INTEGRATED RESOURCE MANAGEMENT AND PLANNING

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Contents

Summary

Land use conflicts are increasing in intensity and frequency as a result of expanding development, a finite land base, and a growing environmental ethic. Reactionary strategies, fragmented bureaucracies, and the legacy of utilitarian management approaches have created disjointed environmental management that is poorly suited to resolve land use conflicts. Integrated approaches to resource and environmental management have emerged as an alternative. Integrate resource management (IRM) applies a number of concepts to balance development and conservation objectives.

1. Stakeholder collaboration: IRM engages a diverse set of stakeholders that represent the full range of existing opinions and knowledge to achieve informed, balanced, and broadly supported resource management strategies.

2. Explicit goals and indicators: IRM is guided by explicit goals with measurable indicators and targets that are an expression of the collective ecological and human values of stakeholders.

3. Tradeoff analysis: an integrated assessment of the tradeoffs between economic and environmental indicators informs the selection of resource management strategies that are consistent with IRM goals.

4. Adaptive management: management experiments reduce uncertainty to improve capacity to select resource management strategies that are consistent with IRM goals.

5. Monitoring: ecological monitoring provides an information feedback loop to assess the impact of management on IRM indicators, thereby guiding when and how land use needs to be adjusted.

6. Development thresholds: IRM strives to establish development thresholds that restrict anthropogenic disturbance to within ecological limits.

7. Zoning: Because all goals can not be achieved through uniform application of land use, varying levels of land use intensity are applied to distinct portions of the landscape, including protected areas where development is prohibited.

1. Introduction

Over the past century evidence of the degradation of ecosystems has become increasingly apparent. Humanity's unprecedented consumption of resources has caused species extinctions at a rate that exceeds natural levels by as much as 1,000 times, and has damaged numerous ecosystem services essential to all life such as climate regulation and the supply and purification of water. Unlike previous eras of colonization, opportunities are few to expand the land base to meet growing demand for resources. At the same time, the environmental movement has grown in prominence and demands to preserve wilderness and biodiversity have increased. The combination of expanding development, a finite land base, and a growing environmental ethic inevitably has caused the frequency and severity of land use conflicts to increase.

Utilitarian resource management approaches with narrow objectives and an assumed capacity to control nature have faltered and a steady stream of environmental crises has ensued. Responses to the crises have typically been reactionary, with new laws and regulations focused on specific issues. As a result, action and tools to mitigate environmental degradation is ad hoc and aimed at treating symptoms rather than systemic effects. Further fragmenting society's response to environmental issues has been the growing compartmentalization of bureaucracies. Most countries have separate laws, institutions and policy objectives to govern sectors such as agriculture, transportation, health, energy, water, and wildlife. The compartmentalization frequently means that decisions to govern a sector are made without sufficient regard for issues outside the sector's narrow mandate, and conflict between agencies and governments can result. Reactionary strategies, fragmented bureaucracies, and the legacy of utilitarian management approaches have created disjointed environmental management that is inflexible and narrow in scope and spatial and temporal scale. In contrast, environmental problems are typically complex, interconnected, associated with uncertainty, multidisciplinary, and broad in spatial and temporal scale. The severity and complexity of these problems has motivated the creation of integrated approaches to resource management worldwide. In North America, for example, environmental controversies such as the spotted owl and degradation of the Great Lakes have been catalysts for integrated approaches whereas in Australia the impacts of unsustainable agriculture such as salinization and eutrophication have been motivational.

2. Defining Integrated Resource Management

Examples of integrated approaches include integrated resource management, integrated environmental management, integrated catchment management, watershed management, bioregional planning, and integrated landscape management. The approaches are characterized by a proactive, holistic, systems-based, and integrated approach to environmental problems. Here we adopt the term integrated resource management (IRM) to refer to integrated approaches to managing environmental and resource issues. While numerous definitions of IRM exist, we adopt Cairns and Crawford's (1991) definition: "*Coordinated control, direction or influence of all human activities in a defined environmental system to achieve and balance the broadest possible range of short- and long-term objectives*."

Four essential characteristics differentiate IRM from other management approaches:

1. *Inclusive*. IRM considers the broad spectrum of ecological, social, political, and economic factors and large spatial and temporal scales that define environmental issues. In contrast to monodisciplinary management approaches such as sustained yield, IRM demands a multidisciplinary approach that engages diverse perspectives and skill sets. Decision making is a collaborative process involving the public. There exists an explicit recognition that empirical science alone can not lead to a solution, but rather that a society informed by science can better arrive at optimal landuse trajectories.

2. *Interconnective*. IRM evaluates how different components of ecological and human systems interact. This system dynamics approach recognizes that ecosystems are complex systems with emergent properties that can not be ascertained through reductionism and that, as a result, environmental problems can not be solved by compartmentalization.

3. *Goal-oriented*. Unlike the reactionary decisions that define much of environmental policy, IRM is goal-oriented and proactively plans for a desired state. The goals are typically broad and defined through a collaborative process involving diverse stakeholders. The goal-setting process therefore not only fosters a proactive perspective, but also inclusivity and broad ownership in planning outcomes.

4. *Strategic*. Goal-setting also focuses attention on key elements of the system of concern. This focus is needed to strategically address environmental issues amongst the complexity and uncertainty of environmental systems. IRM's strategic approach is adaptive and intentionally seeks to improve knowledge of the ecological and social effects of land use. At the same time, IRM is precautionary to limit the risk of unanticipated and undesirable impacts.

3. Elements of an Integrated Resource Management Approach

To further describe IRM, we now discuss seven fundamental elements of IRM: stakeholder collaboration, explicit goals and indicators, tradeoff analysis, adaptive management, monitoring, thresholds, and zoning.

3.1. Stakeholder Collaboration

To successfully balance the broadest range of goals possible, IRM must engage a diverse set of stakeholders that represent the full range of existing opinions and interests. As such, interaction among stakeholders is likely the most important element of IRM and diverse stakeholder involvement is needed to achieve long-term success. Failure to assemble a broad constituency of stakeholders will ultimately lead to an unacceptably narrow definition of issues and problems, and not contribute meaningfully to corrective policy and management actions. Stakeholders that most often should be engaged include: governments that own resources and/or regulate development; companies that develop resources; aboriginal communities that have unique resource rights and perspectives; local communities that are positively and negatively impacted by resource development; and public interest groups that voice concerns for social and environmental issues.

A collaborative approach seeks to build understanding and consensus despite interests and political affiliations. Strategies to support successful stakeholder committee collaboration include providing resources necessary for coordination, communication, administration, and meetings; ensuring that stakeholder committee membership is unbiased; and consensus-based decision making. While time-consuming, these approaches to achieve effective interaction among a diverse set of stakeholders have significant benefits. They foster the development of goals and strategies that represent the full array of information, knowledge and perspectives. Effective stakeholder interaction also builds the social and political capital necessary to implement management strategies recommended by the IRM planning process.

A major impediment to IRM is intra- and inter-governmental fragmentation. Horizontal integration at a given level of government and vertical integration across levels of government (national to local) are needed to achieve mutuality among regulations and management effort. Integration is a major challenge, however, due to the legacy of fragmented institutional structure and poor associational relationships among sectors such that roles and direction of accountability is often unclear. Policy and legislative reform to formally integrate resource management among government agencies is the ultimate answer to fragmentation. For example, an umbrella IRM ministry to inform and guide secondary ministries would reduce the ideological "siloization" of government employees and foster the appetite for integrated problem definition and solution sets. Such reforms may be difficult to achieve due to the numerous agencies and levels of government involved. While policy and legislative reform is being pursued, inter- and intra-governmental integration can also be supported on a case by case basis through collaborative land use planning. A land use planning process that involves all relevant government agencies, as well as other stakeholders, will foster a consistent resource management vision. To facilitate integrated implementation of the vision, a land use plan can specify the roles and direction of accountability of the government agencies that will be responsible for regulating development.

3.2. Explicit Goals and Indicators

As discussed above, goals in an IRM process should be an expression of the collective values of relevant stakeholders. Two types of values are relevant to IRM: ecological values and human values. Ecological values are those understood as necessary for maintaining healthy ecosystems. These include abiotic resources such as water and soil, biotic resources including the full suite of native species, and formative ecological processes such as disturbance regimes, hydrological processes, and nutrient cycles. Human values are those products and services generated by ecosystems that are beneficial to humans. These include harvested and extracted resources and associated economic benefits; recreational opportunities; ecosystem services such as flood control and climate regulation; and spiritual values.

To guide management, goals must be translated into measurable indicators for which quantitative targets can be set. In addition to being relevant to goals, indicators should be sensitive to ecological variability in order to provide early warning of change; understandable by decision makers and the public; and cost-effective to monitor. Maintaining biodiversity, for example, is a frequently expressed goal in resource management. On its own, however, this goal is uninformative due to the overwhelming complexity of ecosystems. To operationalize the goal of maintaining biodiversity, three types of indicators are often used as biodiversity surrogates: representation, focal species, and ecological processes. Representation seeks to protect examples of all ecological communities in order to promote the maintenance of biodiversity without requiring the impossible task of analyzing the individual requirements of all native species. Patterns of biodiversity are dictated by ecological processes such as natural disturbance and hydrology, and management should strive to maintain processes within their natural range of variation. Representation of ecological communities and maintenance of the natural range of variation of ecological processes are coarse-filter approaches which, while relatively efficient, may not always equate to species persistence. Managing for a set of focal species provides a more thorough check of whether management strategies will support the persistence of sensitive wildlife populations.

3.3. Tradeoff Analysis

Tradeoffs are inevitable in IRM because of the diverse environmental and socioeconomic goals that are pursued and the finiteness of natural resources. Balanced goals can theoretically be achieved provided a sufficiently large landscape. However, unrestrained pursuit of economic growth or environmental protection necessarily implies degradation of other values. All evidence to date points to the impossibility of "win-win" solution sets – there are always tradeoffs. Historically, the tendency has been for economic growth to proceed without sufficient consideration of the associated tradeoffs. As a result, ecological tradeoffs such as pollution and species extinction have transpired by default. Resource depletion has also occurred, resulting in economic decline over the long-term and therefore intergenerational tradeoffs. Although flexibility to manage tradeoffs exists early on in a region’s development trajectory, the opportunity is frequently ignored due to the lack of key issues such as environmental degradation and resource collapse. As development proceeds and tradeoffs emerge, management flexibility is often insufficient to balance socioeconomic and ecological goals due to depleted resources and entrenched resource production patterns. There is a clear imperative to begin meaningful IRM conversations with stakeholders as soon as is possible, for the solution set options are greater and the costs less dear.

Tradeoff analysis provides a mechanism to make explicit the tradeoffs associated with land use strategies, and thereby inform the selection of resource management strategies that are consistent with IRM goals. A tradeoff analysis is an integrated assessment of the tradeoffs between economic and environmental indicators. A tradeoff analysis should consider the cumulative effects of land use. Cumulative effects are impacts caused by an action in combination with other past, present and future actions. The premise of cumulative effects is that even small individual impacts can combine over space and time to cause large changes to the environment. Cumulative effects can result from a high frequency or density of the same type of activity such as timber harvest, fishing, or urban growth. Alternatively, cumulative effects may result from multiple types of activities occurring on the same landscape. The later type of cumulative effects is more challenging from a planning and assessment perspective because regulation of diverse activities may not be coordinated.

To assess cumulative effects, a tradeoff analysis should consider the impact of all potential anthropogenic and natural disturbances. The spatial scale of the analysis should be at least as large as that of ecosystem components and processes that are affected by land use. This implies that a tradeoff analysis must consider large spatial scales given the extent of relevant ecological scales such as species home ranges and watershed boundaries. A large temporal scale of at least decades is also required to account for the incremental accumulation of impacts over time and the possibility of rare but very influential events such as large natural disturbances.

Assessment of long-term cumulative effects to ecosystems is problematic due to uncertainty and contingency. Understanding of ecosystems and their response to human actions is incomplete, especially with respect to the potentially synergistic impacts of multiple activities overlapping in space and time. In addition, long-term cumulative effects are contingent on underlying drivers such as human behavior and natural processes which themselves are impossible to predict. To address uncertainty and contingency, a tradeoff analysis should consider multiple possible scenarios rather than attempt to accurately predict a single outcome. In the context of a tradeoff analysis, a scenario is a dynamic account of a possible future that makes explicit assumptions regarding uncertain future events such as rates of development. Considering a range of contrasting but plausible scenarios can provide insight into key drivers and demonstrate the implications of a range of policies, including the status quo. Although scenarios should focus on parameters that can be controlled by resource management decisions, they should also consider the effects of uncertain external drivers such as climate change or international markets. Doing so can help identify policies that are resilient to changes in conditions. As with other components of the IRM process, stakeholders should be involved in the process of evaluating scenarios. Stakeholder participation not only helps ensure the development of relevant scenarios, but also provides a forum for stakeholders to reflect upon the long-term consequences of alternative actions. This process of reflection can help to motivate changes in behavior that are consistent with achieving desired futures.

Assessing the cumulative effects of a range of land use scenarios is an immensely complicated undertaking due to the number of interacting variables and large spatial and temporal scales that are involved. To avoid paralysis in the presence of potentially overwhelming complexity, a formalized process is needed to apply the best available information. Land use simulation models are well suited to this task. These computer programs are mathematical representations of the ecosystem being managed that are designed to project the future effects of land use. The human mind has limited capacity to keep track of numerous interacting variables, especially when nonlinear relationships and multiple feedback loops are involved as is the case in most environmental systems. In contrast, computer models excel at tracking inter-relationships and may demonstrate counterintuitive results that can emerge from complex systems. Once developed to represent known or explicitly assumed relationships between land use and ecological and socioeconomic indicators of interest, a land use simulation model can be readily applied to explore the long-term and broad-scale implications of land use scenarios. Simulating the future effects of land use options allows land use strategies to be tested in order to improve instincts for managing environmental systems. Due to the complexity of ecosystems and the uncertain nature of driving variables such as climate and human behavior, land use simulation models are not able to predict the future state of an ecosystem. Rather, they are designed to foster understanding of how an ecosystem will respond to human actions, in essence allowing the user to practice resource management strategies prior to real-world implementation.

The primary purpose of a land use simulation model is to dynamically articulate current understanding of how land use impacts ecosystems. In so doing, a number of related benefits can be achieved. A simulation model can confront us with inconsistencies in our assumptions about land use and thereby direct land use policy reform. A simulation model can also direct research by exposing key knowledge gaps that limit capacity to simulate the future effects of land use to ecosystems. By providing an unbiased assessment of land use options, a simulation model can inform potentially divisive multi-stakeholder decision making processes. At a more general level, a simulation model provides an interactive tool for sustainable land use education and can motivate resource stewardship by demonstrating tradeoffs. For example, simulation models can help create awareness as to how quickly small incremental changes in land use can compound to large and profound transformations in the landscape.

Numerous land use simulation models exist, some of which are designed for specific ecosystems and others that are meant to be applicable to a diversity of ecosystems provided the appropriate inputs. When selecting or developing a land use simulation model for IRM, the following characteristics should be aspired for. The model should be sufficiently comprehensive to evaluate cumulative effects, which requires that the impact of the full suite of important human activities and natural processes to ecological and socioeconomic indicators of interest are tracked across large spatial and temporal scales. Transparency is necessary so that the underlying assumptions that lead to simulation outputs are apparent to those using the model and viewing simulation outputs. A land use simulation model is of little use to resource management planning unless it is facilitates learning by key participants in the planning process. Model accessibility to managers and stakeholders is therefore needed.

3.4. Adaptive Management

Due to the complexity of ecological and social systems involved in IRM, tradeoff analysis is inevitably limited in its capacity to compare alternative land use options. Understanding the inter-relationships amongst these systems is insufficient to consistently provide clear guidance for resource management decisions. Despite this uncertainty, resource management decisions must be made and these decisions affect ecological and socioeconomic values. Continuing status quo land use policy is itself a management decision with potentially serious consequences and, as a result, inaction until better knowledge is available is often an inappropriate strategy. Adding to the challenge of addressing management uncertainty is that conventional scientific experiments that manipulate simplified systems are ill-equipped to enhance understanding of complex natural resource management systems, and the variability of ecosystems implies that IRM knowledge must continually evolve.

The knowledge acquisition and flexibility needed to successfully apply IRM in the presence of uncertainty can be achieved through adaptive management. Adaptive management was conceived as a management strategy in the presence of uncertainty and a solution to the failure of research to reduce key resource management uncertainties. Under the approach, management and science merge as scientists and managers work together to experimentally manage ecosystems. The integration of science and management focuses research on important management questions, facilitates large scale experiments that are relevant to land use policy, and fosters effective knowledge transfer between scientists and managers. Despite its popularity and apparent simplicity, adaptive management has rarely been successfully implemented. The concept is frequently misinterpreted as trial and error management whereby a single "best guess" land use decision is universally applied and the effects to indicators of interest are monitored to inform land use adjustments if needed. Knowledge acquisition through this so called passive adaptive management approach is low due to the absence of experiments. Also problematic is the high degree of risk that results from universal application of a management strategy with uncertain outcomes. A preferred option is active adaptive management whereby alternative land use policies are compared using management experiments, a practice that greatly increases the rate of knowledge acquisition.

Management experiments should be targeted at key uncertainties that limit capacity to approximate the future outcomes of land use options. As with all experiments, experimental controls are needed to differentiate treatment response from the background variability of ecosystems. In the natural resource management context, controls are frequently referred to as ecological benchmarks. To characterize natural ecosystem function, an ecological benchmark should be representative of the region of management interest, undisturbed by land use, and of sufficient size to allow monitoring of ecosystem-scale behavior. Ecological processes such as natural disturbances and hydrological regimes are often large in spatial scale, implying that large protected areas (i.e. ecological benchmarks) are a pre-requisite for active adaptive management. Historically, society has constrained its ability to learn from land use experiments by not having ecological benchmarks of appropriate size, composition and proximity to make comparisons that generate appropriate dialogue and drive policy change.

3.5. Monitoring

In the context of IRM, monitoring is the repeated measurement of an ecosystem component over time and space to detect change. Monitoring provides an information feedback loop to assess the impact of management on ecosystems, thereby guiding when and how land use needs to be adjusted. By informing the public on the status of ecosystems, monitoring can build the support needed to alter established land use practices. While critical, the task of monitoring should not be underestimated in terms of its technical complexity and cost. Indeed, the majority of ecosystem-scale monitoring programs have failed to adequately inform management decisions.

Prerequisites for a successful monitoring program are well conceived and explicit management goals and indicators. The monitoring program can then be designed to track trends in indicators and stressors. Monitoring over large temporal and spatial scales is often needed because ecological problems are frequently characterized by long-term processes operating over large spatial scales. The paucity of successful large-scale monitoring programs may be attributed, in part, to challenges faced in achieving a sampling design capable of detecting indicator trends over ecological relevant scales. A key consideration when developing a sampling design is statistical power, which is the probability of detecting a change in an indicator if a change has occurred. If a low-power monitoring program is implemented, ecosystem changes may not be detected. The resulting illusion of stability can prevent management action required to prevent ecosystem degradation.

Sampling effort is positively related to power, and monitoring programs with sufficient power will often be expensive due to the natural variability of ecosystems. As a result, a cost-effective sampling design to efficiently allocate sample effort is essential. Due to financial limitations as well as long-term nature of ecosystem change, monitoring will often only provide meaningful information after many years of data collection. To achieve long-term stability of the monitoring program, it is advantageous to have an organizational subunit whose sole responsibility is monitoring. This is also useful for separating monitoring from resource management, thereby reducing the potential for resource management agencies to produce biased assessments of their effectiveness at achieving IRM goals.

3.6. Development Thresholds

IRM's focus on achieving both ecological and socioeconomic goals implies that development must be restricted to within ecological limits. Establishing the amount and type of development that is consistent with the maintenance of biodiversity and ecosystem services is a challenging problem for the field of ecology. If an indicator's response surface is nonlinear, the appropriate threshold is the point at which small changes in key drivers cause large changes in the indicator. This is especially true if the system of interest is characterized by multiple stable states whereby recovery from disturbance is feasible until a disturbance threshold is exceeded and the system permanently switches to a new, and potentially undesirable, stable state.

Nonlinear responses and multiple stable states are undoubtedly common in ecosystems. Some examples are striking such as the conversion of highly productive savanna rangelands to woody thicket in response to grazing pressure or the switch from clear to turbid lakes in response to changes in fish communities. However, thresholds between stable states are difficult to predict, can take years of research to establish, and may often be site-specific. As a result, objective thresholds are most often not available for indicators, with the notable exception of critical loads for air and water pollution. In the absence of objective thresholds, an alternative is to combine available scientific information with input from stakeholders regarding how much change is acceptable. As an example, stakeholders may establish an acceptable risk of population extinction as defined by a scientific model of a species response to stressors. While such a process can still be limited by uncertainty, it is more feasible than identifying critical thresholds in ecological or social systems. An added benefit is that the threshold incorporates stakeholders' perspectives and, as a result, is more likely to be understood and supported.

The emulation of natural disturbances is another promising approach for establishing development thresholds. Under this approach, pattern imposed by natural disturbances is used as a template to establish acceptable levels of development. The premise is that biodiversity will persist if land use approximates natural disturbances to which native species are adapted. In the terrestrial context, wildfire often has a dominant influence on ecosystem composition. Industrial disturbances, most notably timber harvest, can be designed to emulate the rate and spatial pattern of the fire regime in an attempt to maintain landscapes that provide habitat for native biota. In the aquatic context, water level is often a key driver especially at the interface of aquatic and terrestrial ecosystems. In the Florida Everglades, for example, implementation of a water level management regime that is consistent with natural hydrologic variability is a major component of the effort to restore that ecosystem. Some industrial disturbances, including roads, urban expansion, and industrial agriculture, are without a natural disturbance analogue. In such cases, the sensitivity of ecological components to disturbance must be used to establish thresholds that are consistent with negligible ecological effects.

3.7. Zoning

While thresholds can minimize the ecosystem degradation caused by industrial development, ecosystems are sufficiently sensitive to land use that protected areas are necessary to maintain the full suite of native species and ecosystem services. In addition, current understanding of ecosystems is insufficient to assign development thresholds with assurance that negative impacts will not result. According to the precautionary principle, protection is needed in the presence of this uncertainty to avoid irreversible ecosystem degradation. While protected area requirements will vary depending on the region and goals, large areas are typically needed to support conservation objectives. Protected areas targets in the conservation planning literature frequently lie in the range of protecting 50% of a region in order to maintain representation of ecosystem types and native species. Protecting large proportions of landscapes and imposing development thresholds supports ecological goals but limits economic development. The conflict between ecological and socioeconomic goals is likely the largest challenge faced when pursuing IRM. Much work remains, however, to correctly internalize the full suite of ecological services into economic performance metrics that currently drive resource management policies. As societies embrace the concept of natural capital, the perceived loss of economic opportunities in landscapes containing ecological integrity will be lessened.

Land use zoning provides a mechanism to reduce, although not eliminate, the "economy vs ecology" conflict at a regional scale. Zoning explicitly recognizes that all goals can not be achieved via uniform application of land use, and instead applies varying levels of land use intensity to distinct portions of the landscape. An example of a zoning strategy is the triad which divides the land base into three categories: mixed-use, protection, and intensive-use. The relative size of each zone depends on the goals of the IRM process. High resource production generated by the intensive-use component of the landscape makes up for the drop in production caused by protected areas and implementing development thresholds in mixed-use areas. As a result, it may be possible to maintain socioeconomic contributions while protecting the integrity of the ecosystem. The triad was developed as a strategy to maintain timber supply through forest plantations while increasing the use of sustainable forestry practices and protected areas on the remainder of the landscape. The triad is equally applicable to the production of other commodities including fuel and food.

4. Integrated Resource Management in Practice

Full implementation of IRM requires a paradigm shift not yet realized in most regions. On the contrary, IRM terminology has been observed to help resist required resource management reform by providing an ambiguous discourse that appears progressive but is rarely backed up by action. If properly adhered too, however, the concepts that form IRM offer great potential for balancing a broad range of resource management goals. One promising example of IRM is the Dehcho Land Use Plan. The plan was prepared to form part of an integrated land and resource management regime for the Dehcho Territory, a 45 thousand km^2 region in the southern Northwest Territories, Canada. The Dehcho Territory is relatively undeveloped but contains a rich natural resource base with potential for gas, oil, forestry, agriculture, and tourism development. Although currently the subject of negotiations and not yet implemented, the land use plan is a rare example of resource management planning that is consistent with IRM concepts.

Reflecting the intent of IRM, the overriding goal guiding plan preparation was "finding a balance between development opportunities, social and ecological constraints, which reflect community values and priorities while taking into consideration the values of all Canadians". Vertical integration of government policy was promoted by including representatives from three levels of government. Communities and planning partners were extensively consulted to create a vision for the territory, and goals were established that address a broad spectrum of human and ecological values including air and water quality, biodiversity, wilderness, culture, economic development, education, employment, health, and social well-being. Research on ecological, cultural, and economic values provided baseline information from which to develop a plan that was consistent with these goals. This included innovative workshops and mapping exercises designed to apply both traditional knowledge and scientific information.

During preparation of the plan, five land use options were compared using an economic model to help select a plan that achieved an acceptable tradeoff between economic development and conservation. A preliminary scenario analysis that simulated the long-term cumulative effects of land use for part of the territory confirms that the plan balances economic development and conservation. The plan itself divides the territory into zones that permit varying levels of land use. Industrial development is prohibited on approximately half of the landscape to protect ecological and cultural values. Industrial development is permitted across the remainder of the territory but is regulated by thresholds intended to limit ecological disturbance to within acceptable limits. Thresholds exist for corridors and roads, habitat availability, minimum patch size and core area, and stream crossing density. The thresholds are to become part of the permitting process for all types of land use, thereby integrating land use regulation across sectors. The plan explicitly acknowledges that data gaps limit the accuracy of thresholds and other components of the plan, and research and monitoring tasks are identified to reduce data gaps through an adaptive management framework.

5. Conclusion

With each environmental crisis, the inability of established resource management ideology to balance development and conservation becomes more apparent. IRM’s collaborative, comprehensive and proactive approach presents a promising solution. Implementation of IRM has lagged, however, perhaps due to the large shift in policy that is required. Although IRM and related concepts such as consensus-based decision making, adaptive management, and land use thresholds have been written about and discussed for decades, real-world application is rare. One can only hope that this inconsistency between theory and practice is remedied in the near-future as humanity strives to cope with unprecedented resource management challenges and demands.

Glossary

Active adaptive management	**:** A systematic process of modeling, experimentation, and monitoring to compare the outcomes of alternative management actions.
Adaptive management	**:** Under adaptive management, reducing uncertainty becomes an objective of management, and policies are treated as experiments. The ecological effects of management are monitored, and policies are adapted depending on observations.
Biodiversity	**:** The variety of genes, species, and ecosystems in a given place or the world
Cumulative effects	**:** Impacts caused by an action in combination with other past, present or future actions; or, impacts resulting from multiple types of activities occurring on the same landscape.
Ecological monitoring	**:** Repeated measurement of an ecosystem component over time and space to detect changes.
Environmental degradation	**:** Occurs when alterations to an ecosystem degrade or destroy habitat for many of the species in the system.
Eutrophication	**:** An increase in the amount of nutrients, especially nitrogen and phosphorus, in a marine or aquatic ecosystem resulting from human activities.
Fragmentation	**:** Process by which a natural landscape is broken into small parcels of natural ecosystems from one another in a matrix of lands dominated by human activities.
Integrated Resource Management (IRM)	**:** Approach to managing environmental and resource issues characterized by proactive, holistic and system-based principles.
Landscape	**:** A large-scale mosaic of ecosystems often consisting of a matrix with patches (small ecosystems) imbedded within it.
Management threshold	**:** Use of pattern imposed by natural disturbance as a model for resource management.
Passive adaptive management	**:** A more formal approach by which historical information is explicitly used to select what is thought to be the single best management policy.
Utilitarian resource management	**:** Management for harvest of featured species and control of unwanted species through farming, fishing logging, and other similar activities.

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Biographical Sketches

Matthew Carlson completed a Master of Science in conservation biology at the University of Alberta in 2001 where he investigated cost-effective sampling designs for monitoring biodiversity. He is an Ecologist with the ALCES Landscape Ecology Group and the Canadian Boreal Initiative in Ottawa, Ontario. Integrated resource management projects include scenario analyses to evaluate the sustainability of land use options in a range of landscapes including the Mbaracayu Biosphere Reserve, Paraguay and the Mackenzie Valley, Canada; assessing the state of Canadian national parks; and developing a web-based simulation tool to teach sustainable land use concepts in Alberta, Canada (www.albertatomorrow.ca).

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