

EPA/600/R-98/032
April 1998



PB98-136930

**A Study on Integrating Surveys of Terrestrial Natural Resources:
The Oregon Demonstration Project**

by

J. Jeffery Goebel
Natural Resources Conservation Service
Washington, DC

Hans T. Schreuder
Forest Service
U.S. Department of Agriculture
Fort Collins, CO

Carol C. House
National Agricultural Statistics Service
U.S. Department of Agriculture
Washington, DC

Paul H. Geissler
U.S. Geological Survey
Laurel, MD

Anthony R. Olsen,
National Health and Environmental Effects Research Laboratory
U.S. Environmental Protection Agency
Corvallis, OR

and

William Williams
Bureau of Land Management
Denver, CO

National Health and Environmental Effects Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Corvallis, OR

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Abstract

An interagency project demonstrated the feasibility of integrating federal surveys of terrestrial natural resources and offers a vision for that integration. At locations selected from forest inventory and analysis, national forest system Region 6, and national resources inventory surveys in a six-county area in Northern Oregon, experienced teams interpreted and made measurements on aerial photographs and measured onsite a range of soil, vegetation, and animal attributes. The project demonstrated the feasibility of conducting a combined FIA/NFS/NRI survey at the substate level and suggests an approach that will preserve the utility of the critical historic information from these surveys. We suggest a framework for estimating the extent of forest and range land that explains FIA/NRI differences and provides a common basis for both surveys. We suggest indicator and protocol criteria that will allow compatible national and regional estimates over all vegetation types and stress the importance of including measurement repeatability in the design of the combined survey. We envision a program that integrates and/or coordinates inventory efforts measuring status and trends of terrestrial ecosystems under a combined structure supported by probability-based sampling.

TECHNICAL REPORT DATA

(Please read instructions on the reverse before completing)

1. REPORT NO. 600/R-98/032		2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE The Oregon Demonstration Study: a study on integrating surveys of terrestrial natural resources.		5. REPORT DATE <i>April 1998</i>	
		6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) Jeff Goebel ¹ , Hans Schreuder ² , Carol House ³ , Paul Geissler ⁴ Tony Olsen ⁵ , Bill Williams ⁶		8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS ¹ Natural Resources Conservation Service P.O. Box 2890 Washington D.C. 20013 ² Forest Service, USDA 240 West Prospect Fort Collins, CO 80526-2098 ³ National Agricultural Statistics Service, USDA 4801 S Building Washington D.C. 20250-2000 ⁴ U.S. Geological Survey, 12100 S. Building Laurel, MD 20708-4034 ⁵ US EPA NHEERL 200 SW 35th Street Corvallis, OR 97333 ⁶ Bureau of Land Management P.O. Box 25047 Denver CO 80225-0047		10. PROGRAM ELEMENT NO.	
		11. CONTRACT/GRANT NO.	
12. SPONSORING AGENCY NAME AND ADDRESS US EPA ENVIRONMENTAL RESEARCH LABORATORY 200 SW 35th Street Corvallis, OR 97333		13. TYPE OF REPORT AND PERIOD COVERED	
		14. SPONSORING AGENCY CODE EPA/600/02	
15. SUPPLEMENTARY NOTES: Project Officer Tony Olsen			
16. Abstract: An interagency project demonstrated the feasibility of integrating Federal surveys of terrestrial natural resources and offers a vision for that integration. At locations selected from forest Inventory and analysis, National forest system Region 6, and national resources Inventory surveys in a six-county area in Northern Oregon, experienced teams interpreted and made measurements on aerial photographs and measured on-site a range of soil, vegetation and animal attributes. The project demonstrated the feasibility of conducting a combined FIA/NFS/NRI survey at the substate level and suggests an approach that will preserve the utility of the critical historic information from these surveys. We suggest a framework for estimating the extent of forest and range land that explains FIA/NRI differences and provides a common basis for both surveys. We suggest indicator and protocol criteria that will allow compatible national and regional estimates over all vegetation types and stress the importance of including measurement repeatability in the design of the combined survey. We envision a program that integrates and/or coordinates inventory efforts measuring status and trends of terrestrial ecosystems under a combined structure supported by probability-based sampling.			
17. KEY WORDS AND DOCUMENT ANALYSIS			
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Monitoring design, terrestrial surveys, integrating surveys, CENR framework, EMAP			
18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (<i>This Report</i>)	21. NO. OF PAGES: 46	
	20. SECURITY CLASS (<i>This page</i>)	22. PRICE	

**A Study on Integrating Surveys of Terrestrial Natural Resources:
The Oregon Demonstration Project**

J. Jeffery Goebel, Hans T. Schreuder, Carol C. House, Paul H. Geissler, Anthony R. Olsen, and
William Williams

CONTENTS

OVERVIEW	4
STUDY DESIGN AND DATA COLLECTION	6
Location of Study	6
Survey Design	6
Estimation	7
Data Collection	7
FINDINGS and RECOMMENDATIONS	9
Survey Design	9
Variable Selection and Measurement Protocols	11
Estimates of Forest Land and Rangeland Extent	13
Estimates of Animal Relative Abundance	14
Measurement Repeatability	16
Information Management	17
Staffing	18
Future Research	19
Overall Recommendations	20
VISION FOR THE FUTURE	20
Vision	20
Concept	20
Implementation	22
ACKNOWLEDGMENTS	24
REFERENCES	25
APPENDIX I - Natural Resource Surveys	26
Forest Inventory and Analysis (FIA), USDA Forest Service (FS)	26
National Forest System, USDA Forest Service (FS)	27
National Resource Inventory (NRI), USDA Natural Resources Conservation Service (NRCS)	
.....	28
Forest Health Monitoring Survey (FHM), USDA Forest Service (FS)	28
Biological Resource Division, U. S. Geological Survey (BRD), DOI	28
National Agricultural Statistics Service (NASS), USDA	29
Bureau of Land Management (BLM) Inventory and Monitoring, DOI	29
Environmental Monitoring and Assessment Program (EMAP), US Environmental Protection	
Agency (EPA)	30
National Wetlands Inventory (NWI), USFWS, DOI	30
APPENDIX II - Integrated Monitoring Advantages and Concerns	31
Advantages	31
Concerns	32

A Study on Integrating Surveys of Terrestrial Natural Resources: The Oregon Demonstration Project

Authors:

J. Jeffery Goebel, Natural Resources Conservation Service, USDA

Hans T. Schreuder, Forest Service, USDA

Carol C. House, National Agricultural Statistics Service, USDA

Paul H. Geissler, U.S. Geological Survey¹, DOI

Anthony R. Olsen, National Health and Environmental Effects Laboratory, USEPA

William R. Williams, Bureau of Land Management, DOI

Team Leaders:

Mark Tilton, Natural Resources Conservation Service, USDA

Dale Baer, Forest Service, USDA

John Amrhein, National Agricultural Statistics Service, USDA

Carol Chambers, U.S. Geological Survey¹, DOI

Glenn Miller, Bureau of Land Management, DOI

¹ formerly National Biological Service

General Technical Report

RMRS-GTR-XXX

Rocky Mountain Research Station

Forest Service

U.S. Department of Agriculture

OVERVIEW

The Federal Government currently funds several national probability surveys to monitor the status and trends of terrestrial natural resources (Appendix I, Olsen et al. 1997). These surveys are essential to obtain scientifically defensible information because complete enumeration is generally not feasible. Although each has a different focus, considerable potential exists for duplication of effort, for providing conflicting information to policy makers, and for incompatibilities that limit data integration and comparisons. With the existence of these multiple surveys, difficult questions arise repeatedly. Why do we have several national surveys that seem to cover the same ground with similar objectives? Why do we get different answers to the same question when we talk to the Forest Service and the Natural Resources Conservation Service? Why do we have information for part of a State but not for another part of the same State? Why is some information for a state more current than other information? In the context of reducing the Federal deficit and reinventing Government, such questions have become more strident. To answer these questions, we must take definitive steps to develop common data bases and merge data collection efforts for these environmental programs.

An integrated approach has a number of advantages and raises a number of concerns (Appendix II). A common database of environmental information would facilitate interdisciplinary and interagency studies addressing the Nation's major environmental issues. Uniformity of definitions, sample design, and measurements throughout the United States would permit data collected by different agencies to be meaningfully combined and allow agencies to address broader issues and leverage their investments. The use of common definitions and estimators would reduce the occurrence of apparent conflicts in related estimates. The pooling of resources and the elimination of duplicate efforts would improve efficiency in data collection and increase the utility of the data. Greater opportunity for state involvement and funding could be available through participation in interagency efforts. A broad-based interagency survey would increase flexibility to accommodate multiple conditions and objectives. However, integrated monitoring raises concerns about preservation of continuity of historical data series, use of permanent plots, loss of agency ownership, loss of user support, and increased bureaucracy.

To address these issues, we conducted a demonstration project in Oregon that examined the feasibility of integrating Federal surveys of terrestrial natural resources. Combined data collection teams from the US Department of Agriculture (USDA) Forest Service (FS) and USDA Natural Resources Conservation Service (NRCS) made photo interpretation measurements and field plot observations on points that were selected from the Forest Inventory and Analysis (FIA), National Forest System (NFS) Region 6, and National Resources Inventory (NRI) surveys in a six-county area in North Central Oregon. They collected a subset of existing FIA, NRI, NFS Region 6, and Forest Health Monitoring (FHM) variables, supplemented with measures of soil quality and vegetation profile. A team from the US Department of Interior (DOI), US Geological Survey (USGS) Biological Research Division (BRD) made bird, amphibian, ground insect, and flying insect observations on a subset of points that were on Federal lands. The USDA National Agricultural Statistics Service (NASS) produced a combined data base and analyzed the data.

Representatives of the Environmental Protection Agency (EPA) and DOI Bureau of Land Management (BLM) actively participated in the planning and report writing.

This project did not address all of the issues and concerns, many of which have policy and political implications. In particular, we could not identify agency information priorities and develop a comprehensive set of data needs. Rather, we concentrated on the technical feasibility of integrating surveys and set seven specific objectives:

- Ascertain whether the sampling frames used by the existing national monitoring surveys give complete and representative coverage of the populations of interest.
- Determine if any one of these frames, a combination of the frames, or a new frame is preferable. Investigate the statistical and operational aspects of constructing a joint database combining historical and future information from the surveys.
- Investigate the utility of collecting a subset of common information on a common set of ground plots from the existing surveys using joint FIA/NRI data-collection teams. Each variable in the subset must have the same plot design across the common sample points but may be subsampled differently on the plot.
- Explain and illustrate why FIA and NRI can yield very different estimates of area of forest and range land.
- Explore data-collection methods for vegetation and soil attributes in an integrated survey context.
- Determine whether sampling for animal abundance can be included in the survey design.
- Analyze measurement errors associated with the collection of different variables. This is especially important relative to the development of new variables.

The project was conducted as part of the Sample Inventory and Monitoring of Natural Resources and the Environment (SIMNRE) working group of the Federal Geographic Data Committee (FGDC). The project and the resulting vision are consistent with the National Science and Technology Council's Committee on the Environment and National Resources' (CENR) proposed framework for integrating the Nation's environmental monitoring and research networks and programs (CENR 1997).

This paper provides details of the data collection and statistical methodology used in the project, reports results that demonstrate the technical feasibility of an integrated survey, and presents a vision for integration. This study is the first step in the integration process, but many issues still need to be resolved.

STUDY DESIGN AND DATA COLLECTION

Location of Study

The project was conducted in six counties in North Central Oregon: Clackamas, Multnomah, Hood River, Wasco, Jefferson, and Sherman (Fig. 1). This two million hectare area was selected because it provided a mixture of land ownership with coverage by the FIA, NFS Region 6, and NRI surveys (Fig. 2) and its area encompasses a diversity of land cover and land use, including forest land, range land, transition areas, urban boundaries, juniper woodlands, cropland, orchards, tree farms, and major riparian zones (Fig. 3). Considerable inter-agency activity was already

occurring in the region because of the Northwest Forest Plan and a number of key collaborators from the NRCS, FS, EPA, BLM, and various industry and environmental groups are located in the general area. Also, the area is fairly compact, facilitating data collection and is convenient to management staff in Portland.

Survey Design

In this demonstration project, we used a very simple implementation of existing statistical methodology to combine existing independent frames together. In the future, we recommend a more complex implementation of multiple frame methodology that will be more effective. For example, we envision using stratification techniques that would allow us to sample from the FIA/NFS frame intensively in forested areas and the NRI frame intensively in major cropland areas. Considerable additional analysis is needed to develop these details.

Three separate sampling frames were used to select the sample points. The FIA (USFS 1992) and NFS (Max et al. 1996) sampling grids jointly provide complete coverage of the six-county study area; similarly, the NRI (Nusser and Goebel 1997) sampling frame gives complete coverage. The combined FIA/NFS frame and the NRI frame were treated as two independent frames, each with complete coverage of the study area. They were sampled independently, and the estimates coming from the two independent samples were combined using standard multiple frame estimation procedures.

A two-phase sampling design was used. The Phase I sample of 613 sample points included 337 FIA/NFS and 276 NRI survey points. These points were independent subsamples of existing FIA/NFS and NRI samples. A Phase II subsample of 91 points was selected from the 613 Phase I points. The Phase I and II samples were selected following the standard sampling procedures employed by their respective surveys. Phase I focused on photo interpretation and GIS derived information. Phase II focused on field data collection involving field measurements, laboratory analysis of soil samples, and animal abundance.

A measurement-repeatability assessment was incorporated into the survey design. Each Phase II plot was visited by two different field crews. Crew 1 visited subplots 1, 2, and 3, and crews 2 subplots 1, 2, and 4 (Fig. 4). Time constraints did not allow for remeasurement of all subplots. For operational efficiency and to minimize the difficulty in obtaining access to private property and the impact on land owners, both crews visited each plot concurrently. Plot data were collected independently by each crew.

Estimation

Multiframe estimates for Phase I (photo interpretation) totals (Kott and Vogel 1995: 185) were

$$\hat{x} = \sum_{i=1}^{n_1} w_{1i} x_i$$
$$V(\hat{x}) = \sum_{i=1}^{n_1} w_{1i}^2 (x_i - \hat{x})^2$$

where

x_i = observed photo interpretation value for a Phase I point,

n_1 = number of sampled points, and

w_{1i} = weight (expansion factor) for a Phase I point.

The same estimator could also be used for Phase II (field plot) variables.

$$\hat{y}_s = \sum_{i=1}^{n_2} w_{2i} y_i$$
$$V(\hat{y}_s) = \sum_{i=1}^{n_2} w_{2i}^2 (y_i - \hat{y}_s)^2$$

where

y_j = observed field value for a Phase II plot, expanded to the plot,

n_2 = number of sampled plots, and

w_{2i} = weight (expansion factor) for a Phase II plot.

For some variables it is advantageous to use regression estimates to take advantage of correlations between Phase I and II variables (Schreuder et al. 1993: 167-174).

$$\hat{y}_r = \hat{y}_s + \hat{\beta}(\hat{x}_1 - \hat{x}_2)$$
$$V(\hat{y}_r) \cong \left[1 - \left(1 - \frac{n_2}{n_1} \right) \hat{\rho}^2 \right] V(\hat{y}_s)$$

where

$\hat{x}_1, \hat{x}_2$ = are the estimates of x from the Phase I and II samples, respectively,

$\hat{\beta}$ = is the regression coefficient between y and x , and

$\hat{\rho}$ = is the correlation coefficient between y and x .

Estimates of means can be obtained from the respective total estimates as

$$\bar{y} = \hat{y} / N$$

$$V(\bar{y}) = V(\hat{y}) / N^2$$

where N is the number of possible 1-hectare plots in the six-county study area (land area in hectares). Equal weight is given to the NRI and FIA/NFS frames for Phase $k = 1, 2$.

$$\sum_{i \in \text{NRI}} w_{ki} = \sum_{i \in \text{FIA/NFS}} w_{ki} = 0.5N$$

Data Collection

Some variables currently collected by the NRI, FIA and NFS Region 6 surveys were not included in this project because all were not needed for a demonstration and some are expected to change. Excluding some routine measurements saved time and resources. It was more productive to experiment with some new variables for soil quality, range and forest health, wildlife habitat, and animal populations.

Most measurement protocols used in the study were obtained or modified from existing NRI, FIA, NFS Region 6, and FHM protocols. Protocols had to be developed for several new measurements on vegetation, soils, and animal abundance, and some differences had to be reconciled for existing variables. Descriptions of the variables and protocols are included in the appendices.

Experienced USFS, BLM, and NRCS personnel interpreted the Phase I aerial photographs. Joint two- or three-person NRCS and FS field crews completed Phase II vegetation and soil field measurements. The USFS personnel were FIA inventory specialists. The NRCS personnel included soil scientists, soil conservationists, and range conservationists with varying amounts of NRI experience. A three-person USGS crew made the Phase II animal abundance observations.

Phase I Measurements - Measurements focused on earth cover, land class, wildlife habitat diversity, and land class diversity (Goebel et al. 1998). Data were collected in the office from aerial photos, GIS data layers, and hard copy ancillary materials. The photos were 1994 stereo 1:40,000 scale black and white National Aerial Photography Program film positives. Data from photos included earth cover class based primarily on a draft FGDC vegetation classification, evidence of disturbance associated with earth cover, land class, land class specific data, land use context, degree of urbanization, and wildlife habitat diversity. Other data included physical site characteristics (slope, aspect, elevation), soil series, current vegetation class from Oregon GAP, land ownership, USGS 8-digit hydrologic unit, ecoregion (Omernik 1987, Bailey 1995), Major Land Resource Area, and whether the sample point was inside an urban growth boundary.

Phase II Measurements - Measurements focused on vegetation, soils, and animal relative abundance. Riparian or wetland areas were not specifically targeted, although they were sampled if they occurred in the plots. To sample small, linear features such as riparian areas, it would be more effective to use a specialized sampling frame listing these areas. On-site measurements of vegetation and soils were made on 78 of the 91 Phase II sample plots (Goebel et al. 1998). We measured all of the 22 plots on federal land, but we were unable to measure 13 of the 69 plots on private land, because landowners refused access to 9 plots and we could not contact the owners of 4 plots. Soil samples were collected at each of the 78 plots and sent to a soil laboratory for analysis. Animal relative abundance was observed at the 14 Phase II plots that were located on

NFS lands in Douglas-fir and Ponderosa Pine vegetation strata on the Ochoco, Mt. Hood, and Deschutes National Forests (Goebel et al. 1998).

Vegetation and Soils On-site measurements included plot characteristics, vegetation structure, ground cover, herbaceous vegetation species frequency, shrub canopy cover, shrub density, woody debris, tree tallies, and soil characteristics. A field plot was used for ground sampling but was subsampled in different ways for various suites of variables.

Soil Samples Laboratory measurements included organic Carbon, total Nitrogen, pH, aggregate stability, and particle size. These measurements were made on grab samples taken at specified locations within the field plot. Crew 1 collected two pints of soil from the O or A horizon down to a depth of 50 cm, at both 12- and 16-meter distances from the center of subplot 2, along transect 2 (Fig. 4). Crew 2 collected soil samples at 11- and 15-meter distances. Pits were actually dug 2 meters off the transect lines. Rock fragments greater than 0.75 inch diameters were removed from all samples.

Animal Relative Abundance Observations were made of diurnal breeding birds, amphibians, ground insects, and flying insects. There were three visits to each selected plot during a 5-week period. On the first visit, sample plots were flagged and insect traps were set; on the second and third visits, measurements were taken. All three visits were conducted independently of those made to assess vegetation and soils.

Plot Design - The field plot was centered on the Phase I (photo interpretation) sample point, which was selected from the NRI, FIA or NSF sampling frames (Fig. 4). Subplot 1 is centered on the sample point, and the centers of the other subplots were located 36.6 m (120 ft) from the sample point, with the following azimuths: 0° to subplot 2, 120° to subplot 3, and 240° to subplot 4.

Three concentric fixed subplots of radii 2.1 m, 7.32 m, and 17.95 m respectively were defined around each subplot center. Two transects per subplot were also used for data collection. These transects were sighted and measured from the subplot center along fixed azimuths, and run from the center through the fixed radius subplots (Table 1).

Three 16-minute bird counts were made at 14 sample points on Federal land using the variable circular-plot method (VCP, Reynolds, et al. 1980). Counts were made at the sample point and at points 250 m from the sample point at azimuths 60° and 300°. Amphibians were sampled within two 10 by 180 m transects at azimuths 60° and 300° from the sample point, starting 70 m from the sample point. Four pitfall traps for ground insects (primarily beetles) were placed in each subplot, away from the vegetation sampling.

FINDINGS and RECOMMENDATIONS

Our assessment of the findings that follow leads us to conclude that the integration of terrestrial survey efforts, specifically in regard to the USFS Forest Inventory and Analysis (FIA) and the

NRCS National Resources Inventory (NRI), is feasible and desirable. In the following sections, we present findings based on our experiences and analysis of the data collected during the project, identify additional research needs, and make recommendations for an integrated monitoring program.

Survey Design

Both the existing NRI sampling frame and the joint FIA/NFS frame completely cover the study area. The combined NFS and FIA sampling frames provided complete coverage on public and private lands. For this study, we located sampling frame documentation and determined appropriate sampling weights for the respective frames. We only examined the study area and emphasize that these findings may not apply to other areas. Conceptually, both the NRI and the FIA frames cover all land. Although, historically, the NRI has not sampled public lands and the FIA has not sampled non-forested (public and private) lands and some forested public lands, we anticipate that implementing a national sampling frame from existing frames is achievable.

FIA and NRI use permanent sample points, which have been the source of important historical data. The FIA program began in the 1930s, and on some points the current design has been in place for three to six re-measurements since the early 1960s. The current NRI design began in 1982 with revisits once every five years. The most direct way to preserve the continuity of this information is to incorporate existing permanent sample points into the integrated survey design.

There are three concerns about using an integrated survey design based on permanent plots in which a number of agencies participate. These concerns relate to the continued representativeness of the sample plots, plot access, and plot confidentiality. The representativeness of sample plots can be affected adversely by more frequent visits to the plots, by larger crews, or by the landowners becoming more aware of the plot and managing it differently. Access to private land for Federal inventory purposes has always presented some difficulties, but the problem is escalating and becoming increasingly sensitive. In this project, we were refused access to 13 percent of the 69 plots on private land, and we were unable to contact the owners of another 6 percent of these plots. An integrated survey would combine the requests of the individual agencies, reducing the number of requests for access to private land. This would reduce landowner impacts and improve relationships. On the other hand, if an integrated survey increased the visitation frequency, it could exacerbate the problem, especially with large landowners. The greater breadth of variables measured in an integrated survey (e.g., those related to soils, forest and range health, and, possibly, animal abundance) may increase landowner concerns. Landowners, who have had positive relationships with the USFS or NRCS because of their focus on timber production and soil erosion, no longer may be willing to grant access. Plot confidentiality is important to prevent the sample plots from being managed differently from the surrounding area, which the plot is designed to represent and to preserve landowner privacy and business secrets. We believe that these concerns must be addressed explicitly prior to implementing of an integrated program. Guaranteeing site confidentiality can be achieved by modification of authorizing legislation for the surveys to include a data confidentiality provision similar to other federal statistical agencies. Such a provision is likely to minimize landowner refusal rates. Regardless, an integrated survey will need to devise a process for contacting landowners, informing them of the purpose of the survey, and obtaining their permission. The

process would recognize the difference requirements among private, federal, state, and tribal landowners.

Plot Design - Although a modified version of the FHM plot design was used in this project, further research will be necessary to develop a design, which is appropriate for the suite of variables to be measured. However, we have found that some characteristics of plot design used in the project were both valuable and effective:

- All measurement protocols were centered at the sampled grid point, but the definitions of subplots and transects were different. This flexibility allowed the plot design to accommodate protocols that require measurements both within fixed areas and along transects. Also, areas around and between the subplots were available for destructive sampling, if needed.
- Multiple subplots and transects were used to increase efficiency (considering travel costs to reach the point) and provide a better characterization of the plot. An important issue in plot design is determining the number of subsamples (subplots, transects, or observations along a transect) for each set of measurements that will maximize the precision of the final estimates for a specified budget.
- The number of subsamples required often depends on vegetation complexity. One should consider taking more subsamples on plots where the vegetation complexity is greater and within plot component of variance is larger to maximize the precision of the final estimates.
- Decision on the number of subsamples and on what variables to measure in the field should be determined only from information available from all Phase I points (e.g., photo interpretation, historical ground information, etc.). These decisions should not be made in the field. The information on Phase I points is required for statistical ratio or regression estimates of Phase II variables. These estimates usually substantially increase the precision of the estimates. If the number of subsamples or variables to be measured differ among plots, the Phase I points should be poststratified and these values specified for each poststratum. If a decision is made not to measure a variable is a poststratum, one is assuming that its value is zero or negligible in the aggregate.
- Measurement locations within plots should not be changed due to conditions encountered in the field. Any change in location biases the estimates and reduces the credibility of the survey. When conditions make it impossible to make a measurement at a prescribed location, data collectors should carefully record a description of the situation encountered.

Variable Selection and Measurement Protocols

We did not attempt to include all existing variables currently measured by the NRI, FIA, or NFS surveys. Nor did we intend to determine a recommended set of variables to be measured in an integrated survey. Our objective was to demonstrate the potential for including variables which would satisfy the data required by multiple agencies. Hence, we believe that substantial work remains to be done selecting which variables should be measured, what protocols should be used to make the measurements, and how the measurements should be summarized and analyzed.

The aims of the survey and associated costs need to be considered much more carefully when designing an integrated survey. One of our aims was to complete all field measurements at a single plot in one field day. To achieve this, we considered three options: increase the size of

crews, reduce the number of variables, or modify field protocols to reduce the number of subsamples. Usually, we chose the latter.

In a multi-purpose national survey, it is important to select variables and develop protocols which are adaptable for many different conditions of vegetation and terrain. This will facilitate the aggregation of these measures to regional and national levels. Often this can be done easily. For example, the depth of the O-horizon in soil can be measured in forests, but it is absent in range soils. If the depth is recorded as "zero" when the O-horizon is missing, this measurement is defined compatibly across these different conditions. A more complex example is likely to occur with key vegetation density protocols. Such protocols may require many repetitive measurements to get good indications of vegetation density in range conditions. However, repeating the same number of repetitions in areas of high vegetation density would be unreasonable. In this situation, we would recommend maintaining the same basic protocol but adapting it to increase the number of measurement repetitions in areas of low vegetation density and to decrease the number of repetitions in high density areas. This can be done scientifically so that the resulting estimates of vegetation density will have approximately the same precision across terrain types. If different variable or protocols were used in different habitats, the estimates probably could not be meaningfully aggregated to obtain estimates for larger areas. This study demonstrated the difficulty of distinguishing between range land and forest land, because of problems classifying transition areas. In order to use the photo interpretation results to expand the ground estimates, the range or forest decision has to be made from the air photographs. If a plot was classified as range from the photos, it could still have an O soil horizon present, but it would not be measured if the range protocols did not include this measurement. Thus, meaningful aggregate estimates of the O soil horizon could not be obtained because measurements would be missing from areas that were classified as range.

Extensive research is needed to develop protocols which are appropriate for the suite of variables selected. However, we emphasize the following for all core variables:

- Measure all variables on each plot, regardless of whether located in forest, range, cropland, etc. If a feature does not exist, record a zero or a not-present code. The decision on how to classify a plot or subplot is best done by the data analysts using all available information. It is almost a certainty that people with different backgrounds and interests will classify vegetative types differently. Recording the underlying measurements instead of classifications ensures that the data base will be compatible. With this approach, the needs of different agencies and programs can be satisfied using the same data base.
- It is highly desirable to collect a subset of common information on all plots using interagency crews, because the information currently collected by NRI and FIA complement each other well (i.e., information on soil quality, erosion, and species of trees, herbs, forbs, and grasses). Interagency crews combine expertise and experiences with the different measurements and interpretations.
- Measurement of key soil variables is critical in surveys involving permanent plots but less destructive methodologies need to be developed (e.g., soil pits are unacceptable but limited soil coring is tolerable).
- Selection of variables to describe the vegetation is also critical. Much work is still required on the appropriate detail and protocols.
- While our attempts in this project to include some sampling of animal populations in an

integrated survey of environmental resources have been promising, follow-up studies are required.

- Measurement repeatability needs to be addressed. It can often be enhanced by reducing subjectivity, clarifying instructions, and improving training.

The field crews provided some useful feedback on the field protocols: 1) Measuring the height of vegetation in dense brush was complicated by difficulties experienced when positioning the fixed-quadrant measuring device. Some improvements in design of both this device and the nested-frequency measuring device is needed. 2) On steep terrain, all observations along a transect should be done in a single pass to minimize trampling. 3) Observed soil erosion and disturbance should be described qualitatively in the field by the field crew.

More work on protocols and plot design is required to answer the questions: (1) What variables or attributes are important in describing resource health or condition? (2) What is the best way to measure the attributes? and (3) What is the most efficient procedure for measuring an attribute under varying landscape conditions, viz. topography and the life form density of the vegetation?

Estimates of Forest Land and Rangeland Extent

Agreement on common definitions is needed to assure compatible estimation of forest land and rangeland acreage. We found the following differences between FIA and NRI estimation:

- The FIA operational definition for designating an area as forest is 10 percent or more crown cover in trees, whereas NRI typically uses 25 percent or more. The Agencies originally agreed to a definition of forest land as at least a 10 percent stocking in trees, but it is difficult to measure stocking rates in the field, and an operational definition based on crown cover was developed.
- There are differences in which land classes are considered forest or grass lands and in the species that are considered trees. The FIA classifies "oak woodland" and "juniper woodland" as forest land, whereas the NRI classifies them as rangeland. The FIA considers junipers as trees, whereas the NRI often does not.
- FIA only uses ground information as truth for classifying a plot as forest or range and uses double sampling with ratio or regression estimation to estimate forest area. NRI is unable to use a similar classical double sampling technique because of operational practices. All NRI plots were initially field-visited, but subsequent surveys at five-year intervals have relied heavily on aerial photography to update condition and classification, with field visits used mostly where photography was inadequate.

Applying the FIA definitions to the Phase I data would classify 45 percent of the land in the study area as forest land, compared to 36 percent with the NRI definitions (Table 2). Regression estimation utilizing Phase II data adjusts the FIA estimate to 39 percent forest land.

To avoid discrepancies in the future, we recommend that inventories use agreed-to "land class" categories similar to those used for this study. The categories for this land classification system should be objectively defined so that they can actually be observed (determined) by field crews, photo-interpreters, and remote sensing specialists (for example, a crew member would record "juniper" with 15 percent crown cover rather than forest or rangeland). This classification system

will need to conform to FGDC guidelines but may have categories that subdivide the categories specified by FGDC. This system should be constructed in a manner that enables analysts to use the inventory data to reclassify the sample plots into many different groupings, including historical FIA and NRI classifications, as well as new classifications needed for agency programs or ecological investigations.

Estimates of Animal Relative Abundance

Animal relative abundance estimates greatly improve our understanding of forest ecosystems. The development of specific procedures for deriving such estimates in an integrated survey is still in its early stages. Separate crews were necessary for conducting animal counts because there is often a short season when animals are active and observable, bird observations must be made at dawn to be effective, and at least two visits are required to set and collect pit-fall traps for arthropods. Close coordination with the vegetation/soils crews was essential.

Making a single visit to a sample plot would increase the number of plots that could be visited and would reduce the impact on land owners. However, we found that substantially more than twice the amount of information is obtained from two visits, because of the information obtained from the arthropod traps. Whereas bird populations are migratory and reflect conditions on both their winter and summer ranges and their migration routes, arthropod populations reflect conditions on the plot. Taxonomically diverse arthropod populations represent several trophic levels and life history strategies, providing a much better representation of ecological conditions on the plot.

Birds - Bird Counts Eighty-four bird species were detected (76 species at the first plot visits and an additional 8 species at the second). Survey results were compared to lists of species predicted by GAP (Scott, et al. 1996) to occur in the study areas. These lists of expected or predicted species came from three data sets: (1) GAP data - species lists for a 640 km² hexagon that includes the NFS plot, (2) GAP data - species lists by polygon (defined by vegetation class) within the hexagon, and (3) Oregon Species Information System (OSIS). Fewer than 25 percent of the predicted species were detected and 11 species were detected that were not predicted. Some species listed in the GAP data set seem misidentified and/or mislocated (e.g., marbled murrelet and northern spotted owl are predicted to occur in the Ochoco national forest). The comparisons can be used to refine the GAP predictions of species occurrence.

Tape Recordings Portable cassette tape recorders were used to record singing birds. Species detected by the observer were compared with those recorded on tape. Preliminary analysis indicates that 75 to 85 percent of the species observed were tape recorded. Extensive training is required to reliably identify bird calls. These observations suggest that it is feasible to have observers without that training record bird calls in the field and to have a trained observer later identify the birds. This approach will increase the number of bird counts that can be made because the number of trained observers is limited.

Amphibians - Amphibian surveys were unsuccessful, because observations occurred too late in the season, when amphibians were inactive. We observed only 1 species (rough-skinned newt, *Tariccha granulosa*) on a single plot.

Arthropods - Arthropod sampling was successful. Numerous species and individuals were collected, but the sorting and identification of specimens were time consuming and required the assistance of a qualified taxonomist. Availability of taxonomic expertise is likely to be a limiting factor for monitoring programs which include arthropods as an indicator group. The effects of phenology is also a major concern with arthropods, because there often is a short peak period of activity, with few captures before and after the peak.

Carabid beetles A total of 2,309 individuals were collected in pitfall traps, representing 51 species or subspecies. No exotic species were captured. Species richness ranged from 3 to 17, with a mean of 8 species per plot. Sampling problems encountered included animal damage to pitfalls (approximately 5 to 10 percent pulled out of the ground by bears or crushed by cattle). Also, approximately 15 percent of the pitfalls were flooded; this could have accelerated decomposition of the arthropods, but deterioration of samples was not a problem in this study.

Lepidoptera Butterflies and moths are well represented in Oregon and the Pacific Northwest. Their larvae (caterpillars) are plant feeders which often congregate on certain plant species. Black light traps have been used extensively to capture moths, which are nocturnal and thus difficult to sample using other methods. These traps were used at several plots to test the feasibility of using them for a large-scale survey. However, the traps required heavy batteries and repeat visits. Therefore, they appear to be more suitable for intensive studies than for extensive surveys. Butterflies are less abundant than moths in forest environments of the Pacific Northwest, but visual protocols exist which would allow sampling and estimates of abundance. In more open environments, butterflies may be a valuable indicator taxon.

Conclusions - Phenology greatly influences the success of most sampling strategies for animals. Populations change greatly between and within seasons, with various taxa showing differing phenological responses. Therefore, any strategy based on one or two sampling periods per location is vulnerable to significant phenological biases.

Aside from the difficulties with phenology, birds and carabid beetles were the taxa which seemed to have the best potential for inclusion within a large-scale strategy, although further work with other taxa such as lepidoptera and ants seems worthwhile. Reliable bird counts were obtained with a single plot visit.

Sampling for carabid beetles provided a great deal of information with two visits. The sampling method is inexpensive and easily implemented. Carabid beetles are widely distributed and represent all trophic levels. Thus, they may be good indicators of environmental change. However, considerable experience and skill are required for species identification, and availability of qualified taxonomists may be a limiting factor.

Restriction of sampling to one or two visits was a significant constraint, and limited the taxa which could be sampled. It also requires the use of relative abundance indices (simple counts) that do not estimate animal densities and that are affected by many environmental and behavioral factors. Although indices do not reliably reflect small population fluctuations, major effects are detectable. Selected indicators such as arthropods or birds can be monitored efficiently and economically for at least a subset of FIA/NRI plots.

Measurement Repeatability

Measurements must be repeatable in order to be useful, and this is especially true for surveys monitoring resource condition and environmental health. An important part of this study was the investigation of repeatability. Data collection procedures were designed to provide repeated measurements that minimized temporal and spatial differences and preserved independence. Each vegetation and soils plot in the Phase II sample was enumerated independently by two different crews, although each visited a plot on the same day for efficiency and to eliminate temporal variability. The first crew enumerated subplots 1, 2, and 3 and the second subplots 1, 2, and 4. We would have preferred that each crew measure all subplots and transects, but it was not possible due to our "one-day-per-plot" time constraint. Thus, the repeatability of measurements of vegetation and soils was assessed only based on data from subplots 1 and 2. Because the composition of crews varied during the period of data collection, the enumerator effect was treated as random during statistical analysis of the data.

The correlation (r) between the paired measurements of different crews was estimated for selected variables (Table 3). Our results are consistent with findings from other studies that measures of tree counts, mean tree basal area, DBH, and the number of tree species are repeatable; we found $r > 0.90$ for these measures. We found similar correlation in other variables, including average number of plant species per location, total number of species per plot, and shrub density (total count), but for some others the correlations were poor, including percent of total shrubs as seedlings ($r = 0.27$) and saplings ($r = 0.39$).

The difference between the measurements of the two crews, expressed as a percent of the mean, also indicated the repeatability of the measurements. This is defined as $(\sum w_i |y_{i1} - y_{i2}|) / (\sum w_i [y_{i1} + y_{i2}] / 2)$ where w_i is the weight from the sampling design, and y_{i1} and y_{i2} are the crew 1 and crew 2 measurements on the i^{th} plot. Another indicator is the percent of the plot variance that is due to measurement error. This is defined as $s_m^2 / (2s_p^2 + s_m^2)$ where s_p^2 and s_m^2 are the between plots and measurement components of variance. The mean differences between the measurements ranged from 6 percent to 100 percent, while the percent measurement error ranged from 0.4 percent to 73 percent of the plot variance (Table 3).

To determine if measurements are sufficiently repeatable, one should determine whether or not important differences can be detected. If measurements are not repeatable, there will be a large measurement error component to the variance, which will prevent the survey from detecting even large changes. If important changes cannot be reliably detected within a feasible budget, the survey will not achieve its objective. Estimates based on variables with serious measurement errors can be quite misleading. Making independent replicate observations with different crews allowed us to separate measurement variability from the other components of variance. This estimate allows us to identify measurements that would benefit from refinements to make them more repeatable. Estimates of variance components and cost (time) estimates for the various measurement activities allows us to determine the optimal number of subplots, transects, and subsamples to maximize power to detect changes and differences.

Information Management

A unified database was established comprising all the data from photo interpretation, soils, vegetation, and animal relative abundance, and the weighting factors required for estimation. Documentation was developed, covering file format, variable names, missing data conventions, the weighting factors required for estimation, and other information that will allow data users to perform analyses of their own in a statistically valid manner.

Data Entry, Verification, and Editing - Data were recorded on 11 separate sheets designed specifically for the study. One sheet was used for the photo interpretation and ten for the field measurements, each corresponding to a set of related measurements made with the plot, namely condition class, subplot attributes, soils, vegetation structure, ground cover and nested frequency, shrub crown canopy, shrub density, coarse woody debris, tree tally, and animal counts. Plots often required a total of 20 to 25 sheets depending on the vegetation density and number of species. Each data item was assigned a code so that the data could be quickly keyed as a stream in an *item code + value* format. Personnel in the Portland office of the National Agricultural Statistics Service in Oregon key-entered the data. A double entry system was used in which two clerks entered the same data, the second set being used to verify the first.

Computer edits were performed on the Phase I and Phase II data. These edits are discussed in detail in *The Ad Hoc Committee on National Geo-Spatial Monitoring of Environmental Resources, Northern Oregon Demonstration Project, 1995, Data Documentation Manual* available from NASS. As part of the editing process, the data were checked for invalid codes (e.g., condition class) and data falling outside defined ranges (e.g., tree diameters and heights). Invalid codes had to be rectified before the data were determined to be "clean." Data out of range generated warnings that suggested a photo interpreter or field crew member review the raw data. Checks on the validity of species codes recorded in Phase II were included in the edit phase. The NRCS Plant List of Accepted Nomenclature, Taxonomy and Symbols (PLANTS) Alphabetical Listing Report (May 1994) was used as the list of valid codes. Any species code encountered that did not match this list was reviewed for accuracy. If found to be valid, the code was added to the list; otherwise, it was corrected.

Database - The data are maintained in 12 separate SAS datasets, nine for the vegetation data and one each for the photo interpretation data, laboratory soils data, and animal counts data. Documentation concerning file formats and record linkage is in *The Ad Hoc Committee On National Geo-Spatial Monitoring of Environmental Resources, Northern Oregon Demonstration Project, 1995, Data Documentation Manual* available from NASS. The photo interpretation data set contains one line of data per sampled point and can be merged with the field data sets using the variable "plot," which contains the field plot number corresponding to the Phase I sample point. "Photo-to-field" merges are "one-to-many" because the field data sets contain more than one line of data per sampled point. Observations from different field datasets can be combined by merging records based upon various combinations of the four variables: plot, visit, subplot, and transect. For example, if an analyst wanted to merge the subplot attributes from form 2 with the tree tally data from form 9, he/she should merge using the three variables: plot, visit, and subplot. This would attach the subplot attributes to each line of data from the tree tally, that is, to each

tree. Another option would be to first summarize the tree tally to the subplot level and then merge the files.

Even though sample points from FIA, NFS, and NRI were utilized, analysts can treat the data as coming from a single survey. This is because the database contains statistical weighting factors that account for the sample design and because uniform definitions, measurements, and protocols were used for all sample locations.

Staffing

The broad range of measurements included in this project resulted in a substantial increase in the complexity of the field measurements. We successfully addressed this issue by using photo interpretation and field crews jointly staffed by NRCS and FS personnel. These crews brought together the varied expertise and experiences developed on current inventories and resulted in common interpretations of standard protocols. A blending of cultures is desirable to support an integrated survey and highly trained field personnel should be used to conduct field studies.

We have the following recommendations concerning the operation of inter-agency surveys and use of field crews, based on our experience and recommendations of the field crews:

1. There must be an appropriate mix of skills amongst the crew members to match the requirements of data collection. Highly trained crews are essential because specialized skills are required for identifying plant species, making soil measurements, and comprehending the suite of variables requiring measurement.
2. Additional training should be given to crews when they encounter new ecosystems, especially for identifying soils, plants, wildlife, insects, and plant diseases.
3. The crews need access to experts for identifying plant species and applying protocols in unusual situations.
4. A reconnaissance person is useful to obtain permission for access from landowners and to determine the best access routes prior to the arrival of the field crew.
5. The crews must be thoroughly conversant with the objectives and rationales for the field procedures to increase their ability to interpret the instructions and maximize their commitment to quality in their work.
6. Crew members should be fully engaged in inventory assignments during the field season.
7. The size of crews should be so determined that the collection of data is cost effective and impacts on the land owners and the land are minimized.
8. Weekly review meetings for crews should be scheduled during the first month of work because of the complexity of the field work. Subsequent meeting should be organized as the need arises.

Future Research

During the project, a number of issues surfaced that require further research, including:

Indicator Development and Evaluation

1. Development and evaluation of indicators and their measurement protocols
2. Identification and establishment of cause-effect relationships

Sampling Design and Estimation

3. Development of an effective survey design for continuous (annual) inventory and monitoring
4. Integration of complementary surveys such as those by NASS and National Wetland Inventory (NWI)
5. Determination of the feasibility of use permanent plots for an integrated, multi-agency survey
6. Development of procedures for varying subsampling intensities based on Phase I information
7. Development of procedures for modifying the sampling design in response to changing information needs
8. Identification of the advantages of alternate sampling frames It is important to consider the need for time series data for existing terrestrial surveys as well as the desirability of annual measurements on a subset of plots.
9. Development of procedures for re-measurement of a subsample of sites to evaluate measurement errors, measurement repeatability, and hence utility of measurements
10. Identification of alternatives for multiple frame sampling and estimation with a large scale ongoing survey

Plot Design

11. Estimation of the appropriate number of subsample measurements (e.g., subplots, transects) for different land classes as determined by the Phase I observations

Integrated Monitoring Framework

12. Development of procedures to include intensive site and experimental studies in a broad scale survey
13. Development of estimation procedures to link spatially extensive information, such as remotely sensed landcover, with sample survey plot-based information
14. Exploration of methods to include aquatic issues in a terrestrial survey

Overall Recommendations

We recommend a phased transition towards an integrated inter-agency inventory for determining the status and trends of our Nation's natural resources, beginning with a core program based on integration of the NRI and the FIA surveys. This recommendation is consistent with the intent of the National Science and Technology Council and ongoing efforts of the Committee on the Environment and Natural Resources (CENR) "to develop a national framework for integration and coordination of environmental monitoring and related research through collaboration and building upon existing networks and programs" (CENR 1997: 3). A detailed plan has already been submitted to and endorsed by the USDA Under Secretary for Natural Resources and Environment. We present this plan in the following section, "Vision for the Future."

There are various operational/organizational and technical issues which need to be addressed; these are dependent upon refinement of the specific objectives for the integrated survey. The technical considerations fall into several categories, viz., indicator development and evaluation, integration within the CENR monitoring framework, sampling design and estimation, and plot design.

VISION FOR THE FUTURE

Vision

We envision a program that integrates and/or coordinates inventory efforts estimating status and trends of terrestrial ecosystems under a combined administrative structure supported by probability-based sampling. The result would be an information system that cost effectively samples the terrestrial ecosystems of the nation, providing data that are statistically credible, relevant to policy issues, and timely enough to support decision making. Agencies could access information in the system for statistical and policy purposes, could ensure the consistency of information released by cooperating agencies, and would benefit from resource sharing with their partner agencies.

Concept

Most national statistically-based inventory programs have in common a number of critical design elements. Thus, the description of a proposed inter-agency monitoring program will have many familiar features. Points would be spatially sampled across the Nation, and their density could be varied based on geographic location, data needs, and resources; however, all agencies would make observations on a common subset of the points. Data collection would occur in three phases: 1) remote sensing measurements would be made on all sampled points; 2) ground measurements would be made on selected sub-samples of the remotely sensed points; 3) specialized or intensive observations and/or land-owner interviews and/or laboratory analysis would be taken on a sub-sample of the ground points. A basic set of variables would be collected on all plots sampled in each phase of data collection. These would form the core of the integrated database. Participating agencies would have the opportunity to include additional variables during any of the phases, targeted specifically to their individual mission and interests. Inter-agency data collection would be used to ensure both the consistency of definitions and protocols and the availability of expertise for specialty measurements. A governing board of senior managers from data-gathering agencies would set direction for the program, ensuring that the mutual goals of the partnership and the individual goals of each partner agency were met.

[Insert text box here]

We recommend a phased transition beginning with a core program based on the integration of the NRI and FIA surveys. This will create a successful, cost effective, and flexible monitoring framework and a comprehensive information package that will encourage other agencies and programs to participate. For example, the Forest Service is encouraging closer ties between the FIA, the FHM program, and the monitoring programs within the National Forest Systems (NFS). Integration of these programs with the core may be an appropriate second phase of integration. Agencies such as the Bureau of Land Management, the Department of Defense, and the National Park Service could expand the coverage of the core monitoring effort by bringing additional Federal land into the framework. Other Agencies such as the National Agricultural Statistics Service (NASS), the Economic Research Service and the Geological Survey (USGS) could expand the type of information collected. Inclusion of the Fish and Wildlife Service could lead to

more comprehensive and compatible information on wetland resources. This transitional approach will enable faster initial progress and will allow for success within USDA even if no additional integration occurs.

This program would maintain the utility of historical data collected at permanent sampling points. The new design will combine existing sample points from multiple surveys into a aggregate sample. Some permanent points might be changed over time to achieve a more efficient combined sample.

The integrated program would collect data every year on a rotating sub-sample of points within each geographic area. This "continuous" inventory approach would provide estimates annually, with periodic estimates at higher levels of precision. It would equalize workloads and budgets from year to year, and facilitate the training and maintaining of highly skilled field crews.

A critical step in the integration is the creation and maintenance of a standardized, common database that would provide participating agencies with universal access to information for research, statistical, and policy purposes. However, it is equally important to protect survey data and sample point locations from unauthorized disclosure, both to protect the privacy rights of landowners and to prevent sample points from becoming unrepresentative. NASS would be the ideal repository of data because they have both the statistical and computer expertise to manage and distribute the data and the legal mandate and authority to maintain confidentiality.

The integrated survey would focus on terrestrial resources rather than aquatic resources. Hence a major element would be estimating landcover associated with agreed upon national land classification system. Hence land area designated as wetlands and surface water will be included. Detailed ecological measurements of wetlands, surface waters, and riparian areas are not envisioned. However, special surveys for these aquatic related resources could be based on the basic integrated survey.

The CENR framework states that "the many types of environmental information required for effective public discourse, assessment, and environmental policy decisions require monitoring programs of various types and scales" (CENR 1997: 19). Specifically, there are needs for resource mapping, intensive site studies, and specialized designs which target specialized issues and resources. We envision that an integrated survey is an important anchor and core for monitoring, but other efforts will still be needed, and can be coordinated. The Sample Inventory and Monitoring of Natural Resources and the Environment (SIMNRE) Working Group of the Federal Geographic Data Committee (FGDC) should continue to investigate methods to expand this coordination.

Implementation

This section provides more detail on the proposed structure for an integrated program, identifies the initial steps required to begin implementation of the core program, and provides a timeline for that implementation (Fig. 5).

Proposed Structure - We envision a three-phase inventory, designed such that each consecutive phase is a subsample of the preceding phase.

Phase I. Remote sensing at sample points. This phase of data collection, using aerial photography and/or satellite imagery and GIS data layers, is relatively inexpensive, so the sample could be extensive, providing a base from which to sub-sample subsequent phases. Remote sensing could be used to extend the inference from more expensive ground measurements through modeling and to statistically increase the precision of the estimates. A common set of data would be collected for each point, including classification variables such as earth cover, land class, and ownership.

The Phase I sample of remotely sensed points would be selected from the collection of all remotely sensed points in the NRI and FIA. Since this collection would include a total of over 1 million points, some sub-sampling is likely. However, the Phase I sample would include all NRI and FIA points for which ground plots have been established. This structure and sample can be easily extended to include other surveys, such as the FHM and the monitoring within the NFS, that are currently based on spatial grids. Each would bring along a sample from their current operational program, which would be merged into the Phase I sample. The plan recommends eventually migrating the Phase I samples onto a common spatial sampling frame.

Phase II. Ground Measurements. The Phase II sample would be selected from the Phase I points and include current FIA and NRI ground plots. Again this structure and sample can be easily extended to include other surveys, and would include gradual migration of ground plots.

Interagency field teams would visit the selected plots and collect an extensive array of ecological measurements. A core set of variables would be collected at each sampled plot to classify and describe plot attributes and to make basic ecological, soil, and vegetative measurements. These variables will be of general interest to all Agencies. A partner Agency may also collect an additional set of "agency-specific" variables that are targeted directly toward its mission objectives. Examples: variables to compute timber volume and variables which indicate erosion management practices. These variables may be collected on all plots or on a sub-sample, as directed by need and resources.

Joint field crews from participating Agencies would use common plot designs and protocols on common ground plots. Different variables may have different plot designs (points, transects, or plots) as long as the design is centered on the sample point, but a consistent plot design and protocol would be used for each core variable at all plots. A great deal of work still needs to be done to determine data needs and protocols for the integrated program.

Phase III. Specialty Data Collection. Agencies may wish to collect specialized or intensive observations on a sub-sample of the ground points. Examples include interviews with farmers about conservation practices for points falling in cropland, wildlife abundance counts that require additional plot visits or specialized field teams, and intensive management plots targeted for more frequent field visits.

Steps -

Administration:

1. Establish governing board to provide policy direction for integrated program.
2. Establish steering committee to oversee the implementation process.
3. Develop permanent joint administrative structure through which the routine operations of the integrated program will be carried out.

Protocol Development:

A major part of the implementation of an integrated monitoring effort is to decide on the information needed at each phase of data collection and to develop appropriate protocols, specifying how that information should be collected. This involves four steps.

1. Identify information needs.
2. Reassess current variables to determine each's value in addressing those needs. Modify protocols as needed to fit integrated plot design, maintaining links to essential historical data.
3. Develop new variables and protocols to address emerging areas of interest that are not adequately addressed in ongoing inventory efforts. These include such issues as:
 - a. range health
 - b. forest health
 - c. soil quality
 - d. cropland health
 - e. watershed health
 - f. animal abundance / biodiversity

There are a number of efforts currently underway within and among Agencies to accomplish various pieces of this task. These ongoing efforts need to be expedited and new efforts begun to fill identified gaps. Optimally, working groups would be inter-Agency and include both subject matter experts and survey design specialists.

4. Conduct field trials to determine the reliability and validity of identified variables and to optimize the plot designs and protocols.

Database and Geographic Information System Development:

1. Establish interim database of existing NRI and FIA sample points, along with sufficient historical information to aid in sample design and data collection activities.
2. Develop specifications for an integrated database and GIS system that will facilitate data sharing and geographic layering, while protecting privacy rights and sample locations.
3. Construct and populate the database and GIS system.

Sample Design:

Even though the basic inventory design is described in this paper, there is still considerable work needed to complete the detailed specifications.

1. Identify information needs that will require Phase III enumeration.
2. Develop a survey design and estimation procedures to provide annual estimates.
3. Determine the overall Phase I sample size and select that sample from the combined set of sample points in the interim database.

4. Determine the Phase II sample size and select the sample from the Phase I points.
5. Select Phase III sample(s) according to information needs.
6. Determine ground plot design.
7. Develop appropriate methodology for combining samples.

ACKNOWLEDGMENTS

We particularly acknowledge five individuals whose commitment and leadership contributed substantially to the successful outcome of the Oregon Demonstration Project: Mark Tilton (NRCS) and Dale Baer (USFS) provided the local project leadership, managing training, data gathering, and performed innumerable daily tasks; John Amrhein (NASS) developed the database, data documentation, and conducted the data analysis; Carol Chambers (USGS) managed the Phase II animal measurements; and Glen Miller (BLM) stepped in to manage a multitude of critical support activities.

Many other scientists and technicians provided their time, experience, and expertise in various aspects of the design and implementation of this project: Jim Alegria (BLM), Carol Franks (NRCS), Leon Liegel (USFS), David Pike (USGS), Ed Starkey (USGS), John Teply (USFS), Marty Stapanian (BLM), and Al Winward (USFS). Our thanks to the Oregon Agricultural Statistics Service who provided data entry support for the project.

Finally our special thanks for a job well done to those individuals who diligently collected data during one or more phases of the project: From USFS: Walter Grabowiecki (Field Crew Coordinator), Dale Baer, Sarah Butler, Erica Hanson, Dan Kenitz, Sarah Butler, Paul Dunham. From NRCS: Catherine Darby, Steven Fedje, Eileen Larkin, Sara Zimmerman, Rich Edlund, Monte Graham, Ron Myhrum, Matt Ricketts, Lorna Stolen, Randall Wilson. From BLM: Glen Miller. From USGS (formerly National Biological Service): Carol Chambers (Animal Field Crew Coordinator), Becky Faesth, Rachel Johnson.

This study was coordinated by a committee (the authors) of the Sample Inventory and Monitoring of Natural Resources and the Environment (SIMNRE) Working Group of the Federal Geographic Data Committee (FGDC).

The information in the document has been funded in part by the Natural Resources Conservation Service, US Forest Service, US Geological Survey, Bureau of Land Management, National Agricultural Statistics Service, and US Environmental Protection Agency. It has been subjected to the agencies' peer and administrative review, and it has been approved for publication by those agencies. The conclusions and opinions are solely those of the authors and are not necessarily the views of the Agencies. Mention of trade names or commercial products does not constitute endorsement of recommendations for use.

REFERENCES

- Allen, R. 1994. Forecasting crop acreages and yields in the face of and in spite of floods Presented at 1994 FIA ENAR Spring Meetings, Cleveland, Ohio.
- Bailey, R.G. 1995. Ecosystem geography. Springer-Verlag, New York.
- Bechtold, W.A., Ruark, G.A. and Lloyd, F.T. 1991. Changing stand structure and regional growth reductions in Georgia's natural pine stands, *Forest Science*, 37, 703- 17.
- Birdsey, R.A. and Schreuder, H.T. 1992. An overview of forest inventory and analysis estimation procedures in the Eastern United States - with an emphasis on the components of change. Gen. Tech. Rept. RM-214, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.
- CENR. 1997. Integrating the nation's environmental monitoring and research networks and programs: a proposed framework. Committee on Environment and Natural Resources, National Science and Technology Council (<http://www.epa.gov/cludygxb/pubs.html>)
- Dahl, T.E. and Johnson, C.E. 1991. Status and trends of wetlands in the conterminous United States, Mid-1970's to Mid-1980's. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C.
- Fecso, R., Tortora, R.D. and Vogel, F.A. 1986, Sampling frames for agriculture in the United States, *Journal of Official Statistics*, 2(3), 279-92.
- FHM. 1994a.. National Forest Health Monitoring Program. U.S. Department of Agriculture, Forest Service, Forest Health Monitoring Program, Research Triangle Park,
- FHM. 1994b. Forest Health Monitoring: A National Strategic Plan. U.S. Department of Agriculture, Forest Service, Forest Health Monitoring Program, Research Triangle Park, NC.
- Goebel, J., H. Schreuder, C. House, P. Geissler, A. Olsen, and W. Williams. 1998. Field procedures for a study on integrating surveys of terrestrial natural resources: the Oregon demonstration project. Internal Report
- Hazard, J.W. and Law, B.E. 1989. Forest survey methods used in the USDA Forest Service. EPA/600/3-89/065, U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Corvallis, Oregon.
- Kott, P.S. and F.A. Vogel. 1995. Multiple frame business surveys *in* B.G. Cox, D.A. Binder, and B.N. Chinnappa, eds. Business survey methods. Wiley

Max, T.A., Schreuder, H.T., Hazard, J.W., Oswald, D.D., Teply, J. and Alegria, J. 1996. The Pacific Northwest Region Vegetation Inventory and Monitoring System. PNW-RP- 493, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Messer, J.J., Linthurst, R.A. and Overton, W.S. 1991. An EPA program for monitoring ecological status and trends, *Environmental Monitoring and Assessment*, 17, 67-78.

Nusser, S.M. and Goebel, J.J. 1997. The National Resource Inventory: a long-term multi-resource monitoring program, *Environmental and Ecological Statistics*, 4(2).

Olsen, A.R., Sedransk, J., Edwards, D. Gotway, C.A., Liggett, W. , Tathbun, S.L., Reckhow, K.H., Yound, L.J. 1997. Statistical Issues for Monitoring ecological and natural resources in the united states. *Environmental monitoring and assessment*. Forthcoming.

Omernik, J.M. 1987. Ecoregions of the conterminous United States, *Annals of Association of American Geographers*, 77(1), 118-25.

Ouyang, Z., Schreuder, H.T. and Li, J. 1992. A reevaluation of the growth decline in Georgia and Georgia-Alabama, In Kansas State University Conference on Applied Statistics in Agriculture, April 28-30, 1991, Manhattan, Kansas. Kansas State University.

Peterjohn, B.G. 1994. The North American Breeding Bird Survey, *Birding*, 26, 387-98.

Powell, D.S., McWilliams, W.H. and Birdsey, R.A. 1994. History, change, and our Nation's forest inventory, *Journal of Forestry*, 92(12), 6-11.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. *Condor* 82:309-313.

Ruark, G.A., Thomas, C.E., Bechtold, W.A. and May, D.M. 1991. Growth reductions in naturally regenerated southern pine stands in Alabama and Georgia, *Southern Journal of Applied Forestry*, 15, 73-9.

Schreuder, H.T., T.G. Gregoire, and G.B. Wood. 1993. Sampling methods for multiresource forest inventory. Wiley, New York.

Scott, C.T. and Bechtold, W.A. 1995, Techniques and computations for mapping plot clusters that straddle stand boundaries, *Forest Science Monograph* 31, 41, 46-61.

Scott, J.M., Davis, F., Csuti, B., Noss, R., Butterfield, B., Groves, C., Anderson, H., Caicco, S., D'Erchia, F., Edwards, T.C.,-Jr., Ulliman, J. and Wright, R.G. 1993. Gap analysis: a geographic approach to protection of biological diversity, *Wildlife Monographs*, 123, 1-41.

Scott, J.M., Tear, T.H., and Davis, F.W. 1996. Gap analysis: a landscape approach to biodiversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, MD. ISBN-1-57083-03603. [Http://www.gap.uidaho.edu/gap/](http://www.gap.uidaho.edu/gap/)

Stevens, D.L., Jr. 1994. Implementation of a national environmental monitoring program, *Journal of Environmental Management*, 42, 1-29.

USFS. 1992. Forest Service resource inventories: an overview. USGPO 1992-341-350/60861, U.S. Department of Agriculture, Forest Service, Forest Inventory, Economics, and Recreation Research, Washington, DC.

USFS. 1993. A blueprint for Forest Inventory and Analysis research and vision for the future. Program Aid No. 1512, U.S. Department of Agriculture, Forest Service, Washington, DC.

Ueng, C.Y., Gadbury, G.L. and Schreuder, H.T. 1997. Robust Regression Analysis of Growth in Basal Area of Natural Pine Stands in Georgia and Alabama, 1962-1972 and 1972-1982. USDA Forest Service RM Forest and Range Exp. Sta. RM-RP-331

APPENDIX I

Natural Resource Surveys

Our investigation of the feasibility of integrating national terrestrial inventory and monitoring programs began with the identification of a set of programs that were likely candidates (Olsen et al. 1997). We focused on programs that were national in scope, used a probability-based survey design, emphasized estimating national status and trends, and emphasized terrestrial natural resources, especially forest land and range land. In the descriptions of the programs that follow, we provide overviews of the programs and discuss elements that are critical to the conduct of the Oregon Demonstration Study conducted in 1995.

Forest Inventory and Analysis (FIA), USDA Forest Service (FS)

The Forest Inventory and Analysis program, originally known as the Forest Survey, was initiated in response to the McSweeney-McNary Forest Research Act of 1928. The Act directed the Secretary of Agriculture "to make and keep current a comprehensive survey of the present and prospective requirements for timber and other forest products in the United States, and of timber supplies, including a determination of the present and potential productivity of forestland therein, and of such other facts as may be necessary in the determination of ways and means to balance the timber budget of the United States." This resulted in FIA's original emphasis to estimate merchantable wood volume by tree species and diameter class, and to measure the area of forest land by type, stand size, ownership, site quality and stocking. Over time, additional information such as change in forest acreage, growth, mortality, timber removals, and measures of the success

of regeneration became equally important. The National Forest Management Act of 1976 expanded the survey to cover all renewable natural resources (forest and rangelands, public and private). Further expansion to increase the frequency of forest inventories and to include measures related to the health and productivity of domestic forest ecosystems began with the Forest Ecosystems and Atmospheric Pollution Research Act of 1988 (USFS 1993, Powell et al. 1994). More recently, the data are being mined more for their analytic potential, in addition to traditional status and change estimates. For example, FIA data were used to examine the relationship between decreased growth rates in tree basal area and a variety of proposed culprits in the south (Bechtold et al. 1991, Ruark et al. 1991, Ouyang et al. 1992, Ueng et al. 1997). This use (cause-effect analytical analyses) of survey data is controversial.

FIA uses a two-phase survey design (double sampling for stratification) where the first phase is a systematic photo point grid geographically spaced across the United States mainland and the second phase is a permanent subsample of points that fall within forest land. The first phase photo interpretation separates forest from non-forest and classifies forest stand conditions. The second phase ground sample provides data on tree, stand, and site conditions. Historically, measurements were generally made within clusters of 5 or 10 variable radius subplots centered at the sample point with trees selected proportional to their size (Birdsey and Schreuder, 1992). FIA is now shifting to a 1-ha (2.54 acres) ground plot subsampled by four 1/24-acre (.0169 ha) subplots. This plot design was developed for forest health monitoring and was tested there (Scott and Bechtold, 1995). Nationwide, FIA samples approximately 6.5 million photo points and 135,000 permanent forested ground points, with data collection approximately every 10 years. FIA focuses mainly on private or state forest land. The location of the plots is confidential to ensure that the plots remain representative of the population and to protect the rights of landowners. FIA produces inventory reports aggregated to groups of counties, states, regions, and the nation. National reports are produced every 5 years; a report to Congress every 10 years.

National Forest System, USDA Forest Service (FS)

National Forest System (NFS) inventories produce resource information for developing, implementing, and monitoring National Forest management plans, as well as for other purposes. The basic survey unit is the National Forest. The inventory(s) serve multiple objectives or resources, e.g., timber, range, soils, geology, vegetation, fish and wildlife. In some cases NFS inventories are conducted by FIA using FIA procedures. In most cases, however, NFS completes its own inventories, but many of the procedures are similar to FIA's. Generally, they do not use double sampling for stratification; instead, they use stratified random sampling or stratified systematic sampling (Hazard and Law 1989). Of particular interest here is the NFS Region 6 (Oregon and Washington) inventory. In early 1990s, Region 6 developed their Current Vegetation Survey (CVS) based on a 5.47-kilometer (3.4 mile) square grid across all NFS land. The grid is intensified to 2.74-kilometers (1.7 mile) or 1.37-kilometer (0.85 mile) for land management planning or for special needs supplemental sampling. The primary sampling unit, established at each grid point, consists of a 1-hectare circular plot. It is subsampled with a set of five different-sized fixed-area subplots, as well as line transects, to assess all components of vegetation (Max et al. 1996). The location of these plots cannot be kept confidential.

National Resource Inventory (NRI), USDA Natural Resources Conservation Service (NRCS)

The NRI is a longitudinal survey that assesses the conditions and change in soil, water, and related natural resources on nonfederal land (Nusser and Goebel, 1997). The survey is repeated every five years beginning in 1982 and uses an unequal probability stratified two-stage area sample as the basic design. The stratification is geographic, based primarily on the Public Land Survey system, with a typical stratum having an area of 12 square miles. The primary sampling unit (PSU) is a nominally square area, generally containing 160 acres (64.75 ha). Approximately 300,000 PSUs and an approximate 4 percent sampling rate is obtained by selecting two PSUs within each stratum. The second stage selects three point samples within most PSUs according to a strict randomization procedure to ensure spatial coverage. Some data are collected for the entire primary unit and other more specific information is gathered at each point. The purpose of the NRI is to provide information that can be used for effectively formulating policy and developing natural resource conservation programs. Goals include: 1) to provide estimates of resource conditions at precision sufficient to allow analysis of issues at the multi-county or sub-state level; 2) to generate estimates of changes since the previous survey, such as changes in erosion rates for Class II cropland or changes for prime farmland from cropland to urban; 3) to develop the multi-resource concept in greater detail, by collecting information useful in ecosystem-based planning or in analysis of environmental and ecological issues; and 4) to enhance opportunities to examine spatial trends. The exact location of the sample points and PSUs is kept confidential.

Forest Health Monitoring Survey (FHM), USDA Forest Service (FS)

The FHM program's mission is to develop and implement a cooperative multi-agency program to monitor, assess, and report on the long-term status, changes, and trends in forest ecosystem health in the United States (FHM 1994a; FHM 1994b). The survey results in an objective data base capable of supporting appraisals of forest health at the regional and national levels. FHM's sampling design is a spatially and temporally systematic sample based on a 27 km triangular grid. The systematic grid is used to subsample an extended FIA photo point grid. (FHM and FIA are using a modified design in Minnesota. Rather than subsampling FIA photo points, FHM is sampling a subset of FIA ground plot locations.) At each forested grid point, ground observations are recorded periodically from clusters of 4 fixed area subplots that subsample a 1-ha plot (the same plot as earlier described under FIA). If a plot samples different conditions, these conditions are mapped. Monitoring occurs annually with a 4-year spatially interpenetrating panel of site visits. Current design protocols call for all four panels of sites to be measured during the first year, followed by remeasuring 1/4 of the sites on a four-year cycle. In addition, 1/3 of the previous year's panel are remeasured to provide overlap across years. Indicators of forest health include forest growth, forest mortality, forest distribution and structure, canopy condition, and soil condition. The exact location of the sample plots are kept confidential.

Biological Resource Division, U. S. Geological Survey (BRD), DOI

The BRD conducts several national population monitoring surveys such as the Breeding Bird Survey (BBS, Peterjohn 1994) which estimate the status and trends of bird populations. A similar

survey is being developed for calling amphibians. The BBS is a roadside survey, primarily covering the continental United States and southern Canada. The BBS was started in 1966, and the over 3,500 randomly selected routes are surveyed in June by experienced birders. These extensive surveys are supplemented by intensive studies at selected sites. The Gap Analysis Program (GAP, Scott et al 1993) provides broad geographic information on the status of ordinary species and their habitats in order to provide land managers, planners, scientists, and policy makers with the information they need to make better-informed decisions. Gap analysis is a scientific method for identifying the degree to which native animal species and natural communities are represented in our present-day mix of conservation lands. Those species and communities not adequately represented in the existing network of conservation lands constitute conservation "gaps." The Biomonitoring of Environmental Status and Trends (BEST) program is designed to identify and understand the effects of environmental contaminants on biological resources, particularly those resources under the stewardship of the Department of the Interior (DOI). February 17, 1998 The primary goals of BEST are to: (1) determine the status and trends of environmental contaminants and their effects on biological resources, and (2) identify, assess and predict the effects of contaminants on ecosystems and biological populations.

National Agricultural Statistics Service (NASS), USDA

NASS produces and maintains a variety of statistical data bases important to environmental monitoring on agricultural lands. Basic among these are annual estimates of land usage, including crop production and livestock inventories. These statistics have long historical series (Allen 1994; Fecso et al 1986). Additionally, NASS maintains an agricultural chemical use data base, which includes estimates of percent of acres treated, total quantities applied, and application rates for an extensive array of agricultural chemicals. These estimates are available in combinations by crop, chemical and state; and cover all major field crops, vegetables and fruits in major producing states. These data series began in 1990. About the same time NASS joined with EMAP in a partnership to supply the data needs for monitoring resources within the Agricultural Lands Resource Group. That project involves six states in the Mid-Atlantic region, and uses the NASS area sampling frame. This frame has national coverage and is stratified by land use for efficient estimation of agricultural production. For several years NASS was also in partnership with the NRCS and the Economic Research Service to collect information at NRI points in selected watershed areas as part of the President's Water Quality Initiative. Because of the strong expertise in NASS in interview surveys and data analyses, they are uniquely qualified to contribute to NRI/FIA inventories in those regards.

Bureau of Land Management (BLM) Inventory and Monitoring, DOI

The BLM has not maintained a national comprehensive program to survey and monitor resources on the public lands. Two separate programs, a forest land inventory and a rangeland inventory, were initiated in the 1970s. The inventory of forest land covered all "commercial" forest land and followed the design used at the time by Forest Service FIA program. Updates to the inventory

have been done in a few places for specific planning projects. BLM cooperates with the FIA units in the West.

The rangeland inventory, which is now referred to as Ecological Site Inventory (ESI), was intended to be an "in-place" inventory with data collected for each mapped ecological site; the inventory is ongoing today. The difficulty with ESI is that of maintaining and aggregating site-specific data for a national level assessment. BLM monitors rangeland condition on grazing allotments to assess the effects of management actions. Each monitoring plan is designed specifically for the desired objectives of the management actions.

The BLM in Oregon is the exception to the above statements. Oregon has maintained a comprehensive inventory of forest (timber) inventory of the O&C lands. Recently, they adopted the sample design used by Region 6 of the USFS.

BLM is currently (1997) doing a pilot project in Colorado to test the feasibility of applying the NRI design to public rangeland in Colorado.

Environmental Monitoring and Assessment Program (EMAP), US Environmental Protection Agency (EPA)

EMAP's goal is to monitor the condition of the Nation's ecological resources to evaluate the cumulative success of current policies and programs and to identify emerging problems before they become widespread or irreversible (Messer et al 1991). To achieve this goal EMAP developed an integrated monitoring framework that includes a tier of intensively monitored sites, a tier of regional surveys, and a tier of complete coverage. Initial efforts focused on developing the science required to implement regional surveys for all ecological resources. This involved the development of a two-phase survey design based on a systematic triangle grid with a random start that is subsampled by a second independent randomization of each grid point. The design is tailored to the ecological characteristics of each resource (Stevens 1994). EMAP is committed to build the national network from the bottom up starting with effective existing networks and adding to them where gaps exist. A high priority is placed on research to ensure that monitoring is based on strong science especially in the areas of ecological indicators, monitoring design, and integration of environmental data.

National Wetlands Inventory (NWI), USFWS, DOI

The NWI Status and Trends program of the FWS (DOI) has as its primary objective the production of comprehensive, statistically valid estimates of the Nation's wetland acreage (Dahl and Johnson 1991). The program has produced estimates of trends between the mid- 1950's and the mid-1970's and again between the mid-1970's and the mid-1980's, by interpreting data from extant low-level aerial photography of sample plots using NWI procedures and wetland categories. The sample design consists of a stratified random sample of 3,629 permanent plots within the conterminous 48 States, each four square miles (10.36 km²) in size. The strata are

formed using state boundaries and 35 Hammond physical subdivisions. An additional coastal stratum is included in each of the coastal states from Texas to New Jersey. Samples are allocated to strata in proportion to expected wetland acreage to achieve coefficients of variation of 10 percent at the national level. The study produces a quantitative measure of the areal extent and change in areal extent of wetlands by wetland category. The NWI is in the process of converting to a continuous Status and Trends project based on this national sample of fixed plots, wherein new data will be obtained on approximately 10 percent of all plots every year on a rotating basis. The location of the sample plots is kept confidential.

APPENDIX II

Integrated Monitoring Advantages and Concerns

Advantages

- Uniform information would be available for all terrestrial natural resources, whether private or public.
- A common public database of environmental information would facilitate interdisciplinary and interagency studies that could address the Nation's major environmental issues.
- Ecosystem and watershed health assessments have to cover all lands to be meaningful.
- Agencies' objectives are broadening to address ecosystem concerns; hence programs have more measurements in common.
- Uniformity of definitions, sample design, and measurements throughout the United States would permit data collected by different agencies to be meaningfully combined, leveraging their investments and allowing agencies to address broader issues.
- Reduction of actual and apparent conflicts in estimates would result from the use of common definitions and estimates. Apparent conflicts have resulted from the use of different operational definitions of the same conceptual quantity (e.g., acres of forest land and acreage in range land).
- Combining the estimates would result in a single estimate that is superior to either of the separate estimates, and resolve apparent conflicts that result from differences in estimates due to sampling error.
- Improved efficiency in data collection would be possible through the pooling of resources and the elimination of duplicate efforts.
- Annual measurements on a subset of the plots would provide information on rapid changes. Annual measurements may be feasible because of the savings resulting from the efficiencies of consolidation.
- More frequent measurements would be possible if resources were pooled, providing improved understanding of the environmental responses to changing conditions and an early warning of environmental catastrophes.
- Greater opportunity for state involvement and funding could be available through participation in a single, broad-based interagency effort.
- Increased flexibility to accommodate multiple conditions and objectives would be possible from a broad-based interagency survey, compared to highly focused, agency-specific surveys.

- Reduced bureaucratic competition and enhanced budget stability would result from the cooperation and mutual support of participating agencies.
- Increased national commitment to a reliable and complete environmental inventory and monitoring program would be possible from a high profile interagency effort.
- Decrease frequency for access to private lands would result, reducing impact on landowners.
- All information would be equally current and would refer to the same period, reducing the possibility for apparent conflicts and confusion.
- The time is right for consolidating surveys; agencies are giving more emphasis on detecting changes and identifying their possible causes which currently requires information collected by several surveys.
- Improved vigor is likely to result from 'renewal' of the surveys.
- Give an opportunity to reexamine the objectives of these surveys and bring them in line with current needs and knowledge, i.e., variables to be measured, acceptable quality standards, need for highly trained crews that are completely committed time-wise to the data collection effort, organizational structures, etc.
- We have no doubt that existing terrestrial surveys would benefit from a complete review of how best to accomplish such environmental monitoring.

Concerns

We recognize that there are concerns that need to be explored, understood, and addressed prior to implementing an integrated national monitoring program. Some of these concerns are:

- Current surveys each have a legislative mandate with a requirement for the data collected. If an integrated survey is proposed, will a new, or modified, legislative mandate be required?
- Although a new survey design may be advantageous, it is necessary to preserve the historical data series associated with permanent plot locations for existing surveys, such as the NRI and FIA surveys. For example, the FIA began in 1930 (Birdsey and Schreuder 1992), and there are repetitive measurements on some units back to the early 1960s (with three to six visits to a site over this time period). NRI dates from 1982 with approximately three visits per site over this period. Although there are valid statistical and operational reasons to initiate a new survey design for the integrated program, any changes would have to be phased-in to preserve comparability with the historical data.
- There is also concern about using permanent plots, because it may not be possible to keep plot locations confidential and representative when multiple partners visit the plots. The higher visitation rate and visibility might result in more land-owner refusals and may affect the representativeness of the plots. Larger crews required to measure the additional variables necessary for a consolidated survey may affect the representativeness of the plots by causing trampling of plots.
- There is concern that a broader focus to the monitoring effort may lead to a loss of agency, state, industry, and political support that has been present for individual programs that are more narrowly focused. How will state and industry participation be developed; hence incorporating their objectives and concerns into the planning process.

- Individual agencies may not assume ownership in an interagency effort. How will full cooperation of individual agencies be achieved?
- An integrated approach might be implemented in such a way as to increase bureaucratic hassles and reduce flexibility and creativity, rather than to decrease them. Interagency agreements on funding, administrative structure, and transition schedules will be required for implementation. What process will be used to determine what the common objectives will be and how will agency specific objectives, requirements be met?

Table 1. Orientation of transects

Subplot	Transect 1	Transect 2
1	0 degrees	90 degrees
2	180 degrees	270 degrees
3	300 degrees	30 degrees
4	60 degrees	330 degrees

Table 2. Forest and rangeland estimates with USFS and NRCS definitions, in hectares

Land Class ¹	Crown Cover %	Forest Land		Rangeland	
		USFS Estimates	NRCS Estimates	USFS Estimates	NRCS Estimates
Timberland	10-24	36,517			36,517
	≥25	706,972	706,972		
Oak Woodland	10-24	3,036			3,036
	≥25	30,358	30,358		
Unclassified Woodland	10-24				
	≥25	6,361	6,361		
Juniper Woodland	10-24	98,403			98,403
	≥25	43,912			43,912
Chaparral		3,036			3,036
Desert Shrub				169,548	169,548
Grass/ Herbaceous				392,820	392,820
Total (Phase I)		928,595	743,691	562,368	747,272
		45%	36%	27%	37%
Estimates using Phase I (photo) totals, adjusted with a regression based on the Phase II (ground) observations					
		793,246	700,043	613,710	706,913
		39%	34%	30%	35%

¹ Other lands not included are cropland, pasture and hayland, permanent snow, barren land, wetlands, developed land, transportation and utilities, and water which together total 554,906 ha.

Table 3. Repeatability of selected measurements

Attribute	Correlation (r)	Mean Difference (%)	Measurement Error as % of Plot Variance
Frequency of Occurrence			
Average number of species per location	0.89	22.5	6.1
Total number of species per plot	0.96	19.5	2.0
Average to total species ratio	0.39	60.1	44.0
Shrub Density			
Percent seedlings	0.27	100.0	73.0
Percent saplings	0.39	53.4	44.2
Percent mature	0.52	50.4	32.4
Percent decadent	0.74	57.6	15.6
Percent dead	0.87	47.2	7.2
Total count	0.93	24.6	3.8
Tree Tally For Woodlands			
Average DBH	0.90	8.0	5.6
Total Basal area	0.97	10.3	1.5
Number of Trees	>0.99	5.8	0.4
Number of species	0.96	5.8	2.1

TEXT BOX

PRINCIPLES USED IN FORMULATING THIS PROPOSAL

Share resources and control.

Enact change through phased transition.

Provide an integrated, multi-purpose database.

Preserve the utility of historical data.

Enable the comparison and aggregation of information.

Maintain flexibility to address specialized issues.

Provide capability for annual estimates..

Figure Captions

Figure 1. Study area

Figure 2. Land ownership in study area

Figure 3. Vegetation class in study area

Figure 4. Plot design

Figure 5. Integration process











