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A Practitioner-Oriented Decision Support Process for Forestry Pest Management

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Abstract

The article discusses a new decision support process for forestry pest management. Over the past few years, DSS have been introduced for forestry pest management, providing forest growers with advice in areas such as selecting the most suitable pesticide and relevant treatment. Most of the initiatives process knowledge from various domains for providing support for specific decision making problems. However, very few studies have identified the requirements of developing a combined process model in which all relevant practitioners can contribute and share knowledge for effective decision making; such an approach would need to include the decision makers' perspective along with other relevant attributes such as the problem context and relevant policies. We outline a decision support process for forestry pest management, based on the design science research paradigm, in which a focus group technique has application to acquire both expert and practical knowledge in order to construct the DSS solution.

Keyword(s): DSS, pest management, design science

INTRODUCTION

Decision support systems (DSS) have been used in forestry to test different management scenarios to forecast productivity, wood quality and landholders' income and expenses over a rotation (Farm Forestry Toolbox 2008). Within forest health, DSS provide assistance with identifying pest and disease symptoms (About Lucid ID 2010; Farm Forestry Toolbox 2008), risk assessment (Potter et al. 2000) and browsing management (Clark et al. 2010). Through simulation of population dynamics of plantation pests (Nahrung et al. 2008), the optimum frequency and timing of pesticide applications for insect population control can also be evaluated within process-based software such as DYMEX™ (Maywald et al. 2004). Optimising the frequency and timing of pesticide application can provide significant productivity benefits and may enhance environmental impacts by reducing the extent of pesticide residues (Mansingh et al. 2003; Robinson et al. 2002). However, these model-based decision making processes are immature in terms of the involvement of practitioners in system development. Further, pest management knowledge is continually evolving, and any DSS should reflect this by incorporating new knowledge to determine the most appropriate practice. A decision making process that enables interaction between scientists and practitioners is therefore important; it must incorporate knowledge from multiple sources to maximise the quality of the knowledge base as well as provide decision support.

In a socio-technical context of design science literature, the design can be described as product, process, intention, planning, communication, user experience, value, professional practice and service (McKay et al. 2008). This broader

concept highlights the significance of an “*integrated socio-technical view that includes the human social and organizational factors alongside the technical factors*” (McKay et al. 2008, pp. 20). In DSS development, Arnott and Pervan (2008) pointed that a major oversight is the reduced association of the target decision makers and reflection on relevant problem context in most of the DSS development studies. Therefore, this study aims to outline a combined process for decision support in the forestry pest management that can address the interaction between scientists and practitioners. The key research question for this study is: *How can a decision support process in forestry pest management help combine knowledge from scientists and practitioners?*

This question is addressed by outlining a practitioner-relevant process of decision support in which combined knowledge sharing ensures effective management by the decision makers, through the utilisation of pest management knowledge in an existing DSS model (Proposed by Miah, Kerr and Gammack, 2009). The proposed process also builds upon existing research, such as forest simulation visualisation (Chertov et al. 2002), user customisable pesticide DSS (Röpke et al. 2004) and an expert system for pest identification and treatment (Kaloudis et al. 2005). Such studies motivate us to design an integrated process in which practitioners can modify and build decision services according to their context. The study also makes use of design science, since this is able to incorporate input from both end users and scientists (McKay et al. 2008).

We explore the utilisation of pest management knowledge to model a decision support process. We investigate how forest managers as practitioners and scientists as domain experts may improve decision making by collaborative input on how decisions affect productivity (both growth and wood quality) and reduce pest populations. We thus begin by surveying existing DSS approaches in forestry pest management and identifying their key mechanisms for decision support. We then outline a combined decision-making process for pest management. Subsequently, the process is presented through the schema of the model, based on an existing decision system model introduced in the dairy industry Miah et al. 2009), in which knowledge sharing from multiple sources for decision making were supported.

The rest of this paper is organised in the following way. The following section describes the background of our problem. Next, the methods used to develop the decision support process are described, followed by the proposed process model. Finally, a discussion and summary are presented, along with proposed potential improvements to the study.

BACKGROUND

This section provides background on how the current focus of decision support issues in forestry pest management comes to the point of an interesting research platform through both the target problem description and existing DSS literature leading to one of our previously developed DSS systems. This discussion will help reasoning our problem understanding within a design science methodological view.

Problem description

Improving pest management practices in forestry is dependent on understanding the extent to which pest-related damage affects forest productivity and timber quality, determining optimum management strategies to reduce pest population densities and damage to trees, identifying existing and new incursions of exotic pest species and predicting the spread of invasive forest pest species.

Existing DSS processes

Forestry pest management DSS have been developed for diagnosis (Lippitt et al. 2008; Ellis et al. 2005; MacLean et al. 2000; BenDor et al. 2006), advisory support (Trevisan et al. 2009; Mansingh et al. 2007; Mahaman et al. 2002), and management and planning support (Potter et al. 2000; Kaloudis et al. 2005). They include expert systems for risk estimation, pest identification and treatment proposal (Potter et al. 2000; Kaloudis et al. 2005), along with neural network based approaches (Lippitt et al., 2008). They can also encompass multiple perspectives, such as timber production and environmental sustainability, across large sites (Twery et al. 2000).

Typically, existing DSS for advisory, diagnosis and planning support have not addressed this requirement through effective DSS functionalities in which science-based knowledge can be combined with practice-based understanding. Miah et al. (2009) have proposed such a system within a rural industry domain, in which extension professionals and farmers collaborated in operational decision making. This approach was prototyped and evaluated in a DSS design, and its generic utility for other domains was assessed. The rural business problem domain that was used required current states to be assessed to estimate future production goals, and therefore is adaptable to production forestry. The decision support solution had two functions: to allow domain experts to build a knowledge base using established,

peer reviewed sources; and to permit end users (growers) to build their own decision support tool based on their contextual settings. The solution model for pest management presented within this paper is therefore based on this approach, and described in the decision process section.

Table 1: Traditional DSS approaches that are based on scientific knowledge rather than practitioner-based knowledge provision in decision making

<i>Authors</i>	<i>Key aspects of study</i>
Lippitt et al. 2008	DSS approach for identifying requirements of integrating anthropogenic and ecological variables in support of invasive species risk forecasting
BenDor et al. 2006	DSS approach for assessing the damages of tree populations and predicting on economic and environmental impacts
Kaloudis et al. 2005	Expert system approach for identifies forest insects and proposes relevant treatment aiming at reducing spread of insects in the whole forest at minimised forest damage.
Ellis, Nair and Jeswani 2005	DSS approach to assist landowners and extension agents in evaluating potential sites and suitable tree and shrub species for agroforestry planning.
Mahaman et al. 2002	A rule-based expert system approach to diagnose with pest identification and treatment advice for educational and extension purposes.
Potter et al. 2000	Expert System approach for estimating the risk that a forest faces from a North America's exotic forest pests
MacLeanPorter et al. 2000	Alternative management actions and facilitates incorporation of effects of insect damage into forest management planning
Hunter & Deveson 2002	DSS approach for predicting pest infiltration through integrating data on weather and habitat condition with the pest migration

METHODS

Existing DSS research (e.g. Arnott and Pervan (2007) in mainstream DSS, McCowan (2002), Cox (1996) for agricultural DSS) identifies a lack of practitioner involvement in DSS development. Arnott and Pervan (2007) note that the vital oversight in DSS study is “*the poor identification of the clients and users of the various DSS applications that are the focus of investigation* (Arnott and Pervan 2007, p. 67). This implies that practitioners’ view and the relevant business context are ignored in previous DSS development research. In response to this significant gap, the design science research paradigm addresses information system (IS) design artefact in a socio-technical realism paradigm as it associates with relevance and use of context within the technical design (McKay and Marshall 2007). Design science research has two main directions: Hevner et al (2004) and other’s contributions on innovative systems, models, and methods design, subsequently referred as ‘technology-centered’ design science; and McKay et al. (2008) and other’s (Carlsson 2006) contributions on IS design in an organisational and social context, called ‘socio-technical’ design science. The second direction can accommodate a design within organisational and human phenomena, and is thus relevant to this study.

In the design science paradigm, acquiring knowledge and understanding of the problem and its solution can be achieved in the designing and application of the artefacts. Design science has successfully been applied to DSS development and evaluation (Muntermann 2009), with the design value of a solution prototype being evaluated. The definition of March and Smith (1995) define the IT/IS artefacts as system architecture, systems designs or software prototypes that are designed to demonstrate the applicability of the outlined solution. In a recent study, Muntermann (2009) developed a decision solution based on a design-science research paradigm. Motivated by the principles we employ an approach based on a multi phase approaches (adopted by Purao and Storey 2008) in reuse based design under the design science paradigm, as it is relevant to this study. For example, Mahaman et al. (2003) utilised a four step cycle for developing a rule based expert system for pest management in solanaceous crop systems. The steps were acquisition and representation of knowledge, operation of expert system and evaluation of system. This study

therefore uses four similar steps: knowledge acquisition, rule creation and representation, systemisation and evaluation.

Our approach uses multiple research techniques for data collection and verification prior to DSS development, through the evolutionary prototyping approach. For knowledge acquisition, our pilot study is conducting through focus group meetings with the stakeholders. This approach mirrors similar studies, which have used focus group discussion, semi-structured interview and participant observation approaches (for example Mansingh et al. 2005; Miah et al. 2009; Mahaman et al. 2002).

The approach presented in this study uses scientific knowledge inputs from literature, along with practice based heuristics identified through focus groups. This happens during the knowledge acquisition phase. The acquired knowledge is then used to develop rules and represent the decomposed components via a top-down approach. This activity takes place during the rule creation and representation phase. The systemisation phase then incorporates the process development in which the focus group's reflections are vital. The developed process associated with the top-down is then evaluated, leading to system prototype development. The five steps associated with the defined outputs will be undertaken during the prototype development. The prototype development is in planning for demonstrating our proof of concept in a more understandable way to the industry peers. However, the identified outputs corresponding to the steps will enable us to evaluate the entire system design in various checkpoints.

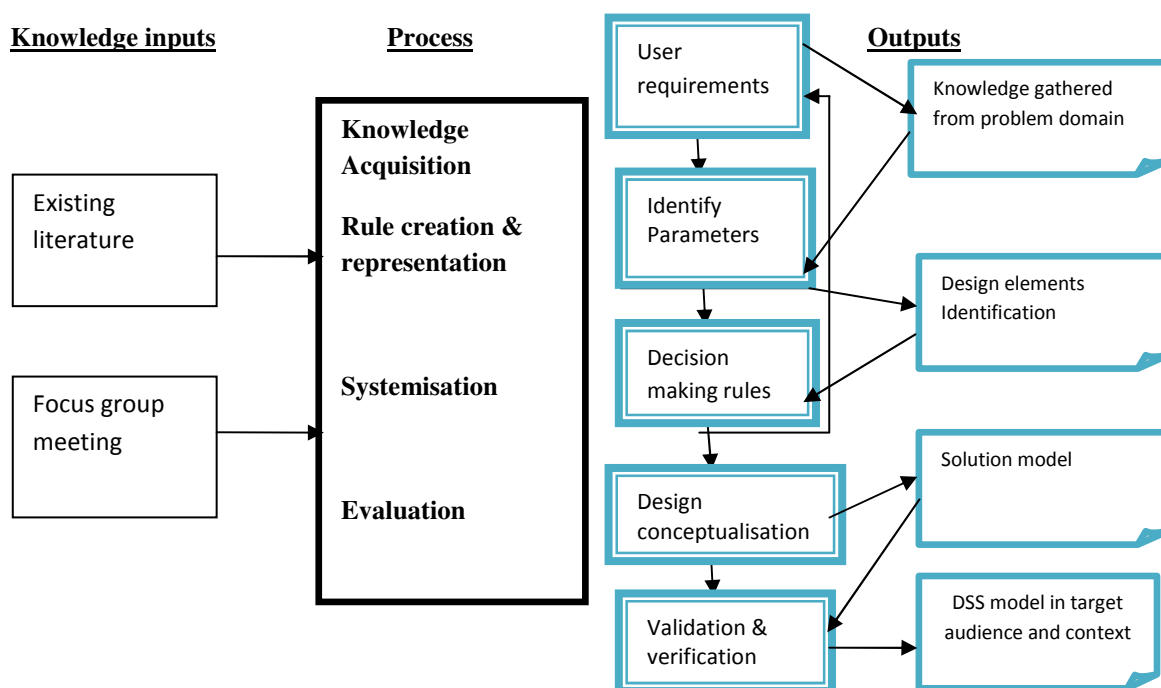


Figure 1: Methodology for the DSS solution development in forestry pest management (partly adapted from Puro and Storey, 2008)

DECISION PROCESS GENERATION

To address the dual requirements for incorporating scientific and heuristic knowledge, we outline a combined decision process that consists of two key activities: knowledge organisation and decision support creation. Consequently, Miah et al. (2009)'s DSS model can be used to illustrate our collected knowledge in the précised way. The activity of knowledge organisation involves creation of a knowledge base by the scientists. The activity model utilises fundamental knowledge components that enable reasoning (parameters, factors and their formulas) under a complete structure of decision support system. A practitioner or end-user can utilise the organised knowledge repository for building context specific decision support. For example, the difference between the desired status and the current status for each parameter can be displayed so that the forest grower can decide which factors, of those that may be changed, need to be improved. Figure 2 shows how domain knowledge is modelled (based on decision model by Turban, Aronson, Liang and Sharda (2007)) in the proposed solution design.

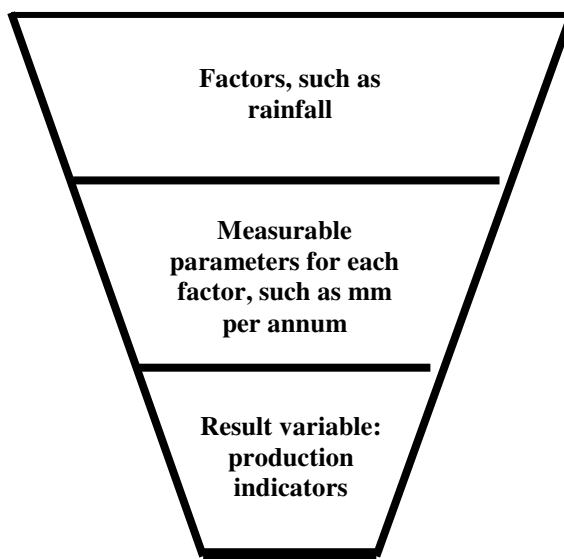


Figure 2: Model of Knowledge repository

Figure 2 illustrates how factors, which may include elements such as rainfall, density of trees and tree species, form the basis of the knowledge model. Each factor has an associated measurable parameter or parameters, such as the number of millimetres of rainfall per annum. Parameters may be quantitative, such as the number of trees per hectare, or qualitative, such as a human evaluation of whether the site is steeply sloping, undulating and so on. The model uses the factors, moderated by their parameters, to determine the result variable. This represents a key production indicator, such as the number of cubic metres of timber produced per annum.

Domain experts determine the factors, parameters and result variables, together with the rules that allow the result variables to be calculated from the factors and parameters. Table 2 shows an example from the forest health application domain, containing factors, parameters and a result variable. The example, extracted from Candy et al. (1992), determines the impact of defoliation on productivity, and thus allows the economic impact of insect defoliators to be determined. The example is important since the growth rate of trees can be reduced by severe defoliation. For example, the model has been used to project that, if seven year old trees that are attacked by a specific species of beetle have their wood volume reduced by three times as much as those that have not, then at harvest age the attacked trees will have suffered a 50% wood volume reduction (Candy et al. 1992; Elek 1997).

Table 2: Forest health factors, parameters and result variables used in the knowledge repository

<i>Factor</i>	<i>Parameter Associated with Factor</i>	<i>Result Variable</i>	<i>Result Variable Calculation Rules</i>
Mean heights of undefoliated trees (C)	cm	Tree height in cm at final measure (y)	$y = C \{ 1 - (0.056D + 0.091P_o + 0.042P_n) \exp[0.516E + 0.388L + 0.873R - 0.295ER] \}$
Removal of foliage after regrowth: disbudding (D)	1 = disbudding, 0 = otherwise		
Old (P _o) and new (P _n) foliage removed	Proportion (range 0 – 1)		
Early season defoliation (E)	1 = early, 0 = otherwise		
Late season defoliation (L)	1 = late, 0 = otherwise		
Repeat defoliation (R)	1 = repeated in the second year, 0 = otherwise		

Extracted from Candy et al. 1992¹

Based on the findings we outline the combined process and present this through the following Figure 3 in which two functional activities are illustrated for decision support in forestry pest management.

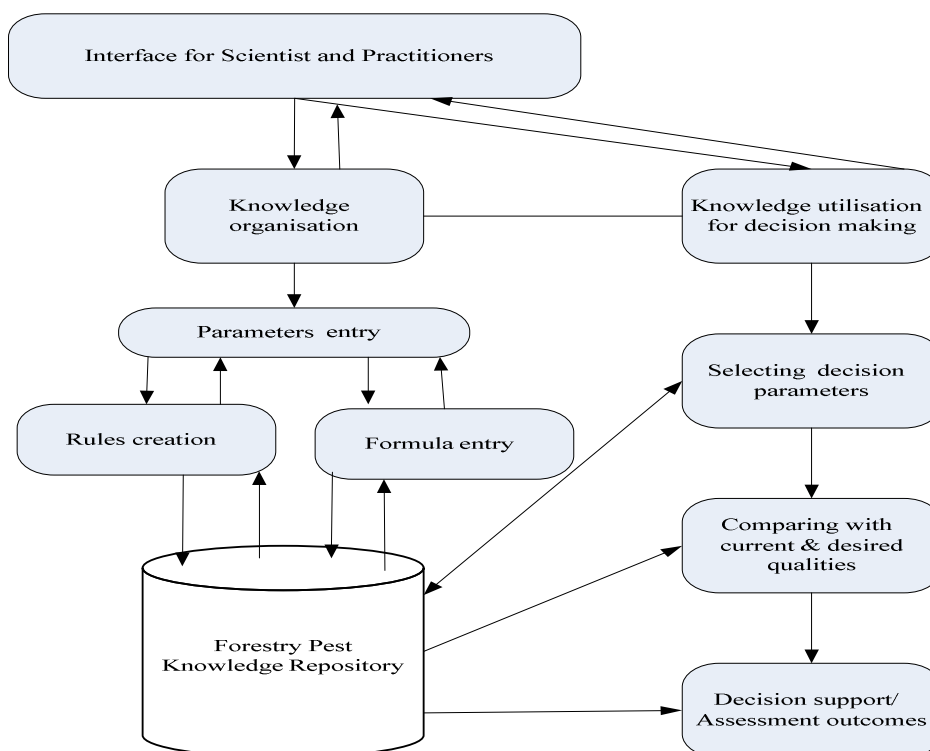


Figure 3: The proposed decision support process (Adapted from Miah et al. 2009)

¹ Our first focus group meeting identified a link between our research goals and Candy’s work. Thus we decided to utilise the findings initially to demonstrate our proposed process.

The two main applications we thus outlined, one for knowledge organisation from the problem domain and the other for knowledge utilisation for decision support building by practitioners, are essential functions in the solution process. The first can help decompose problem knowledge into decision making parameters and rule creation with respect to target problems. Predominantly, the rules are based on scientific knowledge in terms of formulas, and rules of thumb are developed from practice-based knowledge. Through this, scientists can provide effective decision support for practitioners by transferring the latest useful scientific knowledge. For the second application, practitioners can outline their decision support by selecting the most situation specific parameters. By giving current values of their selected parameters, practitioners can obtain the difference between the optimal status and the current status for each parameter with their possible future impacts (Miah et al. 2009). An assessment and further instructions can then be generated as decision support to the specific decision context.

The proposed decision support process shown within Figure 3 may be illustrated using the data from Table 1, extracted from Candy et al. 1992. To apply such data to the process, the scientists would use the interface for knowledge organisation. Specifically, they would define a number of factors, each with an associated parameter (Boolean factors use 1/0 to denote true/false): mean heights of undefoliated trees (C), in cm; removal of foliage after regrowth - disbudding (D); old (Po) and new (Pn) foliage removed, as a proportion from 0-1; early season defoliation (E); late season defoliation (L); and repeat defoliation (R). These factors would then be used in the creation of a rule to determine the tree height (y) in cm at final measure, calculated using the following formula:

$$y = C \{ 1 - (0.056D + 0.091Po + 0.042Pn) \exp[0.516E + 0.388L + 0.873R - 0.295ER] \}$$

Once this details had been incorporated into the forest pest knowledge repository, it could then be used by practitioners for decision making. A practitioner would first enter the values of all factors within the stand of trees to which the decision support would apply; for example, the mean heights of undefoliated trees may be 500, disbudding may be false (0) and so on. The DSS would then use these factors to calculate the tree height at final measure, and the practitioner could then establish the size of the gap between their target tree height and that calculated by the system. The practitioner could then investigate how to reduce this gap, either manually via experimentally modifying factors, or by informing the system which factors could be modified and having the system calculate the optimal modifications to achieve the target tree height.

DISCUSSION AND CONCLUDING REMARKS

This research-in-progress paper outlined a practitioner-relevant process of decision support through the utilisation of pest management knowledge under the socio-technical design science paradigm. The knowledge collected from existing literature has been utilised for outlining the proposed combined process in which a collaboration of activities, for scientists and practitioners, leads to productive decision support, as the process incorporates the latest science-based pest management knowledge. The proposed process is based on a previous decision support model developed for enhancing collaboration in decision making. Methodologically, we promote the adaptability of socio-technical design research in solving a decision making problem in forestry pest management.

We have shown how the complex requirement of decision processes can be supported through the proposed combined process in which practitioners can collaboratively obtain decision support using their combined knowledge. We attempt to address the growing recognition of developing end user-enabled processes or systems for decision support, in which the main challenges are to define the interplaying roles of decision makers, and a line should be drawn between the roles for activities (Miah, 2009). Following this guidance our proposed process is different from standard forestry DSS systems, which are designed for the purpose of diagnosis, assessment or planning. Our solution process applies an existing decision approach to enable knowledge sharing between decision makers at a range of levels. Traditional DSS models, particularly in forestry pest management, often contain a specified or analytical outcome-based solution, rather than the flexible approach presented in this study, within which decision rules can be modified dynamically and continuously tested. The proposed process can also be useful for knowledge acquisition in building new DSS. Further study is required for evaluating the approach thoroughly with potential users and within an industry context. At first a conceptual prototype will be developed for ensuring the identified interaction of users in decision making. The key technical aspect in this design would be the integration with existing simulation-based data models (such as DYMEX) to predict optimum management practices to achieve significant productivity benefits. The prototype design effort will also allow us to evaluate the entire DSS process. In this instance, the evaluation guidelines proposed by Hevner et al. (2004) would be employed to evaluate the applicability of the design in the problem domain.

This decision approach also could help reduce the complexity of knowledge acquisition and modelling in the development of knowledge based systems, since heuristics can be easily created (e.g. by changing parameters and formulas for determining outcome variables) and tested within this approach, and it has the potential to lead to improved practices, individual involvement and enhanced productivity and sustainability in the forestry industry.

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