Computers and Electronics in Agriculture 101 (2014) 55–67

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Review

Decision support systems for forest management: A comparative analysis and assessment

Marina Segura [a,*], Duncan Ray [b], Concepción Maroto [a]

[a] Dept. of Applied Statistics and Operational Research, and Quality, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain
[b] Centre for Ecology, Society and Biosecurity, Forest Research, Roslin, Midlothian EH25 9SY, UK

ARTICLE INFO

Article history:
Received 19 March 2013
Received in revised form 10 December 2013
Accepted 15 December 2013

Keywords:
Decision support systems
Forest management
Multiple criteria decision making
Group decision making
Optimization
Simulation

ABSTRACT

Decision Support Systems (DSS) are essential tools for forest management practitioners to help take account of the many environmental, economic, administrative, legal and social aspects in forest management. The most appropriate techniques to solve a particular instance usually depend on the characteristics of the decision problem. Thus, the objective of this article is to evaluate the models and methods that have been used in developing DSS for forest management, taking into account all important features to categorize the forest problems. It is interesting to know the appropriate methods to answer specific problems, as well as the strengths and drawbacks of each method. We have also pointed out new approaches to deal with the newest trends and issues. The problem nature has been related to the temporal scale, spatial context, spatial scale, number of objectives and decision makers or stakeholders and goods and services involved. Some of these problem dimensions are inter-related, and we also found a significant relationship between various methods and problem dimensions, all of which have been analysed using contingency tables.

The results showed that 63% of forest DSS use simulation modeling methods and these are particularly related to the spatial context and spatial scale and the number of people involved in taking a decision. The analysis showed how closely Multiple Criteria Decision Making (MCDM) is linked to problem types involving the consideration of the number of objectives, also with the goods and services. On the other hand, there was no significant relationship between optimization and statistical methods and problem dimensions, although they have been applied to approximately 60% and 16% of problems solved by DSS for forest management, respectively. Metaheuristics and spatial statistical methods are promising new approaches to deal with certain problem formulations and data sources. Nine out of ten DSS used an associated information system (Database and/or Geographic Information System – GIS), but the availability and quality of data continue to be an important constraining issue, and one that could cause considerable difficulty in implementing DSS in practice. Finally, the majority of DSS do not include environmental and social values and focus largely on market economic values. The results suggest a strong need to improve the capabilities of DSS in this regard, developing and applying MCDM models and incorporating them in the design of DSS for forest management in coming years.

Contents

* Corresponding author. Tel.: +34 963 874 935.
E-mail address: masema@posgrado.upv.es (M. Segura).

0168-1699/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.compag.2013.12.005

1. Introduction

Forest management planning encompasses environmental, economic, administrative, legal and social aspects. The large number of issues relating to forest management, such as fauna, flora, recreation, water, forest resources, etc. make the development of forest plans a complex process. Consequently, Decision Support Systems (DSS) are essential tools for practitioners involved in complex decision-making problems, such as those which arise in forest management and forest planning. DSS have been defined by Holsapple (2008, p.22) as "computer based systems that represent and process knowledge in ways that allow the user to take decisions that are more productive, agile, innovative and reputable", and Muys et al. (2010, p.87) considered DSS as "tools providing support to solve ill-structured decision problems by integrating a user interface, simulation tools, expert rules, stakeholder preferences, database management and optimization algorithms". This paper aims to assess the use of different models and methods in DSS for decision-making in forestry, to gain some insight into which methods have been used in different applications, and to see where novel methods have emerged. The study supports the work of the European Cooperation in Science and Technology (COST) Action in demonstrating to new DSS developers how solutions have been found to different types of problems. Consequently, the literature review is comprised of two parts. Firstly, we review the recent literature on DSS relating to forest management planning, secondly we undertake and report an analysis of the literature in relation to the problem types addressed by different models and methods.

2. Literature review and objectives

An extensive literature review has uncovered a large number of published articles in recent years which use DSS to inform decision-making in forestry. Table 1 shows how simulation and statistical methods have been applied to evaluate wind damage and pest management. Simulation is commonly used in growth models, and wildfire and landscape management. In focussing on Multiple Criteria Decision Making (MCDM) methods, we found the Analytic Hierarchy Process (AHP), Simple Multi-Attribute Rating Technique (SMART), and ELimination and Choice Expressing REality (ELECTRE) have all been integrated in DSS to solve problems, e.g. to indicate weights and to rank scenarios. The Preference Ranking Organization METhod for Enrichment Evaluations (PROMETHEE) has been integrated in the LANdscape-scale, succession and

Table 1
Literature review of decision support systems for forest management.

DSS	Problems/uses	Methods	Reference
4S Tool[a]	Internet-based DSS to inform forest management for private forest owners	Database and GIS[q]	Kirilenko et al. (2007)
EMDS[b]	Environmental analysis and planning at user-defined spatial scale from landscapes to continents Evaluation of management priorities	GIS[q], AHP[r] and SMART[s]	Reynolds (2005); Gärtner et al. (2008)
ESC[c]	Informs decision on tree species choice for given site conditions	Delphi and RA[t]	Pyatt, et al. (2001)
ESDSS[d]	Supports estimation of regional eco-security and decisions about environmental protection and land use	AHP[r], Delphi and GIS[q]	Xiaodan et al. (2010)
FORESTAR[e]	Selects harvesting targets (landscape level) and determines cutting intensity and cycle (stand level)	Simulation and GIS[q]	Shao et al. (2005); Dai et al. (2006)
ForestGALES[f]	Informs decisions on management to reduce wind damage	Risk model, RA[t] and windflow model	Gardiner and Quine (2000); Cucchi et al. (2005)
FTM[g]	Models and analyses tree growth, forest operations, economy, biodiversity and nutrient balances	Simulation and GIS[q]	Andersson et al. (2005)
GeoeSIMAeHWIND[h]	Assessing the short- and long-term risk of wind damage in boreal forests (stand and regional level)	Simulation	Zeng et al. (2007a)
IA-SDSS[i]	Supports land-use planning and local forestry development with consideration of carbon sequestration	Integrate EMDS[b], CBA[u] and AHP[r]	Wang et al. (2010)
LANDIS[j]	Simulates forest landscape (fire, wind, harvesting and insects)	Simulation	Shang et al. (2012)
LMS[k]	Landscape changes integrating landscape-level spatial information, stand-level inventory data, growth models. SFM[o] evaluation in private land-management	Simulation and GIS[q]	Reynolds (2005)
NED	Project level planning and decision-making processes. From small private holdings to cooperative management across multiple ownerships	Simulation (growth, yield and wildlife), Database and GIS[q]	Reynolds (2005)
SDSS[l]	Elaborates silvicultural scenarios, assessment of indicators and comparison of the scenarios (MCDM[p])	Simulation, and ELECTRE[v] III	Pauwels et al (2007)
SprayAdvisor	Decisions for herbicide spray programs	Experiment design and statistical analysis	Thompson et al. (2010)
Woodstock[m]	Pest management decisions on use biological insecticides, rescheduling of harvest and forest restructuring	Simulation and LP[x]	Iqbal et al. (2012)
WRR-DSS[n]	Decisions for effective fire management planning	MCDM[p] and fuzzy set theory	Kaloudis et al. (2008)

Acronyms of DSS: a – 4S Tool: forest stand software support system, b – EMDS: ecosystem management decision support system, c – ESC: ecological site classification, d – ESDSS: eco-security assessment decision support system, e – FORESTAR: forest operation and restoration for enhancing services in a temperate asian region, f – Forest GALES: geographic analysis of the losses and effects of storms in forestry, g – FTM: the forest time machine, h – Geo-SIMA-HWIND: forest growth SIMA and wind damage HWIND models integrated into GIS, i – IA-SDSS: integrated assessment framework and a spatial decision support system, j – LANDIS: LANdscape-scale, succession and DISturbance model, k – LMS: landscape management system, l – SDSS: silvicultural decision support system, m – WRR-DSS: wildfire risk reduction DSS, n – Woodstock: Remsoft spatial planning system.
Acronyms of models and methods: o – SFM: sustainable forest management, p – MCDM: multiple criteria decision making, q – GIS: geographic information system, r – AHP: analytic hierarchy process, s – SMART: simple multi-attribute rating technique, t – RA: regression analysis, u – CBA: cost-benefit analysis, v – ELECTRE: elimination and choice expressing reality, x – LP: linear programming.