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SUSTAINABLE FORESTRY DECISIONS: ON THE INTERFACE BETWEEN TECHNOLOGY AND PARTICIPATION

Anna Lawrence[1], Amy Stewart[2],
[1]*Centre for Human and Ecological Sciences, Forest Research, Alice Holt Lodge, Farnham, Surrey GU10 4LH, UK*
[2]*Forest Research, Northern Research Station, Midlothian, EH25 9SY, UK*

Abstract. This paper explores the evidence for successful participatory forest decision-making which uses computer-based tools. Both the technical and social complexity of forest decision-making are increasing, as managers seek to forecast and provide goods and services on a sustainable basis, while also interacting with a wide range of stakeholders. The paper draws on forest science and management literature, environmental studies and social science to review experiences of success in combining the challenges of participation and technological advancement. It shows that, while there is no shortage of literature outlining methods and processes, the perceptions, attitudes and values of the stakeholders may constrain implementation. The approaches rely on decision support tools, whose workings may be incomprehensible to some of the stakeholders. The paper highlights the concept of 'usability' to assess the value of such tools, and uses case studies to illustrate the need for users to contribute to the design and testing of the tools. More documentation is needed to help understand which tools are used, adopted, and lead to useful outcomes.

Keywords: participation; stakeholder engagement; forestry institutions

1 Introduction

The complexity of forest management decisions has been increasing for the last two decades. The Earth Summit in Rio in 1992 brought Agenda 21 and the Forest Principles, with a focus on multi-purpose forestry, and participation of local communities and indigenous peoples in the process of sustainable development (Slee 2007, Younis 1997). In Europe, legislation protecting species and habitats such as the EC Habitats Directive, and policy protecting forest biodiversity, affect forest management decisions more than, for example, agricultural decisions due to the long rotation periods associated with forestry, and the higher biodiversity of forests (Ray and Broome, 2007; Rauscher et al., 2007). In many parts of Europe and North America, forestry is increasingly integrated into both sustainable rural development, and urban sustainability, requiring foresters to interact with a range of other stakeholders (Konijnendijk et al. 2006, Lewis and Boulahanis 2008, Wiersum and Elands 2002). Prevailing political philosophies encourage public involvement in decisions about allocation of public resources and benefits (Mendoza and Prabhu 2006). The shift to multiple ownership (for example in Finland and Portugal), where forests are increasingly owned by consortia or large numbers of heirs, can mean that every action taken in the forest needs to be agreed by every shareholder (Laukkanen, 2002; Martins and Borges, 2007). Most recently, forestry is seen as an integral part of the response to climate change both for mitigation and adaptation (Jackson et al. 2008; Read et al. 2009).

These demands are not always mutually compatible. In many parts of the world, forests are expected to provide simultaneously for a wide range of demands, supply a wide range of products, and play a part in mitigating the greatest environmental challenge currently facing humankind. Foresters are often expected to work with local communities, land use colleagues, and political stakeholders, whilst at the same time drawing on new scientific knowledge about forests, mitigation and adaptation, as well as local knowledge about less conventional forest products (Duchesne and Wetzel 2003, Emery 2001). These demands are not universal, but they represent significant trends and norms in industrialised countries.

For some, this range of demands understandably represents a threat. New social and communication skills are required, while at the same time new technical knowledge is needed. The increased attention to forests brings concerns that a more rigid, administrative, regulation-based forestry will replace site-specific, professional decision-making (Kimmins 2002). Indeed forestry is a science where local expertise and experiential knowledge is valued perhaps more than in other environmental sciences (Fazey et al. 2006, Lawrence 2009, Ogden and Innes 2009b). Clearly, decision-making cannot be solely site-based, nor solely professional. With the global spotlight on sustainable forest management, decision-making will be expected to engage with ever greater scientific complexity and uncertainty, political and social uncertainty, and a wider range of stakeholders. Ohlson et al. (2005) echo many when they call for adaptive management, based on an iterative approach which combines analytical techniques and structured negotiations between stakeholders.

This paper reviews progress towards combining the analytical technology to address complexity, with participation by a range of non-conventional stakeholders.

2 Decision support and participation

Decision support is widely seen as necessary when the process of making decisions is so complicated that the decision makers are unable to compare the alternatives by themselves, and find an optimal alternative (Vainikainen, Kangas, and Kangas 2008). Boerboom (2010) reviews a wide range of definitions for decision support systems (DSS), noting that some refer to the *processes* used in developing or using those systems, while others refer to the *tools and models*. Typically they use computer modelling programmes developed by experts (Sheppard and Meitner 2005). The challenge then is to make such tools compatible with the engagement of multiple stakeholders.

In this paper we aim to review the relationships between stakeholders, processes and models. Because of the range of definitions referred to above, we avoid the term 'decision support system' and instead focus on the roles of processes, tools and models in participatory decision-making for sustainable forest management.

This allows us to break down the focus of the paper and work towards a framework that helps to analyse this diversity. Participation, or the involvement of a range of stakeholders, can be examined at various stages: the development of models; the use of models; and the uptake and effectiveness of such models. These tools and models themselves consist of several different kinds. To simplify the situation, we explore two broad categories:

1. tools which *support participatory decision-making,* enabling analysis of choices of diverse stakeholders and selection of the most favoured option;

2. tools used to *generate the forest management alternatives* between which stakeholders can choose (e.g. forest planning tools; climate change models).

Taking all of these variables into account, we proceed as follows. First we review the overarching processes which seek to combine stakeholder involvement with modelling in forest decision-making, the methods and attitudes of stakeholders towards participation. We then review ways in which tools have been used to support and analyse participatory decision-making. Then we review the ways in which technical tools have been used to generate forest management alternatives, focusing on the 'usability' of those tools. Finally we look at adoption and application of such tools and processes, and consider evidence about the effectiveness of using them.

3 Processes for involving stakeholders in participatory decision-making

Despite calls for more public participation in forest management decisions, such approaches have not widely been seen as successful. One reason is an apparent lack of rigour, structure, and analytical framework for such processes, making strategic choices between competing forest management alternatives difficult to achieve (Mendoza and Prabhu, 2006). As a result there is growing recognition of the need for methods and tools which help to bridge the technical expertise of scientists, and the knowledge and values of other stakeholders; and which combine structured modelling and DSS with participatory approaches.

In order to combine modelling and participation approaches, modelling must be made transparent, simple and usable by non-technical users. Indeed, transparency is crucial for the social acceptance of decision-making tools, methods, and their ultimate outcomes (Martins and Borges 2007). At the same time, modelling must remain robust and rigorous enough to accommodate the scope and complexity of natural resource management (Mendoza and Prabhu 2006).

Sheppard and Meitner (2005) suggest a framework of criteria for designing an effective process that leads to participant satisfaction, mutual learning and process credibility. It includes:

1. Broad representation of stakeholders;

2. Open access to the process for all stakeholders;

3. A clearly structured decision-making process, with inclusion of stakeholders in the process design and transparency on how final decisions will be reached;

4. An engaging process which attracts stakeholders and encourages them;

5. Easily understandable and accurate information;
6. Multi-attribute analysis methods structured around systems of sustainability criteria and indicators;
7. Spatially explicit and temporal forecasting of ecological, social and economic values over fairly long periods, with varying degrees of uncertainty.

Martins and Borges (2007) suggest an iterative framework for participatory planning which incorporates quantitative and qualitative approaches, modelling and participation. This consists of a simplified three-step planning process with feedback loops between the steps, recognising that the three steps are interdependent and that some methods and tools may be useful at more than one stage of the planning process.

Step 1 – Problem identification involves the acquisition and analysis of information to understand and to define the management problem. Identifying the relevant stakeholders is an important part of structuring the decision problem (Pykäläinen et al., 2007). Once identified, the aim is to gather information to identify and justify the various management objectives and constraints that influence the different owners' management decisions. Computer-based tools can be used in this process which complement but do not replace face-to-face meetings and human interaction. Martins and Borges (2007) argue that user-friendly DSS and knowledge-based systems can 'provide capabilities for enhanced problem definition' in participatory meetings and work sessions, and promote communication, understanding and trust.

Step 2 – Problem Modelling involves model building to represent both the relations between management alternatives, outcomes of interest and policy scenarios. Problem modelling is an adaptive process which allows further structuring of information but may also identify further information needs that require feedback loops between identification and modelling. Tools and methods used in step one may be usefully applied in this stage to further elucidate the relationships between management alternatives and predicted outcomes (Martins and Borges, 2007).

Step 3 – Problem solving. This final stage of the decision process is about coming up with a solution, for example, the design of a forest plan. Methods used for prioritising management alternatives in the problem modelling stage can also be employed when selecting the management plan, and problem solving is an iterative process which could entail returning to the other two stages of the planning process.

These authors address the role of tools and models in the overall process, but another reason for poor perceptions of success, is that the participatory process itself is a challenging one which requires particular skills and experience. There is a very wide literature on this, often in handbooks produced by agencies promoting community development (e.g. Pretty et al., 1995).

Some challenges are however specific to the values and expectations which stakeholders bring to forest management, and we discuss these in the next section.

4 Factors affecting stakeholder involvement in participatory forest decision-making

A few recent papers describe some of the challenges of involving stakeholders, not as a technical but as a cultural challenge. For example, Tuler and Webler (2010) provide evidence to show how different social and environmental contexts affect stakeholders' preferences for participation. A wealth of work from Canada questions the selection of representatives on decision-making panels and highlights a tendency for committees to include those with existing contacts and power (Parkins 2006, Parkins 2010, Reed and Varghese 2007). Furthermore, stakeholders may differ in their interest or willingness to engage with the specific challenges of forest decision-making. Taking the example of envisioning different forest future scenarios, Frittaion, Duinker, and Grant (2010) find that participants differ in their abilities to 'suspend disbelief', and are affected partly by their past experiences and expertise.

A further aspect that affects the adoption of models and processes, relates to the culture of the forestry profession (and other land management organisations). As Borchers (2005) points out, adoption of technological innovations by organisations is the outcome of a trade-off between organisational culture and the benefits brought by the technology. Several authors draw attention to the particularly conservative culture of natural resource management organisations. For example, Linkov et al. (2008) point to an established mindset which aims to achieve optimization (of timber production, for example) rather than adaptation. Allan and Curtis (2005) describe the 'current dominant approach to managing nature' as failing to value reflection, learning and complexity. Others point to a culture of ingrained excessive risk aversion (Borchers 2005, Maguire and Albright 2005).

However, while forestry is often hierarchical and bureaucratic, and is influenced by common historical origins, we cannot assume that this characterisation of forest management is universal and static. There are important variations between countries (Vandergeest and

Peluso 2006). A study by Hoogstra and Schanz (2009) for example shows important differences in foresters' attitudes to planning, between two neighbouring countries.

5 Tools used to facilitate participatory decision-making

The processes outlined above indicate different roles for models, to ensure technology and stakeholders are combined effectively. Criterion 7 in Sheppard and Meitner's list, and step 2 in Martins and Borges' approach (problem modelling), deal with usable forecasting tools, which we address in the next section.

Criteria 3 and 6 in Sheppard and Meitner's list (clearly structured process, and multi-attribute analysis), as well as steps 1 and 3 (problem identification and problem solving) in Martins and Borges' schema, can all be supported by tools to help assess options. In this section we briefly indicate the range of tools that are being developed to assist with this.

Both quantitative and qualitative tools are used, sometimes in combination. Taking the quantitative first, participatory processes can be employed to investigate owners' or stakeholders' preferences which can be converted into scaling constants, and then aggregated. For example, quantitative multi-criteria analysis (MCA) typically focuses on evaluating alternative management scenarios across a range of different criteria and indicators, creating a matrix within which stakeholders can assess predicted outcomes of each scenario (Sheppard and Meitner, 2005). Public participation in such an approach involves stakeholders weighting quantitative and/or qualitative criteria or management objectives which can be aggregated into scores for each scenario. Diaz-Baltero and Romero (2008) have reviewed such approaches comprehensively, focusing on multi-criteria decision-making (MCDM) and in particular group decision-making (GDM).

Alternatively, voting models using social choice theory can be utilised. Stakeholders will inevitably have different aims, objectives and values in relation to the forest and while these will often be contradictory, they need to somehow be made commensurable to find the best solution or at the very least, a good compromise solution (Kangas et al. 2006; Laukkanen et al. 2002). Social choice theory aims to assimilate these individual preferences into one collective choice made up of voters, choice alternatives, information about voters' preferences and an 'aggregation device' (voting model, voting procedure or voting method).

The application of quantitative modelling approaches is limited by data availability. Furthermore, social and cultural aspects that influence management and stakeholder expectations can be difficult to capture quantitatively. In such cases qualitative modelling may be more appropriate. Unlike quantitative modelling approaches, strict qualitative problem modelling approaches focus on the facilitation of discussion for consensus building rather than on formally aggregating individual stakeholder preferences and objectively analysing consistency among individual preferences (Martins and Borges, 2007).

Cognitive or causal mapping is a tool that can be used to represent complex decision problems (Mendoza and Prabhu 2006). Initially, ideas and concepts are generated with the active participation of all stakeholders and are then organized into a 'map'. The ideas are shown as nodes, and the causal links as arrows (with the direction of the arrow showing the direction of influence). In this way they can improve understanding of the relationships and dynamics of a system. Cognitive maps can then be further analysed. For example, the 'domain' of a factor can be explored, which reflects the amount of influence or tactical significance a factor has. The 'centrality' or 'strategic significance' of a factor can also be examined by looking at a factor's scope of influence through its direct and indirect relationships with other factors. The 'criticality' of a factor is also a useful avenue of exploration and can be determined by examining the number of 'critical' nodes linked to it. Cognitive mapping can be taken a stage further where there is more information or experience about different factors to show the system dynamics. Here the relationships between factors are represented as positive or negative and circular causal loops are introduced.

Tools such as Strategic Option Development and Analysis (SODA), which builds on cognitive mapping, can be employed to aid understanding and agreement within the group, and structure subjective concerns and competing objectives through workshops, interviews and analysis (Martins and Borges, 2007).

However, these qualitative tools, while useful in some resource management situations, only provide insights at the general level (Mendoza and Prabhu 2006). Other situations may require more detailed analysis and evaluation. Mendoza and Prabhu (2006) suggest that in these instances, Fuzzy Cognitive Mapping (FCM) may be appropriate, which incorporates quantitative modelling and allows for analysis through simulation. 'Fuzzy logic' is used to extend the ability to tackle imprecise information (Martins and Borges, 2007). However, to be able to use this modelling technique, more information must be known about the dynamic relationships between factors within the system than is the case with the other two cognitive mapping models. This technique for problem modelling can involve the use of logic models and Multi-Agent Systems (MAS) approaches. However, it must be acknowledged that combining inherently qualitative nodes or concepts with quantitative or tangible variables creates analytical difficulties and can lead to loss of precision and oversimplification (Mendoza and Prabhu, 2006).

At the problem solving stage, Martins and Borges (2007) suggest that heuristic approaches may be most appropriate to deal with the complexity of multi-objectives and multi-owner scenarios, although linear and goal programming can also be used. Qualitative approaches can also be used in this stage, using projections made by stakeholders based on their experience and expectations' (Martins and Borges, 2007).

GIS combined with visualisation tools can be important components at any of these stages. GIS can help with targeting land use priorities (van der Horst 2006). Sheppard (2005) discusses the potential of spatial or visual imagery for eliciting meaningful public responses to plans. However, like many tools described here, visualization tools can be susceptible to misrepresentation and should, therefore, be used with caution (Martins and Borges, 2007; Sheppard, 2005).

While all of these tools are used to facilitate discussion and decision-making by stakeholders, some of them are at the same time generating options interactively with the stakeholders. The boundary between 'facilitation tools' and 'forecasting tools' becomes blurred when stakeholders are engaging with the content of models. In the next section we look at how the suitability of tools can be assessed, for use by different stakeholders.

6 Tools used to generate options for participatory decision-making: usability issues

If a wider range of stakeholders are to engage with these models, rather than simply provide criteria to be used in the models, or vote on the options generated by the models, those models must be designed to fit the needs of the users. Such needs will not match those of conventional forest decision makers. For example, in a survey of DSSs, Greer et al. (1995 cited in Stephens and Middleton, 2002) found that the complexity of the user interface employed by a DSS is one of the most limiting factors in their uptake and use.

The concept of 'usability' is valuable here. Usability is a term used to assess a range of information-based tools, from computer systems to participatory species identification guides. The ISO standard ISO 9241-11 applies to the ergonomics of interactions between humans and computers, and can be summarised as effectiveness, efficiency, and satisfaction (Finstad 2010). The concept has been applied more widely however, for example in testing species identification tools (Lawrence and Hawthorne 2006).

Consideration of the literature suggests four criteria that enhance usability:

1. Design: consider ways of designing the tool that make it easy to use
2. Needs analysis: understand the needs and abilities of the intended users.
3. Participatory development: develop the models in collaboration with the intended users.
4. Testing: assess the application of the models with the intended users.

6.1 Good design

The first of these, design, is summarised in a survey of DSS use in Europe. Fürst et al. (2009) conclude that tools must be accessible for all users, allow for iterative integration of experience, and have a self-explanatory user interface (suitable for users lacking experience with electronic tools).

McIntosh et al. (2005) state that design requirements for tools to support processes of participation are challenging. They demand that issues such as context, language, transparency and procedural rationality (how to choose), as opposed to substantive rationality (what to choose), must be considered. Clearly there is a need to define the 'users' in each context. Different kinds of stakeholders are involved in different processes, and so it is important not to generalise, and not to make assumptions about one kind of stakeholder based on experience with other stakeholders.

6.2 Understanding the users

This leads to the second criterion, understanding users and their needs. A large number of examples are documented from the context of private non-industrial forest owners, who need to engage with foresters in order to approve the management plans for their own forest. For example, Leskinen et al. (2009) note that forest planners in Finland are facing a growing demand for more versatile and customer-oriented decision aid systems and practices in which the data are cost-effectively acquired and used. One study identified five decision-making modes among Finnish forest owners and recommended that these should be taken into account when owner-orientated forest planning services for non-industrial private forest (NIPF) owners are developed (Hujala, Pykalainen, and Tikkanen 2007).

Others who have researched user needs include those working in the context of community forestry. For example Ogden and Innes (2009a) researched the decision-making needs of stakeholders in the Yukon. They found that local residents wanted to formalise a monitoring network based on local knowledge as part of a broader adaptive management framework, while foresters wanted to identify ways of managing the forest in relation to climate change. Examples such as this, which identify knowledge needs, are more common than those which identify the ways in which stakeholders make decisions, such as the examples from Finland, above.

We can learn more from the wider field of environmental management, McIntosh et al. (2008) argue that users' needs may be impacted upon by institutional structures such as hierarchies and organisational informational processing norms, including what constitutes knowledge. These need to be taken into account in the development stages and should aim to fit with end-users' preferred communication systems. These authors also note that many failed attempts at computer-based DSS can be attributed to a lack of understanding on the part of the developers of the roles, responsibilities and requirements of the various users.

6.3 User involvement in tool development Related studies in participatory technology development show the value of user involvement in technological design, for example in collaborative software development (Carmichael and Burchmore 2010), or ecological genomics (Roelofsen et al. 2010). The discipline of 'science studies' (or sociology of science) tells us that users are not simply the consumers of the products of technology, but contribute to the context and shaping of technology (Russell, Vanclay, and Aslin 2010).

One way in which this has been done in developing forest management tools, is to use a participatory process to select the indicators that are included in decision support systems (e.g., von Geibler, Kristof, and Bienge 2010). The key lessons for this area come however from closely parallel situations in environmental management. A study on the development of tools to support decision-making in environmental management and policy (McIntosh et al., 2008) suggests expertise can only be built through dialogue between interested stakeholders during the development process and that this collaborative learning is vital to ensuring that when the tools are used they reflect local circumstances and enjoy credibility with users. A lack of credibility with users, they argue, is usually the result of a failure on the part of expert developers to devote a comparable amount of time to convincing users of the benefits of the use of the tools, developing trust and communicating uncertainty as compared with the time spent on technical aspects. Opportunities to contribute and challenge model assumptions before results are reported also helps to ensure stakeholders feel ownership of the model, and committed to its usefulness (McIntosh et al., 2008).

Díez and McIntosh (2009) undertook a review of the factors which have been found to influence the use and usefulness of information systems (including DSS) for environmental management. They found that user participation before implementation is the best predictor of use. This highlights the importance of engaging users in the development process from the outset, utilising mechanisms such as stakeholder analysis and user requirement analysis.

6.4 Testing tools with users Once a tool has been designed it needs to be tested with the users in real situations. There is no other way of knowing whether tools will be accessible to new types of users. Such testing can consist either of

1. setting tasks to be addressed using the tools, and then observing how users engage with the tools, where they encounter difficulties, where they misunderstand instructions, etc.

2. assessing the usefulness of the outcome of using the tools (Lawrence and Hawthorne, 2006).

Both of these can be addressed by thinking about testing as a pilot study. One example is the the learning process that accompanied the piloting of a new hierarchical modelling approach in Ontario, Canada. This approach involved a combination of aspatial and spatial models, and crossed the traditional planning boundary between strategic and tactical planning. The authors conclude that while technical experts needed to learn more about the planning process, planners needed to learn more about technical details (Rouillard and Moore 2008).

Also in Canada, Mendoza and Dalton (2005) report on testing an MCA designed to evaluate options for sustainable forest management. They describe lessons learnt about the process of using the tool. Facilitators discovered they could simplify the process because users did not need to be trained to understand the assessment methods, in order to use them successfully.

Some of the most valuable areas of testing have been in Finland where conflict over conservation in public forests, particularly around cities, has been addressed through participatory planning. Kangas et al. (2006) conclude that voting is a satisfactory solution to the requirements of decision support in sustainable forest management because: it allows large numbers of people to participate, especially if the voting can be done via the post or internet; it can provide structure to the participation process; is usually transparent (with the exception of strategic voting schemes or methods based on randomness); is familiar to participants, elections; and most voting schemes are relatively easy to understand and their results easy to interpret in comparison with other MCDM support tools.

Vainikainen et al. (2008) provide an example of the application of a voting method in forest planning in Inari, Finland. Three voting methods were used to find out about the participants' preferences. Each method produced a different preference order for the criteria. This suggests that voting methods may be problematic. However, the preference data was then used in a stochastic-multi-criteria acceptability analysis which led to one forest plan being considered the best. The authors note that voting can be manipulated with some people's votes having a greater impact than others through strategic voting. This drawback applies not only to voting, but to any decision analysis where group preferences are gathered.

Pykäläinen et al. (2007) provide another example of the application of voting methods in strategic forest planning in western Finland. In this example, ordinal voting methods (to rank options) were modified with a cardinal method which they call interactive utility analysis (IUA). Although the results of the IUA and ordinal voting methods complemented and supported each other, the approach which allowed feedback and modification (IUA) led to one clear choice. Participants also noted that IUA was a valuable tool for promoting learning amongst themselves. The authors conclude that such planning tools must be viewed as support systems, not definitive decision-making tools, and that the ultimate decision must be based on human judgement supported by the planning process and the tools and methods used.

Examples of such testing are scarce however. A comprehensive analysis of decision support needs in participatory forestry concludes that there is a lack of well-documented case studies of decision-making processes that have succeeded in being engaging, open and accountable (Sheppard 2005). Furthermore, several of the papers reviewed here do provide observations about the process of using tools with the users, but do not provide conclusions about how this affects the outcomes. We discuss this further below.

7 Impact and effectiveness of participatory decision-making

All of these innovations are only worthwhile if they lead to better forest management decisions. There is a wide literature on the impact and effect of participation, which foresters will be able to draw on. The key question is, what constitutes a 'better' decision. The answer will vary according to context. In some cases, it is a decision that is more acceptable to a wider range of stakeholders, and which does not attract conflict. In others, it is a more fully informed decision which takes account of local knowledge, and leads to more predictable management outcomes. For example, Diez and McIntosh (2009) define success to include the enhancement of organisational effectiveness, efficiency and the enhancement of user commitment, use and satisfaction.

The studies which consider tools and models as 'pilots' go some way towards assessing this, if the testing process also looks at the effect that the model has on the outcome. For example cognitive mapping tools were used in Zimbabwe, with three groups representing three villages involved in the sustainable management of the Mafungautsi forest. The modelling process was facilitated by a group of local scientists who were knowledgeable about the forest. The cognitive map generated a learning and communication tool, and authors note that it helped guide the villagers in preparing action plans and priorities for their forests (Mendoza and Prabhu 2003).

In Canada, Mendoza and Dalton (2005) describe the outcome of pilot studies using MCA. They note that the most striking difference between the published field tests of MCA and a more conventional forest sustainability assessment is the very large numbers of individuals who can participate across wide geographical distances and from many different perspectives.

As experience builds up with the piloting and actual application of such tools it will be valuable to conduct case studies which explore whether this tool did in fact lead to more publicly acceptable or, perhaps, improved sustainable forest management.

8 Conclusions

In this paper we have reviewed the challenges for participatory decision-making in sustainable forest management, focussing on the interface between technology and participation. The sustainability of forest management is a key societal concern. It is difficult enough for scientists and land-use managers to model and forecast the provision of goods and services into the long-term future. Inviting non-traditional stakeholders into the decision-making process brings new challenges of understanding the tools; differentiating between and evaluating scenarios and options; and weighing up the preferences of diverse stakeholders to arrive at a decision.

Much of the scientific literature on forest decision-making tools does not offer any analysis of the social and institutional processes of designing, testing or using such tools. The concepts of combining technical decision-making with stakeholder participation are well-presented, and methodological manuals are available to help. The challenges lie more in the implementation of these approaches. These challenges relate in part to a conservative culture of forest management, with staff who are poorly prepared to work with new stakeholders, and stakeholders who are reluctant to engage with technology. We should be wary however of generalisations about forest stakeholders; the small number of papers on this suggests instead a wide range of attitudes and a need to document experiences.

In focusing on the use of tools themselves, more attention is given to tools which help to facilitate and analyse stakeholder preferences, than to those which generate the options and forecasts. Both types of tool help decision makers to cope with complexity. Therefore those advocating use need to understand the accessibility, meaningfulness and validity of the tools to stakeholders. We have drawn on a search within the forest science literature, and more widely in the related fields of sociology of science, and environmental studies, to highlight the need to involve stakeholders in designing such tools, testing their usability, and assessing the impact and wider outcomes of using them in a participatory way. Currently the evidence is scattered across mostly scientific literature; this indicates that the issues are of interest to the forest science audience, but are still somewhat hidden.

We hope with this paper to draw attention to the value of questioning, documenting and analysing experiences of testing such tools at the stages of design, application and longer-term effectiveness. The value of decision support tools for sustainable forest management would be demonstrated and enhanced, by a solid body of evidence that understands:

1. the values and cognitive processes of participants in decision-making, including foresters, scientists and less conventional stakeholders;

2. social and institutional contexts in which models are used;

3. experiences of testing technical tools, and the rationale for subsequently adopting or rejecting them;

4. the effectiveness and impact of participatory decision-making on resource management, adaptiveness, and societal benefits of forest management.

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