# Studying the use of forest management decision support systems: An initial synthesis of lessons learned from case studies compiled using a semantic wiki

Sean N. Gordon, Institute for Sustainable Solutions, Portland State University, Portland, Oregon USA, sean.gordon@pdx.edu

Antonio Floris, Forest Monitoring and Management Research Unit, National Council for Research in Agriculture, Trento, Italy, antonio.floris@entecra.it

Luc Boerboom, Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, The Netherlands, boerboom@itc.nl

Tomas Lämås, Department of Forest Resource Management, Swedish University of Agricultural Sciences (SLU), Umeå, Sweden, Tomas.Lamas@srh.slu.se

Ljusk Ola Eriksson, Department of Forest Resource Management, Swedish University of Agricultural Sciences (SLU), Umeå, Sweden, Ljusk.Ola.Eriksson@slu.se

Maarten Nieuwenhuis, UCD Forestry, University College Dublin, Dublin, Ireland, maarten.nieuwenhuis@ucd.ie

Jordi Garcia, Instituto Superior de Agronomia (ISA), Centro de Estudos Florestais, Universidade Técnica de Lisboa, Lisbon, Portugal, jordigarcia@isa.utl.pt

Luiz Rodriguez, Department of Forest Science, University of Sao Paulo, Piracicaba SP, Brazil, lcer@usp.br

# Abstract

In order to share information on the development and use of forest management decision support systems (FMDSS), a European-initiated network has established a wiki website as part of its activities. Case studies and associated lessons learned were solicited from the network using semantic structures built on the wiki. A total of 31 cases from 10 different countries and 80 associated lessons were entered into the wiki. The resulting lessons were categorized (non-exclusively) using four major themes: 1) DSS architecture and design (38 lessons), 2) methods and models (25), 3) knowledge management processes (34), and 4) participatory processes (32). The semantic wiki proved useful for gathering case information and relating it to other information objects, such as FMDSS software descriptions; however, it was not as well suited to the task of analysis and synthesis as commercial qualitative analysis software packages. Future development possibilities for the semantic structures are suggested, and more cases are solicited from the FMDSS community.

*Keywords: decision support systems, forest planning, lessons, collaboration technologies*

# Introduction

Increasingly forest managers must balance the needs of multiple stakeholders with competing demands for a wide array of products and services provided by forests. A variety of forest management decision support systems (FMDSS), computer-based systems that help analyse and display forest data, have been developed to help managers with the complexity of forest planning (Reynolds et al. 2008). The need for more coordination in the development and application of these tools motivated the establishment of a European network for forest management decision support systems (FORSYS) as a project of the intergovernmental framework for European Cooperation in Science and Technology (COST). One of the principle goals of this network was to assess lessons learned and establish guidelines for future FMDSS development and use.

Case studies are a common method used for deriving lessons learned in many fields of study. The term does not refer to a single process or method, but rather the application of a variety of methods (personal experience, interviews, document research, etc.) to one or more particular instances of a phenomenon, such as an organization, event, or initiative (Yin 2003). Case studies have been used extensively in the field of information systems (Walsham 1995; Klein and Myers 1999) but rarely used in the specific field of FMDSS. Most of the FMDSS literature focuses on the system architecture and/or novel models and methods developed for a forest management problem. Rarely have FMDSS articles included information on how a particular DSS was applied in a particular real-world situation and the resulting consequences, or how the DSS was developed. When use of the DSS is discussed, it is often presented in the form of a hypothetical case designed to illustrate functionality (e.g. Pretzsch 2002; Lexer et al. 2005; Gärtner et al. 2008).

A few exceptions exist, including a number of analyses and reflections on the FORPLAN DSS because of its extensive use by the United States Forest Service between 1979 and 1996 (Barber and Rodman, 1990; Cortner and Schweitzer, 1983; Kent et al., 1991). A limited number of reflections on individual real-world cases have appeared more recently (Gustafson et al. 2007; Rouillard and Moore 2008; Shifley et al. 2008), as well as one including 15 brief cases (Johnson et al. 2007).

Real-world case studies have the advantage of enabling detailed understanding both tools and the context in which they are applied or developed. To meet this need for real-world cases and to contribute towards the synthesis of lessons learned and guidelines, the FORSYS management committee established a case study technical committee (CSTC) in 2010 to solicit, organize, and synthesize cases from the FMDSS community. This paper details how we went about this work and our preliminary results, with an emphasis on the lessons learned from the cases submitted. It is also an introduction and invitation to the broader FMDSS community for more case contributions, in order to further develop this knowledgebase of practice.

# Methods

Before soliciting cases from the FORSYS community, a methodology for compiling the information needed to be established. In order to share information among the diffuse group of FORSYS participants (about 150 individuals from 30 countries), the decision had been made early on to use an internet wiki. Wikis are a type of website that is designed to be easily editable by all users, and is the basis for the well-known Wikipedia knowledge repository. Initial project work on compiling descriptions of specific FMDSS revealed the limited functionality of the wiki platform for comparing DSS by specific attributes, such as types of problems addressed, computational methods used, costs, etc. To remedy this limitation, the Semantic Wiki extension was added to the site, which enabled the specification of particular named properties which can be embedded in a wiki page. Thus the first step of the CSTC was to decide how case information would be structured, i.e. what properties each case would have, and how these properties would relate to other objects on the wiki (e.g. DSS descriptions, lessons learned). A list of the properties chosen is presented in Table 1. Once these properties were established, a 'semantic form' was designed to facilitate input of the various properties on a wiki page.

<Table 1 here>

The whole FORSYS project organized itself into four working groups based on major DSS themes: 1) DSS architecture and design, 2) methods and models, 3) knowledge management processes, and 4) participatory processes. The CSTC was constituted by selecting 1-2 representatives from each of these working groups. Forest decision support case studies were solicited from the FORSYS community through an initial email sent by these representatives to their working groups in October 2011, presentations at project meetings in November 2011 (Leuven) and May 2012 (Zvolen), and through two emails sent to the entire FORSYS community in December 2012 and January 2013. The solicitation asked participants to enter information to the wiki for both published cases as well as unpublished cases from their personal experiences.

The initial semantic form included space for lessons learned as part of the case, but this was changed as an independent structure for lessons was developed. This independent structure was needed to accommodate lessons coming from multiple sources, such as a survey of participants (Marques et al. 2013), country reports (Borges et al. In press), and the DSS descriptions on the FORSYS wiki. lists the properties chosen for the lesson category. The cases and associated lessons can be analysed by any of these associated properties. Given the overall project organization by the four working group themes mentioned earlier, the CSTC decided to make these themes the focus of this initial analysis. CSTC members were responsible for transferring the lessons from the old wiki structure, where they were part of their parent case, to the new independent structure. As part of this process, the CSTC assessed and tagged each lesson with the relevant working group themes. Because these themes were broad and each included many lessons, CSTC members were encouraged to develop further sub-categories to effectively summarize the lessons for their working group theme.

<Table 2>

# Results

A total of 31 cases were entered into the wiki, but only 20 were completed to the extent of having associated lessons (Table 3). These 20 cases came from 10 different countries. The total of associated lessons was 80 and the number of lessons per case ranged from one to seven. A listing of the lessons is provided in Appendix 1, along with columns indicating which working group themes each was tagged with. In the subsequent text, specific lessons are referred to using the number from the lesson number column (#) in brackets (e.g. [1]).

<Table 3>

Six of the lessons [1-6] were not tagged with any working group theme because they were either too general [2-4] or the lesson was unclear [1, 5, 6]. Most of the lessons were tagged with two or more themes (Table 4).

<Table 4>

## DSS architecture and design

'DSS development process' was the most oft used of the four major themes (38 of the 80 lessons). Many of the lessons were tagged with multiple themes, and the largest co-occurrence of this theme was with "Models and Methods." There was also some overlap (~25%) with the other major themes knowledge management and participation (Table 4). One example that touched on these three themes was, " …involvement in the system development of professionals who have both computer science and forestry knowledge and competencies is essential: a too marked division between the two figures can determine communication misunderstandings and development delays" [42]. Only 7 lessons were unique to this theme.

In a further sub-categorization of these 38 lessons, the most common subtheme derived was "architecture" (8 lessons). Advice included suggestions such as " Plan the system architecture based on a broad view of future possibilities rather than the ad hoc needs of particular funded projects" [13], using a modular approach [8], and "use a web-based delivery platform" [12]. More surprising was that 8 of the lessons were associated with a subtheme of "participation." Identifying the correct stakeholder community [37], involving users early [34], and recruiting and balancing the needed expertise [42] were three types of these lessons. "Capabilities" lessons (7) involved what capabilities the DSS should have. Some of these lessons appeared quite specific to a particular case and DSS used ("An optimisation module comparing alternative scenarios based on multi-criteria analysis should be included in the software" [21]), but most could be more broadly applicable ("A financial analysis is an important component" [22], "It should be possible to specify the rotation time of a species not only by age but also by target DBH" [28]). Further subthemes identified included user interface design (6 lessons), project management (5), problem specification (5), and documentation (2).

## Methods and Models

Twenty-five of the 80 lessons were tagged as relevant to the 'models and methods' theme. Four of them concern the DSS basic structure and flexibility (e.g., to be embedded in a GIS, the possibility to include models from other countries). The effects of model design and functionality (e.g., any threshold values) and input data quality are also quite naturally of most importance and is mentioned in four of the lessons. The problem formulation (e.g. spatial context) and the number of utilities (goods and services, estimated by forest, ecological and social models, respectively, including financial factors and weighing between utilities) included in the DSS, that is, the scope and width of the DSS is mentioned in nine of the lessons, that is, this area has the highest frequency within models and methods. Finally, three of the lessen concern the implementation and use of DSS including competence in understanding intricacies typically related to models within DSS systems.

## Knowledge Management

Among the 20 case studies analyzed, and their 80 related lessons, 34 of these latter had 'knowledge management' as a major theme. This theme was associated with the 'participation' theme at a much higher rate than either of the two other themes (Table 4)

Considering the six knowledge management processes identified by Vacik et al. (2013) (generation, identification, application, storage, transfer, evaluation), there is great evidence of techniques to transfer and share knowledge, especially web sites and communities of practice, and to store and to process knowledge (databases are integral to the DSS concept), whereas the phases of knowledge identification and application had little representation.

With regard to actor’s perspective, “Facilitator” is the role that is most prevalent in KM themes (19 lessons), even if often associated with other actors.

## Participatory Processes

Among the 20 case studies analyzed, and their 80 related lessons, 32 lessons pertained to participation. Countries represented were Germany, Ireland, Italy, New Zealand, Spain, and the United States. An initial observation (subtheme) is the distinction between lessons about participation in the development process of decision support systems and participation in decision processes where decision support systems are used.

As far as the development process is concerned we further categorized the lessons with three keywords: involvement, institutionalization, and funding. Looking at the lessons learned, one already gets the impression that not only is stakeholder involvement in the development process important but particularly early stage involvement of stakeholders [34, 35]. In terms of institutionalization, the network of human and non-human actors within which the DSS is to function needs to be understood in detail. With respect to funding, lessons exist that point at the success of joint funding and the tension between cheaper generic DSS and more expensive DSS customized to local techniques and people.

Likewise, we classified the "use" lessons related to participation with four key words: learning, process, ease of use, and outcome. Several lessons express the added value of DSS to learning about the decision problem. Also, several cases have lessons that show the added value of the structure DSS provide to the participatory decision making process [63, 70, 71]. In overlap with the 'DSS architecture and design' category of lessons, several lessons emphasize the importance of informative interfaces and ease of use for participatory use of DSS. Finally, the a number of lessons emphasize the role of DSS in enhancing the transparency of the decision process [65, 66, 74, 79], including the point that stakeholders can more directly see how make a difference in decision making. Hence an interesting two-way interaction between the stakeholders and technology exist.

# Discussion

## Categorization of Lessons

Unexpectedly, given the emphasis of case studies on *use* of the DSS, the theme 'DSS development process' was the most often applied to the case lessons. This result may be explained by the interests of the contributors (FORSYS project participants), who tend to be strongly involved in DSS development. A similar prevalence of DSS development related lessons was found in an earlier survey approach to capturing lessons learned from FORSYS participants (Marques et al. in press). The largest co-occurrence of this theme was with 'models and methods,' which is to be expected, given the central role of models and problem solving methods in any DSS. Models and methods are quite natural central parts of DSS and include, among others, growth and yield models, models estimating the output of forest-related goods and services, and models for finding solutions on stated management and planning problems.

The co-occurrence of 'knowledge management' and 'participation' themes suggests the importance of techniques and tools to share and transfer knowledge among participants in forest decision-making processes. The high association of the 'facilitator' role with knowledge management lessons reinforces this finding and emphasizes the importance of a role that can facilitate communications between the different actors involved in a decisional process, from the developer/researcher to the end-user/stakeholder.

Also in regards to participation, two of the four subthemes we found related to the use of DSS matched the DSS criteria identified by Menzel et al. (2012) as particularly relevant to assisting with participatory decision making. We found lessons concerning how DSS can help structure such processes, similar to Menzel's criteria of "structured decision-making process," and their "transparency" criteria also mirrors our finding of lessons demonstrating DSS contributions to more transparent outcomes. Their work was based on comparing criteria from the participation literature to DSS characteristics. In their conclusion they called for future research based on "… assessing actual planning processes as a basis for the evaluation of participatory planning processes that use DSSs." The repository of FMDSS case studies now enables this type of real-world research.

## Use of the Semantic Wiki Platform

Use of an internet wiki platform provided an effective way for an internationally dispersed group to collaborate in gathering case study information. The transition from a traditional wiki (relatively unstructured) to a semantic wiki (relatively structured) required a considerable investment of time for the small group implementing it because the semantic wiki structuring and querying formats are quite different than those used by traditional databases. Once the input forms and output report formats were setup, they were not difficult to use for general contributors. However, the complexity and unfamiliarity of the platform restricted what these general users could do to the available input forms and reports. Therefore, little of the analysis for this paper was done on the wiki platform, instead data were exported to more familiar tools, such as Microsoft Access and Excel. In particular, it was difficult for our team members to add new tags ('properties' in the semantic wiki lexicon) to lessons and summarize by them. This type of functionality still appears to be better handled by qualitative analysis software, such as NVivo or Atlas-ti. On the other hand, the semantic wiki appears to have promise in that it incorporates quite flexible structures for textual information and queries, which allowed the FORSYS team to build and link different structures for cases, lessons, DSS descriptions, and country studies.

## Effectiveness of the Approach

The development and use of DSS is a complex socio-technical process (McCown RL. 2002). Elaborating lessons is not as simple a process as generating a FAQ for a particular piece of software, where the answers can be more specific and mechanical. An earlier survey approach to capturing lesson learned about FMDSS development and use captured and categorized a large number of lessons relatively quickly, but it lacked information on the context and evidence for these lessons (Marques et al. in press). This case study approach was conducted as a complement to gather more information on lesson contexts and specific sources of evidence. Deriving each lesson from a specific case and maintaining this link has addressed these concerns to an extent. However, the links possible in a semantic wiki are less specific than is typical in most qualitative analysis software. In the wiki, the links are between the lesson and the case as a whole, whereas qualitative software enables links between codes (lessons) and specific passages of text within a case study or other document. On the other hand, codes in qualitative software are generally not allowed properties of their own, as they are in the semantic wiki.

We noted a few apparently contradictory statements between different lessons, e.g. simple, user-friendly interfaces are preferred [9, 30] versus users preferred to enhanced functionality rather than useability [16]. Having the case as context helps to reconcile such apparent conflict, and in this case revealed a difference in the DSS experience levels of the targeted users in each case (low experience in the former and high in the latter).

Considering the breadth of the FORSYS project network, the capture of 20 cases and 80 lessons is rather modest, however, it is to our knowledge the largest case repository on this topic (Johnson et al. (2007) assembled 15 cases). Even this number of lessons already can be challenging for someone to access and put to use. The working group major themes provided a start at organization and synthesis, but further categorization appeared necessary. The properties for the lesson object were selected a priori based largely on previous objects created in the wiki (DSS descriptions, problem definitions, case studies). Some of these properties appear promising for future analysis (Has actor perspective, Has decision stage [Tables 1, 2]) but many others seemed applicable to few if any lessons. The ability to easily add and remove properties is an area for further investigation, as it is crucial to such a bottom-up synthesis of information.

Finally, the utility of the lesson statements requires further attention. Some lessons appear so narrow as to only be applicable in their particular parent case, while others are so broad that they lack any guidance in implementation. The FORSYS community discussed this issue in some depth and decided to break the lesson statements into four parts (properties): Has statement (What should be done?), Has evidence (justification in terms of evidence), Has consequences (justification in terms of the consequences to be expected), Has recommendation for action (How should it be done?). While the structure for these divisions exist, initial feedback has shown considerable confusion related to their use and few of the lessons have yet been described in such detail. Ultimately lessons would be most useful if they describe a full set of operational characteristics (who, what, when, where, why, and how), but, as with any knowledge management effort, the complexity of the tool must be balanced with useability.

# Acknowledgements

We would like to express our sincere thanks to the other contributors to the case study database. This research was conducted under the framework of the EU-COST Action FP0804: Forest Management Decision Support Systems - FORSYS (<http://fp0804.emu.ee>). The FORSYS COST-action also provided financial support for a few short-term scientific missions in which some of the case studies were developed.

# References

Barber KH, Rodman SA. 1990. FORPLAN: The marvelous toy. Journal of Forestry 88(5):26-30.

Borges JG, Nordström E-M, Garcia-Gonzalo J, Hujala T, Trasobares A. In press. Computer-based tools for supporting forest management. The experience and the expertise world-wide. Joensuu, Finland: European Forest Institute.

Cortner HJ, Schweitzer DL. 1983. Institutional limits and legal implications of quantitative models in forest planning. Environmental Law 13(2):493-516.

Gärtner S, Reynolds KM, Hessburg PF, Hummel S, Twery M. 2008. Decision support for evaluating landscape departure and prioritizing forest management activities in a changing environment. Forest Ecology and Management 256(10):1666-1676.

Gustafson EJ, Sturtevant BR, Fall A. 2007. A collaborative, iterative approach to transferring modeling technology to land managers. In: Perera AH, Buse LJ, Crow TR, editors. Forest landscape ecology : transferring knowledge to practice. New York: Springer. p. 43-64.

Johnson KN, Gordon SN, Duncan S, Lach D, McComb B, Reynolds K. 2007. Conserving creatures of the forest: A guide to decision making and decision models for forest biodiversity. Corvallis, OR: College of Forestry, Oregon State University.

Kent B, Bare BB, Field RC, Bradley GA. 1991. Natural resource land management planning using large-scale linear programs: The USDA Forest Service experience with FORPLAN. Operations Research 39:13-27.

Klein HK, Myers MD. 1999. A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems. MIS Quarterly 23(1):67-93.

Lexer MJ, Vacik H, Palmetzhofer D, Oitzinger G. 2005. A decision support tool to improve forestry extension services for small private landowners in southern Austria. Computers and Electronics in Agriculture 49(1):81-102.

Marques AF, Ficko A, Kangas A, Rosset C, Ferreti F, Rasinmaki J, Nuutinen T, Gordon SN. In press. Empirical guidelines for forest management decision support systems based on the past experiences of the expert’s community Forest Systems.

McCown RL. 2002. Locating agricultural decision support systems in the troubled past and socio-technical complexity of 'models for management'. Agricultural Systems 74(1):11-25.

Menzel S, Nordström E-M, Buchecker M, Marques A, Saarikoski H, Kangas A. 2012. Decision support systems in forest management: requirements from a participatory planning perspective. European Journal of Forest Research 131(5):1367-1379.

Pretzsch H, Biber P, Ďurský J. 2002. The single tree-based stand simulator SILVA: construction, application and evaluation. Forest Ecology and Management 162(1):3-21.

Reynolds KM, Twery M, Lexer MJ, Vacik H, Ray D, Shao G, Borges JG. 2008. Decision support systems in forest management. In: Burstein F, Holsapple C, editors. Handbook on Decision Support Systems. Berlin, Heidelberg: Springer p. 499-533.

Rouillard D, Moore T. 2008. Patching together the future of forest modelling: Implementing a spatial model in the 2009 Romeo Malette Forest Management Plan. The Forestry Chronicle 84(5):718-730.

Shifley SR, Thompson FR, III, Dijak WD, Fan Z. 2008. Forecasting landscape-scale, cumulative effects of forest management on vegetation and wildlife habitat: A case study of issues, limitations, and opportunities. Forest Ecology and Management 254(3):474-483.

Vacik H, Torresan C, Hujala T, Khadka C, Reynolds K. In press. The role of knowledge management tools in supporting sustainable forest management. Forest Systems.

Walsham G. 1995. Interpretive case studies in IS research: nature and method. European Journal of information systems 4(2):74-81.

# Appendix 1

< Table 5 here>

# Tables

Table 1. List of semantic properties for the case study object

|  |  |
| --- | --- |
| **Property** | **Description** |
| Has flag | Quality check classification: red, yellow, green |
| Has full name | Name of the Decision Support Tool; Case |
| Has country | List of the countries where the tool is used (can have more than one) |
| Has location | More specific location within a country/region |
| Has responsible organisation | Name of the organisation with the lead responsibility |
| Has type of owner organization | Can have more than one owner in cases of multiple-ownership and/or universities, which combine research institution and higher education |
| Has related DSS | Name(s) of the DSS related to the lesson, case, etc. |
| Has start date | Date the activity started or starts |
| Has end date | Date the activity ended or ends |
| Has DSS development stage | What DSS development stages are addressed by the case |
| Has decision stage | What DSS decision stages are addressed by the case |
| Has temporal scale | Temporal scales involved |
| Has spatial context | Spatial problem types involved |
| Has spatial scale | Spatial scales involved |
| Has decision making dimension | Number of decision makers involved |
| Has objectives dimension | Number of objectives involved |
| Has goods and services dimension | Types of goods and services involved |
| Has working group theme | Relations to major FORSYS working group themes |
| Has website | Main website URL |
| Has description | Brief description of the DSS, Case, etc. |
| Has reference | Related scientific and/or commercial publications |
| Has wiki contact person | Contact to be listed on the Forsys wiki |
| Has wiki contact e-mail | Contact to be listed on the Forsys wiki |
| Has DSS development | More specific DSS development categories |
| Has knowledge management processes | More specific knowledge management categories |
| Has decision support techniques | More specific decision support technique categories (models & methods) |
| Has support for social participation | More specific participation categories |

Table 2. List of semantic properties for the lesson object

|  |  |
| --- | --- |
| **Property** | **Description** |
| Has statement | Statement of the lesson |
| Has evidence | How is this statement justified in terms of evidence |
| Has consequences | How is this statement justified in terms of consequences expected |
| Has recommendation for action | How the lesson should be operationalized |
| Has domain | Broad set of categories |
| Has temporal scale | Temporal scales involved |
| Has spatial context | Spatial problem types involved |
| Has spatial scale | Spatial scales involved |
| Has objectives dimension | Number of objectives involved |
| Has goods and services dimension | Types of goods and services involved |
| Has decision making dimension | Number of decision makers involved |
| Has country | List of the countries associated with the lesson |
| Has other relevant information | Other relevant information |
| Has reference | Related scientific and/or commercial publications |
| Has related DSS | Name(s) of the DSS related to the lesson, case, etc. |
| Has related case | Case providing the evidence |
| Has related lesson | Relation to other lessons |
| Has actor perspective | What roles the lesson is applicable to |
| Has researcher role | More specific researcher roles |
| Has developer role | More specific developer roles |
| Has user role | More specific user roles |
| Has working group theme | Relations to major FORSYS working group themes |
| Has DSS development | More specific DSS development categories |
| Has knowledge management processes | More specific knowledge management categories |
| Has decision support techniques | More specific decision support technique categories (models & methods) |
| Has support for social participation | More specific participation categories |

Table 3. Cases with lessons

|  |  |
| --- | --- |
| **Country** | **Case Name** |
| Austria | Improving forestry extension services for small-scale private landowners |
| Belgium | BoLa a specific sDSS to support land use planning in Flanders |
| Belgium | Participative modelling of long-term wood production in the forest complex Bosland |
| Germany | Actor Network Theory to Understand Collaborative Decision Support Systems Development in Forest Management Practice |
| Germany | Using GISCAME to test alternative land-use scenarios under climate change in the Upper Elbe Valley |
| Ireland | PractiSFM multi-resource inventory and decision support for private forest owners |
| Italy | A comprehensive system for forest management planning in Trentino Province |
| Italy | Analysis of logging residues chain for a sustainable bioenergy production in Alta Val di Non |
| Italy | Assessing forest functions at stand scale in a sub-regional forest plan in the Dolomites |
| Italy | ProgettoBosco a data-driven DSS for forest planning: an application in Abruzzo Region |
| New Zealand | Modular Forest Management DSS in NZ |
| Portugal | Pulpwood Supply Chain Planning in a Portuguese integrated Pulp and Paper Company |
| Portugal | Tactical/operational forest planning in a Portuguese integrated Pulp and Paper Company |
| Spain | Sustainable Management of Mediterranean Forest: Valencian Community Case |
| Sweden | The development and introduction of versatile DSS in Sweden |
| Sweden | The history of a successful forest DSS in Sweden |
| United States | Boise-Payette-Sawtooth National Forest Plan |
| United States | The forest plan revision process in the Okanogan Wenatchee National Forest |
| United States | The restoration strategy of the dry and mesic landscape in the Okanogan Wenatchee National Forest |
| United States | Watershed Condition Assessment for the Northwest Forest Plan |

Table 4. Major theme co-occurrence matrix (number of lessons)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **DSS development process** | **Models & techniques** | **Knowledge management** | **Participation** | **Total** |
| **DSS development process** | 7 | 14 | 9 | 10 | 38 |
| **Models & techniques** | 14 | 5 | 5 | 1 | 25 |
| **Knowledge management** | 9 | 5 | 4 | 17 | 34 |
| **Participation** | 10 | 1 | 17 | 5 | 32 |

Table 5. Complete listing of case lessons and and assignments to associated working group themes.   
Key: Dev = DSS development process, Kno = Knowledge management, Mod = Models & techniques, Par = Participation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| # | Lesson | Dev | Kno | Mod | Par |
| 1 | Need for new models for the later use of a tool - either as consulting instrument or in extended science-practice cooperation |  |  |  |  |
| 2 | Use of adequate DSS development methodology |  |  |  |  |
| 3 | Stakeholder involvement in DSS design |  |  |  |  |
| 4 | Stakeholder involvement |  |  |  |  |
| 5 | Actor Network Theory provides a suitable lens for exploring both technical and human aspects of DSS institutionalization in the forestry domain |  |  |  |  |
| 6 | Decision criteria beyond the state of the ecosystem (for example, social values fire risk, economic feasibility and social acceptability) could have been included in the DSS model |  |  |  |  |
| 7 | Operational aspects of the system should be enhanced: client-server application, internal control on consistency, etc | X |  |  |  |
| 8 | A modular approach was helpful in assisting industry uptake by allowing the use of parts of the system | X |  |  |  |
| 9 | The very easy user-friendly interface of the software and the clearness of method can be exploited both by technical personnel and by forest decision makers. | X |  |  |  |
| 10 | The development of large and enduring systems requires a long term approach with considerable commitment of resources. | X |  |  |  |
| 11 | Lack of proper documentation and support services (manual, website, etc) can severely limit the adoption of the system in real-life applications. | X |  |  |  |
| 12 | Using a web-based delivery platform can reduce compatibility issues associated with different versions of desktop software | X |  |  |  |
| 13 | Plan the system architecture based on a broad view of future possibilities rather than the ad hoc needs of particular funded projects | X |  |  |  |
| 14 | The scope of the modeling project can change significantly during the project; initial calls for "back of the envelope" (very simple) analyses for ASQ eventually evolved into a model with 120 vegetation classes. | X | X |  |  |
| 15 | The use of structured output (maps, tables and charts) makes the methodology and the results more transparent and easy-to-share to non-expert stakeholders. | X | X |  |  |
| 16 | When surveyed, users preferred to be enhance functionality rather than useability. | X | X |  |  |
| 17 | Enlarge the decision space by generating a large set of potential management alternatives | X | X |  |  |
| 18 | It is necessary to know which data will be use as variables in the models before designing the DSS | X | X |  |  |
| 19 | Provide help/documentation service | X | X |  |  |
| 20 | The definition of standardized and specific criteria for selecting and zoning forest compartment units and the codification of the qualitative features necessary to provide an exhaustive description of the forest offer a solution to manage the heterogenei | X |  | X |  |
| 21 | An optimisation module comparing alternative scenarios based on multi-criteria analysis should be included in the software | X |  | X |  |
| 22 | A financial analysis is an important component in the discussion about the preferences of different scenarios and should therefore preferably included in the DSS. | X |  | X |  |
| 23 | The use of a DSS can help in varying the treatment according to more than one forest function, especially when they have a similar ranking. | X |  | X |  |
| 24 | Embedding a DSS in a GIS software allows obtaining information at different spatial scales using the standard features of the GIS | X |  | X |  |
| 25 | To compare the current and the past quantitative/qualitative parameters of the forest, great effort must to be paid to maintain, as much as possible, models and metrics used in the past (this was a specific request of the forest administration); | X |  | X |  |
| 26 | The fact that ProgettoBosco is conceived according to the criteria and indicators of sustainable forest management (FSC, PEFC and two Italian national standards), assures that a plan obtains a preliminary step on certification process | X |  | X |  |
| 27 | Afforestion and deforestation options should be included in the management options | X |  | X |  |
| 28 | It should be possible to specify the rotation time of a species not only by age but also by target DBH. | X |  | X |  |
| 29 | Neighbourhood interrelations should be included in the generator. | X |  | X |  |
| 30 | Provide a simple version of the DSS, which new users can try out and learn quickly | X |  | X |  |
| 31 | The kinds of DSS traditionally used to calculate timber harvest levels are now being used to model more complex vegetation dynamics over time for a variety of resource outputs. | X |  | X |  |
| 32 | Need for flexibility of analytical tools - no "overdesigned" tool that provides too much features for the use | X |  | X |  |
| 33 | Adapting the software to make it possible to easily include also the output of other mechanistic and/or empirical models, eg yield tables from other countries | X |  | X |  |
| 34 | It would have been better to involve some end users at earlier stages of the system development | X |  |  | X |
| 35 | Students studying forest management planning procedures and processes were very useful as testers to work with preliminary versions of the system as they questioned every aspect and suggested better ways of doing things. However, the need for professional | X |  |  | X |
| 36 | The adoption of the collaborative learning method made possible to gradually select the conceptual common elements and give them an analytical form to be used in the identification of the structure of the Information System | X |  |  | X |
| 37 | The tracing of the current actor network interactions made the group realize that they need a different kind of stakeholders from what they previously thought | X |  |  | X |
| 38 | Getting joint funding from both the forest and environmental sectors can be a successfull for developing multi objective forest DSS | X |  |  | X |
| 39 | Using Actor Network Theory in the design stage can help in understanding the dynamism of the network | X |  |  | X |
| 40 | A more informative output should be generated with clear graphs and maps indicating long-term changes | X |  |  | X |
| 41 | The ProgettoBosco working methodology, based on cooperation, successive approximations and experimentation assure a bottom-up approach to encompass a broad range of forest standings of the country and to produce a technician-ready-to-use DSS. | X |  |  | X |
| 42 | To meet the needs of customer - the Forest Service - and to obtain satisfying results the involvement in the system development of professionals who have both computer science and forestry knowledge and competencies is essential: a too marked division bet | X | X |  | X |
| 43 | DSS should allow for adjustments to model parameters to incorporate local knowledge | X | X |  | X |
| 44 | SIPAFIT can act sometimes as a referee to settle arguments among experts, users and stakeholders | X | X |  | X |
| 45 | The use of EMDS allowed the planning team to identify priority area for restoration treatments that could achieve multiple objectives. |  | X |  |  |
| 46 | Although Biomasfor use is easy and flexible, working under an external sw environment like GRASS GIS required some specialized skills which could discourage some potential users. |  | X |  |  |
| 47 | The DSS usage enabled the planning team to measure the achievement of the restoration goals. |  | X |  |  |
| 48 | Model building was rapid, it was assembling the data that took by far the most time |  | X |  |  |
| 49 | Regular ongoing engagement with via â€œUsers groupâ€ helped maintain interest of users and contributing scientists. |  | X |  |  |
| 50 | As the core of forest DSS are models describing the development of trees and stands (growth and yield models)there as some large scale advantages developing several applications for different users and problem areas based on the same core of models. |  |  | X |  |
| 51 | Enabling the analyses of several ecosystem services (timber and non-timber resources) in one and the same DSS is fruitful but demanding task. |  |  | X |  |
| 52 | Providing procedures and structure for data flow from selection of field sample, performing field survey and entering data into the DSS proved to be a successful approach. |  |  | X |  |
| 53 | Multiple DSS are often needed to meet complex needs: separate models were needed to handle the strategic (Spectrum) and tactical (RELM) aspects of planning; a simulation approach (VDDT) was also done to provide an alternative view. |  |  | X |  |
| 54 | From a management perspective, to avoid the complication of testing something new, the models used for the forest planning must to be widely accepted, peer-reviewed and in use for a while. |  |  | X |  |
| 55 | Results are always strongly dependent on the quality of the underlying data. |  | X | X |  |
| 56 | DSS should help managers assess how treatments at the stand scale effect processes at the landscape level |  | X | X |  |
| 57 | Despite the widely use and acceptance of the DSS there was still a lack of expertise to understanding the intricacies of the model in the US Forest Service |  | X | X |  |
| 58 | Projection of stand development increases knowledge base |  | X | X |  |
| 59 | Analysis at the landscape level allowed the integration of concerns about multiple resources as well as unique restoration opportunities. |  | X | X |  |
| 60 | The user has to be aware of the possibly large impact that the chosen land indicators and threshold values or weights have on the results. |  |  | X | X |
| 61 | The analysis of the actor network interactions allowed to identify the criticalities to be solved in order to develop the collaborative process |  |  |  | X |
| 62 | The tracing of the actor network supported the identification of the key actors influencing the collaborative DSS implementation and institutionalization |  |  |  | X |
| 63 | Group participation with knowledgeable people is a good way to ensure that the decision hierarchy is a logical and complete structure |  |  |  | X |
| 64 | Need of a moderator function - "the user as such" does per se not exist, but by doing a participatory development of a tool, trust in its results is created by "consumers" of its analytical results, but the researcher as such should mostly do the analysis |  |  |  | X |
| 65 | Involving local stakeholders in ranking the functions allowed to show them tangibly how their contribution in establishing the hierarchy of importance of functions can influence the management decisions. | X |  |  | X |
| 66 | The activation of an iterative process through periodical meetings permitted to all the stakeholders to contributed to define a series of common elements related to a certain subject. |  |  |  | X |
| 67 | The software did not provide much support for formatting of the outputs in a format that could be easily shared with others, so this process required considerably more time and effort than anticipated |  | X |  | X |
| 68 | The analysis team used internal prototyping, which helped train the staff and identify possible problems with the model |  | X |  | X |
| 69 | Spatial variation between regions led to the development of different regional models, which led to a slower and more costly DSS development but with the key advantage of having the support of local technicians and managers |  | X |  | X |
| 70 | Present DSS results in an iterative manner to the subject experts involved |  | X |  | X |
| 71 | DSS helped document and apply decision criteria consistently, and therefore produced a more transparent and consistent evaluation |  | X |  | X |
| 72 | The use of the DSS improved communication among the planning team by providing a framework of the space where the members of the ID team made analysis and took decision exploring the restoration management opportunities. |  | X |  | X |
| 73 | DSS can give the forest manager the opportunity to experiment how their emphasis towards certain resources influenced priorities |  | X |  | X |
| 74 | Using FORFUN DSS allowed to explain better some technical concepts, like the difference between nature conservation and landscape conservation, to non-professional stakeholders. |  | X |  | X |
| 75 | End user engagement throughout the development and deployment cycle is very important |  | X |  | X |
| 76 | Visualization of the preliminary actor network made the people explicitly include the DSS in a planning process. |  | X |  | X |
| 77 | Use of the DSS has been considered successful by the participating organizations, even though it has not affected decision making in any obvious way |  | X |  | X |
| 78 | Interpretative case studies can help reduce the gap between research and practice |  | X |  | X |
| 79 | SIPAFIT sub-systems have been useful in training activities, and can be very useful to explain and motivate choices performed by the forest owner and the forest manager; |  | X |  | X |
| 80 | Running the DSS required special skills, therefore the local planning team required considerable technical support. |  | X |  | X |