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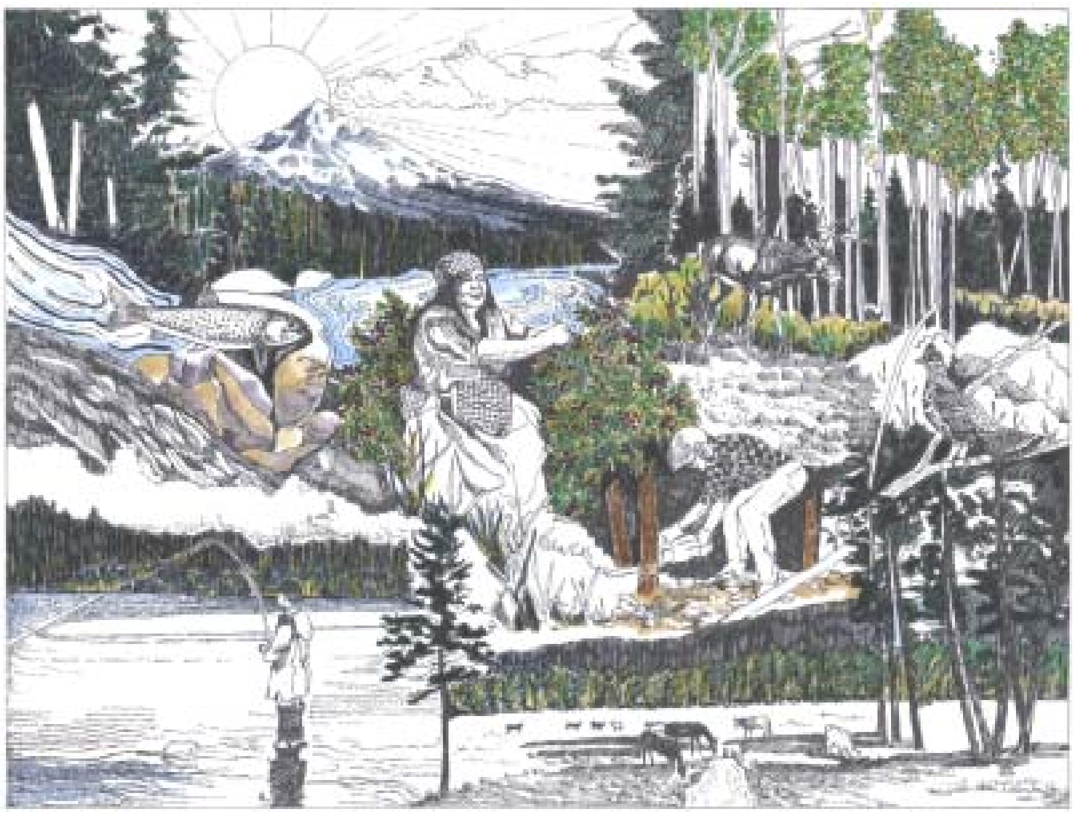
Monitoring for Forest Management Unit Scale Sustainability:

The Local Unit Criteria and Indicators Development (LUCID) Test



Management Edition

Guide to the Report

The Local Unit Criteria and Indicators Development (LUCID) test was a collaborative initiative among eight national forests, their leadership teams, and the Inventory and Monitoring Institute (IMI). IMI has a wealth of additional material available about the LUCID Test Project, its results, toolkit, and implementation strategies. To better serve diverse interests, the results of the LUCID test are presented several ways. This Management Edition, prepared with the assistance of Forest Service CAT Publishing Arts, summarizes the highlights of the LUCID test and the recommendations for implementation.

The Technical Edition of the LUCID test, USDA Forest Service Inventory and Monitoring Report No. 4 (Wright et al. 2002) supplements this Management Edition and serves as a desk guide. The Technical Edition contains:

- Background and Context,
- Methods,
- Criteria and Indicator Results,
- Analysis and Synthesis, and
- Implementation.

Chapters are followed by summaries of key points and findings. Icons throughout the document indicate focus areas, such as background information, tools, and additional resources, which are available in CD-ROM format only. The appendixes provide additional reference documents, the full core suite of LUCID criteria and indicators, models and tools, further discussion of technical considerations, and a science review supplement. The Technical Edition and other supplemental materials, reports, newsletters, and related links are available at http://www.fs.fed.us/institute/lucid/.

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Monitoring for Forest Management Unit Scale Sustainability: The Local Unit Criteria and Indicators Development (LUCID) Test

Management Edition

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Preface

The Forest Service has a strong commitment to its motto: "Caring for the Land and Serving People." Monitoring for sustainability of our national forests and grasslands, as a result of ecosystem management, is a key component of this commitment. Our goal in the Forest Service is to work with our partners, the American public, to strike the right balance between sustainable social, economic, and ecological systems. In this way we can satisfy the values of the present without compromising the needs of future generations.

This report documents the second major step the Forest Service has taken to establish sustainability monitoring on national forests and grasslands. In the first project, completed in 1999, the Inventory and Monitoring Institute (IMI) tested the application of the Center for International Forestry Research (CIFOR) forest management unit scale "Criteria and Indicators of Sustainability." The Boise National Forest, Forest Service Research, and International Programs cooperated in this effort. While the CIFOR project showed very promising results for the application of sustainability assessments on national forests and grasslands, it also highlighted the need for a more thorough test of the methodology in a variety of social, economic, and ecological settings.

In 1999, the Chief's office asked the IMI to undertake the Local Unit Criteria and Indicators Development (LUCID) project. This report, and supporting documentation, is now available to assist and guide the development of sustainability assessments on national forests and grasslands, as part of the planning process. The LUCID monitoring methodology will continue to evolve, as national forests and grasslands tailor sustainability assessments to local ecological conditions, and to meet the needs of collaborators in both public and private venues. There is not a single sustainability assessment for all national forests and grasslands. The LUCID test has identified common social, economic, and ecological threads that can be woven together to tell the sustainability stories of our national forests and grasslands. Sustainability is the common ground between all public values. Sustainability assessments provide the information that we, and the American people, can use to assure the continued long-term integrity of the social, economic, and ecological systems we depend on from the lands we manage. I am proud to convey this report to the Forest Service and to the American people. Sustainability assessments provide a blueprint for us to use as we work together toward the next 100 years of public land management.

DALE N. BOSWORTH
Chief

ACKNOWLEDGMENTS

The LUCID Project was initiated as a result of the CIFOR-NA test in Boise in 1998. The United States Department of Agriculture Forest Service Research and International Programs, who sponsored the original CIFOR-NA test, continued to advocate for, and support, the LUCID Project from the outset. We benefited in many ways from the strong work of the Center for International Forestry Research, particularly the assistance of Dr. Ravi Prabhu.

The LUCID Project was a true partnership between the forests and the Washington Office. The eight national forests, participating in six forest teams took the germ of an idea and a rough protocol and worked together with the IMI, with their collaborators, and with each other. They were constantly innovating, providing constructive comments with good humor, and were always willing to go the extra mile. Most teams were developed through strong partnerships with universities, or staff from other national forests and regional offices and these individuals provided fresh ideas and alternative perspectives that were very helpful.

The forest supervisors and deputy forest supervisors for the Allegheny, Malheur, Modoc, Mt. Hood, Ottawa, Wallowa-Whitman, Tongass, and Umatilla National Forests were advocates for their forest teams and played an active role throughout the project. We thank in particular the Allegheny National Forest leadership team who strongly supported the Project during several forest supervisor transitions. Each of these forests also benefited from strong support of the regional foresters and state foresters who supported the project from its initiation.

The Boise National Forest, the host for the 1998 CIFOR-NA test, continued to play a valuable role in the LUCID Project. At their own initiation the Boise, in conjunction with the other forests in the Southwest Idaho Ecogroup, were able to implement some of the preliminary ideas for incorporating sustainability monitoring into their forest plan revision. We thank in particular Lynnette Morelan and David Rittenhouse who championed this initiative and participated in the LUCID Project in a review capacity throughout and were always willing to make presentations to those interested in implementation realities.

A number of people from both inside and outside the Forest Service provided valuable suggestions, support, and review comments throughout the project including: Washington Office Ecosystem Management Coordination staff; Michael Sieg, Field Sampled Vegetation staff; Andrew Gillespie, Forest Inventory Analysis; Connie Carpenter, State and Private Forestry; Great Lakes Forestry Association staff and volunteers; Brad Holt, Boise Cascade Industries; staff and volunteers with the Canadian Model Forest Network; and the whole staff of the IMI. Ravi Prabhu, Timothy Allen, Joseph Tainter, Donald Floyd, and Stephen Woodley provided very useful review comments.

Elisabeth Reite, graduate student at Colorado State University, provided assistance in many, many capacities. Beth helped prepare databases and publication material, provided great suggestions for revisions, and was always willing to do whatever needed to be done.

We wish to specifically thank Management and Engineering Technologies International, Inc. (METI), particularly Renard and Al Johnson who managed and coordinated staffing, keeping all of us happy and well supported. METI staff were consummate professionals and were always interested in what we were doing and in finding ways they could help.

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MONITORING FOR FOREST MANAGEMENT UNIT SCALE SUSTAINABILITY:

THE LOCAL UNIT CRITERIA AND INDICATORS DEVELOPMENT (LUCID) TEST

MANAGEMENT EDITION

THE QUEST FOR SUSTAINABILITY

The term *sustainability* expresses the human desire for an environment that can provide for our needs now and for future generations. Our collective journey to find a way to live harmoniously with each other and within our social, economic, and ecological environments is a quest for sustainability.

Sustainability is a compelling societal goal with widespread public appeal. However, what the term implicitly conveys and what it explicitly means are not necessarily the same. Finding a specific definition of sustainability that is broadly acceptable is difficult because it is about values that vary among groups and over time.

The quest ultimately requires decisions about what to sustain, for whom, for how long, at what cost, and how. Clearly, this is not a simple task because issues of generational equity are involved (i.e., balancing the distribution of benefits and costs within this generation and across future generations). Despite ongoing scientific and political debate regarding specific definitions of sustainability, the term has proven to be a useful organizing concept for exploring the relationship between social, economic, and ecological systems, their current conditions, and trends (Floyd et al. 2001). Although people may not easily define sustainability, they more readily recognize its antithesis.

Over the past several decades, the quest for sustainability has emerged as a central theme of economic development, social policy, and natural resource management at local, regional, national, and international levels. Scientists, resource managers, policymakers, and citizens alike increasingly recognize the interconnectedness, complexity, and dynamism of social, economic, and ecological systems. However, the very complexity of these systems poses significant challenges to our ability to study and understand them. Our ever-expanding technological capabilities along with our unique ability to exploit dense energy sources, such as fossil and nuclear fuels, and our species' widespread population dispersal means that humans are now the dominant keystone species worldwide. Our technological ability to manipulate the biophysical environment now extends from the molecular scale of genetic engineering to local and regional scales of urbanization and land use patterns visible from satellites to the global atmospheric scale of climate. This ability has caused increasing concern for the current and future consequences of our actions. We are beginning to recognize and confront the undesirable outcomes of past human activities that may be redressed only with significant effort and cost, if at all.

Sustainability is a human value, not a fixed, independent state of social, economic, and ecological affairs. It requires human judgment about the condition or state of a set of tangibles. Inherent in sustainability is our positive valuation of tangibles that we wish to persist in time and space.

Sustainability is not absolute because it is dependent on social values and involves multiple dimensions and scales, including those of time and space. As we become more aware of cross-scale interactions, decision makers increasingly seek a triple bottom line from which tradeoffs can be more clearly defined and simultaneous social, economic, and ecological benefits can be achieved and maintained over time. Given the range of human values and differing objectives for future social, economic, and ecological conditions, engaging in a public discourse about sustainability is critical.

Images of the blue sphere of the earth taken from the Apollo space missions in the late 1960s highlighted the finite nature of natural resources. International concerns about environmental change led the United Nations to convene various expert panels to assess current conditions and trends. One of these panels, the Bruntland Commission, used a report, "Our Common Future" (World Commission on Environment and Development 1987), which popularized the concept of sustainable development. Since that time, sustainability has become a central theme in many different venues, from natural resource management to community development to business planning. Within the United States, many agencies, industries, organizations, and citizens have undertaken the quest for sustainability through many of their own initiatives.

Nowhere has the struggle for sustainability and the debate over its meaning and goals been more focused than in relation to forests. As the debate has shifted focus from tropical to temperate forests, the larger dialogue about sustainability has been brought into our backyards. The 1992 United Nations Conference on Environment and Development held in Rio de Janeiro renewed the international commitment to protect the integrity of the global environment while respecting the interests of all people. The United States and the other 173 signatory nations negotiated a non-binding companion agreement for sustainable forest management, Agenda 21, LUCID Technical Edition, Appendix 1 (Wright et al. 2002), and agreed to monitor, evaluate, and report on progress. The United States has committed to report periodically on the status of sustainable forest management across all ownerships, not just on National Forest System lands.

MONITORING FOR SUSTAINABILITY

In pursuit of sustainability, we first must ask where we are now, how we are doing, and where we are going. A primary strategy is to focus on monitoring and assessment. To do so, we need to identify the critical components of social, economic, and ecological systems and then attempt to gather the appropriate information over time to help answer these questions.

Indicators

Information about specific elements of interest needs to be measured in a consistent fashion: defining and using indicators is one common approach. Indicators are simplified parts within complex systems that tell us something about a specific component or process of interest and are commonly used in everyday life. For example, an indicator of the state of the economy is the unemployment rate and an indicator of personal health is a blood pressure reading. Any individual measure of an indicator is merely a signal of the larger phenomenon or event. An integrated array of indicators is necessary for understanding a more complete picture. For instance, an individual's high blood pressure reading may signal cardiovascular disease. Blood pressure is a common indicator of underlying physiological processes such as plaque deposition in blood vessels, but it is not a direct measure of these processes. While results from one indicator can provide some information, a physician needs a broader set of tests and a patient history to make a firm diagnosis, evaluate the relative risk for a heart attack, and prescribe appropriate treatment.

Individual indicators are neither sustainable nor unsustainable; they do not reveal causality or direction. By considering a suite of systems-based indicators and measuring them over time, we hope to better understand social, economic, and ecological conditions, albeit in simplified form. This is one step on our quest for sustainability.

Using Criteria and Indicators Frameworks

Many government agencies, non-governmental organizations, and academic researchers use hierarchical frameworks to help design sets of indicators for sustainability monitoring programs. These frameworks are typically composed of two basic groups and are referred to as **criteria** and **indicators** (**C&I**). A recent Food and Agriculture Organization (FAO) review of C&I for sustainable forest management (Castaneda et al. 2001) used the following definitions:

> "*Criteria* define the range of forest values to be addressed and the essential elements or principles of forest management against which the sustainability of forests may be assessed.

Each criterion relates to a key element of sustainability and may be described by one or more indicators." *Examples: landscape function, capital and wealth.*

"*Indicators* are parameters that measure specific quantitative and qualitative attributes and help monitor trends in the sustainability of forest management over time." *Examples: disturbance process, recreation facility infrastructure.*

A C&I approach for assessing sustainability is an organizational tool. It can provide a common language for understanding sustainable management and can guide the monitoring process over time. Given the abstract nature of sustainability, the C&I hi erarchy provides a structured approach to defining the parameters and goals of social, economic, and ecological sustainability and assessing progress toward them.

Although the use of a simple two-level hierarchy is common in most national-level initiatives such as the Montreal Process, many people have added levels either formally or informally. For instance, criteria are often grouped under three higher organizing categories, called principles. These commonly are social, economic, and ecological (Figure 1, Table 1).

Indicators themselves do not define the specific characteristics to be studied or the methods to be used in studying them, collectively known as measures. Measures form a hierarchical level below indicators in the C&I framework. These characteristics and methods must be defined before indicators can actually be put to use. For the sample indicator *disturbance processes*, the characteristic to monitor might be fire events, and a methodology would define the dimensions to measure, the measurement scales for each dimension, and the frequency of measurements (for example, acres burned annually by sixth order watershed at specified fire intensity ranges). Associated measures form a level below indicators in the C&I hierarchy. Data elements are the actual information collected for the measures, and reference values are comparison values against which the data may be evaluated.

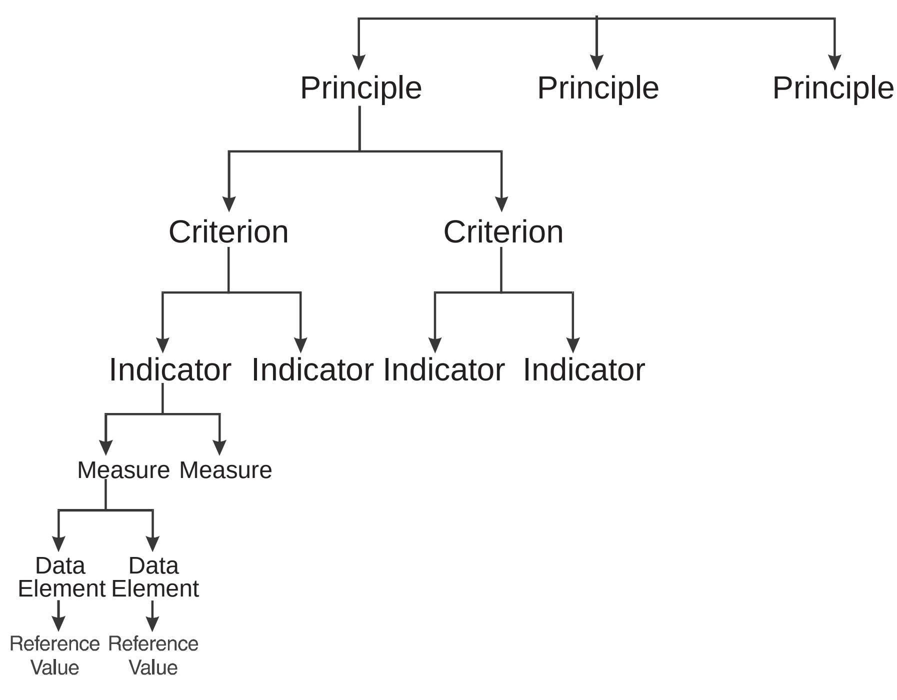

Figure 1. Schematic of a Criteria and Indicator Monitoring Framework

Table 1. Components, Definitions, and Examples of a Criteria and Indicators Monitoring Framework

Component	Definition	Example
Principle	A fundamental law or rule serving as a basis for reasoning and action. An explicit element of the sustainability goal.	Ecological integrity is maintained
Criterion	A component of the structure or function of the ecological, social, or economic systems, which should be in place as a result of adherence to a principle. Criteria form the conceptual architecture of the systems under investigation.	Landscape structure/composition
Indicator	A quantitative or qualitative parameter that can be assessed in relation to a criterion. Note that indicators have no implied direction, measurement method, spatial or temporal scale or reference value.	Landscape patterns
Measure	The methodology and source of information for the indicator. The form, scale, timing, and units of data that are gathered are specified.	Density and distribution of human developed features by use class (e.g., road density, number of road crossings, distance to human developed features)
Data Element	The elemental data that support a measure. Some measures are specific enough that the level of data element is not needed.	Road density by 4^{th} field watershed
Reference Value	The benchmark, standard, or norm against which the data are assessed. Reference values specify the range or threshold expressing the desired future systems condition over a given period.	Open road density in 4^{th} field watershed 0.7-1.7 road miles/square mile

ASSESSING SUSTAINABLE FOREST MANAGEMENT: LUCID TEST PROJECT ORIGINS

Much of the initial focus on developing indicators resulted from the need to report on national progress toward sustainable forest management. However, there has been growing realization that sustainability issues involve multiple scales and so achieving the national goals of sustainability largely rest on actions carried out at the local or forest management unit (FMU) scale. This report presents the results of one such initiative: the Local Unit Criteria and Indicators Development (LUCID) pilot test, a USDA Forest Service project to develop a sustainability monitoring program at the FMU scale.

The LUCID test originated from both the need to report on progress towards sustainability at the national scale and the need for timely, accurate, and integrated monitoring at the forest management unit scale. Current national initiatives focus on the broader policy and institutional frameworks that foster sustainability, while FMU-scale monitoring focuses on management activities and their associated outcomes.

A Need for Forest Management Unit Scale Criteria and Indicators

The FMU scale is generally the scale at which management policy is actually implemented with on-the-ground activity in the USDA Forest Service. A forest management unit includes—but is not limited to—national forest system lands; it can also encompass neighboring communities, economies, and ecological systems across ownership boundaries. Total land area and ownership size may vary among forest management units, but day-to-day decisions about management activities occur at this scale. Criteria and indicators tailored to the FMU scale can help provide insight into the sustainability of associated social, economic, and ecological systems.

The Center for International Forestry Research (CIFOR), an international forestry research organization, has pioneered work on local-unit scale indicators for sustainable forest management. While their primary focus has been on tropical forests, CIFOR staff members have also been interested in applying their assessment methods to North American temperate forests. As a first step toward using FMU scale C&I in North

America, CIFOR staff conducted a test in 1998 in partnership with the International Programs and Research branches and the Inventory and Monitoring Institute (IMI) of the USDA Forest Service on the Boise National Forest and surrounding areas. Experts from government, industry, and nongovernmental organizations from Canada, Mexico, and the United States participated. The CIFOR–North America (CIFOR–NA) test refined and adapted the CIFOR set of criteria and indicators for tropical forests to the social, economic, and ecological conditions of temperate North American forests. The results from this test were quite promising (Woodley et al. 1999).

The CIFOR–NA test produced an initial set of indictors applicable to North America but did not develop associated measures or reference values for them. The CIFOR–NA expert team also did not have time to produce analysis and synthesis tools for use in evaluating any data collected or methods for aggregating appropriate data sets. The CIFOR–NA test did, however, clearly demonstrate that a set of local-scale C&I could potentially provide the information needed for sustainable management of national forests.

The results of this preliminary test were reported at the 1998 North American Forestry Commission meeting[1]. The Chief of the Forest Service chartered the LUCID project to further this work and tailor it to the specific needs of the agency. This pilot project was called the Local Unit Criteria and Indicators Development (LUCID) test. The intent of the LUCID test was for a core team of project coordinators from IMI to work with personnel (forest teams) at six national forest test sites to expand the science-based development and evaluation of an FMU-scale monitoring program for sustainability. Several participants in the CIFOR–NA test served on LUCID core team to build on the knowledge and experience gained from the Boise site. All LUCID participants hoped to develop one broadly applicable set of criteria and indicators that could be used by the Forest Service for both forested and non-forested systems.

[1]Details about this meeting and summarized conclusions are posted at http://www.fs.fed.us/global/nafc/nafc_reports/reports/1991/report_1999.htm.

A SYSTEMS APPROACH

By standard dictionary definitions, systems are groups of interrelated, interacting, or interdependent elements forming a complex whole. Their interactions determine the structure and organization of the system and are in turn are influenced by that structure and organization (Kay and Foster 1999). Because of these interactions, which include positive and negative feedback and self-organization, systems have emergent properties that are more than the sum of the physical ingredients of which they are composed. Nutrient cycling, carbon sequestering, and microclimate maintenance are examples of emergent properties of ecological systems. The multiplier effects from direct employment in the forest sector is an example of an emergent property of economic systems. King (1993) notes that because a system is defined by both its components and the interactions between them, a system description "simultaneously involves both structure and function—what are the components, how are they connected, and how do they operate together?"

Resilience in Systems

Recent research efforts in understanding complex social, economic, and ecological systems have highlighted a property known as resilience (Holling 2001). In essence, resilience is the capability or degree to which a self-organized system can resist perturbation and remain within the functional boundaries that characterize it without flipping to a different set of functional boundaries. Redundancy of elements within systems, such as biodiversity or regional economic diversity, helps to maintain resiliency. This is because multiple components can fill similar functional roles as conditions vary over time. The resilience of a given system is not a fixed state. It changes over time in response to changes in system components and processes.

A highly resilient system alone is neither desirable nor undesirable; desirability depends on human valuation of the system in question. For instance, dictatorships can be extremely resilient, as can be eutrophic lakes, but these system states may not provide the desired level of goods and services for human well-being and sustenance (Carpenter et al. 2001, Holling 2001) as compared to other possible system states.

Resilient systems can withstand greater amounts of disturbance while remaining within their characteristic boundaries than can less resilient systems. Some systems may have little inherent resilience, but can persist due to lack of significant perturbation. Highly specialized island ecosystems commonly fit this category because of their spatial isolation. Therefore, resilience by itself cannot serve as a measure of sustainability. Understanding the concept is important in the quest for sustainability because systems with different levels of resilience will respond differently to both natural and human-induced disturbance processes. Given that less desirable system states can be highly resilient, human activities that cause productive systems to become less productive may be very difficult or costly restore. One example is Lake Mendota in Wisconsin, where the clear lake system has become eutrophic due to gradual phosphorus accumulation from agriculture and urban development (Carpenter et al. 2001).

Systems Properties

The social, economic, and ecological elements of sustainability are organized into inter-related, dynamic systems rather than functioning as stand alone, independent entities, or existing in simple one-to-one and linear relationships. While this observation has been central to the worldview of many human cultures, many individuals and groups tend to overlook this concept while addressing real-world problems. Human cognition is subject to several common conceptual pitfalls including the following:

- Elements or variables are independent;
- Effects are immediate (no lag time exists);
- Effects are linear and constant;
- Effects are one-way (no feedback or emergent properties exist); and
- Systems and their components are static (High Performance Systems 2000).

In a narrow context, any of these assumptions may seem to hold true. However, failing to consider system dynamics over time commonly leads to unwelcome surprises. Decision makers and managers risk failing to achieve their goals when they attempt to sustain components independently and at static levels because other processes and interactions may confound their expectations (Folke et al. 2002). In practice, people often focus more intently on maintaining structure than on function instead of acknowledging the interdependence of the two within functioning systems. The intensity of the public outcry and debate surrounding the Yellowstone fires of 1988 (Rykiel 1998) demonstrates this tendency to attach greater value to static structure than to dynamic process.

Due to the complexity of social, economic, and ecological systems, it is becoming increasingly evident that sustainability is best achieved by focusing on the contexts in which systems operate rather than attempting to sustain specific system elements. Taken broadly, this means sustaining the integrity of systems so that as individual components vary over time, the associated functions and processes characterizing the system's functional boundaries and inherent system resilience are maintained. While the exact dynamics or variability in systems cannot be specifically predicted, changes can be anticipated by explicitly taking these dynamics into account and by gaining more information about these patterns over time.

Although modern scientific theories explicitly recognize the interdependence, non-linearity, and dynamism of many systems, the scientific method often approaches systems in a reductionist fashion, focusing on a small number of individual elements and processes. While this is a crucial means of gaining information through experimentation and observation, there has traditionally been far less emphasis placed on synthesis or system-level analysis.

Scientists tend to work within the confines of their particular subdisciplines, such as hydrology, microeconomics, vertebrate population biology, cultural resource management, or silviculture, aggravating this tendency to focus on components rather than systems. Forest managers and staff also tend to be organized administratively into activity sectors (such as recreation or silviculture), or into ecosystem component disciplines (such as terrestrial vertebrate biology, soils, or hydrology). These divisions are useful frameworks for carrying out programs of work but do not inherently encourage systems thinking or collaboration across disciplines.

A systems-based framework for monitoring recognizes that systems of interest are a group of interrelated, interacting, or interdependent constituents forming a complex whole. This framework uses the structures and functions (processes) of systems as its organizing tools. It focuses on the contexts that allow for the production of goods and services, not just the goods and services themselves. A systems approach focuses on the outcomes or states of systems. A systems approach is particularly applicable to forests and rangelands since they are joint production systems with emergent properties that simultaneously, not independently, produce soil, water, air, plant, and animal material. For example, tree growth is partly dependent on soil fertility, which in turn is dependent on tree decline, death, and decay for providing an array of micronutrients and minerals to feed soil microorganisms, as well as structural elements to provide physical protection against drying, compaction, and erosion. Therefore, failure to consider and manage soil resources may lead to less than desirable stand regeneration.

ASKING WHAT, WHERE, AND FOR HOW LONG: SCALE MATTERS

Social, economic, and ecological systems reveal different characteristics both in time and space. A single tree does not look the same or play the same interactive role within the parent community at 5, 50, and 500 years; and a forest does not look or function the same at 500 or 5,000 or 50,000 acres. Simply stated, scale, both spatial and temporal, matters. Because the systems we are trying to sustain reveal different characteristics at every scale, sustainability questions change at every scale. Allen and Hoekstra (1994) note that there is "no nature-given scale at which a system is sustainable or otherwise." Therefore, we should monitor for sustainability at a variety of scales.

Although critical in framing the issue of sustainability, scale is often neglected in sustainability discussions (McCool and Haynes 1995). Sustainability monitoring initiatives occur at a range of spatial scales. The national scale of the Montreal Process focuses on examining the state of a nation's forests. At a regional scale, a number of states are monitoring for sustainability. Other assessment programs at this scale are defined by ecological region, such as the Mid-Atlantic, the Great Lakes, and the Sierra Nevada.

The question we ask at the local scale will be specific to the dynamics of the particular place and its resources and residents. Thus, employment may be a common factor to many scales, but the meaning associated with monitoring employment at the local scale is very different from monitoring at the national scale.

Monitoring within a systems framework seeks to collect sets of data over time that can provide us with information about the state of ecological, social, and economic systems, not just one-time images of the state of individual resources or elements. The goal of monitoring is to detect change. This means both collecting data and comparing it to what we understand about the ranges within which these systems normally operate (Innes 1998). Since systems are inherently dynamic rather than static, sustainability monitoring programs are intended to discern both the baseline patterns and fluctuations for various components and processes and to estimate human-induced changes over and above this variability. Managers may also be better able to design treatment strategies that mimic natural patterns of variability.

Monitoring in this context is an iterative learning process. As more indicator data are collected and synthesized, the fundamental understanding of sustainability in a systems context will increase. The growing scientific and public consensus surrounding the anthropogenic causes of climate change is one example in which data collection and analyses over time have revealed patterns that allow increasingly accurate differentiation between baseline fluctuations in climate and those likely to have be associated with human activity.

Temporal scale considerations are central to adaptive management, yet managers often treat monitoring as a singular, one-time event dependent on project implementation, agency funding, and reporting requirements. To understand systems, it is vital to consider the temporal scale at which the elements in question interact, and then to monitor the elements accordingly. In this context, sustainability monitoring tracks a suite of indicators over time to identify the changes in the states of systems. Monitoring is an ongoing, multistage process. Periodic sustainability assessments serve to analyze and synthesize data collected at more frequent intervals. Results of the sustainability assessments can then inform management decisions.

A NEED FOR SUSTAINABILITY MONITORING AT THE FMU SCALE

Placed within an adaptive management context, monitoring can engage agency personnel in a systematic and rigorous learning effort as they undertake ongoing applied research to determine if management actions do indeed result in expected outcomes and if so, at what scales. Consequently, monitoring becomes a vital link in the larger land management process and the essential feedback loop of managing for sustainability (Figure 2).

Forest planners and managers confront an ongoing need to tie planning and active management activities to on-the-ground results and to obtain meaningful information from which to make their decisions. Forest planning requires asking a series of detailed questions, often as testable hypotheses:

- What are the desired conditions of the various land areas that we manage? For what reasons? Over what time periods?
- Do our projects move us toward desired future conditions?
- Are our assumptions correct about outcomes, under what conditions and where? Over what time period?
- What are any tradeoffs?
- What off-forest activities affect National Forest System lands, and vice versa?

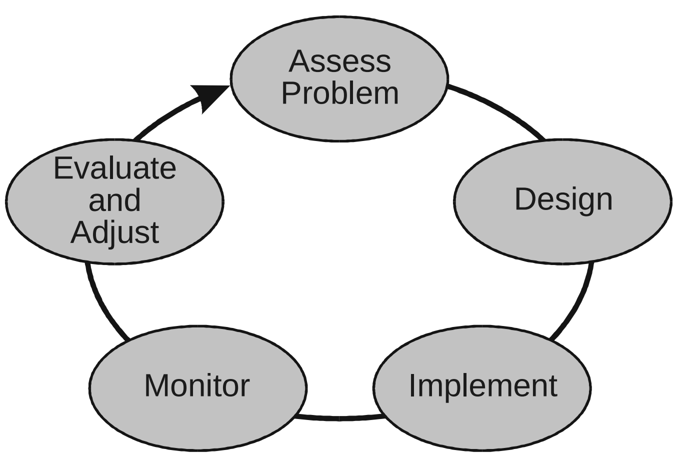

Figure 2. An Application Cycle for Adaptive Management

If models or underlying assumptions are not accurate, then explicit management goals, such as maintaining non-declining timber volume or maintaining watershed health, cannot be met because activities lead to unexpected and potentially undesirable results. Effective adaptive managers need a clear, scientifically sound applied research approach. This includes a mechanism for the analysis and interpretation of the data and a means for the results to feed back into decision making. Monitoring should focus on developing the tools necessary to gauge where we are relative to where we want to be.

The LUCID test aimed to determine whether adopting a program of sustainability monitoring could enhance current monitoring programs at the local scale in the Forest Service. At the FMU scale, agency monitoring efforts have traditionally focused on project and forest plan implementation compliance with minimum legal requirements along with specific local information needs. These efforts vary widely from forest to forest and from year to year. There are widespread concerns, both internal and external, over current monitoring strategies. Efforts are often costly, fragmented, and focused predominantly on project compliance with standards for individual resources or elements. Implementation monitoring focuses on the following kinds of questions:

- Are specific species present?
- Were stream buffer widths achieved for this project?
- What are the road densities in the watershed?

While this work is a vital component of active resource management, it does not necessarily meet the needs of broader forest planning, especially in the context of adaptive management.

Monitoring is too often viewed as a costly incidental activity that takes scarce resources away from on-the-ground activities and outcomes, despite the fact that a well designed monitoring program can greatly assist resource managers. Barriers to effective monitoring and adaptive management include costs, staffing, and budgetary constraints; inadequate scientific methodology during program design; lack of contact and collaboration between researchers and managers, both internal and external; lack of clear connections among monitoring elements or among monitoring elements and management goals and objectives; overlapping or redundant monitoring efforts; lack of institutional connections between data analysis and decision making; lack of reference values; and lack of thresholds or trigger points for concern or action. Specifically, monitoring efforts should support the following objectives:

- Build a base of understanding about the system by revealing patterns and trends;
- Establish benchmarks of the current state of the system for comparison to desired future conditions;
- Detect change in the system and serve as an early warning of further change;
- Evaluate the effectiveness of programs and measure progress toward goals;
- Identify changes in baseline conditions for key indicators that result from management actions, including restoration activities;
- Support planning and management decisions through the identification of key issues and trends;
- Communicate about the state of the environment; and
- Serve as an accountability mechanism for the public, managers, governments, and international communities.

> *"We are working under the assumption that better information on the ecosystem (which includes human social systems) will lead to management decisions that have a better chance of being sustainable. If we assume all management (that is, decisions in the generic sense) is a choice between alternative futures, the value of monitoring is to provide information on the direction and future state of the system. Simply put, for any given decision, where is the system likely to go?"*
>
> *(Woodley et al. 1999)*

ANCHORING THE LUCID TEST IN A SYSTEMS FRAMEWORK

A C&I hierarchical approach is predominantly component-based and can serve as powerful tool to gather information about specific elements of systems. Unless individual elements are explicitly considered within a systems framework, however, standard C&I monitoring results do not reveal interactions between elements or the emergent properties of the systems being studied. One of the most significant innovations of the LUCID test was to explicitly place the development if the criteria and indicators set within a systems framework. The systems approach is a key difference between the LUCID test and other C&I monitoring frameworks.

LUCID project coordinators hoped that FMU-scale sustainability monitoring would provide a robust approach to achieving many of the agency's broad monitoring needs. The core team felt that a systems framework would help participating forests focus on what is really important and what is secondary to systems. This could, in turn, reduce a seemingly infinite number of potential monitoring elements to a feasible number capable of producing meaningful information. The core team was also interested in exploring the interdependence of various system components and addressing scale issues.

The systems approach taken by the core team was based on the most up-to-date knowledge of the components and organization of the social, ecological, and economic systems. The LUCID test systems framework was also developed for potential application across all National Forests. Test participants aimed to produce a broadly applicable set of indicators to capture the wide range of local scale social, economic, and ecological systems present within the United States.

The core team also hoped to develop a clear process that individual forest management units could use to place monitoring efforts in a systems framework. Indicators or individual components alone have little meaning or value in assessing sustainability until they are considered within the dynamic systems of which they are a part. However, traditional forest planning and monitoring is organized primarily within activity sector and component-based frameworks, so providing a clear transition to a systems approach is needed.

METHODOLOGICAL APPROACH

Given the national reporting requirements on forest sustainability and the real needs at the local forest scale for improved monitoring programs, the LUCID core team was eager to appraise the feasibility of sustainability monitoring. They hoped that their approach could establish a logical link from sustainability concepts to on-the-ground monitoring efforts for adaptive management. Starting from the strong foundation provided by the CIFOR–NA test, they hoped to discover whether designing a systems-based C&I monitoring toolkit could provide forest managers and collaborators with the following: feedback that could be used to improve Forest land and resource management plans; enhanced collaboration among National Forests, other governmental agencies, private landowners and stakeholders; and a means to relate forest plan outcomes with regional and national C&I trends. The following five specific objectives were set to guide the project:

1. Test, develop, modify, and evaluate C&I to assess the sustainability of social, economic, and ecological systems at the FMU scale;
2. Develop analysis methods that establish the relationships among indicators and aggregate the results for reporting on sustainability;
3. Examine the relationship between national-scale (e.g., Montreal Process) and FMU scale indicators;
4. Develop a research agenda based on the above work to further understanding and application of FMU scale C&I; and
5. Develop a strategy to implement FMU scale C&I throughout the Forest Service.

LUCID Test Sites

In March of 1999, all Forest Service Regional Offices were asked to nominate pilot areas to participate in the LUCID test. The pilot forests were selected based on having the full support of the forest supervisor and on the extent to which they met a series of other criteria, such as geographical and ecological diversity, opportunities for collaboration across ownership boundaries and with internal and external researchers, and availability of staff resources.

Six interdisciplinary forest teams working on eight different national forests were ultimately selected to participate in the LUCID Project. These included the Ottawa National Forest in the Upper Peninsula of Michigan; the Allegheny National Forest in northwestern Pennsylvania; the Modoc National Forest in northern California; the Blue Mountain Province Forests of eastern Oregon (the Wallowa-Whitman, Malheur, and Umatilla National Forests); the Mt. Hood National Forest in northwestern Oregon; and the Tongass National Forest in southeastern Alaska. These test sites ranged from 500,000 to 17 million acres and from single national forests to one team of three national forests working together within one ecoregion province. In keeping with the fact that the spatial scales of social, economic, and ecological systems rarely correspond to human administrative boundaries, the study areas were not just limited to National Forest System lands, but were left up to each forest team to define.

The LUCID Test forest teams identified three main benefits they were seeking from participating in sustainability monitoring: (1) improved resource management; (2) stronger linkage between inventory, monitoring, and data management; and (3) improved collaboration.

Collaborative Learning Approach

During an approximately two-year period, the core team worked with each participating forest team. Both the LUCID core team and the forest teams required a mix of skills to carry out the test. Ideally, this meant that each team was composed of at minimum: a sociologist, an economist and an ecologist to address the system components for each principle; an analyst/GIS specialist to address data management, modeling, and technical aspects; and a team leader, preferably with some planning background. LUCID test site forest supervisors also participated actively, providing policy insight on sustainability monitoring and making recommendations on practical implementation of FMU-scale sustainability monitoring.

The core team designed a process that provided some degree of flexibility for each of the six forest teams while ensuring consistency among the teams. Each forest team started with the same C&I hierarchy and followed the same steps while choosing its own collaborative partners, defining relevant scales, adapting the initial criteria and indicators, and developing measures, reference values, and synthesis tools appropriate to the test site. The forest teams began with the CIFOR–NA set of indicators (Hoekstra et al. 1999), supplemented with others provided by the core team based on their gap analysis of the CIFOR–NA set (see Figure 3). Each forest team then screened the indicators for applicability to the local unit within the systems framework. The teams then developed one or more measures for each indicator, conducted a field test of the set of indicators, and tried various methods of analyzing, synthesizing, and reporting their results.

Modifications and changes were documented as they were made. The core team worked collaboratively with each forest team, visiting each site to conduct workshops at each major step of the process, and consulting with the teams as needed. The forest team start dates were staggered over a six-month period. The three teams (Ottawa, Allegheny, and Blue Mountains) that started early in the process made suggestions that led to improvement of some of the tools (e.g., the database structure, workshop content, and timing) in order to make them more helpful to other participants. Between workshops, the forest teams worked more independently, consulting with the core team, with other forest staff or collaborators, and with other forest teams as needed. The development, analysis, and implementation of a practical set of local C&I involved forest team discussions with many affected groups. These included other staffs within the Forest Service, other federal agencies administering public lands adjoining the involved national forests, state agencies responsible for administering state interests, university researchers, and local stakeholders at each participating national forest.

LUCID TEST RESULTS

Following the conclusion of the pilot tests, the LUCID core team synthesized the results from each of the forest teams in order to determine whether they could identify a common systems framework and core suite of C&I. The core team found that the six different test site team results did indeed converge into a common systems

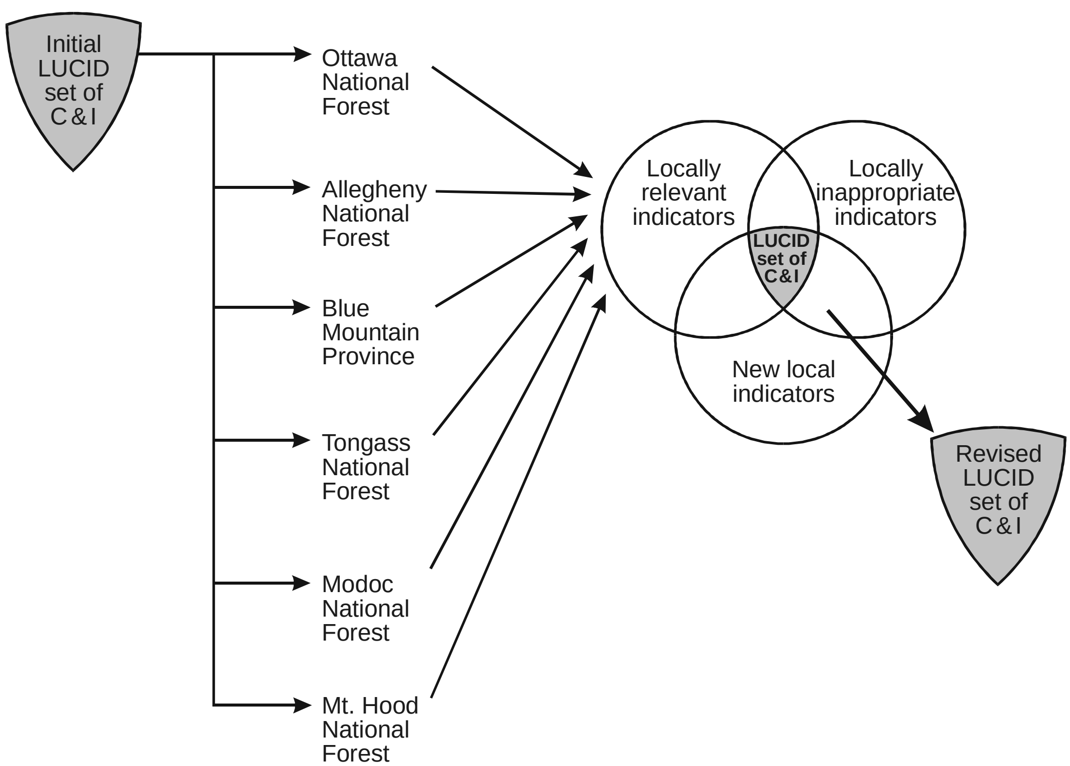

Figure 3. Revising the Initial Suite of Critera and Indicators

framework, a systems-framed suite of broadly applicable core indicators, a revised process for FMU-scale sustainability monitoring, and recommendations for integrating FMU-scale monitoring into forest planning. The final systems-based C&I suite consisted of 3 principles (social well-being, economic well-being, and ecological function), 16 associated criteria and 58 indictors and is described in greater detail below.

Systems Framework Benefits

LUCID participants found that the systems framework provided a new lens through which to view the topic of sustainability, both conceptually and practically. They agreed that a systems framework had several distinct benefits:

- Providing an approach to communicate that sustainability is more than the sum of the individual components that are monitored;
- Providing a strong theoretical, science-based link to understanding sustainability;
- Refining the description of elements for monitoring;
- Developing a more meaningful method for synthesizing and analyzing results to understand the state of systems;
- Thinking through and refining descriptions of the systems to be monitored (i.e., it provided a key tool to learn how components are interrelated);
- Helping to identify and understand critical elements for sustainability monitoring; and
- Providing useful information for adaptive management.

Given that sustainability is a social value, using a systems framework also fosters opportunities to consider, negotiate, and address differing values among managers, researchers, and stakeholders. The interdependence of systems elements and processes at various scales and to differing degrees may lead to tradeoffs between certain values. A systems framework also provides a means for managers and stakeholders to begin assessing these interrelationships and anticipating resulting tradeoffs.

A program of sustainability monitoring using the process pioneered by LUCID test participants shows great promise in fulfilling current monitoring needs at the FMU scale. As a result of the test, LUCID participants from forest supervisors to forest team members concluded that systems-based monitoring for FMU-scale sustainability is feasible and can make significant contributions to improving Forest Service management. The relationship between the revised LUCID process and forest planning is discussed in the final section of this report.

Final Criteria and Indicators Core Suite

By design, the six forest teams represented a range of different social, economic, and ecological conditions across eight national forests. Even so, all forest teams identified a relatively common set of C&I at the conclusion of the test. These were evaluated by the core team and consolidated into a core suite of 58 systems-framed indicators determined to be the minimum set necessary for sustainability monitoring at the local scale. The core team recommends this suite for consideration across the national forest system at the FMU scale. Some adaptation will likely be necessary to ensure that the indicators meet the full range of conditions on each national forest. However, revision, adaptation, and substitution should be made within the systems framework in order to retain the overall context and meaning. Future forest teams may choose to supplement the core suite with indicators focusing on specific system elements or functions of local concern.

An Unexpected Result: The Importance of the Process Itself

A major goal of the LUCID test was to test and refine the LUCID process itself, not just to produce a final suite of indicators. While this was an explicit goal, no one anticipated how predominant the process would become, or how important the forest teams would find it to be as they customized and tested the revised C&I at their sites. The process proved to be central to sustainability monitoring, not just the work required along the way to get to a final suite of indicators. The process of implementing a sustainability-monitoring program at the FMU scale emerged as a tangible product in its own right.

Teams also noted that the collaborative learning approach was fundamental to their success. The Forest Service does not traditionally monitor nor conduct work programs within a systems context. Forest teams were somewhat surprised to find that their ongoing dialogue about monitoring for sustainability in a systems framework was extremely beneficial, despite also being quite challenging.

In the future, local units will be able to start at a very different point from where the pilot forest teams began. Adopting a systems-based framework for sustainability monitoring is a learning tool as well as a work-planning tool. As other forest management units adopt sustainability monitoring, working through the process will provide them an understanding of the supporting concepts as well as the rationale for each element in the core suite.

Given the importance test participants placed on the LUCID process itself, the next section describes it in some detail from a lessons learned perspective. This description intended to give a clearer picture of the experiences of the participants and to help other Forest teams build on them as they consider implementing a systems-based sustainability-monitoring program.

REVISED LUCID PROCESS

The revised LUCID process consists of eight key steps, which can begin after initial preparatory work has been completed, such as gaining approval and support from Forest leadership, staff, and the regional office and assembling a forest team. The revised process starts by clarifying the purpose for undertaking a sustainability monitoring program and identifying spatial boundaries of interest, moves on though exploring, further refining, and applying the systems-framed core suite of indicators, and finally leads into analyzing and synthesizing results and incorporating them into ongoing forest planning efforts and decision making. These steps are diagrammed in Figure 4. An important note concerns the feedback loops and the two-way arrows within the process diagram: while the steps have a distinct order, the process is iterative and forest teams found themselves revisiting previous steps based on new information. Defining the measures for some indicators led to reconsidering whether the indicators themselves should be modified or removed from the suite.

Step 1: Define The Purpose of Sustainability Monitoring and the Study Area

To begin testing a program of sustainability monitoring, forest teams first worked with the core team to pinpoint the common objectives for this undertaking. This gave them the opportunity to consider their current monitoring programs, results, experiences, and any shortcomings; evaluate how sustainability monitoring differed from their current approach; and determine how the two could complement each other. It led them to review agency goals at all levels of the organization, and consider how sustainability monitoring could help achieve them. They could explore how sustainability monitoring could meet the needs of adaptive ecosystem management as the organizational focus of the Forest Service shifts from maximizing individual resource use in the short term to broader and more holistic long-term goals. This, in turn, led to discussions of scale issues, both in time and space, and the various meanings of sustainability itself.

Consider Spatial Scale and Define Study Area Boundaries

Although complementary relationships should exist between sustainability monitoring initiatives at different scales, monitoring initiatives at the FMU scale are not merely an application of national-scale material. Forest teams defined the relevant spatial scale for their own local conditions. To do so, they thoroughly discussed the boundaries of interest, recognizing that the systems and associated sustainability questions would help define these boundaries and that boundaries between social, economic and ecological systems typically do not coincide. Every LUCID team adopted test boundaries that were larger than the NFS lands. The Allegheny National Forest team, for example, used the unglaciated Allegheny Plateau (Ecoregion 212Ga) (Bailey 1995) as the rough bounds of the ecological areas of focus. By contrast, the Blue Mountains Province team included three national forests over a three-state area within the same ecoregion province. Teams used a flexible set of overlapping boundaries because social and economic indicators and questions were often associated with different administrative boundaries such as counties.

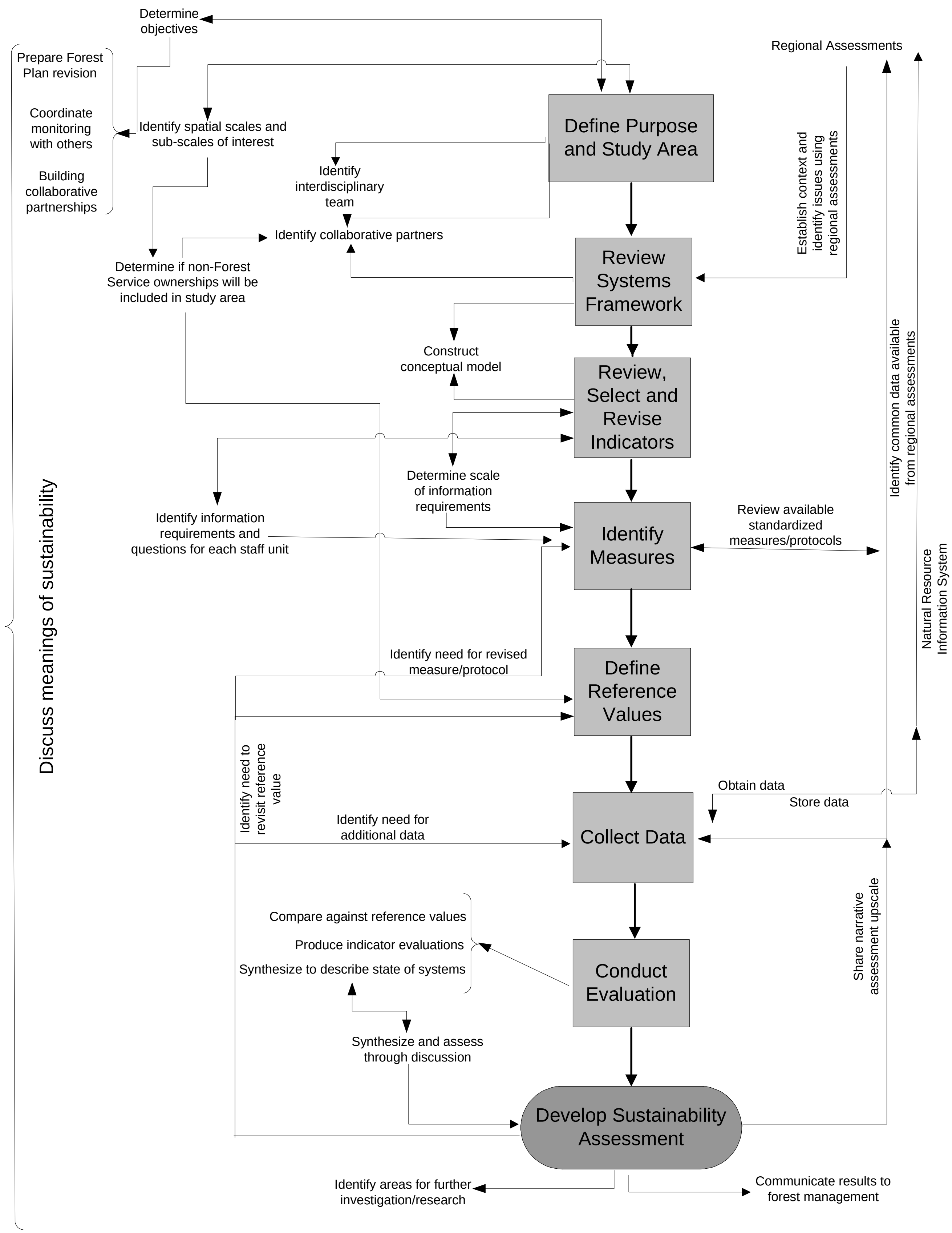

Figure 4. Revised Process for FMU-Scale Sustainability Monitoring

From a process perspective, the LUCID teams found that an explicit discussion of scale issues was critical as they began testing C&I. Discussing the bounds of their study area and the relative influences of boundaries was important for identifying nontraditional relationships and linkages. By understanding the regional context within which they were working, they were better able to focus on the role of forest resources and management responsibilities within a sustainability context that transcended administrative boundaries. These discussions naturally led to exploring the potential roles and needs for collaboration, both internally and externally. This exploration helped them to identify potential partners, such as adjacent private landowners, other public lands managers, stakeholders, and scientists.

This process also helped build an understanding of the relationship between FMU-scale sustainability initiatives and sustainability initiatives at other scales. Forest teams recommend that a structured discussion be conducted early in the process of adopting a LUCID monitoring framework to create a common understanding of scale issues and to focus questions on the FMU scale.

Benefits of a Forum for Discussing Sustainability

The process of engaging the National Forest staff and collaborators in a dialogue about sustainability and sustainability monitoring was invaluable and considered a key finding of the test. Forest-scale sustainability monitoring can help transform the concept of sustainability into real outcomes on the ground (Bosworth 2001) by engaging people in a dialogue about sustainability and placing it within a broader adaptive management context.

Collaborative efforts can play an important role in the sustainability monitoring process in a number of ways:

- Creating a basis for dialogue,
- Helping to identify key components for monitoring,
- Establishing reference values,
- Finding alternative sources of data, and
- Building a collective vision of desired future conditions.

Working toward sustainability revolves around stakeholder and natural resource manager values. Each has a different set of experiences, perspectives, and information. Broader societal values are also embedded in the legal and institutional framework for natural resource management, but may not be explicitly recognized as such. Moreover, the evaluation of stakeholder and internal staff values is not often explicit in forest resource management planning and decision making. Participants found that the LUCID process served as a powerful tool for initiating discussions and clarifying values among stakeholders, managers, and scientists within a collaborative framework. In this way, the LUCID test process reveals the interplay between human values, system components and dynamics, and sustainability.

Step 2: Review Systems Concepts and Adopt a Systems-based Framework

Monitoring by individual forests generally is neither systems-based nor systematic in nature. It typically focuses on data collection and presentation for individual components rather than the synthesis of components to encourage understanding of complex systems. As a result, the utility of monitoring results to management has been at best piecemeal. Likewise, other C&I monitoring programs to this point have remained primarily hierarchical in nature and have also tended to report data for individual indicators rather than assessing interrelationships within among indicators. The core team set out to overcome these limitations by solidly grounding the sustainability monitoring C&I development in a systems framework.

Forest teams were largely unfamiliar with a systems-based framework, so the core team conducted on-site workshops to discuss systems concepts and to place the test goals firmly within this framework. The teams refined the systems framework and components throughout the process, starting from the three principles: social well-being, economic well-being, and ecological function, and then establishing criteria for each. The social framework was structured by four criteria:

1. collaborative stewardship;
2. institutional and community capacity;
3. social equity; and
4. social and cultural values/opportunities examined across a range of kinds of systems including individuals and communities of place and of interest.

The economic framework was also defined by four criteria:

1. capital and wealth;
2. flows of products and services;
3. trade and distributional equity; and
4. efficiency across a range of economic system scales from individuals to communities.

The resulting ecological framework was defined by the criteria of structure and function for organisms, ecosystems, populations, and landscapes across a range of spatial scales.

Although three distinct frameworks were developed, one for each of the principles, participants recognized that they must be considered together as the complete set of structural components and functional interactions that make up sustainability. In addition, the way that the systems are bounded is somewhat arbitrary, a reality inherent in conceptual models. For example, the LUCID test distinguished between frameworks for social and economic systems. These are somewhat artificial distinctions because economic systems are a subsystem of broader social systems. However, for the purposes of FMU monitoring, participants found great utility in distinguishing between the two because these systems tend to be organizationally separated within the Forest Service, the disciplinary training of individuals in these fields are distinct, and the world views of these systems are often different.

The LUCID test participants concluded that a systems approach provides an effective organizing framework to develop a sustainability-monitoring program for National Forests. Specifically, they found that this approach:

- Leads to a richer and more integrated understanding of social, economic, and ecological systems;
- Helps to identify, define, and organize critical indicators and measures for monitoring;
- Serves as a conceptual basis for analysis and synthesis of monitoring data in order to assess the emergent properties of systems and the interrelationships between the ecological, economic, and social spheres; and
- Applies to the FMU scale and provides a consistent organizational approach to understanding, monitoring and assessing sustainability. Adopting a consistent framework would have the added benefit of decreasing the inconsistencies among forests and improving understanding and transparency for the public.

Step 3: Review, Select, and Revise Indicators

At this stage, forest teams concentrated on testing and revising their initial sets of indicators. Monitoring of indicators within a C&I framework can provide essential information regarding sustainability, but the information is only useful if it answers the right questions. Establishing the appropriate criteria and selecting the right indicators is a critical task in the LUCID process. Participants worked to produce a suite of indicators that integrated a diverse array of system components, avoided unconnected and irrelevant indicators, and contained a sufficient but feasible number of elements to be monitored. Continual reference to the principles and criteria within a systems framework was a key method of successfully identifying the essential structural and functional components of systems.

While it may seem like there are an infinite number of possible indicators from which the participants had to choose during the test, systems research indicates that a relatively small number of controlling processes or variables usually contribute to sustaining the functionality of a given system within a range of equilibrium states (Holling 2001). The forest teams continually revisited sustainability and systems concepts as they worked to define the set of key elements and processes relevant to the local scale.

Social and Economic Indicators

The LUCID teams tested, evaluated, and refined all of the initial criteria and indicators within the three principles: social well-being, economic well-being, and ecological function. However, more work was commonly needed on social and economic elements for several reasons. Researchers have applied complex systems theory to ecological systems extensively over the past several decades and the bounds of ecological sustainability are becoming increasingly well understood (see for example Allen and Hoekstra 1992, Flood and Carson 1993, Kay and Foster 1999, and Sterman 2000). A systems approach to studying social and economic systems is less common, however, and so applications to sustainability are limited. Consequently, less research and guidance is available for developing systems-based social and economic frameworks for assessing sustainability at the FMU scale.

Another challenge in developing social and economic indicators was that these disciplines have not traditionally been well represented within Forest Service staffing, and relatively few agency sociologists or economists work at individual forest offices as compared to those specializing in ecological fields or activity-related sectors. Further, teams needed to think about social and economic aspects of systems across the ownership boundaries of their study area. Available data is often reported at spatial scales that do not match administrative boundaries, such as by county or state. Finally, other sets of C&I have not focused on communities and outcomes.

Indicators developed for larger scales commonly do not address the local system structures and functions and local scale questions of sustainability. Sometimes indicators are so inherently scale-specific (e.g., measures of the contribution of forestry to the gross domestic product) that they must be significantly revised. And while very broad and generically worded indicators (e.g., employment) can be applied at multiple scales, the indicators typically must be adapted to meet local conditions for them to have any value.

Core Suite of Criteria and Indicators

By working to identify key factors in their systems of interest at the FMU scale, forest teams were indeed able to arrive at a core suite of indicators that they deemed the minimum suite needed to assess sustainability. Developing and testing indicators and comparing them among sets was often a difficult process. The teams used the same definitions of terms and hierarchical divisions, but some variation resulted from individual approaches. At the conclusion of the test, forest team suites included an average of 56 indicators, ranging from a low of 44 to a high of 77. Indicators were generally equally divided between the three principles, although the economic indicators had consistently fewer indicators across all sets. The core team then compared the indicators submitted by each forest team and produced the recommended LUCID C&I suite of 16 criteria and 58 indicators (Wright et al. 2002). (Also see Appendix at end of this report.)

Core Suite as New Starting Point

The core suite of indicators provides a strong foundation from which additional forest teams can adopt the LUCID test framework, benefiting from the extensive work and experience of the original test participants. This core suite, however, is not simply a pick list. The suite was carefully designed as an integrated tool for use in a systems context, so attempting to remove individual elements from the whole robs them of any particular relevance to sustainability monitoring. Therefore, even as a complete set, the suite itself does not have any great value without explicitly being interpreted within a systems framework and within an interdisciplinary, collaborative environment.

Step 4: Identify Measures

Indicators in and of themselves were designed to be broadly applicable across a range of potential forest conditions and to have no assigned directionality. Each indicator needed at least one measure, or specified methodology for data collection. The three different kinds of measures in the final core suite include the following:

- Recommended measures that are relatively consistent from FMU to FMU. Where possible, these are based on standard Forest Service protocols or ideas.
- Proxy measures as substitutes for recommended measures. While the recommended measure is preferred or more common, the proxy measure provides an alternative means of obtaining the information.
- Optional measures that forests might use to supplement the core suite based on local issues of interest and concerns.

As the teams worked, scale-dependency figured prominently in selecting FMU scale C&I and in determining how to measure them. Living systems operate in similarly at multiple scales in time and space. For example, landscape systems on a decomposing log can have the same structural and functional characteristics of landscape systems that operate in a watershed. However, the tools and protocols used for measuring components of systems are scale-dependent and must be appropriate to the spatial scale of interest. For example, the decomposing log system may be measured with magnifying tools at close range whereas remote sensing technologies may be appropriate for evaluating a watershed landscape system. Consequently, although an indicator of a system component may appear to be common across multiple scales, it may require different measures and metrics.

The scale of study will impact the ability for monitoring efforts to detect changes. King (1993) notes that choosing the grain of detail (increment points along a given measurement scale) for study is a key step. Large-scale measures smooth out fine-scale variability, and this option may remove noise and make detection of meaningful signals or trends more obvious. A coarser analysis may also, however, filter out fine-scale signals of developing problems. These considerations led some teams to add a fine-scale approach to monitor land use and change because they felt that some potential important problems were being overlooked with the current scale of monitoring on their national forest.

Given the nature of systems and scale, the choice of measures and associated data elements cannot be exactly prescribed for every forest management unit. Selecting measures depends on the specific questions that are unique to each FMU. Consequently the suite of possible measures may be used only as a guide and each local unit will need to identify the specific questions associated with the indicators for their site and then determine the appropriate measures for data collection. Standardized protocols should be used wherever possible if they address the appropriate questions and provide the right data at the right scale.

Step 5: Define Reference Values

Reference values are comparison values against which data collected for indicator measures can be gauged. Reference values may be used to help interpret an indicator. This comparison process may be used to guide discussion about the meaning of measurement results; to assess progress toward desired outcomes; and to identify interactions among other components in the system. In short, reference values tell us how we are doing. Consequently, their utility hinges on the rationale for their selection. The source of reference values can range from current conditions to legal standards to historic range of variation.

The core team anticipated that the development of reference values would be very difficult and a task that forest teams would not fully complete within the test period. However, exploring the utility and feasibility of reference values was considered an important component of the test and the forest teams became the real experts on reference value development. Each team experimented with different approaches, so the process of developing reference values varied from site to site. Some forest teams were able to access literature or external resource specialists to help in the development of specific reference values while other teams had limited time for external consultations.

Monitoring for sustainability seeks to identify change. Because system elements are interrelated, dynamic, and nonlinear, monitoring should filter out the expected noise of these fluctuations from potentially out-of-range larger human-induced fluctuations. For this reason, forest teams often found that using ranges rather than single target data points as reference values was more useful. Comparing measures of an indicator against a reference value may trigger a range of responses including management action to correct an undesired situation: special cause and effect monitoring; intensified sampling; or changes in management standards, thresholds, or measurement protocols.

Participants had no preconception of the complexity and challenge involved in comprehensively using reference values and did not know what would be learned or what would be the value gained. Forest teams reported that developing reference values was the most difficult part of the process and they provided many suggestions for modifying it. Key suggestions include the following:

- Take time to clarify the rationale and implications of the reference value;
- Document assumptions used;
- Start early in the process, to clarify and revise indicators and measures;
- Be specific;
- Establish reference values using a collaborative, interdisciplinary approach rather than leaving these to individual specialists.
- Discuss interrelationships between reference values, and use this information to help clarify

systems relationships and tradeoffs between reference values;

- Recognize that clarifying these tradeoffs will lead to some conflict;
- Carefully assess the usability of legal standards, their underlying assumptions and scientific validity, and consider a second reference value if necessary; and
- Seek external expert judgment and input.

The experience of setting reference values proved to be challenging and often imprecise, but LUCID participants found it to be a critical part of the process of monitoring for sustainability.

Step 6: Collect Data

Forest teams were directed not to develop indicators based solely on what was already being monitored at their site or what sources of data were currently available. In doing so, the core C&I suite is designed to meet the needs of sustainability monitoring rather than fit to the limits of current data availability. While much of the data are already available and collection is fairly straightforward, this is an area that will present many fruitful opportunities for collaboration between researchers and managers and advances in accepted methodologies for collection and storage.

Corporate data systems (e.g., NRIS) and remotely sensed technologies provide a potential source of data to be used for FMU-scale sustainability monitoring; the latter holds great promise in providing efficient and spatially integrated data. Other useful sources may include internal and external research partners, other external databases, and the development of valid sampling techniques and the tools for applying them across FMUs with similar systems characteristics or elements. Data collection can also be integrated into on-the-ground ongoing project and forest plan monitoring programs of work. Some preliminary overlaps have been identified, but additional work and discussions are needed to ensure the best fit between corporate data sources and repositories and those required for FMU-scale sustainability monitoring. Further development is needed:

- Improved standardized measurement protocols to address questions at the FMU scale.

> ***On What Basis Are Reference Values Constructed?***
>
> *"The large fluctuations over time of most social and economic data quickly became apparent and resulted in a variety of approaches to standards. Choosing two points for comparison was often not useful or instructive. In these cases the best approach for standards seemed to be to use a historic range of data for high and low standard values. In many other cases an increase of one thing could lead to a decrease in another, and choices for standards would inherently be value driven. A static state, or preservation of the highest level, isn't necessarily beneficial, either. In many situations the forest plan year was used as a reference for setting standards. In these cases we determined that the difficulty for the community was adapting to change, so we used a somewhat arbitrary level of + or – 20 percent to indicate an abrupt level of change…. Economics is a world of tradeoffs and substitutions. In this sense, small is not important. Magnitude of change and adjustment to it are important. In summary, the lesson learned was that sustainability equals balance and constant adaptation to change in order to rebalance."*
>
> *(Allegheny National Forest Team)*

- Cooperation of various inventorying, monitoring, and data-management initiatives (e.g., corporate data collection and storage systems) to develop an approach for facilitating the supply, storage, and ready access to data that are suited to a range of multiscaled questions.

Steps 7 and 8: Conduct Evaluations and Develop a Sustainability Assessment

Ensuring that a monitoring program is useful involves the functions of synthesis, analysis, interpretation, and presentation so that monitoring data are converted to useable knowledge as part of the broader adaptive management process. The final step of an FMU-scale sustainability monitoring program involves evaluating monitoring data and developing a sustainability assessment.

Establishing a sustainability-monitoring program improves management decisions and activities by providing feedback on the state of systems and through engaging collaborators in a dialogue about sustainability. Too often treated as an afterthought, the analysis process involves determining in advance the purpose for the monitoring program and who needs information for what purposes at what spatial scale and at what time intervals.

The sustainability assessment using a suite of C&I can provide a comprehensive way of looking at the state of systems, as well as the state of our knowledge. An assessment provides a way of analyzing the current state of FMU systems and developing a better understanding of the place of national forests within the larger context. It can also identify the need for change. The evaluation stage involves comparing current conditions against a reference value (e.g., trend, standard, norm, benchmark, or desired future condition) and is not a consolidated measure of sustainability. The sustainability assessment involves engaging stakeholders in a dialogue to help evaluate the assessment of sustainability, not make an absolute determination.

Modeling Tools

Given the large amounts of data to evaluate, the LUCID core team looked for tools that could facilitate indicator analysis, could be structured according to a systems-based hierarchical model of criteria and indicators, and could manipulate spatially variable information with a range of different types of reference values. LUCID participants tested and adapted a knowledge-based modeling tool, NetWeaver[2] (Rules of Thumb, Inc. 2000) and developed a spatial extension of this tool[3], GeoNetWeaver, to facilitate the analysis process. Although their development was challenging, these programs were very useful for organizing and framing evaluations consistent with systems-based C&I, for processing large quantities of data, for normalizing the values on a common scale, for displaying spatial variation of results, and for assessing the status of a group of related phenomena, such as all indicators within a criterion. Evaluations, either spatial or numeric generated through NetWeaver analysis were then further interpreted by team members in narrative form to inform the sustainability assessment discussions. Team members concluded though that technical tools such as models are only aids to help us organize, synthesize, analyze, and present large quantities of complex information. Interdisciplinary, collaborative dialogue remains the primary tool for sustainability assessment.

Analyzing and Presenting Results

At its most basic level, an analysis procedure must interpret the results of individual indicator assessments. This is the most common approach in sustainability C&I initiatives and often is the analysis step. As the fundamental unit for monitoring, indicator-based analysis provides the information necessary for other forms of analysis. The resulting detailed indicator profiles are useful in providing specific feedback to assist day-to-day management and to provide a refernce database. forest teams included the following information in their detailed indicator profiles:

- An overview of the indicator and its relationship and importance to sustainability and to the study area;
- A description of the methods used to verify the indicator including any measurement or data challenges;
- Current conditions of the indicator based on available spatial or non-spatial data;
- A comparison of the current data value over time (e.g., trend data) or against some other reference value (e.g., a benchmark); and
- Possible management implications.

At this stage of the LUCID test, most forest teams prepared summary indicator evaluations with specific focus on indicators or measures of concern including those that did and did not meet reference values. One key weakness of individual indicator-based analysis and reporting is the difficulty in highlighting and analyzing interrelationships among indicators. Examining these interactions is critical to understanding sustainability. Any single indicator is only a small signal in the overall assessment of sustainability. Examined in isolation, these signals may be incomplete or appear contradictory. Greater

[2] The use of trade names is for the benefit of the reader; such use does not constitute an official endorsement or approval by the USDA Forest Service to the exclusion of others that may be suitable.

[3] Chapters 12 and 13 of the Technical Edition (Wright et al. 2002) describe this tool in detail.

understanding comes from probing how the indicators work together as a suite to assess the status of a system's structures and functions. The image that comes from the assessment of the whole system can help determine if a negative trend in one indicator affecting the overall system.

A systems-framed suite of C&I is one of the first techniques to overcome this weakness. The systems framework and the indicators selected to represent the key structural and functional components of those systems is inherently integrative. A reason for adopting a systems approach was not only to aid in the selection of indicators but also to serve as a guide for analysis. The conceptual and analytical models were designed by the LUCID forest teams as conceptual road maps to guide analysis. Evaluations that compare data to reference values could be used for groups of indicators organized at the criterion level to add context and meaning to individual indicator results. LUCID forest teams recommended spatially-based analysis to illustrate relationships among indicators, even if only conceptually. Finally, LUCID participants noted that the most powerful analytical tool in understanding relationships was human dialogue and discussion.

Although forest teams organized their results differently (by criterion or indicator, by management issue, or by physical area or watershed), the most popular and meaningful method of presentation was narrative description. Narratives varied but commonalities included definitions of the indicator and measures; discussion of the standards set; descriptions of the data or at least specific pieces of data of concern or interest; and discussions of missing data, potential causal influences, and tentative management implications. Adding charts, graphs, or maps displaying numeric summaries to these narratives can very effectively improve communication of results. This approach to analysis and presentation is relatively easy to follow and is fairly straightforward to assemble. This approach serves as the cornerstone for broader analysis and communication to many different audiences.

The development of methods and tools for analyzing indicators and synthesizing results to help understanding of the state of systems is in its infancy. Forest teams did not feel they achieved a complete sustainability assessment product given the intense amount of time spent on placing the C&I suite in a systems framework, developing measures and reference values, and experimenting with various software tools to aid in analysis. The LUCID test made strides in identifying how a systems approach and consistent technical tools can help guide meaningful sustainability assessments. However, much more work remains to be done, including improving to existing tools, examining alternative approaches and techniques, and developing guidance for widespread application across the National Forest System.

Engaging Stakeholders

The sustainability assessment process may be used to engage stakeholders in discussions about forest management and desired future conditions. A sustainability dialogue with collaborators from other government agencies and research institutions facilitates improved participation throughout the forest plan revision process (see Figure 5). It can be particularly useful during development of the analysis of the management situation report, identification of management issues, and the need for change.

Informing Forest Management

The final step in sustainability assessment is communicating results to management including recommending areas for further research, identifying the need for change, and contributing input for larger scale monitoring efforts. These topics are elaborated on in the final sections of this report. The results of the sustainability assessment may also lead to revising subsequent monitoring activities.

MANAGEMENT RECOMMENDATIONS

LUCID test participants concluded that sustainability monitoring is a valuable approach, is feasible, and should be adopted more widely at the FMU scale. Given that the forest teams were participating in a test process that was new territory for them and that refining the process itself was one of the goals, the teams faced challenges along the way. These challenges were also opportunities for reappraisal and growth, and the value in the process itself is a key finding of the LUCID test.

The LUCID project was initiated to develop a method for assessing systems sustainability at the local scale. The primary intent was to develop a tool that would provide feedback specifically at the FMU scale. In their evaluations, however, LUCID participants noted that the tool and techniques have application on a daily basis at a range of scales including at the project scale. Teams reported many other specific benefits, including the following:

- Using a systems framework for resource management enhances interdisciplinary work and provides a forum to discuss and consider how elements and activities interact among complex social, economic, and ecological systems;
- Sustainability monitoring can serve as the core of forest planning and monitoring;
- The C&I framework, a core indicators suite, and supplemental indicators provide both consistency and flexibility. Consistency allows for reducing duplication of effort and for better integration of data; flexibility allows local units to tailor indicators and measures;
- The LUCID process provides a framework for public collaboration in forest planning and a forum to discuss and recognize differing staff, collaborating partner, and stakeholder values;
- The LUCID process forges stronger ties among managers and external collaborators to provide a larger pool of data sources and expertise and to build relationships;
- The LUCID process can facilitate coordinated monitoring efforts among local, regional, and national administrative levels within the Forest Service and between agencies;
- Explicitly addressing issues of scale, data collection and aggregation, and reference values forces forest teams to define and redefine sustainability within a broader social, economic, and ecological systems context.

Integrating the LUCID Process into Local Forest Planning and Management

The LUCID test process and tools for sustainability monitoring can be used throughout the forest planning cycle to inform the process of adaptive management. Sustainability monitoring at the FMU scale can provide forest managers and collaborators with assessment information that can be used to improve land and resource management plans, enhance collaboration between national forests and other government agencies, and relate forest plan outcomes with regional and national C&I trends.

Figure 5 shows the points of the forest planning cycle at which sustainability monitoring can enhance the process. These are described in greater detail below.

A sustainability assessment using a suite of C&I can provide a comprehensive way of looking at the state of systems, as well as the state of our knowledge, in preparation for Forest Plan revision. An assessment provides a way of analyzing the current state of FMU systems, facilitating understanding of the place of the National Forest in the larger context, and identifying the need for change. The sustainability assessment involves engaging stakeholders in a dialogue to help evaluate the assessment of sustainability, not make an absolute determination.

Results from ongoing sustainability monitoring efforts can be used at this stage for issue identification. Data collection over time can provide a strong foundation of knowledge around which to develop desired future conditions and alternatives.

A collaborative approach to sustainability monitoring provides an opportunity for more participatory development of the analysis of the management situation and identification of the need for change. Although a C&I-based sustainability-monitoring program will not eliminate conflicting perspectives, the approach can facilitate a deeper understanding of different perspectives because the topics are discussed using a common language of C&I. The common set of C&I can be used to compare scenarios or alternatives or to discuss the potential outcomes and interactions among social, economic, and ecological aspects of alternative scenarios. Alternatives can be compared against a set of common reference values or a comparative analysis can be completed based on differing perspectives on outcomes (e.g., short-term versus long-term outcomes or reference values prepared from different perspectives).

From a forest plan perspective, sustainability monitoring is focused on FMU conditions rather than project implementation monitoring. The

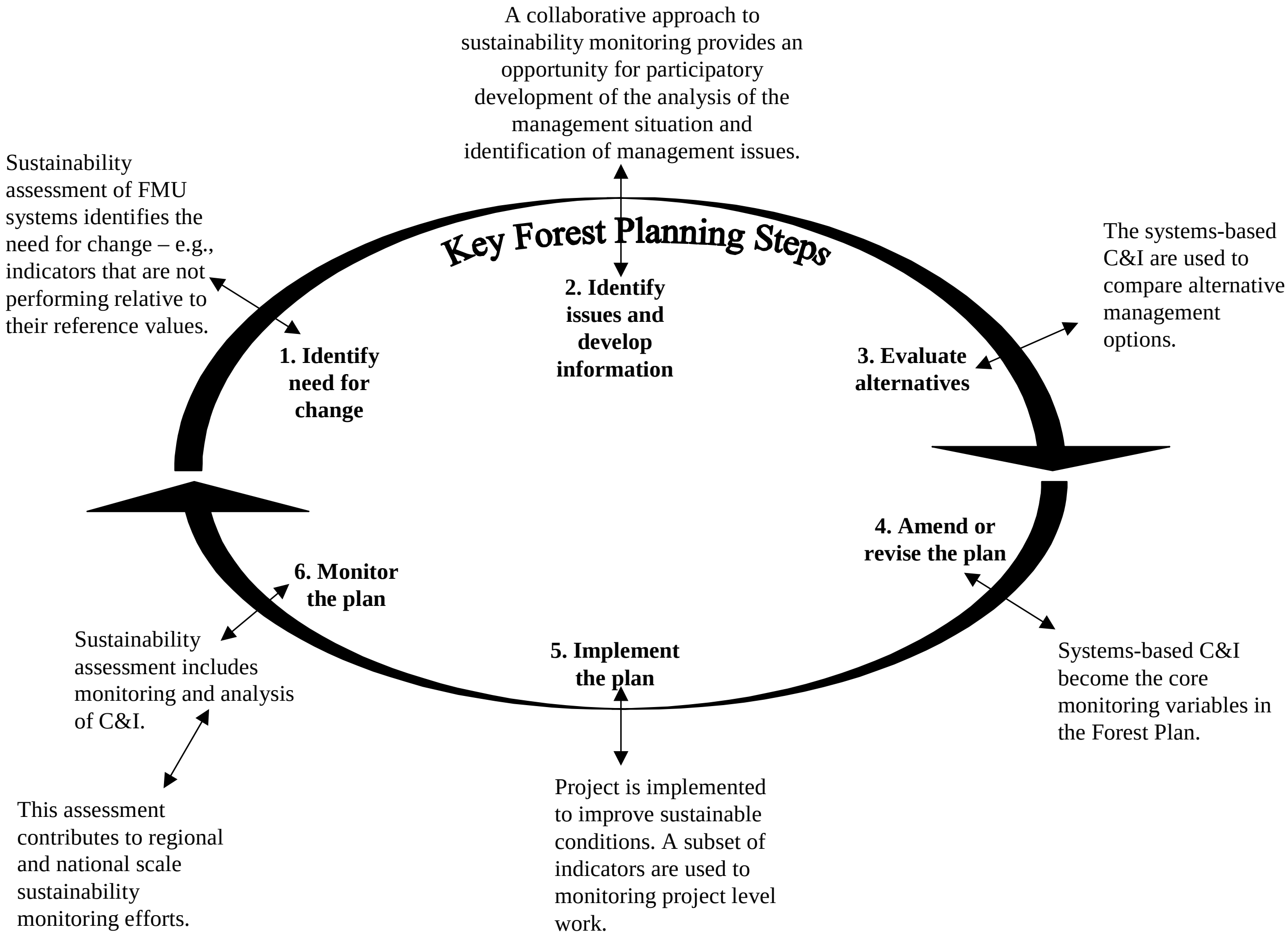

Figure 5. Relationship Between FMU-Scale Sustainability Monitoring and Forest Planning

systems approach framing the monitoring protocols can have broader application throughout forest planning and management by being used as a framework for understanding complex living systems. Implementation monitoring and other monitoring requirements will still be necessary, but they can be organized within this comprehensive monitoring framework to bridge short-term actions with long-term outcomes.

A common monitoring framework that focuses on understanding the broader systems is also useful for streamlining and coordinating monitoring efforts. Often, each functional or ecosystem component group (e.g., soils, aquatics, or silviculture) will propose monitoring items that are clearly related if not identical. Developing a systems-based monitoring program that frames and coordinates disciplinary measures can help identify those overlaps and reduce redundancies. Based on their experience in reorganizing the forest monitoring plan for the Southwest Idaho Ecogroup forests, forest planners found that it was relatively simple to fit the monitoring needs for each group within a common framework and that groups usually could agree on measures or data that would meet a broad range of purposes.

Systems-based sustainability monitoring supports the analysis and synthesis of information in a way that is more useful for program management decisions. Comparing indicators to reference values over time and synthesizing individual comparisons into an overall system assessment can help identify whether management actions and priorities should be revisited. In an active management context, the process of developing reference values requires analysis of the question, "What variation from the reference conditions would initiate further evaluation and/or change in management direction?" If progress is being made, then management actions continue; if progress is not made, then the plan may need to be revisited or adjusted. Areas of concern may include the appropriateness of the indicator or measure, the quality of the data, and the appropriateness of the reference value. An area of concern identified through monitoring might require a more detailed assessment or analysis. Using the systems framework as a guide, users may be able to hypothesize the possible effects of a problem in one area on interrelated issues in order to anticipate future problems.

FMU-Scale Sustainability Monitoring Offers Clear Benefits

From a forest planning perspective, sustainability monitoring switches the focus from short-term implementation monitoring to monitoring long-term outcomes. A common monitoring framework that focuses on understanding the broader systems helps to rationalize and coordinate existing monitoring efforts. LUCID test participants found that by using a common framework and indicators to organize monitoring items, they were able to identify fewer data items to measure. This ability clearly increases monitoring efficiency.

The system approach that frames the monitoring system can also have broader application throughout forest planning and management as a framework for understanding complex living systems. As the agency's focus moves toward ecosystem management goals, sustainability monitoring can inform our decisions while contributing to greater public trust and improved accountability. In this way, forest managers and stakeholders can better answer how we are doing, and where we want to be in the future.

Pilot test results clearly demonstrate the great potential of the LUCID approach for monitoring at the FMU scale. The suite of core indicators applied within a system framework can provide information needed for adaptive management at the local unit scale, as well as certain types of data that can be aggregated and utilized at regional and national scales. Experience shows that sustainability monitoring can effectively replace most existing forest plan monitoring. Specific legal and regulatory monitoring requirements and required implementation monitoring components may fit as measures to verify the core indicators or be supplemental to the core indicators. The LUCID core suite includes optional measures for tailoring C&I to local conditions, but forest teams will need to examine their context and questions carefully. Revision, adaptation, and substitution can be made within the systems framework while maintaining the overall context and meaning as long as the core suite itself is not treated as simply a pick list. The core suite itself is designed to be the basic set needed for systems-based sustainability monitoring.

While a great deal of work remains in refining and developing this method and its tools, the approach is far enough along to begin wider implementation beyond the initial six test forest teams. IMI staff can provide technical assistance during implementation of FMU-scale sustainability monitoring, including assistance in using a systems framework and tools such as the C&I and analytical methods. Additionally, Forest Service research staff can provide assistance in identifying the most suitable measures for a particular FMU area, designing cost effective and reliable protocols, and researching appropriate reference values for indicators. Regional office specialists may also be able to advise and assist in supporting the use of FMU-scale sustainability monitoring in forest planning, helping to coordinate initiatives between forests, facilitating access to specialists, and clarifying relationships with regional and national monitoring requirements.

Contributions to Multiscale Monitoring

Sustainability is a multiscaled problem and consequently there is no right scale to assess or manage for sustainability. Although sustainability can be studied at multiple scales, once the components of systems are identified for monitoring, selecting the correct scale is critical. The context of the systems that we are trying to sustain change at every scale because the constraints change. Using the wrong scale to look at certain system properties could be like trying to see an elephant through a microscope. Managing for sustainability requires consideration all scales, but monitoring and assessing sustainability must be based on the recognition that different questions and different methods are appropriate for different scales.

Just as matching the scale of the question to the scale of data collection is important, so are issues of data aggregation. Scale issues are complicated by whether or not systems are nested or unnested. For nested systems, the issues of sampling and data aggregation are straightforward. Data are typically sampled at least one scale finer than the question of interest and are then aggregated upward to the scale appropriate to the properties of the system component. Sampling and data aggregation in non-nested systems are more difficult because the emergent properties of systems mean that simply aggregating data will overlook the synergistic effects of systems. For example, percent soil carbon can be aggregated using weighted area values because it is a process-independent measure while the volume of soil carbon/cubic meter cannot be aggregated because it is a process-dependent measure.

Examination of the relationships across the various scales of sustainability monitoring requires consideration of the nature of human values and the role of communities of place and communities of interest in forming these values; the nature of living systems and the inherent variability in their form and expression; and, the methodological challenges associated with data integrity, sampling, and aggregation.

Relationship to National Criteria and Indicators Framework

National and FMU scale C&I programs represent complementary tools that can be used in our quest for sustainability. Each tool helps answer a set of questions and provides feedback for different kinds of purposes and decisions at different scales.

A strong national framework provides the policy context and structures to enable local management for sustainability. National sustainability reports, for example, may identify broad trends and trigger interest and attention on specific issues. Likewise, improvements in national progress towards sustainability are facilitated by local actions. There is clear philosophical overlap and interdependence between the national and FMU-scale sustainability monitoring initiatives although the purposes, tools, and approaches are by intent different and therefore not easily translated one to the other.

Many of the indicators included in various C&I initiatives are conceptually similar. In some cases, not only are the indicators the same, but also the questions to be addressed are similar enough between scales that the same measure could be used for the indicator. Although the same type of raw data may be useful at multiple scales, the sampling locations, intensity, and analytical methods may often vary because the sustainability questions change between scales. Where shared data elements can be identified between national and FMU scales, monitoring efficiencies can be achieved. As measurement protocols and data elements are more clearly specified for Montreal Process monitoring at the national scale, it will be easier to identify potential opportunities for data sharing.

In addition, to a desire to identify efficiencies in shared data, there is some desire in understanding how sustainability assessments at one scale can contribute to sustainability assessments at another scale. If we look at the results of the FMU sustainability assessment as a whole, aggregating the results of one FMU assessment to another scale is not appropriate or feasible. The emergent properties of a system make it unique. In understanding the relationship between initiatives at different scales, we found that the most value comes from narrative descriptions that describe the results in a context fashion. Narratives can be used to describe this rich picture.

Monitoring programs at the national and FMU scale have commonalities with respect to the lessons learned about the process of monitoring. The growing literature on the Montreal Process C&I and the suite of indicators provided a valuable context and starting point for the LUCID test. The 2003 national sustainability report will highlight many new issues, ideas, data requirements, and data sources that will also be useful for local forest units. From a process perspective, the LUCID forest teams learned a series of valuable lessons about systems approaches, the need for specificity, the balance between consistency and flexibility, reference values, and approaches and tools for analysis and synthesis that may be of benefit to the national program.

Broader Implementation of the LUCID Process

Several of the original LUCID test sites and a number of other units are continuing to integrate a systems-based approach to sustainability monitoring into their work. LUCID products appear to be valuable in assisting forests currently in their forest plan revision process, forests re-examining their monitoring strategies, and for other initiatives from project level application to contributing to analytical approaches for monitoring at other scales. The core team continues to work on the most effective implementation strategies for the LUCID process in consultation with local units. The LUCID Technical Edition (Wright et al. 2002) discusses some of the strategic and tactical implementation strategies in detail; highlights of these issues are summarized here.

Adopting the LUCID process of sustainability monitoring faces several challenges, both in technical development and in practical implementation. While forest teams did make significant progress in identifying measures, the social well-being measure in particular needs further development; this area is not a traditional agency strength and staff resources are limited. This challenge is neither unexpected nor insurmountable. Continuing to define and test reference values is another challenge. Issues of data availability for indicator measures are significant. The compatibility among LUCID data measurement protocols, corporate data sources such as the Natural Resource Information System (NRIS), and external data sources present another opportunity for productive advances toward more effective sustainability monitoring.

Supporting individual national forests in their efforts to integrate an FMU-scale approach to sustainability monitoring as a part of their work plans will require not only the enhancement of tools, techniques, and relationships among other Forest Service units but will also require building skills at each forest. Technical assistance, regional, and national support will be vital to the success of this process. LUCID participants found that a forest team consisting of five or more people, representing the social, economic, and ecological disciplines, Geographic Information Systems (GIS) analyst, and a team leader with planning or public information skills was optimal. Sociologists, economists, and GIS staff are in relatively short supply in the Forest Service, but regional office staff support and use of external collaborators could be used to help bridge gaps in expertise. A network of research and regional office specialists could be built to support forest-scale sustainability monitoring initiatives. National guidance and support for creating this network would mean that individual Forests would not need to duplicate efforts. Like any new program, implementing a sustainability-monitoring program would demand additional investments at the outset, but as this approach became more widespread among Forests and staff move between units, the skills gained would mean that in the initial investment levels would gradually taper off. Adoption and use of this common systems framework, defined by the principles and criteria, can provide a consistent organizational approach to understanding, monitoring, and assessing sustainability at the local forest scale.

CONCLUSION

The journey and lessons learned by a group of dedicated Forest Service employees and stakeholders is documented by this report and the LUCID Technical Edition (Wright et al. 2002). Although participants shared a common goal, they all had different understandings of how to make progress, how quickly to proceed, and even in what direction. However, they gradually developed a common language to discuss values and perspectives. As a result, they made significant steps in developing a set of tools and a process to help others monitor progress in the quest for sustainability.

LUCID test participants affirmed that sustainability is a social concept and one that is incredibly valuable in practical application even though its definition may be elusive. They agreed that sustainability cannot be achieved by any one group of people, at one scale, and certainly not by the Forest Service acting alone. They recognized that agency personnel need to act on multiple fronts, on multiple scales, and with internal and external partners across physical, conceptual, and administrative boundaries. In the face of uncertainty and a multitude of competing stakeholder values, sustaining the fundamental systems contexts that sustain people is the surest way to move forward.

Establishing and implementing a sustainability-monitoring program at the forest management unit scale represents one approach to sustaining these systems. The LUCID test has clearly demonstrated that its approach can serve as a practical tool for managers, stakeholders, and citizens in their quest for sustainability at the local scale. The approach provides a means to share diverse perspectives on individual and collective values about healthy communities, healthy economies, and healthy lands in moving toward a sustainable future.

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APPENDIX: FINAL SUITE OF LUCID PRINCIPLES, CRITERIA, INDICATORS AND MEASURES

Principle P1: Social Well-being

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C1.1 Collaborative stewardship	I1.1.1 Contribution of local and traditional and ecological knowledge	M1.1.1.1 Projects with traditional ecological knowledge/local knowledge component (e.g., number of projects)	
			MO1.1.1.2 Participation in traditional ecological knowledge workshops (number workshops, person hours participation)
C1.1 Collaborative stewardship	I1.1.2 Collaborative decision-making	M1.1.2.1 Projects done collaboratively (e.g., number of projects)	MO1.1.2.1 Assessment of Memo of Understand/Memo of Agreement and other agreements (e.g., number of agreements)
		M1.1.2.2 Participation in public review opportunities (e.g., number, representativeness, satisfaction with)	
			MO1.1.2.3 Environmental Assessment/Environmental Impact Statements resulting in appeals/lawsuits (e.g., number or proportion resulting in appeals)
			MO1.1.2.4 Requests for participation in decision making beyond requirements (e.g., number by type)
C1.1 Collaborative stewardship	I1.1.3 Stewardship activities	M1.1.3.1 Participation in stewardship activities (e.g., number of volunteer days, number of individuals involved)	MO1.1.3.1 Cooperative stewardship initiatives (e.g., number of initiatives by type)
			MO1.1.3.2 Partnership contributions (e.g., dollars, in-kind contributions, cost shares)
C1.1 Collaborative stewardship	I1.1.4 Local area empowerment and development	M1.1.4.1 Skill base development and retention (e.g., number of training hours, days, sessions)	
C1.2 Institutional and Community Capacity	I1.2.1 Community resiliency	M1.2.1.1 Community capacity index	MO1.2.1.1 Socioeconomic resiliency index
C1.2 Institutional and Community Capacity	I1.2.2 Institutional adequacy	M1.2.2.1 Areas with sustainable management plans, policies or commitments (e.g., acres by ownership and type of agreement)	MO1.2.2.1 Assessment of land tenure policies that restrict sustainabile forest management
		M1.2.2.2 Adequacy of inventories (e.g., index of completeness and currency)	

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C1.2 Institutional and Community Capacity	I1.2.3 Ownership patterns	M1.2.3.1 Land ownership/tenure (e.g., area by use type)	MO1.2.3.1 Parcel size by ownership type
		M1.2.3.2 Land value by type of use/tenure (e.g., change in per capita value of assessed property; average property value of forest land by commercial/private)	
C1.2 Institutional and Community Capacity	I1.2.4 Government to government relationships	M1.2.4.1 Assessment of government-to-government agreements/plans (e.g., number of by Tribe, State, etc.)	MO1.2.4.1 Government to government interactions/relationships (e.g., number of informal interactions/relationships by Tribe, State, etc.)
C1.3 Social equity	I1.3.1 Environmental justice and civil rights	M1.3.1.1 Civil rights violations (e.g., number or severity by type)	
		M1.3.1.2 Small business/minority set asides (e.g., number, dollar value, extent by program area)	
		M1.3.1.3 Distribution of workforce (e.g., gender, ethnicity, age, etc.)	
		M1.3.1.4 Environmental justice issues (e.g., number of analysis issues identified, remedial actions as result of analysis, number of complaints, etc.)	
C1.3 Social equity	I1.3.2 Disabled access	M1.3.2.1 Accessible facilities (e.g., proportion/number facilities available by activity)	
C1.3 Social equity	I1.3.3 Worker health and safety	M1.3.3.1 Worker safety incidents (e.g., lost time injury frequency rate; number per year)	MO1.3.3.1 Worker health and safety claims (e.g., number or value of those filed per year)
		M1.3.3.2 Intensity and extensity of workforce trained (e.g., number of workers or months of training by program/topic area)	
			MO1.3.3.3 Compliance with inspections (e.g., number of violations or # outstanding violations by severity)
C1.3 Social equity	I1.3.4 Public health and safety	M1.3.4.1 Public safety incidents (e.g., number of incidents by type/severity)	
C1.3 Social equity	I1.3.5 Community/environmental health	M1.3.5.1 Human health violations (e.g., number of by type, air quality violations, potable water)	
		M1.3.5.2 Fire hazard or risk index	

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C1.4 Social and cultural values	I1.4.1 Gathering	M1.4.1.1 Participation in harvest for personal use (e.g., number of persons participating in harvest for consumption/cultural purposes)	MO1.4.1.1 Availability of subsistence use programs (e.g., number by type, knowledge of availability)
		M1.4.1.2 Participation in harvest for Native American use (e.g., number of persons participating in harvest for consumption/cultural purposes)	MO1.4.1.2 Availability of Native American subsistence use programs (e.g., number by type; knowledge of availability)
			MO1.4.1.3 Conflicts between Native American use and other activities (e.g., number of by type such as FS policy, commercial harvest, etc.)
C1.4 Social and cultural values	I1.4.2 Aesthetics and Solitude	M1.4.2.1 Scenic quality index (e.g., acres by visual quality objective class, acres needing rehabilitation by visual quality objective class)	
		M1.4.2.2 Availability of places for solitude (e.g., acres of forest buffered from collector or arterial roads, acres of forest not under flight paths, etc.)	
C1.4 Social and cultural values	I1.4.3 Education and research	M1.4.3.1 Interpretive facilities available (e.g., number of by type)	
		M1.4.3.2 Interpretation, education, and research participation (e.g., number of contacts by type)	
			MO1.4.3.3 Interpretation, education, research expenditures (e.g., total expenditures or proportion of total expenditures on educational/interpretive/research materials)
			MO1.4.3.4 Research activities (e.g., number of efforts to promote/enable research)
C1.4 Social and cultural values	I1.4.4 Cultural values and historic features	M1.4.4.1 Protection of cultural and historic sites (e.g., total number, number with minimum buffer protection widths or other protective mechanisms)	MO1.4.4.1 Cultural and historic sites identified (e.g., number of sites that have been evaluated)
		M1.4.4.2 Cultural and historic sites that have been negatively impacted (e.g., number of sites impacted)	MO1.4.4.2 Cultural and historic site monitoring for protection (e.g., number sites monitored annually, archaeological field monitoring days)

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C1.4 Social and cultural values	I1.4.5 Spiritual values and special places	M1.4.5.1 Areas managed for special places/values (e.g., acres/proportion old growth, deer management, wetland areas, etc.)	
C1.4 Social and cultural values	I1.4.6 Access and use rights	M1.4.6.1 Road access (e.g., miles by road class)	
		M1.4.6.2 Access restrictions (e.g., acres of forest with restricted access by restriction type)	MO1.4.6.2 Access restrictions (e.g., special acts/closure orders; number permits denied due to access concerns; restrictions by inholdings; number of non-access days)
		M1.4.6.3 Special use permits (e.g., number of special use permits by type)	
			MO1.4.6.4 Areas available for recreation (e.g., Scenery Management System by Recreation Opportunity Spectrum)
C1.4 Social and cultural values	I1.4.7 Recreation and tourism	M1.4.7.1 Recreation use (e.g., Recreation Visitor Day by Recreation Opportunity Spectrum)	MO1.4.7.1 Visitors use (e.g., number of visitors)
		M1.4.7.2 Recreation user satisfaction (e.g., visitor survey by activity type)	
			MO1.4.7.3 Recreation supply (e.g., Persons at One Time by Recreation Opportunity Spectrum)
C1.4 Social and cultural values	I1.4.8 Customs and culture	M1.4.8.1 Public satisfaction with management for sense of place (e.g., public survey, interviews, etc.)	
			MO1.4.8.2 Facilities available to support customary and traditional activities (e.g., number of facilities)
			MO1.4.8.3 Services and mechanisms available to support customary and traditional activities (e.g., number of special use permits for recreation events)
			MO1.4.8.4 Conflicts between United States Forest Service and customary users (e.g., number of conflicts)

Principle P2: Maintain Ecological Integrity

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C2.1 Landscape function	I2.1.1 Disturbance processes	M2.1.1.1 Intensity/extensity/frequency of disturbance processes (e.g., degree of organic matter removal by fire, proportion of landscape disturbed by wind annually, return interval for fire)	
			MO2.1.1.2 Risk assessment of disturbance processes (e.g., area at high risk of mortality due to insects or disease, fire risk condition class)
C2.1 Landscape function	I2.1.2 Hydrologic function	M2.1.2.1 Watershed condition index (e.g., hydrologic condition assessment)	
		M2.1.2.2 Drought/Flood severity measures (e.g., Palmer drought severity index)	MO2.1.2.2 Precipitation measures (e.g., inches of rainfall/ snowfall, snowpack depth)
			MO2.1.2.3 Snow/Ice phenology (e.g., rate of glacier recession, date of lake ice on/off)
C2.1 Landscape function	I2.1.3 Long-term community dynamics	M2.1.3.1 Longevity of current community assemblages (e.g., changes in dominant species based on vegetation history derived from pollen cores, presence of historic soil profiles, fossil evidence of past plant/animal communities)	
C2.2 Landscape structure/composition	I2.2.1 Landscape diversity	M2.2.1.1 Assessment of vegetation community types including permanent conversions (e.g., acres or relative proportion of each type)	
		M2.2.1.2 Horizontal and vertical structural diversity of vegetation (e.g., number of vegetation layers present)	
			MO2.2.1.3 Management guidelines present and utilized by ecological land types
C2.2 Landscape structure/composition	I2.2.2 Landscape patterns	M2.2.2.1 Patch size and patch shape metrics (e.g., mean patch size and edge to interior ratios etc., by forest/non-forest area; by succesional stage; by community type)	MO2.2.2.1 Landscape pattern effect on habitat (e.g., percent of sub-basin with suitable habitat for selected species; HABSCAPES model)

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
		M2.2.2.2 Patch distribution and connectivity (e.g., dispersion index, characterization of random/regular/clumped patches, inter-patch distance, nearest neighbor measurement)	
		M2.2.2.3 Density and distribution of human developed features (e.g., road density, number of road crossings, distance to human developed features, by use class)	
C2.3 Ecosystem function	I2.3.1 Productive capacity	M2.3.1.1 Net primary productivity (e.g., remote sensing measures of site productivity)	MO2.3.1.1 Productive capacity (e.g., estimate based on climate, chlorophyll per unit area, etc.)
		M2.3.1.2 Tree growth rate (e.g., annual increment, basal area growth)	
		M2.3.1.3 Forage condition class assessment	MO2.3.1.3 Forage quantity and quality (e.g., animal unit months, pounds forage produced)
		M2.3.1.4 Animal and fish productivity (e.g., number of individuals or pounds annually, shared measure, in part, with M2.6.1.1)	
C2.3 Ecosystem function	I2.3.2 Functional diversity	M2.3.2.1 Areas impacted by hyper/hypo species abundance (e.g., acres where deer exceed carrying capacity)	
		M2.3.2.2 Diversity within selected guild populations (e.g., number of species, redundancy of species)	
C2.3 Ecosystem function	I2.3.3 Invasive species	M2.3.3.1 Presence of exotic species (e.g., number of exotic plant species)	
		M2.3.3.2 Areas affected by invasive species (e.g., acres invaded, rate of spread)	MO2.3.3.2 Risk assessment of invasive species (e.g., acres at risk)
			MO2.3.3.3 Adequacy of monitoring to detect invasive species
C2.3 Ecosystem function	I2.3.4 Nutrient cycling	M2.3.4.1 Soil organic matter content (e.g., percent organic matter in 'A' horizon of soil)	MO2.3.4.1 Litter accumulation/decay (e.g., pounds per acre, litter extent, 'O' horizon depth, percent cover, percent bare soil)

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
			MO2.3.4.2 Soil macro/micro fauna diversity (e.g., number of species)
	I2.3.5 Carbon sequestration	M2.3.5.1 Soil carbon (e.g., pounds of carbon in soil per acre)	MO2.3.5.1 Soil carbon 'A' horizon (e.g., based on depth of 'A" horizon and percent carbon present) MO2.3.5.1 Soil carbon as determined from CWD (e.g., pounds of CWD by decay class)
		M2.3.5.2 Biomass carbon sink (e.g., timber volume equivalents)	
	I2.3.6 Stream function	M2.3.6.1 Assessment of stream segments in proper functioning condition (e.g., proportion of stream in proper functioning condition)	MO2.3.6.1 Assessment of the quality and extent of riparian vegetation (e.g., stream miles with intact riparian vegetation/ thermal cover) MO2.3.6.1 Presence of stream structural elements (e.g., number and distribution of in stream structural elements such as coarse woody debris and large boulders)
C2.4 Ecosystem structure/composition	I2.4.1 Air, soil and water quality	M2.4.1.1 Air quality attributes (e.g., number of days of non-compliance with standards such as visual quality or ozone level, lichen health index based on coverage of arboreal lichens, direct measures of pollutants per volume of air)	
		M2.4.1.2 Index of biotic integrity for aquatic systems (e.g., index biotic integrity by stream segment or watershed)	MO2.4.1.2 Water quality attributes (e.g., number of water bodies that exceed water quality standards such as temperature, fecal coliform, 303(d) list, EPA "impaired list", turbidity, etc.; number of spills per year, number of fish mercury advisories; PH measures including PH of precipitation)
		M2.4.1.3 Soil quality attributes (e.g., number of departures from BMP for soil quality, level of pollutants per unit volume of soil, bulk density measurement; soil nutrient analysis)	

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C2.4 Ecosystem structure/composition	I2.4.2 Ecological legacies	M2.4.2.1 Assessment of Coarse Woody Debris and Snags (e.g., volume of CWD or number of snags per acre by decay class, by size class, by vegetation community type)	
		M2.4.2.2 Assessment of Snags (e.g., number of snags per acre by decay class, by size class, by vegetation community type)	
			MO2.4.2.3 Assessment of other ecological legacies (e.g., number of, or acres of features such as raptor nests, boulder fields, wallows, ant hills, beaver dams, legacy trees, etc).
C2.4 Ecosystem structure/composition	I2.4.3 Special habitats	M2.4.3.1 Assessment of areas of special interest (e.g., reserve acres, wilderness acres, winter deer yards, etc., by condition class and protection status)	
			MO2.4.3.2 Guidelines are in place for the management of special interest areas
C2.4 Ecosystem structure/composition	I2.4.4 Species richness	M2.4.4.1 Assessment of species richness (e.g., number of species present within target species group such as birds or by species guild such as cavity nesters, by vegetation community type, management type)	
		M2.4.4.2 Assessment of species of concern (e.g., number of extirpated or endangered species)	
C2.5 Population function	I2.5.1 Population viability	M2.5.1.1 Population viability analysis of selected species (e.g., index based on measures of population dynamics, population genetics, environmental variation, metapopulation structure, and habitat suitability, etc.)	MO2.5.1.1 Habitat suitability analysis (e.g., acres of suitable habitat for selected species based on habitat models)
C2.6 Population structure/composition	I2.6.1 Populations of indigenous species	M2.6.1.1 Populations of selected species (e.g., population size, density, age class, sex ratio)	MO2.6.1.1 Habitat suitability analysis (e.g., acres of suitable habitat for selected species based on habitat models)
		M2.6.1.2 Assessment of species' metapopulations (e.g., size, number and distribution of metapopulations)	

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
			MO2.6.1.3 Number of selected species with completed conservation assessment and recovery plans
C2.7 Organism function	I2.7.1 Genetic mixing	M2.7.1.1 Assessment of the existence and use of native and non-native stock rules	
C2.7 Organism function	I2.7.2 Genetic migration	M2.7.2.1 Assessment of migration barriers (e.g., number water control structures per river mile) M2.7.2.2 Assessment of the persistence of species on the edge of their range (e.g., population size of species on edge of range)	
C2.7 Organism function	I2.7.3 Genetic selection	M2.7.3.1 Assessment of the alteration of native species gene pools (e.g., percent of area where selected species do not reach sexual maturity prior to harvesting, acres of vegetation communities where management actions or selection pressures lead to unnatural selection pressures)	
C2.8 Organism structure/composition	I2.8.1 Genetic diversity	M2.8.1.1 Assessment of areas converted to non-native gene pool (e.g., acres converted, proportion of landscape converted) M2.8.1.2 Allele and genotype frequencies for selected species (e.g., difference from expected natural heterozygocity)	MO2.8.1.2 Assessment of minimum viable populations (e.g., population size of species with limited gene pools) MO2.8.1.3 Presence of adequate genetic reserves/gene banks (e.g., acres)

Principle P3: Economic Well-being

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C3.1 Capital and wealth	I3.1.1 Natural capital - forests	M3.1.1.1 Compare productive forest to total forest (e.g., proportion by ownership, forest type, species, etc.) M3.1.1.2 Amount of productive forest (e.g., timber volume by ownership, forest type, species, etc.) M3.1.1.3 Value of productive forest (e.g., $ value by ownership, forest type, species, etc.)	MO3.1.1.1 Total amount of forest (e.g., acres)
C3.1 Capital and wealth	I3.1.2 Natural capital - recreation	M3.1.2.1 Areas available for recreation (e.g., Scenery Management System by Recreation Opportunity Spectrum) M3.1.2.2 Areas of wilderness	
C3.1 Capital and wealth	I3.1.3 Natural capital - wildlife/fish	M3.1.3.1 Wildlife populations	MO2.6.1.1 Assessment of suitable habitat for selected species (e.g., habitat suitability models) MO3.1.3.2 Assessment of fish bearing streams (e.g., stream miles)
C3.1 Capital and wealth	I3.1.4 Natural capital - range	M3.1.4.1 Amount of productive range (e.g., acres by forage condition class)	
C3.1 Capital and wealth	I3.1.5 Other natural capital	M3.1.5.1 Special management areas (e.g., acres of research natural areas, special interest areas, wild scenic rivers, etc.) M3.1.5.2 Water resources (e.g., volume available)	
		M3.1.5.3 Special forest products (e.g., lbs of edible mushrooms)	MO3.1.5.3 Value of special forest products (e.g., $ value of annual edible mushroom harvest)
		M3.1.5.4 Areas of oil, gas and mineral potential (e.g., assessment of proven reserves)	
			MO 3.1.5.5 Natural capital ownership (e.g., proportion public to private forest ownership)

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C3.1 Capital and wealth	I3.1.6 Built infrastructure - roads and trails	M3.1.6.1 Roads and trails (e.g., miles of roads/trails by use type and capacity)	
		M3.1.6.2 Condition of roads and trails (e.g., miles to standard)	MO3.1.6.2 Asset value of roads and trails (e.g., $ value of roads/trails by use type)
			MO3.1.6.3 Roads and trails maintenance cost
			MO3.1.6.4 Roads and trails maintenance backlog
C3.1 Capital and wealth	I3.1.7 Built infrastructure - recreation facilities	M3.1.7.1 Recreation facilities (e.g., number of recreation facilities by type)	
		M3.1.7.2 Capacity of recreation facilities	
		M3.1.7.3 Condition of recreation facilities	MO3.1.7.3 Recreation facilities maintenance cost
			MO3.1.7.4 Recreation facilities maintenance backlog
			MO3.1.7.5 Asset value of recreation facilities
C3.1 Capital and wealth	I3.1.8 Built infrastructure - other facilities	M3.1.8.1 Other facilities (e.g., number of by type)	
		M3.1.8.2 Condition of other facilities	MO3.1.8.2 Other facilities maintenance cost
			MO3.1.8.3 Asset value of other facilities
			MO3.1.8.4 Other facilities maintenance backlog
C3.1 Capital and wealth	I3.1.9 Human capital	M3.1.9.1 Assessment of labor pool (e.g., size/distribution by gender, ethnicity, age etc.)	
C3.2 Flows of products and services	I3.2.1 Production of marketed goods and services	M3.2.1.1 Timber harvested (e.g., million board feet by type)	MO3.2.1.1 Value of timber produced
		M3.2.1.2 Recreation use (e.g., recreation visitor day by recreation opportunity spectrum)	MO3.2.1.2 Value of recreation produced
		M3.2.1.3 Wildlife harvested	MO3.2.1.3 Value of wildlife harvested
		M3.2.1.4 Fish harvested	MO3.2.1.4 Value of fish harvested
		M3.2.1.5 Animal unit month used	MO3.2.1.5 Value of animal unit month produced
		M3.2.1.6 Oil, gas and minerals produced (e.g., volume by type/grade)	MO3.2.1.6 Value of minerals produced
		M3.2.1.7 Electrical power generated (e.g., kw hours)	MO3.2.1.7 Value of energy produced

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
		M3.2.1.8 Water withdrawals (e.g., volume)	MO3.2.1.8 Value of water withdrawals
		M3.2.1.9 Contribution to Gross Domestic Product/Gross Regional Domestic Product	
C3.2 Flows of products and services	I3.2.2 Production of non-marketed goods and services	M3.2.2.1 Special forest products harvested (e.g., lbs of mushrooms)	MO3.2.2.1 number of special forest product permits issued
		M3.2.2.2 Wilderness/backcountry permits (e.g., number of permits issued per year)	
		M3.2.2.3 Special use permits (e.g., number of permits issued per year)	
C3.3 Trade and distributional equity	I3.3.1 Trade balance	M3.3.1.1 Value of imports to exports	MO3.3.1.1 Timber imports to exports (e.g., volume of timber imports/exports)
C3.3 Trade and distributional equity	I3.3.2 Workforce diversity	M3.3.2.1 Distribution of workforce (e.g., gender, ethnicity, age)	
		M3.3.2.3 Assessment of contracts to minority-owned or small businesses (e.g., proportion/value of contracts)	
			MO3.3.2.4 Average commuting time
C3.3 Trade and distributional equity	I3.3.3 Income	M3.3.3.1 Size distribution of income (e.g., percent by tenure type)	
		M3.3.3.2 Technical distribution of income (e.g., by factor type)	MO3.3.3.2 Technical distribution of employment
		M3.3.3.3 National Forest System total program expenditures (e.g., $ annual by program)	MO 3.3.3.3 National Forest System operating budget
			MO 3.3.3.4 National Forest System generated revenues (e.g., receipts)
C3.3 Trade and distributional equity	I3.3.4 Equity	M3.3.4.1 Distribution of rent: timber (percent rent by recipient)	
		M3.3.4.2 Distribution of rent: recreation (percent rent by recipient)	
		M3.3.4.3 Distribution of rent: range (percent rent by recipient)	
		M3.3.4.4 Distribution of rent: stewardship/protection (percent rent by recipient)	
			MO3.3.4.5 Distribution of payments in lieu of taxes

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
			MO3.3.4.6 25% Fund MO3.3.4.7 Other FS distributions (e.g., range betterment fund) MO3.3.4.8 Other non-FS distributions (e.g., coal and gas royalties)
C3.4 Efficiency	I3.4.1 Net Rent	M3.4.1.1 Net rent: timber (income-expenditures) M3.4.1.2 Net rent: recreation (income-expenditures) M3.4.1.3 Net rent: range (income-expenditures) M3.4.1.4 Net rent: stewardship/protection (income-expenditures)	

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