FY91 INDICATOR EVALUATION FIELD STUDY FOR ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM – FORESTS (EMAP-F)

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Atmospheric Research and Exposure Assessment Laboratory
Office of Research and Development
United States Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Environmental Monitoring Systems Laboratory
Office of Research and Development
United States Environmental Protection Agency
Las Vegas, Nevada 89153

Environmental Research Laboratory
Office of Research and Development
United States Environmental Protection Agency
Corvallis, Oregon 97333

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FY91 INDICATOR EVALUATION FIELD STUDY FOR

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Edited By

R.C. Kucera and B.E. Martin

NOTICE

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1. INTRODUCTION

C.J. Palmer[a] and J.E. Barnard[b]

For the past two years, several government agencies have been working together to develop a multiagency program to monitor the condition of the nation's forested ecosystems. The U.S. Department of Agriculture (USDA) Forest Service (FS) has contributed to this initiative under the auspices of their Forest Health Monitoring program (FS-FHM). The Environmental Protection Agency (EPA) has participated through the forest component of the Environmental Monitoring and Assessment Program (EMAP-Forests). Other contributing agencies include state forestry agencies, the National Park Service (NPS), the Soil Conservation Service (SCS), the Fish and Wildlife Service (FWS), the Tennessee Valley Authority (TVA), and the Bureau of Land Management (BLM). In this document; this multiagency program will be referred to as the Forest Health Monitoring (FHM) Program.

A major impetus behind the development of this program has been the concern about documented and potential effects of air pollutants in combination with other multiple, interacting stresses on forested ecosystems. In 1988, Congress directed the FS, through the Forest Ecosystems and Atmospheric Pollution Research Act (Public Law 100-521), to undertake monitoring of "long-term trends in the health and productivity of domestic forest ecosystems." In 1990, Title IX of the Clean Air Act charged the Administrator of the EPA in cooperation with other agencies to "evaluate the effects of air pollution on forests, material, crops, biological diversity, soils, and other terrestrial and aquatic systems exposed to air pollutants."

An important component in the development of the FHM program has been the identification and selection of indicators of forest condition. An indicator has been defined as "a characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics,

[a] Acting EMAP-Forests Technical Director, University of Nevada-Las Vegas, Environmental Research Center
[b] FHM National Program Manager, USDA FS, Forestry Sciences Laboratory, RTP, NC

degree of exposure to the stressor, or degree of ecological response to the exposure" (Hunsaker and Carpenter, 1990). Indicators need to be evaluated to see if they are appropriate and effective representations of status and trends in forest ecosystem condition prior to their regional implementation. This document presents a plan to evaluate several indicators during the 1991 field season.

This introductory section provides an overview of the scope and purpose of this document. A short historical background of the development of an indicator evaluation strategy in the FHM program is given to help the reader put the present planning process in perspective. The organization of the study with the anticipated roles and responsibilities of participating agencies is delineated. The importance of indicator evaluation studies to the overall success of FHM is discussed.

1.1 PURPOSE OF THE PLAN

The first objective of this study plan is to provide a mechanism for the coordination of indicator evaluation efforts by scientists from the participating agencies in the FHM program. This is particularly important as our long-term objective is to evaluate indicators as a set rather than each one individually. As a result, numerous technical and coordination issues have been identified and subsequently resolved in the preparation of this plan.

A second objective of this study plan is to provide a mechanism for input by the scientific community into indicator evaluation activities in the FHM program. This objective will be achieved through the peer review of this plan and the sharing of this plan with interested scientists.

The third important objective is to provide guidelines and direction to those individuals charged with implementing this plan. A study plan must provide enough detail to allow field scientists to carry out the study effectively and efficiently. It should be recognized that this plan does not contain all the details that will be required. Thus, a quality assurance project plan and a methods manual are currently being prepared as supplements to this plan.

The final objective of this plan is to meet agency requirements for field data collection efforts. The EMAP program, for example, requires that a plan be prepared before funds can be spent in the field. The review and approval of study plans by management within each participating agency ensures management input, support, and cooperation.

1.2 CONTENT AND ORGANIZATION OF STUDY PLAN

This plan is organized into twenty-three sections. Sections 2 through 7 highlight the planning elements of design, quality assurance, logistics, information management, and reporting required to conduct the Field Study. Sections 8 through 17 describe the specific indicators that will be tested in the field studies. Sections 18 through 22 describe overall planning topics such as indicator development, integration and assessment, and reporting, and Section 23 combines all references. The incorporation of off-plot information from air pollution and deposition, climate, and landscape characterization data collection efforts is discussed also.

It should be noted that the preparation of this plan has been a team effort requiring the contributions of numerous individuals. In an effort to recognize the contributions of these scientists, the authors will be identified at the beginning of each section.

1.3 HISTORY

A series of pilot studies were undertaken in 1988 and 1989 under the auspices of the National Vegetation Survey in the Forest Response Program, an interagency acid rain research program. The objectives of these studies were to develop techniques to inventory and monitor symptoms of atmospheric pollution-induced stress, damage, and/or death of forest stands and trees. An indicator known as the visual damage indicator was developed and evaluated as a result of this program at 128 plots in mixed hardwood forests, 31 plots in high-elevation spruce-fir forests, 157 plots in natural loblolly pine stands in the piedmont, and 222 plots in loblolly pine stands of the coastal plain region. This indicator includes a number of different measurements of tree crown condition, evaluates trees for symptoms of abnormal growth or pests, and identifies whether or not sensitive plant species have been exposed to air pollutants.

Based on the success of these and other pilot studies, the implementation of forest health monitoring in New England (NE-FHM) was initiated in the summer of 1990. In the NE-FHM project, over 200 plots were established on a grid across New England. This project was a combined effort of the FS and state forestry agencies with assistance provided by the EMAP-Forests staff in quality assurance and information management. Certain visual symptoms indicator measurements, along with standard forest mensuration measurements, were made.

A second field project was undertaken during the 1990 field season to evaluate several additional indicators (Palmer et al., 1990). These additional indicators had been identified during interagency FHM workshops and peer-reviews of the EMAP ecological indicators document (Hunsaker and Carpenter, l990). Twenty plots were established in northern hardwood forests of New England, and 20 plots were situated in loblolly pine stands of Virginia on sites that would not become FHM plots. This second project was named the 20/20 pilot study. In addition to visual symptoms and growth measurements, indicators of soil productivity, foliar nutrients, vertical vegetation structure, and percent transmitted photosynthetically active radiation (PAR) were measured and are being evaluated.

As a result of the 20/20 pilot study, considerable information was collected about these indicators. For example, the PAR measurement was found to be sensitive to light variations on cloudy days and frequent visits within and outside the canopy did not adjust for this effect. A new approach of taking simultaneous PAR measurements within and outside the canopy needs to be tested. The 1991 indicator evaluation study presented in this document provides for such a test.

An important development during the fall of 1990 was a document on the EMAP indicator evaluation strategy (Knapp et al., l990). The value of this document was that it outlined an approach for selecting and evaluating indicators of ecological condition regardless of the ecosystem or indicator type. This framework has been expanded and proposed for interagency FHM program consideration in the *Monitoring and Research Strategy for Forests - EMAP* (Palmer et al., 1991). A summary of this approach is given in Section 21 of this plan. This approach has been used as a guideline for developing 1991 indicator evaluation strategies.

1.4 AGENCY RESPONSIBILITIES IN 1991 INDICATOR EVALUATION STUDIES

The success of this study will depend on the willingness of all participating agencies to participate as full partners in this activity. It is important that the roles and responsibilities be clearly identified to encourage cooperation and successful implementation. These duties are outlined in Table 1.1. In general terms, EPA is responsible for preparing planning documents. Field activities will be coordinated by the FS. Evaluation of results will be a shared activity. The key individuals who are most responsible for the success of this study are the indicator leads, regardless of the agency from which they come.

Table 1.1 Agency responsibilities in 1991 FHM indicator evaluation studies.

	AGENCY RESPONSIBILITIES[a]							
TASK	FS	EPA	States	FWS	SCS	NPS	TVA	BLM
Planning:								
Preparation of Plan	C[b]	L[b]		C				
Review of Plan	C	L	C	C	C	C	C	C
Quality Assurance Plan	C	L		C				
Methods Manual Prep.	C	L		C				
Methods Manual Review	C	L	C	C	C	C	C	C
Programming Data Loggers	C	L		C				

(continued)

Table 1.1 Continued

TASK	AGENCY RESPONSIBILITIES[a]							
	FS	EPA	States	FWS	SCS	NPS	TVA	BLM
Implementation:								
Plot Reconnaissance	L	C	C					
Pretraining Workshop	L	C		C			C	
Training Workshop	L	C	C	C	C		C	
Measurement Crew Staff	L		C	C	C		C	
Crew Logistics	L	C	C	C	C			
QA Audits	L	L	C	C				
Plot Remeasurements	L	C						
Evaluation:								
Debriefing Workshop	L	C	C	C	C		C	
Method Manual Revisions	C	L	C	C	C		C	
Quality Assurance Report	C	L						
Indicator Evaluations	L	L		L			C	
Synthesis Report	C	L		C				
Review of Report	C	L	C	C	C	C	C	C

[a] FS = Forest Service (USDA)
EPA = Environmental Protection Agency
FWS = Fish and Wildlife Service (USDI)
SCS = Soil Conservation Service (USDA)
NPS = National Park Service (USDI)
TVA = Tennessee Valley Authority
BLM = Bureau of Land Management (USDI)
States = AL, GA, VA, MD, DE, NJ, ME, NH, VT, MA, RI, CT
[b] L = Lead Agency
C = Contributing Agency

1.5 IMPORTANCE OF INDICATOR EVALUATION STUDIES TO SUCCESS OF FHM

The overall goal of FHM is to provide unbiased, regional estimates with known precision of the status and trends of ecological resources in forests on an annual basis for all of the United States. This can only be accomplished if indicators can be found that accurately reflect ecosystem condition.

The purpose of the indicator evaluation studies presented in this plan is to begin to address the issue of whether or not the right indicators have been chosen and whether or not they will work. This is a complex issue and depends on whether or not answers can be found to a number of questions asked of the indicators. For example, what is the expected variability for indicators if you return to the same location at some other time in the measurement season? What is the feasibility and cost associated with the data collection of this indicator? Which data collection method gives the most accurate and reproducible results? What additional information does this indicator provide regarding the health of the forest ecosystem that is not already addressed by other indicators? Can the indicator information be interpreted given natural variation and changes due to normal stand development?

In summary, the FHM program has made a significant start with the implementation of visual symptoms and forest mensuration indicators in several states. As this program is expanded to additional states, there is a need to evaluate these indicators as well as additional indicators of forest condition to provide a complete picture of the status and trends in our nation's ecological resources in forests.

2. APPROACH AND RATIONALE

R.C. Kucera[a]

The FHM program is expanding gradually due to the diverse nature of forest ecosystems, the state of the sciences, the organizational complexity, and the cost of program development. The strategy for expansion includes developing national and regional support organizations, communicating program goals to agencies in new geographic areas, advancing the research of forest monitoring, and implementing advanced forest monitoring methods. In 1991 twelve states in three Forest Service Experiment Station regions have committed to operationally monitor forest ecosystem health. The approach of the FY91 Indicator Evaluation Field Study for EMAP-Forests (Field Study) is to economically conduct field research for advancing forest monitoring science by combining developmental research with the operational monitoring research conducted in selected areas. This approach introduces the FHM program in new areas and necessitates development of support organizations.

The Field Study is generally composed of two types of studies with additional measurements incorporated according to the opportunities provided by implementation. One type of study is the Nutrient Cycling Demonstration which consists of a core of measurements which are believed to be informative concerning regional ecological nutrient cycling status and which will be measured over the broad region of Georgia and Alabama. The second type of study is the Landscape Pilot which consists of measurements intended to develop procedures for measurement and correlations among different areal scales of measurement in the locality of specific plots. The number and geographic distribution of the Landscape Pilot plots are more limited than in the Nutrient Cycling Demonstration and are selected to achieve more specific objectives.

Each measurement proposed in the Field Study has discrete objectives to develop or evaluate it's usefulness for monitoring. The EMAP-Forests national staff and cooperators provide planning, implementation, and analytical support for this research as described in subsequent chapters on

[a] ManTech Environmental Technology, Inc., AREAL-RTP

design, quality assurance, logistics, information management, reporting, landscape characterization, air pollution and deposition, climate, indicator development, and assessments.

The FHM program is conducting operational forest monitoring in 1991 at different levels of implementation in New England (Maine, New Hampshire, Vermont, Connecticut, Massachusetts, and Rhode Island), the Mid-Atlantic (New Jersey, Delaware, Maryland), the South (Alabama), and the Southeast (Georgia and Virginia). Complete implementation consists of plot establishment and measurement or characterization of tree species, radial increment, regeneration, and certain visual symptoms of forest condition. Some or all of these measures have been selected for immediate operational monitoring in the different regions to provide data for reports of forest conditions. Table 2.1 shows the levels of operational monitoring by region and the additional research measurements planned for the Field Study in 1991. The Nutrient Cycling Demonstration and Landscape Pilot measurements listed in Table 2.1 are described in their separate chapters.

Table 2.1 Core, Demonstration, and Pilot Measurements Schedule

Measurement	New England	Mid Atlantic	South (Alabama)	South East (Georgia)	South East (Virginia)
Plot Establishment	X	X	X	X	X
Operational Measurements					
Diameter	X		X	X	X
Species	X		X	X	X
Visual Symptoms	X		X	X	X
Regeneration	X		X	X	X
Nutrient Cycling Demonstration					
Soils			X	X	
Tree Core Elemental			X	X	
Foliar Chemistry			X	X	
Root Disease Evaluations			X	X	
Landscape Pilot					
Needle Age			X		
Mycorrhizal Soil/Root			X		
Veg. Habitat Structure				X	
PAR				X	
Aerial Photo Interpretation				X	
GPS	X			X	

The Field Study is being conducted in eight of the twelve states that have begun monitoring operationally. The twelve states are in the jurisdiction of three Forest Experiment Stations of the Research Division of the USDA Forest Service. Maine, New Hampshire, Vermont, Connecticut, Massachusetts, and Rhode Island are in the Northeastern Forest Experiment Station area and are referred to as New England (NE). New Jersey, Delaware, and Maryland are also in the geographic territory of the Northeastern Forest Experiment Station, and these states are referred to as the mid-Atlantic states. Alabama is in the Southern Forest Experiment Station area. Virginia and Georgia are in the area of the Southeastern Forest Experiment Station.

The Field Study will be conducted only in Georgia, Alabama, and selected areas of New England. The States of Georgia and Alabama contain contiguous areas of similar forest types and represent two Experiment Station regions, making this combination the most attractive for the Field Study. Researchers in the mid-Atlantic states are limiting their first year's operational work to plot establishment and therefore the mid-Atlantic states were not considered as prime candidates for this additional research. The New England Forest Health Monitoring project determined that only soils and Global Positioning Systems should be measured in New England.

2.1 NUTRIENT CYCLING DEMONSTRATION

Operational monitoring will be conducted on approximately 206 forested plots in New England, 148 plots in Georgia, and 137 plots in Alabama. The Nutrient Cycling Demonstration will be superimposed on a systematic selection of one-fourth of these plots in Georgia (37 plots) and Alabama (35 plots). The measurements to be made on these plots are soil chemistry, foliar chemistry, tree core elemental analysis, and selected root fungi presence and taxonomy (see Table 2.1). These measurements were recommended as candidates for further evaluation in the Monitoring and Research Strategy for Forests - Environmental Monitoring and Assessment Program (EMAP) (Palmer et al., 1991). The Field Study is taking further advantage of the opportunity to utilize the field crews to test methods of height measurement on the Nutrient Cycling Demonstration plots in Georgia, and

Global Positioning Systems measurements in Georgia and the New England states. The measurements are being made for specific reasons which are described in detail in Sections 8 through 11.

There are several reasons for making these measurements as a group. The chemical measurements, when made at the same time and place, are expected to reveal significant nutrient cycling information relevant to the status and trends of the forest ecosystem which may not be apparent if the measurements are made at different times. Analysis of these data in combinations may also indicate forest condition or identify relationships that suggest causes of existing conditions.

The systematic selection of one-fourth of the operational monitoring plots, over the entire area of Georgia and Alabama, as opposed to limiting sampling to a preselected forest type, provides more opportunity for poststratification based on other classification criteria such as climate divisions, soil classifications, or regional land use classifications. There will be certain classification types that do not have enough samples for thorough analysis, but these will provide preliminary information to anticipate conditions that will be encountered when these types are more completely sampled.

2.2 LANDSCAPE PILOT

The Landscape Pilot is a coordinated set of additional measurements that will be conducted on 20 of the Nutrient Cycling Demonstration plots in western Georgia. These additional indicators can benefit from the employment of remote sensing techniques. The additional measurements to be made on these plots are vegetation and habitat structure, intercepted photosynthetically active radiation, aerial photography interpretations for landscape characterization and landscape processes, and finally Global Positioning Systems (GPS) coordinate identification for the purpose of accurately digitizing aerial photo information in a Geographical Information System (GIS) data base. The pilot is designed to focus on an examination of the relationships of some of the field measurements and remotely sensed interpretations from high-resolution aerial photography in addition to the individual indicator development.

The Landscape Pilot has some general objectives that make the Pilot a coordinated effort among the measurements that will be taken. These objectives provide the opportunity to obtain more information from all of the measurements taken than from the independent measurements alone. The primary objective is to investigate linkages of field measurements and the remotely sensed interpretations. This objective includes testing indicator associations at each scale on a selection of plots with diverse physical and vegetative features. This objective and the resulting simplified logistical structure has lead to the decision to sample twenty consecutive Nutrient Cycling Demonstration plots in western Georgia, thus increasing the probability of sampling different forest types and physiographic regions from the upper Piedmont to the Coastal Plain.

Two further measurements in the Pilot category are soil/mycorrhizal fungi sampling technique testing, and foliar chemistry sampling techniques to determine the effect of needle age. These two measurements are being taken on the Nutrient Cycling Demonstration plots in Alabama. This plot selection decision is based on the need to obtain samples from a more homogeneous population of loblolly pine and the advantageous logistical opportunity to decrease the work load in Georgia and more fully utilize the available personnel in Alabama.

The final pilot measurement is the logistical test of establishing plot center with GPS technology. This test is incorporated within the Georgia Pilot GPS measurement plan. Global Positioning Systems measurement methods will be tested on a selection of plots in New England because it can be added to the operational monitoring project without employing additional personnel, equipment is available, and because the additional range of conditions encountered will improve the test.

Geographic Information System technology will be used in the Landscape Pilot as a tool to investigate the general objectives of the pilot and to provide a record for future use in change detection. GIS coverages will be developed from the aerial photography interpretations, the sampling locations of measurements taken, and from auxiliary data such as elevation and land cover.

These measurements are listed in Table 2.1 and are described in their separate chapters. The review of the Monitoring and Research Strategy for Forests - EMAP (Palmer et al., 1991) recommended that further research of methodologies and analytical techniques is needed for these measurements.

3. DESIGN

D. Cassell[a]

The network and plot design for this summer's regional demonstration and pilots are discussed in the *Monitoring and Research Strategy for Forests-EMAP* (Palmer et al., 1991). This document has details of the development of the monitoring network design and field plot design for EMAP-Forests. It has been through the peer review process, and the Forest Service has held conferences to answer specific questions of statistical design. A brief discussion follows, with specific comments applicable to this summer's field season.

The EMAP-Forests statistical design produces a probability sample of field plots in each region. The pilots and regional demonstration will use subsets of the selected plots. The Landscape Pilot will be done on 20 plots in Georgia that are a subset of the plots used in the regional demonstration. In this way, links between demonstration and pilot indicators may be examined.

The plots are selected by laying Forest Inventory and Analysis (FIA) photo point grids over the EMAP hexagon grid and selecting the photo point closest to the center of the landscape characterization hex. When FIA plots already exist at the selected photo point, the study plot will be deliberately offset to avoid disturbing the FIA plot. The EMAP interpenetrating grid will be used to select the plots for this summer's demonstration and pilots. In other words, one fourth of the possible plots will be selected in a systematic grid, as discussed in the *Monitoring and Research Strategy for Forests-EMAP* (Palmer et al., 1991).

The strategy plan also outlines selection of plot centers and the plot design. At each location, a one hectare circle represents the experimental unit of interest. Within each such unit, a cluster of four fixed-area subplots (24 ft radius, 1/24 acre) will be designated (Figure 3.1). The subplot centers will be 120 ft apart, and destructive and extractive sampling will be limited to a 36-ft circular band surrounding each subplot. This will ensure that as far as possible, all studies will be considering the same experimental units.

[a] ManTech Environmental Technology, Inc., Corvallis, OR

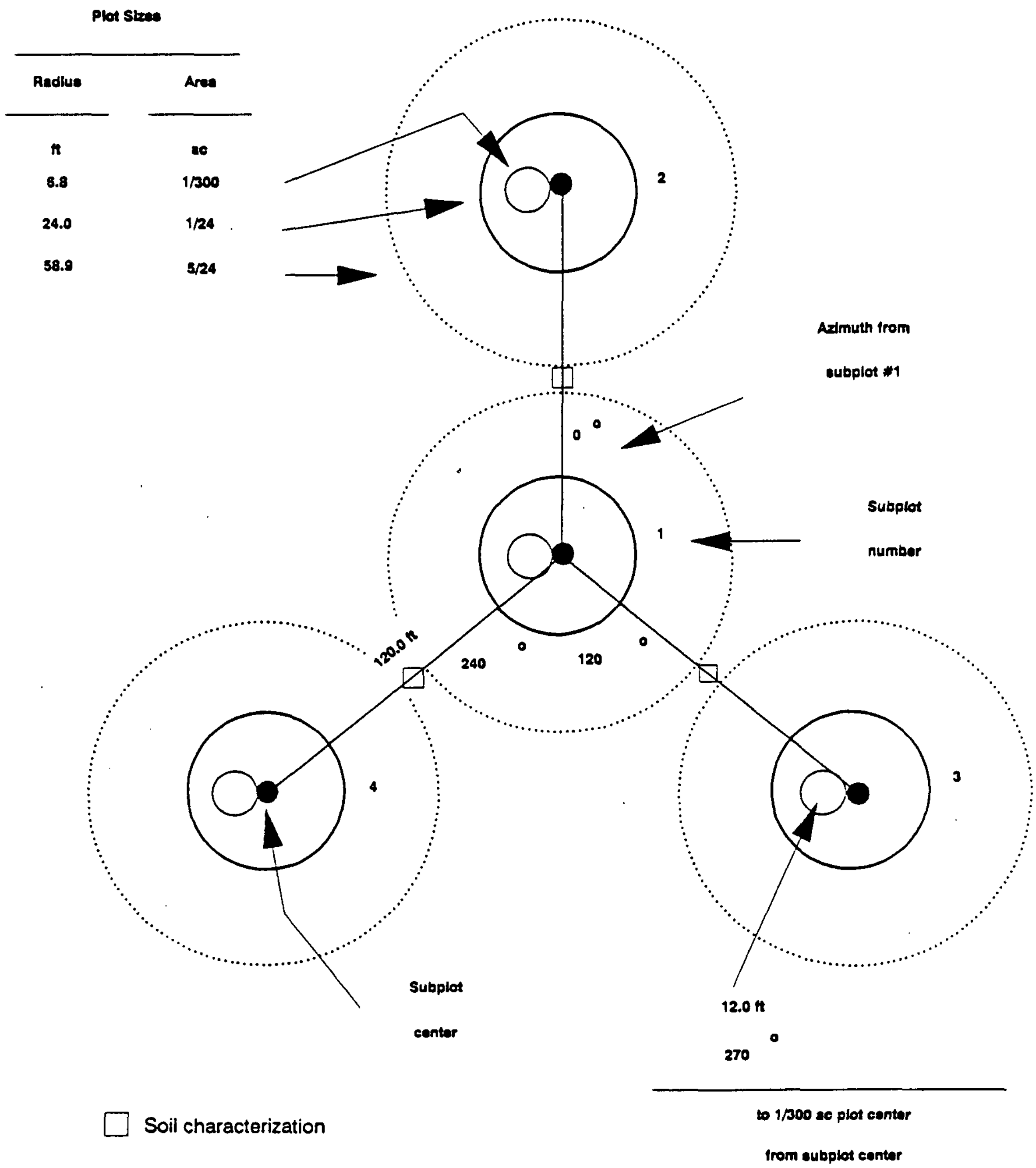


Figure 3.1. Forest Health Monitoring Plot Layout.

A standard method has been developed for selection of trees to be destructively sampled. Within the destructive sampling band of Subplot 1, two trees will be chosen. The portable data recorder will give the field crew a randomly selected azimuth from the subplot center. The crew will take this azimuth to the middle of the destructive sampling band and move in a clockwise direction until the first tree with a dominant or co-dominant crown and diameter of at least five inches is encountered. The crew will also select a tree using the same protocol but using an azimuth that is 180° from the selected azimuth. If the subplot has no sample trees or only one tree then the data for the missing tree(s) are recorded as "missing." The procedure is repeated in Subplot 2, or if this is in a different forest type, in the next subplot of the same forest type. Only two subplots will be used for selection of sample trees. That is, further subplots will not be examined if no trees or only one are found on either of the first two subplots examined in the forest type.

It is expected that some plots will have multiple forest resource types. Forest type will be classified by subplot. Subplots that fall in forest types distinct from that of the center subplot will not be rotated into the original forest type, but will be left in place and measured as is. This will ensure that unbiased estimates can be generated from the subplot data.

Each of the studies presented defines the mensuration and sampling methodology unique to its respective objectives. However, all methods are designed within the context of the overall sampling design and sampling unit design methods described here and in the *Monitoring and Research Strategy for Forests-EMAP* (Palmer et al., 1991).

The Technical Coordinator for statistics will ensure that all indicator studies will be statistically analyzed using the guidelines discussed in Sections 5 and 6 of Palmer et al., as well as in the *Design Report for EMAP*, Part 1 (Overton et al., 1990).

The statistical analyses discussed in Palmer et al. cover a variety of areas. Statistical procedures for regionalization of the data are in general based on the theory of systematic samples (such as Horvitz-Thompson estimators for means and totals) and the utility of the cumulative distribution function. Statistical analyses to separate subgroups of the data include cluster analysis and hierarchical regression. Statistical analyses for examining spatial variability will include subpopulation analyses, semivariograms, and robust forms of kriging.

The methods for estimating components of variability include the one outlined in Pamer et al. This is a modification of Cochran's method for estimating components of variance in nested models (Cochran, 1977) which incorporates measurement error estimates. Bootstrapping data within a plot is an alternative method being used to assess sampling variability and to evaluate within-plot sample size (see Section 8).

The statistical methods for indicator development and indicator linkages include a variety of standard methods. Linear and approximately linear relationships can be evaluated using correlations, multivariate regression, analysis of variance, analysis of covariance, principal components and factor analysis, or canonical correlation analysis. Monotonic relationships can be evaluated using nonparametric correlations, nonparametric regression, and nonparametric analogues to analysis of variance such as Kruskal-Wallis tests. Nonlinear relationships can be investigated using recent methodologies such as projection pursuit analysis and sliced inverse regression. Of course, any results from these statistical analyses must be scientifically interpreted by the respective indicator leads.

4. QUALITY ASSURANCE

G.E. Byers[a]

The FHM program is designed as a major environmental data collection effort and, as such, will operate within the guidelines of the EPA's Quality Assurance Management Staff (QAMS). Utilizing a statistically robust design, the monitoring program will collect data across large geographic areas over long periods of time for multiple ecological resources. The program will employ comprehensive QA techniques to ensure the quality and usefulness of the data. A Quality Assurance Project Plan (QAPjP) is being prepared which is separate from this study plan and which will consist of a comprehensive quality assurance plan.

4.1 QUALITY ASSURANCE PROGRAM

The purpose of the QA program is to ensure that the resulting data bases will yield scientifically valid and unbiased information related to the principal hypotheses being addressed in the project. The fundamental basis for an intensive QA program is that policy makers and the public must have a high degree of confidence in the environmental data and statistics generated by the participants. Hence, the mission of QA in the FHM program is to ensure that all data and statistical products are of documented and sufficient quality to satisfy the needs of data users, policy makers, and the public.

The QA program for the FHM program provides guidance to and is responsible for oversight of the forest ecosystem QA activities. Much of the guidance for the various EMAP Resource Groups is being provided through the EMAP QA Program Plan (Einhaus et al., in preparation; EPA, 1987). The *Monitoring and Research Strategy for Forests – EMAP* (Palmer et al., 1991) delineates in greater detail many of these aspects, including organizational structure. The national QA Coordinator (QAC) for

[a] Lockheed Engineering & Sciences Company, Las Vegas, NV

the FHM program (QAC-Forests) interacts closely with the QAC for EMAP, regional QA officers (QAO), indicator leads, and other FHM participants, including the FS. This interaction disseminates information and relays specific requirements of the project. The QAC-Forests is responsible for QA in all FHM program activities and reports directly to the FHM program manager and EMAP-Forests technical director. Within the FHM program regions, regional QA officers interact with the QAC-Forests to identify and resolve intra- or inter-regional QA issues within the guidelines of the QAPjP. The regional QAOs coordinate specific QA tasks with individuals on the technical staffs that are best qualified to perform them successfully, such as, the indicator leads.

4.2 QUALITY ASSURANCE DOCUMENTS

The overall policies, organization objectives, and functional responsibilities designed to achieve data quality goals for the FHM program activities are described in detail in the *Monitoring and Research Strategy for Forests – EMAP* (Palmer et al., 1991). Included are discussions on QA related to policy, total quality management, organizational structure and responsibilities, data quality objectives (DQOs), documentation and reporting (e.g., QA project plan, standard operating procedures [SOPs], documentation, and reports), and operations (audit program, data verification).

4.2.1 Companion Documents and Other Sources of Information

Information on QA-related activities for the FHM program are presented in several other documents that are in various stages of completion prior to 1991 field and laboratory activities. Current versions of the following documents and information must be distributed among all appropriate FHM program participants and cooperating organizations.

Included are the following.

- EMAP *Quality Assurance Program Plan* (QAPP) (Einhaus et al., In Preparation)
- FHM Program *Quality Assurance Project Plan* (Byers, In Preparation)
- FHM Program *Eastern Forest Health Monitoring Methods Manual for Field Measurements* (Chojnacky, In Preparation)
- FHM Program *Field Methods Manual* (Conkling and Byers, In Preparation)
- FHM Program *Laboratory Methods Manual* (Byers and Van Remortel, In Preparation)

4.2.2 Quality Assurance Project Plan

The QA policy of the EPA (Stanley and Verner, 1985; EPA, 1987) requires that every monitoring and measurement project have a written and approved Quality Assurance Project Plan (QAPjP). This requirement applies to all environmental monitoring and measurement efforts authorized or supported by EPA through regulations, grants, contracts, or other formal means. The purpose of this QAPjP is to specify the policies, organization, objectives, and QA activities needed to achieve the data quality requirements of the joint monitoring program. These specifications are used to assess and control measurement errors that may enter the system at various phases of the project, such as, during the initial field measurement stage or during sampling, preparation, and analysis. The QAPjP will also describe the QA activities and assessment criteria that will be implemented to ensure that the data bases will meet or exceed all data quality objectives (DQOs) established for the FHM program. The QAPjP must identify all environmental measurements within the scope of the project goals and objectives and identify specific processes within each measurement that could introduce possible sources of error or uncertainty in the resulting data. Methods, materials, and schedules for assessing the error contributed by each process must also be addressed. The QAPjP must also define the criteria and procedures for assessing statistical control for each measurement parameter.

The QAPjP will be revised as necessary to reflect changes in procedures that result from continuous improvement. All project personnel, especially indicator leads, should be familiar with the policies and objectives outlined in pertinent sections of the QAPjP to ensure proper interactions among the various data acquisition and management components.

4.2.2.1 Content of the QAPjP

The EPA QAMS guidelines suggest that the QAPjP. should specifically address, in detail or by reference, each of the items listed below. These items describe the QA approach that will be established for each of the data acquisition projects (e.g., implementation, pilot, demonstration) within the FY91 Indicator Evaluation Field Study.

- Quality assurance objectives for measurement data
- Sampling procedure and sample handling
- Sampling custody, transportation, and storage
- Calibration procedures and frequency
- Analytical/measurement procedures and experimental design
- Data reduction, validation, and reporting
- Internal quality control checks and frequency
- Performance and systems audits and frequency
- Preventative maintenance procedures and schedules
- Specific routine procedures to be used to assess data quality
- Corrective action
- Quality assurance reports to project directors

Data collection activities must institute sufficient control procedures, materials, and techniques to minimize measurement errors. Each process that could affect the quality of the data, such as, sample collection, preservation, transportation, storage, preparation, analysis, and data reporting, must be evaluated and documented. In this way, the measurement process can be controlled, the effectiveness of the process can be documented, and the quality of the sample data being produced can be inferred from the QA data.

By using appropriate measurement quality techniques or samples, it is possible to isolate the error contribution and set control criteria based upon specific measurement quality objectives (MQOs). This approach is essential for providing diagnostic information so that real-time corrective action can be taken to ensure control in satisfying these MQOs.

4.2.3 Standard Operating Procedures

Good management of any operation that uses protocols in a routine or repetitive manner includes the use of SOPs, also called "methods" or "protocols" in field and laboratory circles. Environmental monitoring SOPs are devised for sampling and analysis, data management, QA, reporting activities, accounting, project finance and contracts, and in analysis and integration phases of the project. The use of written SOPs helps to ensure consistency in planning, implementation, and analysis activities over time and among personnel for routine activities within an organizational unit. To ensure consistency in data among the FHM program indicators SOPs must be cooperatively developed.

The EMAP-Forests technical director is responsible for determining which activities require SOPs and ensuring that they are developed, reviewed, and implemented. The personnel closest to the actual implementation of an activity (e.g., indicator leads) are the appropriate individuals to develop specific SOPs. The QAC-Forests should identify in the periodic audits the status of all new SOPs in the project. The QAC-Forests works with the technical director, the regional QAO, and indicator leads in the SOP process. The QAC-Forests also has responsibilities in SOP identification, interorganizational consistency, elevation to method or protocol status, and the need for training.

5. LOGISTICS

M. Pappa[a]

5.1 OVERVIEW

The study includes field sampling, sample preparation, and analysis phases and therefore, a large logistics component. The objective of logistics is to provide the necessary assistance to all operational phases of the data collection program to ensure that the program acquires data of sufficient quality for its intended use in an efficient, cost-effective, and timely manner. Logistics will assist in the following operational phases.

- Field sampling
- Sample and data handling/transfer
- Sample preparation
- Sample analysis
- Sample archive

Table 5.1 identifies a number of logistics elements within these five general categories.

Table 5.1 EMAP Logistics Elements for Implementation of Forest Monitoring Programs

1.	Review of Logistical Activities	8.	Safety
2.	Staffing	9.	Information Management
3.	Communication.	10.	QA/QC
4.	Scheduling	11.	Review/Recommendations
5.	Reconnaissance	12.	Inventory/Storage
6.	Procurement and Inventory	13.	Planning
7.	Training	14.	Contracting

Responsibilities for each of these elements have been determined by project managers and logistics leads. The logistics operation can be developed component by component. Each component is not necessarily the sole responsibility of the logistics team. However, the logistics team will identify who is responsible for completing the activity. Figure 5.1 provides a time line of the activities for the study.

[a] Lockheed Engineering & Sciences Company, Las Vegas, NV

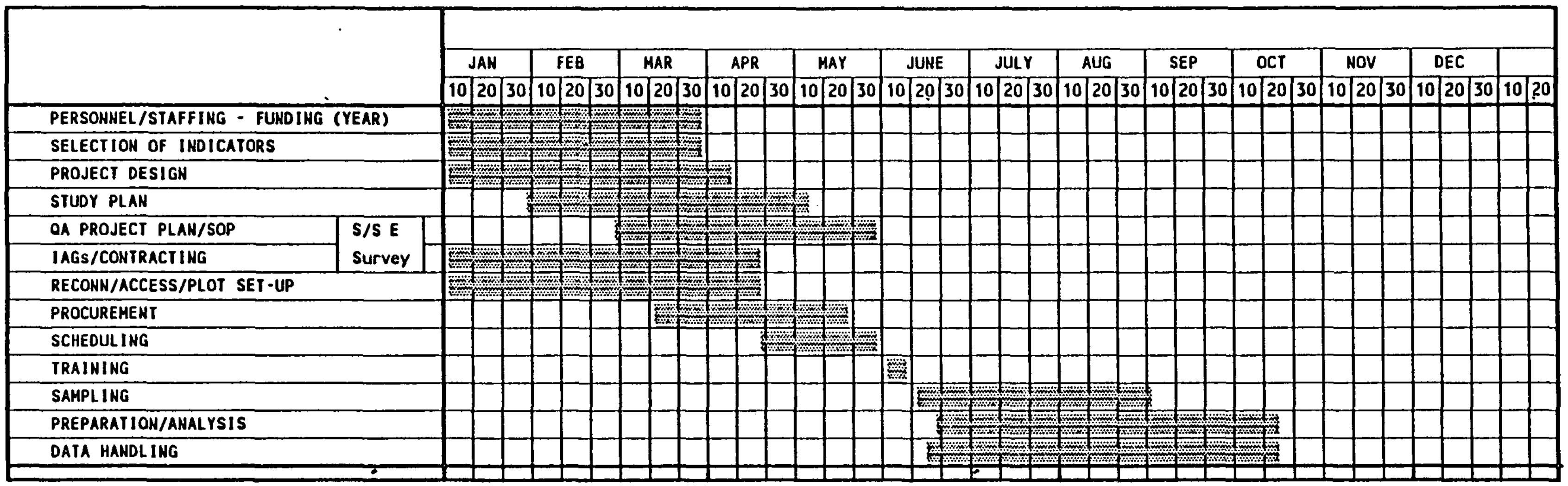


Figure 5.1. Timeline for the South/Southeast Surveys.

5.1.1 Logistics Status

The Logistics Status is a dynamic internal document that tracks the progress and development of each element. This document is not intended to be distributed but provides localized information to allow the technical director, the EMAP logistics coordinator, and EMAP management to determine the progress of the project. It is developed and continually updated by the EMAP-F logistics lead.

5.1.2 Organization of Logistics Section

The logistical elements (Table 5.1) of the study will be discussed in this section. Two studies will be referred to and, where needed, separated under specific headings. The studies, introduced in previous sections, are called the Nutrient Cycling Demonstration and the Landscape Pilot. In addition, the indicators of growth and visual symptoms will also be sampled on all sites.

5.2 STAFFING AND PERSONNEL REQUIREMENTS

The following groups comprise staffing and personnel requirements.

- Field crews
- Logistics personnel
- Preparation laboratory personnel
- Management support
- Training crews
- QA crews

This section will describe the personnel responsible for each assignment. The organization through which each position will be hired (i.e., FS, EPA, cooperators, or contractors) will be discussed. Work schedules will also be discussed.

5.2.1 South/Southeast Nutrient Cycling and Landscape Pilot Field Crews

One field crew in Georgia will be developed to sample both the Nutrient Cycling Demonstration and the Landscape Pilot indicators. One field crew in Alabama will be developed to sample the Nutrient Cycling Demonstration indicators. However, due to the time required to sample the Pilot indicators, two indicators, mycorrhizal root sampling, and needle age separation for foliar samples, will be accomplished by the Alabama field crew. The Georgia field crew will not be responsible for these two indicators.

5.2.1.1 Field Personnel

The information obtained to date (Table 5.2) indicates a six-person crew is needed to sample a site for the Nutrient Cycling Demonstration, Landscape Pilot, and core measurements. The six-person field crew comprises the following.

- Two foresters (visual symptoms, growth) with work-related experience in mensurational-type measurements. These foresters will either be State or FS employees.
- One soil scientist (soil sampling) with emphasis on soil classification. Soil scientists from the SCS are preferred.
- One foliage sampler experienced in tree climbing and foliar sampling techniques.
- One botanist (vegetation and habitat, PAR) capable of taxonomically identifying understory vegetation.
- One aide (GPS, root sampling) capable of recording data, root sampling, soil excavation, and maintaining and shipping samples.

The two foresters are part of the operational program for the collection of measurements of visual symptoms and growth. They are mentioned here in order to represent a complete field crew.

Table 5.2. Estimated Time Requirements for Landscape Pilot with Core and Nutrient Cycling Demonstration Measurements.

Indicator	# People	Hours	Total Hours
Soil Sampling	1	6	6
Foliar Sampling	1	5	5
Growth	2	2.5	5
Visual symptoms	2	4	8
Vegetation/Habitat	2	4	8
PAR	1	2	2
GPS	1	6	6
Mycorrhizae Root Sampling	1	2	2
Tree Cores	2	.5	1
		Total	43

The field crew will be supervised by a designated crew leader. The crew leader will supervise all field operations and, if necessary, resolve all discrepancies or issues at the site. The field crew leader has the following responsibilies.

- Maintaining and revising sampling schedules and itineraries
- Assigning duties according to sampling priorities
- Ensuring that all sampling protocols are followed
- Ensuring proper use and maintenance of field equipment
- Maintaining the integrity of the site and samples collected
- Reporting to proper management staff any problems or difficulties encountered
- Returning all field equipment and supplies

5.2.1.2 Field Crew Division of Labor

In order to collect data for all indicators certain field crew members will be responsible for more than one indicator. A sampling sequence for the efficient use of field crew members to complete sampling in one day will be developed based on the following.

- A full day is 8 h: 2 h estimated for driving and plot location, and 6 h for data collection.
- The crew consists of six individuals.

- The two foresters are needed for the full day to measure growth and visual symptoms with the exception of branch and root sampling.
- The botanist will be responsible for data collection of the vertical vegetation indicator. The aide will assist the botanist on one of the measurements (vertical vegetation).
- The soil scientist is needed for a full day for the description and sampling of soils. The aide will assist with the excavation of sample holes.
- The foliage sampler will be responsible for branch sampling, height measurements, and root sampling (two-root method).
- In Georgia, the aide will assist in the excavation of soil holes, measure PAR, and assist on the vertical vegetation measurement. In Alabama the aide will assist in the excavation of soil holes, evaluate in-hand branch samples, extract tree cores, sample mycorrhizal roots, and separate needle ages for foliar nutrient samples. After 2:00 p.m., this person will leave the site to transport and ship samples.
- Crew members will provide assistance to other data collection activities when completed with their primary responsibilities.
- PAR measurements must be collected between the hours of 11:00 a.m. and 1:00 p.m.

5.2.1.3 Field Crew Task Sequence

Figure 5.2 represents the proposed task sequence for the field crew. During the pretraining and training exercises this sequence will be reviewed and modified to the most efficient schedule.

5.2.1.4 Work Schedules

Because personnel from different organizations will be working on a field crew, a work schedule for the crew should be developed. Within the FS and EPA there are a number of work schedules that can be adapted (four 10-hour days: 8 days straight, 4 days off, etc.). Due to the expenditures relating to this program the most efficient schedule should be determined.

The FS regional logistics leads will determine work schedules.

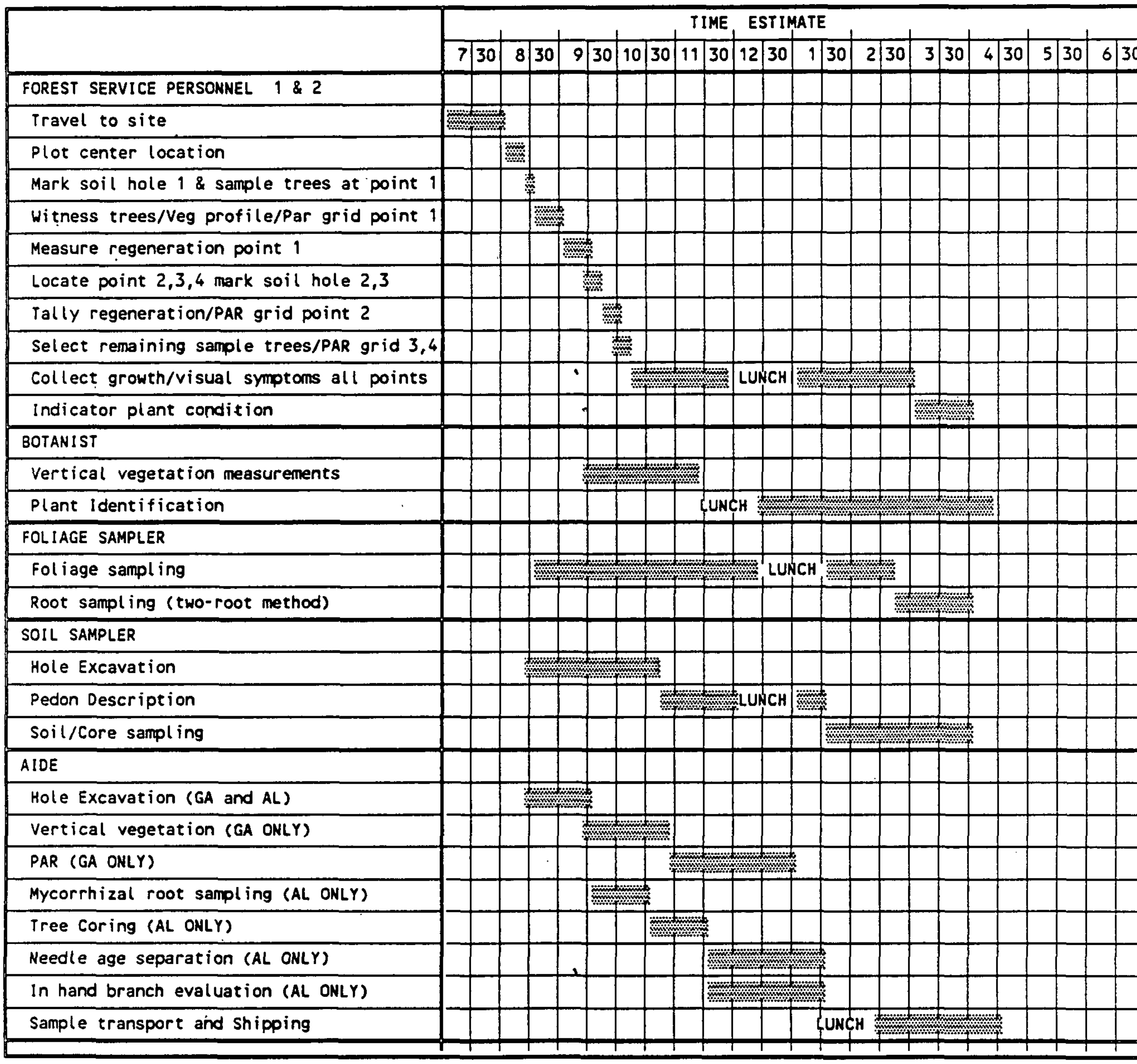


Figure 5.2. Sampling Sequence for Field Samplers.

5.2.2 Aides

Two aides will be available one for each demonstration/Pilot crew in Alabama, and Georgia. Their duties will include sample collection, storage, tracking and shipping, equipment procurement, dispersal, and maintenance. The aides will also act as a liaison between field crews and the FHM program management. Because of the time they will have available, the aides will also assist the field crew by taking part in sampling activities.

5.2.3 Field Crew Funding

An interagency agreement between the EPA and the FS will be developed. Funding will be provided to the FS to acquire personnel for the Nutrient Cycling Study, the Landscape Pilot and the aides.

5.2.4 Logistics Personnel

Field crews will need logistical support in the following areas.

- Equipment and consumable storage, maintenance, and repair
- Vehicle maintenance and repair
- Sample storage, tracking, packing, transfer
- Lodging, timekeeping, and such

The FS regional logistics leads will be responsible to support these activities for FHM program field personnel. Personnel participating in the Nutrient Cycling Demonstration or Landscape Pilots will be the responsibility of EPA logistics leads.

5.2.4.1 Work schedules

The work schedule for logistics personnel should be based on field crew work schedules.

5.2.5 Preparation Laboratory Personnel

The preparation laboratory is designed to be the link between the sampling crews and the analytical laboratories. The primary functions of the preparation laboratory are to prepare homogeneous, anonymous subsamples from processed bulk samples and to transfer batches of those subsamples to the analytical laboratories. For these tasks to be successfully accomplished, the preparation laboratory must accurately track, process, and store all samples.

The preparation laboratory manager assumes the responsibility for maintaining the integrity of all samples upon their arrival at the laboratory facility. The manager is required to be knowledgeable in laboratory methods and procedures, and have demonstrated ability to track large numbers of samples and supervise laboratory personnel.

Ultimately, the laboratory manager is responsible for assigning duties according to the specific project needs. The following division of responsibilities is tentative and may be adjusted.

- Coordinates laboratory operations and time management
- Communicates with QA manager and QA representative
- Communicates with sampling task leaders and indicator leads
- Oversees sample receipt and storage
- Oversees all computer data entry and evaluation procedures
- Oversees sample preparation and analysis activities
- Organizes analytical samples into batches
- Tracks all samples during processing
- Assists other analysts after other duties are complete

5.2.5.1 Soil Sample Preparation

For the study, approximately 1800 soil samples will be prepared. Adequate staffing will be provided to ensure a fast and efficient turnaround of samples from the field to the analytical laboratories. All personnel must be thoroughly trained in the protocols and safety procedures by the laboratory manager before the processing of the samples begin.

A three-person preparation laboratory staff is needed to complete the following activities.

- Sample receipt/tracking
- Sample storage
- Sample drying
- Organic biomass determination
- Bulk density determination
- Sample disaggregation/sieving
- Sample homogenization and subsampling
- Sample batching
- Sample archiving
- Data entry, verification, reporting

5.2.5.2 Foliar Sample Preparation

A two-person preparation laboratory staff is needed to complete the following activities.

- Sample receipt/tracking
- Sample drying
- Sample maceration
- Sample homogenization and subsampling
- Sample batching
- Sample archiving
- Data verification/reporting

5.2.5.3 Work Schedules

The work schedules of the preparation laboratory staff will conform to the field sampling schedule in order for the staff to be available to receive all sample shipments. Therefore, the preparation facility may be operational 6 days a week during the field season.

5.3 COMMUNICATIONS

Communications are critical for the project to proceed efficiently. There should be a method for project management to disseminate directions and information (such as approved protocol changes) to all project participants. Conversely, management needs to obtain current progress information to facilitate decision making. The communications network is described in Figure 5.3.

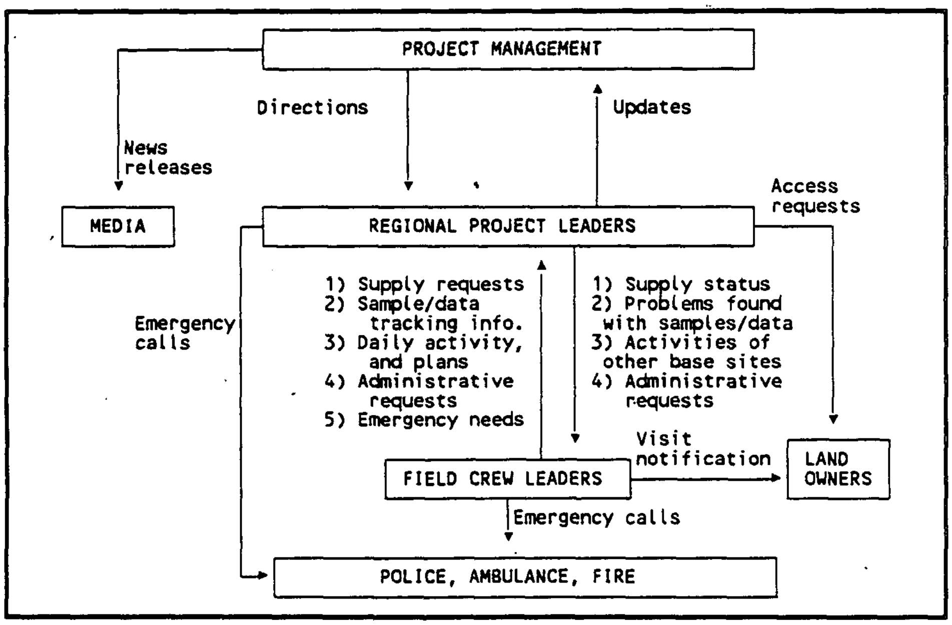


Figure 5.3. Example of a Communications Network.

5.3.1 Line of Communication

The basic line of communication is as follows.

- Project Manager
- Regional Project Leader
- Field Crew Leader
- Field Crew Personnel

5.3.1.1 Project Managers

Project managers are responsible for the dissemination of information vital to the project (i.e., protocol changes, sampling schedule changes, etc.) and will also require progress reports on all aspects of the project.

5.3.1.2 Regional Project Leads

Regional project leads will be individuals who will be available for phone communication or emergency communication during the hours of sampling and for electronic communication at other times. These people are responsible for relaying information to the project managers, other technical support leads (Figure 5.4) and from field crew leaders, as well as disseminating information back to these groups. The regional leads may also need to contact land owners or emergency services.

5.3.1.3 Field Crew Leaders

The field crew leaders will be responsible for informing regional project leaders about sampling progress as well as communicating any problems (e.g., equipment damage or supplies needed) or emergencies occurring in the field. They are also responsible for the direct communication of emergencies to the appropriate authorities, unless personally injured, in which case all field crew members should be properly trained. The field crew leader is also responsible for disseminating information to field crew individuals (e.g., status of sample shipments, data discrepancies, supply disposition etc.).

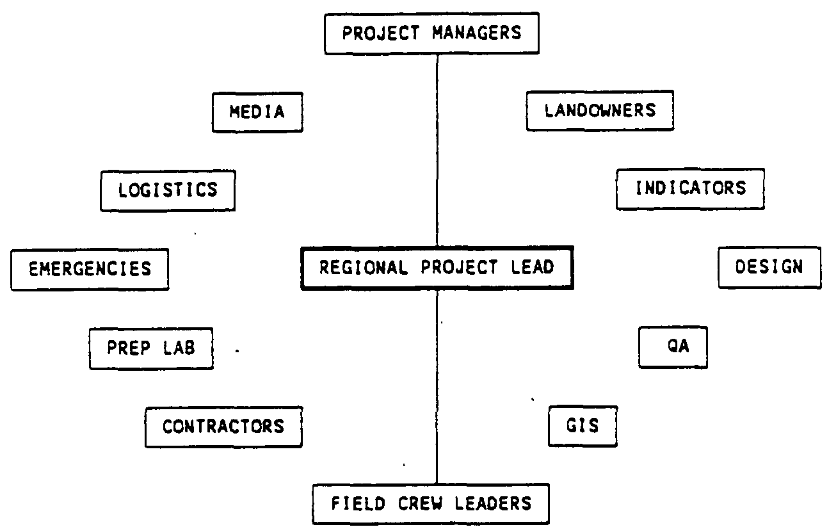


Figure 5.4. Flow of Information to and from Regional Project Leads.

5.3.1.4 Field Crew Personnel

Field crew personnel are responsible for their sampling assignments and all aspects pertaining to this. In order for an efficient relay of information on progress, problems or emergencies occurring in the field, they are requested to report this information to the field crew leader.

5.3.2 Mode of Communication

For this study, communication will take place electronically through laptop computers or phone system. Field crew leaders will be required to log in to the portable laptop computers each day. An "update" screen will appear, which the field crew leader is requested to fill in. It will include the following information.

- Field crew ID
- Field crew location (hotel name, address, phone number)
- Additional personnel with field crew (auditor, EPA personnel, etc.)
- Expected location of next day
- Hexagon sampled that day
- Hexagon expected to be sampled the following day
- Comments/problems

The field crew leader is expected to fill in the update and send it out electronically, whether or not data is being transmitted. This update will be electronically sent to a dedicated PC at Lockheed Engineering and Sciences Company, Las Vegas, NV (LESC) or the EPA VAX, and will then be used to update DG and E-MAIL accounts of appropriate individuals in the program. This year the information manager will attempt to acquire an 800 dial-up number for electronic transmission.

Some hotels "hardwire" phone lines, prohibiting the connection of the laptop to the phone system. In this instance, an 800 number will be available for updates. Either an individual will record the information or a recorder will store this information. An LESC individual will enter this update information and electronically send it to the appropriate individuals.

5.3.2.1 Conference Calls

As illustrated in Figure 5.4, the regional project leaders are the important links with the field crew leader, project managers, other technical leads and various groups. As problems occur in the field or as protocol change, it is important that decisions are made that are consistent for all field crews and regions. Therefore, a weekly conference call should be established where technical leads, regional leaders and project managers are on hand. Discussions should include progress on all operational phases, problems occurring, and protocol changes. Issues can be resolved and disseminated consistently to all field crew leaders. Further, issues do arise where scientific and administrative decisions must be made in a more timely manner. Each scientific and administrative functional position should have a primary and a backup person identified and authorized to make decisions relevant to that function within 24 hours of notification.

5.3.3 Geographical Information Systems (GIS)

The GIS group can assist the project by locating facilities and services that may be necessary for field crews. A list of facilities nearest each hexagon such as the following will be provided by the GIS group.

- Hardware stores
- Express mail
- Automotive repair shops
- Hospitals
- Fire stations

5.4 SAMPLING SCHEDULE

Based on statistical design or other program requirements, an efficient schedule for field activities will be developed. Geographical locations and other factors such as climate and site access constraints will be considered.

The FS logistics leads will be responsible for the development of the sampling schedule with input from EPA logistics lead and indicator leads.

5.5 RECONNAISSANCE PLAN

The FS regional logistics leads will be responsible for all reconnaissance activities for the study.

5.5.2 Sampling Site Reconnaissance

Sampling sites in the NE were located in 1990; therefore, reconnaissance will not be required. In the SE, hexagon centers will be field-checked prior to the field season. Landowner information will be obtained and contact will be made to seek permission for field crews to enter the tract. If permission is denied, the site will not be sampled that year.

Local public agencies (e.g., state forester, SCS) will be contacted for tract information to speed reconnaissance. Also, contact will be made to gain clearance to sensitive areas, such as, military bases and wilderness areas.

5.6 PROCUREMENT AND INVENTORY CONTROL

The EPA will identify what specific equipment and support will be needed to satisfy each of the categories of Table 5.4. The FS will determine where back-up equipment will be stored, how crews will be resupplied and provide contingencies for onsite emergency purchases. Shipping regulations, especially for chemical and biological materials should be considered.

Table 5-4. List of Supply Needs

1. SCIENTIFIC INSTRUMENTATION	4. TRANSPORTATION
a. Measurement devices	a. Vehicles
b. Recording devices/data forms/logbooks	b. Canoes
c. Power sources	c. Maintenance gear
d. Calibration gear	
e. Maintenance/repair gear	5. COMMUNICATION
	a. Radio
2. SAMPLING EQUIPMENT	b. Telephone
a. Containers	c. Computer
b. Labels and markers	d. Facsimile
c. Data forms/logbooks	
d. Collection devices	6. ADMINISTRATION
e. Preservatives	a. Photocopier
f. Shipping containers and accessories	b. Forms (e.g., time cards)
3. SAFETY EQUIPMENT	
a. Clothing	
b. Communication	
c. Flotation	
d. First aid	

The logistics lead will send out an inventory form to each indicator lead to identify the types and amount of equipment and consumables needed to collect data for each specific indicator. Information must be provided on or before April 15, 1991, in order to acquire all items. From this list the logistics team will purchase the supplies not in EPA inventory or that are not available through the FS.

Supplies will be divided by each indicator and an appropriate quantity of supplies will be distributed to each crew at the training sessions. An inventory list will be created for each crew that will be checked off by the crew person responsible for the sampling of a specific indicator. Capital items (e.g., portable data recorder, cameras, etc.) will be tagged. These items will be associated with specific field personnel who will be responsible for their return.

5.7 LABORATORY OPERATIONS

For the study, EPA will be responsible for the procurement of sample preparation and analytical services.

5.7.1 Soil and Foliar Sample Preparation

Soil and foliar samples must be prepared prior to chemical analysis. The fact that "blind" QA samples need to be inserted into batches as part of the sample batching process precludes the laboratory responsible for chemical analysis from preparing the samples. When thinking about a national program the important concept of data comparability exists, both within and between regions. Data comparability can be facilitated by the use of one EMAP preparation laboratory facility for all regions.

The consolidation of sample preparation activities allows the following.

- Rapid and consistent soil drying and preparation
- Establishment of, and consistent adherence to, defined sample preparation protocols
- The ability to track and control progress at the laboratory on a real-time basis
- Elimination of confounded multilaboratory measurement uncertainties at the preparation phase
- Advanced controls against sample contamination
- Minimization of staffing requirements

- Minimal time and expense for conducting technical systems audits

5.7.2 Soil and Foliar Analysis

The following criteria should be applied when procuring analytical services.

- The laboratory's ability to analyze using the stated methods
- The laboratory's ability to meet the MQOs
- The laboratory's ability to provide data in the specified time requirement
- The laboratory's ability to provide data at a competitive cost

Soil and foliar analysis will be accomplished in fiscal year 1992.

For analytical analysis, EPA will procure laboratory services through the government contracting mechanism, which will include developing an Invitation For Bid (IFB), advertising in Commerce Business Daily, analyzing preaward samples, and awarding contracts to compliant laboratories. The IFB contains the Statement of Work (SOW), which includes the methods, as well as the laboratory qualification requirements, and bidders' responsibilities.

Procurement of analytical services may also be accomplished through an Interagency Agreement (IAG) with the FS laboratories. If FS laboratories meet the criteria listed above, quantities of samples can be sent to them for analysis.

5.8 TRAINING PROGRAM

Training for NE field sampling has been proposed for the week of June 17, 1991, in Vermont; training for the SE has been proposed for the week of June 10, 1991 in Asheville, North Carolina. The indicator leads are responsible for training requirements specific to their indicator. The forest training sites contain both coniferous and deciduous cover types.

Training for field crews includes practice performing each of the SOPs. Training time will be reduced because specific data collection activities will be assigned to each crew member and each crew member trained in that activity. For example, a person who is assigned to sample soils, which is a full day activity, will not need be trained in growth measurements, therefore, training sessions can be accomplished simultaneously.

5.9 SAFETY PLAN

In any field operation, emphasis must be placed on safety. Field personnel must be aware of the potential safety hazards to which they may be subjected, follow all project safety protocol and equipment guidelines, and be prepared for emergency situations. The plan is intended to address the potential safety hazards of field sampling and identify required safety protocol. The safety plan has been developed from EPA and FS safety information. All participants in the study (i.e., SCS, private contractors, FWS) as well as the EPA and FS are required to abide by specific agency safety regulations where applicable.

The safety plan will be included in the *Methods Manual* (Conkling et al., In Preparation). All personnel involved in the study must read and fully understand all safety procedures contained in this plan. The following are some potential hazards that will be discussed in the safety plan.

- Travel
- Weather extremes
- Terrain
- Insect pests, poisonous organisms
- Sampling and sampling equipment
- Chemical hazards
- Tree hazards

Personnel protection requirements and required safety equipment will also be discussed.

5.10 DATA MANAGEMENT ACTIVITIES

The information management national and regional technical committee will determine how standardized data recording forms or programs will be developed. Within the methods manuals (field and laboratories) there will be a section discussing data entry activities occurring in the field, and the laboratories and data transfer between various phases of the program. The section will also discuss data security procedures (such as archiving forms, back-up of data files) which should be used and explain how data recording and data management activities will be quality-assured.

5.11 QUALITY ASSURANCE INSPECTION

The national and regional QA technical committee will provide a schedule of site audits, which will be performed to ensure that field personnel are following field sampling protocols. Information will be provided in the QAPjP (Byers, 1991) and will describe who will conduct the audits and explain how and when corrective actions will be implemented.

5.12 PROJECT FOLLOW UP/RECOMMENDATIONS

5.12.1 Debriefing/Reporting

After completion of the study all operational phases of logistics should be summarized in an operations report. Logistics personnel should hold a meeting to discuss all activities in order to determine the correct procedures for next year's implementation.

5.12.2 Inventory

All equipment and consumables will be inventoried by EPA. Any EPA equipment will be checked cleaned, and properly stored at the EMSL- Las Vegas (LV) facility.

5.12.3 Planning

During the logistics debriefing, time should be allotted to planning activities for the next survey.

6. INFORMATION MANAGEMENT

C. Liff[a]

6.1 INTRODUCTION TO INFORMATION MANAGEMENT

Information Management (IM) supports and facilitates many aspects of environmental monitoring. IM personnel work with the technical directors, project managers, logistics staff, quality assurance/quality control (QA/QC) personnel and scientists throughout the FHM project. This starts with planning and coordination to ensure an IM system that is responsive to overall project needs. During implementation and the operational phases of data collection and transfer, software systems will be in place to support the timely acquisition of data into the IM system. After data collection, IM supports the scientists working on integration and analysis of data and presentation and reporting of results. Information Management will also support the dissemination of data and information to users outside of the FHM program.

A key element in the FHM IM system is the Forest Information Center (FIC). The FIC, located at EMSL-LV, is the nexus for software development, data collection (both FHM-generated and historic data), data cataloging, data processing, and data dissemination. The FIC staff will work with appropriate personnel in the FS and the EPA to ensure that the automated data processing (ADP) requirements of FHM are met.

6.2 GOALS AND OBJECTIVES

The design and development of the IM program is guided by the following goals.

- Ensure that the data in the system are of the highest quality possible

[a] Environmental Research Center, University of Nevada-Las Vegas, NV

- Ensure that FHM scientists have access to the data as quickly as possible
- Make the data available to users both within the project and outside the FHM group

To achieve the above goals, an IM program will be developed to meet the following objectives.

- Design an IM program to be responsive to user requirements from within and outside the FHM program.
- Commit to achieving complete data collection and transfer electronically.
- Ensure access to FHM-generated, auxiliary, and historical data.
- Provide an IM program that effectively collects, processes, documents, stores, catalogs, and distributes the FHM data within accepted time frames.
- Develop a flexible IM program that can adapt to the program's future needs.
- Develop an integrated IM program that provides access to GIS systems, other EMAP and FS monitoring components, and other programs.
- Develop a system that is responsive to the needs of the national FHM program, but is flexible enough to accommodate regional differences.
- Provide training and support to the field crews and users of the FHM IM system.

6.3 DESIGN OF THE FHM IM SYSTEM

The IM system for the FHM program will have two major components: (1) a field and laboratory data collection system, and (2) a data management system. The field and laboratory system handles data coming into the FIC. The data management system handles data in the FIC and distributes data to the users.

6.3.1 Field and Laboratory Systems

The field and laboratory systems provide input to the FHM FIC. These systems have close ties to the cross-cutting activities of QA/QC and logistics. The primary objective of the field and laboratory systems is to develop a system to ensure that measurement quality objectives are satisfied, and that data are sent to the FIC in a timely manner. This mandates electronic data collection in the field and the laboratory, and electronic data transfer to and from the FIC.

Verification checks are placed as close to the point of data entry as possible in both the field and the laboratory. Close cooperation with the QA staff will be essential in the development of the computerized verification checks.

Electronic sample, shipment, and crew tracking will be used to give project managers daily updates of field and laboratory activities. These tracking systems will be developed in conjunction with the logistics staff.

6.3.1.1 Field Crew Hardware and Software

Field crew equipment will include portable data recorders (PDRs), laptop computers, and portable printers. If funding is available, selected crew will additionally have GPS hardware and bar code readers. Except for the laptop and the printer, which remain in the motel room, all of this equipment will be used in the field.

6.3.1.2 Field Logistics Data Base

Information describing sample site locations and logistics information will be entered into a GIS data base. The GIS system will produce maps showing the locations of sample sites and support services. With these data, the crew will easily be able to locate sample sites, express mail, motels, airports, hospitals, repair centers, and such. Sampling site information will include location of the site, location of the starting point, field measurements to be taken, and samples to be collected.

6.3.1.3 PDR Programs

The EMAP-Forests indicators are dependent on field measurements such as forest mensuration data, pedon descriptions, and visual damage data. To ensure that field data are of the highest quality possible, EMAP-Forests will be committed to electronic data collection.

To facilitate electronic data collection, each field crew will have one or more PDRs. The PDR is a rugged field computer. The PDR currently used by EMAP-Forests is MS-DOS compatible, which allows for flexibility in programming. Custom software, written in C and BASIC, was developed for the PDR for use in the 1990 field season. The current software will be refined and new programs will be developed for the PDR to meet the needs of the 1991 field season. The PDR programs will include data collection programs, sample tracking information, and communications. A user-friendly menu will allow the crew to choose the appropriate program. The next sections give details about the programs envisioned for use on the PDR.

6.3.1.3.1 Field Data Collection Programs

Data entry will be performed directly on the PDR in the field. Paper forms will only be used for back up, in case the PDR fails in the field. A spare set of PDRs will be available that can be shipped via express mail to a crew within 24 hours.

The PDR will have various data collection programs. Menu choices, based on the data requirements of the current indicators, will include soil pedon descriptions, forest mensuration (including visual damage data), vertical vegetation profile, and ceptometer data transfer. If, for example, the user chooses the forest mensuration data collection program, an electronic tally sheet will be displayed on the PDR screen.

Using electronic data entry allows for QA checks at the point of data entry. These include range checks, validity checks, and logic checks. These QA checks will be designed in close cooperation with the QA staff and the indicator leads. Mensuration data from 1990 will be loaded on the PDR to help the field crews locate specific trees. The distance and direction to a tree will ensure that the same tree is sampled in all surveys, a requirement for some indicators.

6.3.1.3.2 Sample Tracking on PDR

Many types of samples will be collected in the field. Currently, these include soil, root, foliar, and increment cores. The field crews must be sure that all necessary samples are collected, and that samples are correctly identified and tracked. If sufficient funding is available, a bar-coding system will link data on the PDR to samples collected in the field. This will permit a relational join between the sample ID and data in the PDR. The system will check that all samples have been collected before the crew leaves the field. Sample tracking is described in more detail in later this section.

6.3.1.4 Field Communications System

The communications systems will allow for two-way communications between field crews and the FHM FIC. Data and tracking information will be uploaded from the crews to the FIC. Messages, data, and program updates will be sent from the FIC to the crews.

6.3.1.5 Computerized Shipment Tracking

The field crews will collect a plethora of samples, many of which are perishable and require proper handling and quick shipment to the laboratory. A computerized sample and shipment tracking system is necessary to ensure that samples get to the proper laboratory in a timely manner. The field crews will have preprinted sample labels with bar codes. When a sample is collected, data about the sample will be entered in the PDR. The sample will be labeled, the bar code scanned, and the sample number recorded on the PDR. Before leaving the field, a program on the PDR will check that all samples have been collected.

When the data from the PDR are uploaded to the laptop, the sample tracking data base on the laptop will automatically be updated. The crew will use the bar code reader to scan the samples as they are packing the shipment cases. The system will

- ensure that the correct samples are packed together,
- ensure that samples are shipped to the correct laboratory,
- check that all samples have been shipped, and
- provide information about special handling required.

After all samples are ready for shipment, the crew will enter data about the shipment on the laptop. This includes shipment number, carrier name, air bill number, destination laboratory, and estimated time of arrival at laboratory. These data are entered into the tracking data base which is sent to the FIC, and then to the receiving facility.

6.3.2 Laboratory Systems

The FHM program will employ a variety of laboratories for processing different sample types. Computerized laboratory sample tracking, verification, and communications systems will be used by the laboratories employed by the FHM program. The FHM program will have two types of laboratories: preparatory and analytical. This section describes the components common to both laboratory types.

Each laboratory will have an IBM-compatible computer, with a modem and bar code reader. The FHM program laboratory system software will be installed on the computer. The tracking portion of the system will interface with the tracking system described above to create a complete sample trail from field to laboratory. The verification portion of the program ensures that results from the laboratory meet the quality standards of the FHM program.

The communications are similar to the field system. The laboratory will send the following information to the FIC via modem.

- Results, including QA/QC data, since last upload
- Samples received at laboratory
- Samples shipped from laboratory (for preparatory laboratories only)
- Messages from laboratory to central system
- Tracking data

The following information will be sent from the FIC to the laboratory.

- The tracking data base
- Software updates, when required
- Messages from the FIC to the laboratory

Each laboratory will have a bar code reader. As shipments arrive at the laboratory, the bar code label on each sample will be scanned. Those data will be compared against the tracking data base that was downloaded from the FIC.

6.3.2.1 Preparatory Laboratory Systems

Preparatory laboratories receive field samples, process the samples, then ship the samples to analytical laboratories. A data base that relates batch numbers to sample numbers will be maintained based on the information entered in the preparatory laboratory. Data describing samples that have been archived for further analysis will also be recorded.

6.3.3 Data Management System

The core of the distributed FHM data management system is the FHM FIC. The FIC will support the exchange of data with other agencies and organizations. Information Management personnel are responsible for maintaining a comprehensive data inventory, data set index, code libraries, and data dictionary. They will also maintain and disseminate FHM data and ensure that appropriate data are incorporated into the FIC.

6.3.3.1 Data Types

The FHM IM system will contain data generated by the FHM program and data from outside sources. The following types of data will be maintained by the FIC.

- Project management and logistics data
- Raw data files
- Summarized data
- QA/QC data
- Laboratory data and associated QA/QC data
- Spatial data in GIS format
- Historic data
- Pointers to auxiliary data (e.g., climate data)

6.3.3.2 Data Base Structures

The field data collected in the field study, with the exception of the continuous PAR data, will be stored in SAS data sets on the EMSL-LV VAX cluster. A relational schema is being employed in designing the data sets to allow the use of the Structured Query Language (SQL) procedure of SAS version 6.06.

6.3.3.3 Users

Users of FHM data will include the following four groups.

- Group I Users
  - FHM Core Group: Responsible for the day-to-day field operations and data verification and validation. The group will include field crews, logistics staff, QA/QC staff, IM staff, indicator leads, and the technical directors of the FHM program. Both FS and EPA staff are in this group.

- Requirements: This group will need to have access to a comprehensive data set, including project management information, sample and shipment tracking, raw data files, QA/QC reports, logistics, summary reports, and verified and validated data sets.

- Timing of Access: This group will require access to the data on a real-time basis. The data need not be quality-assured prior to access. All raw data used by this group must be used with the understanding that the data have not been verified or validated. This group needs access to all data described in the other categories.

- Group II Users

  - FHM Team: Individuals and groups who will participate in the FHM effort but will not be active in the day-to-day operations of the field programs or the data verification and validation processes. These participants will include FHM staff members involved in reporting, the FHM Integration and Analysis Team, GIS support personnel, FHM design and statistical staff, and program reviewers.

  - Requirements: This group will require access to summary information regarding logistics, project management, and QA/QC. They will also require access to some validated and verified raw data files but will not require real-time access to the data.

  - Timing of Access: Group II users will require data one month from the time of collection.

- Group III Users

  - Inter-Agency Research Group: Includes all researchers who will be active in the design, implementation, and analysis of the national EMAP program, the other FS-FHM groups, and scientists from other participating agencies. These individuals will include members of other EMAP resource groups, EMAP cross-cutting groups, the FS evaluation monitoring team, and the FS research monitoring team.

  - Requirements: This group will require final summaries regarding logistics, project management, and QA/QC. They will require access to some validated and verified raw data files. Document summaries with interpretation and graphic outputs will be most useful.

  - Timing of Access: Group III users will require data approximately six months from the time of data collection.

- Group IV Users

  - Other Users - Includes all potential users outside of those listed above. This group will include state and federal agencies, universities, research organizations, citizen's groups, administrators, and legislators.

  - Requirements: This group will require access to validated and verified data including QA/QC data that is integrated to the plot level. They will need summarized characterization data for each plot sampled and access to an index of available data. They will also require access to some validated and verified raw data files. Document summaries with interpretation and graphic outputs will be most useful.

  - Timing of Access: Group IV users will require data one year from data collection.

6.3.3.4 Data Base Access

Users on the EPA computer network will be able to access the FHM IM system directly through the network. Users who are off the network will have the option to access the system through a dial-up line into the system. In 1991, as in 1990, there will be a heavy reliance on mailing floppy disks for file transfer.

A data catalog and a data dictionary will detail the data available through the data base system.

6.3.3.5 Interagency Computer Links

For the FHM program to function efficiently, there must be a link between the computer networks of all participating agencies. These agencies include the EPA, the FS, NPS, BLM, and possibly others. The link should start with an EPA/FS connection, then progress to other agencies. The interagency link will provide services such as E-Mail capability, file transfer, and data base access to all participants across the FHM program. Additionally, links to other networks such as Bitnet, Internet, and LTERnet should be explored. Those additional links will allow easy access to university cooperators.

6.3.3.6 Data Base Security

The four user groups users will have different access privileges to the data bases. Until the data have been verified and validated, very strict security measures will be employed. Only members of Group I will have access to raw data from the field and the laboratories and project management data. Only the IM staff will be allowed to change the data bases. If discrepancies are found during the QA checks, those data will be communicated to the IM staff. The IM staff will update the data bases and record the change, the person requesting the change, and the reason for the change in a data base. This is to ensure that there is only one official version of the data base that is maintained by the IM staff.

After the data bases have passed QA/QC, the security will be changed so that members of Group II (the FHM analysts) will have access to the data. Members of Group III can have access to the data at this point with permission of the technical director. After the yearly statistical summaries have been published, the data will be made available to other users. At this point the FHM data will be made available to the EMAP-wide EMAP Information Center (EIC).

6.3.3.7 Data Confidentiality

Certain types of data, both FHM-collected and from external sources, may have to remain confidential. Locational data are the most likely candidates for confidentiality. These data include FHM plot location, location of plots in other data bases used by the FHM program (e.g. FIA plot locations), and locations of rare and endangered species.

The GIS representations of point data will be "fuzzed" to hide the exact locations of plots, or the data will be represented on a regional basis to hide the exact plot locations. The locational data in the public data base will be reported at the Tier 1 hexagon center level. Analysts outside of Group III who need exact locational data will need written permission from the senior administrators of the FHM program and will be required to sign a nondisclosure document.

6.3.3.8 Data Base Management System

The FHM data base management system will include a data set index (DSI) also known as a data catalog, a data dictionary, code look-up tables, and a user-friendly interface.

The DSI index will provide users with important information about the contents of each data set. It will also describe how to access a particular data set. Forest health monitoring-generated, historic, and auxiliary data will be catalogued in the DSI.

The on-line data dictionary will provide users with information about parameters stored in the data bases.

6.3.3.9 Yearly Statistical Summaries

Standardized, yearly, data statistical summaries will be one product of the FHM program. Standard software will be developed to produce automatically the tables, graphs, and maps that go into the yearly statistical summaries.

6.3.3.10 GIS Interface

A major requirement of the FHM FIC will be to create maps and perform geographically based analyses. Therefore, the data generated for FHM will be referenced to a spatial entity such as a latitude and longitude. Spatial analyses will be accomplished using ARC/INFO, a GIS that is used throughout the EPA and the FS.

6.3.3.11 EMAP Information Center

The EMAP Information Center (EIC) will be the entry point to EMAP data bases. The EIC will allow users to access data from the seven EMAP resource groups and cross-cutting activities.

For the overall EMAP goals to be met, scientists must have access to all data collected in connection with EMAP data, including FHM data. The design of the FHM Information Management System must be compatible with the EIC design to allow other EIC users access to the data.

6.3.3.12 Standards

Standards are necessary for FHM to be a truly national program. The FHM program and its IM system must be flexible enough to accommodate regional differences, but at the same time be comparable at some level throughout the country. Standards that are used throughout the program are necessary to meet that objective. An interagency workgroup should be formed to resolve standards issues such as the following.

- Codes – Standards for codes that are used across the country, such as species, must be adopted. The FIA has a standard set of some codes. It is recommended that those codes be adopted.
- Computational Algorithms – A standard set of FHM computational algorithms that correspond to ecological, not political, boundaries must be established. Poststratification along political boundaries will always be possible, if required.
- Portable Data Recorders – Must be standardized to the extent that all PDRs used by FHM will run the same programs without modifications.
- PDR Software – The same software should be used on all the PDRs used by FHM. The software should be flexible to allow for regional differences.
- Measurement Units – The FHM should use the same measurement units, preferably le Systeme International d'Unites (SI), in all regions of the country.
- Word processing software – A standard word processing program should be adopted for producing reports and documents. If institutional constraints prohibit this, a standard interchange format should be adopted.

6.3.3.13 Data Sharing and Access

All agencies concerned must come to an agreement on data access. One proposal for data access is given in Section 6.3.3.3 of this document.

If this model of data sharing is not acceptable to all participants, an interagency committee should be formed to draft an alternative policy. A clearly stated policy on data access should be adopted for the entire FHM program.

7. REPORTING

R.C. Kucera[a]

The product of the 1991 field study will be the Synthesis Report referenced in Table 1.1. The data, analysis, results, and conclusions for each indicator will be incorporated. The indicator leads are responsible for reporting their analyses, results, and conclusions within the report. Summary sections will be provided for activities such as QA, logistics, and information management which apply across all measurements. The document will be an EMAP-Forests multilaboratory, multiagency report produced in cooperation with the USDA-FS and FWS. The Las Vegas EPA Laboratory will be responsible for coordination of the Section authors, editing, and producing a peer-reviewed and approved report. The Synthesis Report will be supported by a Quality Assurance Report.

An important dimension of the analysis of results will be the evaluation of correlations between indicators. These correlations will focus primarily on the indicators of nutrient status and the indicators of landscape processes.

Further reports will be suggested, if necessary, by the supporting EMAP-Forests and FHM team members to document the activities and results of their contribution to the field study. For example, the IM, Logistics, Indicator Development, or other groups may propose and make separate reports of their activities and results.

[a] ManTech Environmental Technology, Inc., AREAL-RTP, NC

NUTRIENT CYCLING DEMONSTRATION MEASUREMENTS

8. SOIL PRODUCTIVITY

R.D. Van Remortel[a]

This section describes the soil characterization, sampling, preparation, and analysis that is being undertaken as part of the FY91 Indicator Evaluation Field Study for EMAP-Forests in the eastern United States.

8.1 INTRODUCTION

Soil productivity has generally been defined as the capacity of a given volume of soil to elicit a vegetative response under a specified system of management (SEA-AR, 1981). Initial measurements of key soil productivity parameters are used to establish baseline status in terms of levels and ratios among certain physical, chemical, and biological soil constituents. Periodic remeasurement of these parameters is used to assess trends that might show improvement or degradation in forest condition over time. Short-term changes in the balance of critical soil fertility components may provide an early indication of changes in ecosystem status or function (Johnson et al., 1988a). The component parameters of interest can vary widely across different forested regions of the U.S., but generally include specific soil nutrient elements, exchange capacities, toxic substances, erodibility factors, parent materials, and ancillary data such as estimated soil moisture supply. The soil productivity data can be used to perform statistical analyses with the response indicators, such as visual symptoms, and other exposure indicators (e.g., foliar chemistry).

Soil productivity data can contribute diagnostic information by indicating possible mechanisms to explain responses in forest condition. These data also provide diagnostic information not available through foliar chemical analysis because plants often are able to compensate for potentially limiting

[a] Lockheed Engineering & Sciences Company, Las Vegas, NV

concentrations of soil nutrients and moisture (Barber, 1984). The most reliable interpretations of ecosystem nutrient status would likely include concurrent measurements of both soil and vegetative productivity.

8.1.1 Overview of Soil Monitoring Objectives

The overall mission for the FHM program soil monitoring activities is to "monitor and evaluate the long-term status and trend of the nation's forest soil ecological resources to identify and understand environmental changes through an integrated, interagency process."

The status, changes, and trends of the nation's forested soils and their relation to ecological endpoints should be evaluated and reported on a regional basis and at a known level of confidence. Both natural and human-induced changes should be monitored. The resulting data can have great utility for many ecological resource groups and other interagency programs. General objectives of soil characterization include the following.

- Perform retrospective analyses of existing soil information as part of indicator development and implementation.
- Incorporate analytical results into subsequent environmental evaluations and preliminary conceptual models.
- Develop and implement strategies and designs for integrated regional scale monitoring and evaluations of forest ecological resources.
- Provide several measurements of data uncertainty components.
- Establish linkages between soil measurements and other indicator measurements within and among terrestrial ecological resource groups.
- Provide a basis for the initiation of special studies to diagnose apparent soil-related problems as determined by ecological assessment endpoints during regional scale monitoring.
- Conduct applied research to enhance knowledge of soil processes, monitoring methods, and data interpretation techniques.
- Assess consequences of current practices and future managerial decisions.

Soil is a fundamental source of social wealth and well-being that is essential to sustaining forest ecological resources and is closely integrated with water and air resources. Soil measurements can be an accurate indicator of change and may provide an early warning of ecological perturbations. Specific reasons for characterizing soils are to:

- provide soil information to decision/policy makers and various management, regulatory, and research groups for use in comprehensive planning to maintain and enhance forest ecological resources;
- identify changes and trends in soil resources, and provide early warning of cumulative effects and thresholds of irreversibility;
- provide data to assess effects of forest management practices;
- distinguish adverse from beneficial changes and natural from man-made changes;
- provide comparable soil baseline data among this and other terrestrial-based ecological resource groups;
- contribute to the understanding of global consequences stemming from human actions;
- identify present and potential uses of the soil ecological resource within terrestrial ecosystems;
- provide a mechanism for integration among terrestrial resource groups; and
- provide an important link within conceptual and quantitative models.

Soils should undergo comprehensive baseline characterizations at a statistically relevant sampling intensity across the nation. Ongoing regional monitoring allows scientists to track changes in soil resources. This should be done:

- concurrently with other ecosystem monitoring and measurements when feasible or appropriate;
- by intensifying sampling during other ecosystem indicator measurements; and
- by long-term monitoring on a regular basis.

Monitoring of forest soil resources should be implemented regionally across the nation, including areas adjacent to aquatic systems and other ecotones. Specifically:

- the geographical extent should encompass all forested portions of the United States including Alaska, Hawaii, Puerto Rico, trust territories, and the District of Columbia;
- implementation should be sufficient to provide a statistically valid sample and to characterize uncertainty in the resulting data.

The specific 1991 FHM program soils monitoring objectives are the following.

- Demonstrate that field soil characterization and sampling, optimized for available funding and personnel, can be successfully implemented in two large, subregional forested areas of the eastern United States utilizing a cooperative effort among multiple agencies.
- Continue to develop key components of the soil productivity indicator and evaluate its utility in synthesis and integration with other ecological indicators.
- Begin to construct regional baseline characterizations of the ranges of concentration for critical soil parameters used in the interpretation of soil condition with respect to the overall assessment endpoints.
- Develop draft versions of DQOs for the various phases of soil data collection.

8.1.2 Overview of the Soil Measurement System

The soil field measurement and sampling protocols are based on National Cooperative Soil Survey (NCSS) standard methods with some specific amendments. The procedural steps have been defined through continuous interactions with soil scientists at EPA laboratories in Las Vegas, NV, and Corvallis, OR; at the USDA-FS Forestry Sciences Laboratory in Grand Rapids, MN; and at the USDA SCS NCSS in Lincoln, NE. The procedures were amended where necessary as a result of experience gained in the 1990 "20/20 Study" conducted in the eastern U.S. Soil scientists from the SCS in Massachusetts and Virginia provided expert guidance in the adjustment of specific field protocols.

Soil taxonomic data for the field plots can be obtained from existing soil survey information or by on-site soil excavation and characterization. Where possible, soils on unmapped plots should be classified to the soil series level according to accepted NCSS standards. Each plot must be thoroughly characterized for descriptive soil parameters and landform features while in the field. Detailed protocols for the soil characterization and sampling are contained in a separate field methods manual (Van Remortel, 1991a). The soil field parameters to be measured are outlined in Table 8-1.

Table 8-1. Field Soil Characterization Parameters

Taxonomy	Parent material	Structure
series	bedrock inclination	grade
order	mode of deposition	size
suborder	origin	shape
great group	bedrock fracture	Mottles
subgroup	Hydrologic group	quantity
particle size class	Water erosion class	size
mineralogy class	Water runoff class	contrast
reaction class	Flooding frequency	hue
temperature regime	Ponding frequency	value
other class	Particle size control section	chroma
moisture regime	depths	Field property
Major land resource area	Diagnostic feature	quantity
Slope	depths	kind
percent	kind	Roots
shape	Horizon	quantity
geomorphic position	depths	size
hillslope position	discontinuity	location
aspect	master and suffix designations	Pores
Physiography	Moist color	quantity
regional and local	location	size
Water table	percent	continuity
depth	hue	shape
days	value	Concentration
kind	chroma	quantity
Land use class	Boundary	size
Surface stoniness class	distinctness	shape
Hydraulic conductivity class	topography	kind
Drainage class	Texture	Rock fragments
Elevation	class	volume percent
	modifier	roundness
		kind
		size

Soil samples are to be prepared according to the protocols contained in the laboratory methods manual (Byers and Van Remortel, 1991). The parameters listed in Table 8-2 are measured in conjunction with processing steps at the preparation laboratory.

Table 8-2. Soil Preparation Parameters

Fine and medium gravel: rock fragments (particle diameter 2-mm to 4.75 mm and 4.75 mm to 20 mm) measured gravimetrically.

Forest floor biomass: total mass of organic constituents in a given area of forest floor, measured gravimetrically and by loss-on- ignition.

Core bulk density: the oven-dry density of the $<$ 2-mm soil fraction (minus rock fragments) from replicate core samples, measured gravimetrically.

Soil samples are to be analyzed according to the protocols contained in the laboratory methods manual (Byers and Van Remortel, 1991). The soil physical and chemical parameters of interest to be measured in the samples are described in Table 8-3. It should be noted that a portion of each sample is archived to allow the possibility of initiating further analyses that might be identified at a later date. It has been demonstrated that long-term cold storage of air-dried soil samples does not significantly alter their chemical status for a wide variety of parameters (Fenstermaker et al., 1991).

The analytical parameters have been identified as a result of an intensive review of laboratory methods in collaboration with over 50 soil researchers and laboratory chemists across the United States and Canada. The recommendations of many previous committees and investigators relating to similar types of projects have also been incorporated (Anderson, 1987; Blume et al., 1990; Morrison, 1988; NCASI, 1983; Robarge and Fernandez, 1987).

8.1.3 Overview of Expected Variability

Variability is generally contingent on the form, mobility, and concentration of the parameters of interest. Estimates of the coefficient of variation (CV) for many soil analytical parameters may be derived by accessing existing soil survey data that have satisfied especially stringent QA criteria (Van Remortel et al., 1988; Byers et al., 1989; Papp and Van Remortel, 1990; Byers et al. 1990a). For the analytical laboratory measurements, an average CV of 10% or less is typical for replicate samples. The expected laboratory bias is ±5% or less of the reference value. For the sample measurement system as a whole (e.g., sampling, preparation, and analysis), an average CV of 20% or less is typical.

Soil nutrient concentrations are likely to vary on a within-season, among-season, and among-year basis. Mobile soil nutrients, such as nitrogen, are among the most variable (Armson, 1977). The Logistics staff will attempt to minimize the potential effect of temporal variability by designing the plot sampling sequence in such a way as to ensure that each plot is subsequently remeasured at about the same time within the index period.

Table 8-3. Soil Analytical Parameters

Air-dry moisture: determined gravimetrically by oven-drying at 105 °C (organic soils at 65 °C); used to report all final data values on an oven-dry soil basis.

Total sand: particle diameter between 0.05 mm and 2.0 mm, determined by wet sieving.

Total silt: particle diameter between 0.002 mm and 0.05 mm, determined by pipetting.

Total clay: particle diameter less than 0.002 mm, determined by pipetting.

Electrical conductivity: determined in deionized water using 1:1 mineral soil to solution ratio (1:4 organic), measured with an electrical conductivity meter.

pH: determined in deionized water and in a 0.01M calcium chloride solution using a 1:1 mineral soil to solution ratio (1:4 organic), measured with a pH meter and combination electrode.

Exchangeable calcium, magnesium, potassium, and sodium: determined in a buffered (pH 7.0) 1M ammonium acetate solution using a 1:13 mineral soil to solution ratio (1:52 organic) by atomic absorption spectrometry or inductively coupled argon plasma atomic emission spectrometry.

Cation exchange capacity: determined in a buffered (pH 7.0) 1M ammonium acetate solution usinga 1:13 mineral soil to solution ratio (1:52 organic); this is the effective CEC which occurs at approximately the field pH when combined with the acidity component; samples are analyzed for ammonium content by one of three methods: automated distillation/titration; manual distillation/automated titration; or ammonium displacement/flow injection analysis.

Total exchangeable acidity: determined in a buffered (pH 8.2) barium chloride triethanolamine solution using a 1:30 soil to solution ratio using a back titration procedure.

Effective exchangeable acidity and exchangeable aluminum: determined in an unbuffered 1M potassium chloride solution using a 1:20 soil to solution ratio using a direct titration procedure;

Mineralizable nitrogen: a predictor of soil nitrogen availability due to biological activity; an incubation technique is specified for the determination of anaerobic nitrogen as ammonium-nitrogen.

Extractable phosphorus: determined in a Bray and Kurtz No. 1 extractant (acid soils only) using a 1:13 mineral soil to solution ratio (1:52 organic) using a colorimetric procedure and autoanalyzer.

Extractable sulfate: determined in a deionized water extractant and in a sodium phosphate extractant using a 1:20 soil to solution ratio by ion chromatography.

Total carbon and nitrogen: determined by rapid oxidation followed by infrared detection or thermal conductivity detection using an automated CHN analyzer.

Total sulfur: determined by automated sample combustion followed by infrared detection of evolved sulfur dioxide.

Total phosphorus, calcium, magnesium, potassium, sodium, iron, manganese, copper, zinc, boron, aluminum, lead, chromium, nickel, aluminum, lead, cadmium, nickel, chromium, vanadium, arsenic, and mercury: determined by initial microwave digestion followed by dilution and multielemental readout by direct current argon plasma atomic emission spectrometry. (organic soil horizons only).

It is recognized that a significant amount of soil spatial variability can be present within a given plot. Uncertainty in soil parameter values at a plot can be greatly reduced, however, by the use of a "composite" sample design that recognizes and accommodates the within-plot differences in soil characteristics. It is anticipated that a design will be adopted whereby the samples that are collected can effectively control the within-plot uncertainty to a level that is (1) less than the measurement system uncertainty, and (2) negligible with respect to the regional soil aggregation variability (Taylor, 1987). The resulting data quality would allow the data users to focus on discerning "real" temporal changes in soil productivity within a highly variable regional population.

8.2 RATIONALE

There have been numerous studies of the relationship between tree growth response measures and specific chemical, physical, topographic, and climatological parameters. The soil measurements include those parameters which have been agreed upon as important for the determination and monitoring of soil productivity, and which are also economically and logistically feasible. The forestry literature identifies certain physical parameters (e.g., drainage class) that have been used repeatedly in growth response studies. Many of these same parameters have been incorporated into the soil indicator analyses.

Information that is known to be important to the development of a productivity index will be collected during all phases of the project, beginning with the field measurement and sampling. Topographic features such as slope, aspect, and elevation have been incorporated successfully into models to predict stand composition (Fralish, 1988) and have been shown to influence Douglas-fir responses (Steinbrenner, 1963). It is not unexpected that these parameters would affect forest growth response because they contribute to the overall hydrologic characteristics of a site. The soil drainage classification, along with other moisture characteristics, has long been recognized as vital information in estimating soil productivity (Green et al., 1989; Hamilton and Krause, 1985; Mader, 1976; Storie and Weislander, 1948). Topographic parameters are important in estimating the hydrologic contributions of runoff and lateral water flow (Hewlett, 1961), as well as such characteristics as soil texture (sand, silt, and clay), coarse fragments (fine and medium gravel), and bulk density. These parameters are also important for their effects on nutrient availability (Mader, 1976), aeration (Mader, 1976; Steinbrenner, 1963), and root distribution (Hillel, 1980; Blanchar et al., 1978), all of which directly affect vegetative response.

Soil productivity in forests is affected by a presence or deficiency of essential nutrients affecting plant growth (Edmonds et al., 1989). These effects may be caused by long-term natural perturbations or short-term changes due to human activity, either of which can be manifested in low-level plant stress. In the Douglas-fir forests of the Pacific Northwest, for example, available nitrogen is the nutrient most likely to limit site production (McNabb et al., 1986). Productivity can also be disrupted by a decline in the population of certain microorganisms essential to biological cycling processes within the forest floor nutrient reserve zone. Whole tree harvesting in commercial forests can affect changes in macronutrient cycling (McColl and Powers, 1984; Johnson et al., 1988b). Likewise, a low ambient level of magnesium in some localized forest soils is an example of a naturally occurring stress that potentially could be aggravated by certain management practices (Ballard and Carter, 1985). Timber harvesting can aggravate the depletion of nutrients on already nutrient-poor sites (Entry et al., 1987; Schulze, 1989). Forest floor disturbances can interfere with nitrogen cycling (Peterson et al., 1984), and the effects of burning (Debano and Klopatek, 1988) and disruption of the soil mycorrhizal fungi on tree roots (Vogt and Persson, 1990) are other known stresses. Changes in carbon sequestration may also occur in some forests as a result of heavy disturbance (Harmon et al., 1990).

Soil productivity can also be affected by the presence of toxic substances and contaminants in the soil. This presence can indicate exposure to potentially detrimental chemical compounds and elements possibly resulting from land use practices (e.g., application of pesticides, mineral extraction), atmospheric deposition (e.g. sulfur in acidic precipitation), or naturally occurring phenomena (e.g., overabundance of magnesium in serpentinitic parent materials). Exchangeable iron and aluminum, as well as metals such as lead (Johnson et al., 1982), cadmium, nickel, chromium, and vanadium, can damage root systems and are detrimental to plant growth and forest systems as a whole (Driscoll et al., 1983; Johnson and Henderson, 1989; Ulrich et al., 1980). Plant metabolic processes can be disrupted either directly, through uptake of the substances, or indirectly, through impairment of soil nutrient availability (Zedaker et al., 1987). In the first case, the substances can affect physiological processes and internal physical structure (McLaughlin, 1985), thereby lowering the rate of photosynthesis, growth, and resistance to secondary stresses (McLaughlin, 1985; Miller, 1983). In the second case, mobile substances bind with soil nutrients and migrate to subsurface soil horizons.

Chemical toxicity can also reduce the number and variety of soil decomposer microorganisms, thereby decreasing the rate at which nutrients become available for plant uptake (VDIKRL, 1987) and effectively lowering the site productivity. This has direct implications for management considerations with respect to mineral extraction, pesticide applications, and atmospheric emissions. The degree of toxic effects on plant tissues and growth is related to the duration of exposure, concentration, exposure regime, and chemical dynamics of forested systems. Initial discovery of such substances in the soil could warrant close monitoring of areas exhibiting exposure.

Parameters such as exchangeable cations, cation exchange capacity, extractable phosphorus, pH, and exchangeable acidity have all been incorporated into response studies with species such as Jack Pine (Hamilton and Krause, 1985; Pawluk and Arneman, 1961) and Douglas-fir (Green et al., 1989). Total carbon, nitrogen, and sulfur can be used to characterize the soil organic matter, which is an important part of the forest ecosystem (Mader, 1976; Wilde, 1964). Total iron, manganese, copper, zinc, and boron are essential elements to tree growth and are measured. Exchangeable sulfate, phosphorus, chloride, and nitrate are important constituents of the soil solution and can be measured easily on the same extract using ion chromatography. These measurements, along with electrical conductivity, can be used to estimate the ionic strength of the soil solution (Griffen and Jurinak, 1973). Ionic strength is used to calculate the activity of ions in solution, thus allowing study of chemical equilibria in soil samples and modeling of long-term chemical weathering of soil minerals (Lindsay, 1979).

Monitoring the concentrations of ions, both those known to be nutrients and those which act as toxic substances, is an important measure of the potential for good plant nutrition. However, factors that influence soil moisture imports and exports must be evaluated because of their effects on the availability of nutrients and toxic substances. This evaluation is a developmental aspect of the FHM program soil monitoring and may require the use of ancillary data (e.g., climate data) from other sources.

The FHM program soil monitoring effort presently includes those parameters which are generally agreed by forest soil scientists to be important for a baseline characterization of soil productivity, and which are also economically and logistically feasible at this initial stage of implementation. Although limited research has been devoted to identifying the effect of these individual soil-related components on forest ecosystems, considerable work has been done on identifying the soil processes that are important in vegetative response (Bouma, 1989). The necessary components, however, have not yet been linked together in an index or model that is suitable for application on a regional or national scale of monitoring. Hence, some facets of the soil productivity indicator are considered to be developmental. It is believed that key soil productivity parameters could be combined into an index that identifies, on a plot-by-plot or regional basis, the effects of soil exposure on vegetative response and other indicators of forest condition. The index could be used to track changes in productivity over time (Gersmehl and Brown, 1990). Detailed information on the indexing strategy is provided later in Section 8.10.1.1.

8.3 DESIGN

There are a number of possible ways in which to design a soil sampling program for a large scale effort such as the FHM program (Borgman and Quimby, 1988). The soil sampling design described in the following subsections has been developed in conjunction with critiques and suggestions from forest soil scientists across the United States and Canada. It is believed that this approach provides the best possible data to address the FHM program objectives within the guidelines and constraints provided by the project coordinator. Ultimately, the regional interpretive goals for evaluation of status, trends, and associations are the determining factors in the sampling design. Other considerations, such as specific within-plot parameter relationships, are better served by research that could be undertaken at Tier 3 or Tier 4 levels.

8.3.1 Sampling Constraints

It is recognized that a significant amount of soil spatial variability can be present within and among different locations in a given region (Conyers and Davey, 1990; Mausbach et al., 1980; Van Meirvenne et al., 1990). The variability is often dependent on analyte concentration and is contingent on the plot sampling strategy, such as multi-site composite sampling vs. single-site sampling (Carter and Lowe, 1986).

The overall objectives of the 1990 FHM program soil productivity pilot study were to (1) estimate the within-plot and within-subplot spatial variability in soil characteristics, and (2) test the overall feasibility of implementing the soil productivity sampling design on a regional or national scale. Using the results of the 1990 data analysis and reinforced by data from the 1991 demonstrations, it is likely that an optimal sampling design can be identified that allows control of within-plot data uncertainty to some level that is acceptable to the FHM program data users. Specific constraints to the sampling design include the following.

- The final sampling design used in the FHM program monitoring should "capture" enough within-plot spatial variability (through composite sampling from multiple soil sample holes at each plot) to state with "X" confidence that within-plot soil variability is negligible with respect to regional variability within the soil strata used to report the results of the project. Alternatively, it may be expedient to use a criterion which expresses measurement uncertainty with respect to the amount of change we wish to detect (Cohen, 1969). Although the present design has been based on a sample size of three holes per plot, further investigation of available within-plot information from existing regional survey data bases might yield a different sample size requirement.

- The sampling design should ideally allow data users to make both regional (primary) and plot-by-plot (secondary) evaluations of the changes that have occurred since the last sampling cycle. Therefore, interpretable and defensible classification criteria should be defined. It is possible that plot-level evaluations may not be suitable for the FHM program.
- Destructive sampling, that is, soil excavation and sample collection, is undesirable within the confines of the subplots because vegetative measurements are being conducted in the same general vicinity of the plot from which soil samples are collected. For this reason and because of the "four-point subplot cluster" plot design, a single soil sample hole at the center of each field plot is not a viable option at this time.
- Any such destructive sampling must be highly selective, be conducted outside of the vegetative measurement zones to minimize trampling by the sampling crews, and have a negligible long-term impact on the integrity of the plots. Grid-type or transect-type sampling across the plots are not viable options under this constraint.
- Logistical constraints limit the actual available time to accomplish soil characterization and sampling to one experienced soil scientist in a 6-hour period on each plot.
- Equipment constraints limit the equipment used in soil characterization and sampling to that which can be reasonably hand-carried by the crews to the field plots.

8.3.2 Proposed Sampling Design

The plot design for soil sampling is as shown in Figure 3-1. The entire area represented is approximately one hectare (2.5 acres). Each of the four fixed-radius subplots on which vegetative measurements will be made occupies an area of about 1/60th hectare (1/24th acre), resulting in a total of about 1/15th hectare (1/6th acre) actually measured in each plot for vegetative data. The excavation of soil holes for characterization of soil horizons and collection of soil samples is considered to be destructive sampling with respect to long-term ecological monitoring on forest plots. Therefore, soil sampling is restricted to sites outside of the established fixed-area subplots while representing the soil characteristics of the plot as a whole.

Detailed field measurement and sampling protocols for soils are contained in the field methods manual (Van Remortel, 1991a). The intention is to prepare detailed soil profile descriptions of the soil horizons occurring in three holes equidistant from the centers of the fixed-radius subplots (see Figure 3.1). The holes are excavated to a depth of 1 meter (or to a restrictive layer, whichever is shallower) and a diameter of 0.5 meter. The soil scientist is instructed to collect O, A, E, B, and C master horizon samples, where present, from each of these holes. If the crew leader has identified more than one forest cover-type group within the plot boundaries, samples will not be composited and will be kept separate across the groups. Each of the mineral horizon samples should contain approximately 2 kg (about 1 L volume) of soil material. The organic horizon sample size could vary widely based on the thickness of forest floor material on the plot. A portion of each composite sample is archived at the preparation laboratory to enable additional analyses to be identified at some point in the future of the project.

8.3.3 Sampling Design Issues

It is preferable that a statistically relevant number of plots are sampled within each major forest cover-type group to ensure a large enough sample size to establish significance for a particular data evaluation stratum. Implicit in this criterion is the assumption that all forest cover-type groups generally respond in a manner similar to those being evaluated, and that estimates of data uncertainty derived from the demonstration plots should be representative of the actual regional data uncertainty (Palmer et al., 1990). During any such evaluation, it is preferable to encompass a population of plots that display a wide range of vegetative response, otherwise the true regional population variability could be underestimated.

Initially it may be important to make general characterizations of indicator status on a plot-by-plot basis to use in developing a regional interpretive framework, although a broad regional characterization without regard to plot-specific considerations may be sufficient. This decision has important ramifications for the soil sampling strategy, development of indices, and estimation of data uncertainty. The plot-by-plot approach ensures that the regional interpretations can be derived, but the "broad regional" approach precludes the possibility of making plot-specific or subregional characterizations that would allow for interpretive research or mitigation programs (Riitters et al., 1990). Also, some of the individual state forestry cooperators have expressed a strong desire for plot-specific data. From a soil productivity standpoint, a basic plot-by-plot level of characterization is desirable but can be considered to be of secondary importance to the collection of regional-level information.

The appropriate number of soil samples to be collected from each plot in order to detect regional changes in soil productivity must also be determined. Retrospective analysis using existing soils data bases (Church et al., 1989; Van Remortel et al., In Preparation) are providing statistical estimates of the optimum or average number of samples that must be collected from a particular plot in order to limit within-plot variability to a minor or negligible component of the overall data uncertainty (Dane et al., 1986; Miah et al., In Preparation). To address the issue of sampling intensity, simulations are conducted using "bootstrapping" and "relative difference" statistics; the techniques evaluate within-plot variability by selectively varying the number of sites sampled from each plot (Van Remortel et al., In Preparation). Also, the effects of destructive sampling, logistical constraints, composite vs. single-hole sampling, and horizon vs. depth sampling are examples of issues that continue to be deliberated prior to full implementation of the FHM program monitoring. An acceptable protocol for refilling the holes from which the samples are collected should be adopted, as this issue has long-term implications for plot utility and integrity.

In summary, the primary sampling design issues to be resolved as a result of the 1990 pilot and 1991 demonstration projects include:

- identifying the logistical and financial resources required for soil characterization and sampling;
- estimating the uncertainty from single-hole vs. multiple-hole sampling on the plots (to identify the optimum number of sites per plot that must be sampled);
- determining whether samples should be composited and at what stage (i.e., field or laboratory;
- determining whether provision of a destructive-sampling zone in an annulus encircling the fixed-radius subplots allows collection of soils data that are representative of the plot as a whole;

- determining the required sampling depths and types of horizons that should be sampled;
- examining the utility of characterization, sampling, preparation, and analysis methods selected;
- identifying specific types of ancillary data (e.g., regional climatic data) that may be needed to link the component parameters of the soil productivity indicator.
- defining the appropriate reporting units for the different soil parameters;
- determining the utility of various classification scenarios in the post-stratification and aggregation of data for interpretive reporting; and
- identifying possible regional differences in within-plot variability across forested regions of the United States.

8.4 QUALITY ASSURANCE

Specific QA information related to this indicator has been consolidated into the overall 1991 FHM program Quality Assurance Project Plan (Byers, 1991).

8.5 LOGISTICS

The primary soil logistical issue to be resolved during the demonstration project is the determination of the resources (e.g., time, personnel, funding, equipment, etc.) required to adequately characterize the soils within the plots and to collect, prepare, and analyze selected soil samples from the plots.

The logistics staff is planning to implement a plot sampling sequence for each region that enables each designated plot to be resampled at about the same interval of the index period over the course of the project. In the New England states, for instance, the optimum index period for sampling the test plots is late June through early September. If the field crews always begin sampling in the north part of the region in June and work towards the south part of the region during the remaining index period, some of the temporal variability may be reduced for subsequent sampling cycles. For interpretive purposes, soil sampling should be performed concurrently with the vegetative measurement/sampling at a given plot.

8.5.1 Field Personnel

Each field measurement/sampling crew, hereafter termed "field crew," consists of (1) a crew leader, (2) one or more other crew members (depending on the types of plots being measured) performing vegetative measurements and sampling, and (3) a soil scientist experienced in NCSS procedures performing soil measurements and sampling. The crew leader supervises all field operations and resolves any issues that arise at each plot.

The soil scientist assigned to each field crew has the responsibility of making decisions concerning soil description and sampling including horizon delineation, horizon thickness, and material excluded from the samples. Profile descriptions, logbooks, and sample labels must be legible and accurate, and photographs must have the proper exposure and settings. The field equipment must be properly used and maintained, and all sampling equipment must be cleaned following the collection of each sample. Caution should be exercised to prevent sample cross-contamination that could possibly be the result of soil peds dislodged from adjacent horizons or of free water above or below the horizon being sampled.

The integrity of all samples collected must be ensured by the field crews until the samples are shipped to the preparation laboratory. The appropriate project coordinators are to be notified at the earliest possible opportunity of any problems or difficulties encountered while sampling or during the transport of soil samples. All unused field equipment and supplies should be returned to the preparation laboratory at the end of each sampling period.

8.5.2 Training

All personnel involved in field soil measurement and sampling activities must be trained by an independent regional correlator (IRC) and a QA representative or other designated persons knowledgeable of the procedures and protocols described in the field manual (Van Remortel, 1991a). A week-long training session is conducted immediately preceding the field season, during which all field crew members are to be trained in their specific facets of field measurement and sampling. All field crew members should also be trained in the basics of first aid.

The total time requirement for the soils training session is five days including travel time to and from the training site. Actual training would begin on Monday at noon and end on Friday at noon. The allocation of training time by activity could be as follows.

- Monday afternoon (classroom overview): General orientation of crew members, overview of the field measurement and sampling manual, crew interactions, communications, QA procedures, etc.
- Tuesday morning (plot establishment in the field): All crew members observe protocols for locating plot center, setting up subplot and sampling boundaries, interacting with and supporting other crew members.
- Tuesday afternoon (group soils training in the field): Distribution of equipment to soil scientists, hands-on sequential walk-through of procedures on a practice plot, use of PDRs, question-answer session.
- Wednesday morning (continue group soils training in the field).
- Wednesday afternoon (continue group soils training in the field).
- Thursday morning (individual practice by crews in the field): Soil scientists join their respective crews to practice plot location and establishment, soil excavation, description, sampling, etc.
- Thursday afternoon (continue individual practice by crews in the field).
- Friday morning (summary session): Additional training as necessary, summary discussions, training questionnaire.

8.5.3 Communications Structure

The soil scientist on each field crew is responsible for all soil sampling assignments and support activities as required. All sampling issues should be relayed to the field crew leader so that information on sampling progress, difficulties, or emergencies occurring in the field can be relayed to the appropriate individuals. The field crew leader is responsible for informing the regional implementation leaders about sampling progress as well as for communicating any difficulties, such as equipment damage or supplies needed, or emergencies occurring in the field unless personally injured. The field crew leader is also responsible for disseminating information to field crew members (e.g., status of sample shipments, data discrepancies, remaining supplies, etc.).

The regional implementation leaders (or their representatives) should be available for telephone communications or emergency response on a 24-hour basis during the field measurement and sampling activities. The regional implementation leader is responsible for relaying information from the field crew leaders to the project coordinators as well as disseminating information from the project coordinators to the field crews. The project coordinators are responsible for the dissemination (through the regional implementation leaders) of information vital to the project, such as changes in protocol or sampling schedules, and also should solicit and receive progress reports on all aspects of the monitoring work.

The likelihood that field measurement and sampling issues will be raised and that changes to the protocols will occur requires that resolutions be disseminated in a consistent manner for all field crews and that the resolutions are compatible for both regions. Therefore, a weekly conference call should be established with the project coordinators and regional implementation leaders as participants. Discussion should include field measurement and sampling progress, difficulties encountered, and suggested amendments to the protocols.

8.5.4 Equipment and Supplies

Detailed lists of the equipment and consumable supplies used to perform soil measurement and sampling are provided in the chapter on soils in the field methods manual (Van Remortel, 1991a).

8.6 INFORMATION MANAGEMENT

The IM coordinator is presently working with the FHM program soils staff to plan and develop interactive, relational data bases that are compatible with other data bases being created as part of the field activities. For soils, it is expected that a VAX-based data management system will be developed to service the entire spectrum of soil data collection and management activities. Such a system would greatly enhance the FHM sample tracking ability. Ideally, the system would bring together data entry/verification computer programs that are, at present, discrete units used on individual personal computers to enter and verify data from field measurements, sample collection, sample preparation, and sample analysis. Planning for a possible VAX-based system is already underway.

The soils software programs and data files typically occupy a large amount of disk space. For example, it is expected that the total 1991 FHM program soils data base storage space requirements will be as much as 26 megabytes; specifically, 2 megabytes for the soil field measurement and sample collection data base, 4 megabytes for the soil preparation data base, and 20 megabytes for the soil analysis data base.

Specific IM features for this indicator include computer-automated data entry and verification programs for the field, computer manipulations of soil preparation laboratory data, and data analysis in conjunction with detailed lists of acceptable codes and logic checks. These features are described, where appropriate, in supporting documents such as the QAPjP (Byers, 1991), the field methods manual (Van Remortel, 1991a), and the laboratory methods manual (Byers and Van Remortel, 1991).

8.7 LANDSCAPE CHARACTERIZATION

Due to funding and time limitations, there are presently no plans to perform landscape characterization (LC) with regard to soil classification in the 1991 pilot study. As more time and funding become available, the LC coordinator is expected to prepare soil classification overlays that will tie into other overlays (e.g., forest cover-type group), as part of the FHM program GIS. Upon completion at some future date, these overlays are expected to provide much interpretive information for broad-scale soil/vegetation relationships and regional soils representation.

8.8 INDICATOR DEVELOPMENT

The following subsections briefly describe the work that has been performed on developing the soils indicator components and what is expected to be accomplished in 1991.

8.8.1 Strategy

The FHM program staff has been developing an appropriate way of presenting forest monitoring data in a format that is consistent with the overall program goals. Initially, the soils indicator documentation consisted of general fact sheets that provided a rationale for the monitoring of "soil nutrients" and "soil toxins" (Hunsaker and Carpenter, 1990). These exposure-category "indicators" were intended for use in documenting the status and trends of regional forest soil condition and in identifying associations with other types of indicators. Since that time, the scope has been broadened to facilitate the integration of all essential soil-related parameters influencing forest condition, or "health." As a result, the concept of "soil productivity" has been an appropriate and useful strategy for addressing the monitoring objectives set forth in the FHM program.

Ultimately, it should be determined whether the soil productivity parameters can be incorporated with confidence into some type of index for future application in across-indicator associations and assessment endpoints. The utility of individual soil productivity parameters can be tested with respect to their association with response parameters or indicators. An indexing framework that is suitable for application in a comparable manner across all regions must be defined. The possible use of indices is contingent upon further development and testing in forest systems. Also, exploratory multivariate techniques that would address associations of indicators should be investigated. Ancillary data, such as annual precipitation and temperature, should be gathered from outside sources and used in evaluating and fine-tuning the soil productivity estimates.

Variability is generally contingent on the form and mobility of the productivity parameter of interest. Soil nutrient concentrations can vary according to several different conditions: within-season, among-season, among-year, within-plot, and among-plot variability are prevalent. Within the sample measurement system, there is variability due to within-crew, among-crew, within-run, within-batch, among-batch, and among-laboratory differences. Each of these possible sources of uncertainty must be evaluated and controlled within acceptable standards during the project.

8.8.2 Retrospective Analysis

A repository of particle size and organic carbon data (i.e., the USDA's Soil Interpretations Record [Soils-5] data base) exists for about 22,000 soil series across the United States. Using this data base and others such as EPA's Direct/Delayed Response Project data bases (Church et al., 1989), it is possible to identify strata of forest soils aggregated by average percent clay class or, alternatively, organic carbon content or particle size class (discussed later in this section). In either case, these strata could be aggregated by forest cover-type group to provide a basis for modeling and simulation. For example, an evaluation of the Diagnosis and Recommendation Integrated System (DRIS) techniques (Beaufils, 1973; Walworth and Sumner, 1987) using soil chemistry and dendrochronology data from a Southern Appalachian spruce-fir data base (Kelly and Mays, 1989; Van Deusen, 1988) is presently being performed by the FHM program staff at Las Vegas in conjunction with scientists from the TVA and Oak Ridge National Laboratory. A previous evaluation in 1990 using an acidic deposition gradient data base from the north-central U.S. (Ohmann et al., 1989) was performed by the FHM program staff at Las Vegas and Research Triangle Park in conjunction with FS cooperators in Minnesota. These evaluations are expected to increase our level of understanding of exposure/response phenomena and interactions among indicator components.

8.9 Air and Deposition/Climate

The FHM program soils staff has a vital interest in obtaining regional climatic and deposition data to use as part of its indicator development and assessment framework. Climate data, specifically regional isothermoplethic and isohydroplethic maps, will help to define generalized soil moisture relations across the regional plot network. Some interpolation of existing data may have to be done to enhance the usefulness of these maps. In addition, a time series display of the Palmer Drought Severity Index (Palmer, 1965; Alley, 1984) modified for specific FHM program uses is highly desirable for evaluating drought stresses in long-term forest soils monitoring. Regional information on dry and wet deposition of point-source and non-point-source sulfur, nitrogen, and other elemental compounds will be invaluable for nutrient cycling and exposure assessments. The FHM program climate group has agreed to support the data-gathering effort when funding becomes available.

8.10 DATA INTEGRATION, ASSESSMENT, AND REPORTING

The following subsection describes some of the strategies for integrating and assessing soils data collected during the 1991 field season, and how these data are to be reported.

8.10.1 *Integration and Assessment*

There is some uncertainty as to how the plot-by-plot data are to be aggregated in order to derive regional estimates for specific forest cover-type groups. Simulations using existing soils data bases are being used to test preliminary sample aggregation schemes for different regions of the eastern U.S. Preliminary results using the "forest cover-type group /percent clay class" and "forest cover-type group/percent organic carbon class" simulations are promising (Byers et al., 1990b; Conkling et al., 1990). These classification schemes are being applied to the FHM program study plot framework to assess their utility. Other possible classification schemes, such as higher category taxonomic groups, should also be tested for their utility.

The soils data integration and assessment framework for the FHM program is not yet clearly defined nor understood. Nonetheless, possible features of this framework include the following:

- development of a productivity index that could distinguish nominal, marginal, and subnominal ranges of specific soil productivity indicator components (e.g., parameter groups), with respect to forest health societal values;
- correlation of soil productivity with other FHM program indicators using either a modified version of DRIS or other interpretive frameworks to evaluate indicator components and assessment endpoints; graphical presentations of parameter correlations or ratios of component parameters;
- development of new integration approaches through retrospective analysis of historical soil-vegetation data bases.
- emphasis on integration of parameters and methods with demonstrated utility; with few exceptions, the methodology for field measurements, sample collection, sample preparation, and sample analysis is presently well documented and requires little additional development; and
- testing of measurement parameters and other ancillary components of the soil productivity indicator (e.g., plant-available moisture) for their utility in characterizing and indexing forest soil condition in specific forest cover-type groups.

8.10.1.1 Indexing Strategy

The cornerstone of this ecological indicator is the ongoing development of a soil productivity index that includes configurations of several soil parameters. There have already been significant advances in the development of indexing systems (Ott, 1978), and efforts are underway to broaden the range of contacts and acquiring data from the scientific literature and from resource scientists to support this work. Once developed and tested, the index is expected to provide a reliable synoptic "snapshot" of overall soil productivity status and trends for individual forest cover-type groups in each region, and is based on a soil's ability to supply plant nutrients and sustain forest productivity. An index might also be identified for each of several appropriate aggregations of soils in the different regions and then used in association with the other FHM program indicators to evaluate the overall condition of regional forest ecosystems on a national basis.

It is believed that the single greatest use of the soil productivity indicator is to provide regional-level information on the "exposure" characteristics of soils as they relate to the response indicators (such as visual symptoms and tree growth). Secondary uses of the soil productivity indicator might include the provision of plot-level information for these response indicators and the establishment of linkages to foliar chemistry, soil biological processes, and other FHM program exposure indicators.

The ongoing development of a soil productivity index composed of several soil measurements is expected to provide a reliable synoptic snapshot of overall soil productivity status and trends in relation to forest response indicators. A general history of soil productivity rating systems and general model classes for productivity rating scales in the United States is presented in an excellent review by Huddleston (1984). Much of the research on productivity ratings has been done in an agricultural setting, which resulted from the desire to have a method for using soil survey information to classify the quality of farmland for purposes such as tax assessment (Fenton, 1975; Scholtes and Riecken, 1952) and other loan activities (Berger et al., 1952). More recently, the concept of a productivity index or rating scale has been applied to erosion studies (Bruce et al., 1988; Scrivner et al., 1985; Larson et al., 1983; Pierce et al., 1983), and is generating greater interest for possible applications in forestry and forest soils research. A primary approach is to base the productivity rating on soil and climatic effects on plant growth or yield, where actual yield data are often used to calibrate the model. Two main types of models presently exist: multiplicative and additive. It is also possible to develop a model which combines additive and multiplicative processes.

Soil productivity indices based upon plant root distributions have been proposed, mainly for agronomic crops (Kiniry et al., 1983), although adaptations are being developed for forests (Gale and Grigal, 1987; Henderson et al., 1988). This approach, however, is labor intensive and tends to be crop specific. There have been numerous projects that have studied relationships between some measure of growth response in various forest species and its associated soil chemical, physical, topographic, and climatic characteristics.

Some possible advantages to using an index to assess changes in soil productivity include the following.

- By virtue of the soil sampling design, the index should be a valuable measure of soil condition regardless of the soil mapping unit composition within the field plots.
- The index could provide a direct composite measure of soil productivity status for a particular field plot or region, and can initially be used for the establishment of baseline condition.
- The index could be a nonarbitrary measure of soil productivity trend for a given plot or region over time, both in terms of total plot productivity and individual horizon productivity.
- The index could allow the data users to evaluate the association of the index with other FHM program indicators.
- The index focuses on "operative" soil properties influencing productivity, such as clay content, organic carbon, horizon thickness, or soil depth.
- Component soil parameters could be aggregated or dispersed to the level necessary to define appropriate indices for interpreting the assessment endpoints of interest.
- The index initially could be used in DRIS equations or other interpretive frameworks for determining appropriate ranges or confidence intervals for the independent variables. Later applications could capture response data for the dependent variables from other FHM program indicators.
- The index could accommodate and account for differences in parameters, methods, and procedures used to measure soil productivity across all regions of the United States.

Some possible disadvantages to using an index to assess changes in soil productivity include the following.

- The index may not be useful for making reliable estimates of productivity at the soil order or suborder taxonomic level because of the expected large variability in soil physical and chemical characteristics of soils aggregated within a soil genesis-based higher category classification. Conversely, the soil family or series levels, while desirable from a regional interpretation standpoint, are likely to be too low of a category to allow sufficient statistical degrees of freedom on which to base the data analysis and estimates of change (at the present grid density). Therefore, characteristics other than soil genesis (i.e., "operative" factors such as soil physical and chemical parameters) are probably more useful (Fralish et al., Incomplete Reference).

- The index cannot be fully applied to DRIS-type equations until appropriate concurrently-measured dependent variable values, such as response indicator data, can be collected.

The indexing strategy was selected by considering soil characteristics on an interactive system basis. For example, if an unmanaged stand of rain forest in the Amazon Basin was evaluated using only those response indicators such as visual leaf symptomology or tree growth efficiency, it might be concluded that this tropical forest ecosystem was in "healthy" condition. However, it is known that the majority of soils in the Amazon Basin are naturally infertile and have achieved a delicate ecological symbiosis with the indigenous flora. In this system, annual nutrient cycling from decaying woody and leaf litter provides the only significant buffer against acute productivity depletion. In this sense, it could be argued that the soils in this ecosystem are marginal; that is, the soils display chronically low levels of productivity that are highly susceptible to disruption. Anything that would disrupt this cycling balance, such as wildfire effectively removing the understory plants and ground cover, could abruptly shift the forest health to a subnominal status. Similar scenarios could occur in the United States (e.g., scrub oak/pine forests in Northern Florida).

8.10.1.2 Classification/Aggregation Framework

For interpretation purposes, it is possible that soils could be classified on the basis of one or more specific soil characteristics (e.g., particle size class, organic matter content, depth to bedrock, taxonomic group, etc.). As an example, it was hypothesized that certain Ultisols, Entisols, or shallow rocky soils could possibly be categorized as nutritionally "subnominal" or "marginal" whereas deep Alfisols or Mollisols may have the greatest possibility of being nutritionally "nominal." Although there are a number of soil properties of importance to productivity in forested ecosystems, it is generally accepted that two of the most important soil physical characteristics affecting nutrient status are the organic carbon content and the percentage of clay-size particles in the soil matrix (Soon, 1985; Barber, 1984). Both of these parameters are readily quantified during the FHM program soils data collection activities.

It is anticipated that soils could be aggregated in a number of ways, such as by plot (through a weighting function applied to all master horizons on the plot) or by individual master horizon type. A first-order reference stratum might be "forest cover-type group," as this presently appears to be the intended basis for regional indicator estimates. A second-order reference stratum might be "average percent clay content" on a field plot or in a particular master horizon, as clay is expected to be one of the dominant soil physical factors relating to potential soil productivity. The effect of organic carbon on productivity may be addressed adequately through the aggregation of data by different master horizon types. Using this mode of classification, a soil's baseline potential for specific assessment endpoints can be determined and then rated qualitatively in "nominal," "marginal," or "subnominal" terms.

At this time, a classification scheme is being developed which allows the data users to clearly differentiate between index values for different strata and still encompass enough samples in each stratum to make reliable estimates of changes in status and the uncertainty associated with those estimates. Initial efforts along these lines have been fruitful in that there appear to be distinct ranges of nutrient concentration for a given concentration of clay and organic carbon (Byers et al., 1990b; Conkling et al., 1990). As demonstrated in previous studies, there is significant micro- and macrospatial variability in the ranges of concentration for different master horizons, such as O-horizon vs. A-horizon (Mausbach et al., 1980; Van Remortel, Unpublished Data). A weighting function has been tested which would allow the effect of the relative thickness/volume of each master horizon on the plot to be appropriately weighted in the estimation of plot classification parameters (e.g., average percent clay) and, ultimately, of the overall plot productivity status for a given plot. It is anticipated that algorithms and weighting functions could be developed that have utility for both regional and plot-by-plot evaluation.

8.10.2 Reporting

The soils indicator participants will provide input to the appropriate reports on operations, QA, and data analysis that will be written upon completion of the 1991 field and laboratory work (see Section 7). The disposition of these specific reports and their timeframe for delivery is uncertain at this time.

9. TREE CORE ELEMENTAL ANALYSIS FIELD MEASUREMENT

T. Lewis[a]

9.1 INTRODUCTION

The study of current nutrient cycling in forests in relation to atmospheric deposition and climate change must be examined from the perspective of past, current, and future influences of natural and anthropogenic processes on nutrient cycling. To assess the current status of nutrient cycling in forested ecosystems, it is important to evaluate evidence of their historical nutrient status.

The analysis of elemental concentrations in tree cores may provide evidence of historical trends in nutrient cycling. Most studies of elemental chemistry of tree cores have examined distinct tracers of anthropogenic origins (e.g., lead from leaded gasoline, Strontium-90 from atomic weapons testing). Detection of a close correlation between elemental patterns in shortleaf pine stemwood and historical sulfate emissions from the Copper Hill Smelter in eastern Tennessee (Baes and McLaughlin, 1984) provided early evidence that chemical changes in tree ring chemistry reflected changing inputs of regional pollutants in forests. Increasing levels of iron were found in those tree cores during the 50 years of open-pit smelting operations (1860 to 1910). After emissions were reduced to preindustrial levels in 1910, levels of iron were significantly lower for 40 years. The levels of iron have again increased during the last 30 years, possibly in response to increasing acidic deposition. Bowers and Melhuish (1987) observed a similar pattern in tree cores collected from loblolly and red oak growing near the Chromasco Smelter outside of Memphis, TN.

Examining the relationship between tree ring chemistry and changes in soil chemistry during the life of the tree is a more recent approach (Legge et al., 1984; McClenahen et al., 1987; Guyette and McGinnes, 1987; Bondietti et al., 1990). Bondietti et al. (1989) observed a significant increase in

[a] Lockheed Engineering & Sciences Company, Las Vegas, NV

the ratio of aluminum (Al) to calcium (Ca) in tree rings of red spruce and eastern hemlock in the Great Smoky Mountains of Tennessee. The increase was attributed to increased mobilization of Al and leaching of Ca in the soil as a result of acidic deposition. The increased ratio of Al to Ca had a negative correlation with the radial growth of the species. Bondietti et al. (1990) also sampled red spruce and other species in New England and North Carolina, in addition to Tennessee. The researchers observed an increase in divalent cations present in red spruce wood formed in the mid-1900s that was coincident with rapid increases in sulfate and nitrate deposition in eastern North America and with increases in radial growth. A decrease was noted in divalent cations in the red spruce wood formed in the late-1900s with a concomitant decrease in radial growth.

Most determinations of elemental concentrations in tree cores have involved digestion of tissue with subsequent analysis by atomic absorption spectrometry (AAS) (Bowers and Melhuish, 1987), inductively coupled plasma-optical emission spectroscopy (ICP-OES) (Bondietti et al., 1990), or similar approachs. These techniques have several disadvantages including:

1. several years of wood growth must be pooled in order to obtain sufficient tissue for analysis, and
2. the technique is destructive.

Alternatively, some less destructive techniques have been successfully employed. These include particle-induced X-ray emission (PIXE) (Bondietti et al., 1989) and neutron activation analysis (NAA) (Bondietti et al., 1990). These methods do not require digestion of the tree core sample, but suffer from a lack of spatial resolution (i.e., the dimensions of the tree core sample which can be irradiated, which ultimately corresponds to temporal [seasonal and annual] resolution). Their lack of spatial resolution is due, in part, to the potential loss of those components having significant volatility and the probability of sample damage due to interaction with the charged particles, even when the sample has been coated with a conducting medium to avoid charging.

Early work on the use of X-ray fluorescence (XRF) for the determination of trace elements in plant material depended on the use of various preconcentration methods which were destructive and required significant amounts of material (Reuter, 1975), similar to AAS and ICP-OES techniques. Attempts to obtain annual resolution in tree cores could only be accomplished by the use of microtomed sections, which were treated chemically to produce the analyzed sample. More recently, XRF spectroscopy analysis has been refined to allow direct measurement of the elemental composition of individual tree rings, with subannual resolution (Gilfrich et al., In Press). Within-year seasonal differences can be discerned due to the ability to focus, or aperture, an X-ray beam to sizes approaching tens of micrometers (Jones et al., 1988). Coupled with the intensity of X-rays generated by a synchrotron radiation light source, such as the one housed at Brookhaven National Laboratory, minimum detection limits for most elements by XRF can be as low as 20 ppb.

Gilfrich and co-workers at the U.S. Navy Research Laboratory (NRL) in Washington, DC will provide XRF analyses of tree cores collected during the Nutrient Cycling Demonstration.

9.2 RATIONALE

The elemental analysis of tree cores may provide a critical link between soil nutrient and contaminant levels and foliar chemistry. Elemental analysis of tree cores will provide direct evidence of nutrient status and historical trends in nutrient cycling. Stemwood elemental concentrations will serve to round out the overall suite of nutrient cycling indicators.

9.3 DESIGN

Tree core samples will be collected from the same specimens from which visual injury and foliar chemistry samples are to be collected during the Nutrient Cycling Demonstration in Georgia and Alabama. A total of two cores will be collected from each tree. Tree ring growth measurements are made in the process of elemental XRF analysis. A 5-mm (inside diameter) Teflon®-coated increment borer will be used to collect the sample. Samples will be placed in plastic tubes for shipment to the sample preparation laboratory in Las Vegas, NV.

In the South and Southeast, a total of approximately 72 plots will be sampled in the Nutrient Cycling Demonstration. Two trees on each of the two selected subplots will be cored for elemental XRF analysis. These trees will be the same trees sampled for foliar chemistry and visual injury on the same day.

9.4 QUALITY ASSURANCE

A pretraining and training course will be conducted prior to collection of samples for the Regional Pilot. The purpose of this training is to familiarize the indicator leaders and sampling crews with the sampling design and sample collection methods. Crews from both the South and Southeast will be instructed similarly to ensure consistancy between regions. More detail on field methods is provided in a separate methods manual.

A rigorous QA/QC program will be employed for laboratory analyses of tree cores. This program consists of numerous system and performance audit samples. A laboratory audit will be performed prior to sample analysis. Greater detail on this QA/QC program is provided in a separate QA manual.

9.5 LOGISTICS

Logistical components to be assessed during the Regional Pilot include (1) testing of the feasibility of the sampling protocols, and (2) estimation of costs and time required for each step in the process (e.g., sample tree selection, tree core collection, shipping, sample preparation, and sample XRF elemental analysis). These logistical considerations will be evaluated in light of costs to determine whether the sampling design adequately compensates for temporal and spatial variability.

9.6 INFORMATION MANAGEMENT

Tree location on the subplot will be recorded on PDRs in the field. The plastic tubes in which the tree cores will be shipped will be clearly marked with the appropriate identifying information. When samples are received at the sample preparation laboratory in Las Vegas, NV, the integrity of the sample will be noted. Pertinent information will be entered into a SAS batch tracking data base prior to shipment to NRL. The samples will be allocated into batches for chemical analyses. A batch and sample ID number will identify the samples sent to NRL's analytical laboratory. This unique number will follow the sample through the entire analytical process. Results of the XRF analyses will be obtained by hard copy and electronic format (tentatively ASCII format). The analytical results will be merged with the batch tracking data base by the appropriate sample-tree identifiers.

9.7 LANDSCAPE CHARACTERIZATION

Remote sensing information will be obtained from a subset of the plots in the southeast. Remote sensing will provide information on crown cover, crown condition, land-use patterns, and harvesting. All of the aforementioned landscape characterisitics have a marked influence on nutrient cycling in forested ecosystems. An evaluation of these landscape characteristics in conjunction with the nutrient cycling indicator suite may provide estimates of regional trends in nutrient cycling.

9.8 INDICATOR DEVELOPMENT

Development of this indicator may prove a better alternative to a complicated suite of nutrient cycling indicators. The minute spatial resolution afforded by XRF analysis may be capitalized upon by examining other components of the specimen to obtain better estimates of nutrient compartmentalization.

9.9 AIR AND DEPOSITION/CLIMATE

The opportunity exists for relating historical trends in nutrients and contaminants in tree cores to historical trends in atmospheric deposition and climatological patterns. Linkages are possible between nutrient uptake, radial growth, soil nutrient availability, and environmental atmospheric and climatic data, using tree core elemental XRF analysis as an integrator of past, present, and future condition.

9.10 DATA INTEGRATION, ASSESSMENT, AND REPORTING

Elemental analysis of tree cores will serve as an integral link between below-ground and above-ground processes in forest nutrient cycling. The historical record revealed by elemental tree core analysis will provide valuable information for the interpretation of current levels of nutrients and contaminants in soils and foliar tissue.

The same strategies for the development of the integration and assessment framework for foliar chemistry would be applicable to elemental tree core analysis.

9.10.1 DRIS

One of the essentials in the use of the Diagnosis and Recommendation Integrated System (DRIS) is the establishment of a data base. The use of historical tree core elemental nutrient ratios may be able to provide such a data base.

9.10.2 CERES

CERES is a submodel which can be used to predict short-term and long-term accumulations of solutes when coupled with other submodels of the Unified Transport Model (UTM) (Dixon et al., 1978). The CERES model is separated into various compartments, one representing heartwood. By adjusting the levels of nutrients in the heartwood, as determined by XRF analysis of tree cores, short- and long-term flucuations in elemental concentrations in the other compartments can be modeled.

The model-generated values could be compared to the current levels in the various compartments to detect possible departures from normal nutrient and heavy metal uptake and translocation.

10. FOLIAR CHEMISTRY

T. Lewis[a]

10.1 INTRODUCTION

Previously, this indicator has been termed "Foliar Nutrients." This is considered a misnomer, inasmuch as elemental contaminants are also included in the measurements. Therefore, the "Foliar Nutrients" indicator will henceforth be termed the "Foliar Chemistry" indicator.

Foliar chemistry is an example of an exposure-habitat indicator. This class of indicator is designed to quantify factors which may be associated with changes in forest condition (e.g. visible injury, growth, soil productivity). The foliar chemistry indicator is also a key component in the suite of indicators that contribute to the nutrient cycling assessment endpoint.

The elements to be determined in foliar samples include macro- and micronutrients (e.g., total N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo, and Cl) and potential contaminants (Na, Al, F, Cd, Pb, As, V, Cr, Ni, and Hg). Some essential nutrients may also enter the system in excessive amounts from anthropogenic sources (total N, Fe, Mn, Zn, Cu, B, and Cl). For example, chromium smelters emit Mn, Cr, Fe, Al, Ca, Mg, Na, Zn, K, Pb, Ba, Ti, Hg, Cd, Be, V, and As. These were measured in particulates emanating from the stacks at the Chromasco smelter in Memphis, TN (Bowers and Melhuish, 1987).

Foliar chemistry as a "stand-alone" indicator may not in itself be sufficient for establishing status and discerning trends in forested ecosystems. However, it is believed that in conjunction with other indicators it is a vital component in the nutrient cycling and contaminants assessment endpoint. Further, the combined use of a number of existing procedures which assess foliar nutrient status (e.g., critical levels, DRIS, correlation with various growth variables) will be tested. The foliar nutrient

[a] Lockheed Engineering & Sciences Company, Las Vegas, NV

screening method developed by Timmer and co-workers (Timmer and Stone, 1978; Timmer and Morrow, 1984) may also aid in the detection of nutrient limitations.

Nutrient deficiencies or excesses and metal toxicity can often be detected as visual symptoms on foliage. When nutrient deficiencies are severe, visible symptoms such as leaf yellowing and scorching become apparent. Other symptoms may include stem deformities and loss of leaves. Although some visual symptoms may relate to a specific nutrient limitation, in many cases, foliar chemical analysis is needed to accurately diagnose the cause. For example, twisted, deformed leaders in Douglas fir have been related to copper deficiency (Will, 1972), boron deficiency (Carter et al., 1983), and arsenic toxicity (Spiers et al., 1983). Foliar nutrient chemistry may also correlate with visible injury caused by gaseous pollutants such as ozone, sulfur dioxide, oxides of nitrogen, and peroxyacetylnitrates.

Foliar nutrient concentrations are known to vary in response to a number of biological, structural, geographical, and environmental factors. The effect of some of these factors can be partially controlled by selective sampling (e.g., sampling the upper-third of the crown, sampling at a certain time of year). These selective sampling procedures will be discussed below.

10.1.1 Sampling Considerations

The problems of sampling position involve several considerations:

1. Which trees in a forest stand to sample
2. Where on the trees to sample
3. Number of trees to sample
4. When to sample

Generally, the dominant and codominant trees are sampled because they are more representative of the plot and they are usually of greater economic importance. Also, dominant and codominant trees in a forest stand tend to show less variation among trees in nutrient element levels than over-topped trees growing in various degrees of shading by the larger trees (Lavender, 1970).

The position on the tree for collecting foliar samples has been of considerable controversy in the early stages of indicator development. The nutrient element composition of foliage varies both vertically and horizontally in the tree crown. For conifers, there are several position considerations:

1. Age of needles
2. Vertical position in crown
3. Position of needle in growth flushes
4. Branch order in relation to physiological activity

The age of the needles has been shown to influence elemental concentrations in the tissue. For many years, coniferous foliage sampling for diagnostic purposes has been restricted to foliage of current-year age at the terminal portions of the uppermost lateral branches (Leaf, 1973). However, recent evidence indicates that at least for some species and elements, foliage from other portions of the tree crown and, possibly, from other than the current-year's growth may be more diagnostic (Kabata-Pendias and Pendias, 1984). For example, when the supply of Mg is adequate, its concentration in older needles, such as 4th-year needles, will be similar to that in current-year needles. However, as deficiency develops, Mg moves from older to current-year needles, with the concentration in the older needles dropping to very low levels (Tomlinson, 1990). The nutrient ratio between old and current-year needles may serve as a diagnostic index of nutrient deficiency. This ratio will be examined in the Nutrient Cycling Demonstration in Georgia and Alabama.

Vertical position in the crown is also an important consideration. The outer-crown foliage or "sun-leaves" have anatomical and morphological differences from the internal-crown foliage or "shade leaves" and there are differences in nutrient element status between these two groups of foliage. Generally the upper-third of the crown is sampled. Foliage located in the upper crown also acts as an interceptor of atmospheric pollutants. For that reason, and to stay consistant with other national and international foliar surveys, the upper-third of the crown will be sampled in the Regional Demonstration. However, the logistics and cost of collecting from the upper-third are substantial. Wallihan (1944) reported no significant differences in sugar maple foliage nutrient content in upper and lower crown positions, but this warrants further investigation.

Temporal variability in foliar nutrient concentrations exists between years, within year, and within season. Large variability can exist (e.g., coefficients of variation from 8 to 60%) within and between years (Bickelhaupt et al, 1979; Smith et al., 1970; Wells and Metz, 1963; Mead and Pritchett, 1974). Mobile elements (N, P, and K) tend to increase during the first half of the growing season and decrease during the latter portion. Generally, elemental concentrations in deciduous foliage tend to level off approximately 1 month prior to senescence (Leaf, 1973). Samples will be collected 2 to 3 months prior to this time period during the Nutrient Cycling Demonstration. Nutrient concentration in current-year coniferous foliage has been found to be more stable during the winter months than during the growing season. The concentration in previous-year needles is more stable over the entire growing season than in current-year needles (Wells and Metz, 1963).

Unfortunately, due to financial and logistical constraints, winter sampling is prohibitive. Both current- and previous-year foliage on conifers will be sampled in June and July during the Regional Demonstration. By examining the ratios between these two groups as a diagnostic tool, the seasonal variance component will hopefully be offset. The time scale for which trends are expected to be detected in foliar chemistry are in the order of decades. The intraseasonal , interseasonal, and annual variation in foliar chemistry will probably necessitate monitoring for longer-term changes (i.e., 10 to 50 years). It is anticipated that regional long-term trends will be detected notwithstanding short-term temporal variability. The short-term variability, however, may be useful in understanding the coincident measurements of other indicators.

At a later date, when funding becomes available, we will propose an off-frame pilot to assess temporal variability and fine tune the sampling window. In the off-frame pilot, time of sampling will be used as a covariate. However, using time as a covariate will not solve the problem of interactions between time and climate as one moves from one region to another.

10.2 RATIONALE

The rationale for making foliar chemistry measurements are as follows.

1. Foliar chemistry is an important component in other long-term monitoring programs in Europe and North America. The data generated in the FHM program will be directly comparable to these other programs.
2. The foliar chemistry indicator is an important component in the set of indicators for assessing nutrient cycling in forested ecosystems. It will provide information for the interpretation of other indicators such as soil productivity and visible injury.
3. The foliar chemistry indicator, with the other monitoring data, will be a valuable addition to and basis for evaluation and ecosystem research monitoring.

10.3 DESIGN

Based on the previous discussions on the variability in foliar chemistry the following sampling design strategy is proposed for the measurement of foliar chemistry.

The primary objective is to determine the within tree and within plot variability of foliar elements on a regional scale. At the time of writing of this Study Plan, data from the 20/20 Study have not been evaluated. Therefore, the variance estimates from that study are not available. Additional knowledge will be gained that can be added to the 20/20 Study.

One pilot study has been structured into the study, the Needle Age Evaluation in Alabama. The objective of the Needle Age Evaluation is to evaluate the use of the current-year vs. previous-year coniferous foliar nutrient ratio as a diagnositic for detecting nutrient deficiency. One year of data will be evaluated for detecting such deficiencies. The logistics and data interpretation methods for this measurement will be evaluated.

In Alabama and Georgia, approximately 72 plots will be sampled for foliar chemistry analysis. These plots coincide with those of the Nutrient Cycling Demonstration. Sample tree selection will be based on crown class dominance and codominance. Species are not selection criteria, although this is a factor in the Needle-Age Evaluation, which will be conducted on a subset of the plots in the Demonstration.

In the Nutrient Cycling Demonstration and Needle-Age Evaluation two trees will be climbed on two subplots and branch samples will be collected from the upper-third portion of the crown. These branches will be evaluated for visual damage and the visual damage evaluation will be performed on the whole tree. For all coniferous species encountered, the previous year's (1-year-old) needles will be obtained. Additionally, for the Needle-Age Evaluation, from the first 20 subplots that have two loblolly pine selected, the current year's growth will also be collected.

Foliage collection is considered destructive, therefore, these samples will be obtained from trees off the subplot. Climber's spikes will not be used by tree climbers.

10.4 QUALITY ASSURANCE

A pretraining and training course will be conducted prior to collection of samples. The purpose of this training is to familiarize the indicator leaders and sampling crews with the sampling design and sample collection methods. Crews from both Alabama and Georgia will be instructed similarly to ensure consistancy between regions. More detail on field methods is provided in a separate methods manual.

A rigorous QA program will be employed for laboratory analyses of foliar samples. This program consists of numerous system and performance audit samples. A laboratory audit will be performed prior to sample analysis. Greater detail on this QA program is provided in a separate QAPjP.

Foliar chemistry data collected in the 20/20 and Regional Demonstration Studies will be used in the development and testing of a data verification and validation program similar to the Soil Quality Assurance Template (SQAT) program used for soil chemistry data evaluation.

10.5 LOGISTICS

Logistical components to be assessed during the Regional Pilot include (1) testing of the feasability of the sampling protocols, and (2) estimating costs and time required for each step in the process (e.g., sample tree selection, branch collection, separation of current-year and 1-year-old needles, shipping, sample preparation, and sample chemical analysis). These logistical considerations will be evaluated to determine whether the sampling design adequately compensates for temporal and spatial variability in a cost-effective manner.

10.6 INFORMATION MANAGEMENT

Information management is critical for the implementation of indicators and interpretation of data. Field data describing the location of sampled trees on the plot and other pertinent information will be recorded in the field using PDRs. The PDRs will be preprogramed prior to deployment in the field. Data will be downloaded from the PDRs to PCs at the end of each day's field activities. The hexagon, subplot, tree number, branch number, species code, state, crew identification (ID), needle age (for Alabama Needle-Age Evaluation plots), azimuth, and distance are essential indentifiers for sample tracking.

At the preparation laboratory in Las Vegas, NV, samples will be matched with the field data to verify receipt of all samples. The samples will be allocated into batches for chemical analyses. A batch and sample ID number will identify the samples sent to the analytical laboratory. This unique number will follow the sample through the entire analytical process. Data will be received from the analytical laboratory in ASCII format. The data will be converted to SAS format and merged with the existing SAS data base which contains all the descriptive information recorded in the field.

10.7 LANDSCAPE CHARACTERIZATION

Landscape characterization can be useful in the interpretation of nutrient cycling suite of indicators and vice versa. Large areas of tree mortality or defoliation detected by aerial photography may be linked to nutrient deficiencies or pollutant toxicities. Estimates of leaf area index obtained by high-resolution remote sensing methods may relate to one or more of the nutrient cycling indicators (e.g., visual injury, foliar chemistry, soil productivity). Evidence of extensive drought conditions in the forest stand as determined by high-resolution aerial photography may aid in the interpretation of soil and foliar chemistry data, particularly for highly mobile nutrients. Nutrient deficiencies in crown foliage may be detectable on a broad scale by remote sensing in various wavelengths. These possibilities are actively being investigated.

10.8 INDICATOR DEVELOPMENT

The foliar chemistry indicator is in the developmental stages at the present time. Refining of the sampling window and location in the crown are two issues that must be addressed in order to understand the variability in foliar chemistry. Both these issues have been topics of discussion and active research for several decades. The historical data have not been adequately examined to warrant proposing demonstration research. Furthermore, the variability in the data collected during the 20/20 Study have not been evaluated. Historical data bases are being sought to assist in addressing these important issues.

The foliar chemistry indicator is composed of several measurements of macro- and micronutrients in addition to potentially toxic elements. Deficiencies, excesses, and imbalances in essential nutrients may act as a stressor on the plant, and high levels of toxic elements may also stress the plant. This stress may act directly on a particular tissue of the plant or interfer with the plant indirectly by altering soil chemical and biological activities.

Recent evidence demonstrates the ubiquitous nature of organic contaminants in terrestrial ecosystems, which may impose an additional stress to the system. These compounds include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, dioxins, and many more. These compounds undergo long-range transport and are deposited in forested ecosystems by wet and dry deposition (Levsen et al., 1990). While concentrations of organics in the atmosphere have increased, our knowledge of their movement through terrestrial food chains has remained static. Aromatic hydrocarbons and chlorinated hydrocarbons are solvents and may dissolve in the wax layer of needles and leaves. The leaf surfaces having been perforated by these organics, acids and heavy metals may attack the metabolism of the plants (Muller, 1989). However, to date it is not clear if the concentrations of aromatic and chlorinated hydrocarbons are sufficiently high to be inducers of forest decline. Nevertheless, knowledge about the concentrations of these contaminants in forested ecosystems in remote and polluted areas is indispensible.

Toxaphene, a once widely used pesticide that replaced DDT, has been shown to be highly toxic to soil microoganisms (Saleh, 1991). Such toxicity may influence nutrient cycling in forest soils. PAHs have been shown to accumulate in plants (Edwards, 1989). While little is known about the direct effects of organic contaminants on tree species, the regional distribution of these compounds in forested areas would be of considerable value for anticipatory purposes. A soil screening method for detecting total organochlorine contaminants coupled with a bioassay, such as ATPase activity or Ames test, is being researched as a possible measurement in the soil chemistry suite of measurements.

10.9 AIR AND DEPOSITION/CLIMATE

Evaluating regional concentration and deposition patterns of atmospheric pollutants will be instrumental in the interpretation of the nutrient cycling suite of indicators. Climatological data must also be linked with nutrient cycling and contaminant data to knowledgably make statements about variability in the data and relationships between indicators.

10.10 DATA INTEGRATION, ASSESSMENT, AND REPORTING

Interpretation of foliar analysis data and subsequent extrapolation to a regional scale is crucial to the success of this indicator. The total physical environmental and biological characteristics of the site, together with spatial and temporal variations, must be considered, along with the foliar analysis data to make adequate interpretations. For example, atmospheric composition, temperature, moisture, light quantity and quality characteristics, soil productivity, and the metabolic activity of the tree all can affect the level of a particular nutrient or toxic element in the foliar tissue.

The data integration and assessment framework in the FHM program is still in the developmental stages. However, some potential strategies for the development of the integration and assessment framework are proposed.

10.10.1 DRIS

Problems with the integration and assessment of foliar chemistry analysis have been overcome in agroecosystems by use of the DRIS. The foundation of DRIS is the concept of nutrient balance, the interrelationships between all nutrients being considered simultaneously. The application of DRIS requires four steps: creation of a data base, establishment of DRIS norms, establishment of DRIS indices, and testing of the norms (Schutz and deVilliers, 1987). In forestry, DRIS has been tested on a small-scale, exploratory basis only. Given the increasing evidence that DRIS is a useful diagnostic for agricultural crops, the opportunity exists to evaluate its usefulness during the FHM program activities.

10.10.2 CERES

The CERES model was developed for the purpose of predicting solute transport within vegetation and litter components of a forest ecosystem (Dixon et al., 1978). CERES can be used to predict short-term and long-term accumulations of solutes when coupled with other submodels of the Unified Transport Model (UTM). This model, or a modification of such a model, may assist in linking the foliar chemistry indicator together with other indicators, such as soil productivity, soil biological processes, and PAR.

10.11 QUALITY ASSURANCE

Specific QA information related to this indicator has been consolidated into the overall 1991 FHM program Quality Assurance Project Plan (Byers, 1991).

11. ROOT DISEASE EVALUATIONS

S. Alexander and J. Carlson[a]

Root diseases are significant contributors to the decline and mortality of our forests. The pathogens that cause root disease may act alone or in combination with other factors such as drought, insects, and air pollution. Unlike above-ground pests, root pathogens are difficult to detect and therefore may be overlooked as contributors to the forest condition. The following method of determining the presence and severity of root diseases is the best available for use in a survey mode (Alexander and Skelly, 1973; Wargo and Bergdahl, 1986; Alexander and Carlson, 1989). The single tree evaluation procedure will be applied to each plot in the Nutrient Cycling Demonstration in the South and Southeast.

11.1 OBJECTIVES

To determine the presence and severity of root diseases.

11.2 DESIGN

11.2.1 Plot selection

The plots of the interpenetrating design selected for the Nutrient Cycling Demonstration will be used. The design will obtain regional representation.

11.2.2 On-plot sampling scheme

Root samples will be collected on one pair of sample trees at each of two subplots per plot. These will always be the same trees from which branch data have been collected. All specified trees will be sampled using the following procedure. Two root samples from each of two roots per tree will

[a] Virginia Polytechnic Institute and State University, Blacksburg, VA

be collected. The following symptoms and signs will be recorded on the portable data recorder. Because more than one is likely to be found on diseased roots, there are three fields available on the sheet.

Code Description

Code	Description
0	None
1	Resin-soaked: Bark and outer wood have a brownish, wet appearance.
2	Stain: Streaks of black or brown discoloration within the wood of the root.
3	White rot: The decayed wood is white in appearance.
4	Brown rot: The decayed wood is brown in appearance.
5	Rhizomorphs: Black strings of fungal hyphae attached to root.
6	Mycelial fan: A white sheet of fungal mycelium in a fan shape on the surface of the root under the bark.
7	Mushrooms
8	Conks: Large, leathery fruiting bodies of a fungus protruding from a colonized area.
9	Insects
10	Other: A symptom or sign not falling into one of the above categories. This should be described in the comments section.

Sampling Procedure:

1. On each selected sample tree, starting at due North, locate a buttress root (a lateral root at the root collar). Locate a second buttress root on the opposite side of the tree or as close to the opposite side as possible.

2. Excavate the two roots to a distance of approximately 3 feet. Remove the soil from the top and both sides of the roots.

   A. Hardwoods: Examine root surfaces for dead or sunken bark. Dead bark will appear moist and darker brown to black in color compared to healthy. Examine surface for presence of black to brown shoestring-like rhizomorphs. Rhizomorphs are structures produced by the root pathogen Armillaria mellea and are 1 to 3 mm wide and can be oval, round, or flattened in appearance. They are usually attached fairly tightly to the bark surface. Symptoms and signs will be recorded on the data sheet.

Where a dead, or apparently dead, patch of bark is encountered, remove a plug of bark down to the wood with a 1.25-inch arch punch. If a hatchet is used, a wedge of wood approximately 1 inch long by 1 inch wide by 1 inch deep should be taken. Look for mycelial material or rhizomorphs in the bark or on the wood. Mycelium will be creamy to white and fairly leathery in consistency. Rhizomorphs may be mahagony to black in color. If no mycelium or rhizomorphs are encountered proceed to take a sample 6 inches distal to the necrosis. Note that all four samples from a tree may be taken in the arch punch together, then pushed out into the labeled bag for that tree; the samples do not need to be labeled or packed separately.

B. Conifers: Examine the root surface, especially on pine, for dried resin or the adherence of soil to the root. Using a knife, remove bark from the root down to the wood. Examine for symptoms of resin soaking, stringy white decay, and black to blue-black coloration. The wood of a healthy root will be white. The root collar zone should be examined in the same manner. Symptoms and signs will be recorded on the portable data recorder.

Where symptomatic (resinous, decayed, or black-stained) roots are found, remove root samples with the punch or hatchet as described in hardwood section above.

3. On roots where no apparent symptoms occur take a sample 6 inches from root collar and another 6 inches further down root.

4. Replace soil about roots.

5. The four root samples from each tree (i.e., two arch punch disks or hatchet wedges from each of two roots) will be placed in a ziplock bag or similar container. Bags will be marked with all pertinent plot and tree information and date. Samples must be maintained at cool temperatures, $<65\,^{\circ}F$, to prevent death of any fungi which are present.

11.3 QUALITY ASSURANCE

Specific QA information related to this indicator has been consolidated into the overall 1991 FHM program Quality Assurance Project Plan (Byers, 1991).

11.4 LOGISTICS

11.4.1 Field Personnel Requirements

One field crew member will be required for sampling.

11.4.2 Training

Training will consist of classroom instruction on sampling method and root disease symptom recognition and a field demonstration of sampling techniques.

11.4.3 Estimated Time on Plot

Two hours.

11.4.4 Transportation Requirements

Transportation will be required for training, field work, and debriefing.

11.4.5 Equipment and Consumable Supply Procurement Needs

Shovel - one per crew

Mattock - one per crew

Axe or hatchet - one per crew

Knife - one per crew

Arc punch (1 1/4 in) - one per crew

Plastic spray bottle - one per crew

Bleach (to be mixed 1 part bleach to 5 parts water)

Labels

Water-resistant markers

Portable coolers for field samples - one per crew

"Blue ice" for field use and for shipping

Boxed coolers for shipping samples

11.4.6 Communication

Protocol to adjust procedures: Crew chiefs will contact the regional coordinator. The regional coordinator will contact S.A. Alexander.

11.4.7 Prep Lab and Analytical Lab Requirements

The laboratory will have the facilities for storage of samples and culture and identification of fungi.

11.4.8 Safety Considerations

All safety policy and procedure requirements of the Logistics Section of this Field Study, and all safety considerations suggested by the field crew leader, and all safety procedures of Virginia Polytechnic Institute and State University will be observed.

11.4.9 Debriefing Requirements

Time required: The field personnel responsible for taking the samples and for sample shipment will be interviewed at a debriefing session at the end of the field season. The time required will be 1 h.

11.4.10 Inventory and Storage Requirements

Adequate refrigeration (<65 °) and storage for samples until shipped to lab is required.

11.5 INFORMATION MANAGEMENT

Systems for sample data recording were developed in the 20/20 study in 1990. The authors are working directly with IM to develop improvements.

11.6 REPORTS

Reports will be provided on training activities, field audits, and data evaluation. The authors will contribute their analyses in the Synthesis Report referenced in Table 1.1.

12. ROOT SAMPLING PROCEDURE FOR EVALUATION OF ROOT DISEASES AND MYCORRHIZAE

S.A. Alexander[a] and B.L. Conkling[b]

Soil organisms, important in the retention and release of nutrients and energy transfer in forest soils, are sensitive to process changes in the forest floor. When the key linkages formed by soil organisms are disrupted, ecosystems become fragile and subject to threshold changes (DeAngelis et al., 1986). Among the important soil biological processes are nitrogen fixation, antibiotic activity and metal chelation, nutrient cycling, material transfer between plants through mycorrhizal hyphae, and creation and maintenance of soil structure through the production of humic compounds and polysaccharide glues (Perry et al., 1989). Some measure of species composition is important to help discern and interpret the categorical quantitative changes reflected in microbial biomass measurements. Initially, measurements of key soil biological variables will be used to establish a baseline. Measurements of variables relating to mycorrhizal fungi, soil microbial biomass, and soil respiration are among the initial components of interest.

12.1 OBJECTIVES

A. Determine whether or not the root collection method (proposed for pathogen testing), as described by Alexander (1989), can be used to obtain samples appropriate for morphological determination of mycorrhizal fungi. Expected outputs are the data to answer the above question, and preliminary data describing percent mycorrhizal infection.

B. Conduct the required literature work and information synthesis in anticipation of a soil biological processes pilot study in FY92.

[a] Virginia Polytechnic Institute and State University, Blacksburg, VA
[b] University of Nevada, Environmental Research Center, Las Vegas, NV

12.2 DESIGN

12.2.1 Plot Selection

The Nutrient Cycling Demonstration plots in Alabama will be used for this measurement. The samples will be taken from any subplot with two loblolly pine trees selected as sample trees.

12.2.2 On-Plot Sampling Scheme

Samples will be taken off-plot. One soil-root sample associated with each of the subplots with two loblolly pine sample trees will be collected. The sample will be located near the first sample tree in such a manner that it will maximize the number of tree root systems sampled. A square area 30.5 centimeters (12 inches) is chosen. Within this square, a 76-millimeter (3-inches) diameter by 152-millimeter (6 inches) deep core is taken through the litter layer (Marks et al., 1967). All of the core is then placed in a labeled plastic bag and sealed. The remaining duff layer is then removed from the square and a 0.3 cubic meter (1 cubic foot) sample of soil is removed to a 1 square meter plastic sheet for evaluation. All pine root segments 0.32 centimeters (.12 inches) in diameter or larger are separated and placed in a plastic bag that has been labeled for identification. The remaining soil will be returned to the excavation hole. The root and soil samples are placed on ice and transferred to the Forest Pathology Laboratory at Virginia Tech, Blacksburg, VA, each week for isolation and identification of any root pathogens (Alexander, 1989) and evaluation of ectomycorrhizae. Time on plot to collect samples is estimated at 2 hours.

Samples received at the lab will be logged in and the root samples will be evaluated for root disease symptoms, and isolates (Schenck, 1982) will be taken from symptomatic roots. The large roots will be removed from the soil sample to be evaluated with the root sample. The soil samples will be shaken in a 2-millimeter sieve to separate the organic matter from the soil. Ectomycorrhizal roots will be placed in water in standard 16 x 100-millimeter petri plates and examined under a dissecting microscope and the active ectomycorrhizal tips counted. (Harvey et al., 1976).

12.3 QUALITY ASSURANCE

Specific QA information related to this indicator has been consolidated into the overall 1991 FHM program Quality Assurance Project Plan (Byers, 1991).

12.4 LOGISTICS

12.4.1 Field Personnel Requirements

One field crew member will be required for sampling.

12.4.2 Training

Training will consist of classroom instruction on sample location and sampling method and a demonstration in the field of the technique. Time required is approximately 1 hour for each.

12.4.3 Estimated Time on Plot

Two hours.

12.4.4 Transportation Requirements

One vehicle will be required but transportation sharing will be acceptable.

12.4.5 Equipment and Consumable Supply Procurement Needs

Measuring tape (1 meter) - One per crew.
Soil corer (76mm) – One per crew
Shovel – One per crew
Canvas or plastic sheet (1 m^2) – One per crew
Plastic bags (zip-type) – Eight per plot
Labels
Water-resistant markers
Portable coolers for field samples – One per crew
"Blue ice" for field use and for shipping

Boxed coolers for shipping samples

12.4.6 Communication

Protocol to adjust procedures: Crew chiefs will contact the indicator coordinator (S.A. Alexander).

12.4.7 Prep Lab and Analytical Lab Requirements

The laboratory will have the facilities for storage of samples and culture and identification of fungi.

12.4.8 Safety Considerations

All safety procedures recommended by the FHM program and Virginia Polytechnic Institute and State University will be followed.

12.4.9 Debriefing Requirements

Time required: 1 hour.

12.4.10 Inventory and Storage Requirements

Adequate refrigeration for samples until shipped to lab is required.

12.5 INFORMATION MANAGEMENT

The authors will prepare an adequate quantity of labels for the field crew. The authors will manage sample and laboratory data on hard copy and personal computers. The data will be forwarded to the FHM Information Management System as it is acquired.

12.6 REPORTS

12.6.1 Reports

A. Reports will be provided on training activities, field audits, and data evaluation.

B. The anticipated result of the literature work is a pilot study proposal which meets the research indicator development criteria described in Knapp et al. (1990).

C. The authors will participate in analysis and reporting of results in the Synthesis Report referenced in Table 1.1.

13. VEGETATION AND HABITAT STRUCTURE AS INDICATORS OF BIOTIC DIVERSITY

S. Cline[a]

Maintenance of biotic diversity is an assessment endpoint within EMAP-Forests. Biotic diversity is at risk from six major types of threats: direct population reduction, physical alteration of habitats, chemical pollution and solid waste pollution, global atmospheric change, introduction of alien species, and cumulative or multiplicative effects of interactions among these major threats (EPA, 1990). Monitoring effects due to physical alteration of habitats will be the initial focus of EMAP-Forests because, while the effects of global atmospheric change are potentially more serious and widespread, physical habitat alteration is an immediate concern and may exacerbate the potential impacts of future atmospheric change (Figure 13.1). Furthermore, habitat alteration or destruction was identified as the greatest threat to diversity of birds, perhaps the best studied vertebrate taxon (EPA, 1990).

The Landscape Pilot is part of an overall effort to select, develop, and test indicators of the status and extent, trends, and risks to forests of the United States. Numerous candidate indicators of compositional, structural, and functional aspects of biotic diversity might be measured depending upon the objectives of the monitoring program (Noss, 1990). Given an initial emphasis upon effects due to physical alteration of habitats, the area, range, pattern, and structure of land use/land cover types and animal habitats are leading candidate response indicators (Figure 13.2, Table 13.1). It may be necessary to monitor a suite of these response indicators to make a comprehensive assessment of biotic diversity of forests.

[a] ManTech Environmental Technology, Inc., Corvallis, OR

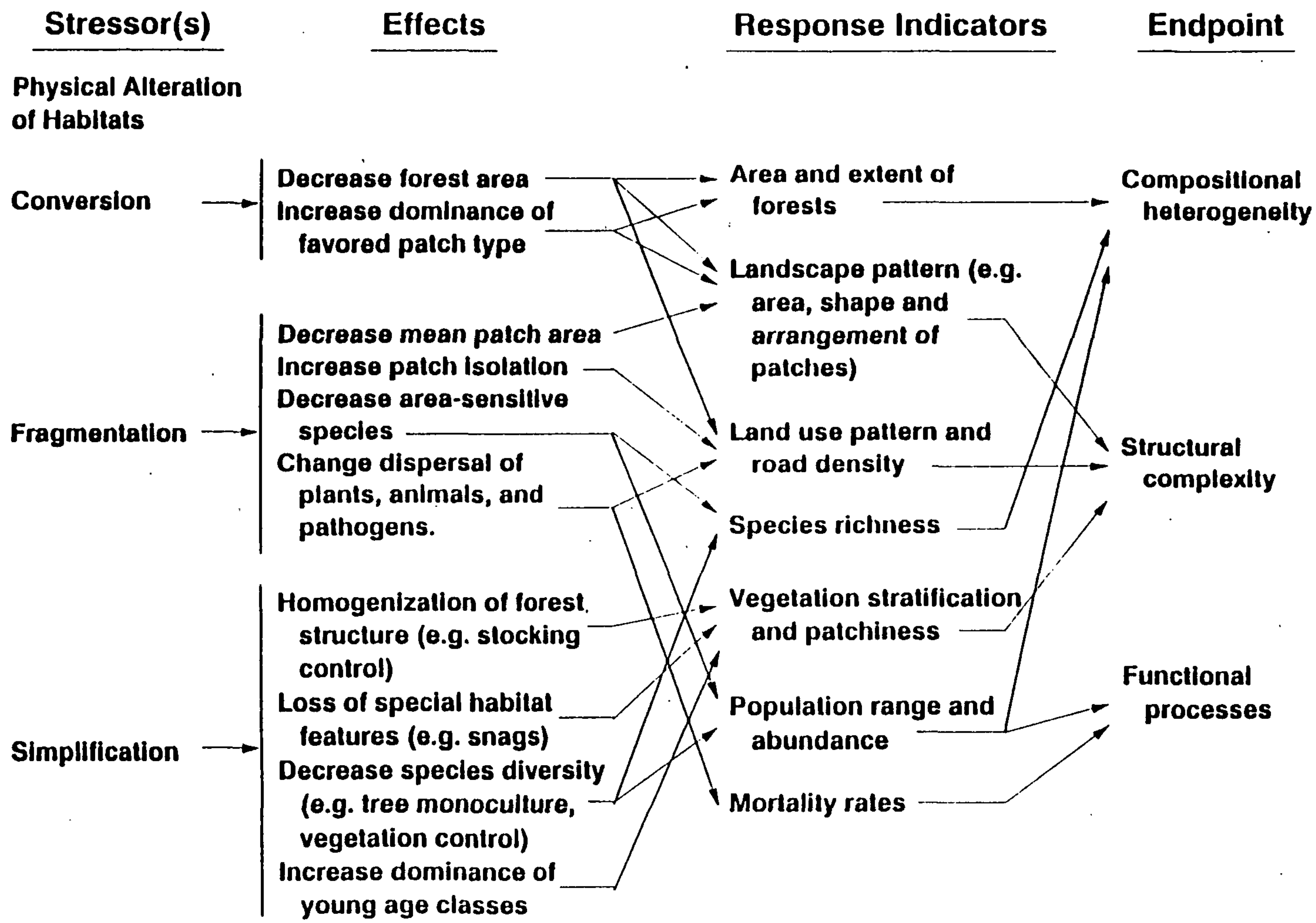


Figure 13.1. Relationship of Stressor, Response Indicator, and Biotic Integrity Endpoint. The stressor, physical alteration of habitats, is considered the most serious immediate threat to biotic diversity in the United States (EPA, 1990).

	Organization level		
	Landscape / region	Community / ecosystem	Population / species
Purpose	Provide extrapolation units for region	Provide check of representativeness of plot data for coarse patches Provide extrapolation unit for internal features of fine patches	Provide ground-truth for external features based on large-scale photos Provide data not accessible from remote sources Provide data to develop relationship between internal and external patch features
Focus	Coarse patch delineation and arrangement	Fine patch delineation based on external features of overstory	Fine patch characterization based on internal features of overstory and understory
Data source	Satellite and small-scale photo imagery	Large-scale photo imagery	Ground measurements on plots
Response indicators	See Table 14.1		

Figure 13.2. Relationship of Response Indicators for Different Organizational Levels of Biotic Integrity.

Table 13-1. Response Indicators of Biotic Integrity

A. Coarse patch delination – Landscape/region level – (by source and person/organization)

Remote-based variables (from small-scale (1:45,000) photos/EPA Environmental Photographic Interpretation Center)

- Forest area by class (conifer/deciduous/mixed)
- Land area by use type
- Landscape pattern (area, shape, juxtaposition, and connectivity of patches)

B. Fine patch delineation based on external features – Community/Ecosystem level (by source and person/organization)

Remote-based variables from large-scale (1:6,000 or 12,000) photos/Hermann and EPA Environmental Photographic Interpretation Center)

- Number of vertical strata
- Understory cover and composition in gaps
- Tree density and height
- Overstory cover, roughness, and patchiness
- Forest area by class (conifer/deciduous/mixed)
- Forest type (Society of American Foresters System)
- Location and area of ecotones
- Land area by use type
- Landscape pattern (area, shape, juxtaposition, and connectivity of patches)

C. Fine patch characterization based on internal features – Population/species level (by source and person/organization)

Ground-based variables from pole and quadrat methods/Cline

- Profile of understory vegetation cover
- Patchiness of understory vegetation cover
- Canopy cover
- Species and growth-form composition
- Species richness

Ground-based variables from 24-ft radius subplots/FIA

- Tree species
- Tree diameter and basal area
- Tree density

13.1 OBJECTIVES

Within the Landscape Pilot, the objectives for the vegetation structure indicator are as follows:

1. To test the operational feasibility of measuring vertical and horizontal vegetation structure with a point quadrat (pole) method.

   RATIONALE: Within EMAP the need to monitor biotic diversity was identified. A vegetation profile indicator was proposed originally to provide better assessment of non-tree, understory vegetation, which comprises most of the plant species diversity in forests, is more sensitive to environmental gradients, and has higher turnover rates and thus a potentially faster reaction time to stress than trees.

   Furthermore, vegetation profile is an important aspect of wildlife habitat structure, which was appealing because monitoring animal habitat in EMAP may be a cost-effective alternative to directly monitoring animal populations. The pole method is an adaption of a proven method used by Short (1990) to ground-truth habitat layers estimated from aerial photos. The method measures quantitatively the vertical and horizontal arrangement of vegetation cover by species and growth form. We limit our measurements to the lowest 10 M of the understory for two reasons: (1) wildlife studies show a need to define finer divisions of strata near to the ground as compared to the overstory (Karr, 1968, Willison, 1974), and (2) data on the tree stratum is collected on the plots by other crew members.

   In 1990 the pole method was tested. Several adjustments have been made for 1991 that require testing: (1) In order to better estimate spatial variability, sampling points will be established on all four subplots (1990 – 2 subplots), (2) in order to save time, data will be recorded in 20, 0.5-meter intervals (1990 – 30, 1-foot intervals), and (3) in order to better estimate plant diversity, species will be recorded (1990 – growth form).

2. To test the operational feasibility of measuring the floristic structure of forest stands using an area quadrat method.

   RATIONALE: *a comprehensive assessment of the biotic diversity of forests requires a* reliable determination of plant species composition, including cryptogams. For example, the reaction of plants to different environmental factors, competition, and disturbance varies on a species-specific basis (Daubenmire, 1959). Furthermore, one can derive structural and functional aspects of vegetation based upon the species present (Mueller-Dombois and Ellenberg, 1974). Finally, more plant species and assemblages can be examined as potential ecological indicators when the species composition of sites is adequately represented. The most abundant plant species at a site, while greatly influencing biomass production and nutrient cycling, are not necessarily the most sensitive indicators of environmental conditions, stress, or change (Poore, 1955; Daubenmire, 1968).

Although floristics data is collected with the point quadrat (pole) method, the primary focus of the method is estimation of the vertical and horizontal structure of vegetation cover. Thus the pole method may not adequately sample floristic structure. For example, how well floristics data from the pole method fully represents the species composition of the site is unknown. Consequently, an alternative area quadrat method for measuring the structure of forest vegetation will be evaluated for use in EMAP. A difficultly in determining plant species composition is that the number of species sampled (species density) increases with the area sampled up to some asymptote or continuously (Pielou, 1977). Use of a series of successively larger contiguous quadrats allows such species – area relationships of plant communities to be determined (Mueller-Dombois and Ellenburg, 1974). The results will be used as an empirical guide to whether most plant species have been recorded and to estimate the degree that vegetation samples over a certain area represent the total plant species at a site. In addition, results will estimate the area that can be routinely sampled at a site given certain time and manpower conditions.

3. To compare plant species lists and quantities generated from the point quadrat (pole) method with that generated from the nested area quadrat technique.

   RATIONALE: The pole and quadrat methods will provide independent estimates of the composition of vegetation cover. The objective is to determine the relative efficiency of each method with respect to full representation of species composition and to the rate of additional species accumulated per sampling or time unit. Results will be used to select a refined method for estimating floristic structure, separate from or combined with a method for estimating vertical and horizontal structure.

   If both methods fully capture the species present (i.e., an asymptote in species number is reached with increasing number of points or area), the minimal number of points or area that still captures all species can be determined. If a species-area asymptote is reached for only one of the methods, then the degree to which the other method represents the species composition can be determined (e.g., 80% of the species sampled). In both of these situations the relative efficiency of the methods can also be determined; that is, the rates of species accumulation by area, point, and time. It is also possible, or even likely, that neither method will produce an asymptotic species-area curve due to self-imposed time limits for sampling. For example, the point method has been allotted 30 minutes per subplot or 2 hours total per plot and the area method has been allotted 60 minutes per subplot or 4 hours. In this case, the relative efficiency of the methods can still be determined.

4. To determine when predictable relationships exist among ground- and remote-based measurements of vegetation structure.

   RATIONALE: We will test whether certain structural and compositional elements of forests – for example, overstory cover and composition, tree and snag density, height, percent coniferous/deciduous, number and position of vertical strata, ground cover and composition in gaps – can be assessed from large-scale aerial photography (or other remotely sensed data) and their comparability to ground-based measurements. It is hoped that results will justify a reduction in the redundancy of measurement variables and the use of expensive ground-based measurements. It is likely that some ground-based measurements will always be needed to (1) to supply data on response indicators that cannot be assessed remotely (e.g., species identification is unlikely using remote data, especially in the forest understory where most of the species are concentrated), and (2) to provide a ground-truth as relationships between remote and ground measurements are developed. Furthermore, these types of studies will be repeated regionally until a baseline relationship can be established. Finally, the data will be used to determine the relative sensitivity of overstory and understory features of the cover types to natural and anthropogenic stress.

5. To recommend a refined and streamlined measurement system for vegetation structure for 1992.

   RATIONALE: We seek sensitive indicators of forest vegetation structure that can be monitored precisely and cost effectively. Based on results from the previous objectives, we will recommend a subset of the current ground- and remote-based indicators most useful for assessing biotic diversity in a cost-effective manner.

13.2 DESIGN

13.2.1 Plot Selection

The 20 plots selected for the landscape pilot will include a variety of forest types and elevations. Plots will be concentrated in Western Georgia. These sites will present challenging and diverse conditions. Experience at the pilot level with such conditions will indicate operational capabilities and analytical difficulties and prepare us for pilots and regional implementation in other regions of the US.

13.2.2 On-plot Sampling Scheme

The point and area quadrats employ different sampling schemes over the same areas (Figure 13.3). The point quadrats of the pole method will be laid out as a subset of the pattern proposed for measuring PAR (see Chapter 14). Vegetation profile will be sampled on a subset of seven of the 19 points used to sample PAR (Fig. 13.3a). This design will provide the data necessary to analyze the relationship between vegetation profile and PAR.

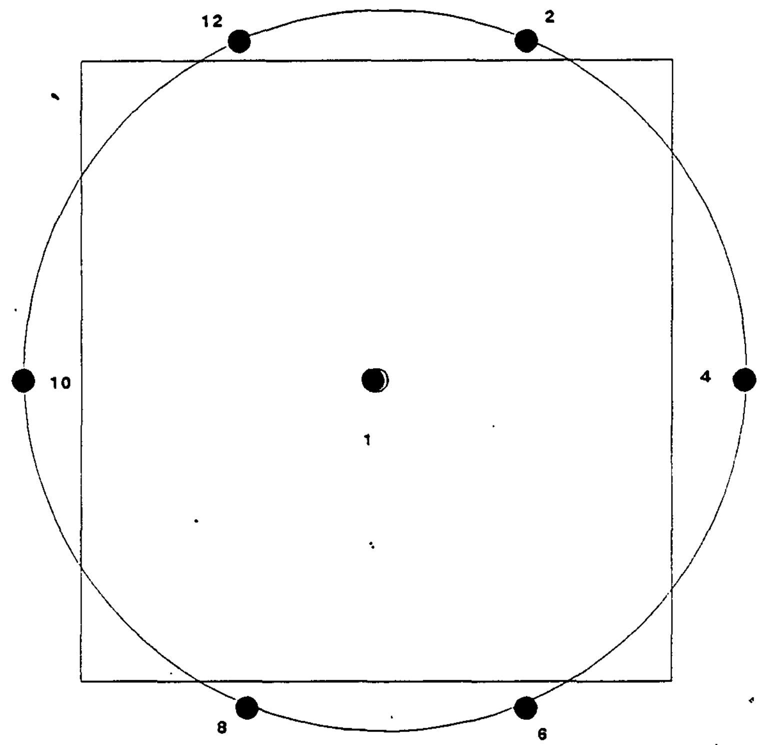
A series of area quadrats of increasing size will be used to sample the vegetation on the same area as the point quadrats (Fig. 13.3b). Plant species with different scale and intensities of spatial pattern can be efficiently sampled using a series of increasing quadrat sizes. Results will be used as a guide to whether or not most species present are sampled. Species lists from the point and area quadrats will be compared.

If all subplots of a plot are in the same land or forest cover type, then the subplots will be measured in order 1 through 4. If subplots are split among different cover types, the subplots will be ordered to ensure that all types are sampled once before any type is sampled twice.

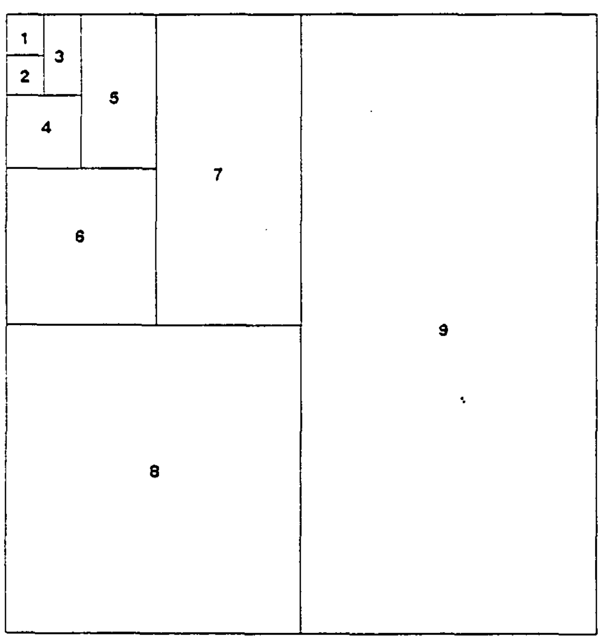
13.3 QUALITY ASSURANCE

Specific QA information related to this indicator has been consolidated into the overall 1991 FHM program Quality Assurance Project Plan (Byers, 1991).

a)



b)



Plot No.	Dimensions (m)	Area (m^2)	Cumulative (m^2)
1	0.75x0.75	0.5625	0.5625
2	0.75x0.75	0.5625	1.1250
3	0.75x1.50	1.1250	2.2500
4	1.50x1.50	2.2500	4.5000
5	1.50x3.00	4.5000	9.0000
6	3.00x3.00	9.0000	18.0000
7	3.00x6.00	18.0000	36.0000
8	6.00x6.00	36.0000	72.0000
9	6.00x12.00	72.0000	144.0000

Figure 13.3. On-Plot Sampling for (a) Plant Quadrats and (b) Area Quadrats in Relation to the Subplot.

13.4 LOGISTICS

13.4.1 Field Personnel Requirements

One person will be mainly responsible for vegetation structure and PAR measurements on the 20-plot Landscape Pilot (see Chapter 15). A primary qualification of this person is the ability to identify, key out, or collect and press plant species found in northern Georgia. This person will be assisted by one or two crew members during plot layout, pole measurements, and possibly for data recording.

13.4.2 Training

The main field botanist and any assistants will be trained. In addition, up to three more people (one each from Rhinelander, WI; Moscow, ID; and TVA) will be trained for a concurrent, off-frame, research project on PAR methodology, in which vegetation structure data will be collected.

The classroom training time will require about 30 min. An overview of the point and area quadrat methods will be presented during this time (10 min each), followed by a question/answer session (10 min). I am assuming that this will be presented to a general audience of all training participants.

Four hours will be needed for field training. First, more detailed instructions for making the vegetation structure measurements will be presented (45 min). Next, the field staff will practice sample point and quadrat lay out, pole and quadrat measurements, and data recording (45 min). Practice will be followed by a testing session during which the trainees will remeasure two test plots (1 h each). These plots will represent different structural and compositional conditions (e.g. deciduous and coniferous, few to many vertical strata, tall vs. short stature, high vs. low plant species richness). Field training will end with an evaluation and discussion session (30 min). Times for each session are approximate and will be adjusted to limit total time to 4 h.

After individualized training on the vegetation structure measurements, the field personnel will work with the rest of the crew during "plot day." Results of plot day will be evaluated to determine feasibility of proposed time, manpower, and sampling estimates, and to estimate remeasurement errors under more realistic conditions. The measurement schemes for vegetation structure will be adjusted accordingly for implementation in the Landscape Pilot.

A debriefing session will be held at the end of the training session to discuss results of "plot day," remeasurement evaluations, and necessary adjustments in measurement procedures for vegetation structure (30 min).

13.4.3 Estimated Time On Plot

The point quadrat method has been allotted 30 min per subplot or 2 h total per plot and the area quadrat method has been allotted 60 min per subplot or 4 h. These estimates assume that the FIA crew will establish the points for the pole sampling. The estimates include travel time between subplots and time necessary to establish the boundaries of the nested area quadrats. The training session will be used to judge the realism of the time estimates and adjustments will be made accordingly. If time estimates are exceeded, sampling adjustments will first be made for the area quadrats measurements. Time will be saved by reducing the total area searched on each subplot. Reduction in the sampling of the point measurements will be made as a last resort, since sampling has already been reduced from 1990.

The person responsible for the vegetation structure measurements will split time with the PAR measurements. The sequence of activities is envisioned as starting with set up of the solar radiometer in a nearby open area. Pole measurements would begin at Subplot 1 upon return to the plot, assuming that the FIA already established the sampling points. Area quadrat measurements would follow. Pole and area quadrat measurement would proceed on Subplot 2 and so on until approximately solar noon, at which time vegetation measurements are stopped and PAR measurements started. PAR measurements begin on Subplot 1 and continue on subsequent subplots until they are completed. At this point vegetation measurements are restarted and proceed until completion.

13.4.4 Transportation Requirements

The field person responsible for vegetation structure measurements will be part of the regional demonstration crew. This person will sample vegetation structure on the first 20 plots selected, beginning in northern Georgia.

13.4.5 Equipment and Consumable Supply List

The pole method requires:

- a telescopic pole capable of reaching 10 meters, calibrated in decimeter increments and read at eye level
- bubble level, affixed to pole to aid vertical positioning
- wire pin markers with flags
- quiver (to hold pin markers)
- hand compass
- loggers tape
- binoculars (to resolve difficulties at top of pole)
- regional/local plant taxonomy handbook
- plant press, labels, indelible ink pens
- access to data recorder or supply of field sheets

The area quadrat method requires:

- collapsable, plastic pipe, sampling frame
- ball or roll of cotton string
- double right angle prism for plot layout
- wire pin stakes with flags and quiver (to hold pin stakes)

- hand compass
- camera for photodocumentation
- loggers tape, metric
- *regional/local plant taxonomy handbook*
- plant press, labels, indelible ink pens
- access to data recorder or supply of field sheets

13.4.6 Communication

The indicator lead will be involved with training prior to data collection. Results of the training session will be discussed by trainers and field personnel and changes in protocols outlined prior to field implementation.

Proposals to make significant changes in vegetation structure protocols once data collection begins will be communicated through the regional coordinator to the indicator lead. Significant changes include reduction in sampling intensity (e.g., fewer plots or subplots sampled, fewer measurements per subplot), changes in time or labor allotments that might reduce data collection on vegetation structure, and changes in prescribed equipment or protocols that might reduce data comparability among plots or reduce data quality (e.g., change in frame size or quadrat area sampled, denial of plant pressing privileges).

Results of program-level QA checks will be reported to the indicator lead in a timely fashion through the QA regional coordinator. Results of QA checks planned by the indicator lead will be communicated directly, and an audit report sent to the regional QA coordinator and the indicator lead. Ongoing data problems, as indicated by measurement errors exceeding quality control objectives, will be reported directly to the indicator lead by the field botanist or through the regional coordinator. Data problems will be discussed with responsible parties to assure improvement.

13.4.7 Preparation Lab Requirements

N/A

13.4.8 Safety Considerations

All personnel working in the field for training, measuring, quality assurance auditing/debriefing will adhere to the safety requirements of the Logistics Section of this Study Plan and of their organization.

13.4.9 Debriefing Requirements

The author will be responsible for participating in debriefing and reporting appropriately to the QA coordinator.

13.4.10 Inventory and Storage Requirements

N/A

13.5 INFORMATION MANAGEMENT

Pole data will be entered into the portable data loggers. The information on the data loggers will be verified nightly by the field botanist. Data not meeting MQOs will be flagged and/or remeasured if possible. Verified data will be down-loaded nightly to a portable computer by the botanist or crew chief. Data transmitted to the central data bank from the portable computers will be verified and validated by the information manager and made available immediately to the EMAP-Forest team.

Area quadrat data will be recorded onto field sheets or entered into the portable data loggers. Area quadrat data on the data logger will be handled as described for the pole data. Standard field forms will be made available to field personnel. Data sheets will also be verified nightly. Field sheets will be maintained by the field botanist or crew chief and copies will be sent weekly to the indicator lead and to the information manager to be entered, verified, and validated. When this is completed the data will be made available immediately to the EMAP-Forest team.

13.6 REPORTS

Results of pretraining and training will be reported. This will be followed by a QA audit report during the field season. Results of QA activities and assessments of data quality will be reported as part of the Landscape Pilot report. The measurement associated with vegetation structure methods will be reported as a component of total variability.

Analytical reports will be prepared on the following topics:

- the operational feasibility of measuring vegetation structure with the pole method and with the area quadrat method,
- the comparability of plant species lists and quantities generated from the pole and quadrat methods,
- the relationships of vegetation structure measurements with each other, with an emphasis upon the relationships among ground- and remote-based measurements of vegetation structure, and to site conditions and others indicators, and
- a measurement system for vegetation structure for 1992, refined and streamlined based upon the reports in 1-3 above.

14. PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR)

J.G. Isebrands[a] and K. Riitters[b]

The goal of the FHM program is to assess the health of forest ecosystems on a national scale. Ecological indicators are needed to assess the effects of climate, pests, and anthropogenic stresses on forest ecosystems, and to monitor the habitat condition of forests, so that assessments can be made (Hunsaker and Carpenter, 1990). One indicator that is potentially applicable to all forest types and that addresses both stress-induced changes in both health and habitat condition is the quantity (e.g., leaf area, leaf biomass) and production efficiency of the forest canopy (Russell et al., 1989). Knowledge of leaf area quantity, distribution, and phenology, coupled with information about canopy efficiency in capturing and utilizing light energy, provides insights about forest health and habitat condition that cannot be obtained from other indicators.

A ratio constructed from canopy measurements and tree growth data known as "growth efficiency" (e.g., Waring and Schlesinger, 1985) has been shown to be an integrative measure (or indicator) of carbon assimilation and allocation patterns. Environmental stresses that change either tree growth or leaf area will often alter growth efficiency, and reduced growth efficiency has been identified as a precursor of insect outbreaks and mortality (Mitchell et al., 1983; Larsson et al., 1983; Waring, 1983). Moreover, leaf area index (LAI) can be a sensitive measure of stress-induced defoliation of the forest canopy and changes in LAI have implications for many ecophysiological processes in forests (Waring and Schlesinger, 1985; Russell et al., 1989). LAI can also be used in modeling efforts in conjunction with remote sensing to predict the effects of global climate change on forests.

[a] USDA Forest Service, North Central Forest Experiment Station, Rhinelander, WI
[b] ManTech Environmental Technology, Inc., Research Triangle Park, NC

Many canopy/growth measures have been suggested for monitoring. These measures range from simple expressions of volume growth per unit of light transmitted by the canopy per unit area per year to more complex formulations that consider phenology, spatial arrangement, and environmental factors such as weather and pollution. However, many of these measures are difficult and time consuming to determine. To be useful for the FHM program, rapid and inexpensive measurements are needed that have potential to be linked to remote sensing approaches. Thus, the general goal of this pilot study is to develop procedures to accomplish those canopy measurements in the context of the FHM program. In the FY91 pilot study, procedures will be tested that allow efficient measurement of PAR.

14.1 OBJECTIVES

14.1.1 General Objective

The general objective of this and related research is to develop and evaluate PAR as an indicator of canopy condition that can be applied in monitoring the health and ecological condition of U.S. forests. This objective includes evaluating alternate means of making the required PAR measurements and developing knowledge that will enable interpretation of data by the FHM program.

The emphasis of the regional pilot and demonstration tests is developing a suite of concurrently measured indicators including PAR in an operational setting. This rationale leads to the following specific objectives of the FY91 field study.

14.1.2 Specific Objectives

1. Develop an efficient and reliable method of using a ceptometer and quantum sensors for measuring forest canopy light (PAR) environments under different stand conditions.
2. Develop and test procedures for linking PAR measurements to vertical vegetation structure (VVS) measurements.

3. Develop and test procedures for linking ground measurements of PAR to photointerpreted measures of stand and canopy attributes.

The pilot field study will help to accomplish the first specific objective above, by (1) evaluating and recommending new or modified field sampling procedures, instrument modifications, and field data handling procedures for measuring PAR with a ceptometer based on 1990 20/20 pilot experiences, and (2) recommending efficient sampling procedures to achieve specified precision for various forest types and stand conditions.

The second objective will be realized by measuring PAR and VVS on common sample points on the subplots on the same day and relating the measurements quantitatively as described in Section 14. For the third specific objective of linking photo- and ground-based measures, the spatially referenced PAR measurements will be correlated with forest canopy attributes derived from the 1:12000 and 1:6000 scale photography as described in Section 17.

14.2 DESIGN

14.2.1 Plot Selection

The PAR measurements will be made on the 20 locations selected for the "Landscape Pilot" project in Georgia. The plot selection rules are dependent on the needs of all participating indicators as well as on logistical constraints. To meet the objectives of the PAR portion of the pilot project, the 20 selected stands should be a representative of available locations (to provide estimates of expected regional variability of terrain, forest type, and stand conditions). PAR measurements in Georgia should be made during a 6-week "window" beginning on or about June 15 after full canopy development and before canopy senescence.

14.2.2 On-Plot Sampling Scheme

At each selected location, the standard FHM four-point subplot cluster will be established (see Figure 3.1). Under-canopy PAR will be measured at each of 19 sample points at each subplot

(Figure 14.1). The 19 sample points in each subplot are on a hexagonal grid overlying the subplot and centered at the plot center. The six outer corners of the hexagon and the center point will be located and marked during plot establishment. The other 12 sample points will be located (but not marked) by pacing between corners. The first sampling point will be at the plot center point followed by the second sampling point at 30° azimuth, 24 feet from the center of the subplot. Subsequent hexagon corner points will be at 30° intervals around the subplot outer circle for a total of six outer corner points (i.e., #2, 4, 6, 8, 10, and 12). The remaining 12 points will be as follows: six additional points (i.e. #3, 5, 7, 9, 11, and 13) will be sampled one-half way between the outside corner points, and six more points (i.e., #14, 15, 16, 17, 18, and 19) will be sampled one-half way between the corner points and the subplot center.

At each sample point, PAR will be measured using a "ceptometer" model SF-80 (*User's Manual*, Decagon Devices, Inc., Pullman, WA). The ceptometer is a linear array of 80 radiometers sensitive to PAR (400 to 700 nanometers) coupled to a data processing and storage device. The standard operating procedures described in the following section and in the methods manual (Decagon Devices, 1989) will result in at least 400 nearly instantaneous radiometer measurements within a circle centered at the sample point. These measurements are taken for about 30 seconds, averaged, and stored (one value per sample point) along with the associated time of day (hours and minutes). The ceptometer also will calculate and store the average percentage of radiometers exposed to a preset threshold PAR intensity.

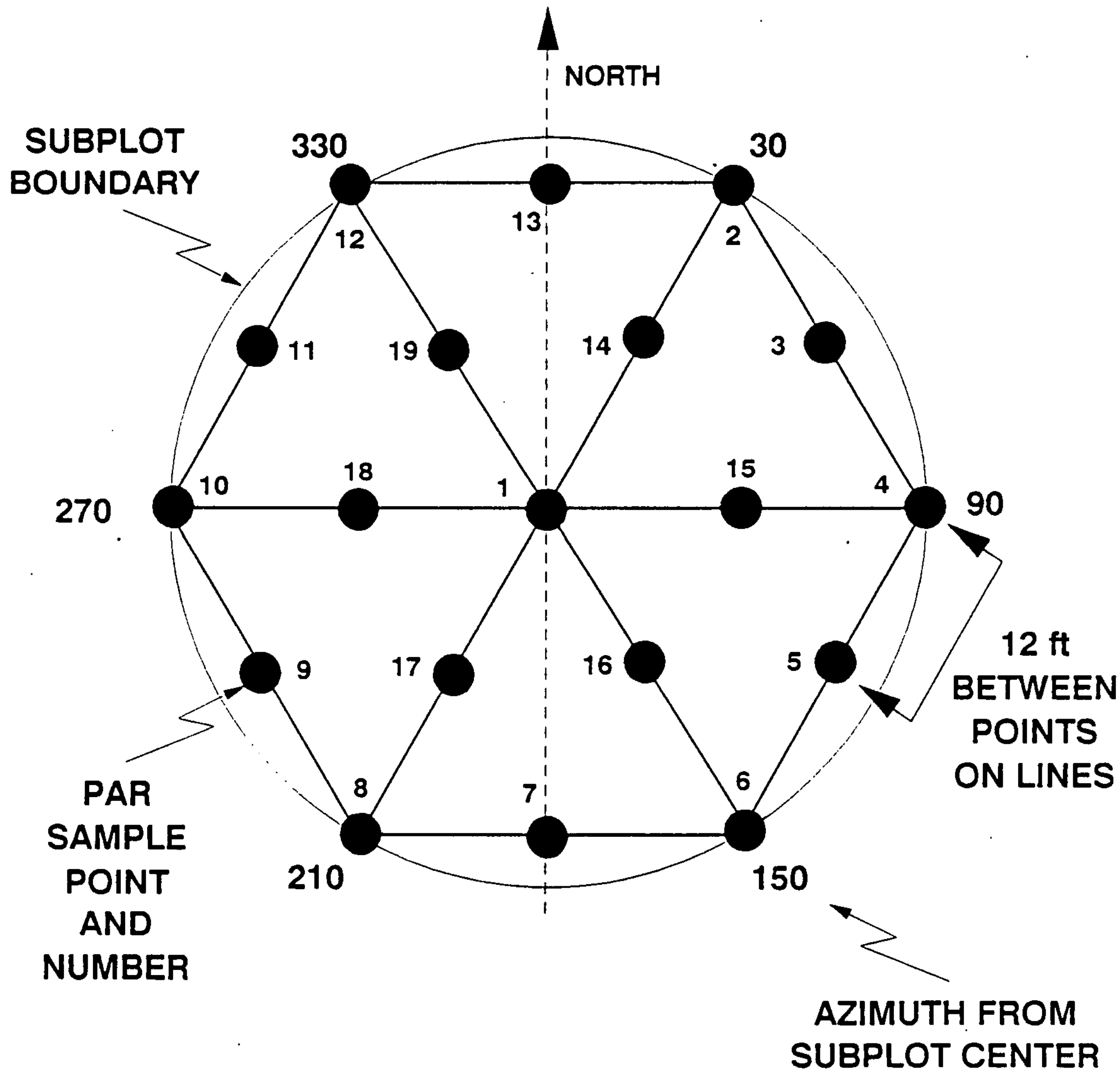


Figure 14.1. Photosynthetically Active Radiation Measurement Plot Layout.

Because incident, and thus transmitted, PAR is affected by ambient cloud conditions, it is necessary to obtain concurrent measurements of incident PAR in an open area. This will be accomplished by establishing a sample location as near as practical to the plot, subject to the location having a clear sky field of view of at least 45°. At this location, two quantum sensors (Li-Cor model LI-190SB or equivalent) mounted on 1 meter PVC poles equipped with a level and attached to a polycorder (Omega Polyrecorder OM-160) will be used to measure and record incident PAR at Ca1-minute intervals during the time that the ceptometer is being operated under the canopy. Measurements will be synchronized between the ceptometer and quantum sensors by synchronizing the time clock on the polyrecorder and the ceptometer. The ceptometer and quantum sensors will be calibrated to a Li-Cor LI-190SB.

The timing of PAR measurements is important because incident PAR and the percentage of PAR transmitted by the canopy vary with sun angle, particularly under cloud-free sky conditions. Variation in incident PAR is accounted for by the concurrent measurements of the quantum sensors. To obtain comparable estimates of the percentage of PAR transmitted by different canopies, it is necessary to account for changing sun angle by fixing either the time (at least) or sun angle (if possible) at which the measurements are made. The PAR measurements will be initiated at 1100 solar time (1200 daylight savings time) and completed by 1300 solar time (1400 daylight savings time) so as to minimize the effects of changing sun angle. Procedures are being developed to permit field crews to determine the appropriate zone time to initiate measurements so as to achieve more comparable sun angles. Standard calculations based on latitude, longitude, date, slope, and aspect will be programmed into the PDRs or PCs (see Section 6) to permit this.

At the end of the day, the field crew leader will transfer the data from the ceptometer and the polyrecorder to a portable computer using software and protocols developed for this purpose. All data then enter the data stream to the mainframe during the daily dump of plot data (see Section 6).

14.3 QUALITY ASSURANCE

Specific QA information related to this indicator has been consolidated into the overall 1991 FHM program Quality Assurance Project Plan (Byers, 1991).

14.4 LOGISTICS

14.4.1 Personnel Requirements

Pretraining:

Sarah Steele, USFS, Rhinelander, WI
Kurt Riitters, ManTech/EPA, Research Triangle Park, NC
Elizabeth Smith, TVA, Norris, TN

Training:

Sarah Steele, USFS, Rhinelander, WI (PAR Trainer)
Ronald Teclaw, USFS, Rhinelander, WI
J.G. Isebrands, USFS, Rhinelander, WI

Crew:

FIA crew member or shared GPS crew member – plot layout
One person – PAR measurements (shared with VHS indicator – see Section 13).

14.4.2 Training Requirements

Time required – 4 hour
- Classroom – 2 hour
- Field – 2 hour

14.4.3 Time on Plot Required

Time required – 2.5 hour
- Plot layout – 0.5 hour (done by FIA or GPS crew member, and shared with VVS, Section 13)
- PAR measurements – 2.0 hour

14.5 INFORMATION MANAGEMENT

The PAR measurements are supported by information management in the following ways.

1. Preparing and testing software and hardware connections to transfer data from the field equipment to the PDRs and PCs, and from those devices to the mainframe. The ceptometer procedures developed for the 1990 field test will be modified slightly and utilized again. The data transfer from the polyrecorder procedures will have to be developed and will be shared with the field crew at training.
2. Programming the polyrecorders to automatically query the quantum sensors and store *time-of-day and ambient* PAR. (Tentative)
3. Managing and maintaining ASCII data files resident on the mainframe, and facilitating access to PAR data and other measurements for data analyses and reports.

The IM function will be supported by the preparation of two reports at the end of the field season:

1. Data editing and verification report, including edit trail
2. Meta-data file to permit archival of crew comments and any other pertinent information about each plot that is not otherwise captured by the IM system

14.6 REPORTS

The following reports will be produced as a result of this study.

1. A training/operator certification report, provided to the project manager and QA personnel (Figure 14.2).
2. A field audit/operator recertification report, provided to the project manager and QA personnel.
3. IM reports as described in Section 14.5.
4. A summary QA report, provided to the project manager and QA personnel.
5. A project report concerning data analysis and significant findings, to be included in the overall project report.
6. Depending on the findings, a research manuscript may be prepared based on the PAR measurements, alone or in combination with measurements at the complimentary research sites.

FHM/EMAP
Certification Form
PAR Procedures

Name ____________
Date ____________
Trainer ____________
Pass: Yes ___ No ___

	Pass	Notes
I. EQUIPMENT OPERATION		
Sampling	___	
Average/store	___	
Erase mistake	___	
Send data	___	
Clear memory	___	
Time of day	___	
Battery change	___	
Calibration	___	
Transport/storage	___	
Safety	___	
Clean probe	___	
II. PLOT PROCEDURES		
Subplot locations	___	
PAR sample locations	___	
Order/number of points	___	
Locating ambient station	___	
Time of day	___	
Rain procedures	___	
Tall shrub technique	___	
Rotation technique	___	
III. PDR PROCEDURES		
Cable attachment	___	
PDR software	___	
Weather entry codes	___	
Comments	___	
IV. BASIC CONCEPTS: PAR	___	

V. TEST PLOT RESULTS

	% TPAR by			
	Crew	Trainer	Difference	Pass
Subplot #1	___	___	___	
Subplot #2	___	___	___	
Subplot #3	___	___	___	
Subplot #4	___	___	___	
Overall	___	___	___	___

Figure 14.2. PAR Training/Certification Form.

14.7 DATA ANALYSIS

The data will be analyzed in several ways to help address the following.

1. Questions about logistics and measurement procedures can utilize the training, audit, and other QA data to develop recommendations for modifying standard operating procedures and to develop DQOs for future tests.
2. Questions related to sampling designs can utilize the experimental layout (nested design with plots, subplots, and sample points as levels) to estimate variance components and develop recommended numbers of samples for future studies.
3. Depending on the plot selection rules, the analysis of variance can also be used to contrast various groups of plots to test hypotheses of interest (e.g., contrasts among forest type, size, or density classes).
4. Exploratory analyses of associations between point- and plot-level measurements of PAR and other ground-based indicators can help to elucidate the inter-relationships among various indices of forest condition and serve to direct future studies.
5. Exploratory analyses of associations between spatially referenced PAR measurements and the photointerpreted measurements of site and stand attributes can help to establish the linkages between ground-based and remote sensing measurements and serve to direct future studies.

It is anticipated that the PAR data will be analyzed using the percentage of transmitted PAR (%TPAR) as the response variable of interest. %TPAR can be estimated by a time-referenced ratio of within-canopy ceptometer measurements to ambient quantum sensor measurements. Several estimation schemes will be tested on other sites to develop the appropriate procedure (e.g., ratios of running averages or minute-by-minute measurements, value of logarithmic transformations, etc.).

15. GLOBAL POSITIONING SYSTEM

K. Hermann[a]

In the Landscape Pilot study, and on a limited basis in New England, GPS technology will be used to accurately determine point locations. In both areas, the x, y, and z geodetic coordinates will be determined for the field plot center. In the Landscape Pilot, coordinates will also be determined for ground control locations for high-resolution aerial photography. The establishment of x, y, and z coordinates for the plot center will be useful for the logistical purpose of relocating the same location in subsequent visits and for the information management purpose of accurate sample location.

The ground control coordinates will be used in the rectification process of the aerial photography in order to obtain a planimetrically correct interpretation of the aerial photography which will be acurately defined to a datum. The North American Datum of 1983 (NAD83) will be the datum employed, that will be visible on the photographs. The ground control locations determined during the first few weeks of the pilot operations will be paneled so that the locations can be interpreted from the aerial photography which will be obtained during the third week of operations. Ground control locations after the third week of operations will be referenced to features or reference points that will be visible on the photograph. The photography rectification procedure, done with an analytical stereo plotter, will enable the accurate capture of the characterization delineations and subsequent entry into a GIS.

Accurate GPS coordinate determination requires simultaneous operation of both a base station GPS receiver and a remote, or field, GPS receiver. One person will operate the base station on a known set of x, y, z geodetic coordinates while another person will accompany a field crew and

[a] ManTech Environmental Technology, Inc., Research Triangle Park, NC

record at the plot center and photo control locations. The data from each of the receivers will be run through a set of programs for differential correction in a postprocessing mode at EPA.

15.1 OBJECTIVES

1. To use GPS technology to accurately determine and record the x, y, and z geodetic coordinates of the FHM field plot center.
2. To use GPS technology to accurately determine and record the x, y, and z geodetic coordinates of ground control locations to be used in the rectification of aerial photography interpretations.
3. To establish a procedure for incorporating detailed and landscape characterization data into a GIS.

15.2 DESIGN

15.2.1 Plot Selection

The plots visited should be more remote locations where physical reference points are few so as to test the utility of GPS in such areas. The GPS field activity in the Landscape Pilot should be accomplished shortly before (0 to 3 weeks) the photography is done so that the panels of ground control locations are visible. If too much time elapses between the paneling and the overflight, panels may be lost. Given the tentative flight schedule of Forest Pest Management for the week of July 8th, the Landscape Pilot field activites should begin at least by June 17th.

15.2.2 On Plot Sampling Scheme

In both New England and in the Landscape Pilot, the GPS coordinate determination of the FHM plot center will accurately determine the plot's geodetic position. In situations where a dense canopy will prohibit reception of satellite signals, coordinates will be determined for the nearest available opening. Surveying techniques will be employed to link the GPS coordinate determination location and the plot center. This plot center determination is the only GPS activity on the New England plots.

Two New England crews will be supported with GPS receivers. The base station will be continuously operated by EPA Region I personnel.

Global Positioning System coordinate determination will be done for the FHM plot centers and the ground control locations on the 20 Georgia pilot plots in the Landscape Pilot. In addition to the plot center, there will be a minimum of 8 ground control locations established for each FHM plot area. All of these ground control locations will be paneled or referenced to visible features. The Landscope Pilot GPS field operator will establish coordinates and record data at each of these locations. These ground control locations will be distributed in an approximately 400 hectare circular area around the plot center. At least 4 ground control locations will be placed near the perimeter of the 400 hectare circle in a fairly uniform spacing in order to attempt to establish a good distribution over the area. The locations of the ground control points should be near existing roads or trails for easy accessibility. The locations should also be in the open so that the panels can be observed on the photography. The Landscape Pilot base station GPS operator will operate the base station continuously on a known benchmark location during the day in order to coincide with the timing of the field operator recordings.

15.3 QUALITY ASSURANCE

Specific QA information related to this indicator has been consolidated into the overall 1991 FHM program Quality Assurance Project Plan (Byers, 1991).

15.4 LOGISTICS

15.4.1 Field Personnel Requirements

In the Landscape Pilot, the staffing requirement is for two people capable of working in the woods and of being trained in the use of electronic instruments for a 7 week period during the summer. One of these individuals would accompany a crew to the 20 pilot plots selected from the set of Nutrient Cycling Demonstration plots. This person will take GPS readings at the plot center and the ground control point locations. These ground control points will be paneled where necessary. This GPS operator should be familiar with basic surveying techniques. Ideally, this person will also take field notes for the aerial photography ground truth purposes. Given that additional task, this person should be also be skilled in aerial photo interpretation. Preferably, a photo interpreter could be the field GPS operator in order to gain first-hand knowledge of the area that he or she will interpret.

In New England there is no aerial photography component, therefore, field requirements are for one person to take GPS readings for the plot center only. If surveying is required another person can assist in that task. This activity will take place with two of the New England crews. The base station GPS receiver will be operated by an EPA Region 1 staff person for a number of summer GPS activites. Therefore, there is no requirement for a separate base station operator. The two field GPS operators in New England should both be capable of working in the woods and of being trained in the use of electronic equipment for a 9 week period in the summer. Both of these people should also be familiar with basic surveying techniques. The GPS operator positions should be incorporated into existing jobs because the time requirement is small.

15.4.2 Training

All GPS operators will need to be trained in the proper use of GPS. Training for both the Georgia and New England crews would require several days in the field and would be done in conjunction with the overall demonstration training.

15.4.3 Estimated Time on Plot

In both New England and the Landscape Pilot, the operation of the field GPS receiver will require approximately one half hour for the plot center coordinate determination. An additional half hour may be required if some surveying is needed due to canopy interference with GPS reception at the pilot center location.

In the Landscape Pilot there is an additional time requirement for the field GPS person to record and panel the photo ground control locations for 5 hours per day. The Landscape Pilot base station operator will need to operate the base station GPS receiver continuously for 6 hours at the same site. This base station site is at a location of known geodetic coordinates which must be located.

15.4.4 Transportation Requirements

One vehicle would be shared among the Landscape Pilot GPS crew. The field GPS operator in the Landscape Pilot should also have a mountain bike with a rack for the GPS equipment in order to get around the 400 hectare area.

The New England operations require that the field GPS operator be able to get to and from the starting point for the plot by vehicle.

15.4.5 Equipment and Consumable Supply Procurement Need

Equipment needs consist of the GPS equipment and supporting materials and tools. Three remote GPS receiver units (two for New England and one for the Landscape Pilot) and a base GPS unit for the Landscape Pilot are required. The New England base GPS unit is already in place. Each field crew requires a laptop computers with a modem and 20 megabyte hard disk. These laptops will be used to store transferred data from the GPS unit each day. The modems will be used in the transfer of the daily GPS recording, stored on the laptop, to the EPA host computers. Sixty 4 x 4 foot black plastic sheets (6 mil) with four inch wide 'V's painted in white are needed for paneling. Eight stakes for each panel are required. Each field crew needs a 30- to 50 meter measuring tape, an inclinometer for surveying requirements, and a 3-5 meter height pole for attaching the GPS field receiver, and a compass. Additionally, plastic protective covering for photographs and computer plots are needed. A mountain bike and a rack for the GPS unit and panels are needed for the Landscape Pilot.

15.4.6 Communication

There should be some type of communications device for communication between the GPS crew members in the Landscape Pilot. There is no communication requirement for New England.

15.4.7 Debriefing Requirements

Debriefing would require 1 day for the base station and each field operator.

15.4.8 Inventory and Storage Requirements

Storage of GPS units, laptops, and other field equipment is needed to prevent damage in transport and when they are not in use during the field season.

15.5 INFORMATION MANAGEMENT

15.5.1 Electronic Data Recording Capability

The time and plot referenced location need to be recorded for each GPS reading on a PDR because the GPS polycorder does not handle this. All GPS data recordings will be captured on the GPS polycorder device for each day's reception.

15.5.2 Description of Codes

Unique plot-referenced GPS site location codes will be established with file-naming conventions for each hexagon.

15.5.3 Explanatory Text to be Used in Help Screens

Menus are available with GPS unit polycorders. Menus and software are also available for the laptop.

15.5.4 Order of Data Collection Within Field Sampling Activity

GPS field and base reception of coordinates in 3-D on the GPS polycorder, then after the day's field work, there needs to be a transfer of the day's data to the laptop computer with specific naming conventions, and finally transporting by modem to the VAX or temporary storage of the data on floppy disk. Nightly recharging of the GPS polycorder is needed.

15.5.5 Data Security Requirements

Plot center coordinates are confidential information that will not be made public access.

15.5.6 Computer Hardware and Software Needs and Availability for Data Quality Assurance, Summarization, and Analysis

A PC with software is required to determine satellite availability, for postprocessing the data, and for datum conversions. This PC has already been obtained and is located at the EPA in Research Triangle Park, NC.

15.6 REPORTS

Data will be reported in the manner described in the general section on Data Reporting. Contributions will be made to the QA report, the Methods Manual, and the Field Study summary report.

16. HIGH-RESOLUTION AERIAL PHOTOGRAPHY

K. Hermann[a]

The purpose of the aerial photography component of the Landscape Pilot study is to evaluate the utility of high resolution aerial photography in the Tier 2 sampling process and provide materials for the linkage of Tier 2 and Tier 1 indicators. In the pilot study effort, the logistical implications and the informational contributions of the photography will be examined.

The high-resolution photography will be used to characterize the landscape of the field plot locations and associated surrounding area. Specifically, the landscape characterization will be performed on a 400 hectare circle centered on a field plot. The characterization includes interpreting and mapping with a detailed classification of both the land cover and land use. This classification is an enhancement of the EMAP-Landscape Characterization classification and will be performed with 1:12000 scale color infrared aerial photography.

The characterization derived from the high-resolution photography will provide an opportunity to develop linkages between field measurements, the remotely sensed interpretations of landscape processes and Tier 1 landscape indicators. Such a linkage is not as apparent between the 40 square kilometer landscape characterization and the field measurements because of the lower resolution of the remote sensing materials used in covering the broader area. The high-resolution photography will provide an intermediate instrument for the linkage of the field measurements and the larger area characterization by allowing more appropriate changes in scale.

High-resolution photography will be used to make specific interpretations in addition to the landscape classification and mapping effort. These interpretations will be made with 1:6000 scale

[a] ManTech Environmental Technology, Inc., Research Triangle Park, NC

color infrared photography which will be obtained for a smaller area around the center. These specific interpretations may provide significant information about forest ecosystem condition which is useful in connection with vegetation structure and wildlife habitat indicators as well as stressor indicator measurements of pest populations. The 1:6000 scale photo interpretations will be performed in a 100 hectare circle centered on the field plot and will focus on field measurement locations.

The USFS Region 8 Forest Pest Management (FPM) group will obtain summer aerial photography at the scale of 1:12000 in the State of Georgia for the purpose of detecting pest conditions at the FHM plot locations. In addition to the 1:12000 scale, FPM will obtain 1:6000 scale photography for the 20 plot locations in the Landscape Pilot.

The combination of the high resolution aerial photography interpretations and the GPS coordinate determination (Section 15) allows for the precise mapping of the field plot location and broader 400 hectare photo plot. An analytical stereo plotter will be used in the mapping procedure to obtain accurate digital results of the interpretations. This precision mapping facilitates the entry of the data into a GIS. Subsequently, this process facilitates the analytical and change detection tasks that will be eventually performed with the data.

16.1 OBJECTIVES

1. To provide detailed landscape characterization information derived from high resolution aerial photography for supporting the development of some response indicators.
2. To use the landscape characterization information for examining associations with response indicators and some remotely sensed indicators. The study will provide materials for investigating techniques to determine the linkages of field measurements and landscape characterization information.
3. To provide high resolution aerial photography for remotely sensed indicators such as forest pest data derived from photo interpretation.

16.2 DESIGN

Aerial photography will be obtained for each of the Landscape Pilot FHM field plot locations. At each of these field plot locations stereo triplet photo coverage will be obtained at both 1:12000 and 1:6000 scales. The coverage of each of these scales will be centered on the FHM field plot.

Interpretations of the 1:12000 scale photography will use an enhanced classification of the EMAP-Landscape Characterization classification scheme to classify a 400 hectare circular area centered on the field plot.

Interpretations of the 1:6000 scale photography will focus on specific locations that are coincident with the PAR, vertical vegetation, and wildlife habitat indicator sampling locations.

Interpretations of disturbance, defoliation, and mortality will also be made within a 100 hectare circle around the field plot.

The design layout of the two photoplots is shown in Figure 16.1. In the top diagram of this figure, the area "A" represents a 40 square kilometer hexagon with respect to the two photoplots. In the middle diagram, "B" illustrates the 400 hectare photoplots with respect to the 100 hectare photoplot, "C", and the FHM field plot, "D". The bottom diagram shows the FHM field plot.

16.2.1 Plot Selection

Twenty field plot locations will be chosen in Western Georgia that represent several different forest cover types and terrain conditions. The plots will be selected from the set of Nutrient Demonstration plots. Selection will be determined from examining existing photography of the field plot locations and from the written descriptions of the plots which will be provided by the FIA plot establishment crews which will visit all the Georgia plots in March, April, and May.

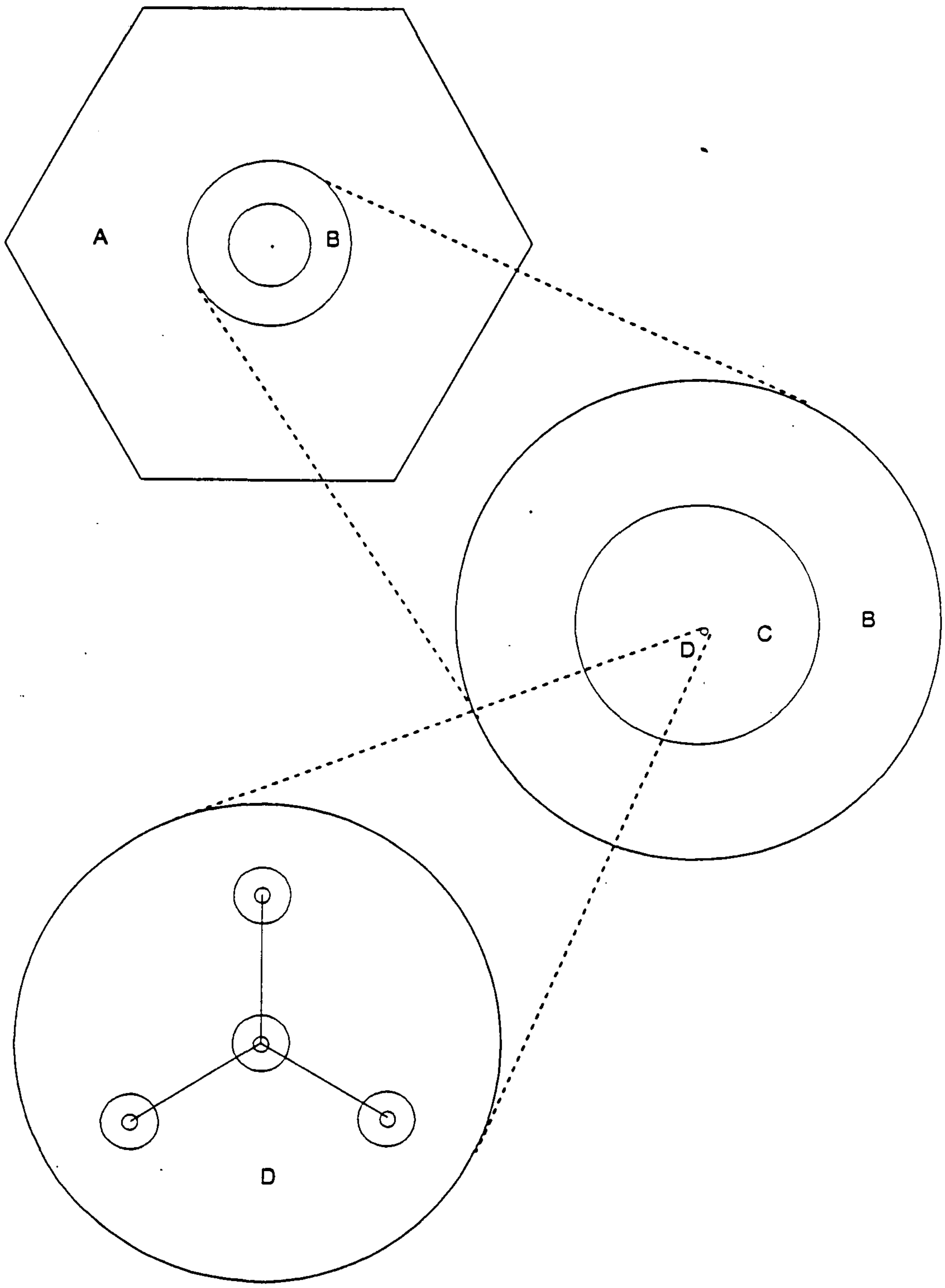


Figure 16.1. High-Resolution Aerial Photography Plot Design. (A) 4000 hectare EMAP hexagon. (B) 400 hectare 1:12,000 aerial photoplot. (C) 100 hectare 1:6,000 aerial photoplot. (D) 1 hectare FHM plot.

16.2.2 On Plot Sampling Scheme

The ground truth notes taken in the field should be distributed around the entire 400 hectare photoplot. These locations can be identified by the GPS ground control locator. Ground truth notes should also be taken at the measurement locations for vegetation structure and PAR.

16.3 QUALITY ASSURANCE

Specific QA information related to this indicator has been consolidated into the overall 1991 FHM program Quality Assurance Project Plan (Byers, 1991).

16.4 LOGISTICS

16.4.1 Field Personnel Requirements

One field person is required to take field notes and to make mapping notes of the composition of land cover and land use of the 400 hectare area. This person will be required to take more extensive notes within the 100 hectare area and in particular at the locations of other measurements. The field person should have knowledge of aerial photography interpretation, mapping techniques, and be able to identify most tree species in Georgia.

Several aerial photography interpreters are required for the post field season photo interpretation tasks which will begin after the false color transparencies of the photography are acquired. At least one of the interpreters should also have operational experience with an analytical stereo plotter. All of these interpreters should have extensive experience with interpreting large-scale aerial photography and forest cover types.

16.4.2 Training

The field person will be trained on how to take field and mapping notes, what to identify, and how extensive the notes need to be.

The aerial photography interpreters will be trained with 10 of the 20 pilot photo plots with the enhanced classification. Photo keys will be developed from these 10 photo plots.

16.4.3 Estimated Time on Plot

The estimated time on the 400 hectare area for taking field notes is 3 hours, however, this activity can easily be integrated with the GPS coordinate determination (Section 15) for efficient plot time activities.

16.4.4 Transportation Requirements

The field person will need to get to and from the plot by vehicle. A mountain bike may be useful in getting around the 400 hectare area.

16.4.5 Equipment and Consumable Supply Procurement Need

A notebook for field notes is required. Additionally, sets of existing photography for each of the field plot locations are required with transparency covers. Fine-tipped color waterproof pens for making notes on the existing photography are also required. Computer plots of the 400 hectare area depicting the transportation network and hydrography will be provided with a same scale transparent base overlay of the full Landscape Pilot design. This overlay will indicate the full configuration of the field plot, photo plot circles, and measurement locations.

The post field photo interpretation work will require at least 2 stereoscopes and light tables and 1 analytical stereo plotter.

16.4.6 Inventory and Storage Requirements

The computer plots, photography, and field notes will need to be organized and labeled appropriately for their respective plot locations.

16.5 INFORMATION MANAGEMENT

16.5.1 Paper Field Form

The field notes should be identified by the appropriate plot location, the longitude/latitude EMAP hexagon-ID. The computer plots and the photography will be prelabeled with the same ID system.

16.5.2 Electronic Data Recording Capability

The photo interpretations will be mapped and entered into a GIS via digital capture with the analytical stereo plotter with standard photogravimetric mapping techniques.

16.5.3 Lists of Acceptable Code

Codes will be developed for the enhanced EMAP Landscape Characterization classification. These codes should be consistent with the Characterization's coding conventions.

16.5.4 Description of Codes

Detailed land use, land cover codes, and specific interpretation codes for defoliation, mortality, and such will be developed.

16.5.5 Computer Hardware and Software Needs and Availability for Data Quality Assurance, Summarization, and Analysis

A workstation with ARC/INFO GIS software and an analytical stereo plotter with an appropriate hardware and software interface are required.

16.6 REPORTS

Data will be reported in the manner described in the general section on Data Reporting. Contributions will be made to the QA report, the Methods Manual, and the Field Study summary report. A separate report will detail the procedures used in the aerial photo interpretation and linkages to other indicators.

17. LANDSCAPE CHARACTERIZATION

K. Hermann[a] and R. Czaplewski[b]

The Landscape Characterization group of EMAP focuses on the documentation of the physical pattern of ecosystem components and land uses. This documentation, in the form of GIS coverages, will provide the materials to analyze the pattern and the changes of the pattern over time. The basic products of EMAP-Landscape Characterization will support all of the resource groups with small-scale remotely sensed materials and auxilary digital data. This level of characterization is focused on full hexagon characterization.

The EMAP-Forests component of EMAP will utilize the materials provided by EMAP-Landscape Characterization in the FHM program, however, there will be additional characterization work done jointly between the two groups that will utilize higher resolution remotely sensed materials and will focus more on specifics of the forested ecosystems.

Given that the FHM program is being designed as a multiagency cooperative endeavor, it is desirable that the systematic EMAP grid sampling design be linked within some type of framework to existing forest health and management monitoring programs such as the FS-FIA and FPM programs. Linkages between these existing sampling frameworks can be facilitated through the application of multilevel landscape characterization monitoring.

The first level of the multilevel sample would be designed to permit stratification on landscape features such as landform, and forest/nonforest. Several strata could occur in any one 40 square kilometers EMAP hexagon. Landform-forest-cover delineations would then be used to select a sample framework for high-resolution, second-level photoplots. For example, nonforested strata

[a] ManTech Environmental Technology, Inc., Research Triangle Park, NC
[b] Forest Service Rocky Mountain Forest Experimental Station, Fort Collins, CO

might be sampled at a lower intensity to monitor aforestation, or deal with errors in detecting forest cover on low-resolution aerial images. Habitat, forest type, or other criteria that are expensive to apply to entire hexagons, might be used to provide a framework for developing extent estimates for hexagons from plot-level indicator measurement data.

The second level would be designed for inexpensive remeasurements of a few basic indicators of forest health. For example, tree mortality and defoliation may be measured using high-resolution aerial photography and/or videography. Because high-resolution imagery has a narrow field of view, complete coverage of each 40 square kilometer primary sampling unit with high-resolution imagery is impractical. A second-level sample plot is proposed using 3 to 10 second-level photoplots in each 40 square kilometers first-level sample unit to accurately estimate tree mortality and tree defoliation. These conditions are often rare and not spatially contiguous (although there are many exceptions), and large photoplots would more efficiently quantify mortality and defoliation than smaller field plots. The least expensive indicator would be the number of dead or defoliated trees per unit area (status and extent). However, to estimate the rate of change in mortality and defoliation extent, the number of trees in each second-level photoplot might have to be estimated from the high-resolution imagery, perhaps via subsampling the imagery. Rate estimation requires that each individual sample tree must be found on two dates of imagery taken 12 months apart, possibly requiring a reduction in the size of the second-level photoplots to save interpretation time. Detection error may be significant, especially for large plot sizes, and methods should be adopted to estimate the proportion of dead or defoliated trees that are not detected with interpretation of aerial imagery. It might be desirable to use aerial photography once every 5 to 10 years for estimating forest type, tree heights, tree species, regeneration, fuel loading, habitat type, stocking density, and stand development, and to use aerial videography for the same plots in intermediate years for less expensive measurements of tree mortality and defoliation. An interpenetrating rotation between aerial photography and aerial videography is also possible.

FHM plots would be nested within the framework of the one square kilometer second level plots to take advantage of the annual monitoring for tree mortality and defoliation at the second-level. Disturbance history for each plot interpreted from remote sensing, the need to quantify the error in detecting tree mortality and defoliation with remote sensing at the second level, and would permit extrapolation of FHM indicator data to the more extensive spatial framework. This integration within the extensive framework would also provide a mechanism for comparative evaluation of FIA, FPM, and FHM data.

17.1 CONCERNS

Efficiencies and precision are gained by emphasizing remote sensing, but there is limited infrastructure in place to acquire, coordinate, interpret, and archive this source of data. To ensure consistency and quality, the remote-sensing activities would have to be institutionalized. Ideally, there would be a small number (maybe one) of units that have direct responsibility for this function. The unit(s) might be branches of existing units with related missions, such as FIA, FPM, or State Forestry agencies.

17.2 SYNERGISTIC BENEFITS

FPM currently produces annual assessment reports on insects and diseases in the West. It might be possible to produce these same reports using annual defoliation estimates from high-resolution aerial photography, and less frequent field examinations of FHM plots. FPM might be able to make minor adjustments to its current program to contribute to FHM, while meeting its current objectives in a perhaps more efficient and rigorous manner. Similarly, there are several new monitoring initiatives in the West: detection of possible effects from global climate change, and changes in condition of wilderness areas. It might be possible to design one or two compatible sampling frames that more efficiently serve several different sets of objectives.

The use of the PROGNOSIS model as the baseline for growth and mortality can also be used to validate and improve this model. PROGNOSIS is commonly used by the FS-NFS for their strategic planning (e.g., FORPLAN), and improvement of planning models will directly improve NFS management. As part of Forest Plan monitoring, assumptions used in the planning process must be verified. Models such as PROGNOSIS are regional in nature, and are collections of numerous assumptions on growth and mortality rates that directly affect the land management planning process. Likewise, the use of fuel loading and forest insect and disease risk models as forest health indicators will lead to improvements in those models, with a potential to improve very expensive management actions for fuels, insects, and diseases.

High-resolution aerial photography could be used to reliably interpret forest type, crown closure, and stand development on a sample of FHM photoplots. A subsample of FHM plots could be very useful for labeling or training digital classifiers of satellite data (e.g., Landsat), and for quality control in the production of vegetation cover maps. Another subsample of FHM plots could be used to estimate statistical calibration models that correct for misclassification bias in areal estimates. This would be valuable to national forests and other agencies for reliable mapping of wildland resources in the West, and unbiased aerial estimates used in local land-management strategic planning.

High-resolution aerial photography may be suitable for estimating leaf area index or photosynthetic efficiency, which are measurements related to other potential indicators of forest health. This might be tested in future research studies.

18. AIR AND DEPOSITION

D. Shadwick,[a] R. Baumgardner,[b] and L. Smith[a]

The FHM program Air and Deposition Group has been examining air constituent monitoring data that will have relevance for regional forest health monitoring. Monitoring data from a variety of sources is currently being examined. The data sources include the following: the Acid Deposition System (ADS), the National Acid Deposition Program (NADP), the National Dry Deposition Network (NDDN), and state monitoring systems for wet deposition ions and precipitation amount; NDDN and National Oceanic and Atmospheric Association (NOAA) for concentrations of dry deposition constituents; and the Aerometric Information and Retrieval System (AIRS) and NDDN for hourly ozone concentrations. Only monitoring sites that are in close proximity to forested areas and not located within urban areas have been selected for data summarization thus far.

Relative to the EMAP sampling frame, the monitoring data, in general, is off frame data. For direct application to the FHM program, suitable interpolation and/or summarization of the monitoring data for regions of interest will have to be carried out. Currently, maps of wet deposition ion concentration and deposition amount on an annual basis over large geographic areas are produced by NADP. There are not any corresponding maps for dry deposition constituents. A few interpolated maps of selected summary ozone statistics have been produced and are available. Interpolated maps specific to the FHM program interests have not been produced at the present time.

Recently, the FHM program Air and Deposition Group cooperated with the National Forest Service New England FHM Program to supply summary air constituent information and descriptions for an annual report on the New England region. Sulphate and nitrate ion wet deposition values on an annual and quarterly basis, sulphate and nitrate dry deposition concentrations on an annual basis,

[a] ManTech Environmental Technology, Inc., Research Triangle Park, NC
[b] U.S. EPA, Atmospheric Research and Exposure Assesment Laboratory, Research Triangle Park, NC

and a summary ozone statistic (SUM06 – the sum of all concentrations greater than or equal to 0.060 ppm) on a seasonal (April-October) basis over the history of selected sites were provided in tabular or graphical form. In addition, isopleth maps of 1989 annual sulphate and nitrate wet deposition amount were obtained from NADP for inclusion in the report.

19. CLIMATE

E. Cooter,[a] P. Finkelstein,[a] and S. LeDuc[a]

19.1 BACKGROUND

Climate conditions impact forest health and productivity directly through disturbance phenomena such as windthrow, hail, flooding, or drought events. Secondary impacts are seen in soil building and erosion processes, nutrient cycling and pest and pathogen outbreaks (Kozlowski, 1985; Henry and Swan, 1974; Pickett and White, 1985; Solomon et al., 1984).

The most important ecological characteristic of a disturbance is its time lag or periodicity. When an environmental factor such as temperature or precipitation oscillates regularly, species distributions change until, at some point this factor can no longer be considered a disturbance. Thus, the distribution through time of climate conditions, including natural variability, can be one measure of ecosystem stability (Forman and Godron, 1986; Woodward, 1987).

These events become disturbances (stressors) when they are extreme or their patterns of recurrence begin to change. Catastrophe theory suggests that a gradually changing system (with its characteristics) converges on and crosses particular points. Only a slight change in the immediate vicinity of such a point will divert the system in a quite different direction. Major alterations in landscape development can take place in this way. An abrupt change in the distribution of climatological events is one factor that, alone or in combination with other factors, can push an ecosystem beyond some critical threshold point. For instance, tree species that normally tolerate degraded air quality conditions may experience a precipitous decline when the frequency and intensity of severe winter conditions changes. The determination of the short- or long-term nature of

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[a] Atmospheric Sciences Modeling Division, Air Resources Laboratory, National Oceanic and Atmospheric Administration, on assignment to the Atmospheric Research and Exposure Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC

such changes in climatological variability will influence present status and monitored trends in forest health (Johnson et al., 1988; Adams and Eagar, 1989).

19.2 CAPABILITIES

For the past year, the AREAL Global Processes Research Branch has been investigating sources of climate data and methods of analysis and presentation that facilitate research into climate/forest interactions – particularly those affecting forest health status and trends. This has been an entirely voluntary effort in support of EMAP-forests and the Forest Health Monitoring (FHM) program.

A digitized national database of severe weather related events such as high winds, large hail and tornados has been obtained. A digitized archive of National Weather Service Cooperative weather data has been regularly accessed. A digitized time series of climate division drought index values has been acquired.

Examples of derived statistics such as occurrence of drought, late spring freezes, and cool growing seasons have been computed from these data. Standard climatological products such as maps of mean annual temperature and precipitation have been provided to the New England Forest Health Monitoring (NEFHM) program (Brooks et al., In Press; Brooks et al., In Review).

Additional products have been developed to characterize the spatial extent of climate disturbance phenomena. Figure 19-1 illustrates the reported occurrence of tornados, winds in excess of 50 kts, and hail in excess of .75" diameter across the New England region during the last 30 years. A Geographic Information System (GIS) is then used to illustrate the relationship between these widely dispersed events and potential FHM sampling locations (Figure 19-2). Figures 19-1 and 19-2 show that although many storm events occur over time throughout the region, the probability of noting the effects of these events at a particular forest sampling point is quite small. This illustrates the importance and difficulties associated with constructing accurate landscape-scale characterizations from point observations. The figures also illustrate the potential value of remote sensing products (aircraft and satellite) to the description of forest landscape/climate interactions.

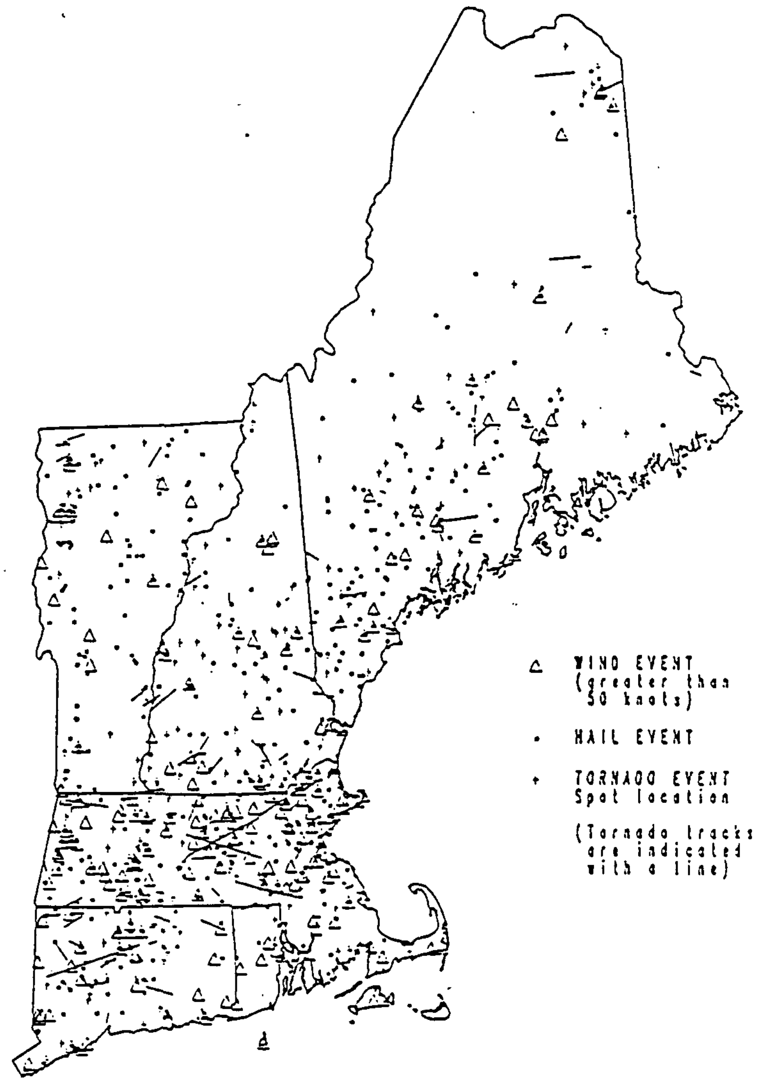


Figure 19-1. Digitized Location of Severe Weather Events. As Reported by the National Weather Service National Severe Storms Forecast Center, Kansas City, Missouri, 1961- 1990.

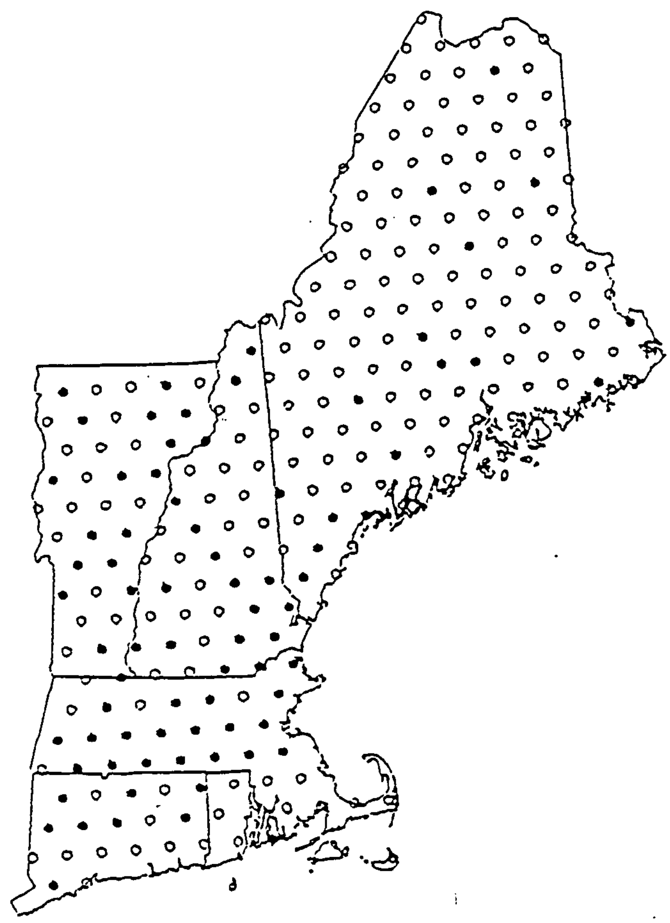


Figure 19-2. Intersections of Digitized Severe Weather Events with NEFHM Program Sampling Hexagons, 1961-1990.

The GIS has also been used to identify those sampling areas of relative climatological stability and stress. Figure 19-3 illustrates for each year from 1981 through 1990, the percent of the New England region that experienced drought (Palmer Drought Severity Index value equal to or less than -3.00), late spring freezes, late spring snowfall, and small growing degree day (GDD) accumulations. "Late" and "small" are defined for each FHM sampling hexagon as a likelihood of the event occurring fewer than once in 20 years. This regional summary is related to the FHM network by highlighting those hexagons experiencing the greatest number of climate stress events. Based on the drought-freeze-snowfall-GDD criteria and the data available, the sampling regions highlighted in Figure 19-4 represent the most climatologically stressful locations within the NEFHM study area for the period 1981-1990.

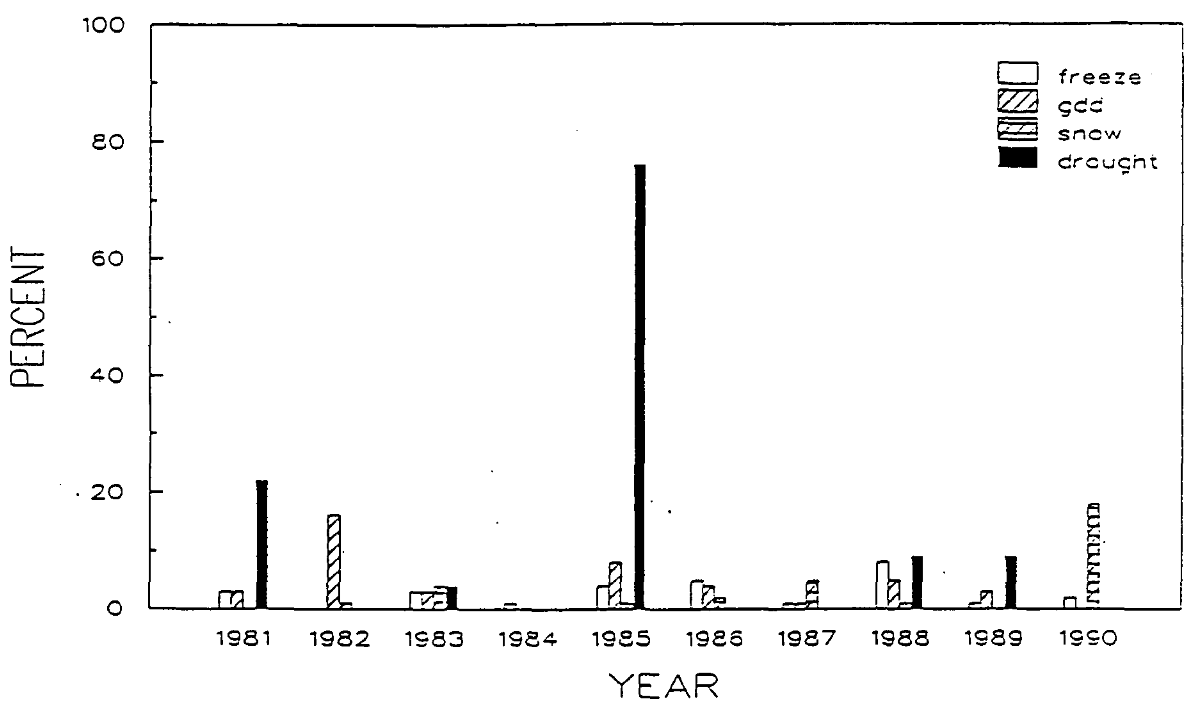


Figure 19-3. Percent of New England Region Impacted by Climate Stress, 1981-1990.

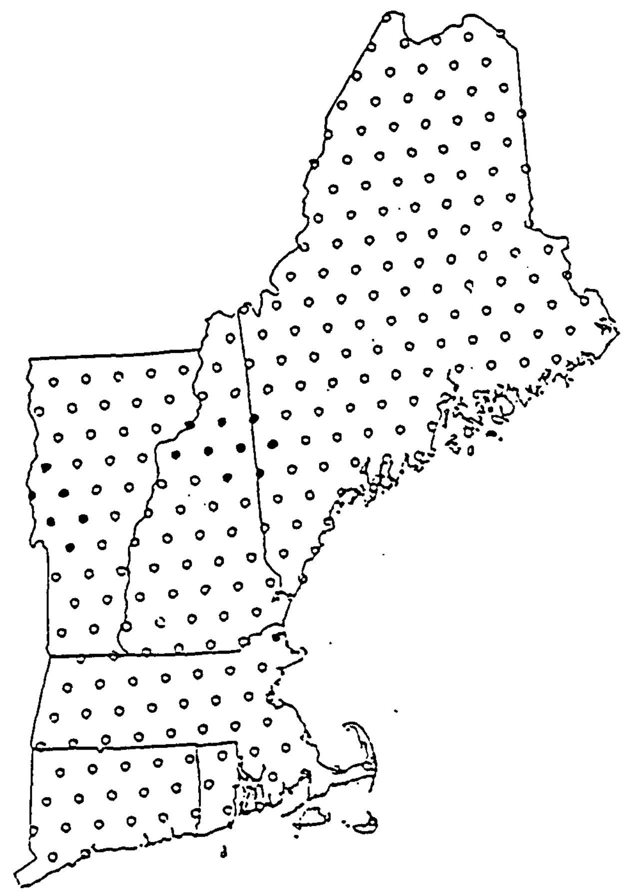
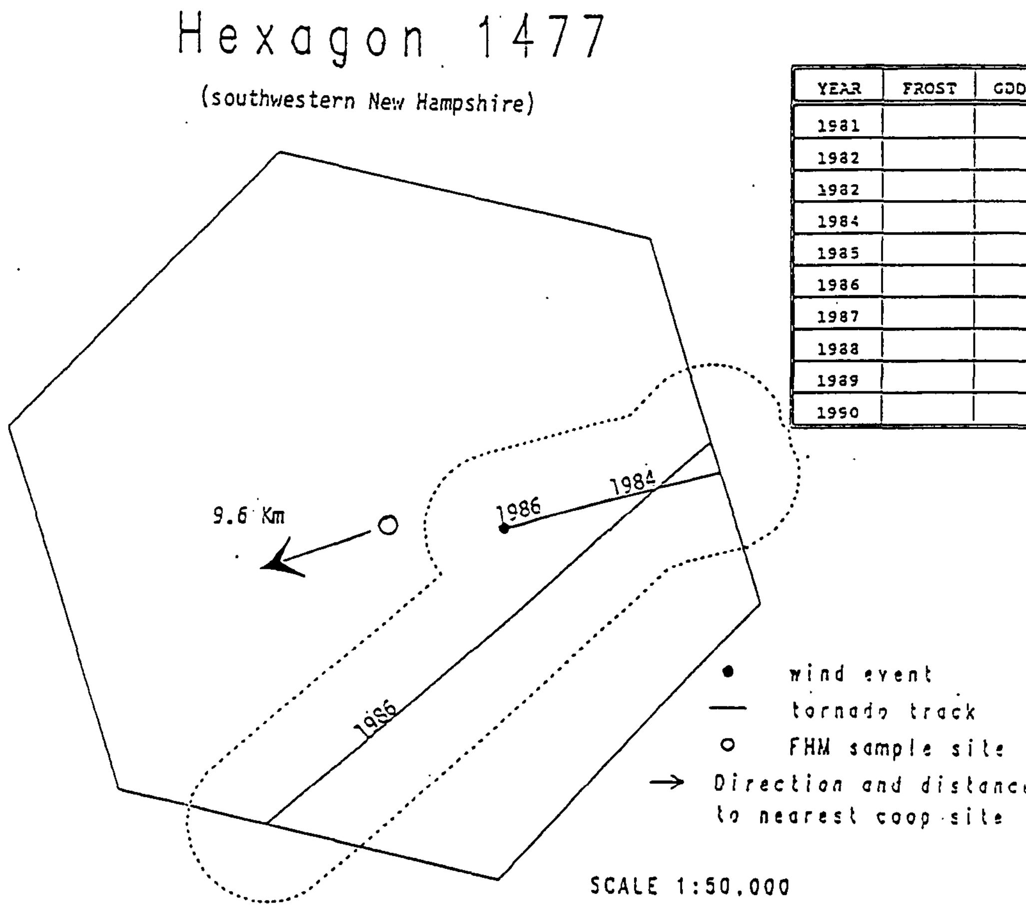


Figure 19-4. Location of Hexagons Reporting Five or More Intersections with Climate Disturbances, 1981-1990.

Finally, climate information for individual sampling hexagons can be used to support associative studies or model development. Figure19-5 illustrates a partial analysis template for a hexagon located in southwestern New Hampshire. Only the climate data are available at this time. To be complete, pertinent FIA and FHM observations must be included as well. The template contains the location of the forest sampling point within the hexagon, the distance and direction to the nearest climate observation location and the location and time of physical disturbance events such as high wind and tornados. Error limits have been estimated surrounding these event locations which reflect imprecision in the National Weather Service digitized record. Stressful climate conditions are summarized in the upper right of the Figure. A filled circle represents a late spring freeze, or cool growing season with a 5% or less probability of occurrence. Drought stress is indicated if at least one monthly PDSI value of -3.0 or less is reported during the year.



YEAR	FROST	GDD	DROUGHT
1981			•
1982			
1982			
1984			
1985			•
1986			
1987			
1988			
1989			
1990			

Figure19-5. Climate Information for a Selected Hexagon, 1981-1990.

19.3 EXPANSION TO THE SOUTHEAST

The assembled and analyzed data are targeted to forest ecosystems of the Northeastern United States. Other geographic regions are expected to require a combination of shared and specialized climate stress information. For instance, while drought frequency and intensity should be an important forest health factor in the South, an index of fire frequency and occurrence could also be helpful. Landfall characteristics of tropical depressions and hurricanes may be useful to the description of coastal forest ecosystem status and trends in Southeastern and Gulf states.

At present there are few limitations to the climatological factors that can either be directly analyzed or indirectly estimated for use by the FHM program. The real value of these products to the program will be determined by the requirements of FHM scientists. Application-specific issues that will need to be addressed before these requirements can be met include: data access; data reduction; selection of spatial algorithms; selection of derived data models (e.g., soil moisture, evapotranspiration); and error estimation. Although general background and sampling season products have been requested and supplied to the NEFHM program, specific analysis needs have not been expressed by FHM participants at this time. The issues just listed can and will be resolved when the level of interest and support for climate-related activities by EMAP-forests and FHM becomes more clearly defined.

20. INDICATOR DEVELOPMENT

T. Strickland[a]

20.1 INDICATOR APPLICATION

The EMAP program seeks to (1) describe current ecosystem status, (2) identify long-term changes in ecosystem status, (3) characterize the components of ecosystem change, and (4) suggest avenues for diagnostic research. To complete these objectives, the program has adopted an indicator-based approach to the assessment of ecosystem condition (Knapp et al., 1990). This approach assumes that (1) indicators of specific interrelationships between ecosystem functions (e.g., rates of nutrient transfer, capacity for nutrient conservation, level of redundancy of function, etc.) are known, (2) indicators can be related within an assessment framework to specific changes in ecosystem condition (e.g., growth, morbidity, mortality), and (3) indicator measurement at a national survey scale is logistically, economically, and technically feasible. When the above criteria for indicators are not met, a procedure has been established to evaluate options for the development of new indicators, to assess their potential utility within the existing assessment framework, or to evaluate the need to develop new or additional assessment frameworks.

The FHM program will assess the effects of multiple stressors on forest ecosystem condition. Because ecosystem processes are linked to spatial and temporal combinations of environmental components (climate, soils, topography, vegetation, trophic structure, etc.), the success of an indicator and of the corresponding modeling and assessment program will depend on the development of an appropriate diagnostic framework for identifying major resources of concern,

[a] ManTech Environmental Technology, Inc., EPA Environmental Research Laboratory, Corvallis, OR

suggesting research priorities, and defining attainable conditions of sustainable ecosystem health. This framework will be developed around a regional concept, recognizing that the nature of problems and their solutions vary among definable, ecological regions. The framework is focused on the development and application of a suite of tested indicators and models that accurately predict risk to specific ecosystem subpopulations; it should also provide guidelines for specifying the most reliable models for determining ecosystem risk for various stressor-management scenarios.

20.2 DEFINING FOREST HEALTH

A major use of indicators in the FHM program will be to assess condition, or health, of ecological resources. Rapport (1989) lists three approaches or criteria commonly used to assess ecosystem health: (1) identification of systematic indicators of ecosystem functional and structural integrity, (2) measurement of ecological sustainability or resiliency (i.e., the ability of the system to handle stress loadings, either natural or anthropogenic), and (3) an absence of detectable symptoms of ecosystem disease or stress. Thus, ecological health is defined as both the occurrence of certain attributes that are deemed to be present in a healthy sustainable resource, and the absence of conditions that result from known stressors or problems affecting the resource.

20.3 INDICATORS AND ASSESSMENT

The FHM program's reports on the condition of forested ecosystems will be based on indicator(s) response(s). These responses represent the quantifiable changes occurring in some components of the forested ecosystem. It is necessary to place the balance of indicator response (net and relative magnitudes of change in positive or negative direction) into a matrix reflecting the value placed upon forested ecosystems by society. The FHM program's assessment framework recognizes the differing uses to which forests are placed. Societal values can therefore be described as fitting into one of the three following broad categories:

- Ecological Integrity – The concept of ecological integrity recognizes the importance of maintaining ecosystem functional capacity, and considers both biological and abiological resources.
- Economic Value – Society places great import in the capacity of forested ecosystems to provide livelihood. This value represents the capacity for the system to generate both direct (e.g., sales) and indirect (e.g., regulation of water availability for agriculture) sources of livelihood.
- Sociologic Value – This value incorporates the intrinsic desires of society to maintain some parts of the world in a "natural state" and includes recreational and aesthetic components.

To provide a structure bridging the gap between societal concepts of value and the measurement of quantifiable components of the ecosystem, the FHM program has identified a number of quantifiable assessment endpoints (Figure 20.1). Using such a structure, it is possible (and likely) that any individual indicator will be interpretable in the context of any of the societal values. For example, soil chemical analysis data will be used in developing interpretations for the assessment endpoints of soil productivity, soil weathering rate, soil contamination, and nutrient cycling balance.

An example of the relationships in the assessment framework is presented in Figure 20.2. Reading the figure from right-to-left, the societal value, Quality of the Vegetative Biotic Resource, serves as the focus through which the assessment endpoints, can be interpreted. The assessment endpoints encompass broad categories of ecosystem component characteristics (i.e., indicator distributions or statistical representations thereof), the aggregation of which defines ecosystem status. Indicators may comprise individual field measurements or aggregations of field measurements and are the technical base for quantifying the characteristics of the assessment endpoints. Indicators carry no capacity to assign a value judgement. They serve as a "tag," marking a point of condition in time and space that can be applied to multiple perceptions of value. Thus, the FHM program will provide quantity information on the condition of the assessment endpoints (i.e., status, and magnitude of change over time).

SOCIETAL VALUE PLACED ON FORESTED ECOSYSTEMS

VALUE	ASSESSMENT ENDPOINT
ECOLOGICAL INTEGRITY	
ABIOTIC RESOURCE →	SOIL EROSION SOIL PRODUCTIVITY SOIL WEATHERING RATE SOIL CONTAMINATION SOIL WATER RETENTION WATER QUALITY WATER QUANTITY AIR QUALITY
BIOTIC RESOURCE →	BIODIVERSITY NUTRIENT CYCLING BALANCE CONTAMINATION ANIMAL QUALITY VEGETATIVE QUALITY LANDSCAPE DYNAMICS
ECONOMIC VALUE →	PRODUCT GNP BIOMASS BY PRODUCT CATEGORY WATER EXPORT HABITAT PROVISION TOURISM & RECREATION
SOCIOLOGIC VALUE →	DESIGNATED USE USABILITY PRISTINENESS/AESTHETICS

Figure 20.1. Societal Value Placed on Forested Ecosystems.

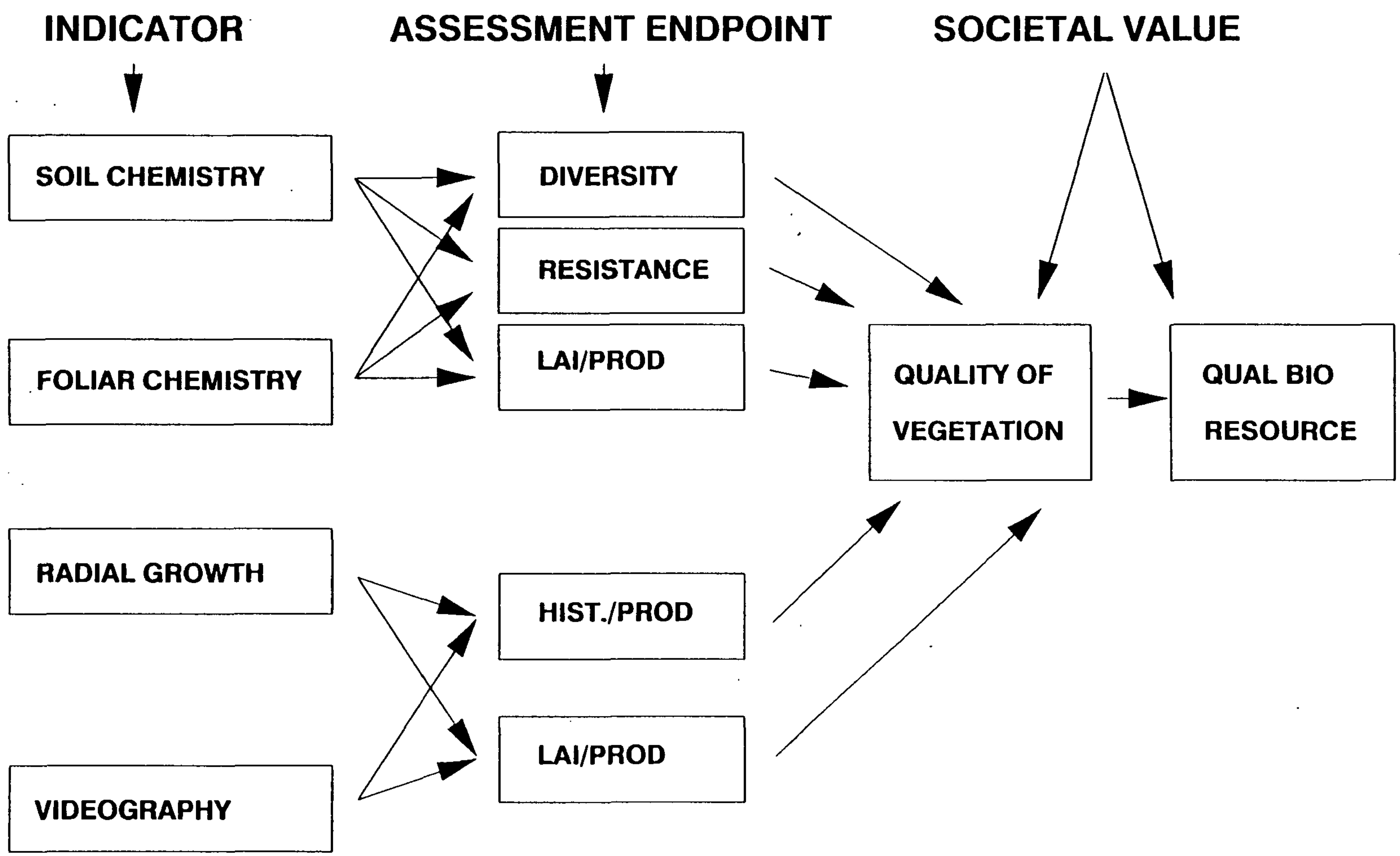


Figure 20.2. An Example of the Relationships in the Assessment Framework.

Based on assessment endpoint information, the FHM program will also provide interpretive assessments as to the relative condition (direction and rate of change in condition) for regional forested ecosystems. The interpretive assessments will thus provide agency policy offices with technically based guidance as to the potential for approaching critical conditions in forested ecosystems. However, policy offices are responsible for making regulatory recommendations relating to societal values (e.g., whether mitigative action should be required); such recommendations are not the purview of the FHM program reporting.

20.4 INDICATOR SELECTION CRITERIA

This section describes the criteria that must be applied in the adoption of indicators. An acceptable indicator must meet the following criteria, thus resulting in the selection of indicators on an interim basis while additional information is collected leading to the use of a more desirable set of indicators.

- Societal Value – Changes in indicator status should result in a willingness to manage stressor sources. Though policy-makers can be advised of the significance of an array of technically relevant indicators, the willingness of society to accept regulation on the basis of indicator changes must also be considered. The values that society places on forested ecosystems can be aggregated into three categories: ecological integrity, economic value, and sociological value. These three categories drive the FHM program. All indicators selected for implementation must be interpretable in an assessment context that has direct relationship to these values.
- Ecological Integrity – The ecological integrity of a forested ecosystem is a function of the quality of, and interactions between, its component parts (i.e., abiotic and biotic elements). There is a growing awareness that the "health and quality" of the human condition is inextricably linked to the "health" of the ecosystems people inhabit and the use to which ecosystems are placed (e.g., waste disposal). Humankind is learning that the term "ecosystem" is a function of multiple scales. For example, the source of atmospherically deposited stressors to a watershed may be thousands of square kilometers, the affected vegetation in the watershed only a few square kilometers, and the area affected by the

watershed's export (larger streams and groundwater) may again be thousands of square kilometers in area.

- Economic Value – The economic value of forested ecosystems lies in marketing the vast quantities of forest products each year as well as exports from the forested ecosystem (e.g., air, water), management of forests for tourism (e.g., National Park System and private souvenir vending), and many other services that are currently treated as external to the goals of forest management per se.

- Sociological Value – The sociological (or aesthetic) value placed on an ecosystem is an intangible quality stemming from a sense of personal value found in nature.

- Conceptual Model Output – Because the FHM programs assessment of forest condition will be made using conceptual models as hypotheses of forest structure, function, and response, indicators included in the monitoring plan must be specifically included (or amenable to inclusion) in conceptual models of forest condition and response.

- Specificity and Sensitivity – Indicators adopted by the program must be sensitive to changes in stressor exposure and/or reflective of the long-term changes in forest structure. They must be operationally definable in terms of some measurement or combination of measurements.

- Application – In addition to the selection of an indicator, its form of expression must also be considered. For example, an indicator such as available N may be expressed in the following ways: (1) as the percentage of samples which fall below or exceed some threshold value, (2) in terms of changes in the median value, or (3) in terms of percentage of map units which contain ecosystems below some threshold value. The choice of an indicator and reporting format will reflect the desire of decision makers as well as the ecological relevance of the information and the structure of available data bases.

- Detection Capability – The utility of an indicator in detecting trends in condition will also depend upon the magnitude of its remeasurement error. For example, there are specific procedures that can be employed to determine whether the size of the remeasurement error precludes indicator use because the change that one wishes to detect with confidence is too small relative to the remeasurement error.

20.5 INDICATOR CATEGORIES

A key element of the the FHM program's approach is the linkage of indicators to assessment endpoints. Potential indicators are identified using conceptual models of ecosystems, followed by systematic evaluation and testing to ensure their linkages to the assessment endpoints and their applicability within the FHM program. The models used may be based either on current understanding of the effects of stresses on ecosystems, or on the structural, functional and recuperative features of "healthy" ecosystems. Important information about assessment endpoints falls into one of the following categories: condition of the ecosystem, exposure of the endpoint to potential stressors, and availability of conditions necessary to support the desired state of the endpoint. To provide appropriate linkage between assessment endpoints and indicators, indicator development in the FHM program will produce indicators that fall into one of the following four categories (Hunsaker and Carpenter 1990).

1. Response indicators represent characteristics of the environment measured to provide evidence of the biological condition of a resource at the organism, population, community, or ecosystem levels of organization.
2. Exposure indicators provide evidence of the occurrence or magnitude of contact of an ecological resource with a physical, chemical, or biological stressor.
3. Habitat indicators are physical, chemical, or biological attributes measured to characterize conditions necessary to support an organism, population, community, or ecosystem (e.g., availability of snags; substrate of stream bottom; and vegetation type, extent and spatial pattern).
4. Stressor indicators are natural processes, environmental hazards, or management actions that effect changes in exposure and habitat (e.g., climate fluctuations, pollutant releases, and species introductions). Information on stressors will often be measured and monitored by non-FHM programs.

20.6 INDICATOR DEVELOPMENT PROCESS

The indicator development framework is designed to provide information about ecosystem condition that is relatively free of interpretation bias. This will provide user flexibility which is vital to the differing needs and priorities of the large client base served by the FHM program. The framework is designed in the form of a progressive flow diagram with specific decision criteria driving progression from one level to the next (Figure 20.3). The framework guides indicator development through an assessment process that considers needs and objectives, acceptable data uncertainty, appropriateness of available analytical procedures, data management procedures, statistical procedures, and the need for integrative assessment among multiple indicators.

Indicators reflect the nature and application of assessment endpoints, must characterize the forest resource, and are the primary vehicle for reporting ecosystem status. Because there are a variety of levels at which assessments may be conducted, the FHM program's indicator development framework is designed to foster comparability among disparate assessment approaches by distilling the process to a common set of steps. Selection of indicators for research and developmental testing will be a function of several interacting factors as follows.

1. Whether or not a linkage can be made with the assessment endpoints (Figure 20.1). Inclusion for development in the monitoring program will be tied specifically to how well the proposed indicator is expected to feed into and enhance the assessment framework.
2. The availability of data. Are data available that were collected in a manner appropriate for application in a national or regional context (i.e., represented in models, representative of regional resource distribution, indicative of ecosystem change, etc.)? Large quantities of data are already in existence that can be analyzed to characterize ecosystem condition and to develop response models. The level of available analytical data will vary among regions because of disparate perceptions of the key operational processes at differing ecosystem scales and varying degrees of data base development for different regions.
3. The consequences of uncertainty. There is always a component of uncertainty associated with an environmental assessment. Because the FHM program's approach will require the linkage of multiple components in the stressor–ecosystem relationship (estimation of stressor exposure, assumption of processes mitigating or exacerbating ecosystem response, and variation in genetic response capabilities of receptor organisms), additive increases in the uncertainty accompanying the representation of system response will result.
4. The characteristics of the ecosystems under consideration. This includes the response characteristics of ecosystems and their spatial distribution. For example, it may be necessary to use different stand biomass algorithms to describe the same species depending upon soil depth, physical structure, chemistry, topography, hydrology, and such. Within any region, these parameters may vary substantially. Hypothetically, this

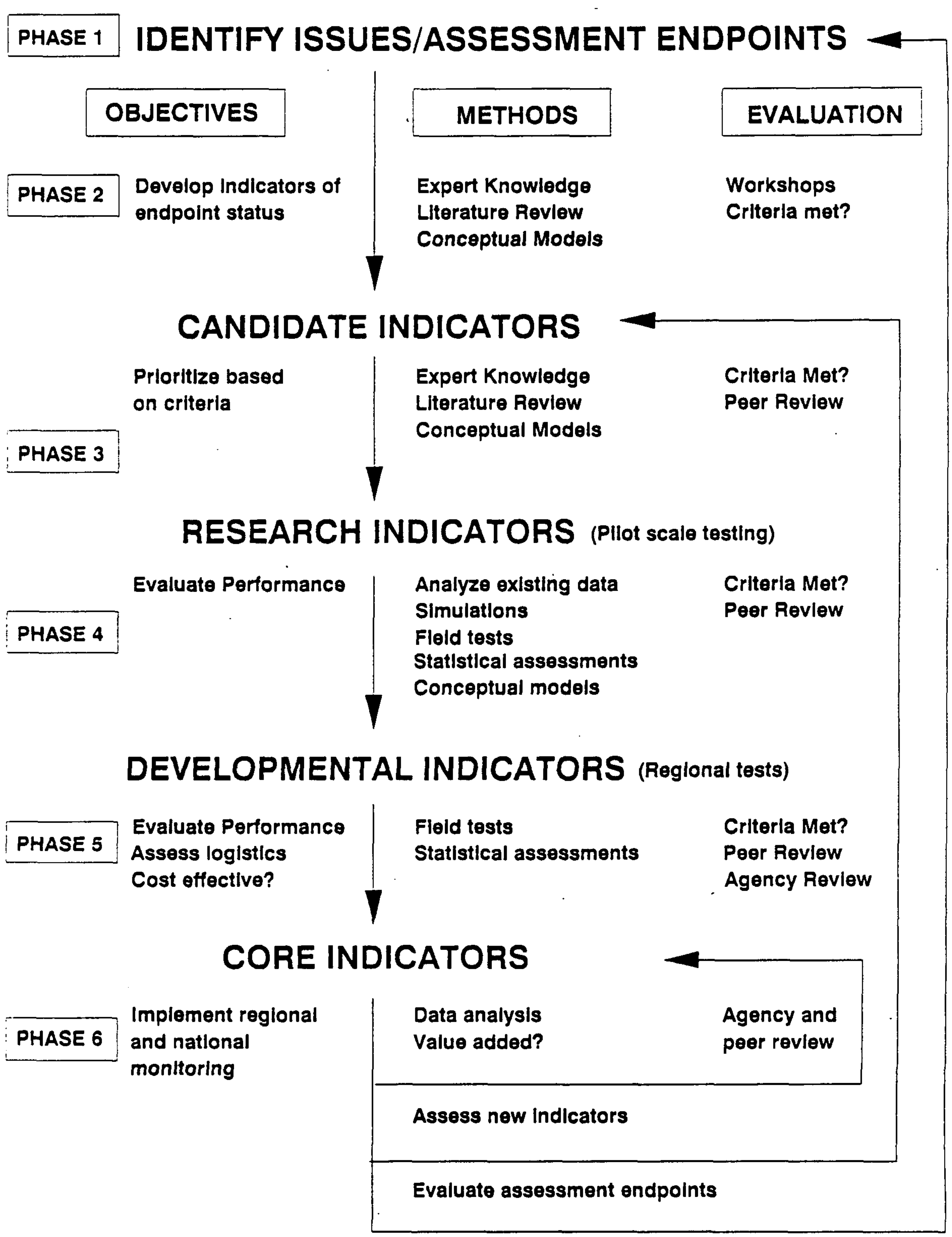


Figure 20.3. The Framework of Specific Decision Criteria Driving Indicator Progression.

would create a range of response potentials and diverse baseline conditions within the same region.

5. The spatial extent, magnitude, and temporal domains over which stressor exposure occurs. Exposure to a stressor may only be detrimental to forest condition during certain times of the year, and thresholds of critical exposures may differ both spatially and temporally. Estimation of ecosystem condition requires an understanding of how an ecosystem will respond over time to differing stressors and stressor loads. This estimation must be based on an understanding of the physical, chemical, and biological processes involved in response and will be further complicated by synergistic effects between stressors (e.g., acidification effects of nitrogen and sulfur). In addition, because the geographic distribution of forest cover types and responses, stressor deposition estimation, and potential for stress abatement may differ, special attention must be given to the spatial scale of analysis and to the spatial representation of data.

Forcing formal consideration of assumptions is perceived as essential to the uniform development of indicators suitable for a national monitoring program because program design and selection of measurement criteria are often based on the "cumulative learning" and/or opinions of the participating personnel.

20.7 INDICATOR ADDITION AND REPLACEMENT

It is important to point out that the program will not continually add new indicators to the field program. As a national monitoring program, the FHM program will add and/or delete indicators depending upon their capacity to provide necessary information to interpretation and assessment. However, the number of indicators to be measured will be strictly limited and prioritized according the value added in characterizing ecosystem status and trends in condition. Redundancy among indicators providing the same information will be perpetuated only as long as it takes to evaluate their relative value.

The objective of the development framework process is to reduce the uncertainty associated with interpretive assessments which are compiled from indicator data (Figure 20.4). The utility of an indicator (or group of indicators) for forest ecosystem health characterization (and thus the decision to retain the indicator in the program) will be a function of its:

- Implementability – Can the samples or data required be collected in a time frame suitable for a national monitoring program? the FHM program has set a 1-day limitation on all field activities for each sampling site visit.
- Interpretability – Does the indicator fit within the assessment and reporting criteria? In other words, does the inclusion of the indicator in the measured suite add a key piece of information otherwise absent from the interpretive assessment framework, and can it be evaluated unambiguously?

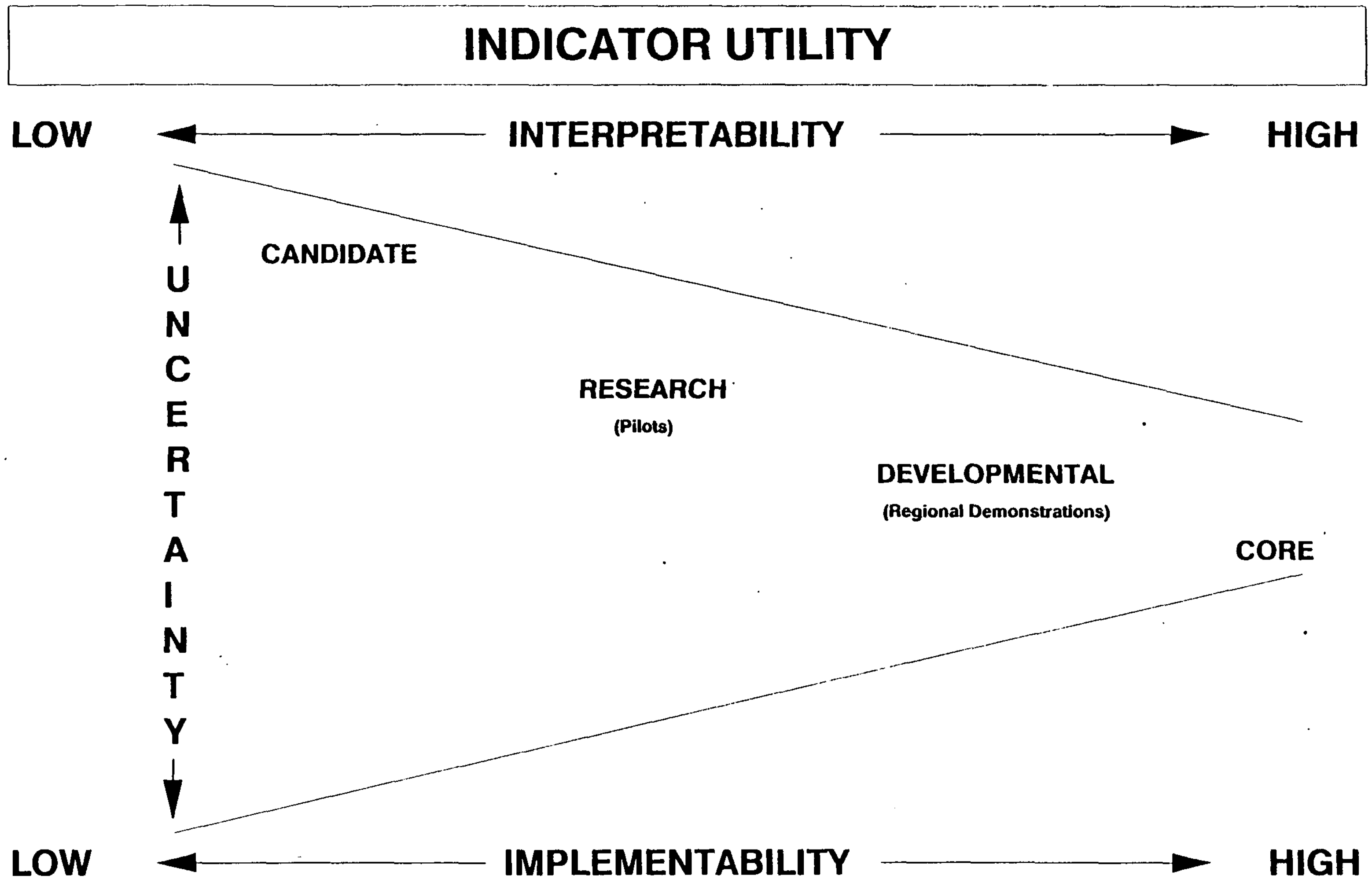


Figure 20.4. Indicator Utility.

21. INTEGRATION AND ASSESSMENT

K. Riitters[a]

21.1 INTRODUCTION AND RATIONALE

In the FHM program, integration refers to a process of coordinating and blending the monitoring activities into a functioning and unified whole (Fabrizio et al., In Preparation) and assessment means the procedures by which data are converted into useful information (NRC, 1990). Integration and assessment processes are essential to improve the conduct of environmental monitoring and to increase the relevance of reports for risk assessments (Streets, 1989; EPA, In Preparation).

Some aspects of integration and assessment are addressed simply by the planning and reporting of the scientific elements of the FY91 field study. Others are addressed by planning and conducting the field work which sets up an infrastructure for monitoring. But many aspects of integration and assessment are beyond the scope of the field study. Thus, the objectives of this section are to describe how the field study is contributing to integration and assessment within EMAP-Forests, and to suggest how the data can be used for development of integration and assessment processes after the field study.

Because the field study is concerned mainly with issues of statistical design, indicator evaluation, and operations, there will be no report of the integration and assessment of the field study data, per se. Rather, the results of the integration and assessment processes will be evident through the success of the coordinated field study and later, through reports that help analysts decide how best to convert data into useful information.

[a] ManTech Environmental Technology, Inc., Research Triangle Park, NC

21.2 CONTRIBUTIONS TO INTEGRATION

Fabrizio et al. (In Preparation) identified the integration activities associated with policy, program, and technical aspects of monitoring (refer to Table 21.1). The field study will make contributions to these aspects as described in this section.

Table 21-1 Policy, Program, and Technical Integration Issues in EMAP*

Policy Integration Issues
Identify and address needs of constituent groups with interests in single- or multiple-resource categories.
DQOs for EMAP.
Program Integration Issues
Coordinate EMAP with cooperating agencies that focus on issues dealing with single- or multiple-resource categories.
Coordinate acquisition of off-frame (stressor) data useful to multiple resource groups.
Assessment of data availability and negotiations for acquisition of off-frame data that will be used by more than one resource group.
Propose modifications of existing networks based on evaluations of existing off-frame data for integration purposes.
Technical Integration Issues
Development of ecological indices for multiple resource groups.
Sufficiency of spatial and temporal distribution for the FHM program indicators that are considered as stressor indicators by other resource groups.
Indicators applicable to multiple resource groups, including those not specific to Forests.
A strategy to analyze and evaluate data from Forests and from multiple resource groups.
Sampling unit density of EMAP grid points.
Frequency of co-occurrence of Forests with other resource groups in an EMAP sampling unit (hexagon).
Frequency of landscape characterization to redefine the Tier 2 sample frame.
Statistical power to detect association between ecological condition and corresponding landscape indicators.
Interannual frequency of site visits.
Guidelines for implementing Tier 3 or Tier 4 sampling.

* Adapted from Fabrizio et al., In Preparation.

21.2.1 Policy Integration

The field study is not designed to identify needs of constituent groups, nor to set DQO's for the FHM program.

21.2.2 Program Integration

The field study is an excellent test of coordinating the FHM program with the FS-FHM program of the USDA FS. The study also involves individuals from other Federal Agencies (USDA SCS, USDI Fish and Wildlife Service, TVA, USDI National Park Service) and states which will help to set up later interagency coordination.

The acquisition of off-frame stressor data is a continuing function of the FHM program Air and Deposition, Landscape and GIS, and Information Management groups. These groups are represented in the field study, and so there is a potential that acquisition of off-frame data will be coordinated among resource groups. The field study does not provide for the assessment of data availability or negotiations for acquisition of off-frame data that will be used by more than one resource group. The field study also does not provide for analyzing or proposing modifications to existing off-frame data collection networks.

21.2.3 Technical Integration

Data from the field study will be useful for developing ecological indicators and indices that are not specific to forests, but this is not a stated objective of the study. Nearly all of the forest indicators can potentially contribute to such indices for terrestrial assessments. The field study will not address the use of forest indicators as stressor indicators by other resource groups.

Each of the reports produced as a result of the field study will help to define the strategy for analyzing and evaluating data from the Forest group. This includes indicator-specific reports and any reports that combine information from more than one indicator. Data from the field study will be available for follow-up studies to address this issue in more detail.

The field study, particularly the large-scale demonstration of selected indicators, will provide data that can be used to evaluate the sampling unit density of the FHM program grid points. Neither the frequency of co-occurrence of resource categories nor the frequency of landscape characterization will be addressed by the field study. Data from the small-scale pilot of selected indicators may be useful for this purpose in later studies. The small-scale landscape pilot will provide some limited information to evaluate the statistical power to detect association between ecological condition and landscape indicators. The interannual frequency of site visits can be evaluated by the Forest group based on simulation studies using a single annual sample of all sites, or by resampling analyses using several annual samples of all sites. This evaluation is not a stated objective of the field study. Guidelines for implementing Tier 3 and Tier 4 sampling are not addressed in the field study.

21.3 CONTRIBUTIONS TO ASSESSMENT

Palmer et al. (1991, Sections 2, 3, and 7) outlined an FHM program assessment strategy in the context of the overall FHM program assessment strategy, the indicator development strategy, and the assessment strategy. The field test may contribute to developing the overall FHM program assessment strategy but that is not a primary goal. In this section, the contributions of the field test to key elements of the FHM program assessment strategy – assessment reports, assessment infrastructure, and assessment paradigm – are described.

21.3.1 Assessment Reports

The field study is not intended to assess the condition of the sampled forests in relation to stresses. However, data from the field study will be used by the EMAP-Integration and Assessment team in subsequent demonstrations of assessment report formats and functions.

21.3.2 Assessment Infrastructure

The assessment infrastructure refers to the arrangement of people and facilities within the FHM program, and their coordination with other FHM program-wide support groups and other agencies, to produce assessment reports. The field study is an excellent opportunity to identify the key working groups, facilities, and communications that are needed to produce assessment reports in an operational monitoring system.

21.3.3 Assessment Paradigm

An assessment paradigm is a point of view for organizing, synthesizing, and interpreting data (Palmer et al., 1991, Section 2). The field study contributes to the unique elements that are characteristic of the FHM program assessment paradigm.

Elements of an FHM program assessment paradigm and the relationship to the EPA risk assessment model are described by Messer (1990; see also Riitters et al., In Preparation) and will not be repeated here. The field study addresses this "long-term, large-scale, policy-relevant" paradigm by emphasizing the following elements.

1. Suites of indicators rather than disconnected measurements.
2. Multistage, systematic sampling and linkage across spatial scales (pilot test only).
3. Distinction between indicators of condition and indicators of stresses.
4. Regional-scale testing, analysis, and reporting (demonstration test only).
5. Detection of important forest changes with a view towards subsequent identification of possible causes of those changes.
6. Indicators that have quantifiable relevance to both social values and biological processes.
7. Selection of indicators appropriate for Tiers 1 and 2 of an operational monitoring system.

21.4 CONTRIBUTIONS TO FUTURE INTEGRATION AND ASSESSMENT TASKS

Data from the field study will be used for several purposes beyond the scope of the current document. The FHM program Integration and Assessment group will utilize these and similar data to prepare an example integrated assessment in FY92 (personal communication with Dan Valero, Technical Coordinator for EMAP Integration and Assessment, February 1991). The field study data will also be used to develop and test assessment techniques as part of the research and development of the FHM program's assessment capabilities in FY92 (Palmer et al., 1991, Section 7).

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TIMELINE FOR PRODUCTION OF EMAP-FORESTS FY91 INDICATOR EVALUATION FIELD STUDY PLAN:

Mar.18	Compiled outlines sent out to EMAP-Forests Team members so they may help with their areas of expertise.
Mar.25	Pilot writers conf. call K.Hermann sponsor 4:00 EST (202) 245-3613
Mar.26	Demo and Pilot Writers' Conf. Call 11:00 EST B.Kucera sponsor (202) 245-3622
Apr.3	Sections sent to AREAL RTP for editing and word processing.
Apr.19	Send plan out for peer review and internal review.
May 3	Receive review comments-copy to editor and author
May 10	Reconciliation sent to editor from author
May 10-13	Editing and wordprocessing
May 14	Document sent to lab for approval
May 31	Lab approval
June 3	Pretraining Asheville for Pilot and Demo
June 10	Training for all SE and all (including NE) demo and pilot personnel. Asheville, NC
June 17	Training for NE FHM.

TIMELINE FOR REPORTING: to be developed.