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Review. A brief overview of forest management decision support systems (FMDSS) listed in the FORSYS wiki

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Abstract

Aim of study: The aim of the study was to overview forest management decision support systems (FMDSS) listed in the FORSYS wiki in terms of software design and architecture.

Area of study: A total of 62 FMDSS from 23 countries were included into the study.

Material and methods: First, all FMDSS listed in the FORSYS wiki were described in terms of functionalities, typologies and elements of architecture. Thereafter, the findings were compared with the desired architectural features of FMDSS to identify success or potential gaps. Finally, some measures were suggested to improve knowledge transfer and smooth integration of system components.

Main results: Most of the systems listed in the FORSYS wiki originate from research projects and are either knowledge- or model-driven. There are only few compound systems or tools that can be used as sub-components in integrated systems.

Research highlights: There is a lack of generic platforms or DSS generators that would facilitate construction of integrated systems. Further efforts are needed to study the potential of cloud services.

Key words: forest management; decision support systems; software architecture; typologies.

Introduction

Since the 1980s, decision support systems (DSS) have become popular platforms for transferring knowledge from science into practical forest management (Reynolds, 2005; Reynolds *et al.*, 2008). The evolvement over time is reflected in the definitions and related taxonomies used for DSS. DSS can be classified, for example, based on the scope (Power, 1997), the user relationship (Haettenschwiler, 1999) or the mode of assistance (Power, 2002) of the system.

In the beginning, systems were often used by researchers themselves for case studies and demonstrations. Gradually, the end-user demand for tools with personalized user-interface and data-interface emerged and the number of various software versions adopted for specific data, users and applications increased. Consequently, the maintenance and further development of software systems has become challenging for the research community. Within forest science, the emphasis has laid on the capability and reliability of models to mimic forest dynamics (Bugmann *et al.,* 2010; Fontes *et al.* 2010; Muys *et al.,* 2010). However, software architecture (Marques *et al.,* 2013a) and interoperability (Rauscher, 1999; Potter *et al.*, 2000) are increasingly important when linking different data and information sources, including other decision support tools.

Luckily, modern software engineering together with information and communication technology offers some solutions for the system integration. First, de-

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composing the software into modules (small pieces of functionality) and components (more complex pieces, with extensive functionality and capabilities) makes software easier to maintain independently, interface with different data sets and other modules, share between applications and re-use in different systems (for example SIMO, see Kangas *et al.,* 2008). Second, internet-based solutions such as web-based distributed DSS (Zhang and Goddard, 2007) or cloud computing (Marston *et al.,* 2011) with related initiatives such as Shared Environmental Information System (Saarenmaa *et al.,* 2002) or principles such as Service Oriented Architectures (Bell, 2010) facilitate faster transfer of research results into practice. They make software easier to be implemented and upgraded. Furthermore, they help to resolve compatibility problems related to different operating system and software platforms.

In this article, the forest management DSS's (FMDSS) listed in the FORSYS wiki were described in terms of functionalities they were designed for, DSS taxonomies applicable to them, and software elements they are comprised of. Thereafter the findings were compared with the desired features related to the DSS architecture to identify success or potential gaps.

Material and methods

The FORSYS Wiki (http://fp0804.emu.ee/wiki/index.php/Category:Decision_support_system, retrieved 15 May 2012) described 62 existing FMDSSs from 23 countries. The emphasis in the design and contents of wiki was laid on the architecture of these systems, the models and methods used to support decision-making, the knowledge management tools and participatory processes adopted by the stakeholders engaged in forest management (Marques *et al.,* 2013b).

In this study, those 62 software tools were first listed together with the information on the country of origin and classified according to the functionalities they were designed for (Table 1), typologies applicable to them (Table 2) and architectural elements included (Table 3). The Boolean operator was selected for all tables to address both exclusive and overlapping properties. The functionalities included non-spatial data analysis, spatial analysis, impact analysis, risk analysis, forest (dynamics) simulation, landscape simulation, optimization, multi-criteria decision analysis (MCDA), multipurpose toolbox, and other (for example generic tools or models dealing with operating environment of forests). Analysis is spatial when topological, geometric or geographic properties of entities are taken into account. In this study, software tools were classified either non-spatial or spatial (as exclusive properties) even if the tools capable of spatial analysis —including software designed for impact or risk analysis— can be often used also for non-spatial analysis. However that is not their main or original purpose. The same applies for many risk and impact analysis software tools: risk analysis often includes capabilities to analyse impacts even if that is not principal or original purpose. In those cases the classification is exclusive. In overlapping cases, the classification tries to address functionalities appearing simultaneously. For example, optimization (*e.g.* LP or MIP) is often based on the matrix of coefficients which can be created by either a matrix generator or a simulator. Simulators can be integrated also with other functionalities such as landscape simulators. However, there are also landscape simulators which track the changes in the form of spatial entities without simulating forest dynamics. A software tool is classified as multipurpose toolbox when the principal and/or original purpose has been to incorporate different functionalities into the same platform so that the tool can be used to tackle many types of planning problems and situations.

Second, systems were classified (Table 2) based on the scope (Power, 1997), the user relationship (Haettenschwiler 1999) and the mode of assistance (Power, 2002). The scope of DSS can be an enterprise-wide system where the DSS is linked to large data sets, and serves many, or a desktop, single-user system where the DSS runs on an individual's PC (Power, 1997). The user relationship of DSS can be passive (aiding without providing explicit decision suggestion or solutions), active (providing solutions or decision suggestions) or cooperative with the aim of consolidated solution through a process of interactive refinement of between DSS and its user (Haettenschwiler, 1999). The modes of assistance (Power, 2002) are communication-driven (supporting more than one person working on a shared task), data-driven/data-oriented (with access to and manipulation of company internal/external data), document-driven (managing, retrieving and manipulating unstructured information), knowledge-driven (with specialized problem-solving based on expertise stored as facts, rules, procedures or similar structures) or model-driven (with access to and manipulation of a statistical, financial, optimization or simulation model).

Table 1. The country of origin and functionalities of the FORSYS wiki software. The sign (–) denotes missing information

Software	Country of origin	Non-spatial data analysis	Spatial analysis	Impact analysis	Risk analysis	Forest simulation	Landscape simulation	Optimization	MCDA	Multi purpose toolbox	Other
AFFOREST-sDSS	Belgium		×	×							
Agflor	Portugal	×		×				×		×	
AVVIRK-2000	Norway	×				×					
Capsis	France	×				×					
CONES	Austria		×			×		×	×		
Conifer Timber Quality	Great Britain	×									
Criterium DecisionPlus	USA	×							×		
HMSS	Great Britain	×			×						
DSD	Austria	×		×							
DSS for managing forest fire casualities	Greece		×	×	×						
DSS-WuK	Germany	–	–	–	–	–	–	–	–	–	–
DTRAN	USA	×						×			
EFIMOD	Russia		×			×					
EMDS	USA		×							×	
EMIS	Great Britain	×									
EnerTree	Finland	×									
ESC	Great Britain	×									
FFIREDESSYS	Greece	×			×						
FMPP	Sweden	×				×		×			
FORESTAR	China		×	×							
ForestGALES	Great Britain		×		×						
FVS	USA	×				×					
ForMIS	Estonia	×									
GAYA	Sweden	×				×					
Geo-SIMA-HWIND	Finland		×		×	×	×				
Habplan	USA		×			×		×			
HaRPPS	Great Britain	–	–	–	–	–	–	–	–	–	–
HARVEST	USA		×			×					
Heureka	Sweden		×			×		×		×	
Hugin	Sweden	×				×					
LANDIS	USA		×				×				
LEaRNForME	Italy		×		×				×		
LMS	USA		×				×				
MAPSS	USA	×									×
MELA	Finland	×				×		×		×	
Mesta	Finland	×							×		
MfLOR	Portugal	×				×		×			
MGC Larch	Belgium	–	–	–	–	–	–	–	–	–	–
Microforest	South Africa		×			×				×	
Monsu	Finland		×			×		×		×	
Monte	Catalonia		×			×				×	
NED	North America	×									
NetWeaver	–	×									×
ProgettoBosco	Italy		×								
PYL	Saxony		×	×			×				
Planflor/SADPOF	Portugal		×			×		×		×	
SADfLOR	Portugal	×				×		×		×	
SADMVMC	Galician Spain	×				×					
SGIS	Norway		×			×		×		×	
SimForTree	Belgium		×			×					
SIMO	Finland	×				×		×		×	
SIMPPLLE	USA		×				×				
SIPAFIT	Italy	×									
Spectrum	Generic, USA	×				×		×		×	
Stormrisk	–	–	–	–	–	–	–	–	–	–	–
TEAMS	Arizona		×	×		×		×		×	
Forest Time Machine	Sweden		×	×		×					
VDDT	North America	×				×					
WIS.2	Switzerland		×	×							
Woodstock	Canada	×			×					×	
WRR-DSS	Greece	–	–	–	–	–	–	–	–	–	–

Table 2. Typologies of the FORSYS wiki software. The sign (–) denotes missing information

Software	Scope		User relationship			Mode of assistance				
	Enterprise-wide	Desktop	Passive	Active	Cooperative	Communication	Data	Document	Knowledge	Model
AFFOREST-sDSS		×			×	×				
Agflor		×	×							×
AVVIRK-2000		×	×							×
Capsis	×				×				×	
CONES		×		×						×
Conifer Timber Quality	×		×						×	
Criterium Decision Plus		×		×						×
HMSS	×		×						×	
DSD	×			×					×	
DSS for management of forest fire casualties		×	×						×	
DSS-WuK	–	–	–	–	–	–	–	–	–	–
DTRAN		×		×						×
EFIMOD		×	×						×	
EMDS		×			×					×
EMIS	×		×						×	
EnerTree		×	×						×	
ESC	×		×						×	
FFIREDESSYS		×	×						×	
FMPP		×		×					×	
FORESTAR		×	×						×	
ForestGALES	×		×						×	
FVS	×		×						×	
ForMIS	×		×						×	
GAYA		×	×						×	
Geo-SIMA-HWIND		×	×						×	
Habplan		×		×						×
HaRPPS	×		×						×	
HARVEST		×	×						×	
Heureka		×			×					×
Hugin		×	×						×	
LANDIS		×	×						×	
LEaRNForME	×		×							×
LMS		×			×				×	
MAPSS		×	×						×	
MELA		×		×						×
Mesta		×			×					×
MfLOR		×		×						×
MGC Larch		×	×						×	
Microforest		×			×	×				
Monsu		×			×					×
Monte		×			×					×
NED		×		×					×	
NetWeaver		×	×						×	
ProgettoBosco		×	×						×	
PYL		×	×						×	
Planflor/SADPOF	×			×						×
SADfLOR		×		×						×
SADMVMC	×		×						×	
SGIS		×			×					×
SimForTree		×	×						×	
SIMO		×			×					×
SIMPPLLE		×	×						×	
SIPAFIT	×		×							×
Spectrum		×		×						×
Stormrisk	–	–	–	–	–	–	–	–	–	–
TEAMS		×		×						×
Forest Time Machine		×	×						×	
VDDT		×	×						×	
WIS.2		×	×						×	
Woodstock		×		×						×
WRR-DSS		×	×						×	

Table 3. The elements of architecture in the FORSYS wiki software. The sign (–) denotes missing information

Software	User interface						Sub-components									
	GUI			No GUI												
	GIS	Web	Windows	Executable	Module	Client	GIS	Spreadsheet	DBMS	Model library	Knowledge-base	Matrix generator	Simulator	Optimizer	MCDA	GUI
AFFOREST-sDSS	×						×									×
Agflor			×					×	×				×	×		×
AVVIRK-2000				×									×			
Capsis			×		×					×			×			×
CONES	×						×		×				×		×	×
Conifer Timber Quality		×								×						×
Criterium DecisionPlus			×												×	×
HMSS		×								×						×
DSD			×			×			×							×
DSS for managing forest fire casualties	×						×	×					×			×
DSS-WuK	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
DTRAN				×								×		×		
EFIMOD				×			×						×			
EMDS	×															×
EMIS		×								×						×
EnerTree			×					×								×
ESC		×					×			×	×					×
FFIREDESSYS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
FMPP				×									×	×		
FORESTAR	×						×									×
ForestGALES			×							×						×
FVS			×		×					×			×			×
ForMIS		×							×	×						×
GAYA				×	×								×			
Geo-SIMA-HWIND	×						×						×			×
Habplan	×						×					×		×		×
HaRPPS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
HARVEST			×										×			×
Heureka			×						×	×			×	×		×
Hugin				×									×			
LANDIS			×										×			×
LEaRNForME			×				×		×						×	×
LMS			×							×			×			×
MAPSS				×									×			
MELA		×		×	×								×	×		×
Mesta		×													×	×
MfLOR			×				×	×	×			×	×	×		×
MGC Larch	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Microforest		×	×				×						×			×
Monsu			×										×	×		×
Monte			×										×	×		×
NED			×				×						×			×
NetWeaver		×									×					×
ProgettoBosco			×				×		×							×
PYL		×							×							×
Planflor/SADPOF		×					×		×				×	×		×
SADfLOR			×						–			×		×		×
SADMVMC		×					×		×				×			×
SGIS	×						×	×					×	×		×
SimForTree			×										×			×
SIMO					×								×	×		
SIMPPLLE			×										×			×
SIPAFIT		×					×		×		×					×
Spectrum			×							×		×		×		×
Stormrisk	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TEAMS			×				×		×			×	×	×		×
Forest Time Machine			×				×						×			×
VDDT			×						×				×			×
WIS.2			×				×	×	×							×
Woodstock			×										×	×		×
WRR-DSS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Third, the elements of architecture were reported (Table 3). The user interfaces were divided into graphical (GIS-, web- or Windows-based) and non-graphical (used as an executable, a module or a client of another system). In addition, different software sub-components (GIS, spreadsheet, DBMS, model library, knowledgebase, matrix generator, simulator, optimizer, MCDA) used to compile the system were identified.

Finally, the findings were compared with the selected desired features to identify success or potential gaps. The selected features included extensibility and re-usability essential to compile integrated, distributed and layered systems (Marques *et al.,* 2013a; Rauscher, 1999; Potter *et al.*, 2000).

Results and discussion

Among the DSS studied, there are fewer systems with spatial (26) than with non-spatial (30) analysis capabilities. Impact analysis (9) is more common functionality than risk analysis (7). A common functionality is forest dynamics simulation (27). Landscape simulation is not as common (5). There are also some compound tools where simulation is linked with optimization (15). This is in line with Muys et al. (2010) who claim that the use of optimization is increasing also in forest dynamics simulators. MCDA is incorporated in four systems. There are 14 systems that can be referred to as multipurpose toolboxes: Agflor, EMDS, Heureka, MELA, Microforest, Monsu, Monte, Planfor/SADPOF, SADfLOR, SGIS, SIMO, Spectrum, TEAMS and Woodstock. There are two systems which are not real forest DSS: MAPSS is a climate model and NetWeaver a generic tool for knowledge management. It should be also noted that the FORSYS wiki does not cover all existing FMDSS, especially the commercially available tools which are not familiar to the research community responsible for the compilation of the wiki contents.

Most of the systems listed in the FORSYS wiki originate from research projects and are either knowledge- (35) or model-driven (22). A major part of the software belongs to desktop applications intended for personal use (45), the rest are enterprise-wide, organizational tools such as web-based services. The user relationship is often passive (34) but also some tools providing more active (14) or even co-operative (11) support exist. Practical forestry seems to favour model-driven compound tools for co-operative user relationship.

User interface is an essential part of a DSS. Most (47) of the systems listed in the FORSYS wiki have a graphical user interface (GUI). However, there are some that are executables without GUI (8), modules (5) or clients (1) to be integrated as sub-components. There are also some software tools with multiple interfaces. A standard Windows type GUI (27) is most common but there also several software where application is built on a GIS (8). In those cases, GIS may have a double role: an integrator and a user interface. Among the sub-components, simulator (32), optimizer (16), GIS (20) and database management system (15) are common, confirming the earlier reviews on simulators (Bugmann *et al.,* 2010; Fontes *et al.,* 2010; Muys *et al.,* 2010) and conclusions by Marques *et al.* (2013a) stating that GIS and DBMS as prerequisites for FMDSS. Some applications exist where a matrix generator (6) is used instead of a simulator. There are only few FMDSSs with MCDA (4), model base (11) or knowledgebase (3). The latter complies with the conclusions by Marques *et al.* (2013a) who report low experience in knowledge management within the FMDSS community. Furthermore, the lack of MCDA is in contrast with the increasing need of participatory techniques (Menzel *et al.*, 2012). Obviously, knowledge management, MCDA and participatory techniques need further consideration when developing guidelines for the construction of FMDSS.

In conclusion, there seems to be a lack of generic platforms (other than GIS) or DSS generators that would facilitate construction of integrated systems. In addition, only few examples exist on the use of distributed and/or layered systems architecture. However, there are some systems where sub-components (*e.g.* optimizers) are re-used or re-cycled. Further research is required to study the potential in cloud computing (Marston *et al.,* 2011), for example, in providing enterprise-level Software as a Service (SaaS), application development Platform as a Service (PaaS) or Infrastructure as a Service (IaaS).

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