Design and use of computerbased tools supporting forest planning and decision making in Austria

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1 Introduction

1.1 Socio-economic and ecological environment

Austria is a predominantly alpine Central European Country with an area size of 83.871 km² and a forest cover of 47.6%. According to the Austrian Forest Inventory 2007/ 2009 the forest cover has a total area of 3.92 mill.ha (BMLFUW 2010). Austria is situated in the Central European climatic zone (moderate, humid), however, the eastern part and the eastern foothills of the Alps are more continental Pannonian climate (hot, dry). The main tree species is Norway Spruce (Picea abies L. K.) with a total share of 61.2% (growing stock in productive forests). According to the Austrian Forest Inventory the share of broadleaved trees has increased over the last years, within these beech, and hardwoods such as maple, ash or horn- beam play a major role. The forest ownership are 53% small private forests (<200 ha), 32% private estates (>200 ha) and 15% federal forests. At present, Austria's forest resource is underutilized because of economic, social and technical reasons. The current annual harvest is around 18-20 mill. m³, while the total increment is estimated 31 mill. m³ per year. The mean stand volume is around 300 m³/ha in commercial forests whereas the mean annual increment is 9 m³/ha. The forestry sector's contribution to gross domestic product growth was about 2.1 % in 2003 according to the most recent calculations (€ 4.8 billions). Therefore, 0.4 % was accounted for by forest management, 0.9 % by wood processing and 0.8 % by paper and cardboard production and processing. Some two thirds of all Austrian citizens live in rural regions and forests as a major renewable resource play an important role in this context. From a nature conservation point of view slightly more than one million hectares of forest are identified as protected forests in accordance with nature conservation law and in natural forest reserves.

The Austrian Forest Act (amended BGBl.I Nr. 55/2007) attributes five functions to the forest: (1) productive function (i.e., sustainable timber production), (2) protective function (i.e., protection against erosion and natural hazards (3) welfare function (i.e., the protection of environmental goods like drinking water), (4) recreational function (use for recreation) and (5) habitat function (protection of the forests as habitat for living organism. The overall principles of the Act are: i) the preservation of forest area, ii) the preservation of the productivity of forest sites and their functions, and (iii) the preservation of yields for future generations (sustainability). Accordingly, forest sites must not be destructed, degraded or damaged and any clearings have to be reforested. The forest may not be used for any other purpose than for forest culture. More importantly, protective forests have to be treated without the impairment of the protective functions. If the preservation of protective functiona or water procurement is demanded, forests have to be banned by the authority. For such a ban, forest management prescriptions have to be prescribed and forest owners have a right to get compensation by the beneficiaries of the forest. Timber production is described as the main use of the Austrian forests. At the same time, this use is under constraint of sustainable management. For this purpose, immature stands (as a rule no younger than 60 years) must not be felled. Stricter regulations of forest management are in force on provincial level in the mountainous parts of Austria. For instance, clear cuts exceeding 0.5 hectares have to be approved by the authority with special supervision for fellings in protective forests. As regards social aspects, everybody has the right of access to any forest for recreational purposes during daytime, no matter if it is private or public property.

1.2 Forest management Problems

In the following, an overview is given on prevalent problem types in Austrian forest management, and how these relate to the key problem types of FORSYS. Furthermore, information is provided on who is involved in the respective planning processes as well as on the relevance of computer based decision support tools.

1.2.1 Selecting options for forest conversion

Since the 19th century extensive areas of natural broad-leaved and mixed forests in warm and partly dry lowlands have been transformed to conifer plantations either dominated by Norway spruce (*Picea abies* (L.) Karst.) due to its superior productivity and wood quality or to pine forests (*Pinus sylvestris* (L.)). Substantial areas of these secondary coniferous forests are close to their ecophysiological limits and particularly vulnerable. In warmer and eventually drier future climates an increased frequency of drought periods and generally an increasing inter-annual variability in climate biotic and abiotic risks for these forests is expected (Lindner et al. 2010). Furthermore, multiple rotations of Norway spruce may lead to soil compaction and increased soil acidification, which in turn may affect nutrient cycling depending on site conditions. To improve crop reliability and to reduce economical and ecological risks, the conversion of pure Norway spruce and pine stands into mixed-species stands, which are better adapted to the specific site conditions, is often recommended (Spiecker et al., 2004). Debating likely impacts of global climate change and possible adaptation strategies much emphasis has been placed on secondary conifer forests. The development of sound stand conversion programs is currently one of the key issues in silvicultural research and forest management planning. Risk rating current stands, support in selecting appropriate species mixtures as well as the treatment of current stands are major issues calling for science-based knowledge and decision support.
This problem type can be characterized with the following dimensions: strategic (choice of tree species) and tactical, spatial with no neighborhood interrelations, stand level, single decision maker, multiple, market wood products, non market services.

1.2.2 Managing Mountain Forests

In mountain forests various ecosystem services have to be met such as producing timber, protecting infrastructure and settlements from natural hazards like avalanches, mud flow and torrents, preventing fragile mountain sites from soil erosion, and providing sustained yield of high quality water resources. Silvicultural treatment plans for such multi-purpose mountain forests need to be tailored to stand and site conditions, and prioritized management objectives. In this context, close-to-nature forestry with single stem and group selection systems attempt to balance these often conflicting objectives. However, standard approaches applying silvicultural and forest engineering measures independently are not sufficient. Particularly challenging is the treatment of mature stands scheduled for regeneration. Decision-making about harvesting and natural regeneration of mountain forests with cable yarding systems requires therefore the consideration of several key issues: (a) meeting minimum economic constraints of harvesting operations, (b) considering mid- to long term effects of damages to the residual stand and to advance regeneration, (c) providing suitable conditions for establishment of natural regeneration, (d) controlling the

mechanical stability of the stand, (e) utilizing the growth potential of the stand. Additionally, results of the Austrian Forest Inventory and of recent game damage monitoring have revealed severe impacts of game on forest regeneration (BMLFUW 2010). More than 2/3 of all Austrian forests are browsed beyond the capacities of natural regeneration.
This problem type can be characterized with the following dimensions: tactical, spatial with neighborhood interrelations, stand level, more then one decision maker, multiple, market wood products, non market services.

1.2.3 Utilization of timber resources

Timber production is the main use of Austrian forests. The current harvest is around 18-20 mil. m³, while the total increment is estimated 31 mill. m³ per year. At present, Austria's forest resource is underutilized because of economic, social and technical reasons. As 53% of the forest ownership are small private forests (<200 ha) mostly comprising a low level of technical equipment and silvicultural know-how, the possibilities for wood mobilization are limited. Therefore, substantial efforts are made to identify strategies for increased utilization of timber. On the other hand, logistics related to timber harvesting, logging and transport have been improved in the last decades, e.g. with innovations in real time spatial localization (using mobile phones, GPS, web technologies) and optimization procedures. In addition, analysis and design of wood-based value chains has raised increased scrutiny, i.e. the sequence from forestry production, to harvest and transport, and industrial processing and trade. This issue comprises sustainability impact assessment of forest wood chains (Wolfslehner et al. 2011), flexible supply chains and logistics (Bajric et al. 2010), and smart use of small-diameter hardwood in Austria (Huber at al. 2010). From time to time, storm, snow and other weather-related disasters with their subsequent mass propagation of forest pests cause quite significant, but usually regionally limited, economic damage and huge amount of salvaged timber. In recent years, storm and bark beetle damages have been particularly severe. The year 2003 saw one of the highest levels of wood loss due to bark beetle in Austria since the records started more than 50 years ago. In this context, huge amounts of timber needed to be processed from the forest to sawmills risking reduced timber quality and the misbalances on the timber market.
This problem type can be characterized with the following dimensions: short to midterm, spatial, regional/national level, more then one decision maker, multiple, market wood products.

1.3 Objectives

This report aims at providing an overview about the design and use of computer-based tools supporting forest planning and decision making in Austria. In detail we are focusing on

(1) inventory of decision support tools in forest management planning with a focus on the key problem types listed
(2) a description of the key features regarding to architecture, development, use of models, methods and knowledge management techniques
(3) lessons learned on the use of computer based decision support tools so far

2 Materials and methods

Information on the use of forest DSSs, models and methods used in forest DSSs, knowledge management (KM) techniques applied and participatory approaches utilized is mostly related to universities and research institutions in Austria. In addition, computer based decision support tools have been identified by a survey among ministries, local forest authorities and forest owner associations. With a set of structured and open questions it was possible to identify the use of existing computer based decision support tools within the organizations contacted, relevant contact persons and the way how these tools are used in forest management planning problems. Some of the material presented here has been already introduced to the FORSYS Wiki. The following institutions can be named as relevant for developing and applying computer based tools in forest management in Austria.

At the Institute of Silviculture, Department of Forest and Soil Sciences at the University of Natural Resources and Life Sciences strong emphasis is set on the development and application of DSS in natural resource management. The Know-Center is a nationally funded application oriented research centre primarily concerned with knowledge management and knowledge technologies. As a knowledge technology provider, a number of techniques and tools developed at the Know-Center can suite forestry decision support systems, but have not been applied to this domain yet. The Knowledge Management Institute at Graz University of Technology is concerned with technical aspects of knowledge management and with web-based mechanisms for knowledge sharing and transfer. The Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) is a multidisciplinary research and training institution of the Federal Government of Austria. Applications developed at BFW support knowledge transfer and provide practical advice to forest owners.

3 Results

3.1 DSS related to forest conversion

ClimChalp: A web-based DSS tool for silvicultural planning and decision making in low-elevation secondary Norway spruce forests was developed to help forestry extension staff to explore adaptation options for silviculture in secondary Norway spruce forests in Austria (Vacik et al. 2010). ClimChalp has a strong focus on the question of suitable stand treatment programmes for currently existing Norway spruce stands at low elevation sites naturally supporting mixed broadleaved forest types given a particular set of management objectives (represented by a set of indicators focusing on timber production, ecophysiological tree suitability, timber yield, harvesting and silvicultural costs, carbon sequestration, biodiversity and groundwater recharge). The tool has three main components: the information base, the DSS generator and a graphical user interface (GUI) which is particularly designed to support the consultation process of the forestry extension services for small-scale private landowners by reducing the necessary user input to a minimum. Stand treatment programmes over 100 years for initial stand types had been designed and were simulated with the forest ecosystem model PICUS under current climate and four transient regionalized climate change scenarios.

Figure 1: Climchalp Screenshot supporting the management of Norway Spruce Forests

The hybrid approach of PICUS v1.42, henceforward referred to as PICUS, aims at bringing together the abilities of a 3D gap model (Lexer and Hönninger 2001) in simulating structural diverse forest stands on an individual basis with process-based estimates of stand level primary productivity. In general, PICUS offers a detailed projection of stand dynamics under the simulated management and climate conditions, including individual-tree information on diameter and height. This core concept forms the nucleus of a modular simulation framework integrating a process-based soil module, a management module (Seidl et al. 2005) as well as a thermo-energetic process module of Norway spruce bark beetle infestation (Seidl et al. 2007). PICUS is sensitive to changes in temperature, precipitation, radiation and vapour pressure deficit. Previous analyses found a realistic response to the climatic gradients in the complex terrain of the European Alps, both in terms of species dynamics (Lexer and Hönninger 2001; Didion et al. 2009) and productivity (Seidl et al. 2005). The user of ClimChalp is supported in comparing decision alternatives by means of multi-criteria analysis and a combined approach of visualized and verbal qualitative ratings. ClimChalp was designed to support the members of the forestry extension staff in Lower Austria. Currently the applicability and use of the tool is explored by a small number of experts within the local authority in order to give feedback for further development and a broader use within the organisation.

Figure 2: DSD Screenshot supporting management of Pine forests in Carinthia

DSD: The decision support system DSD v1.1 (Decision Support Dobrova) was developed for the analysis and selection of silvicultural treatment alternatives for Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) karst.) stands in southern Austria (Lexer et al. 2005). The tool is particularly designed to support the forest resource management consultation process with forest landowners in the course of the management of secondary coniferous forests. In close cooperation with the local forest authorities a generic model of the consultation process had been developed (Vacik et al. 2004). DSD v1.1 supports a planning process which covers the phases of decision making: (i) identification of current states regarding site and stand conditions, (ii) identification of owners expectations and preferences regarding a set of objectives, (iii) selection and evaluation of management alternatives. The stand treatment programmes for representative stand types were designed to support a variety of future target species mixtures. The growth and yield simulator MOSES (Hasenauer 2000) was used to simulate these stand treatment programmes over a period of 30 years, model output was combined with expert knowledge and economic parameters and used to inform the indicator system. MOSES is a distance-dependent tree model which is well suited to study the effects of various silvicultural treatments over short- to midterm planning periods (Hasenauer 2000). DSD was designed to support the members of the local forest authority in Carinthia. After exploring the applicability of the tool it was introduced in the local forest administration to be used by a small number of forest management planners from 2003 onwards. Currently a revision of the tool is planned in order to adapt the decision space to the demands raised by the users during the last years.

Wolschart: Wolschart was designed in response to a heavy snow breakage disturbance which affected almost 100% of the Wolschart property. There were two main objectives: (1) assigning each stand to a treatment category (immediately clear cut and replant, salvage and continue with business as ususal management, salvage and underplant with broadleaves), and (2) proposing suitable species mixtures. Based on an intensive literature review a rule base was constructed to evaluate each stand based on a stand inventory. To assess species suitability a static model was developed based on the concept of the fundamental niche (Steiner und Lexer 1998) which linked key site factors to species requirements as derived from the literature. A multi-criteria decision making methodology was employed to evaluate a set of silvicultural alternatives for the management of the damaged Norway spruce stands with regard to the objectives of the private forest owner (Lexer 2000). The forest growth model MOSES was employed to project stand growth according to the assumptions of a decision alternative. The combined use of these tools to support decision making is described in Lexer et al. (2000). Wolschart was designed for research purposes only to support the forest owner in exploring the silvicultural treatment options.

3.2 DSS related to the management of mountain forests

CONES: The CONES project ('COmputergestützte PlaNung von Nutzung Eingriffen im Seilgelände') aimed at the development and application of a spatial decision support system (SDSS) based on ArcGIS to assist the forester on site in compromising silvicultural and harvest operations (Vacik et al. 2004). The process of decision making about harvesting and natural regeneration of forest stands in steep terrain with a cable yarding system considers three sub-processes to optimize the overall utility of a forest operation: (i) What is the best silvicultural strategy ? (e.g., type and intensity of entry), (ii) Which is the best suitable timber harvesting system? (iii) What is the optimal location of the skyline trails? CONES supports the decision making process by utilizing a forest model (PROGNAUS), damage models for residual stands and advance regeneration and MCA techniques in evaluating different options (Vacik et al. 2006a). The stand treatment programmes are designed and are simulated with the forest ecosystem model PROGNAUS. The distance-independent individual-tree growth model PROGNAUS supplies tree species specific, direct estimates of diameter and height increment, mortality, competition, stand density. In addition, the simulator contains various auxiliary models for the prognosis of stem damage, log size and log quality assortments (Ledermann 2004). CONES was developed for the Austrian Federal Forests Organisation (ÖBF AG) to support a concurrent engineering between silvicultural and forest harvesting operations. After a long period of testing the forest managers evaluated the SDSS as too complex to be used in daily management, this did not allow any further improvement.

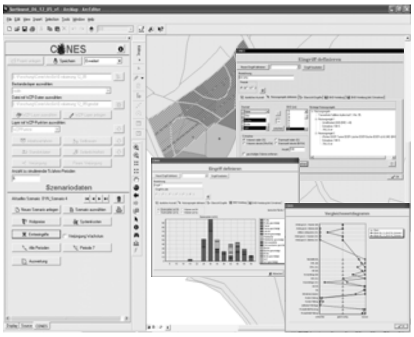

Figure 3: CONES Screenshot – supporting regeneration planning at the ÖBF AG

Wildalpen / KATER : A prototype spatial decision support system (SDSS) for regeneration planning in the protection forests of Vienna was developed for selecting the best silvicultural treatment option for stands scheduled for natural regeneration (Vacik and Lexer 2001). The decision problem is factorized into decisions on time to begin the regeneration process, choice of the future species composition and selection of the regeneration method. A geographical information system and a DBMS were used for the implementation of the core components of the SDSS. A decision model allowed to determinate stands scheduled for natural regeneration by using a model for the potential crown defoliation of Norway spruce

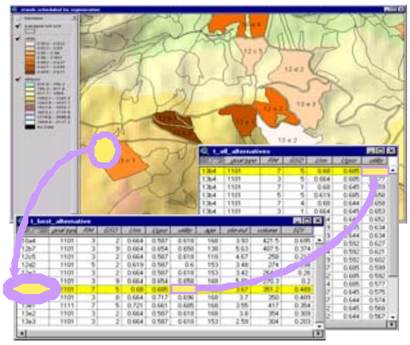

Figure 4: Wildalpen Prototype – Protection Forests - Vienna

and stand information data. A model for assessment of site suitability of tree species determinates site specific species mixtures. Identification of management objectives at the stand level for evaluation of management practices which best meet these forest level goals was achieved by MapModels (Riedl et al. 2000). An additive multiple-attribute utility model was used to find the best combination of growing stock objectives and regeneration methods which simultaneously maximizes the expected utility and satisfies all constraints of the forest decision maker. The KATER project proceeded with the development of decision support tools for the management of the protection forests of the City of Vienna (Fleck and Vacik 2006) and came up with knowledge management techniques to support decision making in the protection forests as well (Magagna et al., 2006). Water resource managers of the City of Vienna make us of the knowledge base developed during the KATER project for making their management decisions in emergency situations. The SDSS prototype was used for research purpose only and not further developed, the expert system based on the knowledge base developed is still under consideration by the local administrative.

Figure 5: ISDW -Webapplication „Initiative Schutz durch Wald“

ISDW: If the preservation of a protective function or a requirement for water procurement is needed, forests are banned by the forest authority inn Austria. For such a ban, forest management prescriptions have to be prescribed and forest owners have a right to compensation by the beneficiaries of the forest. The Initiative ISDW (Initiative Schutz durch Wald) is supporting this process by providing computer based tools to assess the present and future protection function by estimating the effects of specific management options by means of an Expert System (BMLFUW 2004). Regional management plans are used to define detailed management prescriptions at local level, using GIS, database management systems and web based wizards. Regional forest managers all over Austria are using the tool for the analysis of the current and future protection efficiency of protection forests and develop management plans for specific projects. Trainings for the data investigations in the field and the application of the ISDW tool have been provided by the ministry of agriculture and forests, environment and water management for interest users recently.

3.3 Decision support tools related to timber harvest and transport

Several computer based tools have been developed during the last years in order to support the short term planning of timber harvest and the optimization of logistics and transport.

Real-time spatial optimization: This prototype SDSS seeks to optimize the Wood Supply Chain (WSC) in real-time using Geographical Information Science and Technology (GIS&T) coupled with combinatorial optimization methods (Scholz 2010). The system answers the question, to whom timber should be sold – and transported thereafter – to generate the highest profit with consideration of transportation costs as well as the needs of all stakeholders. The results are detailed schedules for each truck, indicating the timber pick-up and delivery locations ordered in a temporal sequence, which forms a tour. To generate a basis for optimizing the WSC a spatio-temporal database is created that serves as central data platform for all stakeholders of the WSC, where data can be accessed by standardized spatial and non-spatial web services. For the purpose of obtaining real-time solutions the position of each truck is tracked using Location-based Services utilizing a Service Oriented Architecture (Scholz et al. 2008). Optimizing the WSC relies on the mathematical definition of the problem as a Vehicle Routing Problem with Pickup and Delivery and Time Windows in terms of a Mixed Integer Program, which is solved with a heuristic optimization methodology. The algorithm used in this approach is Adaptive Large Neighborhood Search (ALNS) (Ropke and Pisinger 2006) that is enriched by the spatial domain and thus called spatial ALNS (Scholz and Bartelme 2010). The results of a first test study in the context of a research project show that optimization increases the profit generated in comparison to an algorithm that behaves similar to human logistics planning (Scholz 2010).

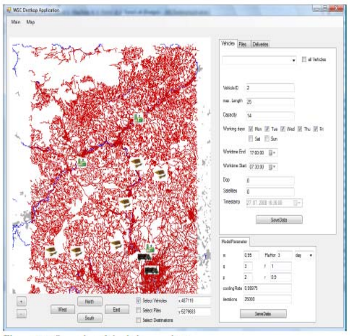

Figure 6: Optimizing the Wood Supply Chain

WoodLogistics: This fully operational supply chain management system is intended to increase the transparency of the WSC and currently focuses on the province of Styria (Holzcluster 2011). WoodLogistics is a project that is pursued by the forest industry - Holzcluster Steiermark GmbH with a number of industry partners - supported by Graz University of Technology and University of Life Sciences, Vienna. A central database is continuous (24h/7d) accessible by all stakeholders of the WSC which allows an intelligent planning of the processes overcoming institutional borders (e.g. timber production or timber haulage). In addition, participants are able to schedule and monitor timber delivery to saw mills on a daily basis. Hence, this tool enables the dispatcher to “order” additional truckloads or to stop further timber delivery to a certain saw mill in case of over delivery. In order to enhance the transparency of logistic operations the stakeholders have the opportunity of an accounting tool for haulage costs or the possibility of using a controlling tool for dispatching costs, which both use a map interface.

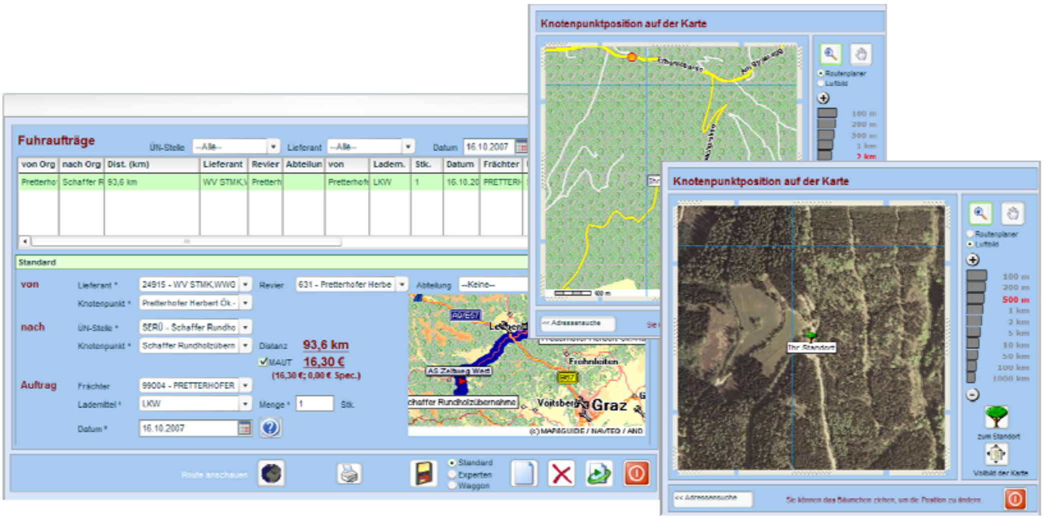

Figure 7: Wood logistic supporting the Wood Supply Chain in Styria

WWG Manager: The WWG Manager is a system for collecting, managing and visualizing of WSC data in near-real time especially developed for the Forest Association in Carinthia (Geochronix 2011). The system consists of a central database, a central management application for managing and visualizing as well as several mobile devices with applications for visualizing and collecting WSC related data. The mobile devices follow the principle of Location-based Services, and thus are able to collect and display information in relation to the present location. The central management application enables the managers of the Forest Association Carinthia to visualize timber ready for haulage in a map interface that is based on Google Earth. Hence, the allocation of trucks to certain routes or timber piles to be picked up is supported by a GIS. An invoicing and accounting system is integrated as well as a notification service that keeps member of the Forest Association informed about the status of their timber.

Figure 8: WWG Manager for supporting the WSC (Geochronix 2011)

TimberControl: The company Forest Mapping Management (FMM) released a complete suite of GIS based tools for forest management for forest enterprises (FMM 2011). The tools follow a web based approach and thus require an Internet connection for 24/7 availability. Two modules offer the possibility to manage and monitor timber flow starting with the harvesting process and ending with timber haulage. Based on a propriety GPS based tracer installed on machines, any forest enterprise is able to visualize the position of forest machines and trucks in real-time. Additionally, timber piles can

Figure 9: Screenshot of TimberControl and Smartphone for Forest Mobile

be managed with a map interface and their haulage can be managed using the system at hand. The application Forestmobile offers the possibility to collect data – e.g. on timber piles – as well as the functionality to display and manage information in relation to the current position on a mobile device for any participant of the WSC. Thus, a constant monitoring of the timber utilizing and haulage processes is possible.

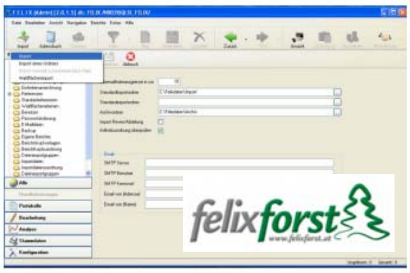

Figure 10: Screenshot of FelixForst

FelixForst: FelixForst supports the selling of timber assortments of forest owners and associations. It offers the possibility to handle contracts and invoices in a digital manner. FelixForst was developed by the forest owner association in Austria and is offered as licensed product to its members. Problems along the WSC can be identified and the timber is being formed out according to the customer's needs.

Figure 11: Screenshot of Praxisplan Waldwirtschaft

Praxisplan Waldwirtschaft: With the tool "Praxisplan" forest owners are able to make a forest plan for their forest property. Without any detailed knowledge about the forest resources the tool allows to predict the annual cut and the likely harvesting costs related to the human and technical infrastructure available. GIS maps allow displaying the forest plan for a total of 10 years. The tool is offered without license costs by the forest consultant services of the chambers of agriculture in Styria. Trainings for interested forest owners are currently scheduled. Forest consultants use the tool currently to get an overview about forest resources independently from owner properties. The extension GEOKONTAKT supports the communication between forest owners, hauling company and saw mills along the WSC.

ToSIA (Tool for Sustainability Impact Assessment of Forest Wood chains) has been developed within the FP6 Integrated project "EFORWOOD" for assessing sustainability impacts of Forest-Wood-Chains (FWCs). FWCs are defined as chains of production processes (e.g. harvesting–transport–industrial processing), which are linked with products (e.g. a timber frame house). Sustainability is determined by analysing environmental, economic, and social sustainability indicators for all the production processes along the FWC (Päivinen et al. 2010). Multi-criteria analysis is implemented as a separate software tool that is linked to ToSIA via a data interface. It facilitates the selection of indicators, their specification for a specific decision problem via thresholds and weighting of indicators with regard to their importance for a sustainability impact analysis. The analysis part provides relative sustainability impact ratings (i.e., an aggregated dimensionless index representing the relative preferences for a set of alternatives) for individual segments of the forestry wood chain (i.e., forestry, transport, industrial production, trade) or for the entire chain. Sensitivity analysis informs about the effects of changing weights on the overall rating.

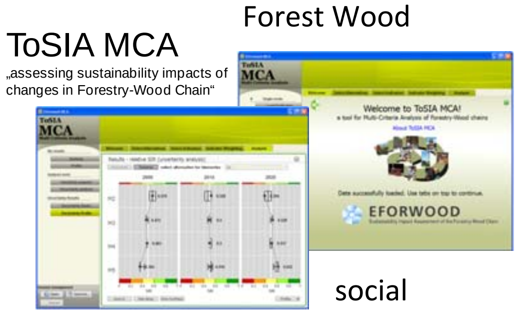

Figure 12: ToSIA - Tool for Sustainability Impact Assessment of Forest Wood chains

Uncertainty analysis allows judging the impact on the assessment result arising from uncertain input data. The MCA tool has been developed by the Austrian research group at BOKU, testing prototypes in Baden-Württemberg, Germany (Wolfslehner et al. 2011). The ToSIA approach is currently used in Austria to analyze the smart material use of small diameter hardwood.

3.4 Categorization of computer based tools

According to the forest management problems in Austria several computer-based tools were identified which are addressing to some extend these problems which are linked to the key decision problems of FORSYS.

Table 1: Categorization of computer based tools developed and/or applied in Austria according to problem types described

Problem type	DSS/Tool	Models and methods	KM techniques	participatory planning
strategic (choice of tree species) and tactical, spatial with no neighborhood interrelations, stand level, single decision maker, multiple, market wood products, non market services.	ClimChalp	PICUS PBS, MAUT	DBMS, WebGIS	Preference elicitation; prioritization of management strategies
	DSD	MOSES AHP, MAUT, niche model	DBMS	Preference elicitation; prioritization of management strategies
	Wolschart	AHP, MAUT, niche model	DBMS, GIS	prioritization of management objectives
tactical, spatial with neighborhood interrelations, stand level, more then one decision maker, multiple, market wood products, non market services.	CONES	Prognaus, Damage Models BPS, MCA	DBMS, GIS	prioritization of management strategies between forest engineer and mangager
	Wildalpen / KATER II	AHP, MAUT	DBMS, GIS, Ontology	Preference elicitation; prioritization of management strategies
	ISDW		Expert System DBMS, WebGIS	Justification of subsidies

Problem type	DSS/Tool	Models and methods	KM techniques	participatory planning
short to midterm, spatial, regional/national level, more then one decision maker, multiple, market wood products.	Real-time spatial optimization	Combinat-orial optimization (heuristics)	Spatio-temporal DBMS	prioritization of transport strategies
	WoodLogistics		DBMS, GIS	prioritization of transport strategies
	WWG Manager		DBMS, GIS	prioritization of transport strategies
	Timber Control		DBMS, GIS	prioritization of management strategies, accounting and marketing
	FelixForst		DBMS	prioritization of assortments, accounting and marketing
	Praxisplan Waldwirt-schaft, Geokontakt		DBMS, GIS	design of alternatives prioritization of management strategies, communication
	Tosia	Promethee, AHP, Scoring	DBMS	prioritization of management and transport strategies

4 Discussion and Conclusions

Regarding to the prevalent problem types described several computerized decision support tools have been developed in Austria. In the context of the impacts of global climate change and possible adaptation strategies much emphasis has been placed on the management of secondary conifer forests. This is partly reflected in the development of tools supporting these activities and related to stand conversion as well. DSS specifically devoted to management of mountain forests are rare.

Concerning the architecture of forestry DSSs, there is a noticeable shift from desktop DSSs towards a modularized architecture with mobile and static clients or with web interfaces. Thus, DSSs (or relevant parts of) have to designed in a way that they are executable on a mobile device. In order to support a 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 DSSs for timber utilization. In addition, as contemporary mobile devices detect their own position with Global Navigation Satellite Systems (GNSS) this information can be incorporated in the decision making process. Location-based Services may be useful for providing “mobile” decision support, and for evaluation and calibration of decision support models at hand. The activities of FHP Austria to support the WSC with common data protocols and reports (FHPDAT) are in that context relevant as well.

In analyzing the development and use of KM tools related to the identified forest management problems it was not possible to link the tools to a specific problem type because of their universality and generality. KM techniques cover a broad range of different topics for the creation, consumption, analysis, presentation and sharing of knowledge (Lindstaedt et al. 2002). Since forest decision support systems rely on managing knowledge, nearly every KM technique can be considered as important. Creation and elicitation of knowledge can be considered as the very first step in knowledge management with the goal to create a common understanding on a particular domain. Several KM techniques, like for example “Expert Interviews” or “Expertise Profiling” support this step. Expertise profiling supports employees when searching an expert within their organization. The objective is to create and provide a profile about skills, experiences and knowledge of all experts within an organization or a domain. Expert Interviews directly target to externalise knowledge form experts and make it available for later use. KATER II (Karst Water Research Programme) has been one example related to both techniques. Kater II is a EU Interreg IIIB CADSES project with the goal to develop a decision support system for Karst regions in Austria, Italy and Slovenia. It combines different stakeholder interests from tourism, agriculture and water pollution control. Knowledge which has been identified through profiling was organised and structured, preferable by using information technology. In this context MindMaps were considered as simple form of knowledge maps allowing to organise concepts hierarchically.

However, human centred capture approaches like Knowledge Maps or simple text based documentation conflict the needs of information systems for more formal representations of knowledge. Ontologies, understood in Computer Science as formalisation of a conceptualisation (Gruber 1993), focus on making knowledge explicit through using formal, logical theories. Creating such ontologies becomes labour intensive and hence requires either collaboration among experts or support through data mining techniques. The IDIOM (Information Diffusion Across Interactive Online Media, http://www.idiom.at/) Project provides data mining techniques and creates ontologies through analysing textual information contained in online media. The IDIOM Project has been a research project on acquiring, managing and applying knowledge to monitor Climate Change reports in media (Scharl et al. 2008). The web portal aggregates, filters and visualizes environmental Web content from 150 Anglo-American news media sites and creates a formal representation of the underlying knowledge by using ontologies (Weichselbraun et al. 2008).

However, besides visualizing knowledge, understanding and supporting users becomes even more crucial. Especially in narrow domains, accessing knowledge depends strongly on the skill and expertise of the user herself, and, clearly, the ease of access. Knowledge sharing has become a key issue in knowledge management. This is clearly shown by the advancement of the Web (i.e. Web 2.0) as new media to connect different communities with each other for sharing expert knowledge and best practices. Two projects, namely COCOON and waldwissen.net, demonstrate the importance of easy and contextualized access to knowledge.

At the University of Natural Resources and Life Sciences, Vienna, students learn to cross-link ecological, socio-economic and technical knowledge of maintaining, regenerating, tending and utilizing forests in a sustainable way. The principle of blended learning, a combination of online phases and face to face meetings is applied. Within COCOON a content management system and an authoring tool was developed (Vacik et al. 2006b). Beside the content information COCOON includes interactive features, search engines, questionnaires, a glossary and communication tools (discussion forum, chat). The authoring tool supports content processing by various editors which makes the use of any HTML-editor nonessential for authors to transfer learning material to hypertext.

Recognizing the growing importance of the internet for knowledge sharing, the Austrian Forest Research Center (BFW), jointly with three other research institutes from Freiburg, Freising and Birmensdorf, has established the information platform "waldwissen.net" which offers specially processed information for forest practice. This goes from research articles to guidebooks and technical notes to the review of books and database CDs. Additionally to this information platform a series of online forums have been established for supporting specific forest management planning problems. In addition to that several online platforms support forest management planning. "www.herkunftsberatung.at" is used for selecting appropriate provenances for afforestation, "www.borkenkaefer.at" is used for the online monitoring of the outbreak of bark beetle populations in selected traps, "www.wildeinflussmonitoring.at" is supporting the documentation of damages by game and its comparative analysis between provinces, "www.waldinventur.at" allows the in-depth analysis of the results of the Austrian national forest inventory , "bfw.ac.at/ws/sdis.schadenstypen" supports the identification of forest diseases and pathogens by means of standardized criteria.

Beside the information platforms many forest practioners and forest planners make use of the web-GIS-tools offered by the nine provinces in Austria (e.g. SAGIS, TIRIS, DORIS). This web tools allows the regional administration to display and communicate relevant environmental information about forest resources. Restricted access is offered for the documentation of forest owner specific information, public access mostly allows the display of various land cover and land use maps (e.g. forest types, forest roads, forest functions, conservation areas, topographic maps).

Knowledge Management is strongly related to DBMS – spatial, spatio-temporal or non-spatial – which is one way of structuring and storing knowledge. Interdisciplinary science "forces" researchers to exchange knowledge about objects and their behavior. Due to the fact that different disciplines do seldom share a common "view of the earth", every research area has its own semantics, which makes it hard to identify the tools and techniques relevant for a specific problem domain. Thus, exchanging knowledge stored in databases becomes a critical issue, not from a syntactic but from a semantic viewpoint. Incorporating a semantic-ontological view in knowledge representation and management would enhance the interdisciplinary collaboration and communication. A number of techniques and tools developed at the Know-Center can suite forestry decision support systems, but have not been applied to that domain yet. In particular techniques like for example semantic technologies, search and visualisation techniques as well as technology enhanced learning solutions developed within the APOSDLE project (http://www.aposdle.tugraz.at/) could be applied to forestry decision support systems.

It can be stated that participatory elements are still weakly represented in forest management planning in Austria. In summary, the proposed tools are mainly designed for supporting single forest owners/managers/decision makers. On the other hand, in participatory forest policy-relevant issues such as the Austrian National Forest Programme the modes of participation (workshops, group work etc.) as still mostly conventional without OR methods or computer-aided tools. Initially, there is progress towards model-supported stakeholder involvement and MCA relating to a form of collegial vulnerability assessment with a team of the Austrian Federal Forests (Lexer and Seidl 2009), and the designed facilities for group ToSIA-MCA to be further developed and applied for a 'real-life' participatory evaluation of sustainability impacts of forest-wood chains. Other MCA-based approaches e.g. by SERI (http://seri.at/) are from outside the forestry domain but provide relevant projects such as ARTEMIS (sustainability impact assessment energy production, http://seri.at/projects/completed-projects/artemis/) or Optima Lobau (Weiglhofer et al. 2006). However, a sound emphasis on participatory elements is constraint to inter- and trans-disciplinary needs to combine natural science (e.g., ecosystem modeling), social sciences (e.g., policy and stakeholder analysis), and decision analysis (e.g., MCA) to not reduce participatory planning in the context of DSS to a purely technical exercise (Wolfslehner and Seidl 2010).

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