Vegetation Inventory Data: How Much is Enough?

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Abstract: *Recognition of the value of forest vegetation data has increased in recent years, especially when it is collected using consistent methods over many forest types. Because the cost of collecting large datasets is substantial, managers must balance the cost of collection with the utility of the conclusions that may be drawn from the data analyses. There is no single standard for collecting vegetation data; sampling protocols should be developed to address clearly defined analysis objectives. We compare the utility of the established Phase 3 Vegetation Diversity and Structure Indicator data with the proposed vegetation data to be collected with the Forest Inventory and Analysis Program's Phase 2 Vegetation Profile.*

Keywords: biomass, carbon pools, wildlife habitat potential, fuel characterization, diversity, species distribution, plant community classification, spatial scale

Introduction

Recognition of the value of forest understory vegetation inventory data has increased in recent years. When collected in a consistent fashion over large regions, vegetation inventory data allow for quantitative assessments of existing conditions across broad areas. Repeated visits to permanent plots permit change and trend analyses. The focus of data collection may be relatively simple – such as total foliage cover by height layers or the abundance of general growth habits – or more detailed vegetation composition, such as which species are present or dominate the area sampled. The cost of data collection can be substantial and demands a planning process with clearly defined objectives and a balance of cost and utility. This is especially important when the inventory is designed to monitor trends over time.

The Forest Inventory and Analysis (FIA) program has traditionally conducted timber inventories of the nation's forests. The enhanced program, organized in three phases, is well-suited for collecting vegetation data at different scales and intensities. Phase 1 (P1) uses remotely sensed data to stratify the landscape by coarse physiognomic filters; at its most basic level, P1 might stratify by forest vs.

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non-forest lands. Phase 2 (P2) data include the plot-based observations of traditional tree variables, with plots established approximately every 2430 hectares (6000 ac) on forested lands. With this spatial density of plots, population estimates can be derived for some county-sized areas (Bechtold and Patterson 2005), but estimates are more commonly derived for larger land management units (e.g., National Forests, National Parks) or state-wide reports. Moving beyond its commodity-driven origin, many researchers have recognized the value of FIA data to analyze tree species composition and structure that influences wildlife habitat, range, recreation, hydrology and more (Rudis 1991, 2003). Phase 3 (P3) data are collected on a subset of P2 plots (1 out of 16 plots; approximately 1 plot every 38 880 hectares [96,000 ac]) and include additional measurements for monitoring forest health conditions (Bechtold and Patterson 2005). These data are used to establish valuable baseline conditions and detect more detailed changes not assessed in P2 and to provide indications of potential impacts to ecosystem functions that may be worthy of additional investigation. The P3 grid spatial intensity affords population estimates at regional and national levels.

Each FIA regional program has some history of collecting non-tree vegetation data in conjunction with timber inventories. In fact, some of these programs have long histories of collecting data on understory plants (O'Brien 2003, O'Brien et al. 2003). Although methods have been similar among programs, they have varied enough that is difficult to compare or combine data across regional boundaries.

Forest Inventory and Analysis' P3 Vegetation Indicator (P3VEG) provides a method to collect data on all vascular plants growing on forested plots (U.S. Department of Agriculture, Forest Service 2005). Estimations of vascular plant species richness and the distribution and abundance of those species, including the relative abundance of introduced species, may be calculated using the P3 vegetation data. Pattern recognition, such as indicator species analysis and presence/absence of introduced species, may also be performed using P3 species composition data. In addition, composition data can be used to compare differences in species mix with differences in the physical attributes across plots and to develop plant community classifications (Schulz et al. 2008). Data collection requires a dedicated crew member with specialized botanical skills.

Because of the growing recognition of the value of forest understory vegetation inventory data, a team was recently assigned to develop a core-optional method that could be used on P2 plots by any FIA unit to yield comparable data across regions. In order to minimize demands on time, training and staffing and gain efficiencies of resources, data collected with the P2 Vegetation Profile (P2VEG) will be limited to structure, recorded as cover by growth habit by layer, with an option to collect additional information on the "most abundant" species. The objective of this effort is to produce estimates of biomass and structural characteristics that will allow for evaluation of carbon pools, wildfire fuel hazard, wildlife habitat suitability, forage availability, and grazing potential in a consistent way across regions. The option to collect information on the most abundant species would afford refinements in the above estimates as well as allow for plots to be classified beyond forest type using pre-defined community classifications.

It makes sense in efficiency to take advantage of FIA's infrastructure to collect these valued vegetation data in addition to the traditional tree inventory: logistics for training and moving field crews across large regions, and the data management to collect, edit, process, manage and store data are in place. However, the costs of an extra crew member on plot to collect additional variables can be significant and should not be done without careful consideration.

Clearly defined objectives are required when allocating resources to vegetation data collection. Although there is little reason to collect more data than required, it is also inefficient to leave the plot without enough data to address the issues at hand or looming in the future. When planning vegetation inventories, it is important to consider the uses for vegetation inventory data, the level of detail, thoroughness, and spatial scale required to produce desired estimates, and the benefits of data at each level of detail.

We discuss a variety of objectives for collecting vegetation data and compare how the established P3VEG and proposed P2VEG measurements can support these objectives. Differences between the two methods are summarized in table 1.

Table 1: Summary of differences in scale, measured structure, and species data collected with P3VEG and the proposed P2VEG methods.

Method	Scale	Structure	Identify	Species Abundance	Arrangement
P3VEG	1 plot / 38 880 ha	Total foliar cover by layer	All vascular plants	Total cover	Cover by layer
P2VEG	1 plot / 2430 ha	Cover of growth habit by layer	4 most abundant per growth habit with cover of at least 3%	Total cover	Tallest layer

Objectives for Collecting Vegetation Inventory Data

There are many potential uses for vegetation inventory data. The basic inventory objective – how much of what is where? – can include:

- Biomass and carbon pools
- Fuel characteristics
- Wildlife habitat
- Diversity
- Species distributions
- Plant community types (species composition and structure)

Both P3VEG and the proposed P2VEG methods, where implemented, will yield cover and height distribution measures that can be used to estimate biomass and describe structure, which are key elements for the first three objectives listed above. Species abundance data can help refine these estimations and assessments, even when species data are limited to only the most abundant species present. Data from thorough species inventories are used to assess both the species richness and frequency components of diversity, to define both species distributions and range, and to develop plant community classifications.

Biomass and carbon pools

The ability to estimate biomass and describe vegetation structure is central to estimating standing carbon pools, characterizing fuel conditions, and assessing wildlife habitat potential. Estimations of carbon pools in forests is essential to understanding carbon cycles, and changes in stored carbon pools, which are critical as society develops policies to mitigate emissions of CO_2 and other greenhouse gasses. Without complete inventories on forest carbon pools and their dynamics, it will be difficult to develop effective policy and monitoring systems to manage these pools and sustain the services of forest ecosystems to carbon sequestration (Ingerson and Loya 2008). Researchers are continually refining tools to estimate carbon stocks in U.S. forests (Smith et al. 2007), although uncertainties associated with carbon pools in non-tree forest components remain admittedly high (Smith and Heath 2008). Above-ground live tree biomass is estimated at less than one half of total carbon found in forests (Ingerson and Loya 2008). Soils and forest floors are hold a large proportion of carbon in most forest, followed by standing dead and downed wood. Understory vegetation is generally assumed to contribute a small fraction to the overall carbon stock in most forest ecosystems (Birdsey 1992). However, better calibrated estimates will be possible with the availability of direct measurements of abundance and height of understories from many forest types and to clarify the dynamics.

Fuel characterization

Data on vegetation structure and composition are essential to characterize fuel. Understory vegetation influences fire behavior through the quantity of burnable biomass, the vertical structure and arrangement of vegetation, and the species present (Riccardi et al 2007). Some growth habits and species are particularly combustible while other species are very hard to ignite and can act as fire breaks (U.S. Department of Agriculture, Forest Service [Online]). Most fuel analysis tools require data that describe how much vegetation is present and how the existing vegetation is arranged (ladder fuels). For further detailed analysis, information on the species present is necessary.

Many of the same models are currently used to quantify biomass for both carbon pools and fuel characterization. Current tools vary in required data inputs (e.g., the Carbon Calculator Tool [CCT] [Smith et al.] Fire and Fuels Extension [FFE] [Reinhardt and Crookston 2003] of the Forest Vegetation Simulator [Dixon 2002], the Fire Effects Monitoring and Inventory Protocol [FIREMON] [Lutes et al 2006], and the Fuel Characteristic Classification System [Ottmar et al 2007]). The most accurate estimates of biomass can be made when abundance, height, and bulk density of the species are known, but these data are rarely available.

Thus, most models include basic approximations that are based on tree cover data to estimate biomass of understory vegetation. Some use direct measurements of total cover by life form to account for biomass, but use approximated values for bulk density of understory components. Measured attributes of percent canopy cover for herbaceous, grassy, and shrubby growth habits could aid in further calibration of biomass estimates for both carbon modeling and fuel characterization.

Wildlife habitat

Forest management plans often consider impacts and maintenance of particular wildlife habitat elements. Important features for assessing wildlife habitat include overall vegetation structure; cover by growth forms, canopy complexity, presence of dead standing or downed trees, and plant species composition data (Thomas and Verner 1986). Habitat may be assessed at a number of scales – broad regional, landscape, or fine (plot level) scales. At broad scales, course filters such as dominant vegetation type, successional stages, and canopy closure are used to assess habitat conditions for particular species. At finer scales, habitat assessments are highly dependent on specific features required by a species or guild of species at spatial and temporal scales (Noon et al. 2003). Some species have particular habitat requirements and others are more generalists. It is impossible to design a single vegetation inventory that is suitable for every species. However, additional information generated with the core-optional FIA P2VEG methods could be extremely useful for the development of more specific models to predict habitat features at spatial scales that are useful for land use policy makers.

Diversity

Established baseline levels of diversity are critical for assessing changes over time in response to natural succession, disturbance events, or global climate change. Diversity can be evaluated at a variety of scales from ecological regions to genetic materials. The thoroughness of data collection affects the scale at which diversity can be assessed. The FIA program's P1 and core P2 samples can be used to describe regional-scale tree diversity of land cover, forest type, and structure, but provide very limited information about the vegetation under the forest canopy. The proposed FIA P2 vegetation plot measurements can assess diversity in terms of structure (canopy complexity) and growth habit distribution.

Species richness, the number of species present over a standard area, is a fundamental and easily understood measure of diversity. Overall species richness and species richness of each growth habit can only be addressed with a complete inventory of species on standard-sized sampling areas. A complete inventory also allows for the estimation of baseline species richness, comparing native to introduced species richness, and the examination of diversity patterns in measured stands and across large regions. Although standard P2 data and the proposed P2VEG data can provide information on regional forest type diversity, growth habit, and structural diversity, only the P3VEG can address overall species richness, species richness by-growth habits, and the diversity of native and introduced species.

Species distribution

Determining the distribution of individual species or groups of species is a common use of vegetation inventory data. Investigators may be concerned with invasive species, indicator species, or species with particular characteristics (e.g., important as wildlife forage or cover, species that burn readily or act as suppressants to fire, subsistence use). Species composition data from multiple plots yield frequency and distribution data, affording assessments of where an individual species occurs, how abundant it is, and if it co-occurs regularly with other species. The types of possible analyses of species distribution again depend on the thoroughness of the inventory of species.

For some purposes, data collection is limited to a finite list of species; for example, the top 20 most unwanted invasive species. Researchers can reach some conclusions about how widely those particular species are distributed, but can not determine how those species interact with other species present such as the impacts of introduced species on native flora. For other purposes, species data are limited to the most abundant or dominant species present. This method is informative about the dominant species present and can be useful for assessing wildlife habitat quality and fuel characterizations. However, researchers will not know where a species is absent or present with an abundance below a designated threshold (e.g. a species must be present with a cover of at least 3% to be recorded). This information gap is limiting when assessing species distributions.

When the inventory includes all species present, data can be used to examine any species of interest, including species co-occurrence with other species. If many plots over large areas are included in the sample, the distribution of any species found in the sample can be estimated. Studying the patterns of species distributions and co-occurrences is extremely useful for predicting where species occur in places not sampled.

Finally, FIA Vegetation inventory data based on a grid sampling design is not usually very informative about rare or endangered species distribution – these species are most often found in rare or unique habitats – which systematic sample grids will usually miss.

For analyzing species distributions, the P3 VEG all-species inventory is more valuable than the P2 VEG. Although there is some value in list-based or most abundant data, the conclusions that can be drawn from the limited species data are restricted. Analyses of broad scale species distribution, relative cover of introduced species, indicator species, or patterns of species co-occurrence are most informative when all species are recorded and assessed.

Plant Community Types

Classification of existing vegetation uses species data and data derived from site physical characteristics to group ecologically-like items together. Mapped classes of vegetation describe the landscape and provide vital information concerning the ecological systems a land manager must consider before taking some management action. The ability to describe the plant community where a forest health issue has been observed is an important communication tool. Although FIA plot locations are confidential and scientists cannot reveal exactly where an invasive plant species was located, they can describe the forest plant community, thus providing a detailed search tool for locating areas where problems could occur.

There is no single standard technique used to develop vegetation classifications, but there are efforts to standardize the data required (Tart 2005). The newly revised Federal Geographic Data Committee's National Vegetation Classification System (NVCS) defines standards for classification plots (with enough data that help define vegetation types) and occurrence plots, (plots with fewer data but sufficient to document the occurrence of a previously defined vegetation type) (FGDC 2007).

There is also a hierarchy of classification levels. At the upper level, physiognomic and ecological factors are used to define broad combinations of dominant general growth forms adapted to basic physical conditions. At the mid-level, physiognomic and floristic characteristics define the groups, similar to the forest types used by FIA. The lower level units are defined within the above two groups, with the alliance level defined by a characteristic range of species composition, habitat conditions, and diagnostic species usually found in the uppermost or dominant stratum of vegetation, reflecting regional to sub-regional climate, hydrology, moisture/nutrient conditions, and disturbance regimes. The association is a finer level of detail defined by the characteristic range of species composition, diagnostic species occurrences, and habitat conditions reflecting the local topo-edaphic climax, geological substrate, and hydrologic conditions.

NVCS specifies the detail of data required to develop classifications. The complete species inventory data collected using the P3VEG protocol is sufficient to develop classifications. The limited number of species that can be collected with the proposed P2VEG method restricts its use to occurrence plots – that is, to describe the plant community based on classifications developed from plots with full species inventories. The addition of some species information can increase our understanding of the distribution of classified plant communities – allowing for the mapping of vegetation types with more detail than just forest cover type.

Summary

The plot-based system of the FIA program provides an excellent platform for collecting understory vegetation data. Between the proposed core-optional P2VEG and the P3VEG measurements, FIA has the potential to address many current and emerging issues that tree data alone cannot (table 2). To answer the question "how much vegetation inventory data is enough?" investigators must consider the objectives, spatial scales, and level precision and accuracy required.

Table 2 – Utility of FIA vegetation measurements to address objectives[1]

Objective	P2 Vegetation Profile (1 plot / 2430 ha)		P3 Vegetation Indicator (1 plot / 38 880 ha)	
(How much of what is where?)	Cover by growth habit	Most abundant species	Total foliar cover*	All species
Biomass[2] (carbon/fuel)	Good	Good	Good	More than enough
Structure (fuel/wildlife)	Good	Good	Good	More than enough
Diversity				
Structure	Good	Okay	Good	Good
Growth habit	Good	Okay	Derived	Good
Species richness	---	Not possible	---	Required
Species distribution	---	Presence of most abundant only	---	Best: presence/absence with abundance
Plant community classification	---	Can be used with pre-existing keys to alliance level	---	Can be used to build to association level.

[1]Assumes at least 30 plots per forest type to reduce variance: small land management units may require intensification of sample grid to increase confidence of estimates.
[2]Assumes bulk density of growth habit types or species are known or can be approximated: Biomass (kg/m^2) = Height (m) x Cover (%/100) x Bulk Density (kg/m^3)

When evaluating the utility of each set of measures to address specific objectives, the difference in spatial scale at which they are collected is just as important as the detail of the data collected.

The spatially dispersed P3 vegetation indicator data is more detailed, providing data for the development of vegetation classifications, assessing species distributions and impacts of introduced species on native plant communities, as well as a better detection measure of change while assessing regional and national trends. This information is used to make regional or national assessments for FIA reporting as well as by others concerned with national or regional assessments of the state of forest ecosystems (e.g., Resource Planning Act, Heinz Center's State of the Nation's Ecosystems, Wilderness Society Science and Policy briefs) and is not designed for establishing baseline data at local levels.

Although the proposed core-optional P2 vegetation profile methods will provide general structure and less complete species information, it will be collected on a higher spatial density than the P3 vegetation indicator and will be potentially useful at more localized scales. Land managers can use the data in forest planning, monitoring forest plan standards and effectiveness, monitoring and management of wildlife habitat, monitoring and management of fuels. However, sample size may need to be increased above the intensity of the P2 grid in order to decrease variance and increase confidence in the precision of the estimates (O'Brien et al 2003).

Beyond making population estimations based on direct measurements as discussed here, implementing both P2VEG and P3VEG data collection would provide a wealth of data to help refine current tools and models for estimating carbon pools, describing fuel characteristics, and identifying potential wildlife habitat. Forest plant community classes can be identified and described, improving manager's ability to map areas of concern and improve their ability to monitor the effectiveness of management plans.

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