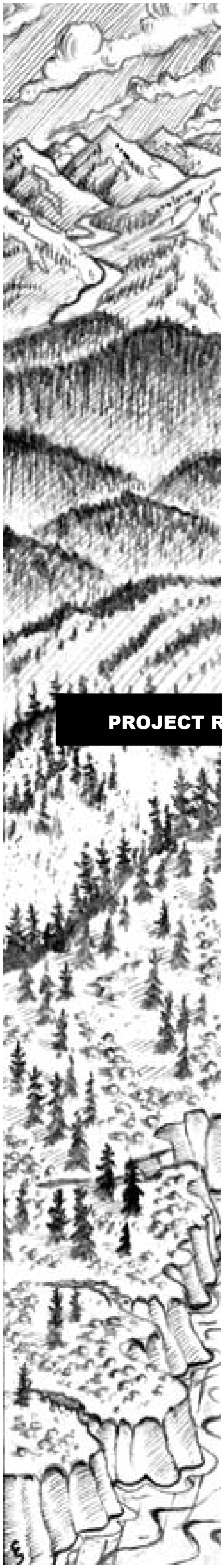

PROJECT REPORT

Tradeoff Analysis for Decision Making in Natural Resources: Where We Are and Where We Are Headed

Draft (In Review)

FORREX
Supporting Sustainable Natural Resource Management Decisions

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THE BIG PICTURE

Tradeoffs Considered

The productive forest land in British Columbia is overwhelmingly public owned. This ecosystem 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 these are exceedingly difficult to value. Nonetheless, we know that these free goods have a value and must be represented in our land use plans.

As managers of public land we have been long entrusted to ensure that society benefits from our management practices and these benefits to society are sustainable. In the past the twin principles of sustained yield and multiple-use attempted to serve this goal. While sustained yield only directly addressed the economic benefits from the forest, it did attempt to insure inter-generational equity. The requirements toward multiple-use seemed to address non-timber resources, but they were focused solely on *use*. Obviously much has changed with the current paradigm of sustainable forest management.

The concept of a "tradeoff" in forest land use planning comes about because the characteristics that define the forest are both inputs and outputs. Some goods and services from the forest can be produced at the expense of others. For example timber extraction can affect visual quality, water quality and recreation. Recreation can also affect water quality. Certain types of recreation (downhill skiing) are inconsistent with other types of recreation (wilderness solitude). Other goods and services are complementary. Timber extraction encourages certain wildlife species preferring browse, and is consistent with many types of recreation that require road access.

However, the word tradeoff is misleading because the word implies two things: first, that all of the forest outputs are not attainable at the same time; and, second, that we must give up one forest output to achieve another. Both of these are false. A forest, if large enough, is capable of producing many competing outputs simultaneously through careful management and zoning.

Citation—

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Objectives of Tradeoff Analysis

BC's forests were once considered inexhaustible. The *Forest Act*, implemented in 1912, mainly concerned 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 the rapid harvesting and poor regeneration practices led to the amendment of the *Forest Act* in 1947, and the concept of sustained yield was brought to BC Forests by creating private sustained yield units (eventually implemented as Tree Farm Licenses) and public sustained yield units.

Over the past century forest management has evolved from sustained yield to multiple-use. 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 Bruntlandt report *Our Common Future* (Bruntland 1987). That report described sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Toman (1994) asserts that two key issues arise out of this definition: 1) the degree to which current generations are responsible to future generations (intergenerational tradeoffs); and, 2) the degree to which different forms of ecosystem and social capital are substitutable (ecosystem tradeoffs). SFM specifically addresses each of these key issues.

However, the relevant question is not really about tradeoffs but, instead, about how we manage our activities such that the resulting forest has the combination of attributes to sustain itself and us. So it is more about balancing than trading off. Since we are creatures living within our ecosystem, this means first and foremost sustaining the ecosystem that gives us life. Since we also derive much of our social welfare from the forest (especially in BC), this also means sustaining the means for providing that welfare for future generations.

Ecosystem Tradeoffs

The idea of SFM means many things to many people. In its simplest form, SFM has been described by three trends in forest management: accountability of forest practices, sustaining the forest structure, and the integration of environmental, economic and social considerations (Wang 2004). It builds from New Forestry in the recognition of ecosystem sustainability, and goes beyond New Forestry in recognizing the importance of public participation and a learning approach.

However, before you can sustain something it must be defined. The importance of forests was recognized in the 1992 United Nations Conference on Environment and Development. This conference led to an international seminar on sustainable development of temperate and boreal forests that was held in Montreal. This international initiative, known as the Montreal Process (1995), recommended that criteria and indicators were 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.

Toman et al. (1998) describe the characteristics and use of indicators of sustainability. In general they should simplify information to improve understanding and quantify information to help us see the significance of changes. Leading indicators are particularly important: they provide important clues to likely future outcomes.

The idea of sustainability, at least as it is applied to forestry, challenges many of the long held theories of neo-classical economics (Kant 2003a). Sustainable Forest Management, if we use the criteria and indicators approach as the means for implementing it, has very strict guidelines that requiring strong sustainability once the indicators have been developed. It does not, for example, allow substitution between indicators to the point of exhaustion. Thus it raises serious questions about the hypotheses regarding substitution that are the underpinnings of classical economics (Kant 2003a).

The CCFM Criteria and Indicators

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 in 1995 and a public process was launched to develop a science based set of criteria and indicators (C&I) that can be used 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). The CCFM 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 six criteria are listed below with the number of indicators in each one.

- Biological Diversity
    - Ecosystem Diversity: 2 indicators
    - Species Diversity: 2 core indicators, 2 supporting indicators
    - Genetic Diversity: 2 indicators
- Ecosystem Condition and Productivity: 5 indicators
- Soil and Water: 2 indicators, 1 supporting indicator
- Role in Global Ecological Cycles:
    - Carbon Cycle: 3 indicators, 1 supporting indicator
- Economic and Social Benefits:
    - Economic Benefits: 2 indicators, 3 supporting indicators
    - Distribution of Benefits: 2 indicators
    - Sustainability of Benefits: 3 indicators, 3 supporting indicators

- Society's Responsibility:
  - Aboriginal Rights: 2 indicators
  - Aboriginal Traditional Land Use and Forest Based Ecological Knowledge: 1 indicator
  - Forest Community Wellbeing and Resilience: 4 indicators
  - Fair and Effective Decision-making: 2 indicators
  - Informed Decision Making: 4 indicators

These indicators have been designed specifically for national reporting, but they are commonly used as a baseline for developing operational C&I by companies undergoing forest certification.

The forest certification process, with its requirements for public consultation is a good starting point for understanding how criteria and indicators are used, and how tradeoff analysis is actually conducted in the field. For example, Canada's national standard on Sustainable Forest Management (CAN/CSA Z809) requires the following: 1) the establishment of a representative public participatory group, 2) the definition of a complete set of indicators for defined criteria based loosely around the CCFM C&I system, and 3) a continuous improvement system with a SFM Plan, a monitoring strategy and public participation.

This evolution in forest management has taken us from a focus on *conservation* as a means for sustaining the uses of the forests to the current focus on the sustainability of the ecological, social and economic facets of the ecosystem; thus the triple bottom line.

The Triple Bottom Line: Solution or Paradox?

The concept of a triple bottom-line (3BL) is an advance in thinking about ecosystems in several ways. However, it does not actually solve the problem. At best it is a rhetorical device that reminds us of our responsibilities. At worst it may actually distract us from the type of interrelationship thinking needed to solve the problems we face.
The first difficulty with the 3BL management terminology is that it is misleading. There is in fact no bottom line for any of the 3 components of SFM, although something like a bottom line could plausibly be argued for the economic leg. What we have in fact is a large group of indicators, only some of which are actually measurable, which cannot be reduced to a bottom line in any quantifiable or usable way.

The second difficulty with the 3BL management terminology is that it is contradictory. The phrase "bottom-line" has two possible meanings[1]. The first meaning is literal and is the origin of the word: the bottom line of a financial report that subtracts costs from benefits. This is obviously not what we are talking about with SFM. The second meaning is perhaps more useful: a) the essential or salient point, b) the primary or most important consideration.

[1] From Merriam-Webster Dictionary.

A *triple* bottom line however, is an oxymoron. It presupposes that the three bottom lines are commensurable, or that there is some known lexical ordering that has all been worked out. Nothing is farther from the truth. The result is that it may distract managers from more effective approaches to social and environmental reporting.

Intergenerational Tradeoffs

Economically, BC is one of the world's most forest dependent regions. Timber revenues from crown land contributed nearly $1 billion to the provincial budget in 2003. Direct employment in the forest industries was 91,600, and these jobs primarily occur in the communities of BC where the forests are. The value of exports from the forest sector was over $12.6 billion – a giant shot in the arm to the provincial economy.

Generally when we think about trade offs we tend to think of it as jobs versus the environment, as if the environment was a set of external factors not impacting the economy. This is essentially the expansionist's viewpoint – that technology and substitutability will be able to compensate for the loss of natural resources. It is a simple argument that sells. However, reality it is not so conveniently simple. Rees (2003) argues for a new paradigm, one where the economy is integrated with the environment. The question is not one of understanding tradeoffs per se, it is a matter of reducing the total load that the economy places on the environment through changes in human nature, technology, and government policies.

The actual tradeoff that we are making may not be jobs versus the environment, but actually "well being" now versus "well being" in the future. The trend in British Columbia over the past 15 years has been decreasing financial returns and decreasing employment from the forest despite the fact that harvest levels have remained relatively constant[2]. The average harvest level in BC over the last 15 years is 74.5 million m^3. The harvest levels over the last 3 years have been 77.8, 65.4, and 87.0 million cubic meters. These harvest levels are more tied to performance in lumber markets than to the environment. Over the same period of time BC revenues have decreased from $25 per m^3 to $12 per m^3 in real (1992) dollars. Real exports per m^3 harvested rose in the early 90's and have since declined from $217/$m^3$ in 1994 to $135/$m^3$ in 2004. Jobs per thousand m^3 hit an all time low of 0.92 in 2004 even though there has been steady growth in the value added sector over the period. Nonetheless, lumber production in 2004 hit an all time high of 39.2 million m^3.

Provincial AAC's are predicted to decline further in the future. One reason for the decline is that we are gradually replacing an older natural forest with a second growth forest. As this transition occurs we will see not only reductions in volume, but also in piece size and timber quality. Economic performance in a sawmill is strongly related to piece size and quality – log recovery is higher both in volumetric and value terms with larger trees. From an economic viewpoint, the forest we are leaving the next generation

[2] The statistics cited in this paragraph were obtained from Stats Canada reporting in July 2005. The most recent year statistics are often corrected in the following year.

is in no way comparable to that which we enjoy today. This represents a generational tradeoff. This rapid conversion of an older natural forest to a younger second growth forest is the same force that is putting pressure on the ecosystems and it is the same force that is causing concern for the future of communities. Interestingly, it is not jobs versus the environment. It is, simply put, the draw down of ecosystem capital.

The general argument in favor 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. First, whether the hypothesized investments are actually undertaken or even feasible. One doesn't have to look too far to answer this question. For example, what are the relevant compensatory investments that have been undertaken on the BC Coast while the resource was drawn down? Second, whether compensatory investments that substitute technology for ecosystem degradation are ethically defensible in the first place.

Another argument offered in favor of ecosystem capital draw down is that technological increases will make smaller trees more valuable in the future. If the past is any guide, the opposite has been proven to be true. The technology that has been implemented in the forest sector of BC has mainly served to commoditize the sector. It is focused on cost reduction and volume recovery. It moves us away from our natural competitive strength which is the high quality of the remaining natural forests in BC.

By commoditizing the sector we subject ourselves to a downward spiral in wood value putting us directly in the path of intense global competition. Don Roberts, a financial analyst in the banking sector, has pointed out that commodity prices are expected to 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 m^3 per year (Roberts 2004).

If these predictions are true then here is the potential trade off: potentially high quality timber harvested today for a commodity-based forest sector which could have been used to stimulate value-oriented manufacturing in the future. This value-oriented manufacturing sector may be needed in the future to offset predicted job and revenue losses in the commodity sector. Whatever system we use to investigate tradeoffs must allow us to examine these types of strategic choices from a public policy point of view.

What the real trade off may come to is: is the current generation willing to reduce its total load on the environment in order to protect future generations? Again, our mechanisms for exploring tradeoffs must allow investigation of this choice.

CHALLENGES IN CONDUCTING TRADEOFF ANALYSIS

Socially Efficient Allocation of Resources

At first glance it would seem that maximizing social welfare just requires that we know the relative value of different ecosystem goods, services, and attributes. In a recent article published in *Science*, a group of respected scientists in their fields have 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, and 2) we should infer people's values as they are revealed by actual decisions whenever possible (Daily et al. 2000).

Principles 1 and 2 are both 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 3 major problems with this model. First, the externalities cost caused by industrial production are often not included in the market price of the good. Hardin (1968) in his 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 presented with the full choice. Secondly, there are no markets for most of the ecosystem goods and services. Third, ecosystem capital has been traditionally considered a free good. Consumers have not traditionally paid for these ecosystem outputs and are resistant to the idea of paying for them now.

Social welfare theory provides a framework for identifying the allocation of resources that maximizes social well being3. Within this framework, there is a social welfare function that predicts utility from consumption of forest outputs and a joint production function that produces outputs from inputs. Maximizing social welfare subject to the production function yields the socially efficient solution. The socially efficient solution can be described by three conditions: 1) the relative values of any two forest outputs (Marginal Rate of Substitution) must be the same across all consumers, 2) the marginal rates of technical substitution is the same across all outputs, and 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).

Of course there is no social welfare function, nor is there a known production function. This simple social welfare framework is insightful nonetheless. First, it shows the importance of understanding how consumers value different outputs in a relative way – this is given in the first condition. Considering all three conditions demonstrates both how stakeholders value outputs and how the opportunity cost of producing them are equally important in tradeoff analysis.

[3] See Stevens and Montgomery (2002) for a full treatment of this framework.

Understanding Public Preferences

The next choice would be to value ecosystems by studying people's preferences. Yet relying solely on public preferences is equally problematic. Ecosystems are exceedingly complex. If the public is uninformed, then their preferences are also uninformed. The outcome of land use decision will not be more informed than the people whose values are being assessed. There is an even bigger hurdle. Arrow's Impossibility Theorem argues that 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).

However, as pointed out by Constanza (2000), preferences are used for valuation for different reasons. For simple economic efficiency, individual preferences are useful, as in the invisible hand. To ensure fairness, we need the preferences of the community; discussion and consensus become important. However, sustainability is another matter altogether. In this case, the valuation is connected to the long term functioning of the ecosystem. Scientific information and a full understanding of the ecosystem are critical components.

Another consideration is that preferences are evolving and that they 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 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 realm of preferences expands beyond the human community to the natural community. Constanza (2000) agrees stating that if we take preferences as fixed then we are saying that the ethical problem has been solved once and for all.

Most of our work on studying stakeholder preferences sidesteps the ethical and fairness issues completely by focusing on individual preferences. Shindler (2000) states that most research on preferences have focused 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.

Gregory (2002) describes six reasons why value trade-offs in environmental risk decisions are so difficult for community stakeholders. These are briefly described below. Interested readers are encouraged to read the entire article for the details.

- *Multiple Value Dimensions:* SFM's criteria and indicators are measured in many units, for example dollars, hectares, population, and human health. In addition, some of these values are not well understood by the public.
- *Uncertainty about Consequences:* Due to uncertainty, experts usually describe probable impacts, sometimes in very wide ranges. This makes trade-offs hard to think about.

- *Unfamiliar Evaluation Contexts:* These groups have very little experience making these types of decisions.
- *Balancing Effort and Accuracy:* Obviously making these types of decisions is a difficult and time consuming process. Stakeholders have jobs and lives to lead.
- *Incorporating Feelings:* Emotions, such as anger and frustration at past decisions is difficult to incorporate in to the decision process.
- *Learning Over Time:* Values change over time as the stakeholders learn more about the system.

Taken together, all of these considerations point out that simply asking stakeholders for their preferences without involving them in the planning process is not a panacea for decision making. Instead, if we simply ask user groups to provide the valuation for us at a single point in time it is an admission that we aren't up to the task of planning.

A Case for Leadership

What is required is leadership. Leadership guru Stephen Covey (1992) argues that leadership should be based on principles, and the most important decisions to get right are the big ones – the ones that have the biggest impact. Once the principles have been established we need to know the costs and benefits of our decisions in terms of the principles. Then it is much easier to make decisions. Asking stakeholders to do this is tantamount to abdicating our responsibility.

New information is constantly arriving and our goals are evolving. No static prescriptions can solve a problem when this is happening. In this situation a continuous improvement program is called for Deming (1982) is credited as the father of continuous improvement. His famous 14 points for transforming management starts with: "create constancy of purpose". Rather than focusing on minutia, we must first understand and agree on the big picture. Then we have to adopt the new philosophy. Next we have to institute education and training programs so that professionals understand the big picture and their jobs. If this is done, and done true to purpose, then we can let professionals get on with their jobs, substituting leadership for quotas and slogans. Each year new goals are set based on experience and new information.

CONDUCTING TRADEOFF ANALYSIS

The section below provides a review of current methods for conducting tradeoff analysis from the scientific literature. It is by no means an exhaustive review. Marinescu and Maness (2005) provide an annotated bibliography of the trade-off literature for those more interested in exploring the different methods in use.

Determining and Validating the Set of C&I

Before any kind of trade-off analysis can precede a set of criteria and indicators must be developed. These criteria are strategic and should reflect the values and important considerations of both the stakeholder groups and the best scientific knowledge available. They will evolve over time.

The indicators are tactical and are used to give us a target to shoot for and a measure to see how well we are doing. The indicators make the criteria operational. Good indicators should have the following attributes.

1) They indicate if the sustainability criterion is being met.
2) They are measurable and verifiable.
3) They have both thresholds and targets.

Establishing thresholds and targets is part of the process of developing the indicators. The threshold represents a constraint that cannot be violated. There should be a built in safety factor in the threshold. The target is the desired indicator level. The tradeoffs occur between the threshold and the target of each indicator.

It is the opinion of this author that far too much time and effort has gone into establishing stakeholder rankings of indicators based on the CCFM national scale indicators, and far too little effort has gone into developing meaningful criteria and indicators that can be used operationally. This is an area ripe for research.

Methods for developing good C&I fall along two lines, stakeholder learning based and expert based. Toman et al. (1998) describe an iterative 7 step process for stakeholder involvement in determining the important indicators. This is an involved process which educates the stakeholders, determines community preferences, and shows them the likely outcome of their preferences through modelling. Results are reviewed with stakeholders and the process repeated until consensus has been reached. This learning based procedure is very well thought out and overcomes many of the challenges described Gregory (2002).

Mendoza et al. (1999) and Mendoza and Prabhu (2000) developed guidelines for applying multi-criteria analysis to determine C&I for Sustainable Forest Management in Kalimantan, Indonesia. Two methods were used, ranking and rating by a team of experts to select the most relevant criteria from a large initial set of criteria. The authors found that these methods were highly transparent and easy to understand. However, this expert based method relies on having available experts that are trusted by the stakeholders. Also, since there is 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.

In a region with sophisticated stakeholder groups the 7 step approach prescribed by Toman (1998) is useful and thorough. Where the stakeholder groups are less knowledgeable about economic and ecological forecasting the latter approach has been found effective at achieving buy-in in the process.

Determining Stakeholder Values and Preferences for C&I

Once a working set of C&I have been established it is important to establish the weights or importance levels of each of them. Weightings can be established at the criterion or indicator level – the latter is much more detailed and difficult to establish. The weightings allow tradeoffs to occur between the threshold and the target. If no weights are given then we must assume the criteria are weighted equally.

In the second phase of the study described above Mendoza and Prabhu (2000) used ranking, rating and the Analytical Hierarchy Process (AHP) to determine the appropriate indicator weights. AHP is a technique that develops relative weights based on pair-wise comparisons. The assessment took place after a field visit in which the experts became familiar with the indicators pertaining to each SFM criterion. However, the experts felt the least comfortable using the pair-wise comparison (AHP) method (as opposed to ranking and rating) because of the amount of one-on-one judgment required. For interested readers more information on AHP can be found in Schmoldt et al. (2001).

Sheppard et al. (2003) reviewed four procedures for determining stakeholder values: choice experiments, approval rating, ranking and weighing, and willingness to pay (i.e. contingent valuation) methods. A classification of trade-off analysis methods was also provided, which grouped the methods in three categories: formal explicit (e.g. contingent valuation, choice experiments, and trade-off gaming), formal implicit (e.g. multi-criteria analysis), and informal implicit (e.g. negotiation methods) trade-off analyses. The authors showcased the development of a participatory framework in a case analysis applied to the Lemon Landscape Unit in the Slocan Valley of British Columbia and tested it during a series of workshops. The results suggested that the public was willing to engage in trade-off gaming; however, the authors propose that more research is necessary to develop comprehensive procedures.

Kangas et al. (2001) evaluated two outranking methods, ELECTRE-III and PROMETHE-II for application in strategic natural resource planning. The authors highlighted that the benefits of employing these methods originated from their ability to deal with ordinal and less descriptive information. The studies concluded that, although not directly comparable, the results of the outranking methods were easier to implement in strategic planning because they could not deal with the large number of indicators generally found in tactical planning. They recommended that AHP is more suitable to tactical planning for this reason.

Determining the Opportunity Cost of Alternatives

Knowledge of the opportunity costs of decisions is an important part of establishing good C&I. 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 forgone 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 costs to assess the other components. The results showed that the timber benefits dominated all other benefits, mainly because the plantations were found to exhibit few other amenities.

Stevens and Montgomery (2002) describe the evolution of analytical methods for multi-resource forest management in the Pacific Northwest Region. The authors 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 so far has been too specific or too theoretical to be directly applicable by land managers and that increased research efforts were necessary to develop models capable of generating realistic trade-offs between different values.

Interactions between criteria are complex and happen over a long period of time. For this reason, operations research models are often used to make the 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, BC, Canada. The author analyzed the allocation of land amongst alternative uses and determined the impacts on employment, government revenues, and the ability to meet annual allowable cut requirements. The goals were generated by a group of specialists and assumed to reflect the public expectations. The goals were then ranked based on two public surveys. Four allocation scenarios showed that, despite attaching high values to non-timber uses (e.g. tourism jobs, 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 sustainable forest management for an industrial forest area in southeast British Columbia. They determined the opportunity costs for different threshold levels for each of the indicators. The technique was effective at exploring tradeoffs, but improved methods for predicting how non-timber indicators change over time and better baseline data are required before the technique can be used with confidence.

These techniques could be used to help inform stakeholders in the costs of various alternatives. As such they should be integrated into the consultation process.

Developing Management Plans using Multiple Criteria

Weintraub and Bare (1996) provide a thorough review of the development of multi-criteria planning methods that address spatial requirements, multi-resource planning, hierarchical systems, multiple objectives, and uncertainty. They noted that the trend toward ecosystem management favors 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 multi-objective forest 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 1990's 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 costs 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. The author cautions in over relying on such models because our ability to build and solve complex models exceeds the scientific credibility of the data that we use. Therefore, we should emphasize the importance of reliable data in our planning research.

A serious criticism for most of the models used to support forest level planning 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 simply 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 attempt to reconcile this.

Determining Social 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 plan and ask for their feedback on the plans. 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. The 3 participating stakeholders were asked to perform both ordinal and cardinal ranking of the management alternatives and attributes. These rankings were amalgamated into final rankings, which were then analyzed for 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

The highest evolution of stakeholder participation methods is in involving the stakeholder in the actual process of generating management plans. In this way the stakeholders learn through doing. Sheppard (2004, 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 in order 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 consisting of nine guidelines for successful development and implementation:

1) accurate problem formulation,
2) a structured selection of stakeholders,
3) the design of participatory sessions that encouraged collaboration,
4) the use of accurate data,
5) an appropriate use of technology,
6) the selection of a manageable number of scenarios/alternatives,
7) transparent analysis and decision processes,
8) the use of more than one evaluation method, and
9) documentation and accountability at each stage in the process.

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

Sheppard and Meitner (2005) modelled a system which incorporates visualization capabilities into a participatory DSS to enhance the presentation of the effects of different management alternatives located in the Arrow Forest District of BC. 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.

TRADEOFFS IN PRACTICE

It is important to keep in mind that tradeoffs are established in forming strategic policy, not in tactical planning or monitoring. Firstly, we have to decide what is important to us. This is done in practice by defining the criteria and then establishing measurable indicators, targets and thresholds. Most of the big decisions are made in this process, so it should be taken very seriously. Since this involves ethics as well as economics, it is important to engage and educate the public.

Daily et al. (2000) argue that the most important decisions to get right are ones where the benefits greatly outweigh the costs or vice versa. For example, cities are discovering that it is far cheaper to protect watersheds than it is to purify water.

The Safe Minimum Standard

Since land use decisions contain ethical and ecological considerations, collaborative decisions cannot be made strictly on economic grounds. Two issues in particular cause deep divisions between ecologists and economists: issues of 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 considering standard economic tradeoffs 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 higher burden of proof on the big picture items that can have serious consequences.

This is an interesting idea that deserves consideration. Many ecologists are hesitant to agree to a strategic policy that allows tradeoffs because they feel they will lose control when the actual decisions are made. This would establish strict guidelines on the big, high risk decisions, with enforcement power similar to the Species at Risk legislation.

RECOMMENDATIONS

Therefore, to fully reflect all of these considerations, the tradeoff system should have the following objectives.

1) Fully identify the costs, benefits and reversibility of land use decisions (including the long term impact on our sustaining ecosystems) where possible to do so.
2) 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 higher standard required for high cost and/or irreversible land use decisions that should be made based on the Safe Minimum Standard argument.
3) Build a public trust in the process of resolving conflicts about the balance of inputs, outputs and attributes to support the vision.
4) Continually improve our performance and goal setting as learning occurs and new information becomes available.

The first objective is achieved by studying and understanding what economists refer to as the production possibilities frontier. Modelling and field research is an important part of this exercise, and this is the realm of the scientist. Much of the technical side of trade-off analysis falls in this category and most of the research that we conduct goes toward identifying these costs, benefits and tradeoffs. Public decisions should be based on a full accounting of all of 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 achieved by focusing more on the strategy and goals of sustainable forest management. It is an inward looking learning and discovery process that asks the question: how do we wish to live? How can we possibly steer a ship toward an unknown destination? This is a process which requires visionaries and leadership, involves shakeups to the status quo, and ends up setting new direction. Here is where the research on working with the public to build a shared vision comes in. It helps to be able to use models as learning tools to educate the public on both the challenges and the possibilities. Our research in working with the public should focus on building shared visions.

The third is achieved in practice 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 factor 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 we have turned to the public for the preferences on the minutiae of management instead of relying on a carefully constructed shared vision. If we do our jobs right the public won't feel like they need to micromanage us.

The last one is achieved by implementing a structured continuous improvement program, constantly and forever improving both our understanding of the goals and our response to them. It is in this continuous improvement program that we collect data, study the indicators and make in-process corrections to the system. As continuous improvement is constantly reworking the vision in addition to the process details it is important to have stakeholder involvement in this step as well. 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 recommended strategic direction of our research, much work remains to be done to provide supporting tools to support sustainable forest management planning.

First, we should put a lot more effort into developing meaningful operational criteria and indicators. It is in this process where strategy is developed and we have been woefully inadequate at this task. Many of the indicators used are not measurable and poorly correlated with the criteria. By and large the ecological criteria and indicators are the best developed, the economic criteria and indicators 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, the actual indicators turn into things like the number of meetings held, letters received, or reports generated.

Second, we need to put serious work into obtaining valid data, especially for the non-timber criteria related to SFM. This is coupled with the need for better data and retrieval mechanisms so we can integrate these with planning models. It goes without saying that first we have to get the right criteria and indicators defined, then to get the data to support them.

Third we need better ways of forecasting the future forest condition on non-timber resources as a result of various management prescriptions. This work is ongoing, but extremely complex and time consuming. Forest level models now have the ability to incorporate models like these through hierarchical planning techniques if reliable models were available.

Fourth, we need to better integrate existing models into a cohesive package that supports decision making at the strategic level. 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.

CONCLUSION

We have come a long way toward understanding the tradeoffs involved in natural resources planning. Unfortunately we have not made significant gains because we still don't have a clear vision or agreement on what it is we want to achieve. Trying to establish better methods for the minutiae of detailed land use decisions without this vision is counterproductive. We are simply trying to build a workable system around a strategic plan that developed 50 years ago to use ecosystem capital drawdown as a strategy for community development.

This paper argues that leadership is required to build this vision. Stakeholder participation methods should be developed to better serve this visioning process instead of involving stakeholders in day to day decisions. Once the big picture has been agreed to, we should establish a set of meaningful C&I that allows tradeoffs to occur between the targets and thresholds, and constrains us to a safe minimum standard.

Then, and only then, can we get around to developing practical methods for making land use decisions.

LITERATURE CITED

Arrow, K. 1950. A difficulty in the concept of social welfare. Journal of Political Economy. 58, 328–346.

Bruntland, G (ed) (1987). Our Common Future: The World Commission on Environment and Development, Oxford: Oxford University Press.

Canadian Council of Forest Ministers. 1997. Criteria and Indicators of sustainable forest management in Canada: Technical Report. Canadian Forest Service, Natural Resources Canada. Ottawa.

Canadian Council of Forest Ministers. 2000. National Status 2000: Criteria and Indicators of sustainable forest management in Canada. Canadian Forest Service, Natural Resources Canada. Ottawa. ISBN 0-662-28705-3. http://www.ccfm.org/ci/2000_e.html

Canadian Council of Forest Ministers. 2003. Criteria and Indicators 2003: Background Information on the CCFM C&I Review. http://www.ccfm.org/review_e.html

Clinch, J.P. 2000. Assessing the social efficiency of temperate-zone commercial forestry programmes: Ireland as a case study. Forest Policy and Economics 1: 225-241.

Costanza, R. 2000. Social goals and the valuation of ecosystem services. Ecosystems 3: 4-10

Covey, S. 1992. Principle Centered Leadership. Summit Publishing.

Daily, G. C. et al. 2000. The Value of Nature and the Nature of Value. Science. 289(5478):395-396. 21 July 2000.

Deming, W.E. 1982. Out of the Crisis. MIT Press.

Gregory, R.S. 2002. Incorporating value trade-offs into community based environmental risk decisions. Environmental Values. 11(2002):461-488.

Hardin, G. 1968. The tragedy of the commons. Science. 162(3859):1243-1248.

Kangas, A, Kangas, J., and Pykalainen, J. 2001. Outranking methods as tools in strategic natural resources planning. Silva Fennica 35(2): 215-227.

Kant, S. 2003a. Extending the boundaries of forest economics. Forest Policy and Economics 5, 39-56.

Kant, S. 2003b. Ecosystem choices without discounting and prices. Environmental Monitoring and Assessment, 86(1), 105-127.

Kant, S., and S. Lee. 2004. A social choice approach to sustainable forest management: An analysis of multiple forest value in northwestern Ontario. Forest Policy and Economics, 6(3-4), 215-228.

Leopold, A. 1949. A Sand County Almanac and Sketches Here and There. Oxford University Press.

MacQuillan, A. 1993. Cabbages and kings: the ethics and aesthetics of new forestry. Environmental Values 2(1993): 191-221

Maness, T.C. and R. Farrell. 2004. A multi-objective scenario evaluation model for sustainable forest management using criteria and indicators. Canadian Journal of Forest Research. 34:2004-2017 (2004).

Marinescu, M. and T. Maness. 2005. A annotated bibliography of the literature in trade-off analysis for forest policy decision making. BC Forum on Forest Economics and Policy. University of British Columbia. Available from www.bc-forum.org.

Martin, W. E., Bender, H.W., Shields, D. J. 2000. Stakeholder objectives for public lands: Rankings of forest management alternatives. Journal of Environmental Management. 58(l): 21-32.

Mendoza, G.A., Macoun, P., Prabhu, R., Sukadri, D., Purnomo, H., and Hartanto, H. 1999. Guidelines for applying multi-criteria analysis to the assessment of criteria and indicators. C&I Tool No. 9 in The Criteria and Indicators Toolbox Series, Center for International Forestry Research (CIFOR), Jakarta, Indonesia.

Mendoza, G.A. and Prabhu, R. 2000. Multiple criteria decision making approaches to assessing forest sustainability using criteria and indicators: a case study. Forest Ecology and Management 131: 107-126.

Montgomery, C.A., D.M. Adams, and G.M. Brown. 1994. The marginal cost of species preservation: the northern spotted owl. Journal of Environmental Economics and Management. 26:111-128.

Montreal Process. 1995. Criteria and indicators for the conservation and sustainable management of natural forests. Canadian Forest Service, Natural Resources Canada. Hull, Ontario. http://www.mpci.org.

Nelson, J.D. (2003) Forest-level models and challenges for their successful application Can. J. For. Res. 33(3): 422-429, NRC Press

Norton, B.G. and M.A. Toman. 1997. Sustainability: ecological and economic perspectives. Land Economics. 73(4):553-568.

Rees, W. 2003. Economic development and environmental protection: an ecological economics perspective. Environmental Monitoring and Assessment 86: 29–45, 2003.

Roberts, D. 2004. Changes in the global forest products industry. BC Forum on Forest Economics and Policy. Working Paper Nbr SP 01-01. University of British Columbia. Vancouver, BC. Available from www.BC-Forum.org

Schmoldt, D.L., J. Kangas, G.A. Mendoza, M. Pesonen. 2001. The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making. Kluwer Academic Publishers. Dordrecht, The Netherlands.

Sheppard, S.R.J. 2004. Participatory decision support for sustainable forest management: A framework for planning with local communities at the landscape level. Collaborative for Advanced Landscape Planning, Department of Forest Resources Management and The Centre for Landscape Research, Department of Landscape Architecture, University of British Columbia, Working Paper No. 2.

Sheppard, S.R.J, Campbell, C., and Achiam, C. 2003. A review of trade-off analysis methods and recommendations for sustainable forest management. Collaborative for Advanced Landscape Planning, Department of Forest Resources Management University of British Columbia, Technical Report, Task 1.4, Submitted to Slocan Forest Products March 31, 2003.

Sheppard, S.R.J., & M. J. Meitner. 2005. Using multi-criteria analysis and visualization for sustainable forest management planning with stakeholder groups. Forest Ecology and Management. 207(1-2): 171-187.

Sheppard, S.R.J. 2005. Participatory decision support for sustainable forest management: A framework for planning with local communities at the landscape level. Canadian Journal of Forest Research 35(7): 1515-1526

Shindler, B. 2000. Landscape level management. It's all about context. Journal of Forestry. December 2000:10-14.

de Steiguer J.E. 2003. Multi-criteria decision models for forestry and natural resources management: an annotated bibliography. Northeastern Forest Experiment Station, USDA Forest Service. General Technical Report. NE-307.

Stevens, J.A. and C.A. Montgomery. 2002. Understanding the compatibility of multiple uses on forest land: a survey of multi-resource research with application to the Pacific Northwest. USDA Forest Service. General Technical Report PNW-GTR-539.

Toman, M.A. 1994. Economics and "sustainability": balancing trade-offs and imperatives. Land Economics, 70(4):399-413.

Toman, M.A., R. Lile and D. King. 1998. Assessing sustainability: some conceptual and empirical challenges. Discussion paper 98-42. Resources for the Future. Washington DC.

Van Kooten, G.C. 1995.Modeling public forest land use tradeoffs on Vancouver Island. Journal of Forest Economics 1: 191-217.

Wang, S., 2004. One hundred faces of sustainable forest management. Forest Policy and Economics 6 (2004):205–213.

Weintraub, A. and B.B. Bare. 1996. New issues in forest land management from an operations research perspective. Interfaces. 26(5):9-25.