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The Role of Information Systems in Sustainable Forest Management: Comparison and Future Direction

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Abstract
Forest management is gradually changing from a model of maximum economic yield for timber management to a multi-objective, sustainable practice using criteria not just for timber production but for carbon storage, recreation, and wildlife preservation. Policies could encourage stakeholders to identify and assess the economic interests of key actors and hold them accountable for sustaining forest ecosystems. Decision-makers need access to a combination of ecological and socio-economic information for making proper business decisions. The literature suggests that economic values have been rarely utilized in forest decision support systems. We posit that managing for sustainable forest ecosystems requires adequate economic data. This paper provides a critical review based on subjective analysis of six existing forest management information systems and their extent of economic valuation analysis. We conclude that three of the six models are unclear for their application of non-market economic valuation, while the other three models indicate no usage. We posit that although reliable and valid non-market values can be difficult to obtain because predicting stakeholder behavior and preferences are not always directly observable, future research should attempt to integrate such measures (e.g., cost-benefit analysis, contingent valuation, hedonic property value) into forest information systems for improving decision-making and stakeholder negotiation, and increasing forest ecosystem sustainability.

Keywords: Green IT, economic modeling, ecosystem management, forest information systems, sustainability

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INTRODUCTION

Sustainable forest management relies on effective information. Forest information systems (FIS), also referred to as decision support systems (DSS) were initially intended for timber, cultivation and pest management (Reynolds, 2005). Forest management has modified its emphasis from maximizing profits for timber production to sustaining multi-objective elements such as carbon storage, recreation, and wildlife preservation within the ecosystem, (Thomas, 1995). Ecosystem management is a relatively new concept in forest planning. Although still in theoretical development, forest ecosystem management has shifted to larger spatial scales, longer time intervals with greater emphasis on socially acceptable and economically feasible management decisions (Reynolds, 2005). The failure to account for multi-objectivity and biodiversity has led to environmental consequences. Forest information systems can play a critical role in facilitating sustainable forest management practices and policies, and shaping beliefs about our environment (Melville, 2010). Society sets numerous, vague and conflicting preferences and goals. Ideally, corporate social responsibility practices which use self-regulation as part of a company’s business model can be one venue to balance preferences, goals and profits with ecological sustainability. Conversely, policies could encourage stakeholders to identify and assess economic interests, preferences and goals of key actors and hold them accountable for sustaining forest ecosystems. But, finding the right key actors, stakeholder consensus and the time and effort that they contribute in the decision-making process can be a barrier for sustaining forest ecosystems. Regardless of the approach, decision-makers need access to ecological and socio-economic information for making proper management decisions.

Sustainable forest management includes the integration of economic and ecological objectives (Li et al., 2000). Whether for direct-use (timber management), indirect-use (soil conservation or carbon storage) or non-use (forest protection), total economic value of a forest ecosystem, entails a financial return (Adger et al., 1994, Pearce, 1993). Non-market values have become important in environmental economics (Adamowicz et al., 1998). Non-market values are acknowledged at the hypothetical level and can be measured by conducting a cost-benefit analysis through stated preference techniques such as contingent valuation or revealed preference techniques such as travel cost and hedonic pricing. Presently, forest information systems primarily provide integrated data for soil type, forest cover type, road networks, which contain minimal economic information. The optimization of direct-use economic values has been built into forest information system models (Balteiro, 2004). Optimization tools like Geographic information Systems are used for the management of spatial data, system queries and summary display (Rondeaux, 1991). Similarly, forest expert systems provide cultivation prescriptions that meet ecological objectives for timber management, vegetative growth, wildlife, and forest health (Nute et al., 2004). Geographic information systems and forest expert systems both lack passive non-use economic values. We posit that managing for forest ecosystems requires reliable and valid socio-economic data. This paper provides a critical review of existing DSS that deal with multi-objectivity and biodiversity that is required for sustainable forest management. We subjectively compare how they function, inherent strengths, capabilities, limitations, stakeholders they service and extent of economic estimation in the decision-making process. We answer the following research questions. To what extent do forest information systems –

- To what extent do forest information systems treat multi-objectivity and biodiversity required for sustainable forest management?
- To what extent do forest information systems adequately provide socio-economic information for manager and stakeholder decision-making?

- To what extent do forest information systems adequately analyze estimated use and non-use economic values?

BACKGROUND

In the long term, economic sustainability depends on ecological sustainability.
— "America's Living Oceans" (Pew Oceans Report, 2003)

The Concept of Forest Ecosystem Management

Decision-makers and stakeholders may vary in their views of ecosystem management. The concept continually evolves by social, economic, political and policy implications (Kohm and Franklin, 1997). However, the main goal is the long-term protection of the environment for an increased demand by a growing population that needs resources for maintaining and improving well-being (Rauscher, 1999). Ecosystem management requires multi-objective information systems that have quality, applicability and effectiveness, but not to replace stakeholder reasoning in the decision-making process (Janssen, 1992; Larsen et al., 1997; Reynolds et al., 1998). Given its complexity, three levels of organization are necessary for implementing a setting for ecosystem management. In Figure 1, the three levels are the decision-making environment, organization and processes, and decision support systems decision-makers and software support tools (Adelman, 1992).

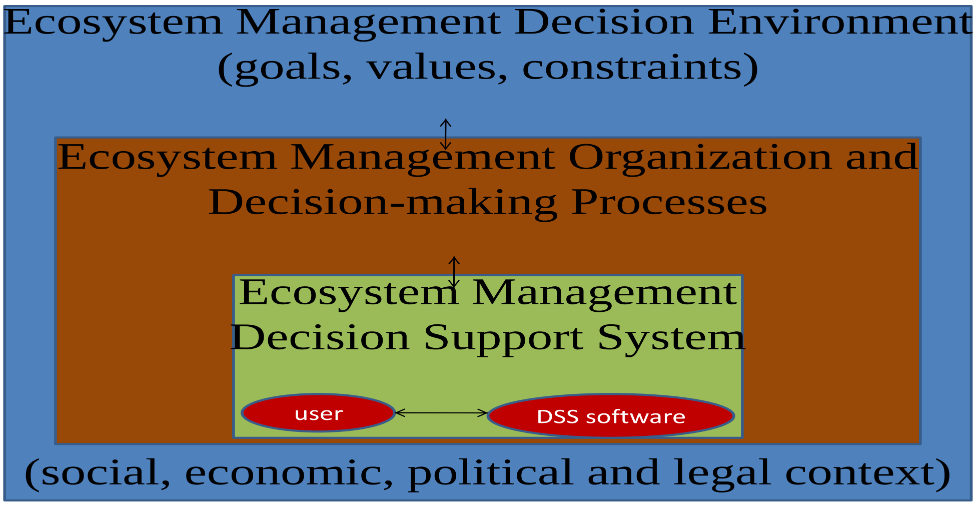

Figure 1. Three levels of organization in ecosystem management decision-making process. (Adapted from Rauscher, 1999)

The management environment is a complex network of stakeholders and decision-makers with different values, goals and constraints. In figure 2, the management environment is divided into a management and ecological subsystems. The management subsystem consists of stakeholders and managerial decision-makers. The stakeholders, for example, are landowners, special interest groups and the public. They are part of the community that makes direct-use of the ecological subsystem. The decision-makers, for example, managers and specialists, determine objectives and evaluate risks and value. Decision-makers are influenced by socio-economic and political pressure from local, national and international influences. As part of the social process, stakeholders and decision-makers negotiate values, goals and constraints for public choices and needs. The ultimate goal is to achieve a socially acceptable, economically feasible and ecologically sustainable result (Rauscher, 1999). Group negotiation is the most difficult part of the management process (Bormann et al., 1993). As goals and conditions change, so can value associated with the object that is judged (Garland, 1997). Stakeholder, public preferences, negotiation conflict skills, and economic valuation are necessary for understanding forest ecosystem management.

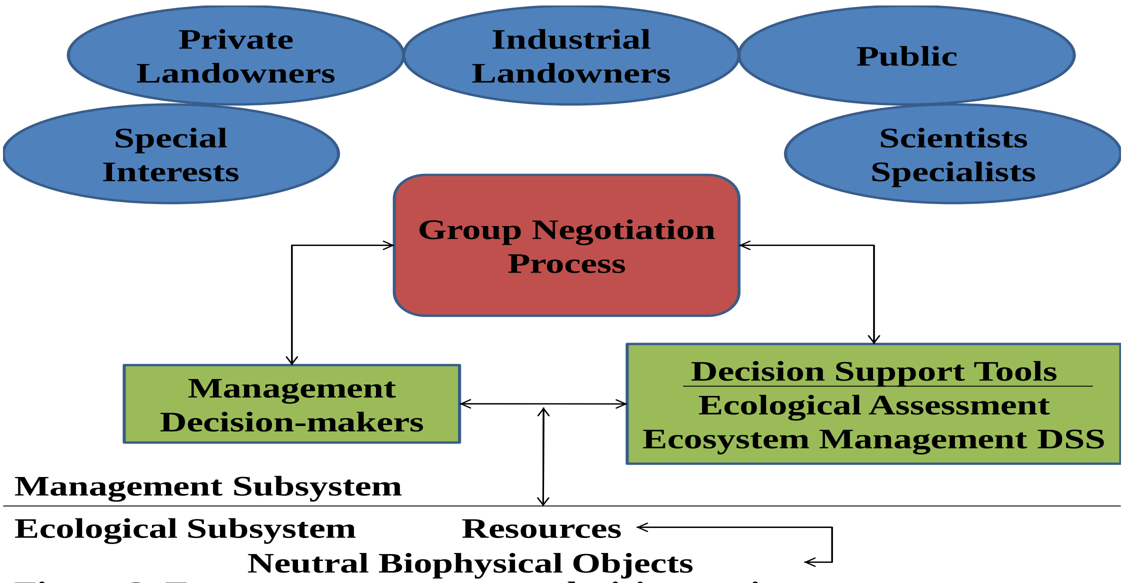

Figure 2. Ecosystem management decision environment. (Adapted from Rauscher, 1999)

Economic Valuation

Economics is a way for a society to manage and provide necessities for human well-being. The economic theory of value is based on satisfying human needs and wants, thus human-centered for increasing individual welfare. Valuation is a measure of contribution for human welfare. Some economists believe economic value is instrumental, a means for some other use (Costanza and Folke, 1997). The primary purpose of instrumental economic value in environmental planning is to resolve management issues. Valuing the environment is a human-centered way to recognize and value goods and services, manage for multiple objectives, and recognize and sustain biodiversity. Other economists believe economic value is intrinsic – a value and perspective not derived from utility by someone else, but "an end-in-self, not just a means to another's ends" (Callicott, 1989). The aesthetic value of Mt. Kilimanjaro has economic value in itself. How do we compare the direct market value of timber products from forests, for example, to the picturesque non-use value of Mt. Kilimanjaro? The value for timber is derived by direct market methods, the value for what it is worth in today's market, and is more tangible to derive. The picturesque view of Mt. Kilimanjaro is more intangible and is estimated by elicitation methods that may underestimate or vary in its total value. As a limitation, use and non-use environmental services cannot be determined or estimated on an even playing field. Freeman (2003a) provides a good example – "an acre of wetland might trade in the market for land on basis of its value for commercial or residential development; but this value could be quite different from the value of its services as wildlife habitat and as a means of controlling floods and recharging groundwater aquifers."

Labor, capital and natural resources are the three most important factors for the production of economic goods. For stakeholders and managers, quality information about natural resources is more limited than labor and capital. The natural resource environment is complex and produces four types of service flows (Freeman, 2003b): material input to the economy, life-support services, variety of direct and passive use values, and disperses, transforms, and stores the waste products of economic activity. For example, a forest not only provides wood and fiber for human needs, but also services for outdoor recreation activities (i.e. hiking, scenic vistas), stream flow regulation, soil erosion control, atmospheric carbon dioxide absorption, and protection for a variety of species (Freeman, 2003b). Far from this idealist perception, forests are typically managed for basic demands like fuel and shelter. These demands have created deforestation in developing regions such as the Amazon, Indonesia and developed countries like the U.S and Canada. The valuation for alternative environmental services may be useful globally.

METHODOLOGY

It is doubtful that one model can fairly assess forest management. A system appropriate for local analysis may not be appropriate at the regional level. A system used for risk and uncertainty management may not be appropriate for stakeholder collaborative planning. A model may simulate timber management and harvest strategies better than other factors within the ecosystem. This paper compares six decision support systems in forest and biodiversity management. We use qualitative research with subjective analysis that focuses on a literature review and website descriptions. There are limitations for qualitative content analysis: trustworthiness, credibility, dependability and transferability (Granheim, 2004).

ANALYSIS

Table 1. Analysis of forest and biodiversity models

System	Approach	Socio-economic	Key players
CLAMS	• simulation	• employment income, timber value and production • contingent value of biodiversity	• managers • landowners • policy-makers • analysts
LUCAS	• simulation	• econometric model outputs • economic and social information • social choices and regulatory action	• managers • land owners
MRLAM	• simulation • optimization • evaluation		• managers • land owners
WBAFA	• simulation • evaluation		• managers • land owners • “diverse stakeholders”?
HARVEST	• simulation • evaluation		• managers • researchers • land owners?
NED	• simulation • evaluation	• eco- socio-economic interactions • timber outputs • social negotiation/learning ability	• natural resource managers • clients

Coastal Landscape Analysis and Modeling System (CLAMS) **Harvest (HARVEST)**
Land-Use Change and Analysis System (LUCAS) **NED (NED)**
Multi-Resource Land Allocation Model (MRLAM) **Willamette Basin Alternative Futures Analysis (WBAFA)**

CONCLUSIONS

Sustainable forest management is emerging and can complicate traditional forest management practices. Sustainability of the forest ecosystem has always been a concern of ecologists, biologists and environmental scientists. In contrast, forest managers and economists are concerned about the forests ability to provide wood products for public demand. This study aims to describe and compare six advance information systems used in sustainable forest management in terms of how they function, inherent strengths, capabilities, limitations, stakeholders they service and level of economic valuation in the decision-making process. We follow a qualitative content research methodology, and compare and summarize advanced information systems used in forest biodiversity management.

Limitations of Environmental Valuation Methods

Environmental valuation methods are generally based on stated preferences for a hypothetical scenario or revealed preference/observed behavior for an individual. Three limitations are offered by economists (Brown. 2003). Individuals may have inadequate information about the nature of the environmental service flows and how service flows affect their well-being (especially indirect and intermediate services). And, individual choices and responses to valuation questions may be inhibited by their income, and the nature of the preferences relevant for public policy decisions. The UNEP (1998) found two general methodological limitations for environmental valuation – the availability and quality of information (inputs) and the quality of the estimated value that was produced (outputs). Valuing environmental amenities for future generations can be difficult to achieve (Brown, 1984).

Future Use and Limitations of Expert Systems in Forest Ecosystem Management

Even though total economic value for the compared models is unclear, information systems should develop objective measures for the integration of economic value. Given the varied utilization of forest information systems in any given region, future research should also investigate socio-economic, policy, and technical drivers and inhibitors for the adoption of such systems. Even though various systems are implemented around the world, the level of utilization for stakeholder and decision-maker participation, and economic value and benefits of environmental services are unclear. Our analysis illustrates that most of the systems studied need to improve socio-economic information. If a system offered any economic information, it was based on the market value of timber products rather than other non-timber or environmental services. From a traditional forest management perspective, forest information systems should recognize and report the economic effects of various cultivation practices that are important for forest management. It is unclear if the decision support system addresses the economics for cutting and logging strategies, and disturbance effects for soil, water, and wildlife within the forest ecosystem. The economic value of soil, water and wood would help assess the socio-economic impacts for policy decision-making. Extending forest information systems to include economic value information could improve decision-making and stakeholder negotiation, and increase ecosystem sustainability. Future research could study the effectiveness for such components on systems integration.

Traditional forest information systems provide inventory updates and timber market values as part of their economic inputs. Future research in sustainable forest management should look at site specific cultivation treatments or investments, from a broad environmental approach and possibly map economic value of ecosystem assets. Forest information systems do not adequately integrate spatial relationships, which affect ecosystem functions. Future research can study the spatial arrangement of forest stands and how it affects the value of wildlife and other non-use functions. In addition, the total economic effects (use and non-use) of clearing a forest ecosystem in exchange for agricultural production can be studied.

Physiological processes (e.g. carbon absorption, nutrient cycling and water balance) are concern for its effect on photosynthesis and climate change. Productive tree growth variation can be reduced by the integration of tools to monitor physiological processes throughout the ecosystem. Sustainable measures may involve national and international policies, treaties and agreements due to the global nature of managing ecosystems. Future research could examine the economic benefits of forest information systems monitoring physiological processes. Green information technology may be a solution to sustainability.

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