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PÔVODNÁ PRÁCA – ORIGINAL PAPER

Decision support systems in Slovak forestry planning: a review

Systémy na podporu rozhodovania v lesníckom plánovaní na Slovensku: prehľad

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Abstract

Project COST Action FP 0804 – FORSYS summarizes European experiences in developing and applying decision support systems for forest management. This paper introduces FORSYS methodology for the classification of current forest management problems and for the description of existing decision support systems. The paper identifies the general forestry planning problems that need to be solved in Slovakia, lists the DSS tools available in Slovakia and evaluate their ability for addressing the identified problems. Finally, the research needs and gaps in this field were identified. A comparison of the situation regarding decision support in Slovakia and both in Europe and neighbouring countries (Austria, Hungary) is introduced in order to justify the identified needs. The paper is focused on the overview of models, methods and knowledge management techniques which are available in Slovakia now. We found out that the Slovak decision support research follows the state in Europe with a significant time delay and a lack of adequate instruments for addressing the contemporary planning problems exists. Consequently, there is a strong need for the development and application of computer-based tools to support decision-making problems in forest management.
Key words: decision support; forest management; computer-aided decision making; planning problems; Slovakia

Abstrakt

Projekt Akcie COST FP 0804 – FORSYS zhŕňa európske skúsenosti v oblasti rozvoja a využívania systémov pre podporu rozhodovania v obhospodarovaní lesov. Predložený príspevok sa zaoberá metodikou FORSYS pre klasifikáciu súčasných problémov lesného hospodárstva a pre opis existujúcich systémov pre podporu rozhodovania. Identifikuje základné problémy lesníckeho plánovania, ktoré je potrebné riešiť na Slovensku, uvádza DSS nástroje ktoré sú k dispozícii a hodnotí ich schopnosť riešiť identifikované problémy. Na záver sú identifikované potreby výskumného riešenia a existujúce nedostatky v tejto oblasti. Na odôvodnenie zistených potrieb sa tiež uvádza porovnanie situácie v oblasti podpory rozhodovania na Slovensku so situáciou v Európe a susedných krajinách (Rakúsko, Maďarsko). Článok je zameraný na prehľad modelov a metód rozhodovania ako aj techník na manažment znalostí, ktoré sú aktuálne na Slovensku k dispozícii. Všeobecne možno konštatovať, že výskum v oblasti podpory rozhodovania na Slovensku síce sleduje stav v Európe, avšak so značným časovým oneskorením a výrazným nedostatkom vhodných nástrojov pre riešenie aktuálnych plánovacích problémov. V dôsledku toho existuje silná potreba pre vývoj a aplikácie počítačových nástrojov na podporu rozhodovania problémov hospodárenia v lesoch.
Kľúčové slová: podpora rozhodovania; obhospodarovanie lesov; počítačom podporované rozhodnutia; plánovacie problémy; Slovensko

Introduction

A general model for the decision-making process consisting of 4 characteristic phases – problem identification, generation of solution alternatives, selection of optimal solution and authorization to implement the best solution – was proposed originally by Mintzberg et al. (1976) more than 30 years ago. This framework is still widely accepted today as a general description of the multiple alternative processes and pathways, including feedback loops, that individuals and organizations use to get from problem recognition to problem resolution, which culminates in some course of action.

Any software system that explicitly assists with the implementation of one or more components of the overall process can be described as a decision support system (DSS). Holsapple & Whinston (1996) captured the basic features of a DSS as "*a computer-based system composed of a language system, presentation system, knowledge system, and problem-processing system whose common purpose is the support of decision-making activities*". Two key components in the Holsapple and Whinston's definition are a subsystems for processing problems and purposeful support of a decision-making.

Active application of a DSS in forestry planning, management and decision-making helps to maintain the processes in the forest ecosystem in balanced and sustainable order while attempting to satisfy the needs of society for a broad variety of demanded ecosystem services (Reynolds et al. 2008). The DSS used in today's natural resource management can be divided into three major classes: (i) multicriteria decision models (using optimization techniques such as mathematical programming, heuristic optimization, analytic hierarchy and analytical network methods, including the Promethee and Electre methods and so on), (ii) artificial neural networks, and (iii) knowledge-based expert systems (Reynolds & Schmoldt 2006; Reynolds et al. 2008; Kangas et al. 2008).

In forestry, DSS are actively and successfully used to support decision-making mainly in adaptive forest management

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(FM) utilizing the iterative improvement of the results of FM by using the knowledge of the managed system gained over time. On the other hand, although one of the basic features of decision-making and DSS application is their flexibility and adaptability, the practical application in adaptive FM is rather complicated (Reynolds 2013). The reasons may be divided into institutional, technological and conceptual ones. They are primarily related to the long production period closely related to problems of accurate assessment of the current and future ecosystem state and also complicated evaluation of the quality of management results in terms of economic, ecological and social goals.

At the same time, new demands are being made on the planning process in contemporary forestry. The public's interest in management approaches continues to grow. Currently a specific shift is under way in the understanding of the concept of sustainable forest and landscape management (Hahn & Knoke 2010). Attention is being given to a broader understanding of the portfolio of ecosystem services. Besides primary production and raw materials, wood, foodstuffs, feed and water, also biomass, greenhouse gasses, carbon sequestration, recreational use of forests and landscape, soil conservation and the protection of biodiversity are aimed for (Johnson et al. 2007; Reynolds et al. 2008).

Social aspects are increasing in importance, encouraging the application of multicriteria decision-making, group decision-making and the participation of local communities and other stakeholders (Reynolds & Schmoldt 2006; Hjortsø 2004; Menzel et al. 2012). Moreover, the already high level of uncertainty in forestry decision-making further increases with changing environmental conditions (Yousefpour et al. 2012; Pasalodos-Tato 2013). Also, the scope and quality of research results and scientific discovery continue to increase at a dynamic pace and to grow intensively. All these tendencies lead to increased demands on the development of methods for management, decision-making, planning and optimization.

The issue of decision-making in FM has attracted great attention. Several bibliographies and technological overviews have been published, documenting research progress in the field, e.g. by Mowrer et al. (1997), Johnson et al. (2007) and Reynolds et al. (2008). An excellent overview of the state of the art of systems to support decision-making in ecosystem management was published by Rauscher (1999), and an evaluation of the results in recent years was written by Reynolds (2005). Optimization methods have been reviewed by Garcia (1990), and Hof & Haight (2007) and Bettinger et al. (2009) reviewed applications of both mathematical and heuristic methods for optimization of spatial problems. The review by Segura et al. (2014) is very complex and structured and highlights most aspects of the issue – problem definition, model/method applied, performance measure, decision variable and criteria used for a huge list of DSS software products, including synthesis notes and identification of trends.

However, typically, the FM DSS are not described specifically enough in most of these studies in relation to the problems they are intended to solve. The scope of systems covered by previous literature is typically limited or biased. Recently, a European-wide framework with core processes and information standards for decision-making in a sustainable multifunctional FM environment was defined in the COST Action FP 0804 – FORSYS (Anonym 2013). The project summarizes European experiences in developing and applying forest DSS for FM and provides a solid foundation for technological innovation and collaboration between EU countries' research partners/institutions. Furthermore, it defines requirements for DSS implementation and provides a consistent European-wide quality reference for the development of decision systems enhancing sustainable FM. A list of about 60 systems, mostly of European origin, is among the most important project results (Anonym 2013). It is based on the development of common information standards and guidelines for the development, testing, evaluation and application of DSS for multifunctional and sustainable FM.

The objectives of this paper are: (i) to introduce a robust FORSYS methodology for the classification of FM problems solved by existing DSS and for the description of existing DSS; (ii) to identify the forestry planning problems that need to be solved in today's FM in Slovakia; (iii) to overview DSS tools available in Slovakia, assess their ability for solving the identified problems and identify research needs and gaps in this field, (iv) to compare the situation in DSS development in Slovakia and both in Europe and neighboring countries (Austria, Hungary) in order to justify the identified needs.

2. Methodological aspects of the study

In this study, except for the vast literature describing DSS development, design, evaluating and testing in general, we have focused on the results of the COST Action FP 0804 – FORSYS survey of existing DSS applied in multi-objective and sustainable FM across Europe. The DSS survey was aimed at the identification of a prevalent problem in FM decision support in a specific country, followed by a DSS survey used to addressing it. The FM problems are understood as the definition of the timing and location of FM options in order to approximate or optimize management objectives, which are single or multiple and relate to market or nonmarket goods and services subject to resource constraints (Borges et al. 2014). A DSS is defined as any computerized tool with a graphical user interface that includes a data management module and a optimization module, which provides guidance and support to define the timing and location of FM options.

A description and classification of DSS in terms of problem dimensions was given (Table 1). Also other spatial and temporal projection capabilities, knowledge management functionalities and existence of explicit support for participatory processes were taken into account (Borges et al. 2014). Consultations with DSS developers and users, questionnaires and different kinds of documentation were used as data sources. Documents typically studied include articles, scientific reports, reports, manuals, technical and scientific references, journals, laws, regulations, technical documents, plans, proceedings, textbooks, surveys and web pages. There were 26 country reports written by 94 authors. As a result, a semantic wiki was also developed to include additional information and publish it in a flexible manner in a web environment.

Table 1. Definition of forest management problem dimensions.

Dimension	Possible values	Description
Temporal scale	Long-term (strategic)	Planning horizon extending over more than 10 years.
	Medium-term (tactical)	Planning horizon extending from two to 10 years.
	Short-term (operational)	Planning horizon extending over one year or less, typically including planning periods of one month or less.
Spatial context	Spatial with neighborhood interrelations	The interactions of decisions made for neighboring stands (or other areal units) are of importance, i.e. a decision made for one stand may constrain decisions for neighboring stands or influence the outcome of decisions made for neighboring stands.
	Spatial with no neighborhood interrelations	Locations of forest operations are important, but it is assumed that a decision made for one stand does not constrain decisions for neighboring stands or influence the outcome of decisions made for neighboring stands.
	Nonspatial	Stands may be aggregated into strata or analysis units without considering their mutual locations. There is no concern over locational specificity or neighborhood interrelations.
Spatial scale	Stand level	Focused on units with homogeneous ecological, physiographic and development features.
	Forest level	Focused on forest landscapes with several stands managed for one objective.
	Regional/national level	Focused on sets of landscapes that may all be managed for different objectives.
Decision-making dimension	A single decision-maker	Makes the decision on his/her own, e.g. the forest owner.
	One or more decision-makers	Have the power to decide. In addition, there can be other parties (stakeholders) with no formal decision-making power that are influenced or may influence the decision.
Objectives dimension	Single	The management planning problem addresses one and only one objective.
	Multiple	The management planning problem addresses two or more objectives, any pairs of which could be conflicting, complementary or neutral with respect to each other.
Goods and services dimension	Market wood products	The management planning problem addresses the supply of wood products that are traded in the market (roundwood, pulpwood, biomass...)
	Market nonwood products	The management planning problem addresses the supply of nonwood products that are traded in the market (fruits, cork...)
	Market services	The management planning problem addresses the supply of services that may be traded in the market (recreation, hunting, fishing...)
	Nonmarket services	The management planning problem addresses the supply of services that are typically not traded in the market (public goods, aesthetic values, water, biodiversity...)

The results consist of a list of systemized problem groups for forestry DSS application, a list of DSS systemized by application area, applied models and methods, system architecture, a knowledge management approach and a participatory approach in the form of a semantic wiki structure (Anonym 2013; Borges et al. 2014).

The information necessary for the compilation of the country report content in terms of COST Action FP 0804 – FORSYS for Slovak conditions was obtained from scientific works and discussions with the DSS developers from the Technical University in Zvolen as well as from the National Forest Centre. In addition, the information published on the relevant web portals (e.g. Forestry GIS, Hunters GIS, ITIS Portal) and on the web sites oriented to the introduction of particular tools, models, procedures and knowledge management techniques (e.g. SIBYLA Suite) were used.

3. Results

3.1. Description of FM concept in Slovakia and the identification of current planning problems

The FM process in Slovakia is obtained on the information in forest management plans (FMP), which are regularly updated at 10-year intervals. The information acquisition and following planning is divided into two levels: (i) complex forest and environment survey utilized mainly for so-called framework planning in a strategic dimension for operational sets of forest stands, (ii) detailed forest inventory and planning – used in tactical and operational planning at forest stand level.

Framework planning for a rotation period is based on the idea of the predefined forest management model (FMM). The FMM is a set of main management goals, basic decisions, rules and instructions on how to achieve the defined goals within the rotation period. Identification of FMM for a particular stand is done through the determination of 17 different input variables characterizing mainly forest category, site conditions, forest type, current species composition and degree of ecological stability. The forest category is an important input that fully determines the main management goals. Three forest categories are distinguished according to identified and ranked set of forest functions – production, protective and restricted management forests.

Subsequently, the FMM identified by specialists one year prior to the beginning of FM plan (FMP) elaboration becomes a framework for the proposal of substantially more detailed management measures for a particular forest stand in the given decade during the tactical planning. The whole procedure is denoted as a functionally integrated FM, because of the aim to simultaneously fulfill production and non-production ecosystem services (Papánek 1978; Midriak 1981). The ultimate general goal is sustainable FM with the maximum attainable economic yield (Sedmák et al. 2013).

Using an FMP in practical management is obligatory for all owners in Slovakia (state, private, municipal, church, community, cooperative owners). Hence, all forests in Slovakia are managed under the FMP. The duty of elaboration of the FMP, the list of its mandatory components and exact descriptions of steps and terms/dates applied in the FMP elaboration process are stated in Act No 326/2005 Coll. on Forests (also known as Forest Law). The elaboration process results in only one FMP proposal, which is considered to be optimal.

Despite its maturity, complexity, precise documentation and practical applicability, this approach is rather traditional and inflexible without a deeper introduction of decision-making methods and decision support systems into the forest practice. Focusing on dynamic economic and ecological changes in the last period, it has strong challenges regarding data and information gathering, management and application, preservation of sustainability principles, balancing nature conservation, and facilitating wider society participation. The application of a predefined FMM is associated with several problems (Kulla et al. 2010; Sedmák et al. 2013; Machanský 2013).

Firstly, most strategic goals, decisions, approaches and rules recommended by a particular FMM are defined only qualitatively, i.e. verbally or by a range of possible values. Consequently, a high degree of subjectivism is allowed within the scope of tactical planning at a stand level. Moreover, the contemporary system of framework planning is probably too general and schematic if applied at a stand level. The utilization of general qualitative management rules valid for an operational set of stands does not necessarily lead to optimal management in a particular stand (especially from a multiple-objective perspective).

The predefined FMM is considered as optimal because it does not contradict the today's scientific knowledge and theories, or any long-term practical experience. Quantitative evaluation of these assumptions, however, has not been performed due to the long-term character of management. Thus, there exists no feedback or any evaluation that the predefined management model is really optimal. There are also other problems mentioned by Kulla et al. (2010): (i) missing risk analysis of FMM application; (ii) low flexibility in the implementation of new knowledge, for example missing adaptive actions against the negative impacts of climate change, etc.; (iii) restricted opportunities for forest owners to participate in the process of model and FMP elaboration. A strong need for complex changes in this field is identified. Based on this and in accordance with the more conceptual and prognostic materials (e.g. Moravčík & Konôpka 2012), we can synthetize urgent FM tasks in Slovakia (Table 2).

Rational solutions to all the identified complex tasks can be and should be facilitated by objective decision support tools or whole systems because the complexity of problems quickly exceeds the capacity of the human brain.

3.2. Description and classification of existing DSS tools in Slovakia

Surveyed decision support tools are described and systemized using standardized typology of FM problems (Table 3). First, it should be stressed that there is no fully developed decision support system documented in Slovakia (consisting of all characteristic modules according to Bourges et al. 2014). Instead there is a series of partial DSS tools potentially utilizable as a module of a complete DSS.

Several GIS-based information systems, which are mostly published as Web Map Services (WMS) and enable available information to be browsed about forests by foresters directly in the field, were developed. They support sustainable FM on operational or tactical time level. The environment of these systems is user-friendly and can be easily used by a person who does not have special skills in working with a computer. It is limited only by the GSM signal availability in the field.

Table 2. Tasks needed to be solved in Slovak forest planning.

Identified task	Description and justification	FORSYS classification
More balanced combined FM objectives	FM planning in Slovakia would be characterized by rigid regulation mainly within an even-aged concept with low adaptability to environmental changes. FM goals are determined by site conditions and state of forest with minimal acceptability of owner/manager demands. The goals are primarily oriented to sustainable FM with maximum attainable economic yield based on timber wood production. Multifunctional management is guaranteed through forest zonation (i.e. forest categorization) only partly at landscape level. The need to fulfill a broader, more balanced variety of ecosystem services at stand level has been emphasized in recent years.	Tactical and strategic planning, spatial dimension with neighborhood interrelations, spatial scale is represented by individual tree and stand level, more than one decision-maker is involved in decision-making process, multiple objectives dimension, providing market wood products and non-market services, participatory process is required.
Low flexibility of FM planning, absence of adaptive strategies for climate change mitigation, need to strengthen the sustainability aspect of forest production	The special role of forestry in Slovakia is the preparation and implementation of adaptation strategies to optimize the management of forest ecosystems in the country due to the impacts of climate change. Currently, there are institutional and political barriers to effective response to climate change. In forestry, there are still a few requirements for the development of specific adaptation strategies and in the sector there are only a few specialists able to effectively implement these procedures. Currently, the National Forest Programme of the SR and its indicative action plan are considered tools that provide some procedures at the political level.	Tactical and strategic planning level, individual tree and stand level with neighborhood interrelations, more than one decision-maker is involved in decision-making process, multiple objectives dimensions, providing market wood products, non-market services, participatory process is required.
More effective use of forest as wood and nonwood material and renewable bioenergy source	Particular attention is paid to practical tasks of forest ecosystems management, the optimization of their allocation in the country, efficient production of biomass, soil protection, water retention, as well as fulfilment of other sociocultural functions. At the same time, development and implementation of unified state policy and strategy for wood-processing industry development are required in order to provide intensive support for domestic renewable resource complex utilization, with an emphasis on promoting the support for wood processing as an ecologically sustainable reconstituted material in the final products, with particular regard to the use of biomass in bioenergetics and domestic finalization of timber into wood products	Operational to tactical planning, regional to national spatial level, more than one decision-maker, multiple objectives dimension, provision of market wood products.

Table 3. List of existing DSS tools in Slovakia.

Problem type	Computerized tool / Decision Support System	Decision support models and methods (if applicable)	Knowledge management techniques (if applicable)	Methods for participatory planning (if applicable)
Sustainable FM	Foresters GIS	Explicitly not applied. Individual stand data, forest maps and stand register, cadastral maps, orthophotos.	Explicitly not applied. GIS-based IS, WebGIS http://lvu.nlcsk.org/lgis/ (extended access only for registered user).	Explicitly not applied.
Sustainable FM	Hunters GIS	Explicitly not applied. Individual stand data, forest maps and game management register, cadastral maps, orthophotos.	Explicitly not applied. GIS-based IS, WebGIS https://lvu.nlcsk.org/polovgis/Login.aspx (extended access only for registered user).	Explicitly not applied.
Sustainable FM	ITIS WebGIS	Explicitly not applied. Individual stand data, forest maps	Explicitly not applied. GIS-based IS, WebGIS (available only for registered user).	Explicitly not applied.
Sustainable FM	SIBYLA (Simulator of Forest Biodynamics)	Empirical modeling, individual tree, stand level, virtual reality, mathematical models and algorithms, simulation tools.	Explicitly not applied. GIS, Expert MCDS http://etools.tuzvo.sk/sibyla/slovensky/model.htm (manual, download link, user support).	Explicitly not applied. Freeware character of the software.
Adaptive Strategies to Climate Change	FFRA (Forest Fire Risk Assessment)	Statistical analysis and modeling, knowledge maps, model built in EMDS environment	Explicitly not applied.	Explicitly not applied.
Timber Harvesting, Transport and Utilization Renewable energy sources identification	OTLT (Optimal Timber Loggin Technology selection)	Individual stand conditions database, knowledge maps, model built in EMDS environment, multicriteria analysis based on the criteria weighting and using the fuzzy logic arguments.	Explicitly not applied.	Explicitly not applied.

The "Foresters GIS" WMS (http://lvu.nlcsk.org/lgis/) allows users to browse and easily apply information about forests – individual stands classified by FM units. The information about individual stands is obtained by the spatial query on the vector layer of stand borders that is displayed in the overlay with the orthophoto imagery. It also allows information to be selected on forest stands based on the criteria defined, as well as information regarding real estate (cadastral register). It is in the testing phase and will be implemented in practice and used by workers responsible for planning and organizing FM activities. It is specified for use in state and private forests. The applications are based on the following technology: MS SQL 2008 + ArcSDE, IIS 7 + .NET 4, ArcGIS Server Advanced 10, ArcGIS Desktop 10, MS Visual Studio 10, Componentone Studio for Silverlight 2010, Silverlight v. 4, WCF RIA Services and ArcGIS API 2.2 (Jankovič et al. 2011).

The "Hunters GIS" WMS (http://lvu.nlcsk.org/polovgis/) provides similar functionalities in relation to hunting management: hunting areas and responsible persons, division of land related to the particular hunting areas of the Slovak republic, register of hunting organizations, searching a hunting area by name and zooming in. Among the information available after the login is the information related to individual hunting areas – the division of land, stocks and hunting of deer, standardized game stock and data for site classification of hunting areas. In addition, it allows online editing of hunting area borders and the creation of print output – elaboration of hunting statistics. It is used in practice by workers responsible for hunting activities. It is used in state and private forests.

Both systems are produced by the National Forest Centre in Zvolen. Both allow the user to work with GIS applications without any special knowledge or practice. To complete the database with the current data from the field or forestry administrative bodies, the foresters and forest managers themselves are involved to input it interactively into the system.

"ITIS WebGIS" is a specific WMS (http://gis.vlm.sk/itisportal) due to its connection to online mobile data collection in the field. ITIS WebGIS with the TerraExplorer application enables working with a 3D model. It enables work with overlays of cadastral and forestry maps. The dynamic layers, e.g. skidding ways, could be created by the foresters themselves, according to their need. The Timber skidding application allows foresters to get information directly in the field about the costs for the timber skidding of 1 m^3 timber volume and this also obtains information about the price that the forester would pay to the working group. The Timber Register application has a direct connection with the FM Register. It has already been implemented in practice as a common tool for mapping and decision-making for foresters directly in the field. On the other hand, the managers of the enterprise also have daily access to all necessary information about timber cutting and logging volume and timber volume classified by species and assortments, which allows them to effectively manage forestry practice and operatively react to the timber market demands.

It was produced in cooperation with the Military Forests (S.E.) and private company YMS Ltd. dealing with the development of enterprise information systems. The system is updated every day, because all the field data that are recorded by foresters (working for Military Forests) using the mobile geoinformation technologies, and who participate this way in its development, are sent to the ITIS system directly, followed by its next publication through the WebGIS application. All these systems use Web portals, respectively Web Map Services and geodatabases, as the knowledge management techniques.

For implementation of sustainable FM principles on tactical and strategic level SIBYLA Suite can be applied. Data used for the development of partial submodels and algorithms of the forest growth simulator SIBYLA come from an extensive experimental database consisting of data from Slovakia, Germany, Austria and Switzerland (Fabrika 2007). The SIBYLA system has already been used in practice for the modeling of forest growth and natural hazards (management of risks in the forest ecosystems). SIBYLA Suite is calibrated for Slovak and German conditions, but it is also applicable successfully in Czech, Austrian and Hungarian conditions (after carefull calibration and validation). It is appropriate for all temporal planning levels. No participatory processes oriented to the stakeholders were applied. It is used mainly for scientific purposes and takes into consideration all relevant production, ecological and economic criteria.

For sharing the information about the system, the web page http://etools.tuzvo.sk/sibyla/slovensky/model.htm was developed (containing the manual and download link). The spatial scale of this system is represented by individual trees for growth modeling and by a forest stand in the case of natural hazard modeling. The model is suitable for growth modelling mono-specific as well as mixed species stands. From the timescale point of view, it is appropriate for a tactical and operational planning of management activities in the forest. Moreover, model is able to take into account changing environment (including changing climate). Therefore, it is also suitable for use on a strategic time level and can be applied also for the generation of adaptive strategies to climate change mitigation on a tactical and strategic level.

Most of the attention of natural resources protection management goes to the conservation of natural life, ensuring a sustainable and beneficial use for society, which is very closely related to the planning of adaptive strategies to climate change. Recently, there has been a growing demand for wildland such as a place to live or to spend a pleasant vacation period. This situation leads to the consideration of a new scenario of natural resources planning and management. Under our conditions, forest fire is an undesirable phenomenon, damaging not only the forest ecosystem, but also, if the fire spreads behind the forest borders, endangering the property and lives of people. For the purposes of fire risk assessment, a method called FFRA (Forest Fire Risk Assessment) was developed. The method was developed on the basis of data related to the forest fire occurrences over a 20-year period in the Slovensky raj National park experimental area, which were managed and stored in paper form at the District Directory of Fire and Rescue Corps (Tuček & Majlingová 2009).

It is based on two types of analysis. In the first type, the forest fire risk is described by means of probability, which reports the assumed disturbance of the forest, based on its species composition and age during a year. In the second type of analysis, the influence of relevant geographic factors (elevation, slope, aspect, the nearest road distance, the nearest settlement and urbanized area distance) is tested on the fire occurrence. This is performed based on a comparison of populated proportions of the analyzed factor values on areas disturbed by fire and the whole experimental area. For its application, the GIS environment is used, in particular the Map Algebra tools. A model was also developed in the NetWeaver (Ecosystem Management Decision Support System – EMDS) environment for automated processing data – risk assessment based on the FFRA method. There have been no participatory processes oriented to the involvement of the stakeholders applied.

Currently, it is used only by specialists (researchers) from the field of fire safety or forest protection. The results of the assessment (digital or printed maps of fire risk distribution in an area) are used by forest planners for planning FM activities, in particular silvicultural, to reduce the vulnerability of the forest due to fire (by means of changing the species composition of the stands, or conversion of the homogenous stands to mixed stands). Next, it is used and implemented in fire warning systems. In this case, the results of fire risk assessment, together with the current meteorological situation and vegetation drought index, represent the background for the production of daily fire risk maps and serve as a decision-making support for members of crisis staffs and firefighters and rescuers. From the spatial scale point of view, this method is appropriate for its implementation in GIS/spatial-based systems. The spatial scale of this model is represented by the individual forest stand. The methodology is appropriate for homogenous as well as for mixed stands. From the timescale point of view, it is appropriate for a tactical and an operational planning of management activities in the forest.

To adapt forestry to the changed conditions also requires the intensification of silvicultural operations, and the decreasing of soil erosion, in order to improve the state of health of forest stands and mainly the use of forest machinery in a more ecological way. The differentiated FM, oriented to the integrated functions and the keeping of sustainable development principles, is based on the rational (ecological) use of machinery in the timber logging process. For that purpose a model for the optimization of timber logging processes (OTLT) was developed, which was applied for the selection of optimal timber cutting and logging technology in the forests of Krivan (Slančík et al. 2009), the branch of Forest of the SR, S.E.

The results of assessment (digital or printed maps representing the appropriateness of each machinery/technology use for each stand) can be used by forest planners, mainly for an operational and a tactical planning of timber harvesting and logging operations in the forest. The optimal technology variant is selected on the basis of assessment of ecological criteria (terrain accessibility, skidding distance, erosion caused by logging, cutting method, soil capacity, forest stand structure and hauling places), economic criteria (salaries and levies, depreciations, propulsive matter, repairs and service, other material expenses, profit, timber losses occurring by wood processing) and ergonomic criteria (risk of injury occurrence, risk of work illness occurrence, the energetic distribution). The model is built as an open system.

The selection of optimal machinery or technology for every forest stand is based on the commonly used machinery in the forestry of the Slovak Republic, as well as the modern perspective machinery and technologies that are used rarely or not at all at the moment. The spatial scale of this model is represented by the individual forest stand. The model is not available for free use this time. It is appropriate for tactical and operational planning of forest activities. The analyses are produced based on the need of any forestry subjects by specialists (researchers) from the Technical University in Zvolen. In the development phase, no participatory processes oriented to the stakeholders are applied.

3.3. Research activities oriented to decision support in Slovak forestry

The first specific overview of the topic of spatial decision support systems in Slovakia was published in Tuček & Sitko (2000). Other details, in particular with an emphasis on applications in harvest and transport technologies, are published in the study Tuček & Suchomel (2003). The connection of a growth simulator with a spatially oriented forest information system was published by Fabrika (2002) and Fabrika & Ďurský (2006). Tuček et al. (2002) presented an SDSS concept for the location of forest roads using economic and technological criteria. Other more complex works included Tuček & Majlingová (2007) and Tuček et al. (2012), with the former focusing on the application of decision support tools in terms of forest fires and the latter on terrain and technological classification and the optimization of harvest and transport technologies.

A summary of the results related to specific applications of precision forestry was provided in the Tuček et al. (2011) study, with focus given to the analysis of the availability of forest biomass resources, terrain and technological classification as well as the opening up of forests for fire prevention measures. Applications for flood protection activities were published by Majlingová & Lubinszká (2011) and for improving forest opening up for fire prevention measures by Majlingová (2012). Sitko & Scheer (2013) focused on the application of knowledge bases and decision support systems to identify the areas with forest stands that serve as avalanche protection. Sedmák et al. (2013) presented one of the first attempts to implement approaches using decision support in planning the FM activities in Slovak conditions after a long period, following the completion of an application using optimization principles based on linear programming. To be specific, in Slovak conditions there remains a lack of research focused directly on the development and application of decision support system tools within FM activities. A study dealing with such an application was conducted in the form of overviews and systems classification published by Majlingová & Sedliak (2011).

Based on the information on climate change development and on information from the Evidence of FM Activities, which includes records related to the occurrence of abiotic and biotic harmful agents in the forest – recorded for each stand, management unit and performed forest activities – the specialists from the National Forest Centre model the development of several abiotic and biotic harmful agents in the forest. Web-based applications for monitoring forest health status (STALES, Anonym 2014) and the response of forest ecosystems to climatic change (SATLESYS, Anonym 2014) were developed. The problem with the bark beetle arose in particular due to the conflict with the State Nature Conservation of the Slovak Republic, which disproportionately placed the protection of nature and the landscape before the need to remove the fallen timber from disturbed stands in protected areas (Hlásny & Turčáni 2009; Hlásny et al. 2009). For that purpose, mathematical models and geostatistics are used. The analyses are processed in a GIS environment.

Apparently, the application of DSS tools is oriented mostly to those that were produced at domestic research institutions. Those are mostly used and validated by solving national and international research projects. The Technical University in Zvolen and National Forestry Centre in Zvolen are the main institutions responsible for tackling them. Except for the Sibyla Suite, most of the tools introduced in Table 3 represent more (spatial) information systems and/ or experimental solutions as real DSS for implementation in forestry practice. The specific decision models and methods are implemented only partly. There is also a specific and reasonable approach to knowledge management and user support missing, as well as development and improvement of complex systems. Participatory approaches, i.e. group decision making, are also completely absent.

3.4. Comparison of the Slovakian results with neighboring countries

The two countries participating on the FORSYS project survey were selected – Austria and Hungary. Austria is country with well-developed forestry and forests growing in mountain central Europe conditions similar to Slovakia. In the same time, Austria can serve as example of country with excelent state of art in the decision support field made possible by continual market economy (without any artificial political changes of ownership structure). Hungary is neighbouring country from central Europe also with well developed forestry sector, similar to Slovakia in regard to political development during the socialist era characteristic by nationalization of private forest owners leading to centralised management of forest by state.

The results of the survey in the form of a country report for Austria were published by Vacik et al. (2014). Austria has documented three problem types – selection options for forest conversions, managing mountain forests and utilization of timber resources. They belong among spatial problems with or without neighborhood interrelations, representing either a strategic or tactical dimension. Two of them represent stand-level problems and one represents regional/national-level problems.

The country report documented multiple visually appealing DSS tools for all three problem types. DSS tools are mainly developed in the framework of R&D projects and they are used by forest professionals in different organizations, and in some cases also by stakeholders and forest owners. Typically, the Austrian DSS tools are built on the WebGIS platform offering real-time mobile use. There is a strong focus on knowledge management and prioritization using multi-attribute utility functions (MAUT) in the Austrian DSS. The tools address well at least some aspects of the problem types, but because the problems defined are rather wide, the tools appear to provide solutions for "sub-problems."

The categorization of computer-based tools developed and applied in Austria presents a well-developed situation in this field with a balanced distribution of systems/tools among prevalent FM problem types. Concerning the architecture of forestry DSS, there is a noticeable shift from desktop DSS towards a modularized architecture with mobile and static clients or with Web interfaces. Thus, DSS (or relevant parts of them) have to be designed in such a way that they are executable on a mobile device. In order to support seamless communication of such heterogeneous systems, standardized (Web) services are of interest, which lead to generic Service-Oriented Architectures (SOAs). Such concepts are realized in DSS for timber utilization.

The results of the survey in the form of a country report for Hungary were published by Jáger et al. (2014). Hungary reports 16 problem types: four stand-level problems (two operational, two strategic); one forest-level strategic problem (on market-wood products); five forest-level tactical and operational problems; and six regional/national problems (three strategic, three tactical). In general, all goods and services are considered but some problem types concentrate only on market-wood products. Hungary reports 20 DSS tools, which address all prevalent problem types.

The presented tools range from the the Hungary National Forestry Database (relational database linked to GIS/mapping) to forest fire simulators or tools for harvest optimization. Altogether, 20 computerized systems/tools were presented with different levels of development maturity. It is stated that practically none of these programs deal with the core part of FM planning as it is fully covered by the system organized by the state forest service. The Hungary National Forestry Database is the main tool for FM planning and is clearly addressed to practical use. The other presented tools are applied to some extent but mainly used by researchers. Many of the tools use knowledge management (relational databases, GIS/mapping). Some tools are used in participatory processes (although they do not integrate a specific module for these).

3.5. International/European situation in DSS application in forestry

Complex evaluation of data from the COST Action FP 0804 – FORSYS survey is introduced by Borges et al. (2014). In total, 250 problem instances were reported, reflecting the diversity of environmental, socioeconomic and institutional contexts in respective countries. It contains clustering (frequency analysis) of the occurrence of problem types in DSS reported in country reports using different categorizations – for example, spatial scale and/or goods and services dimensions versus country origin, a technology component (DBMS, GIS, knowledge management tool, growth simulator component) and/or spatial scale, goods and services dimension, etc.

The most common type of problem solved with the use of DSS is FM planning at the regional level with a long-term time horizon, without taking into account the spatial context, carried out by more decision-makers in the pursuit of the objectives aimed at both market and nonmarket products and services (Borges et al. 2014). This is a typical problem of strategic scenario analysis focused on the sustainability of resources at regional and national level. The second most common problem is planning aimed at the level of the forest and/or stand. In the case of the stand, it takes in a particular long-term time horizon with a spatial context, without taking into account the situation in the neighboring stands with multiple objectives and a number of market and nonmarket products and services. This is a typical problem in the management of public forests, using the multipurpose management plan, taking into account the interests of more participants.

The predominance of DSS appears to be related to the importance of the country's forest industry as well as to the problem cluster characteristics. The forest- and stand-level problem clusters characterized by long-term planning horizons and the supply of wood products are addressed by DSS in over 85 percent of the reporting countries. Tactical and operational forest-level problems targeting the supply of wood products are also typically addressed by DSS in most countries (over 85 percent of reporting countries too). The stand-level cluster characterized by medium- or short-term planning horizons and the supply of wood products is less frequently addressed by DSS.

Despite the large variability and diversity of systems, majority of them have a modular structure. A typical system includes a module for data management, modeling (simulation) module of forest growth and production subject to different management actions, the module for the evaluation of different management alternatives and the decision-making and a graphical user environment (Borges et al. 2014).

From the point of view of the technological basis of the system, the use of a database environment is preferred over GIS. The use of techniques for the management of knowledge is common, in particular with regard to the solution of regional problems and planning at the forest level. In accordance with expectations, the use of forest growth simulators is very advanced, in particular in relation to the solution to the long-term problems.

The use of quantitative optimization techniques (e.g. mathematical programming, heuristic approaches) to model and solve long-term management planning problems with an emphasis on timber production at the forest level is very frequent. On the other side, the use of qualitative approaches and explicit support to participatory processes is reported as being less frequent. In general, the information regarding the development of the DSS is scarce. Success in the application of DSS in practice based on assessments from managers or consultants is reported only in about a third of cases.

More detailed and sophisticated analysis of the data from the COST Action FP 0804 – FORSYS survey has been published by Segura et al. (2014), who precisely evaluated models and methods that have been used in reported forestry DSS development. All important features of the categorization of the forest problem solved by these systems were taken into account. 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 that Multiple Criteria Decision Making (MCDM) is closely linked to problem types involving the consideration of the number of objectives, and 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 FM, 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 FM in coming years.

On the basis of wide range of publications, including research results directly corresponding to the COST Action FP 0804 – FORSYS project (Majlingová & Sedliak 2011, Borges et al. 2014; Segura et al. 2014), it can be stated that the use of computer-based tools in decision support in FM in Europe and in the world represents a unique and permanent general trend. In addition to the standardization of FM problem dimensions, the benefits of the survey within the framework of the project also include the monitoring and explicit definition of the links between the solved FM problem solved and used system/tool.

4. Discussion and conclusion

Analysis of the contemporary FM methods, approaches and complete forestry planning system used in Slovakia linked with the identification of new socioeconomic and public demands on forest ecosystem provisions showed three major problems that are to be solved in the near future: (i) the problem of more balanced multi-objective management reflecting the growing societal demand for better provision of environmental and social values; (ii) the problem of the low adaptability of current FM, which is not able to cope with the worsening of forest ecological stability caused by climate change, inducing concerns about forest sustainability in vast areas of Slovak forests; (iii) the problem of more effective use of available timber and biomass resources identified as a prospective renewable bioenergy source.

The big problem with Slovak forestry lies in the fact that any rational solution of identified tasks is not obligatorily supported by computer-aided decision models and/or methods. In this regard, our review revealed the absence of fully developed DSS (consisting of a database, simulation, optimization and reporting/vizualization module) immediately applicable for a solution of defined planning problems. The review showed that only a few partial DSS tools developed within R&D projects were used in solving the specific research questions.

At the same time, existing DSS tools are oriented to support correct decision-making in order to improve the provision and effective utilization of wood, timber and biomass production, and also to its optimal harvesting, skidding, processing and transporting or proper risk assessment in forest production. That means they are not suitable for multi-objective or multi-attribute optimization of a more balanced set of ecosystem services (in accordance with the whole European situation). Moreover, no tool is actively used in operational forestry practice, partly due to low development maturity, and partly due to the absence of user-friendly interfaces and mobile applications (except for some databases and GIS applications). Finally, only one available tool (the growth simulator Sibyla) can be directly applicable in adaptive setting.

On the other hand, the big advantages of Slovak forestry decision support are: (i) in contrast to the European situation, excellent availability of different permanently updated databases about the state of forests (Foresters GIS, Hunters GIS, National Forest Inventory and monitoring or data of complex and detailed survey of forest done within the FMP elaboration process) needed for any kind of optimization, and (ii) the existence of the very flexible, detailed and easy-to-use growth simulator Sybila, valid for the complete Slovak territory (good even from the European point of view). Nevertheless probably the most limiting factor causing the relatively low stage of DSS development is the absence of widely applicable optimization modules containing a set of flexible optimization methods easily applicable for a solution of wide range of practical tasks.

As regards the situation in the Slovak Republic, it can be stated that the development in the main features follows the realities in Europe with a significant time delay and a lack of adequate instruments development to fulfill existing needs. With regard to the details referred to in previous chapters, there is a strong need for the development and application of computer-based tools to support decision-making problems in FM. Research and development activities are broadly well placed to address this. The situation is also significantly affected by the specificity and the historical development of FM planning in relation to the economic situation of the society, the forest owners' and managers needs' as well as the legislation and forestry policy environment.

The definition of the prevalent problems reflects the situation in Europe and in neighboring countries – especially when compared to those reporting their situation in the form of country reports, within the framework of the project COST Action FP 0804 – FORSYS: Austria and Hungary. Typical problems are in the area of long-term and tactical planning at the forest level and stand level. There are also corresponding, however only partly developed, systems and tools to deal with them, although not in an operational sense.

An important lesson learned is that no system is in place for solving key/core issues in FM decision support. High potential in this respect has the Sybila Suite. It is proposed to combine a growth simulator with techniques of multicriteria optimization, or Pareto optimal frontiers and interactive decision maps (Lotov et al. 2004). The first results of a rather simple case study focused on the optimization of forest stand thinning with regards to site conditions, tree species composition, degree of forest ecological stability, forest category and personal preferences of decision makers were published by Sedmák et al. (2013).

When compared with neighboring countries we can point to a well developed situation in a given area in Austria. With regard to the similarity of natural conditions, it would be challenging and motivating to follow their results including a systematic approach to the issue, tools development and implementation and especially knowledge management technique support. The details referred to in the previous chapter show the similarity of the situation, as well as the approaches to the solutions applied, with Hungary. This is caused by specific methods of FM in terms of historical development.

It can be stated that knowledge management and participatory elements are still weakly represented in FM planning in Europe and are completely missing in Slovakian conditions. The low number of instances of knowledge management techniques reported may be a consequence of the fact that while currently being used, they are not recognized as such. Developing ontologies and standard terminology would enhance the functionality of DSS, increase the transfer of system components, and support metadata application and Web service implementation (Borges et al. 2014). In the European context, some DSS may be used for supporting more stakeholders' decision-making, but there are still no specific tools and functionalities for explicit support of participatory processes that allow collaborative and participatory planning processes to be addressed. The lack of involvement of stakeholders in systems development processes is one reason for their rare practical implementation. Many systems remain as research and/or consultancy tools.

In conclusion, it is considered necessary to stress the importance of the results of the COST Action FP 0804 – FORSYS project for the development of the field of the application of computer tools in support of FM. According to the description of the situation given in country reports, the majority of countries in Europe, along with a number of non-European countries that were reported (People's Republic of China, Brazil, the USA, etc.), created an extremely rich, extensive and structured knowledge base with high potential for further use. The possibility to benefit from gained experiences and learned lessons, also have the countries that had directly not participated in the survey. For example, the countries of Central Europe – Czech Republic, Poland and Slovakia – and also south-eastern European countries like Bosnia and Herzegovina, Bulgaria, Croatia, Serbia and Romania can be mentioned.

The need to carry out a consequent survey in accordance with a unified methodology can be seen from two points of view. On the one hand, it is a review of the situation in each specific country in terms of the domestic situation, needs and capabilities. This in itself is very important and challenging. In addition, it is also important to supplement the knowledge about the situation in those countries with the overall mosaic of knowledge across Europe. Researchers, DSS developers and users involved in the project survey and also other countries might benefit from benchmarking and knowledge sharing.

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