Component of British Columbia's
Land Use Strategy

North Coast LRMP

Background Report

Criteria & Indicators Briefing Paper

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This report was prepared by independent consultants, Dr. Pamela Wright (Coordinator of the Local Unit Criteria and Indicator Development, LUCID, Project for the Inventory and Monitoring Institute, USDA Forest Service) and Dr. Barbara Beasley (Co-chair of the Criteria and Indicator Working Group for the Long Beach Model Forest), as background information on Criteria and Indicators of Sustainable Forest Management for the North Coast LRMP. The information in this report was collected from a wide range of sources and was reviewed by government staff for accuracy and completeness. The final product is presented as the professional judgement of the authors and does not necessarily reflect the view of the Province.

1 Executive Summary

International processes proposed "Criteria and Indicators" in 1994 as a means of advancing the development of international conservation and sustainable management of temperate and boreal forests (Montreal Process, 1994). Criteria help define what is important about our forests and what goals should be achieved through management. Indicators help show whether there is progress toward these goals. This report describes criteria and indicator frameworks used at international to local scales for planning, monitoring and demonstrating sustainable forest management. Challenges in developing and applying indicators are addressed.

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3 Defining Sustainability

The question of sustainability has become a key consideration in most human endeavors. Whether it is in forests or farmland, rivers or oceans, we are increasingly challenged to consider the consequences of our actions. The key to deciding how much we should harvest or how much we should protect lies in being able to assess whether the overall system is sustainable.

There are many definitions of sustainability or sustainable development[i], the most frequently quoted being "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). Sustainability is recognized as an emergent property resulting from the interactions of ecological, social and economic systems. Thus, sustainability can only be addressed if we investigate *systems* and *system interactions* rather than just 'parts of systems' or 'isolated systems'. This counters definitions of sustainability that are based on individual stakeholders' interests in sustaining one system only or one component of a system, e.g., timber flow or old growth forests.[ii]

[i] See also various Centre for International Forestry Research (CIFOR) definitions for adaptations specific to forested environments including: "Sustainable forest management aims to meet the needs of the present without compromising the ability of future generations to meet their own needs. Two conditions indicate sustainability for this definition: (1) Ecosystem integrity is ensured/maintained. (2) Well-being of people is maintained or enhanced" (Colfer, C., R. Prabhu and Wollenberg 1995), or sustainable forestry ~ "a set of objectives, activities, and outcomes consistent with maintaining or improving the forest's ecological integrity and contributing to people's well-being now and in the future" (Prabhu et al. 1996).

[ii] The involvement of a wide range of perspectives, either through an interdisciplinary planning approach or a public involvement program to develop, refine or agree to indicators increases the chance that the collective indicators will address the broadest range of perspectives. In addition, when stakeholders are involved in agreeing initially to the set of parameters (indicators) of interest to sustain, prior to the collection of data or prior to standard/threshold setting, it is much easier to come to collective agreement on the validity of a broad range of parameters.

4 Using Criteria and Indicators to Measure Sustainability

A framework of criteria and indicators is a tool for assessing whether plans, strategies and practices are achieving progress toward sustainability. Criteria define what is important about the systems that we want to sustain in broad terms. In other words, a criterion describes a goal that we want to achieve through management. Examples of criteria include: "maintain or restore viable populations of all native species", "maintain hydrological processes", "maintain or enhance tourism". Indicators are monitored to measure progress toward our goals. An indicator, like a milepost, tells us whether we are on the right road and how much farther we have to go to achieve our objectives. Indicators of the criteria above might include: "habitat availability for species at risk", "stream channel morphology" and "retention of visual landscapes", respectively.

Criteria help define the systems that we are interested in sustaining and, ideally, indicators reflect the breadth of those systems and interactions between different systems. Indicators have been described as "small bits of information that reflect the status of larger systems" " the presentation of a trend" and "presentations of data that show changes and trends over time" (Redefining Progress et al.). Indicators are described as "ways of getting feedback about a system that might otherwise be too big and complex to understand" (Redefining Progress et al.). It is important to realize that our ability to use criteria and indicators to measure sustainability is limited by our understanding of the systems. Indicators are just that – they indicate what condition the system is in but in their entirety they are not the system – they are a representation (indeed indicators) of the system.

Much of the initial interest in criteria and indicators arose from interest in reporting both nationally and internationally on progress towards the sustainability of a nation's forests. Criteria and indicators were endorsed by the 1994 United Nations "Montreal Process" and the subsequent 1995 "Santiago Declaration", along with a number of other organizations and initiatives, to provide a common understanding of what is meant by sustainable forest management and to frame the monitoring process. The Montreal Process Working Group membership currently stands at 12 countries including Canada, Mexico and the United States, covering over 90 percent of the world's temperate and boreal forests (www.mpci.org.). Canada reports on the Montreal Process agreement through monitoring based on the Canadian Council of Forests Ministers (CCFM) set of C&I[iii]. This set of C&I is used to measure Canada's progress in achieving the goals of sustainable forest management (see appendix A).

Criteria and indicators at the national scale contain limited practical guidance for those wanting to make specific changes in the way they manage the forest at the local level. Moreover, since ecological, social and economic conditions vary from place to place, there is no single universal formula (or set of C&I) for sustainable forest management. Hence the importance of developing local level C&I to suit local and regional conditions has been recognized. The international forestry community through the Centre for

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[iii] The CCFM set of C&I are slightly different although generally equivalent to the Montreal Process C&I to reflect the different conditions within the Canadian social, economic and ecological environment.

International Forestry Research (CIFOR) began much of the work in this area through a series of studies in different parts of the globe. In 1998, Canada, Mexico and the United States jointly conducted an initial study of criteria and indicators for monitoring the sustainability of forested systems in southwest Idaho (Woodley et al., 1998). As a result of the CIFOR test in Idaho, the United States Department of Agriculture (USDA) Forest Service through the Inventory and Monitoring Institute, the Local Unit Criteria and Indicator Development project (or LUCID) has been piloting a series of tests across six National Forests to refine criteria and indicators at the forest management unit scale (www.fs.fed.us/institute/lucid). With the assistance of the USDA Forest Service and the US Agency for International Development (USAID), Mexico has also begun a similar project in the northern, temperate forests of Chihuahua (www.fs.fed.us/institute/lucid). A similar initiative, the Local Level Indicators (LLI) initiative has been ongoing in Canada for several years sponsored and hosted by the Canadian Model Forest program (www.modelforest.net.). Each of the eleven Model Forests in Canada has been intensively involved in selecting, measuring and, recently, reporting local level indicators (see appendix B).

4.1 Criteria and Indicators: The Organizing Framework

The concept of sustainability is complex and corresponds to the complexity of the related ecological, social and economic systems from which it is measured. Consequently, it is not uncommon to see a variety of problems with indicators including:

- Collections of interesting and relevant indicators (often interest or issue driven) with little organization or inter-relationship between indicators;
- Indicators that are vague and lack clarity or, conversely, are too measurement specific or threshold specific to address the criteria adequately;
- Indicators that address a variety of spatial and geo-political scales with no means of reconciling scales or do not correspond with the scale of decision-making or management; and
- Indicator sets for different systems (e.g., ecological and social) that are not explicit about assessing inter-relationships.

As an attempt to address these challenges more recent initiatives for monitoring for sustainability have developed criteria and indicator frameworks. Frameworks help to deconstruct the complex goal of sustainable ecosystem management into parameters that can be managed, planned for, and monitored. Ideally, the use of such a framework:

- Increases the chance of complete coverage of all the important aspects of the system to be monitored or assessed;
- Avoids redundancy and limits the set to a minimum without extra parameters;
- Results in a transparent relationship between the parameter that is measured and the system element it is related to; and
- Helps define a conceptual model which links forest conditions to social, economic and environmental indicators of sustainability.

Various C&I initiatives have defined the elements of these frameworks differently. While commonly referred to as criteria and indicators there are typically more than two levels. The Long Beach Model Forest used a framework similar to that developed by the USDA Forest Service Local Unit Criteria and Indicator Development (LUCID) project. Both of these C&I frameworks are refinements and adaptations of the approach developed by the Tropenbos Foundation (Lammerts van Bueren and Blom, 1997) and used in part by the North American C&I test of the Centre for International Forestry Research (CIFOR). The definitions are as follows:

1. Principle: An overarching goal statement that serves as a fundamental guide to achieving a desired state or condition related to one or more forest systems.
2. Criterion: A more specific goal statement that describes a desired outcome of sustainable forest management. Typically, an aspect of the ecological system, or of the interacting social or economic systems, which frames or defines the major system components.
3. Indicator: An attribute or feature that can be measured quantitatively, qualitatively or descriptively and will show directional change over time.
4. Measure: A specific description of the way the indicator is measured, i.e., the unit of measure, method, timeline, etc.
5. Standard/Benchmark: The benchmark or reference value against which the measure is assessed. Benchmarks can be set by legislation, certification standards, desired future conditions, or known values for the natural range of variation.

5 Applications of Criteria and Indicators

Local level indicators can be used in scenario modeling to predict whether proposed landscape plans, strategies and practices will achieve management objectives. Indicators that are monitored after plans are implemented provide an assessment of the effectiveness of those plans. Modeling and monitoring of indicators improves our understanding of forest dynamics resulting from both human-induced and natural factors. Reporting on indicators is a means of demonstrating successful and unsuccessful management strategies and policies to other forest managers and government bodies at local to international scales. Indicators can also be used to demonstrate compliance for certification purposes. Finally, indicators help us define and describe the elements of sustainability that we are interested in, that is, those most affected by our land-use decisions.

5.1 Planning and Monitoring

Planning teams commonly use indicators to evaluate scenarios to decide on the final schedule of interventions to be applied to a forest ecosystem. Indicators used in planning describe the state of the landscape in terms of quantifiable forest conditions that exist now and can be predicted into the future. From data on the initial condition of the forest and knowledge of how natural disturbance and management scenarios create change, models forecast forest conditions over multiple spatial scales and produce “predicted outcome conditions”. The level of the indicator of these conditions is compared to standards or benchmarks to evaluate whether a given management scenario will meet a particular criterion or goal.

"Monitoring is repeated observation, through time, of selected objects and values in the ecosystem to determine the state of the system...Monitoring is an integral part of the sequence of management activities that also includes inventory and planning."

(Clayoquot Sound Scientific Panel, 1995, Report 5)

The role of monitoring within resource management has a variety of purposes principle among them *implementation monitoring* and *effectiveness monitoring*. Implementation monitoring entails monitoring the extent to which a program or set of activities proposed were carried out, i.e., compliance. Effectiveness monitoring is best described as examining whether or not the management program or activities had the desired effect. Effectiveness monitoring is the focus of programs that use criteria and indicators as a tool for sustainable forest management.

Effectiveness monitoring is used to measure indicators of forest condition after ecosystems have responded to management activities and natural disturbance. By comparing the level of indicators to standards or benchmarks, we can assess whether management activities led to forest conditions that yielded our desired forest values or criteria. When we monitor the outcomes of plans that were developed through scenario evaluation, we can test whether the assumptions used in planning were valid. These include assumptions about the links between forest condition and forest values (criteria) as well as assumptions about the effects of management activities and natural disturbance on initial conditions.

5.1.1 Types of Indicators and Their Uses

Indicators have been classified in a number of different ways, however, most commonly in the sustainability arena, indicators are typed as *input*, *output* or *outcome* indicators. *Input* and *output* indicators refer to measures of management effort or stressor input (e.g., kilometers of streams restored; # of public meetings held; litres of oil spilled). *Outcome* indicators refer to the resulting state of the system regardless of cause (e.g., salmon populations; community cohesion; soil quality). Outcome indicators are the best way to measure progress toward sustainability because they most closely reflect forest values, but outcome indicators may be difficult to predict or measure. Thus, input and output indicators are often used in planning and monitoring when: a) there is an inability, given current knowledge, costs or technologies, to model or monitor outcomes; b) the input indicator (e.g, amount of oil spilled) serves as an early warning indicator whereas monitoring the associated outcome may be too late; or c) when the relationship between inputs/outputs (e.g., roads) and outcomes (e.g., wildlife mortality) is well documented, and it is more efficient to model and monitor the input or output.

5.1.2 Planning vs. Monitoring Indicators

Different indicators are used during the *planning* and *monitoring* phases of the adaptive management cycle. *Planning indicators*[iv] describe the state of the landscape in terms of quantifiable forest conditions, for example, connectivity of late seral stands, the

[iv] For further discussion of the distinction between planning and monitoring indicators see Kneeshaw et al.

maximum distance from any microsite to the nearest seed-tree, or the ratio of the area of a watershed that is harvested to the area of the receiving body of water (Yamasaki et al. 2001). Monitoring indicators describe the status of forest values that emerge from forest conditions, for example, the structure and abundance of the avian community, stocking rates of disturbed sites and dissolved organic carbon and turbidity. Planning indicators must be easy to quantify and, for practical purposes, it must be possible to represent them physically in dimensional space. Planning indicators tend to be inputs and outputs that serve as surrogate measures of forest values that we want to sustain. Monitoring indicators may include inputs and outputs, but ideally, they focus on outcomes.

Planning indicators can have longer temporal and spatial horizons than monitoring indicators. They are often spatial summaries (e.g., effective clear cut area, total amount of riparian habitat, growing stock), spatial statistics (e.g., connectivity of late seral stands) or maps (e.g., grizzly bear habitat). They can also be output from scenario analysis as time series (e.g., change in riparian habitat over time) or spatial averaging (e.g., mean grizzly bear habitat value in each hectare over an entire time horizon). Monitoring indicators are measured repeatedly over time and at numerous locations and they tend to be temporally and spatially specific. Even after extrapolation, monitoring indicators tend to have relatively high certainty compared to planning indicators because they are based on measuring actual future forest conditions rather than projected conditions.

In most cases indicators used for planning are a subset of the indicators that are monitored. This provides the opportunity to test the hypothesized relationships used in scenario building with the results observed after plans have been implemented. In many subjects, e.g., biodiversity, knowledge is just being developed. Therefore, during planning, it is necessary to make assumptions about links between forest conditions and related forest values. For example, we might assume that a certain threshold level of connectivity will maintain avian communities typical of naturally disturbed forests. Monitoring connectivity, i.e., forest conditions, as well as avian communities, i.e., forest values, after implementation of a management plan is the best way to test our assumptions.

The McGregor Model Forest has been using a select set of indicators for the basis of scenario planning; these could be described as *planning indicators*. The indicators selected by the McGregor MF are those that can be physically represented (or their known and predicted outcomes can be physically represented) in dimensional space on a landscape model. An examination of these indicators shows that while these indicators are a small subset, there is almost complete overlap with indicators selected as monitoring indicators on the other Model Forests.

5.2 Relationship of Certification to C&I Monitoring

Criteria and indicator monitoring initiatives arose in large part from international agreements (e.g., Santiago Declaration) between governments and conventions on sustainability and forestry. The global movement that drove these government responses to sustainability also drove environmental non-governmental organization and industry responses expressed through green labeling, or certification initiatives. Although the intent between certification and C&I monitoring is the same the tools are different:

auditing vs. monitoring. There are a wide range of certification programs and as each of these evolves, some of the differences between certification programs and C&I monitoring are dissolving, however many certification programs[v] have more of a focus on parameters best described under the *implementation* monitoring umbrella and characterized largely by *input* and *output* indicators.

A growing number of land managers are using both C&I monitoring and certification in a complementary way. Most certification programs assess the status of management programs including inventory and monitoring systems and C&I monitoring programs meet these requirements. In addition, the data from C&I monitoring is used to inform the rest of the certification evaluation.

6 Challenges in Applying Criteria and Indicators

There are a number of challenges in determining and applying appropriate indicators to planning and monitoring. As discussed, there are often uncertain linkages between an indicator and the criterion that it is meant to address. It is difficult to trust simple measures of complex systems without strong evidence of a relationship. There may be difficulties acquiring data to use in modeling and the whole question of how to deal with data management and quality control is expensive and challenging. Planning and monitoring occur at multiple spatial and temporal scales which are difficult to integrate. Benchmarks and standards are often unknown, and there are few quantifiable measures for socio-economic indicators. Currently, there is little commitment to effectiveness monitoring programs and to accepting feedback to decision-making. Each of these challenges is described briefly below.

6.1 Uncertain Linkages between Indicators and Criteria

The challenges for choosing indicators to use in a planning context include: 1) limited knowledge about the relationship between specific parameters (e.g., forest conditions) and other forest parameters or values[vi]; and 2) limited number of parameters that can be represented in dimensional space on landscape models. Planning indicators are chosen primarily on the basis of what knowledge is available from expertise (domain experts) accessible to the planning process. Over the long term, these challenges will be overcome only if effectiveness monitoring follows the implementation of forest management plans and through research.

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[v] This is particularly true of the Canadian Standards Association (CSA) certification program as well as the ISO 14000 series certification initiatives.

[vi] For example the complex inter-dependencies between ecological, social and economic systems and their associated indicators are only briefly reference in the limited applications of *planning* indicators that we have seen. To date, analyzing the relationship between ecological, social and economic sphere is very limited and most modeling efforts are limited to representations of physical landscape structure. In the same way, the relationships between many more complex ecological components (e.g., genetics indicators) and the ability to represent them spatially is weak.

6.2 Data Acquisition and Management

Problems with data acquisition fall into two categories, technical challenges and human challenges. In many cases inventory data are not available, or not at the required spatial scale. Some data are kept for regions with different boundaries than the forest district and there can be inconsistencies or technical incompatibilities in data collected by different contractors or during variable periods of time. These present technical challenges. On the human side, people with data may be busy, worried about misinterpretation or concerned that negative trends will be politically incorrect and therefore, are reluctant to release information. In these cases, it is important to convince the agency that information is only valuable if it is used, draft reports can be reviewed before release to avoid misinterpretation, and indicators are meant to examine the big picture rather than focus on particular issues that may be portrayed negatively.

For monitoring, it is important to obtain explicit agency buy-in to the data-gathering plan at a sufficiently high level to ensure agency commitment. Clear protocols regarding what data (e.g., cultural values data or rare species distributions) can be made available, in what formats and to whom must be resolved. Data specialists recommend that data management proceed in stages to allow for experimentation and to help develop truly collaborative relationships on data access and quality control.

6.3 Issues of Scale

Scale issues of particular concern for C&I programs include: definitions of scale with respect to sustainability; relevance of indicators at a range of scales; reconciling scale differences between indicators; measurement challenges across scales.

In its fullest sense, sustainability can only be understood at a global scale however this scale is not feasible for monitoring or data management. Given that structures and functions, be they ecological, social or economic interact across a wide range of different spatial (and equally temporal) scales in unequal fashion, selecting any subset scale e.g., a nation or a forest, for monitoring or assessment will result in an artificially and incomplete bounded area.

A frequent pitfall facing indicator developers is the selection of indicators that were designed to address a question at a different scale. Contribution of the forest industry to the Gross National Product (see Montreal Process C&I) is an indicator that has relevance at a national level but is irrelevant at a local (e.g., forest) level. Many are tempted, however, to simply step down (or up) indicators developed at one scale to another.

As the scale of interest or the indicator changes so does the measurement approach. Since measurements are scale dependent, generating meaningful results at a number of scales is difficult. Some data can be aggregated, or disaggregated to answer questions at different scales and, at times, specific tools (e.g., GIS based tools) can help resolve questions across scales. Often, however, instead of being able to aggregate indicator data collected at one scale to reach a conclusion at another scale the indicator must be changed. Some propose developing indicators relevant at a local level and simply aggregating them up to a regional or national scale. While some data may be useful at different scales (although the question and indicator answered with that data will likely be different) systems cannot be understood simply by aggregation. Ecological systems for example are not simply the sum of their parts. When a fine focus is used, certain ecological structures and processes can be observed and measured while at other scales, other structures and processes are observed. The same is true for social, economic and the collective 'sustainability' systems.

6.4 Unknown Benchmarks

A benchmark is a reference value or condition against which the value for an indicator is compared. Benchmarks can be absolute or relative thresholds and ranges. Sources for benchmarks include legislation, natural range of variation, certification standards, specific desired future condition and scientifically-based standards. In some cases it is relatively easy to decide on benchmarks, for example, *all* salmon-bearing streams are to be buffered by riparian reserves according to the B.C. Forest Practices Code. In other cases, there is no clear benchmark from legislation, e.g. there is no guideline for the amount of downed wood to be retained in B.C. In these cases, benchmarks may be set by consulting experts who have reviewed the scientific literature or by monitoring unharvested areas to obtain a benchmark value based on the range of natural variation.

6.5 Long-term commitment to accept monitoring feedback to decision-making

Most organizations and agencies in a resource management context have been involved in monitoring, either formally or informally, for a long time. Unfortunately, monitoring has been an afterthought, or at least resourced as an afterthought, in most management scenarios. Valuable monitoring programs are often discontinued before long-term trends have been determined. In other cases, the monitoring focus or measurement approach shifts over time resulting in incompatible information. Monitoring data are often collected in a form that renders them un-useable by management. This disconnect between monitoring and decision-making leads too often to the phenomena of "monitoring for monitoring sake" (Grumbine 1994).

An adaptive management approach acknowledges uncertainty about the outcomes of management policies and deals with this uncertainty by treating management activities as opportunities for learning how to manage better (Taylor et al. 1997). Management activities are modified as a result of new information obtained through monitoring, but more importantly, management activities are deliberately designed to increase understanding about the system being managed. Resource managers must understand and appreciate the benefits offered by monitoring in order to support it.

7 Methods for Developing Indicators

The development or choice of indicators can be challenging. There is a growing body of literature on the process and methods for developing criteria and indicators for monitoring (see for example Lautenschlager, 1988 and CIFOR, 1996). Generally there are two broad approaches: 1) starting with existing sets of indicators (compilation sets) and screening these lists (screening approaches) or 2) starting with issues of concern or stresses and developing indicators for each of these stresses (clean-slate approaches). Where the management focus is concerned with specific stresses, a clean-slate approach, often focused on stressors or current issues is typically the most appropriate — where the management focus is broad-based ecosystem management, a screening approach may be more likely to cover a wider range of ecosystem elements/functions. Indicators are not generic, however, and while valuable sources for developing indicators exist, they must be adapted and tested in the local context.

For both the Long Beach Model Forest (LBMF) and the USDA Forest Service LUCID projects a combination of screening and clean-slate approaches was selected. The first task was to develop a model, or framework of the systems (ecological, social and economic) we were trying to monitor (see appendix C). For LBMF, the framework for the ecological systems was provided by the Clayoquot Sound Scientific Panel. The social systems framework expanded upon the initial C&I project and was supplemented with a community visioning project and a First Nations project resulting in more of a 'clean-slate approach' for this component. The economic systems framework was adapted largely from the USDA Forest Service LUCID project. After constructing a systems framework, we assembled a macro-list of criteria and indicators and then used successive filters (both public and technical) to screen indicators. Throughout this process, however, issues and stressors were reviewed to help determine our priorities. The LUCID project similarly started with a systems framework and then assembled a macro-list of possible C&I. Successive public and technical filters were used to select the best set of indicators.

A number of criteria are typically used to evaluate indicator quality and appropriateness. These include assessing whether an indicator is:

- sensitive or responsive to management actions; will it show trends over time as conditions change?
- meaningful in terms of the criterion that it is measuring;
- affordable to monitor or one that has existing data that are available for use in planning;
- reliable to interpret; does the indicator measure something that is relatively unresponsive to external factors compared to the effect of a management action, i.e., have a high signal-to-noise ratio?
- trackable, predictable and measurable with accuracy at an appropriate temporal and spatial scale.

8 Lessons Learned About Selecting and Applying Local Level Indicators from LBMF and the USDA Forest Service

- Starting with very clear and specific purposes of why you are developing indicators is important. If the intent of monitoring is to examine the state of sustainability of a given region or area the focus of the indicators is substantially different than if you are monitoring to assess the status of a set of known stressors.

- Scale is key. Too often the approach to indicator development is simply to borrow indicators that appear useful and well-tested. The reality is when you change the scale you need to change the indicator: at least how you define it, measure it, and what it means at that scale.

- Indicators that are outcome indicators are best to describe the state of the system while input indicators may provide early warning signal and are useful in assessing whether you are doing what you said you were doing (e.g., implementation indicators).

- Indicators are not generic and while valuable sources for developing indicators and many lists of indicators exist, they must be adapted and tested in a local context. Until data is collected on indicators and standards/benchmarks are constructed, indicators are just tentative.

- The devil is in the details. The further you go into the process of measuring indicators the more likely the indicator is to change. As measurement methods and data are investigated, not only does what you can measure become much clearer, often so does what you should measure.

- Development of standards/benchmarks/norms is messy, difficult, value-laden, challenging and necessary. Without going through the process of discussing standards what you should be measuring is never particularly clear. Finding an approach that allows you to test or benchmark multiple standards is key to a consistency with recognizing that there is not one common definition of sustainability and given the great deal of complexity and uncertainty that surrounds the sustainability question.

- Attempting to integrate across social, economic, and ecological systems is critical to understanding sustainability. Indicators of interactions, however, are very difficult to construct. While modeling efforts (such as through the use of NetWeaver or GeoNetWeaver) help to some degree a great deal of work on integration, both theoretical and practical is needed.

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Appendix A: Canadian Council of Forest Ministers (CCFM) Criteria and Indicators

Background

Conservation and sustainable management of forests is a clear priority and central policy focus of Canada's provincial, territorial and federal governments. This priority is based on at least three considerations. First, Canadian commitment to sustainable forest management is well enshrined in the Canadian National Forest Strategy endorsed in March 1992 by the federal, provincial and territorial governments as well as others concerned with the multiple uses and diverse values of Canada's forests. Second, as stewards of about 10 percent of the world's forests, Canadians are committed to maintaining their forests in a healthy state both for the socio-economic and environmental well-being of Canadians and as a contribution to maintaining global environmental quality. Third, Canada is obliged to implement the Forest Principles and other commitments related to sustainable management of forests made at the UN Conference on Environment and Development, held in Rio de Janeiro, Brazil, in June 1992.

Since the adoption of the National Forest Strategy in March 1992, and the Earth Summit in June 1992, Canada has been active, domestically as well as internationally, in a number of initiatives concerned with the elaboration of the notion of sustainable forest management. While there are many divergent views on this topic, the Canadian approach to sustainable forest management is based on the following four principles:

1) Forests simultaneously provide a wide range of services and benefits to Canadians, and sustainable management of forests involves managing forests as ecosystems.

2) Sustainable forest management involves an integration of (i) environmental benefits and values, (ii) socio-economic and cultural benefits to meet human needs, and (iii) institutional arrangements to formulate and implement appropriate policies and programs and to monitor their effectiveness. These three elements are dynamic and change over time.

3) The responsibility for the sustainable management of Canada's forests lies with the Canadian forest community as well as with other components of Canadian society. Meeting this responsibility involves minimizing impairment to forest ecosystems, and avoiding irreversible damage due to forest-based human interventions (e.g., harvesting, reforestation) and stresses associated with other production and consumption activities outside forests (e.g., airborne pollutants, increase in the concentration of greenhouse gases).

4) Criteria and indicators that characterize sustainable forest management should be based on the best available scientific knowledge and should meet international acceptance.

Within the general context described above, the Canadian Council of Forest Ministers (CCFM) agreed in the autumn of 1992 to implement the forest-related commitments made at Rio largely through the National Forest Strategy, and to initiate a process to formulate the criteria and indicators of sustainable forest management.

The process involved the establishment of a steering committee composed of 30 members representing a wide range of special interest groups such as the federal, provincial and territorial governments, industry, non-governmental organizations, Aboriginal groups, small woodlot owner associations and the academic community. A science panel and a technical committee were created to carry out specific tasks, to conduct consultations and research, and to draft a set of criteria and indicators for the consideration of the steering committee. These groups included scientists; representatives from all provinces and territories; and specialists in socio-economic statistical data, forest monitoring, and national forest data and statistics.

The criteria and indicators for sustainable forest management are intended to:

- characterize sustainable forest management and to provide a quantitative and qualitative basis to assess progress;
- provide the basis for domestic policies on the conservation, management and sustainable development of forests;
- contribute to the clarification of issues related to environment and trade, including product certification; and
- develop concepts and terms that would facilitate the on-going domestic and international dialogue on sustainable forest management.

The six criteria identified include:

1. biodiversity;
2. forest condition and ecosystem productivity;
3. soil and water conservation;
4. global ecological cycles;
5. multiple benefits to society; and
6. accepting society's responsibility to sustainable development.

The approach to forest management reflected in the criteria and indicators is the management of forests as ecosystems. Taken together, the set of criteria and indicators suggests an implicit definition of the conservation and sustainable management of forest ecosystems at the country level. It is recognized that no single criterion or indicator is alone an indication of sustainability. Rather, individual criteria and indicators must be considered in the context of other criteria and indicators.

These criteria, with their associated indicators and the National Forest Strategy document to which they correspond, contain a recognition and commitment that it is these elements of the forest ecosystem, as well as our social and economic system, that must be sustained and enhanced. It is important to note that the National Forest Strategy includes a commitment not only to conservation of the environment, but also to economic development, Aboriginal peoples, communities, workers, recreation, science, and the creation of wealth from our natural resources. In this framework on criteria and indicators, no attempt is made to set standards for desired or objective levels at this time. Canada may in future, however, wish to define these objectives and harmonize public forest policy within the framework proposed.

This set of criteria and indicators represents a cohesive and comprehensive framework, based on the best available knowledge. A considerable proportion of the data required for national reporting on criteria and indicators of sustainable forest management can be provided through current federal and provincial information systems, including the National Forestry Database Program, Statistics Canada, and other sources. Collection of other data would require allocation of additional effort and resources. Furthermore, while some of the indicators have been included in order to formulate a comprehensive framework, it is recognized that data on these may be unavailable at present. In some cases also, the scientific basis may need still further elaboration.

While it will be possible to aggregate some indicators at the national level, other indicators may be of value only at the provincial and territorial or at the local levels. Presentation of indicators as trends over time would allow for an evaluation of change in the variables being monitored.

Collectively, these criteria and indicators may be considered to provide a framework to describe the state of forests and forest management, and to periodically demonstrate achievement in implementing sustainable forest management. The elements in that picture include both conservation and stewardship of the forest and the organization of forest management policies to ensure that the forest provides long-term opportunities for wealth and social benefits to Canadians. The framework must be considered a "living document". As our knowledge of forest ecosystems and factors promoting social and economic dimensions and enhancement improves, the criteria and indicators will evolve further. Our collective efforts to monitor and report on trends and changes in indicators will identify where changes that are occurring may influence our ability to sustain the key values Canadians hold for their forests.

CCFM C&I

Criterion 1.0 Conservation of biological diversity

- **Element 1.1** Ecosystem diversity
- **Element 1.2** Species diversity
- **Element 1.3** Genetic diversity

Criterion 2.0 Maintenance and enhancement of forest ecosystem condition and productivity

- **Element 2.1** Incidence of disturbance and stress
- **Element 2.2** Ecosystem resilience
- **Element 2.3** Extant biomass

Criterion 3.0 Conservation of soil and water resources

- **Element 3.1** Physical environmental factors
- **Element 3.2** Policy and protection forest factors

Criterion 4.0 Forest ecosystem contributions to global ecological cycles

- **Element 4.1** Contributions to the global carbon budget
- **Element 4.2** Forest land conversion
- **Element 4.3** Forest sector carbon dioxide conservation

Element 4.4 Forest sector policy factors

Element 4.5 Contributions to hydrological cycles

Criterion 5.0 Multiple benefits of forests to society

Element 5.1 Productive capacity

Element 5.2 Competitiveness of resource industries

Element 5.3 Contribution to the national economy (61K/Pages 92-97)

Element 5.4 Non-timber values

Criterion 6.0 Accepting society's responsibility for sustainable development

Element 6.1 Aboriginal and treaty rights

Element 6.2 Participation by Aboriginal communities in sustainable forest management

Element 6.3 Sustainability of forest communities

Element 6.4 Fair and effective decision making

Element 6.5 Informed decision making

Appendix B: Criteria and Indicators for the Long Beach Model Forest[vii]

Definitions

The LBMF C&I framework consists of a hierarchy of 4 levels:

Principle: An overarching goal statement that serves as a fundamental guide to achieving a desired state or condition related to one or more forest values.
Criterion: A more specific goal statement that describes a desired outcome of sustainable forest management.

Indicator: An attribute or feature that can be measured quantitatively, qualitatively or descriptively and will show directional change over time.

Measure (M): A specific description of the way the indicator is measured, i.e., the unit of measure, method, timeline, etc.

Standards/benchmarks for each measure have not been listed except a possible standard is given for A1.2.1 as an example.

Economic Framework (example)

The underlying principles for sustainability from an economic perspectives are assumed to be:

1. Maintain a sufficient capital base consisting of natural, built, human and social/institutional resources, such that the system, e.g., the Forest, will allow the sustained use of non-declining levels of goods and services over the range of expected physical, economic and social conditions into the foreseeable future, i.e., it has resiliency in the face of external shocks. This is consistent with the ideal of living off the interest and not the capital while producing a variety of goods and services. (Inter-generational Equity).

2. Distribute the goods and services in ways that “equitable” access and benefit are achieved for all groups within society. (Intra-generational Equity)

Achieving a sustainable forest use pattern is inherently about providing future generations with an adequate capital base to enjoy at least the same level of goods and services that current users' enjoy. The determination of the capital base to pass on to future generations is a normative social decision about intergenerational welfare.
The second important component of sustainability from an economic perspective is the equitable distribution of costs and benefits intra-generational equity. Costs and benefits are distributed through employment mechanisms, through investment in community members and by community members, and through other distributional mechanisms such as taxes.

[vii] *The original list of C&I in Pam Wright's report was produced after a technical review of the C&I discussed at the 1998 LBMF Workshop. There were significant gaps in C&I of social and economic values (originally framed under Principle C. Human Activities and Values). Pam Wright and Barb Beasley extracted C&I related to social and economic values from two community workshops held during 1999: the Central Region Board's "Sustainable Forestry in Clayoquot Sound Forum" and the Ucluelet and Area Community Vision Society's Symposium, "Building a Shared Vision". We modified the original list to include C&I from these workshops under a revised Principle C, Maintenance of Economic Well-Being and a revised Principle D, Social Values. Underlying principles for sustainability from economic perspectives formed the basis for structuring these C&I (see below). We acknowledge the U.S. Forest Service's LUCID projects for providing an economic C&I template from which we worked.*

PRINCIPLE A. MAINTENANCE OF WATERSHED AND COASTAL INTEGRITY

CRITERION A1. Maintain water quality and water flow on seasonal and event basis.
- INDICATOR A1.1 Seasonal and event stream flow, precipitation and suspended sediments
  - MEASURE A1.1.1 Maximum flow in harvested vs. control streams
  - MEASURE A1.1.2 Monthly precipitation at coastal vs. inland sites
- INDICATOR A1.2 Dissolved oxygen and water nutrients
  - MEASURE A1.2.1 Levels of dissolved oxygen and water nutrients in harvested vs. control streams *Standard: harvested streams do not vary from control streams (X year average)*
- INDICATOR A1.3 Marine to terrestrial nutrient (nitrogen) transfer and vice versa
  - MEASURE A1.3.1 Rates of marine to terrestrial nutrient transfer
  - MEASURE A1.3.2 Measurement of nutrient loading by drainage
  - MEASURE A1.3.3 Population sizes and reproductive success of salmon species by drainage
- INDICATOR A1.4 Ground water
  - MEASURE A1.4.1 Hillslope ground water levels (need unit and time period)

CRITERION A2. Maintain soil condition and productivity
- INDICATOR A2.1 Hillslope failures
  - MEASURE A2.1.1 Number of hillslope failures by source
  - MEASURE A2.1.2 Volume of displaced material
  - MEASURE A2.1.3 Number of failures reaching main stem
- INDICATOR A2.2 Forest land conversion to non-forest land cover, classed by major forest type
  - MEASURE A2.2.1 Rate of change of conversion within forest type
  - MEASURE A2.2.2 Hectares of forest cover change by forest type
  - MEASURE A2.2.3 Hectares of conversion to permanent and semi-permanent non-vegetated conditions
- INDICATOR A2.3 Soil compaction, mineral soil exposure, and/or loss of organic material
  - MEASURE A2.3.1 Percentage of area with soil compaction, mineral soil exposure and/or loss of organic material
  - MEASURE A2.3.2 Area of land by yarding technique
  - MEASURE A2.3.3 Area of roadedness
  - MEASURE A2.3.2 Number of sites with significant soil impacts
- INDICATOR A2.4 Productivity
  - MEASURE A2.4.1 Foliar nutrient analysis
  - MEASURE A2.4.2 Rates of decomposition in harvested vs. control sites

CRITERION A3. Maintain stream channel morphology and function
- INDICATOR A3.1 Morphology and function of stream channels
  - MEASURE A3.1.1 Stream audit comparisons of harvested to control streams for morphology (e.g., channel width, bed material size, substrate size, organic debris)
  - MEASURE A3.1.2 Number and length of streams by streams persistence class in harvested vs. control areas

CRITERION A4. Nearshore marine environments are maintained

INDICATOR A4.1 Nearshore marine vegetation
MEASURE A4.1.1 Percent cover of kelp and eel grass
MEASURE A4.1.2 Growth rates/vigor of kelp and eel grass
INDICATOR A4.2 Structure and diversity of intertidal communities
MEASURE A4.2.1 Species distribution and abundance of intertidal species
INDICATOR A4.3 Beach stability and patterns of sedimentation
MEASURE A4.3.1 Aerial mapping of developed and undeveloped watersheds
INDICATOR A4.4 Subtidal exploited species
MEASURE A4.4.1 Distribution and abundance of subtidal exploited species (e.g., clams, urchins)
MEASURE A4.4.2 Harvest levels of subtidal exploited species

PRINCIPLE B. MAINTENANCE OF BIOLOGICAL DIVERSITY

CRITERION B1. Maintain known ecosystem diversity
INDICATOR B1.1 Forest types
MEASURE B1.1.1 Percentage and distribution of forest types by site series
MEASURE B1.1.2 Percentage and distribution of stand types by seral stage
MEASURE B1.1.3 Percentage and distribution of forest types by disturbance type class
INDICATOR B1.2 Roadedness (roads/trails by type)
MEASURE B1.2.1 Area of roads/trails by type
MEASURE B1.2.2 Density of roads/trails by type
MEASURE B1.2.3 Use levels by type
MEASURE B1.2.4 Kilometers of roads by landscape position (e.g., high slopes, riparian)
MEASURE B1.2.5 Number of stream crossings by road type
INDICATOR B1.3 Fragmentation and connectedness of forest ecosystem components
MEASURE B1.3.1 Area and distribution of interior habitat conditions (patch size)
MEASURE B1.3.2 Indices of patch proximity

CRITERION B2. Maintain known genetic and species diversity
INDICATOR B2.1 Coarse woody debris and snags
MEASURE B2.1.1 Volume of CWD by decay, species and size classes
MEASURE B2.1.2 Number of snags by wildlife trees, species and size classes
INDICATOR B2.2 Naturally occurring species
MEASURE B2.2.1 Species presence by sub-region
MEASURE B2.2.2 Relative abundance of functional taxonomic groups
INDICATOR B2.3 Species at risk
MEASURE B2.2.1 Habitat availability for selected species at risk (specify species)
MEASURE B2.2.2 Population size of selected species at risk (specify species)
MEASURE B2.2.3 Reproductive size of selected species at risk (specify species)
INDICATOR B2.4 Genetic diversity of species undergoing selective pressures
MEASURE B2.4.1 Harvest age and method match species silvics/life history
MEASURE B2.4.2 Availability of reserves for species undergoing selective pressure
INDICATOR B2.5 Effects of exotic species
MEASURE B2.5.1 Impacts (area, number of locations and rates of spreads) of exotics on special habitats (e.g, riparian)
MEASURE B2.5.2 Availability and compliance with seed source rules

MEASURE B2.5.3 Hectares of out-sourced genetic material

CRITERION B3. Changes in forest condition are not detrimental to indigenous species

INDICATOR B3.1 Species dependent on interior forest conditions

MEASURE B3.1.1 Presence of interior forest condition species (e.g., brown creepers, varied thrush, ephiphytic lichens)

MEASURE B3.1.2 Relative abundance of functional taxonomic groups

MEASURE B3.1.3 Area and distribution of interior habitat conditions

INDICATOR B3.2 Vertical habitat complexity (canopy etc.)

MEASURE B3.2.1 Percent canopy cover by canopy layer

PRINCIPLE C: MAINTENANCE OF ECONOMIC WELL-BEING

CRITERION C1. Maintain natural and human-built capital

INDICATOR C1.1 Land

MEASURE C1.1.1 Hectares in timber production emphasis

MEASURE C1.1.2 Percent of acres by timber suitability class

MEASURE C1.1.3 Hectares in protected areas, different types of visual landscapes are retained across the Sound, (other recreational breakouts of interest??)

MEASURE C1.1.4 Hectares in other special uses, e.g., salmon habitat

INDICATOR C1.2 Timber

MEASURE C1.2.1 Cubic metres of harvestable timber

INDICATOR C1.3 Other Harvested Goods and Services

MEASURE C1.3.1Mushroom stocks (pounds) / BOTANICALS

MEASURE C1.3.2 fish stocks (by major sub-basin)

MEASURE C1.3.3 Wildlife (HUNTED)

INDICATOR C1.4 Value Added Capacity

MEASURE C1.4.1 Workshops and training to support value-added (e.g., # of training days)

MEASURE C1.4.2 Land available for value-added

MEASURE C1.4.3 Funding for value-added start-ups

MEASURE C1.4.4 Diversity of funding opportunities

MEASURE C1.4.5 Access to forest resources (links to small business opportunities)

MEASURE 1.4.6 Availability and affordability of light industrial sites

CRITERION C2. Maintain production

INDICATOR C2.1 Timber and non-timber forest products

MEASURE C2.1.1 Harvest of timber (by type/quality)

MEASURE C2.1.2 Harvest of mushrooms (kg)

MEASURE C2.1.3 Harvest of other forest-derived products

MEASURE C2.1.4 Harvest of cedar for shake/shingle/value-added

INDICATOR C2.2 Fish products

INDICATOR C2.3 Recreation (e.g., hiking/climbing, fishing)

MEASURE C2.3.1 Number of visitor days for hiking/climbing

MEASURE C2.3.2 Number of visitor days for fishing

MEASURE C2.3.3 Number of visitor days for wildlife viewing

MEASURE C2.3.4 Developed recreation
MEASURE C2.3.5 Number of camping permit sales
INDICATOR C2.4 Changes in Efficiencies associated with Modified Forest Practices
MEASURE C2.4.1 Change in Costs (including road building)
MEASURE C2.4.2 Change in People/labour needs
MEASURE C2.4.3 Change in time required for harvest
MEASURE C2.4.4 Change in safety problems

CRITERION C3. Ensure equitable distribution
INDICATOR C3.1 Employment of local population in forest-related activities (by sector e.g., recreation vs. timber)
MEASURE C3.1.1 Number of Job types (seasonal, non) (full-time vs. part-time)
MEASURE C3.1.2 Unemployment levels (including long-term unemployment categories)
MEASURE C3.1.3 Local vs. imported labour
MEASURE C3.1.4 Number of youth returning to community after schooling
MEASURE C3.1.5 Employment diversity index
MEASURE 3.1.6 Origin of trainers (e.g., local/non-local)
INDICATOR C3.2 Wages and other benefits (by sector, e.g., recreation vs. timber) (benchmark - local conform to national standards)
INDICATOR C3.3 Demographics of workforce
MEASURE C3.3.1 Age class
MEASURE C3.3.2 Race
MEASURE C3.3.3 Gender
INDICATOR C3.4 Local revenue sharing
MEASURE C3.4.1 Payments in lieu of taxes
MEASURE C3.4.2 Other distributional mechanisms (FRBC)
INDICATOR C3.5 Local production
MEASURE C3.5.1 Small business forestry program
MEASURE C3.5.2 Ratio of local manufacturing to exported raw product
INDICATOR C3.6 Ownership Pattern
MEASURE C3.6.1 Hectares of forest land by type of owner including public, small business enterprise, private, community forest, joint management (e.g., Iisaak)

CRITERION C4. Investment in human capital is maintained or enhanced
INDICATOR C4.1 Job Training/Retraining opportunities
MEASURE C4.1.1 # of days by type
MEASURE C4.1.2 Youth training opportunities/apprenticeship
MEASURE C4.1.3 Affordability of training opportunities (presence of subsidies, bursaries, loans)
INDICATOR C4.2 Educational recreation opportunities
INDICATOR C4.3 Community environmental education opportunities
MEASURE C4.3.1 local visits to museums/RIC
MEASURE C4.3.2 attendance at talks, slideshows, workshops

PRINCIPLE D: SOCIAL VALUES

CRITERION D1. Maintain tourism, recreation and scenery
INDICATOR D1.1 Retention of visual landscapes

MEASURE D1.1.1 # of complaints associated with visual quality

INDICATOR D1.2 Recreation and tourism opportunities

CRITERION D2. Maintain Sense of Place (Connectedness to Environment)

INDICATOR D2.1 Local knowledge

MEASURE D2.1.1 Level of understanding of local environment

MEASURE D2.1.2 Use of local place names/resource names

MEASURE D2.1.3 Use of TEK (see Ha-hulthi study measures)

MEASURE D2.1.4 Sense of attachment to local special places (e.g., Kennedy Beach)

INDICATOR D2.2 Gathering and subsistence

MEASURE D2.2.1 Amount/quantity of food and non-food goods for personal/family use

MEASURE D2.2.2 Amount of time (number of trips) spent in local area

CRITERION D3. Maintain or enhance diversity of interests and inclusion

INDICATOR D3.1 Access to information about diverse interests

MEASURE D3.1.1 # people subscribing/reading Ha''-Shilth-Sa

MEASURE D3.1.2 # youth attending forum where speakers present treaty

INDICATOR D3.2 Diverse community social opportunities

MEASURE D3.2.1 # of joint social events bringing communities together

INDICATOR D3.3 Recognition of diverse interests

MEASURE D3.3.1 # joint ventures

MEASURE D3.3.2 # representatives at treaty meetings

INDICATOR D3.4 Cooperation

MEASURE D2.2.1 level of personal involvement (diversity) in community work groups

INDICATOR D3.5 Stewardship

MEASURE S 3.5.1 Number of volunteer hours by task (e.g., monitoring, restoration etc.)

MEASURE 3.5.2 Kms of stream restored (and equivalent)

PRINCIPLE E. INSTITUTIONAL FRAMEWORKS ARE CONDUCIVE TO SUSTAINABLE ECOSYSTEM MANAGEMENT

CRITERION E1. Concerned stakeholders have a right to participate in open and meaningful public participation processes in order to influence management.

INDICATOR E1.1 The process is inclusive with all interests, including youth, represented

MEASURE E1.1.1 Proportion of range of interests represented in age participation process

MEASURE E1.1.2 Number and type (ladder of citizen participation) of participation processes

MEASURE E1.1.3 Stakeholder evaluation of inclusivity of process

INDICATOR E1.2 Stakeholders have detailed and meaningful reciprocal background information necessary to provide quality input into the public participation processes

MEASURE E1.2.1 Amount of time/effort for background information exchange

- MEASURE E1.2.2 Availability of raw data as part of background report (# of original reports – non-summarized – available for participants)
- MEASURE E1.2.3 Stakeholder evaluation of adequacy and timeliness of background information

INDICATOR E1.3 Management staff and stakeholders recognize and respect the interests and rights of each other

- MEASURE E1.3.1 Stakeholder and management evaluation of mutual respect

INDICATOR E1.4 The decision-making processes must be transparent such that participants are confident that their opinions and values will be considered during the process and reflected in the final product

- MEASURE E1.4.1 Stakeholder evaluation of transparency of decision-making
- MEASURE E1.4.2 Presence and satisfactions with records of decision for explaining decisions

CRITERION E2. Continuous management planning is in place

INDICATOR E2.1 Effective instruments for inter-institutional co-ordination on ecosystem management exist

- MEASURE E2.1.1 Number and range of MOU's, joint management agreements etc., by type
- MEASURE E2.1.2 Number of personnel hours made available to other institutions for ecosystem management
- MEASURE E2.1.3 Number of joint projects
- MEASURE E2.1.4 Number of interagency meetings

INDICATOR E2.2 There is sustained and adequate funding and staff for ecosystem management

- MEASURE E2.2.1 Dollars and FTE's devoted to ecosystem management
- MEASURE E2.2.2 Ratio of dedicated to special project/temporary funds for ecosystem management

INDICATOR E2.3 Planning and management are based on recent and accurate information

- MEASURE E2.3.1 Number of adaptive management programs
- MEASURE E2.3.2 Support (number of participants, funding for) from governments, First Nations, industry, partners, public of adaptive management programs
- MEASURE E2.3.3 Timeliness and completeness of inventories
- MEASURE E2.3.4 Number of harvest units/area with monitoring protocols being applied

Appendix C: USDA Forest Service Local Unit Criteria and Indicator Development (LUCID) Project

Brief Description of LUCID Methods for Selecting Indicators

The LUCID project was a collaborative sustainability monitoring development program between the Inventory and Monitoring Institute (IMI) and six pilot national forests from the 19 million acre Tongass National Forest in Alaska to the half million acre Allegheny National Forest in Pennsylvania. Monitoring for sustainability at the forest level has recently become a requirement under Forest Service legislation (Planning Rule §219.1(a)(2)) and the LUCID project is charged with developing possible methods and an approach to sustainability monitoring and assessment at the forest level. An interdisciplinary core team of IMI researchers developed the methodology, guided the pilot teams through implementation and will do the analysis and report writing at the projects conclusion. Operationally, the work with the pilot teams occurred in the form of 5 primary meeting/workshops with the core team with work time in between. These meetings/major tasks are described below.

Meeting 1. Briefing

- Overview with management team
- Initial project briefing
- Discussion of team composition

Meeting 2. Orientation and Indicator Development

- Workshop on monitoring, C&I and LUCID approach
- Systems frameworks discussion
- Initial review of principles, criteria and indicators

Meeting 3. Review and Verifier Discussion

- Review of indicators
- Development of verifiers
- Standards discussion

Meeting 4. Conceptual and Analytical Model Development

- Develop standards
- Complete analytical model
- Collect data and prepare GIS overlays and databases

Meeting 5. Sustainability Assessment

- Correct or finalize database and overlays
- Complete analysis
- Report writing

The LUCID project's use of systems frameworks in the development of C&I for sustainability monitoring is a bit different than most other C&I initiatives. The LUCID project's C&I development approach is based on the concept that sustainability is an emergent property of systems, and that sustainability is most relevant where social, ecological and economic systems interact. Taken a step further, the LUCID project's C&I development is framed within a "systems-approach" an approach that can be defined generally by the theory that *an item of knowledge or behavior can be studied only within the context of how it fits into other larger and smaller systems*. By definition then, C&I's developed in the LUCID project represent elements of the system we are studying (*i.e.* the ecological, social and economic systems) and these elements are understood by examining the way in which they interact with other elements of the system.

In the development of C&I, the LUCID project made an effort to consider the elements of different levels in a recursive hierarchy of a system (ecological or socio-economic). In this way the systems approach will lead to the following:

- a more complete selection of items or elements to monitor (as opposed to the selection of C&I based on a limited knowledge base or on biases using a 'threat-specific' or 'issue specific' approach); and
- a preliminary model of the context part of the system (*i.e.* how the elements fit together and what the relationships between them are).

The development of a framework to the assess sustainability of these three systems adopted a two-stage approach. In the first step separate economic, social and ecological systems models were developed to act as representations of the real world and in a second step specific attempts were made to portray the interrelationship of elements among the systems.

Most efforts at assessing sustainability have stopped at the identification of which C&I should be measured and have not attempted to actually measure and evaluate those C&I as an integrated suite. A main premise of the LUCID pilot tests was to not only develop and measure a C&I set at the local level, but to go the next step into evaluating the C&I set to gain insight into sustainability. This was to be accomplished by gathering the necessary data to measure the C&I set, to evaluate this data against known or developed standards, benchmarks or reference conditions, and then to analyze in an integrative way the results to gain insights into the sustainability of the pilot forests and into the key management issues that face those forests.

To accomplish this integration, a modeling technique was adopted for both conceptual and analytical modeling purposes. NetWeaver[viii] is an expert-system, object-oriented model and during the tests models were built using the combined knowledge of the pilot teams, the IMI core teams, and various stakeholders involved in the process. The object-oriented feature allowed the pilots to not only share data between domains but attach different standards but the teams used the object-oriented nature to regroup various aspects of the model to explore specific management issues. NetWeaver is built around the mathematical concept of fuzzy logic, which

[viii] Developed by Mike Saunders and Bruce Miller at Pennsylvania State University.

allows degrees of attainment (or non-attainment) of a data standard as opposed to a typical bivalent standard that either is, or is not, attained.

The pilots began the modeling stage by first building a conceptual NetWeaver model of their C&I set. A conceptual model is a non-data based diagram of schematic of components. The conceptual model was described by building networks (dependency networks) and data links representing the various Principals, Criteria, Indicators, Verifiers, and Data Elements of the social, ecological, and economic frameworks. The pilots then converted the conceptual model to an analytical model by adding standard, benchmark, and reference condition information to each data link. A spatially oriented component, GeoNetWeaver[ix], was developed for the LUCID project to enable uploading of spatial data, resolution of monitoring data across scales and display of attainment of standards in tabular, network and spatial representations.

[ix] Developed by Mike Saunders and Bruce Miller at Pennsylvania State University.