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Project Summary

Forest Health Monitoring Plot Design and Logistics Study

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Concern over the condition of forests in relation to natural and manmade stresses has led to an interagency Forest Health Monitoring program. To improve the efficiency of forest monitoring, the forest group of EPA's Environmental Monitoring and Assessment Program conducted a field test of selected measurements. The objectives of the field test were to decide statistical, plot, design, and logistical issues.

Measurements of soil, vegetation structure, foiliar chemistry, mensuration, light transmittance, and visual symptoms were made at 40 plot locations in New England and Virginia. The data were used to derive optimum multistage sampling intensities for different cost assumptions. The field test also provided a realistic test of logistics.

The number of different types of measurements are recommended for monitoring in these forest types and regions. Specific recommendations are also made to streamline field sampling. In general, the plot designs and sampling intensities currently used for forest modeling are adequate for the measurements tested.

This Project Summary was developed by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

The Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP-Forests) has joined the U.S. Department of Agriculture Forest Service and other government agencies in an effort to monitor and assess the condition of the nation's forested ecosystems in relation to natural and man-made stresses. A long-term and multi-tiered strategy for monitoring and assessment includes elements for detecting, evaluating, and explaining changes in forest condition. To improve the efficiency of monitoring, part of the strategy is to test and optimize field measurement procedures.

A preliminary set of measurements was chosen for testing in the detection phase of monitoring based on workshops, a review of the literature, expert opinion, and reports from studies done elsewhere. The interagency Forest Health Monitoring (FHM) program is now conducting research to expand that set and to verify the capabilities of measurements to accurately represent and respond to changes in forest condition over time. Research is needed to optimize the deployment of selected measurements, because any per-unit cost reductions will be multiplied many times in a nationwide program.

Thus, the FHM program conducted a field test of plot design and logistics for previously selected measurements in 1990. Not all of the possible measurements were tested, and not all of the questions that have been asked about the selected measurements were asked in this study. The objectives of the field test were:

- to evaluate plot design and subsampling procedures,
- to quantify time and resource requirements,

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- to assess the relative efficiency of competing methods in some cases, and
- to supply information to improve the national FHM program.

The purpose of this report is to summarize the results that were obtained. Recommendations are made to guide further planning of the monitoring program.

Section 1 provides an overview of the rationale, objectives, and approach to the field study. Section 2 describes the site and stand characteristics of the forests that were sampled. Sections 3 and 4 are the main focus of the report; they summarize the results obtained for plot design and logistics. Recommendations are based on the detailed results obtained for different groups of measurements as reported in Sections 5 through 9. These measurements include the following.

- Visual Symptoms - selected mensurational variables such as tree size and the percentage of live crown, and tree crown dieback, transparency, discoloration, defoliation, and density.
- Soil Productivity - soil chemical and physical properties.
- Foliar Nutrients/Chemical Contaminants - chemical analyses of foliage from sample trees.
- Vegetation Structure - vertical vegetation structure.
- Growth Efficiency - canopy transmittance of photosynthetically active radiation.

The starting point for measurements and plot design was based on several interagency committee reports, the FHM measurement strategy, and the current plans for monitoring. From this starting point, a suite of measures of forest site and stand "condition," broadly defined, were selected for testing. The potential efficacy of these measures has been established through peer review. The question of their efficiency is important because many are likely to be included in the collection of measurements deployed in the field. The type of information needed about these measurements includes, for example, how many sites should be measured, how frequently should measurements he made, how should measurements he physically arranged in the field, how much do different methods cost, and what infrastructures are required to make the measurements.

The field test was conducted in the New England and the Southeast regions of the United States. In New England, 20 field plots were located in northern hardwoods forest types. In Virginia, 20 field plots were located in loblolly pine-hardwoods forest types. The plot locations were selected systematically (Virginia) or randomly (New England) from candidate locations defined by the EMAP sampling grid and by the U.S. Forest Service forest inventory system. At each selected location, a plot consisting of four subplots was established. Within subplots, further subsampling tules were devised according to the particular objectives for each set of measurements. This sampling design established a multistage sample framework to address the objective of sources of variance. It also established a realistic setting for the test of logistics.

In New England, the field plots were located on a wide variety of site conditions, but all were contained in the maple-beech-birch forest-type group. In Virginia, the coastal plain sites were less variable, but both the loblolly- shortleaf pine and the oak-pine forest-type groups were sampled. The field plots are representative of uniform, fully stocked, mature stands on typical soil types in these forest types and regions. Stand density (basal area) ranged from 19 to 48 m^2/ha in New England and from 13 to 47 m^2/ha in Virginia. Stem density was between 500 and 1300 trees/ha in New England and between 400 and 1550 trees/ha in Virginia. Species composition was different for the two regions, but the range and average number of overstory species were similar between regions. The New England stands had structures approaching uneven-aged, and the Virginia stand structures were suggestive of multistoried stands.

Plot Design

Standard statistical procedures were used to estimate the optimum number of sample units for different measurements and stages of sampling under two sets of cost assumptions. These results should be considered guidelines rather than rules for sampling. In most cases, the sample designs developed for the 1990 and 1991 field tests are adequate for a regional monitoring program, but generalizations to untested species and regions may be tenuous. The optimum solutions were not particularly sensitive to cost reductions in the final stage of sampling. In comparison to locating field plots and establishing subplots, the costs of the final stages are less important than the information gained, suggesting that the measurement effort not be unduly constrained by logistical considerations once personnel are on the plot. Spatial correlation was not an important factor to consider when calculating optimum sample sites for measurements that were made on systematic grids within plots.

The recommended sample allocations suggest that the current design of four subplots per field plot location is more than adequate for most of the measurements that were tested. The estimates of sample allocation suggest that two trees per each of three or four subplots should be sufficient for visual symptoms measurements for any single species. If separate statistics are desired for each species, then the total number of trees measured at each location depends on the number of species present. Analyses of typical mensuration variables suggested that two subplots were sufficient for characterizing average tree sites and total stand basal area, but the subplots may be too small because not enough trees were present on them to adequately portray stand structure.

The soils data suggested that two to three soil pits will be sufficient. These pits should be systematically arranged so as to represent the entire field plot location. The foliage chemistry data were quite variable and only two species were tested. The suggested allocation is for five to six branches from each of one to two trees taken from each of two to three subplots, or a total of between 15 and 30 branch samples per species per plot location. If interest centers on the subset of macronutrients, then only one-third as many branches are required. The larger sample sites would be required mainly to characterize the heavy metals in foliage.

A conservative estimate of the number of vegetation structure measurements required in the forest types tested is six subplots and four measurement stations per subplot. The results for photosynthetically active radiation (PAR) suggest between two and six subplots, more on cloudy days and fewer on clear days, and two measurement stations per subplot. Both the vegetation structure and PAR measurements need to be tested under a wider variety of forest canopy types before firm recommendations can be given, because the results obtained were highly conditioned upon the subplots being "rotated" into similar canopy conditions.

Logistics

The elements of logistics that were examined included: staffing and personnel, procurement and inventory control, training, reconnaissance, sampling, communications, and safety. It was feasible for a five-person crew to make the measurements on a plot in a ten-hour day. Six specific recommendations are made to improve the efficiency of field activities:

- Specify the criteria for eliminating sampling sites prior to reconnaissance.
- Provide reconnaissance prior to field sampling to reduce the time it takes a field crew to locate a sampling site.
- Review all equipment and consumable items with measurement coordinators to determine exactly what is required.
- Determine staff requirements early and ensure that contracts are established before field sampling activities commence.
- Provide an assistant to the field crews to stock equipment and consumables and to receive, maintain, transport, and track samples.
- Provide a better communications network. The regional project leader or an identified assistant should be responsible for all communication with the field crew leader. The logistics personnel should have early and close communication with other groups (design, indicators, QA, information management) to develop efficient field implementation.

Visual Symptoms

Measures of visual symptoms and mensuration are important elements of forest monitoring in most countries, but care must be taken to obtain comparable measurements for different species and locations. This study sampled trees according to the protocols that were used for implementation of FHM in New England in 1990, and despite the comparatively small sample sizes in thick study, the results were generally similar to those reported by the FHM program based on New England monitoring effort. There was no comparable sample for Virginia, however. The variance analysis of crown density yielded results similar to those obtained in a field test in Great Britain. Most of the variability of crown density can be attributed to tree-to-tree variability, and most of the remainder to stand-to- stand variability. The quantitative analysis of these sources of variance allow FHM to derive optimum numbers of trees to sample within each stand. Additional analyses are needed to determine which of the competing measurement methods are most efficient or accurate. Additional analyses of root and tree increment core samples are also needed.

Soils

Measurements of soil physical and chemical properties are fundamental to forest monitoring. The study focused on logistical concerns and on quantifying the measurement variability that may be expected when soil measurements become a routine part of monitoring. Two different statistical techniques were applied to a set of laboratory chemical parameters that were measured on soil samples collected from eight intensively sampled field plots in each region. The results suggest that the present systematic sampling design of three soil holes per field plot is sufficient. The variance among pits within clusters was the same as the variance among pits among clusters, indicating that a sampling design with individual pits as the subsampling unit provides a better allocation of resources.

Foliar Chemistry

Sugar maple (in New England) and loblolly pine (in Virginia) foliage samples were obtained from the upper crowns of dominant and co-dominant trees on 10 plots in each region. A suite of chemical analyses were performed which included macro- and micronutrients, total C, N, and S, and selected trace elements. Between-plot, between-subplot, between-tree, and between-branch variances were calculated. Between-branch variances could not be estimated for sugar maple because the samples were collected incorrectly. The sample optimization suggested five to six branches from each of one to two trees on two to three subplots for most elements, but fewer branches were required to characterize just the macronutrients. Most of the relatively large branch-to-branch variability observed for the trace elements may be attributed to concentrations at or below the analytical detection limit.

Vegetation Structure

Physical alteration of habitats is a threat to biotic diversity. For this reason, the structural features of land use, land cover types, and animal habitats are candidate indicators of biotic integrity. The primary objective of this study was to compare an ocular method to a pole method for measuring the amount, arrangement, and composition of forest vegetation. These methods differ in their conceptual and procedural approaches to estimate foliage occupancy and distribution. The results indicated that ocular estimates of total foliage occupancy are significantly (3 to 13%, $p <0.01$) larger than pole estimates. The advantages of the ocular method include speed and a capability for generating a complete stand profile (the pole method was limited to the lowest 30 ft of the profile). The advantages of the pole method include lower measurement error, more flexibility for data manipulation, and better variance estimates. Both methods were successfully implemented, but additional analyses of associations among measurements and of existing data bases are required before a definitive judgement can be made about which method is preferable for FHM program needs.

Photosynthetically Active Radiation (PAR)

Ground-based measures of canopy density and processes are considered to be more of a research topic than a candidate for full implementation at this time. In the uniform-canopy stands that were sampled, it was possible to estimate the plot median percentage of transmitted PAR with a relative standard error of between 0.1 and 2.7% using a portable integrating radiometer in less than one hour. Under ideal sky conditions, relatively few measurements are needed to estimate plot-level statistics with a high precision in uniform canopies. In this situation, it may be better to choose a plot design that characterizes a larger plot area, so that PAR measurements can be better related to remotely sensed measurements. Cloudy sky conditions reduced the sampling efficiency but they did not invalidate the sampling design. To alleviate problems associated with cloudy skies, fewer samples per subplot but more subplots, or the simultaneous measurement of both ambient and under-canopy radiation, should be investigated.

Summary

The field test of plot design and logistics provided information to help plan the detection phase of forest monitoring for selected measurements. In general, the plot design and sampling recommendations are within the realm of practical possibilities. Most measurements will require further testing in other forest types and regions before definitive national recommendations can be made. Some measurements will require a critical evaluation to determine if it is practically possible to implement them everywhere. It is anticipated that the indicator development research currently underway in other FHM projects will suggest additional procedures for which plot design and logistical questions may be tested in the future.

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The complete report, entitled "Forest Health Monitoring Plot Design and Logistics Study," (Order No. PB92-118 447/AS; Cost: $26.00; subject to change) will be available only from:
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