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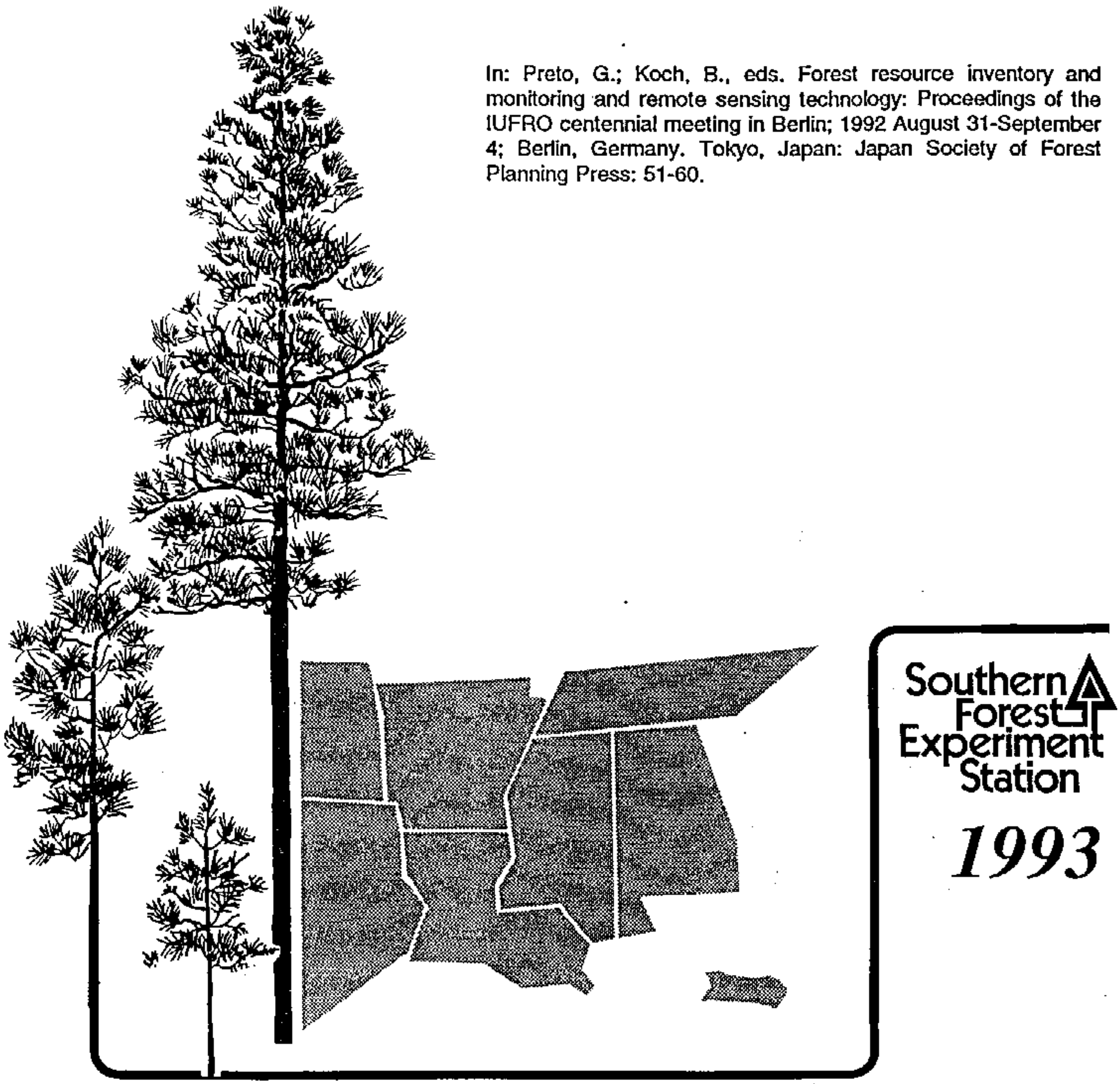

TRANSFORMING ROUND PEGS TO FILL SQUARE HOLES: FACING THE CHALLENGE OF FOREST INVENTORIES AS TOOLS OF ENVIRONMENTAL POLICY FOR THE 21ST CENTURY

Victor A. Rudis

Research Forester, USDA Forest Service
Southern Forest Experiment Station
Forest Inventory and Analysis Unit
P.O. Box 906, Starkville, MS 39759 USA

SUMMARY

Today's forest inventory specialist is challenged to combine inventories and analysis of timber with range, recreation, soil, water, and wildlife resources, related human uses, and social and economic concerns. Lessons learned in adapting timber-oriented forest inventories toward holistic forest resources assessment are provided. Discussed are ways to maintain dialogue with other disciplines, make holistic assessments from disparate functional inventory efforts, resolve transborder monitoring disputes, and reorient forest assessments toward ecological concerns. Examples are drawn from the United States Department of Agriculture, Forest Service, forest inventory and analysis program.

Keywords: Forest ecosystem inventories, holistic forest assessment, multiple resource surveys, social science, wildlife habitat evaluation.

INTRODUCTION

An increasingly environmentally conscious public and sophisticated special interests throughout the world are questioning traditional forest uses and related inventory activities. Critics argue the need for sustainable ecosystems and preservation of biodiversity. This situation suggests the need for inventories that are holistic and that transcend political boundaries.

Early in the 20th century, the public's desire to determine the adequacy of timber supplies dominated forest inventory designs in the United States and elsewhere. With the growing importance of environmental issues in the 1960's, strictly timber-oriented inventories were no longer seen as sufficient to assess the timber supply or to monitor forest resource changes (Wikstrom and Alston 1985). The 1970's and 1980's heralded an effort to conduct integrated, multiple resource inventories and analyze interdisciplinary forest resource issues.

Many foresters see integrated, multiple resource inventories as logical, cost-effective alternatives to independent assessments. Not all resource inventories can be integrated, however (Bastedo and Theberge 1983). Lessons learned suggest ways to adapt timber-oriented forest inventories to interdisciplinary forest resource issues. The focus is on inventories conducted and issues analyzed by United States Department of Agriculture, Forest Service (USDA-FS), Forest Inventory and Analysis (FIA) units.

Adapting timber inventories toward holistic forest resource assessments is a process analogous to using round pegs to fill square holes (Figure 1). Square holes are the information needed. Round pegs are the existing, timber-oriented data. Information needs are more extensive than existing inventory data can provide. Thus, there are knowledge gaps. Some of the existing data, though not ideal, do provide answers.

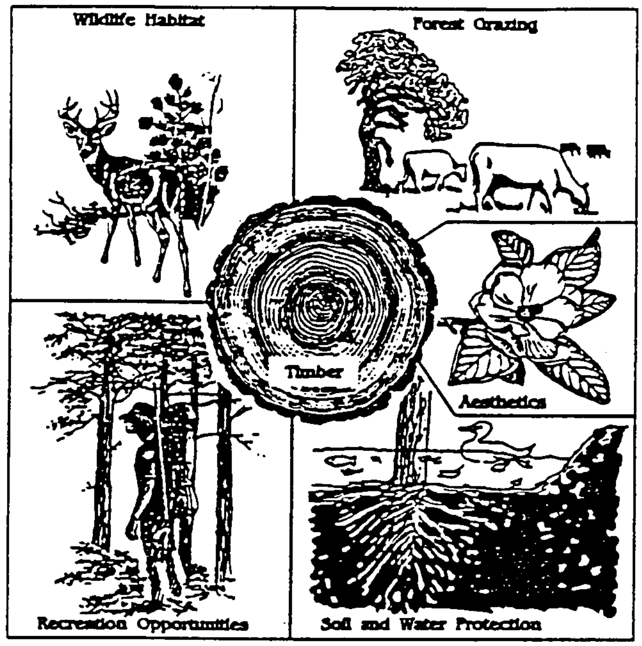

Figure 1. "Round pegs," timber-oriented inventory data, and "square holes," information needed to assess forest grazing, aesthetics, soil and water protection, recreation opportunities, and wildlife habitat.

Efforts to assemble multipurpose inventory and analysis techniques are highlighted in this report. Some of the associated problems and present-day solutions are suggested as guides to address landscape-level environmental and social concerns for the 21st century. There are four major themes: (1) maintaining dialogue with other disciplines, (2) uniting disparate functional inventories, (3) resolving transborder inventories, and (4) reorienting forest assessments toward ecological concerns.

ASSEMBLING MULTIPURPOSE TECHNIQUES

U.S. legislation in the 1970's mandated a comprehensive assessment of forests. In 1975, a program to expand the FIA timber resource inventory toward a multiple resource inventory began. During the next 15 years, inventory procedures were modified, measurement techniques were adapted, and analyses were developed to address emerging issues. FIA units worked with groups in each of the 50 States and U.S. territories to plan the expansion of forest inventories toward holistic assessments.

Progress in this effort is annotated in a recent conference proceedings (Rudis 1990). More than 400 citations published between 1974 and 1990 are documented that made use of the expanded FIA data effort for temperate and boreal forests of the United States (Rudis 1991). In addition, more than a dozen articles associated with tropical forest inventories in the State of Hawaii and several United States territories were published.

A content analysis of titles compiled in Rudis (1991) indicates the scope in the past and the direction for future efforts. Listed in Table 1 are unique words that occur 10 or more times within 422 titles of articles published between 1974 and 1990. There are 4,177 words and 1,005 unique words. Excluding articles, prepositions, and names of political and geographic subdivisions, there are 3,214 words.

Multiple resource inventories share terminology with many scientific disciplines other than forestry. Yet there are only a few common words widely used among disciplines (Table 1). Those words that occur 1 percent (32 occurrences per word) or more of the time are probably the major communication bridges across disciplinary barriers. Content analysis of the articles themselves would reveal that common words have different meanings in each discipline.

Word frequencies between 0.5 and 1.0 percent (16 to 31 occurrences) suggest subjects that have contributed widely to the past dissemination of inventory information among other disciplines. Word frequencies below 0.5 percent (15 or fewer occurrences) suggest subjects that have received limited attention.

All major tangible values or resource products are represented: timber, wildlife, range, recreation, soil and water. Wildlife and wildlife habitat are popular subjects. Sociological issues, such as owner studies, and intangible values, such as beauty, also appear. Biomass, ecological studies, remote sensing, and insect and disease studies are also prominent. Some of these topics could very well represent subjects of importance in the next decade.

*Table 1. Unique words and their occurrence within 422 titles in Rudis (1991)**

Occurrence	Unique word or word group
217	Forest[s], forested, forestland, forestry, forests.
111	Analysis, analyses, analytical, analyzing, application[s], applied, appraisal[s], assess, assessing, assessment[s], estimate[s], estimating, estimation, evaluating, evaluation[s], monitor, monitoring.
111	Inventories, inventory, inventorying.
90	Area[s], land[s], region[s], regional, regionally.
83	Resource[s].
46	Change[s], changing, trends.
44	Use, using, utility, utilization, utilizing.
37	Wildlife, wildlife habitat[s].
35	Data, data base, database.
35	Landowner[s], owner[s], ownership[s], private owner, privately owned.

Table 1. Unique words and their occurrence within 422 titles in Rudis (1991) (Continued)

Occurrence	Unique word or word group
30	AVHRR, LANDSAT, imagery, photo, photographs, photography, photointerpretation, photointerpreting, remote sensing, remotely sensed, thematic.
28	Equations, model[s], modeling, modelling.
28	Multiresource.
26	Timber.
25	Hardwood[s], pine[s].
23	Biomass.
22	Wooded, woodland[s], woody.
22	Vegetation, vegetative.
21	Survey[s].
18	Hydrological, riparian, soil[s], water, watershed, wetland[s].
18	Tree[s].
16	Ecological, ecoregions, ecosystem[s], geoecology, landscape, spatial.
16	Growing, growth.
16	Management, managing.
16	Timberland[s].
15	Volume[s].
15	Shrub[s], understory.
14	Beauty, norms, perception, preference, psychological, scenic, sociological, visual.
14	Browse, forage, grazing, livestock, range, rangeland[s].
14	Cover. [Includes (canopy, crown, foliar, forest, forestland, land, land/forest, land use, understory) cover, and cover(-class, types).]
14	Characteristics, characterization, characterizing.
13	Habitat[s]. [Excludes wildlife habitat(s) but includes (bird, deer, forest, mammal, nesting, raptor, riparian, woodcock, woodpecker) habitat.]
13	Integrated, integrating, integration.
13	Macroplot, plot[s].
13	Non[-]industrial.
13	Recreation, recreational.
13	Sample, sampling.
13	Statistics.
11	Technique[s].
10	Status.
10	Damage, defect, defoliation, disease[s], insect[s].
10	Deposited, deposition.
10	Renewable.

* Articles, prepositions, and names of political and geographical divisions are omitted. Words of similar meaning or common to one subject or discipline appear in a single group; occurrences are combined. Due to limited space, 787 other words that occur fewer than 10 times are omitted.

MAINTAINING DIALOGUE WITH OTHER DISCIPLINES

Identifying and involving users in disciplines other than forestry can be effective in broadening the inventory and analysis effort. Making the forest inventory sampling design, data collection, and analysis useful to other disciplines is a necessary, yet daunting, task (Rudis 1991). Few individuals are likely to sift through information that is not directly addressed to their discipline or agency concerns. Nor are individuals in disciplines other than forestry likely to define their need for forest inventory data.

Besides obvious differences in terminology, other barriers hamper communication among disciplines. First, there is a lack of skill to coordinate inventories among disciplines. Second, there are incompatible inventory priorities and perceived responsibilities among agencies charged with disciplinary inventory efforts. Third, there is an absence of administrative, political, social, and legal structures to support interdisciplinary communication for forest inventories (Rudis, in press).

Barriers can be bridged, however. FIA units use several approaches, including: (1) hiring specialists from other disciplines to conduct portions of the inventory and the analysis, (2) convening a group of potential data users from timber and other disciplines to reach a consensus on important inventory components, (3) establishing research units to address multipurpose inventory techniques and to assess multiple resources, (4) making raw observations, not just summaries, available to and usable outside the inventory unit, and (5) keeping track of nontraditional measures, methods of analysis, and users. Inventory units have funded several approaches through cooperative agreements with universities and other research institutes.

Theoretically, each of the approaches above supports integrated, multiple resource inventories and multidisciplinary analysis of forest resources. The approaches are not equally successful in practice, however. For example, there continues to be only a limited consensus on the selection of the wildlife habitat components for a national forest resource assessment (Brooks 1990). FIA units have not standardized inventory components for range, recreation, soil, and water resources. One reason may be that the interdisciplinary infrastructure needed for such inventories is not developed (Rudis, in press).

UNITING DISPARATE FUNCTIONAL INVENTORIES

Forestry traditionally inventories immovable woody species and biophysical features of stands in the landscape. This emphasis is not common to some of the other natural resource disciplines. Game management scientists use animal population censuses that vary in space and across seasons. Hydrologists study watersheds rather than forest stands. Conservation biologists often conduct studies of nonwoody species and ephemeral conditions. Other disciplines, such as sociology and recreation, inventory the pluralistic values attached to natural resources through user surveys. Values are quantified by a human population census that is grouped by political subdivision, organization, or land management unit.

Historically, FIA forest inventories obtain much information from samples placed systematically on timberland, i.e., land with commercial wood production potential. Rare forested habitats are infrequently sampled. Forests with few commercially desirable species, and nonforested areas are estimated from aerial photos and other public agency records.

Inventories of forest pests, forest-dwelling wildlife, and recreation opportunities are incomplete and sometimes even irrelevant without consideration of noncommercial forests and nonforested areas.

The lack of comparable samples for designated wilderness areas, urban forests, nonforested areas, and rare habitats limits the types and number of other resources inventoried and issues addressed. Yet extending the inventory to areas without commercial wood production potential is costly.

Holistic assessments can be pieced together from disparate functional inventories. The growing use of high-speed computers and geographic information systems (GIS) makes it easier to reconcile data with other sampling frames. Independent inventory data from nonforested areas and rare habitats can be integrated in a GIS. Some of the biophysical data can be reexamined with social data by linking common physiographic and political subdivision boundaries. With improvements in global position technology, plot attributes can be associated spatially with other mapped data for selected landscapes of interest.

Inventory data are routinely organized by political subdivision and ownership in FIA inventories and in many other landscape-level forest inventories. Opportunities for both analysis of interdisciplinary issues and interaction with other disciplines are greater if observations are registered by location in a GIS.

A sample analysis of black bear (Ursus americanus) habitat is discussed for the southern United States (Rudis and Tansey 1992). To assess potential habitat, i.e., wooded area with restricted human access, county estimates are assembled. Data come from: FIA field inventories of timberland, FIA photointerpreted estimates of noncommercial forest area, and other Federal agency records of wilderness area. At present, only FIA data can be recalculated to estimate area with restricted human access. Other data sources are added with simplifying assumptions about human-access restrictions.

To assess the proportion of potential habitat that is occupied, one adds observations of black bear sightings obtained from management specialists. Overlays of black bear sightings with potential habitat show that 80 percent of black bear habitat area corresponds with permanent residence of black bears. In this example, knowledge gained can be used to rate counties for black bear reintroduction.

At a county scale of resolution, there are 5 distinct regional groups of black bears. The location of potential habitats and corridors among groups can be used to explore hypotheses about potential genetic interaction among black bear populations. Accessible forests with bear sightings indicate potential human-bear interaction problems. These areas can be targeted for additional black bear conservation education efforts. The combined data also can be useful for regional forest management plans, e.g., to establish priority forest regeneration zones that serve as potential habitat corridors.

The combined data are registered by county--the smallest land unit common to these disparate inventory efforts. "Wall-to-wall" coverage is obtained--a prerequisite for many multidisciplinary studies. Discrepancies in data collection procedures remain, but they are discussed as assumptions in the analysis. Contacting other agencies and disciplines to determine available inventory data is time-consuming but valuable.

RESOLVING TRANSBORDER INVENTORIES

Often, forest inventory data and analyses are organized by political or geographic subdivision, owner, forest stand type, land use potential or some combination of these. In the United States, 50 States and U.S. territories are inventoried by six FIA units. Each unit has funds to inventory State, private, and some federal land in selected states. All units are administratively similar.

State and local agency interests, forest industries, environmental groups, and other special interests play a role in advising FIA units and influencing the type of data collected. Also, historical, biophysical, and geographic differences alter inventory procedures, data gathered, and subsequent analyses. Nonetheless, many similarities in sampling timber resources exist. Each unit must provide forest area and volume statistics for a national assessment every decade.

In contrast, only a few components are used in a national assessment of wildlife, range, recreation, soil, and water resources. Components available from selected regions have been employed to model multiple resource interactions (Joyce and others 1990). A consensus is lacking, however, on what attributes, techniques, and analyses are appropriate standards for national and other regional assessments. Thus multiple resource inventories frequently vary across FIA unit boundaries and even some State boundaries.

Several approaches used by FIA units can overcome transborder problems. One approach is to adapt field measures from different units to satisfy common analytical requirements. Another is to use an alternate enumeration of the area, e.g., remote sensing through satellite image interpretation. A third possibility is to standardize data collection and analysis procedures. A fourth is to compare methods by sampling the same plot of land among different units.

Adapting measures. In the black bear example mentioned above, data from the Southeastern and Southern FIA units are used. Because sampling procedures differ, the analysis can only be performed using a common unit, such as by county.

The Southeastern FIA unit uses a random sample of plots within a county to estimate forest characteristics. Each plot represents an average of 1,200 hectares (ha) of forest area with that characteristic. Remote areas are defined as those that are forested and 0.8 kilometers (km) or more from well-maintained roads or other land uses. Inaccessible areas include all bottomland forests and upland forests 0.8 km or more from access (i.e., dirt or gravel) roads and other land uses. The Southern FIA unit uses a systematic sample of plots within a county to estimate forest characteristics. Each plot represents an average of 2,300 ha of forest area with that characteristic. Remote areas are defined as forested and part of forested tracts 1,000 ha or larger. Inaccessible areas include all bottomland forests and upland hardwood forests 0.8 km or more from all-weather roads.

Alternative enumeration. Recent advances in satellite image interpretation provide an easy way to resolve border differences and to assess forest area and broad forest types. Remote sensing is especially useful where forest cover is too sparse, or estimates are too costly, out-of-date, or otherwise incompatible to justify extensive ground-based sampling (Eggen-McIntosh and others 1992; Kelly 1990).

Limited ground verification of satellite image interpretation increases decision-making risks. Risks are magnified for satellite image interpretation without a consensus on classification, such as in defining politically volatile old-growth forests. Nevertheless, advances in the accuracy of satellite image interpretation are likely to reduce transborder problems for several resource assessments in the near future.

Standardization. A recent effort among FIA units throughout the eastern United States has been to create a standardized data base for that area. The objective is for each unit to supply comparable inventory information. All files are in the same format and contain forest components common to each unit's inventory. Data are available to any interested party for a low access fee (Hansen 1990).

FIA unit leaders and staff in Washington, DC, have long sought standardized definitions for a host of forest components. Increasing data accessibility enables a broader constituency to examine and rapidly compare inventories across FIA unit boundaries. Questions of wider geographic scope are being addressed. As a consequence, standardization efforts are receiving higher priority.

Much of the information and terms in the data base are timber-oriented. But by making the data accessible to users outside the agency, differing perspectives can be assimilated into the inventory design and analysis effort. The open architecture of the data base permits summaries for a variety of attributes at the tree, species, plot, county, and State level of resolution. With the conversion of this data base to a GIS, one can accommodate information that is not part of the FIA sampling frame. Ready access to FIA plot observations, soil surveys, and data from other independent inventories provides additional opportunities for multidisciplinary analysis.

Comparing field techniques. To further harmonize computational and field procedures, several FIA unit leaders cooperated in comparing field techniques. Field staff sampled forest resources on the same plot of ground. Office computations suggested differences existed among procedures used. Adjusting procedures to rectify these differences is planned in the years ahead.

Joint efforts to create a data base, to standardize data computations, and to work together in field situations creates a positive atmosphere. Each unit has a say in the process. Each unit has access to the data of other units. And each unit has, to some degree, become proactive by acting to end discrepancies before more serious problems erupt.

REORIENTING FOREST ASSESSMENTS TOWARD ECOLOGICAL CONCERNS

Public forests in the United States are undergoing a change in perspective toward forest management that is ecologically sound, economically viable, and socially acceptable. One interpretation of this perspective for forest inventories is to sensitize forest assessments to the local ecosystem, the regional landscape, the regional economy, and society.

The regional description of forest resources as graphic images has achieved early progress in this arena. New technologies, such as automated remote sensing and GIS software to examine forest inventory data in a spatial context, have become affordable only recently. Assessments that incorporate ecological classification with new technologies are planned.

Samples taken systematically across the landscape have built-in opportunities for landscape-level description. Forest inventory attributes displayed as points on a map communicate thematic features of a large data set (e.g., Rudis 1986). Use of more sophisticated geostatistical analyses (e.g., Newton and Bower 1990) can advance the visual understanding of many patterns from both random and systematic samples.

Social influences and ecological classes have been described on a regional scale. Recent efforts have examined air pollution (Ohmann and Grigal 1990), human influences (Rudis 1988), roadless forest recreation opportunities (Rudis 1986), use of fire in forest management (Rudis and Skinner 1991), timber supply in urbanizing areas (Oswald 1986), and wildlife habitat components (Ohmann 1992).

At the national level, traditional timber vegetation types are being revised toward ecological, social, and economic community types. National direction formally began with a USDA-FS workshop entitled "Taking an Ecological Approach to Management" in April 1992 in Salt Lake City, Utah. New inventory components encompass biophysical, social, and economic attributes. Components integrated with the timber inventory are likely to require estimates of downed wood, human and natural disturbances, landscape relationships, soils, water, understory species, and other components affiliated with nonmarket and market values.

FUTURE PROSPECTS

If the past is an indicator of future progress, timber inventories will continue to be transformed to incorporate environmental concerns. Forest assessments will likewise evolve toward holistic evaluations. Greater use of standardized and accessible data will permit broader dissemination of forest inventory information among other disciplines. Advancements in GIS technology, geostatistics, landscape-level analysis, and remote sensing will provide increased opportunities for interdisciplinary interaction.

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