Discussion Paper

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Trade-off analysis for decision making in natural resources: Where we are and where we are headed

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Abstract

Forest management involves making trade-offs to balance social, ecological, and economic objectives of the forest. In the past this decision making was primarily done by trained professionals. Forest certification requires a greater involvement by the public, and has created a need for formal methods to make trade-offs in a transparent and balanced manner. This paper explores the nature of trade-offs in the historical context of forest management in British Columbia. It describes the development of forest management in the context of ecosystem and intergenerational trade-offs that have been made which are often in conflict with the public's value system. The difficulties in using public preferences to make decisions are discussed, and the available methods used for conducting trade-off analysis in forest management are critically reviewed. The author recommends a set of guidelines for public participation that are learning-based and designed to build public confidence in the decision-making process. A continuous improvement approach for implementing management decisions is also recommended. Research needs to provide supporting tools for sustainable forest management planning are described.

KEYWORDS: *multi-objective decision making, public participation, sustainable forest management, trade-off analysis.*

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Introduction

The productive forest land in British Columbia is overwhelmingly publicly owned and is a capital asset that provides a vital flow of goods and services to its public owners. Some of these goods and services are easy to value because they have a market; others have traditionally been free goods and are exceedingly difficult to value. Nonetheless, we know that these free goods have a value and must be represented in our land use plans.

Managers of public land have long been entrusted to ensure that society benefits from management practices and that these benefits are sustainable. The concept of a "trade-off" in forest land use planning is based on the input and output characteristics that define the forest. Some forest goods and services can be produced to the detriment of others. For example, timber extraction can affect visual quality, water quality, and recreation. Recreation can also affect water quality. Certain types of recreation (e.g., downhill skiing) conflict with other types of recreation (e.g., wilderness solitude). Other goods and services are complementary. Timber extraction encourages certain browsing wildlife species and is in harmony with many types of recreation that require road access.

Trade-offs are a normal part of any decision making process. Those involving public policy are especially difficult. Charles Lindblom in *The Science of Muddling Through,* describes how public decision makers actually make decisions by evaluating a limited number of alternatives, implementing the best one, and then constantly "tweaking" policies to respond to new information and changes in goals or values (Lindblom 1959).

There are a number of reasons why decisions about forest planning go through successive limited comparisons. First, the capability to accurately determine society's preferences (despite constant and ongoing public opinion and willingness-to-pay surveys) is limited or simply does not exist. For starters, it isn't known who comprises the public (or stakeholders)—citizens, local residents, tourists? Second, if the stakeholders are a number of diverse groups or people, how are the preferences of each group weighted when they all disagree? Third, even if decision makers could accurately determine a set of preferences to guide them, they have neither the time nor forecasting ability to wade through all of the possible alternatives and find the best one. Finally, even if they could do that, by the time they implemented the policy, society's preferences may have changed. Nonetheless, professional forest management on public lands is—or should be—the act of balancing such trade-offs to meet society's objectives.

In previous decades, decisions were made based on a limited set of values: timber, water, forage, recreation, and wildlife habitat. Over time society's values have become more diverse (i.e., the importance of maintaining biodiversity). Simultaneously, the understanding of the complexities of maintaining the functionality of the ecosystem has increased (i.e., in promoting resilience and dealing with climate change). There are a number of tools aimed at assisting decision makers to evaluate trade-offs. The choice for the appropriate tool should be based on the magnitude of the impact, the time frame, the budget, and the degree to which the public should be involved.

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The first section of this paper explores the major trade-off decisions that professional foresters are asked to make for British Columbia, where nearly all of the available commercially harvestable timber is still part of the original forest. It then reviews socio-economic theories about determining society's preferences and discusses the longstanding difficulties in realizing optimal social welfare. The next section reviews methods that have been used for trade-off analysis in natural resources, and guides the reader to further reading and resources. The final sections make recommendations for practitioners, and identify research needs for moving forward.

The Nature of Trade-offs

British Columbia's forests were once considered inexhaustible. The *Forest Act* implemented in 1912 (Government of British Columbia 1912) dealt mainly with: streamlining timber sale licensing procedures; ensuring land licensed for forestry was not alienated to another use; and providing financial incentives for local manufacturing. Concern over rapid harvesting and poor regeneration practices led to the amendment of the *Forest Act* in 1947 (Government of British Columbia 1947), and the concept of sustained yield—private and public sustained yield units— was implemented in British Columbia.

Over the latter part of the past century forest management evolved from sustained yield to multiple-use to integrated resource management. The advent of "New Forestry" in the United States opened the door for a broadening of values including aesthetics and sustainability of ecosystems (McQuillan 1993). The current paradigm of Sustainable Forest Management (SFM) has grown out of the focus on sustainable development initiated by the Brundtland report entitled *Our Common Future*. The report describes sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland [editor] 1987). Toman (1994) asserts that two key issues arise from this definition:

1. the degree to which current generations are responsible to future generations (intergenerational trade-offs); and
2. the degree to which different forms of ecosystem and social capital are substitutable (ecosystem trade-offs).

Sustainable forest management includes this notion of sustaining resources for the future, but goes even further by targeting a desired future forest condition that may be an improvement over the existing one. In its simplest form, SFM has been described by three principles in forest management:

1. accountability of forest practices,
2. sustainability of forest structure, and
3. the integration of environmental, economic and social considerations (Wang 2004).

It builds from "New Forestry" by recognizing ecosystem sustainability, and goes beyond "New Forestry" in recognizing the importance of public participation, social goals, and a learning approach to planning.

Ecosystem Trade-offs

Many trade-off decisions made in forestry are described under the simple heading "jobs versus the environment." A longstanding problem in economics is that goods and services with a market tend to be overproduced in comparison to unpriced or public goods. The problem is particularly apparent in forestry where many unpriced "goods" are necessary to support life and (or) are considered by many to be an important quality-of-life amenity. Clean water, wildlife habitat, and scenic beauty are all important examples. This means that decisions cannot be based solely on the "market" value or the "invisible hand."

An important question for the practitioner to think about is the degree to which forest attributes and outputs can be substituted. Obviously, there is no substitute for a grizzly bear, but an extensive intact reserve for bears in a distant region might be a substitute for habitat in a contentious area. Tourism jobs might be a realistic substitute for timber jobs. Practitioners working with advisory groups could compile a list of management criteria, and then identify with the group which criteria were potentially substitutable and (or) what conditions would make them substitutable. This gets people thinking about trade-offs without actually making the trade-offs.

Intergenerational Trade-offs

In the British Columbia forest industry, financial returns and employment have decreased, despite relatively constant harvest levels. (The statistics cited in this paragraph were obtained from Statistics Canada reporting in July 2005. The most recent year statistics are often corrected in the following year.) The average harvest level over the last 15 years was 74.5 million cubic metres. Over the same period of time, revenues decreased from $25/m^3 to $12/m^3 in real (1992) dollars. Real exports per harvested cubic metre rose in the early 1990s and have since declined from $217/m^3 in 1994 to $135/m^3 in 2004. Jobs per thousand cubic metres hit an all-time low of 0.92 in 2004, despite steady growth in the value-added sector over the period. Nonetheless, lumber production in 2004 hit an all time high of 39.2 million cubic metres. The harvest levels over the last three years were 77.8, 65.4, and 87.0 million cubic metres. These harvest levels are tied to performance in lumber markets rather than to the environment. These statistics demonstrate that despite higher production and high harvests the financial returns derived from our forests are declining rapidly.

For a variety of reasons, provincial harvest levels are predicted to decline in the future. One reason for the decline is the gradual replacement of older natural forests with second-growth forests. During this transition, volume, piece size, and timber quality will decline. Economic performance in a sawmill is strongly related to piece size and quality—with larger trees, log recovery is higher in volumetric and value terms. From an economic viewpoint, the forests left for the next generation will in no way compare to those we enjoyed in the past. This represents a generational trade-off. This rapid conversion of older natural forests to younger second-growth ones is the same force that puts pressure on the ecosystems and causes concern for the future of forest-dependent communities.

The usual argument used in favour of ecosystem capital draw-down is that investments drawn from current profits will generate new forms of economic activity in the affected regions. Toman (1994) describes two potential flaws in this theory: (1) whether the hypothesized investments are actually undertaken or even feasible; and (2) whether compensatory investments that substitute technology for ecosystem degradation are ethically defensible in the first place.

Using British Columbia as an example, the coastal forest industry is a shadow of its former self. Many forest communities are in serious trouble. One reason consistently cited for this is the run-down state of the technology on the coast. So what were the relevant compensatory investments that were undertaken on the British Columbia coast while the resource was draw-down?

Another argument for ecosystem capital draw down is that technological increases such as the development of engineered wood products will make smaller trees more economically harvestable in the future. If the past is any guide, the opposite has occurred. The recent technology that has been implemented in the forest sector has mainly served to commoditize the sector. New engineered wood products have been developed that replace high-value products like plywood and timber beams with laminates made from small low-quality timber. This favours areas of the world with fast grown plantation wood and has moved away from British Columbia's natural competitive strength based on high quality timber.

Solely relying on commodity products puts our forest sector directly in the path of intense global competition. Don Roberts, a financial analyst in the banking sector, has predicted that commodity prices will decline further as global competition increases. The wood supply is expected to increase dramatically as Russian timber becomes available and plantations in the southern hemisphere increase. Russia alone is biologically capable of producing an increase of 100 million cubic metres per year (Roberts *et al.* 2004). In addition, the near-domination of the high-volume low-value approach in our forest products sector strategy has caused trade problems that have further weakened the value of our timber.

Today, the higher quality timber that is harvested for a commodity-based forest sector in certain regions of British Columbia could instead be used to stimulate a "value-oriented sector" for the future. Alternatively, high conservation-value forests could be retained to stimulate jobs and revenue related to ecosystem services. This "value-oriented sector" may be needed in the future to offset predicted job and revenue losses in the commodity sector. The system that investigates trade-offs must allow the examination of these types of strategic choices from a public policy point of view, especially on public land in British Columbia.

Unfortunately, all too often in British Columbia trade-off decisions are simplistically framed around the impact on annual allowable cut (AAC) and predicted employment. It is sought to maintain a committed AAC determination while at the same time balancing the increasing social demands from the forest. This is a process doomed from the outset. The big trade-off has already been made.

Practitioners must clearly identify the intergenerational trade-off when developing their management plans. This can be done by forecasting indicators into the future and by looking at the value of outputs rather than the volume of outputs. This requires a complete change in thinking from the current AAC-based management paradigm in British Columbia.

Difficulties in Conducting Trade-off Analysis

Finding the Socially Efficient Allocation of Resources

At first glance it would seem that, in order to maximize social welfare, it is sufficient to know the relative value society places on different ecosystem goods, services, and attributes. In a recent article published in *Science* (Daily *et al.* 2000), a group of respected scientists in their fields identified two important principles on valuing ecosystem capital:

1. In a democratic society, values used in social decision making ought to be derived from those held by its individual citizens.
2. We should infer peoples' values as they are revealed by actual decisions whenever possible.

These two principles are observed in the marketplace.

Consumers spend their hard-earned money on a variety of goods and services. They vote, so to speak, with their pocketbooks. The market responds. However, there are at least three major problems with this model. First, the unintended externality costs (such as pollution or habitat loss) sometimes caused by industrial production are often not included in the market price of the goods. Hardin (1968) in his classic essay *Tragedy of the Commons* argued that an open access "free" resource will eventually be destroyed by users. So even where consumers can vote with their pocketbooks, they are not required to pay the full cost of production. Society pays the externality costs. Second, there are no markets for most of the ecosystem goods and services that we enjoy. Third, ecosystem capital has traditionally been considered a free good. Consumers are resistant to the idea of paying for it now.

Social welfare theory provides a framework for identifying the allocation of resources that maximizes social well-being (Stevens and Montgomery 2002). Within this framework, there is a social welfare function that predicts utility from forest output consumption, and a joint production function that produces outputs (i.e., jobs or visual quality) from inputs (i.e., intact forests). Maximizing the production function with respect to social welfare yields the socially efficient solution. This solution can be described by three conditions:

1. The relative values of any two forest outputs (Marginal Rate of Substitution) are the same for all consumers.
2. The marginal rates of technical substitution are the same for all outputs.
3. The relative value of any two outputs (Marginal Rate of Substitution) is equal to the relative cost of producing them (Marginal Rate of Transformation).

Therefore, practitioners must know stakeholders' preferences for different types of outputs and they must understand how their preferences change when they learn about the opportunity cost of achieving their preferences. Opportunity costs are the benefits forgone from an alternate use of the forest. Far too often stakeholders are asked to value or rank different forest outputs, as if all outputs were possible. Then, managers develop a single set of scenarios for evaluation using their preferences as a guide. The task is far more complex than that. For stakeholders to make decisions about the opportunity cost of producing each output, they must know more about the forest's productive capability and resilience. This requires an iterative process in which stakeholders express their preferences, see the results of those preferences for every output, and then react to that knowledge by re-evaluating their preferences. The process with stakeholders should be seen as a mutual learning process, not an opinion survey.

Understanding Public Preferences

Relying solely on public opinion surveys to make trade-off decisions is problematic for other reasons. Before launching into another opinion survey, practitioners should consider some of their limitations.

First, as professionals, they know that ecosystems are exceedingly complex. If the public is uninformed of this complexity, then their preferences are also uninformed. If they use uninformed opinions to make decisions then the outcome of the land use decision will not be more informed than the people whose values are being assessed.

Second, who is the public? Should the opinion of locals in the community be given more weight than distant urbanites? This is a question that is nearly impossible to answer.

Third, even if we could solicit sound preferences from individuals, there is no way to consolidate these preferences into a fair ordering that represents society. Arrow (1950) won the Nobel Prize for his *Impossibility Theorem* that proves the mathematical impossibility of averaging individual preferences into a valid societal preference.

Fourth, individual preferences are not enough. To ensure fairness we need the preferences of the community. Therefore discussion and consensus are essential. When we make decisions about sustainable development the valuation is connected to the long-term functioning of the ecosystem. In the discussion, scientific information and a full understanding of the ecosystem are critical components (Costanza 2000).

Fifth, preferences are not fixed. They evolve and are intricately tied to ethics. Leopold (1949) argued in his landmark essay *A Land Ethic* that ethics serve as a check on economic efficiency, and that as we evolve as a society we develop a more expansive sense of ethics. In other words, as ecosystem capital becomes increasingly scarce, we develop an ethic around it to protect it from economic expediency. Thus, the fairness of preferences expands beyond the human community to the natural community. Costanza (2000) agrees that if we take preferences as fixed then we are saying that the ethical problem has been solved once and for all.

Sixth, an individual elicits different preferences depending on the type of question asked. Shindler (2000) states that most research on preferences has focussed on individual preferences—what people *want to happen* for their own reason—instead of what people believe *should happen* for the overall good of the community or ecosystem. There is a big difference between these two viewpoints. The first is polarizing. The second pulls people together.

Studies on stakeholder preferences sidestep these ethical and fairness issues completely by focussing on individual preferences and often simply averaging them. It is very important to realize that this does not result in anything like a measure of societal preferences.

These considerations lead to the conclusion that it is important to involve stakeholders in the decision-making process instead of just determining their preferences and making the decision based on those preferences. While this is where this discussion on trade-off analysis is headed, it is not without problems. Gregory (2002) describes six reasons why value trade-offs in environmental risk decisions are so difficult for community stakeholders. (Interested readers are encouraged to read the entire article for the details.)

1. *Multiple Value Dimensions:* Sustainable forest management criteria and indicators (C&I) are measured in many units, for example dollars, hectares, population size, and human health. Some of these values are not well understood by the public.
2. *Uncertainty About Consequences:* Due to uncertainty, experts usually describe probable impacts, sometimes in very wide ranges. This makes trade-offs hard to think about.
3. *Unfamiliar Evaluation Contexts:* Public advisory groups have very little experience making these types of decisions.
4. *Balancing Effort and Accuracy:* Making these types of decisions is a difficult and time-consuming process. Stakeholders have jobs and lives to lead so there is pressure to cut corners and make quick decisions.
5. *Incorporating Feelings:* Emotions such as anger and frustration at past decisions are difficult to incorporate into the decision process.
6. *Learning over Time:* Values change over time as the stakeholders learn more about the system. The process must allow for this.

Practitioners designing public consultation processes are encouraged to consider these issues and develop a proactive plan for dealing with each of them.

Restoring Public Trust

The management of ecosystems is so complex that stakeholders almost need a degree in natural resource management to fully engage in the process. But isn't this exactly what natural resource managers are trained to do? There was a time when the public trusted natural resource managers to make these decisions. That trust has been compromised because managers' decisions have appeared to favour exploitation of the forest.

Therefore, practitioners could look at the public consultative process as a way to earn the public trust so their decisions will be accepted. From this perspective the consultative process could be used to establish the principles. Once the two principles identified by Daily *et al.* (2000) have been established, the costs and benefits of the decisions can be determined. Then it is much easier to make decisions. Asking stakeholders to do this is tantamount to abdicating the managers' responsibilities.

New information is constantly arising and goals are evolving. Therefore static prescriptions cannot solve problems. A continuous improvement program is called for. Deming (1982) is credited as the father of continuous improvement. His famous 14 points for transforming management start with "create constancy of purpose." He recommends that rather than focus on minutiae, understand and agree on the big picture then adopt a new philosophy that agrees with the purpose. Then, institute education and training programs so that professionals understand the big picture and their jobs. If this is done, and done true to the original purpose, the professionals can get on with their jobs. Each year, set new goals based on experience and new information.

Approached in this manner, the consultative process seeks a common understanding of the basic principles and gets the public involved in the continuous improvement process based on learning. When the public sees managers acting on the principles, engaging them in the process, and making new principle-centred decisions, managers will earn back the public's trust. This can be done at any level from local public advisory groups to the entire province.

Getting the Scale Right

A large forest is capable of producing many competing outputs simultaneously by careful management and zoning. However, as the attention is focussed to more specific areas on the ground, it becomes more difficult to produce many outputs simultaneously. When this happens, a trade-off must be made.

National indicators report on the state of Canada's forests from a very broad perspective. When very specific areas are considered, the C&I must also become more specific. Many trade-offs are made at the strategic level when deciding on a set of management objectives. In making trade-offs, careful consideration of the importance and uniqueness of local features in the context of the larger region is required.

If every hectare of forest land must produce every desired forest output in the socially-desirable ratio then land management on the ground is doomed from the start. Careful zonation allows planners to take advantage of each region's strengths and to develop a regional strategy. Forest outputs that are considered high value for that particular region can then be emphasized in the management plan, and those that are weak in those areas can be de-emphasized. Such strategic considerations should guide the process of making trade-offs.

The key to success when working with advisory groups is helping them to:

- understand the regional significance of the criteria;
- understand the cumulative effects of activities in other regions and economic sectors; and
- see the big picture when making trade-offs on their own piece of ground.

This is a lot to ask of people serving on a public advisory panel. They are usually not familiar with decision making at this level, so special tools should be developed to aid in this process.

Should Some Trade-Offs be Off Limits?

Since land use decisions reflect ethical and ecological considerations, collaborative decisions cannot be made strictly on economic grounds. Two issues in particular that cause deep divisions between ecologists and economists are resource substitutability and the reversibility of ecological change (Norton and Toman 1997).

Toman (1994) and Norton and Toman (1997) describe a two-tier system whereby land use decisions can be made using standard economic trade-offs when they are relatively small and reversible. As the potential consequences become larger and more irreversible, the method for considering trade-offs is superseded by social rules established for preservation of ecosystem capital. This places a heavier burden of proof on the big-picture items that can have serious consequences.

This two-tiered approach is an interesting system that deserves consideration for use in forest planning. Many ecologists hesitate to agree to a strategic policy that allows trade-offs because they fear they will lose control when the actual decisions are made. This type of policy would establish stricter guidelines on the big, high-risk decisions that require developers to prove that the cost of conserving the resource is unbearable to society.

A Review of Methods for Conducting Trade-off Analysis

Methods for Determining and Validating a Set of Criteria and Indicators

The importance of forests in global sustainability was recognized in the 1992 United Nations Conference on Environment and Development. The conference led to an international seminar in Montreal on sustainable development of temperate and boreal forests. This initiative, known as the Montreal Process (1995), recommended that C&I was the best system to help define and monitor progress toward sustainability. The initiative endorsed a system of 7 criteria and 67 indicators for the conservation and sustainable management of temperate and boreal forests.

The Canadian Council of Forest Ministers (CCFM) was created in 1995 to provide leadership on national and international issues and set direction for the stewardship and sustainable management of Canada's forests. A task force was created and a public process was launched to develop a science-based set of national C&I to measure progress toward sustainability in the management of forests. Two years later the CCFM agreed to a set of 6 criteria encompassing 83 indicators (Canadian Council of Forest Ministers 1997). They launched a review of the C&I in 2001, and released a revised framework on September 19, 2003 (Canadian Council of Forest Ministers 2003). The revised framework consists of 6 criteria with 36 core indicators and 10 supporting indicators.

The Montreal Process and CCFM indicators are helpful starting points for local planning. However, they are designed for national reporting on Canada's forests as a whole rather than as a framework for conducting local trade-off analysis. Therefore, most planning projects start by creating a set of local C&I that are often based on the CCFM indicators. While this may seem like "reinventing the wheel," it is a useful process by which the local C&I are developed to clarify the management objectives in everyone's mind.

Trade-off analysis cannot take place until it is known what is being managed for and whether the things being managed for are currently being achieved. Toman *et al.* (1998) describe the characteristics and use of indicators of sustainability. They should simplify information to improve understanding, and quantify information to help demonstrate the significance of changes. Leading indicators provide important clues to likely future outcomes. Bunnell (1997) lists four characteristics of useful indicators; they must be measurable, operable, credible, and relevant to the management objectives or criteria.

The criteria are strategic and should reflect the values and important considerations of both the stakeholder groups and the best scientific knowledge available. It must be recognized that they will evolve over time.

The indicators are tactical. They make the criteria operational. Good indicators should:

- indicate if the sustainability criterion is being met;
- measure and verify progress; and
- have both thresholds and targets.

Establishing thresholds and targets is part of developing indicators. The threshold represents a constraint that cannot be violated and should have a built-in safety factor. The target is the desired indicator level. Trade-offs occur between the threshold and the target of each indicator, and sometimes new targets and thresholds are determined after a sensitivity analysis is conducted.

The forest certification process, with its requirements for public consultation, is a starting point for understanding how C&I are used, and how trade-off analysis is conducted in the field. For example, Canada's national standard on SFM, CAN/CSA Z809 (Canadian Standards Association 2002) requires the following:

- the establishment of a representative public participatory group;
- the definition of a complete set of indicators for defined criteria based loosely around the CCFM C&I system; and
- a continuous improvement system with an SFM plan, a monitoring strategy, and public participation to oversee implementation and help define the objectives.

Two difficulties with using indicators are: (1) there are too many of them, and (2) many of them have nothing to do with actual management activities. To make these indicators operable, a person engaged in the planning process must first have the ability to forecast the impact of a management decision on all the indicators. If the indicators have nothing to do with the management decisions then they should be dropped.

Methods for developing good C&I fall along two lines: *expert based* and *stakeholder-learning based*. Currently in British Columbia experts are relied upon to develop the C&I and stakeholders to rank or weight them. In some cases this has served to create suspicion. Instead, the criteria should represent the values of the broad community of stakeholders being asked to participate in the process.

An example of expert-based methods is described in Mendoza *et al.* (1999) and Mendoza and Prabhu (2000). They developed guidelines for applying multi-criteria analysis to determine C&I for SFM in Kalimantan, Indonesia. They started with a large set of potential criteria and used ranking and rating by a team of experts to narrow the field. Ranking involves asking participants to rank the indicators by the importance that they place on them. Rating is asking them to allocate points (or weights) to each indicator. The authors found that these methods were highly transparent and easy to understand. However, this method relies on having available experts that are trusted by the stakeholders. Also, since there was no formal process for forecasting results, it is not known if the indicators that were developed in the process were actually effective at gauging sustainability.

Prabhu *et al.* (2002) published a set of guidelines for selecting and evaluating C&I for SFM in third world countries. Their method consists of creating a large set list of possible C&I from published sources and expert opinion, then applying a series of filters through expert analysis, workshops, and stakeholder interviews to narrow down the list. The authors propose a comprehensive list of generic C&I as a starting point and suggest workshop agendas, forms to be used, and a detailed step-by-step procedure. The process involves the community in filtering the C&I, but it is not a learning process where experts and stakeholders work together to define the C&I. However, the authors provide a thorough basic understanding of SFM and C&I for newcomers to the field or stakeholders wanting to know more about SFM prior to engaging in public advisory groups.

When stakeholders attempt to agree on a set of SFM criteria, it is important for them to see how everything is connected, and to get a sense of the values that individuals in the community place on different criteria. Mendoza and Prabhu (2006) describe a series of soft system dynamics models and illustrate how they are used in a participatory approach. Three models are presented: (1) cognitive mapping, (2) qualitative systems dynamics, and (3) fuzzy cognitive mapping. They report that stakeholders confidently participated in the full process and responded favourably to these models. All three methods were used to build a graphic map of the interactions between forest inputs and outputs, and to demonstrate the feedback loops and circular causality in the system. These methods hold promise for practitioners who are starting at ground zero and want to get everyone to buy in on a set of operational C&I that reflect the community's values.

For working with more advanced groups, Toman *et al.* (1998) describe an iterative 7-step process that involves stakeholders and experts in determining the C&I. The process starts with informing the community about the resources and the possibilities. Next a participatory process is used to determine community preferences. Participants learn about the viewpoints of other community members and how different values are interrelated. In the next three steps experts establish the linkages, scientific principles, and costs and effectiveness of the proposed C&I. In step 6 various types of models are used to forecast results of the scenarios and evaluate their impact at other scales, such as regional and provincial ones. The results are reviewed with the community in step 7 and the process is either restarted at step 1 to improve the policy approaches or the policy is implemented.

This *learning-based* procedure is very well thought out and overcomes many of the challenges described by Gregory (2002) in the preceding section. In a region with sophisticated stakeholder groups, the 7-step approach is useful and very thorough. In areas where there is no general agreement on a set of C&I and (or) a limited understanding of the interactions between desired forest outcomes, the soft systems approach should be investigated. Regardless of the chosen method, it is critical to get stakeholders involved early on in the development of management criteria.

Methods for Determining Stakeholder Values and Preferences

One method for determining stakeholder values and preferences is to develop preferences (or weights) for different management criteria and then use these "weights" to guide decision making. Weightings can be established at the criterion or indicator level—the latter is much more detailed and difficult to establish. The weightings allow trade-offs to occur between the threshold and the target. If no weights are given then it must be assumed the criteria are all weighted equally.

In the second phase of the study described earlier, Mendoza and Prabhu (2000) used ranking, rating, and pairwise comparisons to determine the appropriate indicator weights. The pairwise comparisons approach is based on the Analytic Hierarchy Process (AHP). It develops relative weights based on a series of one-on-one comparisons of every indicator against every other indicator. The assessment took place after a field trip in which the experts became familiar with the indicators pertaining to each SFM criterion. They felt most comfortable using ranking and rating, and least comfortable using the AHP method because of the large number of pairwise judgments that are required by AHP. For interested readers, more information on AHP can be found in Schmoldt *et al.* (2001).

Mendoza *et al.* (1999) developed a manual for using multi-criteria analysis to evaluate stakeholders' preferences and weightings for different C&I, and to blend these scores into something like a bottom line. They illustrate the AHP in this process. This is a very useful technique for establishing a baseline set of indicators and the relative importance of each indicator at a fixed point in time. These weights could be used to develop and evaluate management scenarios. To be a comprehensive solution, however, the stakeholders would have to be involved in the development of the scenarios, and given the opportunity to change their preferences and develop new scenarios after reviewing the results and learning more about the system.

Sheppard *et al.* (2003) reviewed four procedures for determining stakeholder values: choice experiments (CE), approval rating, ranking and weighing, and willingness to pay (WTP). Choice experiments present people with a series of choice sets. Each choice set contains two or more alternative bundles of attributes (or policy alternatives containing a number of attributes). The alternatives are carefully described and the participant is asked to choose the preferred bundle of attributes in each set. Contingent valuation (in general) asks people for their willingness to pay (WTP) for an improved environmental characteristic or willingness to accept payment (WTAP) for a degraded environmental characteristic. The advantage of CE over WTP is that it helps the researcher to better understand the trade-off relationship between environmental goods by looking at how the individual attributes of that good are valued.

A classification of trade-off analysis methods was also provided that grouped the methods into three categories: formal explicit (e.g., contingent valuation, choice experiments, and simulation exercises called trade-off games), formal implicit (e.g., multi-criteria analysis), and informal implicit (e.g., negotiation methods). The authors showcased the development of a participatory framework in a case analysis applied to the Lemon Landscape Unit in Slocan Valley, British Columbia, and tested it during a series of workshops. The results suggested that the public was willing to engage in trade-off games; however, the authors propose that more research is necessary to develop comprehensive procedures.

Kangas *et al.* (2001) evaluated two outranking methods for application in strategic natural resource planning known as ELECTRE-III and PROMETHE-II. Outranking indicates the degree of dominance one alternative has over another. The authors found that the ability to deal with uncertain and fuzzy information is the principal advantage of outranking methods. They are also good at dealing with ordinal and less descriptive information. However, the methods are complex and difficult to explain to non-specialists.

The above papers illustrate that there are a number of good methods for establishing the weightings or rankings that stakeholders can assign a set of C&I. Most authors report that the challenge is limiting the number of C&I to a manageable set. There are good resources to help practitioners learn the application of these methods. They must keep in mind that knowing preferences is only one step in the participatory process, that preferences can and do change as stakeholders and experts learn from each other, and that scenario development must respond to the principles and values of the public instead of a set of indicator weights.

Determining the Opportunity Cost of Alternatives

The knowledge of the opportunity cost of a decision is an important part of finding the socially efficient allocation of resources. For example, Montgomery *et al.* (1994) estimated the marginal cost curve for northern spotted owl survival. In this study they used the Timber Assessment Market Model (TAMM) to estimate the opportunity cost of foregone timber harvests for different levels of survival. This is important information that stakeholders and scientists can use in establishing targets and thresholds related to habitat protection.

Clinch (2000) used cost-benefit analysis to perform a valuation of market and non-market forest values in Ireland. The study was undertaken as the Irish government was preparing a strategic plan aimed at doubling the forest estate area through afforestation in the next 35 years. Since the plan involved a substantial land use change, the effect of its policies on the environment, economy, and society was required. They surveyed the public's willingness to pay to assess non-market values such as recreation, wildlife habitat, and carbon sequestration, and used opportunity cost to assess the other components. The results showed that the timber benefits dominated all other benefits, mainly because the plantations exhibited few other amenities. The methods used in this study may interest readers.

Niemi and Whitelaw (1999) describe trade-offs occurring in forest management between four sets of forest users:

1. those who profit from exploitation of forest resources;
2. those who incur costs from the exploitation;
3. those who see forest resources as a quality of life; and
4. those who place an intrinsic value on the undisturbed forest.

The authors describe a framework for evaluating economic consequences associated with each of these categories and demonstrate its use in the southern Appalachian Mountains of the United States. This U.S. Department of Agriculture Forest Service guidebook helps readers understand the nature of trade-offs and their economic consequence, and is good background reading for stakeholders and consultants unfamiliar with these issues.

Stevens and Montgomery (2002) describe the evolution of analytical methods for multi-resource forest management in the Pacific Northwest region. They compiled empirical results from studies that employed production possibilities methods to analyze the compatibility between wood production and other uses. The study concluded that this type of joint production research is too specific or too theoretical to be directly applicable to land management, and that increased research is necessary to develop models capable of generating realistic trade-offs between different values.

Operations research models are often very useful to make connections and predict future outcomes. In a land use management problem, van Kooten (1995) used Goal Programming to examine the impacts of the stakeholder process for allocating public forest land on Vancouver Island, British Columbia. He analyzed the allocation of land for alternative uses and determined the impacts on employment, government revenues, and the ability to meet AAC requirements. The goals were generated by a group of specialists and assumed to reflect the public expectations. The goals were ranked according to two public surveys. Four allocation scenarios showed that, despite attaching high values to non-timber uses (e.g., tourism jobs and recreation), the net social benefits were substantially reduced under the current land use practices.

Maness and Farrell (2004) developed a multi-criteria optimization model that utilized 10 indicators of SFM for an industrial forest area in southeast British Columbia. They determined the opportunity cost for different threshold levels for each of the indicators. The technique was effective at exploring trade-offs, but better baseline data and improved methods for predicting how non-timber indicators change over time are required before the technique can be used with confidence. This research is ongoing and will be published in the near future.

Models such as these can help inform stakeholders of the costs of various alternatives. Their proper use would help integrate stakeholders into the planning process instead of simply asking them to review a fixed set of prepared scenarios.

Developing Management Plans using Multiple Criteria

Weintraub and Bare (1996) provide a thorough review of the development of multi-criteria operations research methods that address spatial requirements, multi-resource planning, hierarchical systems, multiple objectives, and uncertainty. They noted that ecosystem management favours planning strategies that achieve a future desired condition over those that find an optimal plan to produce a desired mix of resource outputs. To achieve this, model development should concentrate on hierarchical systems that incorporate uncertainty and fuzzy goals.

The two most widely used models for management planning have been multi-objective linear programming (MOLP) and Goal Programming (GP). The need to incorporate spatial attributes to model adjacency and green-up constraints requires a mixed integer formulation. Model development throughout the 1990s concentrated on mathematical formulations and solution mechanisms for large, usually single criteria spatial models. Current model development is directed toward strategic models that deal with multiple criteria using SFM indicators. Instead of seeking an optimal solution, these models provide solutions that satisfy goals and report on the consequence and opportunity cost of various targets, thresholds and indicator values.

These types of models are very useful in a participatory planning environment where teams of experts work with stakeholders iteratively to seek collaborative solutions. Nelson (2003) describes several challenges for building effective forest-level models for decision support. However, he cautions that overreliance on such models is problematic because the ability to build and solve complex models exceeds the scientific credibility of the data. Therefore, the importance of reliable data should be emphasized in planning research.

A serious criticism for most of the forest-level planning models is the total lack of integration of manufacturing and marketing products from the forest. This deficiency has serious consequences. For example, the timber objective in most forest-level models is expressed solely in terms of volume. These models fail to fully consider the impacts of changing timber size and quality due to the draw-down of ecosystem capital. Thus, they are seriously flawed on economic grounds. Future modelling efforts should reconcile this by looking more at the value of all forest outputs instead of volume harvested.

Determining Acceptability of Plans or Reviewing Plan Alternatives

One of the oldest techniques for incorporating stakeholder preference is to present stakeholders with a set of fully developed plans and ask for their feedback. On the surface this seems to greatly reduce the complexity of the task that stakeholders are asked to do. However, this method asks that stakeholders determine the impact of all the plans on the values that they care about—a daunting task.

For example, Martin *et al.* (2000) developed and demonstrated a method of ranking forest management alternatives in the San Juan Forest, Colorado. The method involved a high degree of stakeholder involvement in the decision process. Three participating stakeholders were asked to perform ordinal and cardinal ranking of the management alternatives and attributes. These rankings were amalgamated into final rankings which were analyzed by each stakeholder. The differences between the cardinal and ordinal rankings indicated the risk for potential conflicts in determining the desired management alternative. The study recommended that stakeholder input should take place earlier in the decision making process, at the stage where the alternatives were defined.

Involving Stakeholders in Generating Planning Alternatives

By involving the stakeholder directly in the process of generating management plans, the stakeholders learn through doing. Sheppard (2005) reported on the state of participatory decision support systems (DSS) for SFM and provided a conceptual framework to address its special needs in tactical planning at the landscape level. The study emphasized that to have increased public participation in forestry decisions, integration was needed between forest sustainability assessment, public participation, decision analysis, and computer technology.

Sheppard recommends a framework for developing a rigorous participatory DSS for successful development and implementation which should include the following elements:

- an accurate problem formulation;
- a structured selection of stakeholders;
- a design of participatory sessions that encourage collaboration;
- the use of accurate data;
- an appropriate use of technology;
- the selection of a manageable number of scenarios and (or) alternatives;
- a transparent analysis and decision process;
- the use of more than one evaluation method; and
- documentation and accountability at each stage in the process.

Clearly much research remains to develop such a system, but these guidelines offer insight into the practical requirements.

In the Arrow Forest District of British Columbia, Sheppard and Meitner (2005) modelled a system that incorporates visualization capabilities into a participatory DSS to enhance the presentation of the effects of different management alternatives. Alternative forest management scenarios were presented using three-dimensional landscape visualizations and stakeholders participated by selecting and weighing the criteria. The authors concluded that this participatory DSS was an effective tool in areas of conflict. They suggested that this research be further validated and improved through more in-depth pilot studies, involving social, economic, and ecological elements.

Lessons for Planners

Perhaps more important than the specific methods, is engaging the stakeholders and planners in the discovery process of learning about the ecological, economic, and social functions of the system, and about each other.

It is important to keep in mind that trade-offs are established with the purpose to form strategic policy, not for tactical planning or monitoring. It is paramount that stakeholders and planners start by determining what is important to them. This is done by defining the criteria and then establishing measurable indicators, targets, and thresholds. These things should be carefully developed for each region, and stakeholders must be involved in this process for the criteria to have validity. Careful scenario analysis will then identify the weak points, those points which are most sensitive in the system. These are the most important points to get right. It is also important that stakeholders are involved in the analysis of the scenarios. Through this process they will learn about the opportunity cost of producing outputs, protecting important ecosystems, and creating economic opportunities. It should be expected that their preferences will change as they learn more about the productive capacity of the system.

What We Have Learned

We have learned a lot from the early days of multi-criteria planning. Most importantly we have learned that there are no easy answers. Balancing the trade-offs in natural resources management requires a deep knowledge of both the production possibilities and the sensitivity of every factor to every other factor. Involving the public must be done intelligently. The following simple guidelines will go a long way to head off problems before they occur:

- *The public's values and beliefs must guide the development of policy alternatives*. Too often the scenarios and alternatives are developed by the experts, and then the public is asked to choose between them. When the public sees their values actually built into the scenarios they are asked to choose from, they will start to trust the managers.

- *The public and the planners must be educated and informed throughout the process.* The consultation process is an excellent mechanism to build trust with the public if the management plans are actually based on the public's values.
- *There is no optimal plan.* Seek instead to attain consensus on the principles and values and not the "indicator weights" or preferences. Implement the best plan and a continuous improvement system based on careful analysis of the indicators and a rethinking of the goals. Allow for future changes. It is necessary to build mechanisms in place to ensure that the public are equally involved in the continuous improvement program.

Therefore, to fully address all of these considerations, the trade-off system should have the following objectives:

- Fully identify the costs, benefits, and reversibility of land use decisions (including the long-term impact on sustaining ecosystems) where possible.
- Use discussion and consensus to carefully craft a vision of the overall goals of the management paradigm, including the ethical considerations that define the boundaries of decision making. The vision should describe the high standard required for high cost and (or) irreversible land use decisions based on the two-tiered approach to development decisions. This will require leadership.
- Build public trust in the process of resolving conflicts about the balance of inputs, outputs, and attributes to support the vision. Planners must show courage in standing up for the principles, and not cave in to financial interests.
- Continually improve data collection, performance to criteria, and goal setting as new information becomes available, learning occurs, and attitudes change.

The first objective can be achieved by studying and understanding what economists refer to as the production possibilities frontier. Modelling and field research are important parts of this exercise. This is the realm of the scientist, but these models must be redesigned to present better information to the public and allow interaction. Much of the technical side of trade-off analysis falls into this category, and most of the research goes toward identifying these costs, benefits, and trade-offs. Public decisions should be based on a full accounting of all the costs and benefits, now and in the future. Full cost accounting alone could solve many of the big problems inherent in sustainability issues. Sponsored research programs and technological developments should be designed to encourage technology that provides benefits to society while reducing the total load on the environment.

The second objective is achievable by focussing more on the strategy and goals of SFM. It is an introspective, learning, and discovery process that asks: *how do we wish to live?* How can we possibly steer a ship toward an unknown destination? This is a process that requires vision and leadership, involves shakeups to the *status quo*, and results in setting new directions. Here is where the research on working with the public to build a shared vision becomes useful. Using models as learning tools to educate the public about the challenges and the possibilities is helpful.

The third objective can be achieved by making decisions that are in harmony with the strategic vision. Trust is earned, not bestowed. If we err, we should err on the side of protecting future generations. A generous safety margin is also important. If the stakeholders are supportive of the vision and they see that decisions are being made that serve the vision, then they will allow the professionals to do their job. All too often planners have turned to the public for the preferences on the minutiae of management instead of relying on a carefully constructed shared vision. If planners do their jobs right, the public won't feel like they need to micromanage hem.

The last objective can be achieved by implementing a structured continuous improvement program: improving the understanding of the goals and the responses to them. During the continuous improvement program, data is collected, the indicators are studied, and in-process corrections to the system are made. As continuous improvement reworks the vision and the process details, it is important to have stakeholder involvement in this step. This entire area is open and ripe for research. In the end, what we know as SFM might be a classic continuous improvement program.

Supporting Research Needs

While the recommendations above describe the strategic direction of research, much additional work is necessary to provide supporting tools for SFM planning.

First, a lot more effort needs to go into developing meaningful operational C&I. In this process, the strategy developed has been woefully inadequate thus far. Many of the indicators are not measurable, and are poorly correlated with the criteria. By and large, the ecological C&I are the most developed, the economic C&I are weak, and the social criteria are vague. Most of the latter are not measurable, not really correlated with forest management in particular, and have serious scale issues. As a result, indicators are developed into ineffective concepts such as the number of meetings held, letters received, or reports generated.

Second, serious work is needed to obtain valid data, especially for the non-timber criteria related to SFM, but more generally for estimating the value of forest outputs instead of the volume. This is coupled with the need for better data and retrieval mechanisms so they can be integrated with planning models. It's essential to get the right C&I defined then gather the data to support them.

Third, better ways are needed to predict the effect of various management prescriptions on non-timber resources. This work is ongoing, but extremely complex and time consuming. Forest-level models now have the ability to incorporate such predicting sub-models through hierarchical planning techniques when reliable models are available.

Fourth, better integration of existing models into cohesive packages that support strategic-level decision making is needed. Tools should be designed to allow learning and experimentation over a wide range of possible outcomes. It is also essential to model the full value chain of the forest products sector to take full advantage of the synergies between non-timber objectives and higher-valued products.

Fifth, research should be conducted to establish principles for developing a safe minimum standard in land use decisions. It is likely that such a standard would greatly reduce the level of contention in planning exercises.

Sixth, research should be undertaken to develop specific continuous improvement techniques for planning monitoring activities, studying the appropriate data, and taking action to improve the system.

Conclusions

There are four big problems with conducting trade-off analysis. First is the issue of valuing unpriced outputs. It is important that stakeholders understand the opportunity cost of production of all forest outputs. This requires an iterative process where stakeholders can see the outcome of their preferences. Sensitivity analysis can help them to understand the value of the unpriced outputs.

Second, planners must understand that gauging public preferences is a complex endeavor. Surveys and opinion polls are merely a starting point. Average criteria weightings do not represent societal preferences. The public must be engaged early in the process and consulted often as new plans and ideas are developed. Stakeholders will never completely agree on a set of preferences or weights for different criteria, but they may agree on some common principles.

Third, planners must see the consultative process as a mechanism to restore public trust. To achieve this they must act in the public interest. That means redesigning the consultative process from an industry-led process of constrained timber maximization to a socially efficient resource allocation process.

Fourth, the scale of decision making must be considered in the process of making trade-offs. Stakeholders should see the unique features of the region under study and the overall planning process from a strategic point of view. If every potential output is to be preserved or enhanced then planning is doomed—stakeholders are unwilling to make any trade-offs. In bringing ethics into the process, planners should realize that some forms of economic development may be off the table. The action of "watchdog" organizations is very important for monitoring the process.

An important aspect of trade-off analysis is the process. Stakeholders and planners learn more about the capabilities of the system and the beliefs and attitudes of the public. Working to develop a set of C&I for a specific regional plan is an excellent way to bring everyone together and establish a common set of principles. Public trust will be restored when planners are seen to be acting on this set of principles. The decisions made through such a process will be legitimized, even if the stakeholders do not agree on all of the points of the plan. Then, perhaps, the minutiae of planning can be entrusted to professionals.

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Test Your Knowledge . . .

Trade-off analysis for decision making in natural resources: Where we are and where we are going

How well can you recall some of the main messages in the preceding Discussion Paper? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. To understand how stakeholders value competing forest outputs, practitioners should use:
   A) The stakeholders' rankings of the value of the different outputs through a mail survey
   B) The opportunity costs of the outputs in terms of the other outputs
   C) The stakeholders' preferences for the different outputs taken after they understand the opportunity costs of producing the outputs

2. Unpriced outputs are usually under-produced because:
   A) There is no incentive in the market-based economy for producing these outputs
   B) The public does not really value these outputs
   C) The outputs are too expensive to produce

3. Continuous improvement is an important part of forest management planning because:
   A) The public doesn't really know what they want
   B) The managers are incompetent
   C) The uncertainty of outcomes and the complexity of the task mean that there is no optimal solution

Answers

1.C 2.A 3.C