover were recomputed from species and basal area (or trees per area or other dbh-based density metrics).

Down Deadwood

The other example on down deadwood in Maine illustrates DDW estimated from a subsample. The FIA program has recently combined with the Forest Health Monitoring national network of plots, which are sampled at about 1/16th the intensity of the FIA grid. These plots are being called the third phase (P3) of FIA's sample design, with first phase (P1) being the remote sensing for stratification points and the second phase (P2) being the full sample of FIA field plots.

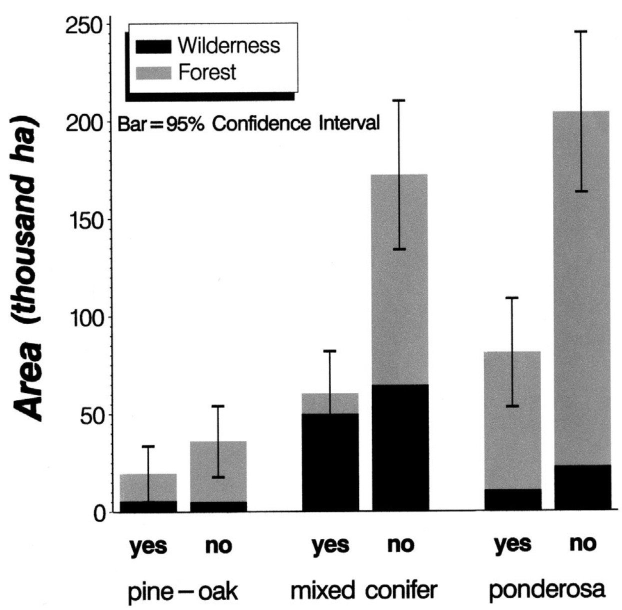

Figure 2—Area of hypothetical Mexican spotted owl habitat for Gila National Forest, 1994 FIA inventory. The scenario illustrates habitat can be determined from FIA data within about 20 to 35 percent of the estimates for mixed conifer and ponderosa pine forest cover.

A method for including DDW in an FIA assessment is to model DDW from the P3 plots and then apply the model to the more intense P2 design. A regression model $(R^2 = 0.20,\ n = 135)$ fit to P3-plot data is:

$$DDW = 6.2092 - 3.3003 * d_i - 1.3542 * d_{cr} - 2.2594 * X_1 + 0.3527 * X_1^2 + 0.9124 * X_2 + 0.3487 * X_3 \quad (1)$$

where

DDW = down deadwood greater than 7.6 cm diameter (Mg/ha)

d_i = 1 if forest industry ownership, 0 otherwise

d_{cr} = 1 if conifer forest type, 0 otherwise

X_1 = FIA stand size class (seedling, poletimber, sawtimber)

X_2 = basal area of dead trees 7.6 - cm dbh and larger (m^2/ha)

X_3 = basal area of recently cut trees 7.6 - cm dbh and larger (m^2/ha)

Application of the P3-based model to FIA P2 data compared favorably (fig. 3). There was little statistical difference between methods because the 95 percent confidence intervals overlapped for the total and for all species groups, except spruce-fir.

These results illustrate another aspect of the FIA design where subsampling can be used to add in new attribute variables such as DDW without the expense of collecting the variable on every plot. The results could also have been summarized directly in a three-phase sample design instead of using the regression model, but the details of this application for FIA data have not yet been worked out.

As for the owl example, the key FIA variables include dbh, tree species, and live/dead/cut tree status. Additional classifications for ownership and stand size class were used to construct the P3-model, but stand size class could have been redefined from basal area and numbers of trees.

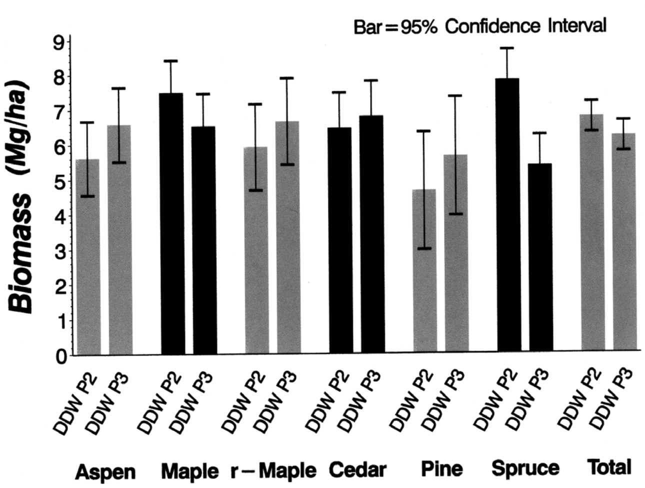

Figure 3—Down deadwood (DDW) biomass estimated from FIA plots (DDW P2) for Maine's 1995 inventory compares well to a model-based estimate (DDW P3) from a 1/16th subsample. The model was developed from P3 plots but applied to P2 plots for forest type groups (aspen/birch, maple/beech/birch, red maple/other hardwoods, cedar/hemlock, pine/oak, spruce/fir).

CONCLUSION

Of all the FIA variables, (1) dbh, (2) tree species, and (3) live/dead/cut tree status seem most important for ecological use. As shown in the examples, these can describe forest structure for two different uses. By adding in tree age, height, a few social/political variables (such as county, ownership, measurement period, and geographic coordinates), and the sample design variables, one has foundations for a strong ecological database.

Because FIA already collects these variables to some degree, it would be fairly easy to construct an ecological subset of the FIA database. Key items should include the following:

Attribute variables

- Diameter for all trees at a consistent height above groundline regardless of where the tree was actually measured. (Because diameter is so important, it would also be desirable to have conversion capability between groundline and breast height measurement points for all species. Groundline diameter makes much biological sense because it is at the interface between roots and bole.)
- Meta-data explaining age measurement, and future development of field procedures that consistently subsample tree ages in a statistical design.
- Meta-data explaining height measurement and development of field procedures that consistently subsample tree heights in a statistical design.

Category variables

- Live/dead/cut tree status code that also includes a decay class for dead.
- Tree species and all other discrete observations and classifications that are consistently recorded throughout the entire FIA program, such as State, county, measurement period, ownership, tree damage, slope, aspect, and so forth.

Sample design variables

- Trees-per-area expansion factors (plot sizes) for every live, dead, cut, and missing tree within a plot regardless of size or classification.
- Phase 1 sample sizes and strata information necessary to calculate a variance for any estimate.

This list is meant to emphasize priorities but not include exhaustive detail. Needed is consistently available information for calculating stand structure metrics and variances from tree-level data. FIA has recently done a good job of including noncommercial tree species and all forestlands without regard to timber utility into its inventories. However, many tree-level and plot-level compilation procedures still include gaps when considering all trees. Creating an ecologically oriented subset of FIA data would simplify data access for users who need to carefully account for every for every live, dead, cut, or missing tree regardless of value judgments.

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