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Determination of forest type and stand size class across FIA inventory years

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Background

Quantifying forest change across forest inventory years is a common problem when inventory designs change, especially for classification variables such as forest type and stand size class. Here we address this problem for the USDA Forest Service, Forest Inventory and Analysis (FIA) program and field plots observed over the period 1977 to 2018 in Minnesota. This note provides specific algorithms to facilitate comparable classifications and meaningful interpretation of change across this period and the different inventory designs.

Key words: models, forest inventory, classification, algorithms, forest type, and stand size class.

1. Inventory designs: Within Minnesota, FIA has been inventorying forestland since the 1930s, with data from 1977 through the present now online and publically available. In general, the 1977-1998 FIA program conducted and reported on these periodic inventories approximately every 10-years. Data came from plots comprised of 10 variable-radius, 37.5 basal area factor (BAF) points. Since 1998, this design transferred to an annual design that measures 14-20% of eastern U.S. plots and 10% of western U.S. plots, with full state inventories being completed every 5-10 years. The design uses four, 1/24th acre fixed-radius subplots for large trees (≥ 5-in diameter breast height (dbh)) and four 1/300th acre fixed-radius microplots for smaller stems (1-in ≤ dbh < 5-in). See Bechtold and Patterson (2005), LaBau et al. (2007), and Burrill et al. (2018) for further details on the FIA program. Note that FIA conducts a multiphase inventory, with plots initially examined remotely for being forested or not. Secondly, the forested plots are visited and inventoried. Both sets of plots are necessary for computing percent forest cover. Table 1 describes the FIA data for Minnesota (USDA 2019).

Table 1. Number of all and forestland only FIA plots by measurement year in Minnesota (includes the double intensity plots), along with forestland acreage.

Years	Forestland Acres	Number of Forest Plots	Total Number of Plots
1977	16,536,576	10,129	36,478
1990	16,681,068	13,511	43,957
1999-2003	16,230,326	5,165	16,383
2004-2008	16,989,668	6,144	18,147
2009-2013	17,378,347	6,221	18,095
2014-2018	17,621,098	6,307	18,074

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In addition to the FIA design change from periodic to annual, algorithms for determining the forest type and stand size class also changed between the two designs. Failure to account for different definitions could result in misleading analyses through identifying artificial shifts in forest conditions, rather than actual changes. Consultation with FIA personnel confirmed the need for common definitions and that back-applying the new algorithm to the periodic data should be avoided (Mark Hansen, FIA, personal communication). Therefore, to standardize definitions across inventory years, custom algorithms were developed to determine forest type and stand size class, intentionally similar to those used in FIA.

2. Forest type algorithm: The forest type algorithm used plurality of live basal area (ft^2) within species and species groups to define forest types for each plot, rather than FIA stocking values as in the new algorithm (Arner et al. 2001). Algorithm steps follow a tiered, nested approach: First, the plurality of basal area within softwoods or hardwoods was computed and compared (Tier 1). Second, depending on the result, the nested softwood groups or hardwood groups were compared for the plurality of basal area (Tier 2). Finally, depending on the second result, the associated forest types nested within the selected group were compared for plurality of basal area and the forest type assigned (Tier 3). Figure 1 provides an illustration of this nested algorithm. Note that if total plot basal area < 10 ft^2/ac, the FIA assigned forest type was used, since the custom algorithm did not include seedling information that may influence the forest type at low densities.

In order to aggregate basal area into specific forest types, a tree species-forest type crosswalk was created. Most tree species show a strong association with one forest type. However, for species representing a component of different forest types (e.g., elm species), the basal area was added to all pertinent forest type groups. Thus, the common species helped influence the selections in Tier 1 and Tier 2, but the associates of the common species determined Tier 3. An exception was red maple (*Acer rubrum*), which was dropped after Tier 1 due to its relationship with most forest types and groups. Instead, red maple associates were allowed to determine the forest type group and individual forest type.

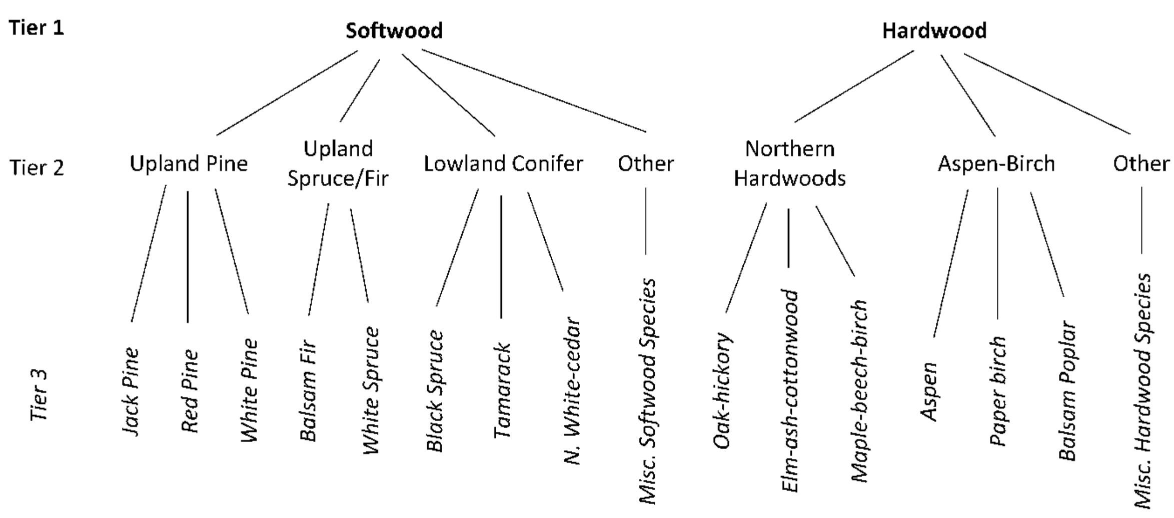

Figure 1. Schematic representation of the custom algorithm for determining forest type on an FIA plot.

This algorithm provided a forest type classification for the majority of plots (89.0%). However, the algorithm failed to converge for the remaining plots, due to low or zero basal areas in live trees ≥ 1-in dbh, or due to the plurality of basal area being in a species associated with multiple forest types. For these plots, the default FIA forest type algorithm was used, if available (10.8%). If the FIA assigned forest type did not match those recognized or proved ambiguous (e.g., “other hardwoods”), the field call was substituted if possible (0.2%). Less than 0.1% of plots required manual investigation and assignment of forest types. Analysis was conducted using the R statistical program (R Core Team 2018). Finally, we note a similar basal area sorting method in Jaakko Pöyry Consulting, Inc. (1992) that had similar success, though for a somewhat different problem involving projections of forested plots over long time periods.

3. Stand size class algorithm: The current FIA algorithm uses plurality of stocking in diameter classes (small: < 5-in dbh; medium: > small and < 9-in dbh (softwood) or < 11-in (hardwood); large: > medium). Several candidate custom algorithms were explored for estimating stand size class that were trained by the default FIA size classifications. The selected approach used a random forest classification scheme (Liaw and Wiener 2002) that considerably outperformed the other alternatives. A total of 500 trees were grown with three branches each. The final set of explanatory variables included quadratic mean diameter (in), stand age (years), basal area (ft^2/ac), site index (ft), trees per acre, mean crown ratio (%), mean crown position (1 – open grown, 2 – dominant, 3 – codominant, 4 – intermediate, 5 – overtopped), and forest type (as defined above). The out-of-box classification error was 20.3%. The random forest algorithm was then applied to both the periodic and annual FIA data to provide a consistent estimate of size class (88.8% of plots). For those plots without a full set of explanatory variables, the default size class from FIA was used (11.2%), with less than 0.1% of plots requiring manual investigation and assignment. All non-stocked plots received the associated non-stocked size class. Analysis was conducted using the randomForest package (Liaw and Wiener 2002) in R.

Applications: While inventories may differ, especially as new designs are developed, it appears quite possible to develop meaningful comparisons in terms of forest type and stand size class. This note highlights an approach that may work for other datasets. Finally, the code for these algorithms is available from the authors upon request.

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