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Lifo2008

„Linking Forest Inventory and Optimization“

an international conference of the IUFRO units 4.02.00 and 4.04.00

LIFO 2008
LIFO

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Zentrum
Wald Forst Holz
Weihenstephan

Contents

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Final Program

Tuesday, 01.04.2008

KDH				Registration & Come Together
	16:00	22:00	06:00	Registration – Registration desk Kardinal-Döpfner-Haus (open up to 10 pm)
	18:00	Open end		Dinner Buffet
	18:00	Open end		Come Together ("Klause"; saloon of KDH)

Wednesday, 02.04.2008

	08:00	08:45	00:45	Breakfast (dining hall)

KDH				Welcome Notes
	9:00	9:05	00:05	Knoke
	9:05	9:20	00:15	Keidel
	9:20	9:35	00:15	Wenzel
	9:35	9:45	00:10	Anneser
	9:45	10:00	00:15	Neft
	10:00	10:15	00:15	Brosinger

	10:15	10:45	00:30	Coffee (at the balcony)

KDH				Opening Statements	
	10:45	11:15	00:30	Knoke	The starting point: present information gaps
	11:15	11:55	00:40	Boungiorno	Economic and ecological effects of diameter caps: A Markov decision model for Douglas-fir/western hemlock forests
	11:55	12:00	00:05	Buffer	

	12:00	12:45	00:45	Lunch (dining hall)
	12:45	13:00	00:15	Buffer

KDH	"Aula"			S1: Up-to-Date Collection of Terrestrial Data	
	13:00	13:20	00:20	Kangas (Keynote)	Value of forest information
	13:20	13:40	00:20	Chang	Forest inventory and forest management
	13:40	14:00	00:20	Westfall	Optimizing forest inventory design
	14:00	14:20	00:20	Lei	Forest inventory in China: status quo and challenges
	14:20	14:40	00:20	Lei (Hong)	Forest resource information data updating at FMU level

	14:40	15:10	00:30	Coffee and Cake (dining hall)

KDH	"Aula"			S1: Up-to-Date Collection of Terrestrial Data		"Roter Saal" (parallel)				
	15:10	15:30	00:20	Ramezani	Comparison of wall-to-wall and sample plot approaches for estimating landscape metrics	**15:10**	15:30	00:20	Nothdurft	Random parameter calibration of nonparametric estimations for forest stand variables
	15:30	15:50	00:20	Chirici	Harmonization of national forest inventories for monitoring forest biodiversity: first results from the COST action E43	15:30	15:50	00:20	Salas	Statistical analysis of ratio estimators with measurement error in the auxiliary variate: a forestry applicationy
	15:50	16:10	00:20	Scheuber	Potentials and limits of the kNN-Method for regionalising sample-based data in forestry	15:50	16:10	00:20	Duvemo	Increasing realism in cost plus loss analysis of data for forest management planning
	16:10	16:30	00:20	Kantola	Spatial pattern of coarse woody debris in managed forests	16:10	16:30	00:20	Mäkinen	Error characteristics of different inventory methods and their effect on forest growth projections

	16:30	16:45	00:15	Break

KDH	"Aula"			S1: Up-to-Date Collection of Terrestrial Data		"Roter Saal" (parallel)				
	16:45	17:05	00:20	Talvitie	Impact of stand variables on the extent of rare forest phenomena	**16:45**	17:05	00:20	Biber	Forest growth models for modern forest management
	17:05	17:25	00:20	Mandallaz	Contingency tables with inventory data	17:05	17:25	00:20	Moshammer	Forest growth simulators as a parameter component of forest management
	17:25	17:45	00:20	Kleinn	A short story about *k*-tree sampling	17:25	17:45	00:20	Röder	A software system for using a forest management simulator in practice - from design to application
	17:45	18:00	00:15	Buffer						

	18:00	18:45	00:45	Dinner (dining hall)
	19:00	20:00	01:00	City tour of Freising with Joachim Hamberger (optional program)

Thursday, 03.04.2008

	07:00	07:45	00:45	Breakfast (dining hall)

	08:00			Leaving to the bus stop down the hill ("Kriegerdenkmal") Transfer to TUM School of Forest Science and Resource Management

TUM		HS 22		**S2: Applications of Remote Sensing**		HS 23 (parallel)				
	8:30	8:50	00:20	Wezyk (keynote)	Integration of LiDAR (ALS and TLS) technology in traditional forest management planning					
	8:50	9:10	00:20	Kotamaa	Integration of ALS based bioenergy inventory data and optimal bucking for stand level decision making	**8:50**	9:10	00:20	Krzystek	3D mapping of forests with full waveform LIDAR data
	9:10	9:30	00:20	Vauhkonen	Applied 3D texture features in ALS based forest inventory	9:10	9:30	00:20	Waser	Assessment of forest structure and prediction of main tree species by menas of airbone digital sensor data and LIDAR
	9:30	9:50	00:20	Holopainen	Effect of tree and stand level LIDAR measurement accuracy on the expected value of harvest decisions	9:30	9:50	00:20	Kändler	Determining forest area using TerraSAR-X data
	9:50	10:10	00:20	Wijaya	Integration of field measurement and remotely sensed data for estimation of stand volume and above ground biomass of tropical rainforest in Indonesia	9:50	10:10	00:20	Breidenbach	Estimating forest parameters using random forests

	10:10	10:30	00:20	Break

TUM		HS 22		**S3: Forest Management Optimization & Risk Modelling**	
	10:30	10:50	00:20	Strimbu (keynote)	A harvest scheduler using perfect bin-packing theorem
	10:50	11:10	00:20	Yousefpour	A non-linear optimization for post-simulation planning of a forest enterprise
	11:10	11:30	00:20	Bitter	Planning of target forest types by means of linear optimisation

	11:30	11:50	00:20	Break

TUM		HS 23		S3: Forest Management Optimization & Risk Modelling (continuation)	
	11:50	12:10	00:20	Wurm	A management support system – methodology and the integration of uncertainty
	12:10	12:30	00:20	Dirsch	An optimal thinning strategy - Solutions with dynamic programming and complete enumeration
	12:30	12:50	00:20	Hankala	The use of micro compartments in forest planning and its effect on forest owner's net income
	12:50	13:10	00:20	Sang	Optimal rotation for carbon sequestration of Eucalyptus urophylla and Pinus merkusii plantations in Vietnam
	13:10	13:15	00:05	Buffer	

TUM / Munich				
	13:15	14:15	01:00	Departure // travelling time
	14:15	15:30	00:45	Lunch at "Alter Wirt" on invitation of *Bayerische Staatsforsten*

Munich				Forest district of Munich as part of *Bayerische Staatsforsten*:	
	15:30	18:15	02:45	Parcours about forest management planning with three presentations:	
				Grünvogel	The forest inventory scheme applied by Bayerische Staatsforsten
				Felbermeier, Gieler	Optimization of the sustainable prescribed cut: A case study for the forest management planning in the state forest district of Munich
				Neufanger, Seerieder	The preparation an implementation of the forest management plan at Bayerische Staatsforsten

	18:15	19:00	00:15	Transfer to Munich
	19:00	Open end		Conference dinner at "Weisses Brauhaus München" (www.weisses-brauhaus.de)

Friday, 04.04.2008

	07:30	08:15	00:45	Breakfast (dining hall)

KDH		"Aula"		**S3: Forest Management Optimization & Risk Modelling (continuation)**	
	8:30	8:50	00:20	Steinbeis	Optimisation of ecosystem portfolios
	8:50	9:10	00:20	Beinhofer	Producing softwood of different quality - does this provide risk compensation?
	9:10	9:30	00:20	Hyytiäinen	Evaluation of forest management systems under risk of wildfire
	9:30	9:50	00:20	Hildebrandt	Financial evaluation of mixed species plantations in central Chile considering the risk of timber price fluctuations
	9:50	10:10	00:20	Deegen	Analysis of intertemporal profitability of an uneven-aged forest ("Plenterwald") in a long-time research plot in the Emmental (Switzerland)

	10:10	10:30	00:20	Coffee (at the balcony)

KDH		"Aula"		**S4: Sustainability Assurance**	
	10:30	10:50	00:20	Irland (Keynote)	Sustainability assurance: Lessons from time series (C&I) and cross-national comparison methods
	10:50	11:10	00:20	Solana	Multiple-use forest planning model for second-growth forests of Roble-Raulí-Coihue
	11:10	11:30	00:20	Hahn	Towards sustainable forest management: How to implement the precautionary approach
	11:30	12:15	00:45	Final discussion	

	12:15	13:00	00:45	Lunch (dining hall)
	13:00			Conference ending // Coffee (dining hall)

KDH: Kardinal – Döpfner Haus, Domberg 27, 85354 Freising

TUM: School of Forest Science & Resource Management, Technische Universität München, Am Hochanger 13, 85354 Freising

Abstracts

Opening Statements

The starting point: Information and decision making in forest management

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Forestry is about decision making in forest ecosystem management, decisions that carry extremely long-term consequences. The long production period in forestry implies a disconnect between the original decisions one draws today, and the risky consequences that will affect future generations. High quality information is needed to assure that these decision-making consequences don't conflict with the requirements of sustainability as well as present needs. Sustainable management denotes not compromising the ability of future generations to fulfil their needs due to fulfilling today's present needs. In order to implement this very general, yet necessary principle, sound information is required regarding the objectives of the forest owner and stakeholders, sustainability requirements of the present state of the forest as expected short and long term consequences of decisions and on the uncertainty involved with expected decision consequences. Furthermore, we must steadily update our information regarding the current state of the forest so that objectives and/or decisions may be adjusted to the given situation.

This paper introduces the philosophy of our conference: Lifo2008: "Linking Forest Inventory and Optimisation". Questioning if adequate information is provided by forest inventory and other sources to fulfil the given informational needs, and whether or not adequate optimisation techniques are available. By means of optimisation, based on simulating decision consequences, forest managers may contribute to sustainable decisions within forest management. However, there are yet many open questions, and our conference can contribute to identifying and partly explaining some of these issues. As a starting point, one could ask:

- What information is needed for decision-making under severe uncertainty and sustainability requirements?
- Is this information provided by the classical forest inventory?

- Is forest inventory at all based on decision-making?
- How much information is enough? How can the consequences of given information precision be quantified from the perspective of decision quality?
- How can forest inventory be developed towards decision-oriented collection of information?
- How can the information be efficiently updated?
- Are the available optimization approaches theoretically sound and adequate to support extremely long-term decision-making?
- How can stand level and enterprise/landscape level optimization be connected?
- How can severe uncertainty regarding the future be integrated in optimization?

Developing research needs would already be an advance in bettering the link between forest inventory and optimization. Such a research agenda could be an important result of our LIFO conference. Looking back at more than 200 years of history in forest science, and given the high qualification of the LIFO attending scientists, it should be possible to solve this task and bring forest management a step forward.

Economic and Ecological Effects of Diameter Caps: A Markov decision model for Douglas-fir/western hemlock forests

Mo Zhou, Joseph Buongiorno*, Jingjing Liang

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We evaluated some of the effects of not harvesting trees of 41 cm (16 inches) diameter at breast height or larger with uneven-aged management of Douglas-fir/western hemlock forests. The opportunity cost of diameter caps was measured by the difference in maximum expected net present value (NPV) or equivalent annual timber income, with or without diameter caps. For the two policies, Markov decision models were used to determine the best decision rules and their effects on the NPV, the forest area with late-seral structure, and the forest area with northern spotted-owl nesting habitat structure. The opportunity cost of diameter caps was computed for 64 initial stand states defined by basal area of small, medium, or large trees of shade-intolerant species (mostly Douglas-fir) or shade-tolerant species (mostly western hemlock). The opportunity cost fell in four distinct quartiles. The 16 stand states with high basal area in large shade-intolerant and large shade-tolerant trees had the highest opportunity cost (\$798 to \$816 $ha^{-1}y^{-1}$ or 58 to 76 percent, expected over an infinite horizon), while the 16 stand states with low basal area in large shade-intolerant and large shade-tolerant trees had the lowest (\$59 to \$89 $ha^{-1}y^{-1}$ or 11 to 13 percent). The diameter caps policy increased considerably the expected area of forest with late-seral structure, over an infinite time horizon, and the expected area with spotted-owl nesting habitat structure, compared to their current level in the study region.

Session 1

Value of forest information

Annika Kangas

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Traditionally forest inventory has defined the quality of data as root mean square error of interesting variables. In many occasions, however, even this information has not been available for all variables of interest, as the main focus has always been on the accuracy of timber volume estimates. In recent years, the quality of data as a basis for decision making has also been considered, using s-called cost-plus-loss analysis. In this analysis, the optimal data acquisition method is defined to be the one which minimizes the total costs of inventory, i.e. the direct inventory costs and the losses due to suboptimal decisions based on incorrect data. It would, however, be possible to go even further, and estimate the value of certain information, or even information concerning a certain forest variable / parameter in decision making. This is possible when utilizing Bayesian decision theory. It would enable inventory researchers to concentrate on important issues, and managers to invest optimally on data acquisition process. This review presents the research carried out in valuation of information in different fields and discusses the possibilities to use it in forestry applications.

KEYWORDS: Bayesian decision analysis, cost-plus-loss, Monte Carlo

Forest Inventory and Forest Management

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Foresters collect lots of data during their periodic forest inventories. With the exception of the mean, all of the information is ignored in making forest management decisions. In this paper, I will show that the mean together with the standard deviation association with the stand volume estimate are critical in determining the value of a stand. Furthermore, data gathered in past forest inventories provide valuable information about the current stand conditions in determining its value.

Random Parameter Calibration of Nonparametric Estimations for Forest Stand Variables

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This study aims at the development of a model to predict forest variables in management units (stands) from sample plot inventory data. For this purpose we apply a non-parametric nearest-neighbour (NN) approach. The study area is the municipal forest of Waldkirch, 60 km north of Freiburg, Germany, which comprises 328 forest stands and 834 sample plots. Low-resolution laser scanning data, classification variables as well rough estimations from the forest management planning serve as auxiliary variables. In order to avoid common problems of k-NN-approaches caused by asymmetry at the boundaries of the regression spaces and distorted distributions, forest stands are tessellated into subunits with an approximate area equivalent to an inventory sample plot. For each subunit only the one nearest-neighbour is consulted. Predictions for target variables in stands are obtained by averaging the predictions for all subunits. Additionally, global multipliers for bias correction are derived from the unbiased Horvitz-Thompson estimates. After formulating a random parameter model with variance components, we calibrate the prior predictions by means of sample plot data within the forest stands via BLUPs. The averaged and calibrated results are shown to be approximately unbiased. Based on bootstrap simulations, prediction errors for most management units finally prove to be smaller than the design based sampling error of mean.

Optimizing Forest Inventory Design

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The success of a forest inventory and monitoring program often depends on adequate planning prior to initiating data collection. The objectives of the inventory must be identified and clearly stated so the design can be tailored to the information needs in an efficient manner. This entails optimization of the sampling design subject to precision or cost criteria. A planning tool is presented that considers fieldwork time, cost estimates, population variability, plot configuration, and measurement options in a holistic framework. The output provides a range of design options, which allows the user to select the design that best aligns with their inventory objectives and cost/precision constraints.

The planning tool is part of a larger suite of inventory support software designed to assist with all aspects of inventory implementation from planning through data analysis. The other components include portable data recorder software, database and processing systems, and an analytical tool. This allows entities to collect and analyze data independently or in conjunction with other existing inventory efforts, such as the U.S. Forest Inventory and Analysis (FIA) program.

Forest inventory in China: status quo and challenges

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China has established its relatively integrated forest inventory and monitoring system. New and expanding information needs required it to be improved and optimized, however. This paper reviews development of the forest inventory system in China, which includes the National Forest Inventory (NFI, Level I), forest management planning inventory (Level II) and forest operation design inventory (Level III). Sampling strategy, plot design and information outputs are intensively discussed. Besides forest resource inventory, China also lunched key ecological program monitoring, desertification monitoring, wetland resource inventory and wild animal and plant inventory systems, which are partly overlapped or conflicted with forest resource inventory in monitoring indicators and periods. It is possible to integrate them within a whole system. Therefore, the idea of the integrated inventory and monitoring of forest resource and ecological condition has also been addressed and tested recently.

Furthermore, current forest inventory system is faced with the challenges from the transfer of forestry development strategy from timber production to ecological–oriented management, the ongoing reform of forest ownership and the information needs from the national public and international society. Possible improvements and strategies, especially the intensive link between Level II inventory and forest management planning are discussed. They will cover the introduction of additional ecological indicators, their respective plot designs, wider use of remote sensing techniques, data analysis and the dissemination of information output report at Level I inventory, and biotope investigation and forest development type design based on close-to-nature forestry at level II inventory.

Investigation of sampling method for western oak coppice forest, west of Iran

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To study a sampling method for western oak coppice forests, 341 stumps shoot groups in 30 sample plots, were chosen randomly. Two crown diameters, dominant; number of shoots in each group was measured. Each stump shoot group has been weight after cut.

Relationship between other measured parameters and weight was calculated.

An estimating table for weight based on measuring average crown diameter and dominant height of group has been calculated. Specific gravity of wood was determined as well. A two-entry volume table was set up .first entry is average crown diameter of group and second entry maximum height.

The accomplished study showed that by measuring 30 sample fragments and each of them with 200 square meters area we calculate the relation between weight and shoot group’s volume and 3characteristics which can be measure easily (maximum diameter, minimum diameter, maximum height of shoot groups) and this relation could be used regarding this study’s above cohesion coefficient (r = 0.902) for estimating volume or weight in forest hectare. In other words, instead of measuring diameter at breast height or collar diameter all shoots in 1000 square meters (10 R) with 200*500 meters which in each sample fragment diameter and height of each shoot group’s measured, just the maximum height and two diameters of each shoot group measure .in summery, the advantages of this method in coppice forest oak could be as follows:

Estimating wood production (weight &volume) in surface level is applicable easily and with high accuracy cases that should be measured are rare and simple.

Forest resource information data updating at FMU level

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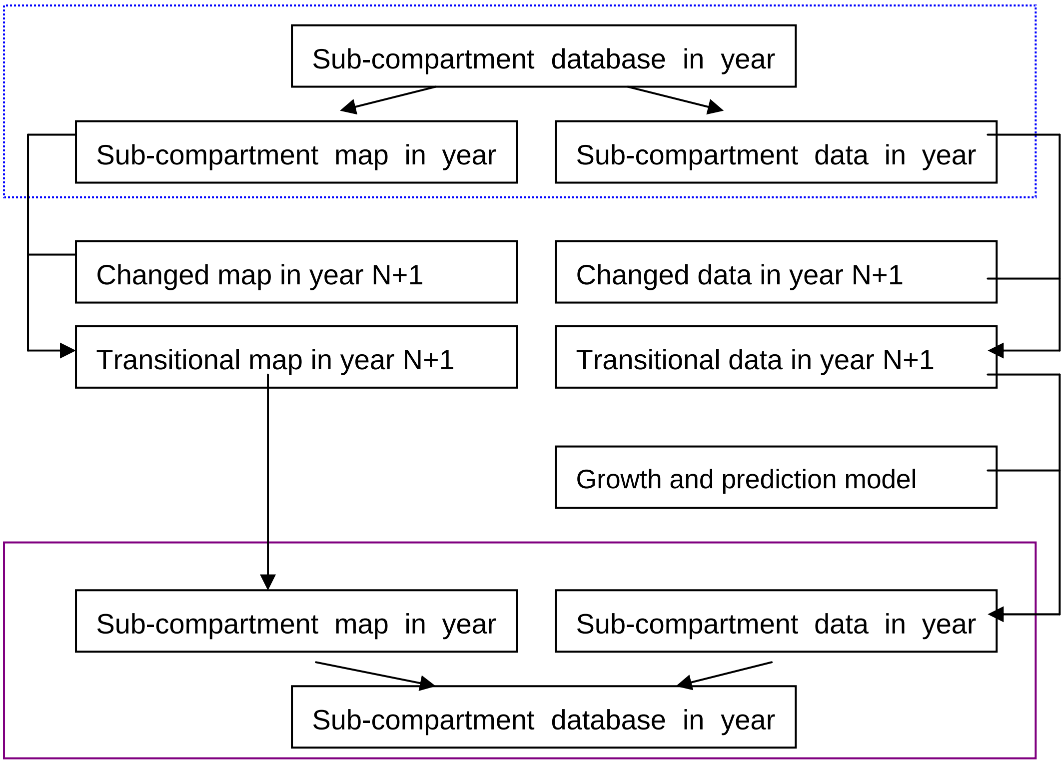
There are three levels of forest inventory in China: national level; regional or forest management unit (FMU) level; plot or stand investigation for special purposes (plantation, cultivation, thinning, harvesting).Traditionally, the time interval of forest inventory at forest management unit level is ten years. The silvicultural activity is done annually, so the forest information data should be changed annually. In this paper, we introduce a method of updating the forest resource information database of FMU by computer program automatically. The forest resource information database of FMU include natural forest sub-compartment map and related information data The reasons for forest resource change are divided into three types: natural growth without disturbance, management activities and natural disasters. We develop an integrated stand growth model to update the data of sub-compartment without disturbance. It is a group of empirical models which is composed of several equations: 1) average tree height growth model; 2) site index model; 3) average tree height prediction model; 4) basal area prediction model;5) density index prediction model; 6) mean diameter prediction model; 7)number of trees per hectare prediction model; 8)form height model; 9) volume formula; 10)crown density model; 11)volume of open grown tree formula. We use the data of plot or stand investigation to update the sub-compartments which are changed by management activities or natural disasters. The steps of updating the sub-compartment database are in the following Figure. A case study on forest resource data updating is done in Wangqing forest bureau, Jilin province, China. Results show that the predictions by using the model are much better than those by using growth rate. In this way, the forest managers can get the up to date forest information to help them evaluating and regulating their management plan.



Key words: forest inventory, forest resource information, data updating, integrated stand growth model.

Optimizing the characteristics of sample plots for crown cover measurements in Persian Oak (*Quercus brantii var. persica*) forests of Iran

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Zagros forest is the most important site of Persian oak in Iran and has an important role in the living of the residents due to its area, distribution, species and forest products. Also it is one of the most important biologic sources and genetic reservoirs of Iran. Regarding to the structure of this forest that is mostly coppice with standard and can not produce industrial wood, the stand volume and basal area are not suitable factors. On the other hand, the results of different investigations have shown that crown cover is a suitable parameter for studying this area. So crown cower can be an important criterion for detecting changes and forest monitoring in Zagros region to move toward sustainable forest management planning of this valuable ecosystem. In this research, it was aimed to determine the suitable surface area and shape of sample plots for crown cover estimation in Persian oak forests. In Kohgiloye-Boyerahmad Province, a 30 hectare plot in Servak Forests near Yasuj was surveyed by full callipering method and the position of each tree was tagged. Using GIS, the stem–map of trees in the study area was prepared. Then 30 sample plots in three shapes of circular, rectangular and square were chosen in a systematic random network (100×100 m). The surface area varied between 500 to 2500 sq. m. with 100 sq. m. intervals. Standard deviation of the crown cover percent for each surface area and each shape was calculated. The results showed that the least sample surface area for crown cover measurement is 1300 sq. m. for circular and rectangular and 1200 sq. m. for circular shapes. Comparing the ratio of perimeter to surface area of three chosen shapes, 1300 sq. m. circular sample plot was chosen as the suitable sample plot for the study area. The results can be used in the forests with similar spatial pattern and the number of trees per hectare to the study area. Also it is possible to study the results of this research in different networks to choose the suitable network in the study area too.

KEYWORDS: crown cover, Persian oak, plot shape, plot surface area, Zagros.

Comparison of wall-to-wall and sample plot approaches for estimating landscape metrics

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In landscape ecology, the assessment of landscape metrics has become an important tool for purposes of monitoring and management over the last decades. Traditionally, such metrics are derived based on information in wall-to-wall maps of landscapes, delineated into polygons representing different patch categories. While this has proved to be an efficient method under many circumstances, a new trend is to use sample based approaches to deriving landscape metrics. In many cases, sample based assessments are less costly than the tradition approaches. On the other hand, the consequences in terms of statistical accuracy implications are not fully investigated. In this study, Monte-Carlo sampling simulation was used to study the cost-efficiency and the statistical properties of Shannon's diversity index and edge length estimators. These metrics were tested with two different sampling designs (random and systematic), two classification systems (7 and 20 classes), four sample sizes (49,100, 225, and 400 grid points), and five buffer widths as a means of estimating edge length (5, 10, 20, 40 and 80 m). As expected, the root mean square error (RMSE) and bias of both metrics estimator decreased when sample size increases. Further, it was shown that the bias was smaller when a systematic design was implemented. In the edge length case, with a given sample size, in both sampling designs the bias increased with increasing buffer width. Other analyses included the performance of the edge length estimator for specific classes, the cost-efficiency under different assumptions, as well as methods to reduce the bias of the edge length estimators. The latter issue is important, since sample based estimators often will be biased, whereas wall-to-wall based estimation is not. Overall, the conclusion is that sample based methods from a cost-efficiency point of view have many advantages, as compared to wall-to-wall based methods.

KEYWORDS: point sampling, pattern metrics, root mean square error, Monte-Carlo simulation, bias, Shannon's diversity index, edge length

Statistical analysis of ratio estimators with measurement error in the auxiliary variate: a forestry application

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Forest inventory relies heavily on sampling strategies. Ratio estimators use information on an auxiliary variable (x) to improve the estimation of a parameter of a target variable (y). We evaluated the effect of measurement error in the auxiliary variate on the statistical performance of three ratio estimators of the target parameter total τ_y. Monte Carlo simulations were conducted over a population of more than 14:000 loblolly pine (*Pinus taeda*) trees, using tree volume (v) and diameter at breast height (d) as the target and auxiliary variables, respectively. In each simulation three different sample sizes were randomly selected. Based on the simulations, the effect of different types (systematic and random) and levels (low to high) of measurement errors in x on the bias, variance, and mean square error of three ratio estimators was assessed. The ratio-of-means estimator perform the best, even better than an unbiased estimator. The mean-of-ratio estimator was found highly biased (20%). Neither the accuracy of ratio estimator is affected by type and level of measurement error nor its precision. Our results show that ratio estimator's statistical performance is fairly resistant to the presence of either systematic or measurement error in the auxiliary variate.

KEYWORDS: Sampling, forest inventory, Monte Carlo simulation, bias, variance.

Harmonization of National Forest Inventories for monitoring forest biodiversity: first results from the COST action E43

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National Forest Inventories (NFI) have traditionally been designed to assess the productive functions of forests. During the last decades, the demand and need for information on non-productive forest functions has increased. A primary information need is an assessment of the current state of and changes in forest biodiversity. NFIs are conducted in many European countries and may contribute with relevant information for describing aspects of forest biodiversity in Europe.

Within the activities of COST action E43 "Harmonisation of National Forest Inventories in Europe: Techniques for Common Reporting" the Working Group 3 is specifically devoted in analysing the possible contribution of existing NFI data for deriving harmonised indicators and estimation procedures for assessing different components of forest biodiversity.

At a first stage of the project the WG3 of COST action E43 selected core variables for forest biodiversity assessment and acquired a detailed description of NFI methods and definitions used in EU and in the USA to acquire in the field those variables potentially useful for calculating biodiversity indicators. Reference definitions were defined and bridging functions proposed as a practical solution for harmonising and making comparable the information acquired in NFI for selected core variables of forest biodiversity monitoring.

In a second stage of the project raw field information acquired from different existing NFI were structured in a common database. Reference definitions and bridging functions were tested on such a database for harmonizing core biodiversity variables.

The present contribution briefly introduce the general organisation and final aims of COST action E43, then it illustrates the steps followed in the activities of WG3 on biodiversity and finally presents first draft results of the NFI harmonization process for forest biodiversity monitoring on the basis of the common NFI database acquired in different EU Countries and in USA.

Increasing realism in cost plus loss analysis of data for forest management planning

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Cost plus loss analysis can be a useful tool to evaluate the level of investments in forestry planning data. Generally, the costs of forestry data is easily assessed or calculated. The losses incurred by erroneous decisions caused by data errors are more difficult to decide. Previous research in this field has often simulated losses in management planning systems without considering the iterative nature and hierarchical structure of planning and its spatial components. In this study, the aim was to increase realism by incorporating a planning hierarchy and some of the spatial considerations present in practical forestry planning. A model was designed to mimic a specific, iterative planning process of a large Swedish forest owner. Starting by solving a tactical planning problem that consists of determining which stands to harvest in each of ten consecutive years, the results for the first three years were transferred to a more short-tem, operative level. Forest data of selected stands were replaced as to simulate a reassessment of data prior to the operative phase. Then, a new optimization problem with a three-year planning horizon was solved. The decisions for the first of these years were assumed to be applied in reality, after which the planning problem was forwarded one year and a new tactical plan for year 2-11 was generated. The procedure of switching between solving a tactical and an operational planning problem was repeated ten times until an operative plan had been obtained for each of the first 10 years. The model will be used for cost plus loss analysis of data from different sources. Specific analysis of the profitability of pre-harvest inventories is possible and will be carried out within this study.

Potentials and Limits of the *kNN*-Method for Regionalising Sample-Based Data in Forestry

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The k-nearest-neighbour (kNN) method is known as robust nonparametric method with a wide range of application. It is used to estimate unknown values of data sets by means of similarity to reference data sets with known values.

In forestry the kNN-method is widely used in order to regionalise sample based data of forest inventories. In former studies it could be demonstrated that the kNN-method results in unbiased estimates for various variables important to forestry with remarkable precision on pixel level. Application examples are (1) the detection, quantification and localisation of target parameters like basal area, stem volume or number of trees per diameter class and tree species, (2) the estimation of biomass potentials, forest debris and non-wood goods and services as well as (3) the production of wall to wall information for modelling and risk management and logistics. On the other hand different limitations with respect on methodological characteristics as well as the selection of suitable variables must be taken into consideration.

The scope of this article concentrates on the demonstration and discussion of application potentials and limits of the kNN-method in forestry, based on data of forest management inventories. The respective results are compared with the traditional outcome of inventory data analysis. The discussion is accompanied by examples of own research results as well as contributions from the available literature. Results are partly presented in thematic maps produced for a test site near Rottenburg, Germany. As common characteristics in the kNN estimation process the spectral information of satellite remote sensing data is used

Error characteristics of different inventory methods and their effect on forest growth projections

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Developments in the field of remote sensing have led to various cost-efficient forest inventory methods at different levels of detail. Mostly compartment-wise field data has been used both in tactical and operational forest planning in Finland. Remote sensing techniques such as LIDAR and digital photogrammetry are now becoming feasible alternatives for providing stand-level or more detailed data for forest. None of the inventory methods is perfect and each of the methods have their characteristic uncertainties and weaknesses. Forest growth projections play an important part in forest planning as the predicted future states of forest are used to determine the different forest treatments which in turn influence the present value of the forest. Errors in the input data affect the simulated growth projections and these effects vary depending on what growth models are being used and what is the error distribution like. The error distribution shape and properties are largely dependent on the inventory method that was used to produce the data. As a forest planning system is a fundamental decision support tool for a forest planner it is important that we know how much uncertainty the errors in the input data cause in the growth projections. Our objective in this study was to study how the errors typical to different inventory methods affect the forest growth projections at stand level during a planning period of 30 years. Another objective was to examine how the errors in input data behave when different types of growth models are used. The different inventory methods we compared in this study were: compartment-wise field sampling, stand-level LIDAR and tree-level LIDAR. For analysing the differences between growth models, we compared two forest simulators consisting of either distance-independent individual tree models or stand models. The data in this study consisted of 2000 ha of forest in central and southern Finland with 270 tree-wise sample plots. The analyses were conducted as Monte-Carlo simulations where the effects of the errors typical to each inventory method were examined in both tree-level and stand-level simulators.

KEYWORDS: forest planning, growth modeling, monte-carlo simulation

Spatial Patterns of Coarse Woody Debris in Managed Forests

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Coarse woody debris is an important indicator of biodiversity in forests; it is e.g. the source of organic material and carbon dioxide in the atmosphere and the habitat for a wide variety of organisms. In southern Finland, the amount of coarse woody debris per hectare in fresh mineral soils of old spruce dominant forests can be as much as 90-120 m^3 ha^{-1}. In managed forests, however, it is only about 10 m^3 ha^{-1}, due to the management methods used in the forests. The spatial pattern of coarse woody debris in managed forests is an essential research area, although it has been studied only little. With the knowledge of the spatial pattern of coarse woody debris in managed forests, it is possible to investigate inventory methods of rare phenomena, such as adaptive cluster sampling or line intersect sampling.

Field measurements were made in eastern part of Finland; it has been one of the biggest inventory projects in Finland to invent rare phenomena. In this study, the spatial pattern of coarse woody debris and large deciduous trees are examined with Ripley's K –method. The method allows spatial assessment in different scales among a species and between different species. With the method, it is possible to find out how coarse woody debris is located in the study area used. In the future, the results of the study will be used as background information of examining inventory methods of rare phenomena in managed forests.

KEYWORDS: Spatial pattern, coarse woody debris, inventory for rare forest phenomenon, Ripley's K

Optimizing forest yield data collection efforts for forest management planning

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Forest yield estimates are an essential component of linear programming forest planning models and this information is normally acquired by a forest inventory or using growth and yield models that predict future yields. Forest inventories and growth and yield models are often subject to multiple errors. In this framework, a trade-off develops since underlying the acquisition of data is the belief that better data leads to better decisions and also obtaining better data costs money. In regard to yield data from forest inventories and growth and yield models, and their utilization for forest planning, some research questions arise concerning the relationships between the yield information and the decisions that are adopted using uncertain yield data.

This work uses a harvest scheduling linear programming model to calculate optimal inventory and growth and yield modeling efforts. The harvest scheduling model maximizes the net present value of harvest plus the value of the forest remaining after the planning horizon. Different instances of this basic harvest model, including a reference “Real” model, were used to calculate the value of a variable we called *Loss*, considered to be a measure of monetary losses as a result of the use of imperfect yield information in prescribing optimal harvest policies. Variable *Loss* was used to estimate the trade-offs between making better decisions – i.e., harvest policies – when better information is available, and the cost of obtaining better information. Using a *Cost-plus-Loss* approach we calculate optimal inventory sampling sizes, optimal inventory plot size and the optimal number of experimental plots. An example was developed with radiata pine information in southern Chile.

Results from the minimization of the *Cost-plus-Loss* functions indicate that when the expected monetary losses are considered, sampling sizes for the inventory are much larger than the current practices in Chile and the number of experimental plots is much smaller than the current system used in the example although the growth models were simpler than the current models used for radiata pine management in Chile. The results were inconclusive in regard to the size of the inventory plot.

Impact of stand variabiables on the extent of Rareforest Phenomenon

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Rare forest phenomena are usually of diverse nature and irregularly located, and therefore cannot be measured accurately by means of inventory method focused on timber production planning. With conventional forest inventory methods, large areas must be covered to achieve acceptable precision of biodiversity objects. With the help of auxiliary data, it is possible to reduce the amount of expensive field measurements.

The significance of global carbon dynamics and preserving biodiversity has led to growing interest in the quantity and quality of coarse woody debris. Coarse woody debris has many meanings in the ecological processes of forests, e.g. it is the environment for many organisms and the source of organic material and carbon dioxide in the atmosphere. However, the impact of forest site type, development class, and other compartment-wise information on the extent of coarse woody debris have been studied only little. If knowing the effects of auxiliary data to the variable of interest, it is of help in focusing field measurements to most valuable areas.

During summer 2007, the data used in this study was measured in managed forests in Sonkajärvi, eastern part of Finland. The data consisted mostly of young stand and it was dominated by *Pinus sylvestris*. In this study, attention was laid to coarse woody debris and its performance area in order to find out whether and to which extent auxiliary information is of help in inventorying the interesting variable. In the future, results of this study will be useful information in planning new inventory methods of rare phenomena.

KEYWORDS: Rare forest phenomenon, coarse woody debris, forest site type, compartment-wise information

Forest Growth Models for Modern Forest Management

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The perception of sustainability in forest management has dramatically changed from a onedimensional, timber-production oriented towards a multi-criterial view during the last few decades. Finding an optimal management concept for forest stands and enterprises has become a high-dimensional problem. Therefore forest managers' need for information and decision support has multiplied. On the other hand, the supply of forest and forest related data has greatly increased, too. Especially, large forest areas in Central Europe are covered by statistically elaborate grid based forest inventories.

This information demand on the one and the available data on the other hand provide the environment for a new generation of forest growth models which are very flexible with regard to silvicultural concepts, species mixtures and site conditions and which offer a broad multicriterial spectrum of output variables.

We present the concept of the forest growth simulator Silva as an example of how agentbased, age-independent and spatially explicit dynamic growth models can contribute to modern forest management, and how such models can be fit into the information flow of forest practice. One of the most important steps towards this goal we undertook with Silva, was to make the model applicable not only on stand but also on forest enterprise level based on raster inventory data.

This presentation gives the conceptual background for the presentations by R. Moshammer, S. Seifert, and A. Röder.

Contingency Tables with Inventory Data

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It is surprising to see how often papers submitted for publication present standard chi-squares tests for contingency tables based on inventory data. The standard tests are only valid under the assumption that the units, i.e. the trees, have been included in the sample independently of each other and with equal probabilities. This is almost never the case with forest inventory data. This paper will present a technique which, in principle, can deal with complex sampling schemes. An example illustrates the theory.

Forest Growth Simulators as a Permanent Component of Forest Management

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It is common that forest growth simulators can provide essential information for the management of forest enterprises. But before such programs can be implemented in practical forest planning as a permanent component, two conditions must be complied: 1.An uncomplicated and easily comprehensible handling. 2.In order to obtain unambiguous results it's important that users can rely on clearly defined model settings for each management concept.

Both can be reached only by a high level of automation and standardization relating data processing and control of the growth model. As an instance, routines for standardized data processing and model control of the growth simulator Silva, as customized for the Bavarian State Forest Enterprise 'Bayerische Staatsforsten' (BaySF) will be shown.

The aim is to reach better foundations for planning and operational decisions without needing extra time for data acquisition. This is only possible if the model calculations are based on already existing or regularly recorded forest management data and if their information potential is intensively used. In the case of BaySF, the simulations are based on the sample plots of the standard forest inventory.

Via an interface, Silva is directly connected with the enterprises' central forest inventory database. After selecting a definitive dataset, the sample plot data pass through a stratification routine which performs a grouping by stand types, site conditions and development stage of the stands. For each stratum, Silva generates a virtual representative stand, using the real plot data. Based on the actual tree height measurements, regiontypical species-specific growing potentials are derived for the following model calculations.

For the simulation of realistic silvicultural activities the conventional thinning concepts of BaySF are embedded in the program along with guidelines for thinning intensity, harvesting intervals and upper limits for the harvested wood volume. Therewith, a large number of management options can be simulated. The simulator automatically decides which concept to use for which stratum dependent on its characteristics. As default, three different scenarios of thinning intensity are calculated automatically in order to make the corridor of action for the forest management evident.

This presentation continues the presentation by P. Biber and is the basis for the presentation by S. Seifert and A. Röder.

A short story about *k*-tree sampling – and what insights we may gain about the practical relevance of precision and accuracy in forest inventory and ecological sampling

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k-tree sampling is what we call the class of sampling techniques for which, from a selected sample point, the *k* nearest trees (or other objects) are selected for observation. The practical advantages of this plot design are frequently emphasized and the estimation problem is notorious: unbiased estimators have long been unavailable and only recently a design unbiased estimator was presented. Practical implementation of that estimator, however, is complex.

Even in the absence of unbiased estimators, despite explicit advises from some authors against it and with the knowledge (from simulation studies) that the systematic errors of the estimations may be considerable under some, not always predictable, conditions: *k*-tree sampling was and is being applied again and again and in some cases even promoted as an efficient solution – because of its practical advantages.

In this paper, some properties of *k*-tree sampling are discussed, the state of the art is presented what concerns estimation. As a consequence, also the guiding principles are analyzed that govern – some times - the definition of sampling design and plot design in the practice of inventory sampling in forestry and related fields.

A Software System for Using a Forest Management Simulator in Practice – From Design to Application

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Forest management and growth simulators often lack of an intuitive user interface and their settings and data handling are so complex that they are not used in practice but only by a small number of experts. Therefore, the growth simulator Silva was redesigned to allow quick and robust use by incidental operators and nevertheless have an even more flexible and extensible tool for experts at hand.

The basic idea behind the software design of Silva Version 3 was to build an object-oriented, modular system which provides a framework for all possible tasks concerning the long term planning in forestry. This framework provides diverse modules for data access, processing, evaluation, and reporting of inventory data as well as data from sample plots. Another important set of modules are the core algorithms for single tree growth, mortality or thinning. Those modules are encapsulated from each other to allow easy integration of other algorithms. Only the core data structures and interfaces are specified.

For beginners a very easy to use graphical user interface (GUI) was designed which guides through the whole simulation process. By incorporating expert knowledge into the system, the overall difficulty for the common user is extremely reduced. The knowledge rules necessary for data handling, stratification, site settings and management issues are separately defined by experts, stored together with the parameters for the tree growth functions in a database and automatically applied in relation to the stand properties. The minimum users must decide, is, which region they want to process and which management variants they want to compare. By implementing rule systems the stratification and assignment of the management plan to each stratum is automated.

For more experienced users a second GUI has been implemented, which allows to define the processing path by drawing flow-graphs. Here, users can individually decide which algorithms they want to apply to the data. The individual modules are combined through a graphical programming language. Therefore, expert users can easily design new re-usable modules. In this way the complete model processing path is arranged in aggregated modules.

This presentation builds up on the previous ones from P. Biber and R. Moshammer which presented the theory and models implemented in this software tool.

Session 2

Integration of LiDAR (ALS and TLS) technology in traditional forest management planning.

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For more than hundred years forest management in Europe has been based on the assessment of timber resources to carry out sustainable production. The most common methods in forest management planning are based on the networks of circular inventory plots.

Nowadays, technologies are sought for, that would be faster and require less financial costs, moreover, provide even more detail information than collected so far in the forest inventory. The increase of the accuracy in the estimation of biomass and useable timber is expected to be encountered in the technologies of laser scanning (LiDAR - Light Detection and Ranging): airborne (ALS) and terrestrial (TLS) or even satellite (SLS) as well.

This paper indicates potential opportunities and problems related to the integration of data derived from two different platforms i.e. ALS and TLS. Contemporary airborne laser scanning and digital photogrammetry are complementary and do not directly compete with each other. The application of TLS data defining precisely taxation parameters of individual trees and selected forest stand. They should be used in the search for the input parameters that are used in regression analysis between ALS and ground truth data. This integration can provide more precise results. However, it is very important to integrate correctly point clouds of ALS and TLS in one reference system. It can be done in different ways, among others: DGPS measurement, matching to objects (turning, moving) in the canopy area (e.g. gaps) or a single good visualization of a tree crown or other characteristic objects (e.g. elements of infrastructure); adjusted on „vertical objects" (parts of tree stems); applying so-called color points among other methods. The problem of combining the information coming from different measurement instruments is not the problem of the technique applied in those very instruments, but the problem of smart processing of the information and offering the users a quite new quality. This open new opportunities to approach planning and monitoring forest areas not only on local circular plots, but also on the whole forest areas. Model objects (stratification groups), measured in every detail with TLS technology can prove a new approach in the application of ALS and digital photogrammetry (true ortho and GeOBIA) through the integration of these technologies in forest management planning.

Integration of ALS based bioenergy inventory data and optimal bucking for stand level decision making

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Airborne laser scanning (ALS) and digital aerial photograph based metrics were used for estimating bio energy resources. In the first phase species specific diameter distributions were estimated by using above mentioned data sources. Information on derived diameter distribution, taper curves and biomass models were then used to characterize the amount of bio energy in different stands. There were four different categories of silvicultural operations in these stands: energy wood thinning, thinning, final cut and no operation. Bio energy proportion was defined to be one timber sortiment. Reliability of sortiments was estimated in study area where field measured plots were used as reference. Furthermore, dynamic bucking optimization was used to demonstrate use of remote sensing based inventory data in management planning. These optimizations include energy wood accumulation under different price and harvesting cost scenarios.

3D Mapping of Forests With Full Waveform LIDAR Data

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The development of new approaches to automatic forest inventory utilizing remote sensing data has been an important research issue in the past. Especially, methods for single tree extraction from LIDAR data have been investigated to map forests on the tree level and identify important parameters like tree height, crown size, base height and tree species. Most of the techniques reconstruct at least locally the canopy height model (CHM) just using the LIDAR points on the canopy surface and find tree positions from the local maxima. The detection rate is limited due to unavoidable smoothing effects in the interpolated surface. However, the main drawback is that trees in the middle and lower forest layer are invisible from the CHM surface and hence cannot be detected. Recent advances in LIDAR technology have generated new full waveform scanners that provide a higher 3D point density and additional information about the reflecting characteristics of the internal forest structure. These new LIDAR scanners render possible a more reliable estimation of the breast height diameter and the stock of wood.

This paper highlights two new approaches to segment and reconstruct trees from LIDAR data. First, we combine a standard segmentation, which is based on the digital canopy model (CHM) and a watershed technique, with a special stem detection method. Stem positions in the segments of the watershed segmentation are detected in a special algorithm that hierarchically clusters points below the crown base height and reconstructs the stem with a robust RANSAC-based adjustment of the stem points. This extension of the watershed segmentation helps to improve the tree detection in case trees grow close together or the surface reconstruction smooths out two neighboring trees. Secondly, we have set up a new 3D segmentation of single trees using the normalized cut method which is very well known from image segmentation. It tackles the problem to segment young regeneration which cannot be seen from the CHM. The segmentation approach uses features derived in tree voxels from the LIDAR data to set up a similarity matrix. We can also use auxiliary data like, for instance, the information about the local maxima of a CHM in order to weight the similarity between the voxels below the CHM maxima. Also, the stem position – if detected in advance - can be introduced to provide special weights for the voxels similarity.

The second part of the paper describes the results of the two different segmentation approaches if applied to full waveform LIDAR data acquired in the Bavarian Forest National Park. The data set was captured with the Riegl LMS Q-560 full waveform scanner in leaf-off situation at an average point density of 25 points/m2. The first segmentation method leads to an overall detection rate of 49 %. When applying the stem detection we get an overall improvement of the detection rate in the intermediate layer of 8 % and in the upper layer of 4 %. Additionally, we found that the detection rate is on average for coniferous trees 61 % and for deciduous trees 44 %, respectively. 7 % of the detected trees are false positives. As expected, the second segmentation method based on the normalized cut segmentation provides the best results. For instance, in the case of the full waveform data we can improve the detection rate by roughly 12 % for all forest layers. The improvement in lower forest layers is significantly better. The study results prove that the new 3D segmentation approach is capable of detecting young regeneration. This was practically impossible so far if tree segmentation techniques based on the CHM were applied to LIDAR data. It turns out that full waveform data contribute substantially to the detection rate of single trees.

Applied 3D texture features in ALS based forest inventory

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Airborne laser scanning (ALS) data are usually considered not to be very informative with respect to tree species and the information needed regarding them is often obtained by combining the ALS data with spectral image material. In this study, the tree species discrimination was based on variables derived solely from very high density ALS point cloud. The study tested the ability of different height, density, intensity, and applied 2D and 3D texture variables to describe the special characteristics of species specific crown shape and structure. Linear discriminant analysis was utilized to find optimal variable combinations within different predictor groups. The classification based on variables of different groups was compared. To find out the sensitivity of the pulse density to the tree species identification methodology presented here, thinned data sets were simulated by reducing the initial pulse density. The reliability of estimates was analyzed both with the functions generated with the original data and with new functions for each thinning level. Using full density data, alpha shape metrics, developed for describing tree crowns constructed from the ALS data, proved to be able to discriminate between all three species groups evaluated. Furthermore, several height distribution and textural variables were found out to discriminate within the coniferous tree species, whereas variables based on distribution of intensity values were somewhat useful in discriminating between the coniferous and the deciduous trees.

KEYWORDS: lidar, tree species classification, pulse density, alpha shape, intensity, 3D texture

Assessment of forest structure and prediction of main tree species by means of airborne digital sensor data and lidar

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Assessment of forest parameters have grown over time and will continue to do so in the future since exact information on forest extend, structure and composition is needed for many environmental, monitoring or protection tasks.

The present study focuses on modeling forest structure and composition as required by the Swiss National Forest Inventory (NFI).

Specific models are tested and calibrated in a test site in the Pre-alpine zone of Switzerland which is characterized by deciduous and coniferous dominated forests.

The models are based on explanatory variables derived from spectral information of CIR RC30 aerial images (near infrared, red, green, scale 1:5’700, 0.3 m) and RGB ADS40 images (scale 1:30’000, 0.25 m) and high-quality DSMs (0.5 m) derived from it, Lidar DTMs and DSMs. For calibration and validation 600 tree objects from field surveys and NFI data were used.

In a first step, a canopy height model (CHM) was generated by adjusting and subtracting the DSMs from medium footprint LiDAR DTM. Then forest area was modeled using explanatory variables derived from digital surface models. In a second step, different forest structure types (on forest stand level) were modeled using height information of the CHM. Composition on stand and tree group level was then modeled using a combination of smoothing and segmentation methods of the ADS40 images. Then, for each segment of a stand or for each pixel of a tree group probability belonging to different tree genera was calculated. For this step logistic regression models were used with additional spectral information obtained from the channels of the scanned aerial images and the digital sensor images as explanatory variables. The present study shows good results for extraction of forest area, structure and stand composition (kappa > 0.8). However, prediction of and main tree genera (kappa = 0.5 to 0.8) was good for *Abies alba, Picea abies, Fagus silv., Fraxinus exc*. but only satisfactory for deciduous trees in groups (*Alnus, Acer*) which

are characterized by small crowns or spectral similarities. This study underlines that high-quality DSMs and spectral information derived from airborne imagery are sufficient for derivation of relevant forest parameters. The assessed information on structure, composition and main tree genera is important for monitoring and protection tasks, and may also support management and other tasks of the NFI.

KEYWORDS: forest structure, stand composition, tree species, multi-image matching, high-resolution digital surface model, LiDAR, ADS40, National Forest Inventory (NFI)

Effect of tree and stand level LIDAR measurement accuracy on the expected value of harvest decisions

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Airborne high density laser scanning (LIDAR) provides new methods for forest inventory with high accuracy in stand and tree level. Extraction of forest variables using laser scanner data can be divided into two categories: inventories performed at the stand or plot level based on laser canopy height distribution and individual tree detection. Stand or plot level laser surveys are more cost-efficient; however, tree level approach would be interesting because it provides the ability to better plan the forest operations.

The aim of the present study is to analyse effects of tree and stand level LIDAR accuracy in tree and stand level forest management planning simulations. Comparison is based on the differences in the expected net present value (NPV) of next harvest in the stand. The accuracy of tree level laser detection is result of accuracies of crown delinetion and tree height and crown size measurements. These accuracy factors are analysed in tree level simulations.

Study is based on standwise forest management planning database, totalling of 2000 ha, in Evo forestry field station, Finland. For comparison of Lidar based simulations, 270 circular tree wise measured field plots are used as material for reference simulation. The data is simulated with a SIMO simulator, which is a stand- and tree-level analysis tool that can be used to assess the effects of alternative forest management practices on growth and timber yield.

Accuracy factors of individual tree detection are based on EUROSDR/ISPRS Tree Extraction Project in which the quality, accuracy, and feasibility of automatic or semi-automatic tree extraction methods based on high-density laser scanner data and digital image data have been evaluated by global science network that contained more than 10 international research groups. Accuracy of stand level LIDAR inventories are based on existing research papers.

KEYWORDS: Forest inventory, forest management planning, simulation, optimization, laser scanning, tree extraction, net present value

Determining forest area using TerraSAR-X data

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Forest area is a crucial parameter to be determined in forest inventories. Optical (satellite) remote sensing data are well suited for its estimation. However, data of passive sensor systems have the draw back of a high dependence on weather and light conditions. TerraSAR is a new satellite system operating a synthetic aperture radar in the X-band that has the potential to overcome the afore mentioned problems widely. The sensor can operate either in Spotlight, Stripmap or ScanSAR mode that result in varying geometrical resolutions between 1 and 16 meters. TerraSAR is funded as a public/private partnership between the German Aerospace Agency (DLR) and EADS Astrium.

The DLR provided a high resolution Spotlight mode radar image for a 5x12 km test site close to Munich. The data were processed by the DLR and provided as radiometrically enhanced, spatially enhanced, and enhanced ellipsoid corrected image products. We calculated the standard deviation and mean of the backscatter within a 12 m radius area around more than 400 points within the study site. Every plot was classified as agriculture, forest, housing area and water bodies based on a Google Earth™ scene. Half of the classification plots were used as training and the other half as test data.

Agricultural areas tend to have smaller and housing areas tend to have larger standard deviations of the backscatter in the classification plots than forests. The radiometrically enhanced image product was found to be best suited to separate the classes. It was used in a discriminant analysis that resulted in an overall accuracy of 83.2%. The classes agriculture, water and forest were separated with high accuracy. However, due to the high variability of the standard deviation of plots within housing area, the producer accuracy for this class was just 44.0%. If housing plots with an estimated proportion of buildings of less or equal than 10% are excluded, the producer accuracy for the class housing area increased to 76.9%.

We think that the classification results can be considerably enhanced using more advanced measures (such as textural parameters), multipolarized and multitemporal data.

Integration of Field Measurement and Remotely Sensed Data for Estimation of Stand Volume and Above Ground Biomass of Tropical Rainforest in Indonesia

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Tropical rainforest is the largest ecosystem in the world. This forest has a major role for global carbon cycle. Nowadays, deforestation and forest degradation are of the major problems for sustainability of the tropical rainforest. These problems impact the forest biomass as a source of carbon sink. Disturbance on the forest substantially reduced forest biomass and triggered more carbon released to the atmosphere, altogether these can attribute to the global warming. This work aimed to estimate above ground biomass (AGB) using equation derived from the stand volume prediction and to study spatial distribution of the AGB over a forest area. The potential of remote sensing and field measurement data to predict the stand volume and the AGB were studied.

This study concerned on a tropical rainforest in East Kalimantan, Indonesia. The satellite remote sensing data was atmospherically corrected using Dark Object Subtraction (DOS) technique, and topographic correction was conducted using C correction method. Stand volume was estimated using field data and remote sensing data, thus using Levenberg-Marquardt algorithm neural network method was employed. Due to unavailability of actual biomass data, the stand volume estimate was converted into the above ground biomass using equations developed for the tropical Amazonian forest assuming similar forest vegetation over both areas. Spatial distribution of the AGB and the error estimate were then interpolated using kriging. The results showed integration of field measurement and remote sensing data has better prediction of stand volume validated with the actual stand volume data. The AGB estimate showed a great correlation with predicted stand volume data, number of stems, and basal area. Spatial distribution of the AGB described a correlation between forest biomass and land use/land cover in the study area.

KEYWORDS: above ground biomass, remote sensing, neural network, kriging

Estimating forest parameters using random forests

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In the recent years, non-parametric methods (e.g. Most-Similar-neighbours, MSN) were reported to be well suitable to estimate forest parameters based on laser scanner data. In these methods, the average of the *k*-nearest observations are used for the prediction (imputation) of a test dataset for which only the independent variables are known. Distances are calculated considering some kind of weighing matrix (e.g., the canonical correlation matrix for MSN).

A somewhat newer approach are random forests. Here, many (e.g., 500) regression trees are established based on a bootstrapped sample of the training dataset. The distance between two observations is given by the probability of sharing the same final node. Crookston and Finley (2006) extended random forests for multivariate response variables. Therefore, a separate forest is computed for every response variable and the nodes matrices of all trees are joined.

We applied this method to estimate plot-level stem volume and top-height in the municipal forest of Waldkirch (south-western Germany) using airborne laser scanner (ALS) data. Ground truth data stem from a conventional forest inventory on a 100x200 m sampling grid. More than 770 concentric sample plots with a maximal radius of 12 m were available. Since tree species cannot be derived from ALS, additional information were used from an inventory by compartments in which the forest type and age class were identified as only variables. We found that best results can be obtained by using the laser-derived variables mean vegetation height, canopy cover and coniferous proportion; the forest type and age class form the inventory by compartments; and a Boolean variable that indicates if the plot intersects a forest border as independent variables.

Since we were interested in the influence of the amount of sample plots, we conducted 200 jackknife simulations with different numbers of sample plots. Root mean squared differences (RMSD) of 175.71 m^3 (40.2%) and 4.76 m (17.7%) for volume and height were obtained with 90% and RMSD of 178.40 m^3 (40.9%) and

4.95 m (18.4%) were obtained with 60% of the sample plots. We were somewhat surprised by the small differences between the two simulations. We are now analysing the datasets to find explanations for these results.

Literature:

Crookston and Finley 2006: yaImpute: An R Package for k-NN Imputation. http://forest.moscowfsl.wsu.edu/gems/yaImputePaper.pdf.

Session 3

A harvest scheduler using perfect bin-packing theorem

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The use of heuristic techniques in forest planning has been promoted by the need to solve complex problems that cannot be solved using mixed integer programming. We proved that for merchantability standards ensuring the perfect bin-packing theorem (PBPT), the maximum volume that can be harvested annually equals the sum of the maximum MAI of the stands. The method accommodates optimality criteria at the stand level, regarded as maximum MAI, and at the forest level, regarded as maximum annual allowable cut. We scheduled the harvesting by adjusting the first fit decreasing algorithm (FFD) to the PBPT conditions. When PBPT conditions were not met, we developed a mixed integer programming solution to adjust the merchantability standards of the stands to the distributional requirements of the PBPT, an adjustment that ensured the optimal performance of the FFD. The adjusted FFD was compared with simulated annealing (SA) using two harvesting ages (i.e., one based on MAI maximization and one determined as the minimal age) and the same set of spatial-temporal constraints for three areas in north-eastern British Columbia, Canada. We found that the adjusted FFD performed 100 times faster than SA and for annual allowable cut (AAC) supplied results that were more homogenous and at least 10% greater than the AAC supplied by SA. Furthermore, the adjusted FFD seemed to be relatively insensitive to spatial constraints (i.e., adjacency), while SA displayed a 45% reduction in AAC in response to an increase in adjacency delay from 1 year to 10 years. The results suggest that both adjusted FFD and SA are impacted by the selection of the harvesting age, but the adjusted FFD could still outperform SA. Having a deterministic character, the adjusted FFD seems to be more sensitive to the violation of assumptions than SA, as for the same area it supplied the largest and the smallest AAC depending on the presence – absence of the uniform distribution of the volume of the stands with respect to the harvesting moment.

Optimization of final cutting planning for sustainable timber self-supply strategy based on dynamic programming: A case study for periodic rebuilding of Japanese traditional shrine.

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The Jingu is a Japanese traditional shrine, located in Mie prefecture. The "Shikinen Sengu Ceremony", the periodic rebuilding of the shrine has been carried out every 20 years since the seventh century. In this event, the timbers harvested from natural forests outside Mie prefecture have been used. However, the Forest Administration Department of Jingu shrine has decided to make its own supply for the next Shikinen Sengu Ceremony in 2013. For the self-supply of large timbers for the construction of Jingu shrine, it is necessary to develop harvesting plan in plantations and accomplish the sustainable use of forest resources. Thus, this study aims to predict forest resources based on the forest inventory data in this shrine forest and optimize the cutting plan with dynamic programming based on the stand density management calculated by Local Yield Table Construction System (LYCS). First, we estimated growth parameter of Chamaecyparis obtusa stand in the shrine forest and predicted the forest resources in Jingu shrine forest with growth model constructed by these parameters. Second, we checked the accuracy of the prediction by comparing forest inventory data obtained from ground survey with forest resources predicted by the growth model. Excluding the timbers larger than 80cm DBH produced by selection cutting, which accounts for 2% of all the required timbers, we optimized self-supply ratio by dynamic programming, focusing on the trees less than 80cm DBH which will be harvested through thinning or clear cutting. The results of our study showed the following two points as Timber Self-Supply Production Strategy. First, the supply ratio could be temporarily improved by shortening the cutting age in some stands without any negative influence on long term sustainability. Second, 2 % of the required timber including trees larger than 144cm DBH should be supplied from the reserved forest older than 200 years. This research proved it possible to suggest practice strategies to improve the supply rate of timber if the demand for forest resources was fixed on a regular and quantitative basis.

A non-linear optimization for post-simulation planning of a forest enterprise

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This paper introduces a two-steps optimization procedure to support decisions on sustainable forest management and presents the associated utility function to be optimised. In the first step, elementary silvicultural scenarios in finite time are simulated with a forest growth simulator. In the second step, parameters issued from the first step are used to find a management decision in terms of combination of elementary scenarios within the available space for the whole forest enterprise.

A utility function and a set of constraints are defined to describe the multi-objective problem to solve. Both utility and constraints can be linear or nonlinear.

The defined additive utility function includes economical as well as ecological sub-utilities. Here, in addition to traditional wood harvest revenue, the values of carbon sequestration and biodiversity (Shannon Index) have been monetized and integrated as revenues. In addition, important forest enterprise constraints, namely: wood even flow, financial limitations like maximum investigation and minimum expected income and protection of a proportion of oldest stand area, have been integrated into the description of the optimization problem. As an example, some treatments have been defined and tested for an age-class forest of Norway spruce. Prediction of the effects of these treatments on some criteria and indicators of sustainable forest management has been done by “Bwinpro-S”, a distance-dependent forest growth simulator. To monitor the evolution of the state of the forest for some nonlinear elements such as the Shannon Index, they are computed at the whole forest enterprise scale. At last it is shown how the optimization could find the optimal composition of silvicultural prescriptions of forest stands. And, moreover, it gives a tool to calculate the global utility of potential forest strategies and comparing them together, calculate the related subsidies for state dictated strategies. At last, the post-optimality analysis alerts the decision makers about the shadow price of disposal activities. So, consequently, the procedure provides a realistic baseline to decide on the most adaptive forestry plan with regard to the goals and priorities of forest policy makers.

Planning of target forest types by means of linear optimisation

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As a consequence of the forecast global climate change and the resulting shift of site types, the optimal mixture of tree species and the planning of target forest types are increasingly under consideration. The relevancy of this discussion becomes all the more obvious in the face of considerable changes of the range of benefits expected by owners and society which are currently being observed. Both the increased demand for wood as raw material and energy source as well as a heightened profit orientation of the owners will lead to an increasingly yield-oriented forest management. Therefore, a GIS based procedure for the planning of target forest types has been developed for the Forest Administration of Brandenburg and implemented within the Forest Management Planning Project Eberswalde, aiming at a precise optimisation of the tree species distribution at the stand level by means of linear programming.

First, the almost innumerable number of mapped soil types of the > 43.000 ha enterprise was classified into a manageable number of so-called ‘site type clusters’. The site units, which are grouped into these site type clusters in consideration of the growth districts, are relatively similar with respect to the characteristics relevant for stand development. In a second step, a table of tree species adequacy was created for each cluster, precisely evaluating the suitability for cultivation of the main tree species based on competitiveness, degree of soil conservation, stability, yield and climate change sensitivity.

Considering the spatial distribution of the site type clusters and species adequacy tables on the one hand and the current stocking of the individual stands on the other hand, a linear-programming model was created aiming to maximise the net revenue of the desired, long-term target forest type. The procedure yields a stand-level optimisation of tree species mixture allowing for manifold restrictions which can be formulated at the level of stands, site type clusters or growth districts, as well as for protected areas or the entire enterprise.

A management support system – methodology and the integration of uncertainty

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In this paper a methodology is developed on how a management control system that assists the operational management of forest land can be set up. This is done against the background that currently in Germany management decisions on the operational level, i.e. the implementation of mid-term management plans, are largely made without any supportive instruments. Up to now the consequences of such decisions are not transparent and the development of key indicators on physical and economic features of the managed forest land cannot be followed. Consequently, at the time when the decisions are made managers are not able to evaluate whether their decision leads to a development in accordance with the long- and mid-term goals. The need for a system that facilitates such assessments is therefore evident.

In this complex process of finding optimal management pathways for a planning unit the introduction of advanced planning techniques seems very promising. Using planning techniques like linear programming (LP) or nonlinear programming (NLP) respectively can lead to a financial optimization of management. Moreover, it is possible to find financially optimized management pathways while trade-offs between the economic targets and other demands on forest management practices are being realized simultaneously. In addition such planning techniques allow a great flexibility and adaptability in view of an ever-changing planning environment. Fluctuating timber prices as well as biotic and abiotic risks like bark beetle infestations or windfall events are standard. So the possibility of adjusting the planning assumption to the current situation is inevitably necessary. With LP/NLP such adjustments are easily realized and operational plans adapted within seconds by a repeated run of the optimisation algorithm.

Speaking of risks the integration of uncertainty (being a broader term for risk) into the planning process is essential in view of this unsteady planning environment.

Therefore, two approaches are applied: First, the in forest science already established μ-σ-approach and, second, the information gap decision theory. This integration of uncertainty generally leads to more evenly planned timber harvests as in comparison to planning scenarios without.

An optimal thinning strategy – Solutions with dynamic programming and complete enumeration

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The analysis is based on model stands from the 2nd national forest inventory (BWI²) in the Ostalb region and different thinning strategies simulated with the growth simulator SILVA 2.2. Allowing for 5 different management options each period between no thinning, light, medial and heavy thinning as well as harvesting the whole stand, the optimal stand treatment was found in two ways. First dynamic programming identifying the optimal policy step by step and second with a complete enumeration, having the whole decision tree simulated, both realized in a SAS programme. By comparison the results show the limits of the applied techniques. Considering the wide range of different stand treatments in practice, forecasting and optimisation techniques are very powerful tools, making it possible to analyse a substantially wider range of varieties which no thinning experiment, using empirical data, is ever able to cover.

The use of micro compartments in forest planning and its effect on forest owner's net income

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In Finland, forest compartments are usually the primary unit of both planning calculations and forestry operations. The compartment size varies normally between 0.5 – 5 hectares. Such compartments are often quite heterogeneous and generally subjectively delineated. In this study, the effect of the planning unit's size on the operation plan is studied using SIMO, a new simulation and optimisation software developed at the Department of Forest Resource Management, University of Helsinki. The focus of this paper is especially in the forest owner’s net income. The data consists of 682 sample plots measured systematically on a 30 m x 30 m grid on a managed forest area of 71 hectares in Juuka, Eastern Finland. The study area was also divided into normal forest management compartments and stand-level variables for the compartments were aggregated from the sample plots located inside the compartment. The forest growth and forestry operations were then simulated with four different simulation scenarios. In the first simulation the compartments were used as operational units, whereas in the other simulations the variance of the operational units was minimized by dividing the area into small sub-compartments consisting of only one sample plot. The differences between the simulations were in the levels the treatments were defined: the decisions were assumed to be either both made and carried out in the same level, or they were based on the compartment level information but carried out in the sub-compartment level. Growth and forestry operations were then simulated for the (sub-)compartments, following similar guidelines for forest management operations in each simulation. The results were aggregated from the sub-compartments to the compartment level to enable comparison. The differences in the suggested timing of the operations and in the net present values (NPV) of the operations for the forest owner over the planning period of 20 years were then compared between the actual compartments. The preliminary results show that compartment-level calculations tend to prepone the operations and overestimate the net income of the owner.

Optimal rotation for carbon sequestration of Eucalytpus urophylla and Pinus merkusii plantations in Vietnam

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Tropical forests play a major role in the global carbon cycle. It is estimated that tropical forests store about 46% of the world's living terrestrial carbon pool and that carbon stored in tropical forest soil accounts for approximately 11% of the global soil carbon pool. We examined carbon sequestration of two different plantations in Vietnam and measured tree and understorey growth, biomass, litter fall, carbon content and soil properties. The two studied plantations are adjacent each other and were established on degraded soils where forest cover had been replaced by grasses and shrubs.

We developed empirical models of growth processes and the relationships between growth variables. Parameters were calculated and used for input into carbon accounting models CO2FIX to estimate optimal rotation for carbon sequestration of *Eucalyptus urophylla* and *Pinus merkusii* plantations. Simulation results were validated by empirical data.

The *Eucalyptus urophylla* plantation had a high rate of biomass accumulation but soil carbon declined somewhat over three continuous 10 year rotations by an average of 0.02 tons carbon ha^{-1} $year^{-1}$.

The highest tree biomass productivity occurred in seven year old plantation with maximum mean annual timber increment of 7 tons carbon ha^{-1} $year^{-1}$.

The *Pinus merkusii* plantation attained highest mean annual increment of carbon sequestration of biomass and soil after 18 years (4.5 tons carbon ha^{-1} $year^{-1}$). Soil carbon stock of the plantation declined in the first years and increased above pre-plantation level thereafter. Setting the model to a 30 year rotation length which is common practice in Vietnam for harvest of pine resin, we calculate that soil,

aboveground and belowground carbon biomass had increased by 11 and 39 tons carbon ha^{-1}, respectively.

Despite some soil carbon loss from soil, *E. urophylla* sequestered overall more carbon than *P. merkusii*. However, the decline in soil organic carbon in *E. urophylla* plantation suggests that continuous 10-year rotations are unsustainable, while *P. merkusii* plantation may improve soil conditions by increasing soil organic carbon.

The measured soil data of *E. urophylla* and to some extend of *P. merkusii* plantations diverted from the modeled data indicating that the CO2FIX model overestimated soil carbon content by 4 tons carbon ha^{-1} over the rotation length. This may due to the steep slopes (27 and 30%) of the two plantation sites. Further possible causes for discrepancy of measured and modeled soil carbon data include crown cover and management practice and are also discussed here.

KEYWORDS: Dynamic Programming, growth model, Local Yield table Construction System, Shikinen Sengu Ceremony, sustainable timber production

Optimisation of ecosystem portfolios

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Natural capital, which can be regarded as the present portfolio of worldwide ecosystems, is considered to be essential to human welfare: Ecosystems support human, animal and plant life on the planet. Economic activity is based on the extraction of merchantable goods from ecosystems and their subsequent transformation. Ecosystems offer also services, which are not merchantable and therefore can be valued only indirectly. Several approaches have been developed to value intangible ecosystem services. Based on published studies, Costanza et al.have estimated the aggregate direct and indirect value of the goods and services of 16 biomes of the world's ecosystems portfolio to be about two times the world wide gross national product. By converging forests into arable land or by draining swamps, humankind is transforming terrestrial ecosystems. This modifies the goods and services, the concerned ecosystem is able to deliver, thus altering its return and risk profile. Given an arbitrary conversion of terrestrial ecosystems on a global scale, it is astonishing that the portfolio analysis of terrestrial ecosystems has received little consideration. Based on the findings of Costanza et al., this paper compares the current portfolio to an optimal portfolio of terrestrial ecosystems, obtained by mean-variance optimisation. First results show that the current spatial distribution among worldwide terrestrial biomes is not optimal; hence a combination of biomes exists, with a higher annual flow value for the same risk. This theoretical ecosystem portfolio would suggest having a larger proportion of boreal and temperate forests, as well as a larger area of tidal marsh/mangroves and lakes/rivers.

Given the human dependence from ecosystem services and goods, optimisation of ecosystem portfolios might at least increase the awareness for modified risk and return trade-offs resulting from anthropogenic alteration of ecosystems. Of course such optimisations can be questioned: The calculation is based on a crude aggregate of annual ecosystem flow values; consequently only estimation errors may be optimised. Correlations between biomes are unknown and only the surface area of ecosystems is considered as a variable. State and robustness of an ecosystem are not considered. Further research could contribute to these two aspects.

Regional log market impacts of a management change on federal forest lands in western Oregon, USA

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In the 1860’s the Oregon and California (O&C) Railroad Company received a checkerboard of land for 32 kilometers on either side of a proposed railroad to be built from Portland to California, USA (approx. 1.6 million hectares). The land was to be sold to the public. Mismanagement and fraud brought about the eventual return of 800 thousand hectares to the public.

Management of the O&C lands has been highly politicized for over a century.

An intertemporal, spatial equilibrium model of the western Oregon forest products sector was employed to estimate the market impacts of a policy change that adopted revenue maximization goals on one half of the federally managed O&C lands and placed the other half in a permanent reserve.

The O&C inventory is based on the USDA Forest Inventory and Analysis Integrated Database version 2 overlaid with the Northwest Forest Plan land use allocations in a geographic information system. The result was 466 thousand hectares of revenue forest, with the remaining 437 thousand hectares assigned to reserve. For the revenue lands, growth and yield tables were constructed following the same procedures employed for private lands.

The timber resource is modeled at the sub-plot level and future stand development projected using individual tree models under an array of possible silvicultural regimes. Projected future tree lists are stored, facilitating detailed descriptions of future stands and potential harvest.

Log demand is modeled at the processing center level (individual mills or milling clusters) with capacity changes determined endogenously as well as the volume of logs demanded. Regional markets are linked to national and international log and product trade via econometric models of these higher level markets.

System solutions are found via linear or mixed integer programming depending on the desired model configuration using high-capacity solvers.

As computational and data storage capabilities continue to improve, we believe this model will be a prototype for expanded and still more detailed future resource analysis and planning systems. The basic approach can also be linked to data derived from satellite imagery to reduce the effective plot size or expansion factor through "nearest neighbor" methods.

Producing softwood of different quality-does this provide risk compensation?

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This study analysed whether the production of high quality assortments, sawtimber and pulpwood in Norway spruce and Scots pine stands leads to effects of risk compensation. Mixtures of conventionally treated pruned and non-pruned stands as well as mixtures of stands which had been optimised concerning the occurrence of assortments and financial criteria were considered. To avoid the assumption of a certain distribution of timber prices and to preserve the correlations of the timber prices from different assortments, the price simulation was done by bootstrapping. The financial valuation was done with annuities within a Monte-Carlo-Simulation with 10,000 repetitions. To quantify the effect of natural hazards, the calculations were repeated with and without this factor. Minimum risk portfolios were determined and optimization performed using both a utility function as well as the value at risk approach.

The mixtures with minimum risk were dominated by pine stands, as they are less affected by natural hazards and prices for pine timber have a lower volatility, but they are generally lower compared to spruce timber prices. These pine dominated portfolios showed risk reductions up to 92 %. However, they are not efficient, as the annuities were reduced even more.

In contrast to this, the portfolios optimised with the utility function and the value at risk approach consisted of spruce stands. These spruce portfolios showed an efficient risk reduction of up to 60%. Additionally, higher annuities and larger diversification effects occurred in the portfolios containing the optimised stands. Integrating the risk of natural hazards, the annuities, as well as the correlation of the annuities of the different stands decreased while risk increased. Altogether these effects lead to higher relative risk reductions when forming optimal portfolios.

Evaluation of forest management systems under risk of wildfire

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This study focuses on evaluating the efficiencies of even-aged and uneven-aged management systems under risk of wildfire and stochastic tree diameter growth. The any-aged management problem is formulated by integrating empirically estimated models for fire effects and individual-tree stand growth model calibrated for mixed conifer stands. The stochastic stand management problem is solved numerically by the means of sample average approximation method. A North Idaho variant of the Forest Vegetation Simulator and its Fire and Fuels Extension are used to predict stand growth and fire effects, respectively.

Sensitivity analysis is carried out with respect to values of economic parameters and level of fire risk. Increase in the rate of interest is demonstrated to reduce the efficiency of even-aged management relative to uneven-aged management. Increased rate of interest reduces rotation length and investments in reproduction under even-aged management. This leads to markedly reduced long-run timber supply. With uneven-aged management, in contrast, the level of timber supply is less sensitive to changes in the rate of interest. The price ratio between the planted and naturally regenerated species is another critical factor determining which management system is superior.

Increased fire risk is shown to improve the relative efficiency of even-aged management. Single cohorts of mature trees (either cultures or naturally regenerated) are less susceptible to fire damages than uneven-aged stands. Fire risk somewhat reduces optimal diameter limit under uneven-aged management, but has only minor effect on rotation period, planting density and thinning intensity under even-aged management.

Financial evaluation of mixed species plantations in central Chile considering the risk of timber price fluctuations

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In line with the project „*Diversity and economic success: Mixtures of native and exotic species as a possibility for rehabilitation of secondary forests in central Chile*" also mixed species plantations and their economic profitable efficiency are investigated. The data were taken from plantations in central Chile between 39°10´ and 39° 50´ south latitude. As an example for mixtures of native and exotic species the increments of different mixtures of Rauli (*Nothofagus alpina*) and Douglas fir (*Pseudotsuga menziesii*) have been modelled and changed volume growth has been taken into consideration for mixtures of large blocks and single-tree mixtures of both species.

As natural hazards have only quite low impacts on forestry in Chile, timber price fluctuations were considered as the only source of investment risk. Possible financial returns of different mixtures have been calculated. The results have been evaluated with classical mean variance approaches in order to detect effects of diversification.

Keywords: Mixed species plantations, diversification, portfolio, Sharpe ratio

Analysis of Intertemporal Profitability of an Uneven-Aged Forest ("Plenterwald") in a long-time research plot in the Emmental (Switzerland)1

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By means of a linear, deterministic and discrete growth model the dynamic of an uneven aged forest is described. To overcome the problem of unknown age in uneven-aged forests we have used Buongiorno and Michie (1980) ingrowth-approach. Admittedly some adaptations were made, e. g. to differentiate between tree species.

Data based on a 100 year research series of an uneven-aged forest in the Emmental (Switzerland) are used for model calibrating.

The growth model is embedded in a linear optimization model (based on Buongiorno and Gilles 2003) to study the relations between the diameter distribution, the tree species composition and NPV profit maximization.

The actual state of the forest in the Emmental, cited as reference, is compared with two optimization experiments: to achieve the Schuetz ideal diameter structure (SIDS) under different financial constraints and to maximize NPV for different harvest cycles under some diameter distribution constraints. The three experiments are done by variations of the interest rate and other prices.

At the first sight the results show a large difference between the SIDS and the NPV maximum. However, there is a wide range to find out harvesting regimes provided with both requirements to be close to the NPV maximum and to the ideal diameter structure. That's possible particularly with extensions of the medium diameter classes. Discrepancies between the NPV maxima and the SIDS decrease with increasing interest rate. However the harvesting cycles play an important role. A five

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[1] The paper bases at the diploma thesis by Dana Sonnemann

years cycle leads to the best NPV and leads in most cases also to the least deviation from SIDS.

All regimes to maximize the NPV are very sensitive to harvesting costs and to timber prices. To consider the general Faustmann approach (Chang 1998) uneven aged forest management cannot work with constant management concepts. Instead permanent alignments are necessary. That means linear optimization isn’t so much a planning tool but a helpful equipment to understand the economics of uneven-aged forests.

Poster Presentations

Spatial variability of forest plantation stock using geostatistics in the Caspian region of Iran

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This study investigates the spatial variability of a forest plantation stock in the Caspian region of Iran. Field sampling was performed based on, 50×125m systematic rectangular grid in a maple stand (*Acer velutinum* Boiss.) at age of 18 years using circular samples of 200m^2 area. Overall, 87 sample plots were measured in 63 hectare. Experimental variogram for variable of forest stem basal area (BA) was calculated and plotted using the georeferenced inventory plots. The calculated variogram showed a high spatial autocorrelation, which fitted by spherical model. Estimation was made by ordinary block (15×15m) kriging and cross-validation results showed that all the estimations are accurate. Therefore, geostatistical approach is able to capture and describe the spatial variability and estimate the plantation stock in this forest, accurately.

KEYWORDS: Caspian region, Geostatistics, Plantation stock, Spatial variability.

Optimizing the management of multi-functional forest stands: A case study from Switzerland

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The management of multi-functional forest stands is one of the main challenges of contemporary forestry. This is because the needs of society regarding timber and non-timber forest products are divers and often compete with each other. To meet the different needs in an optimal manner and avoid conflicts requires suitable decision support tools for forest management. The goal of our study was to optimize the management of multi-functional forest stands using the following objectives: (i) increase habitat quality, (ii) maximize harvest volume, (iii) minimize storm damages, and (iv) minimize logging damages. The study area comprises forest stands of different age, structure and tree composition in the canton of Zurich, Switzerland. We used simulated annealing as the optimization approach. This allowed us to examine near-optimal alternative forest management solutions, and evaluate their effects on the objective over an entire planning horizon. The study was designed in order to meet the specific demands on multi-functional forest stands in Switzerland.

Valuation of browsing damages

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The regeneration of forests has a key position in the business of forestry as regeneration determines stability and flexibility for future forests. Due to the reason of the long term of the production and prospective risks, coupled with the background of the discussion about non adapted game inventory, the research on consequences by losing ad-mixed tree species will gain importance.

While a lot of private forest owners do not take care about game browsing and it's effect, the selection of tree species in mixed regeneration leads to a loss in biodiversity. Destabilisation of biotic and abiotic environments poses risks. Furthermore a lack of cushion for the impact of timber prices can be observed as well.

By using methods of valuation which include future risks, the financial loss of tree species shall be made transparent. The analysis will be a result of growth projections on the data of Bavarian forest inventories, differentiated by site classes and tree species combinations. Using a portfolio calculation, the effects of de-mixing shall be assessed.

Providing an assessment of the de-mixing by deer browsing, the information base for decisions in wildlife management processes will be improved. So far, the ongoing project can be seen as a contribution to a sustainable planning of natural resources.

Using line intersect sampling for assessment of coarse woody debris in Caspian forests

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To introduce a suitable method, based on precision and cost for estimation of coarse woody debris(CWD) in Caspian Forests, a line intersect sampling method based on probability theory, was selected. Parameters were volume, number of logs and projected area per hectare. Considering all the sampling factors, a grid of 100*100m was determined for random-systematic sampling. Length of transects were determined as 100m in line intersect sampling method. To compare the results of these methods with the real population statistical parameters, a 100% survey of coarse woody debris was take over 132 hectare including three compartments with same characteristics. The results of t-test show that the population means was similar to means of line intersect sampling method based on probability theory for all parameters (t =1.12, P>0.05), the means being within the range of confidence intervals. With respect to cases of above, line intersect sampling method based on probability theory is the best method for estimating of coarse woody debris in Caspian forests.

KEYWORDS: volume, number and projected area estimation, coarse woody debris, Line intersects sampling, probability theory

Transect-plot inventory, a method for arid and semi arid forest

A new edition method

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Determining the proper inventory method in arid and semi arid region is great importance. Hence, transect-plot inventory method was proposed for Gharah-Ghermez *Juniperus* forest with an area about 1234 ha locates in 75 km of Chenaran city north. These forests belong to arid and semi arid floristic regions. This method integrates sampling with transect and permanent plots. According to the results, these forests are coppice with standard and *Juniperus*, *Berberis*, *Crataegus*, and other species constitute 93, 5, 1.6 and 0.4 percent of species composition. These forests are not enclosure and they have highly grazed. Regeneration situations are not satisfactory and most of the trees have been attacked by pests and diseases, So that 92% of *Juniper* trees have been attacked by *Juniperus* Wasp larvae. Based on forest vegetation map, 424, 561 and 299 ha of forest area have dense canopy (5-10%), spare canopy (1-5%) and without canopy, respectively. The percentage of crown coverage in *Juniper* forests is 3.02% and its density is 43.5 individual per ha. Also tree density for *Junipers, Berberis, Crataegus* and other species are as follows; 40.5, 2.2, 0.7, 0.1, respectively. These forests were studied in forestry and silviculture points of view. Due to conservation and environmental aspects of these forests, they deserve to be planned for development and area extension. And with directing traditional husbandry to industrial one, we can help husbandry and forest sustainability continue for future.

KEYWORDS: Forest, Tansect Plot Inventory, Density, *Juniperus*, Gharah Ghermez, Canopy cover, Cattle, Silviculture, Forestry

SIMO: An adaptable forest management planning framework for multi-scale forest resource data

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Forest management planning is facing new objectives and diversified data sources. To succeed in the new context, a forest management planning framework should support integration of the new goals, knowledge, and technology as well as embrace multiple scales to match our sharpening view of forests. The aim of the SIMO framework is to provide a hierarchical, extendable simulation and optimization framework for forest management planning. Current implementation includes a four modules that support the planning process of importing data into the planning framework, simulating several alternative development scenarios for the forest area under planning, using optimization to select the scenario that best matches the goals and constraints for forest management, and reporting the planning results.

In the forest growth and yield simulator module all aspects of the simulation are modifiable by the user. This adaptability is achieved by using XML documents to define the simulation system: the kind of data used, the growth and operation models that modify the data, and how the models are applied to the data. The different components are connected together through a common framework ontology; i.e., a hierarchical description of the kind of objects the forest consists of and the different properties that the objects have. Two different forest growth simulators implemented for Finnish conditions demonstrate the adaptability of the framework: one simulator is based on the stand level view of forest and uses stand-wise growth models, whereas the other one is based on individual tree level growth models. Both simulators can be run on top of the SIMO framework.

The optimization module currently contains implementations for a variety of metaheuristic optimization methods including HERO, Tabu Search, Simulated Annealing and Threshold Accepting. The module also has an interface to the Linear Programming optimization package J developed at the Finnish Forest Research Institute. The optimization problem is specified independently of the optimization

method; i.e., an unified XML definition for the goals and constraints of the optimization task is used.

The SIMO framework is published as open source software and is available at http://www.simo-project.org.

KEYWORDS: simulation, optimization, hierarchical, adaptability, extendibility; XML

Excursion

Excursion to the State Forest District of Munich

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Bayerische Staatsforsten

Organization

The *Bayerische Staatsforsten* was established on 1 July 2005 and is responsible for the management of 720,000 hectares of state forest and about 85,000 hectares of other areas of the State of Bavaria according to the State Forestry Act. The *Bayerische Staatsforsten* is oriented according to the economic principles of private companies with the legal form of a company under public law (AöR). It developed out of the Bavarian State Forest Administration, which had carried out the forest management for the last 250 years.

The company has more than five million cubic meters under bark of annual cut forming one of the largest forestry companies in Europe and the main provider of roundwood in Germany. The company currently employs over 3000 people and is therefore a major employer in rural areas.

The supervisory board (chairman of the supervisory board: Minister of State Josef Miller) is in charge of the management of the board. The advisory committee (chairman of the advisory council: Helmut Brunner, Member of the Bavarian Parliament) of the *Bayerische Staatsforsten* provides social concerns on the management of the state forest and hunting. The advisory board comprises of a large number of social interest groups from business, politics, environmental and recreation associations.

The headquarters of the *Bayerische Staatsforsten* is located in Regensburg. The company is divided into 41 forest districts with 370 forest ranges.

Mission

The mission of the company - derived from the Forest Act for Bavaria and the State Forestry Act - is the best management of the state forest in accordance with the principles of closed to nature forestry and to secure the protective and recreational forest functions. The *Bayerische Staatsforsten* realizes this under the principle of ecological, economic and social sustainability. Therefore the *Bayerische Staatsforsten* seeks for the goal of the optimization of the overall benefits maximizing profits and taking care of the social responsibility.

What does sustainability mean for the Bayerische Staatsforsten ?

Sustainability - in economic, environmental and social terms - is the key for the future success of the company. It is the foundation and heritage of the 250-year-old history of forestry in Bavaria. This means that the timber yield can be achieved permanently and the increment is used without endangering the substantial value of the state forest. The *Bayerische Staatsforsten* also actively secures the protective and recreational functions of the forest, which form a prerequisite for the preservation and improvement of the ecological value of the whole forest ecosystem. Sustainability also shapes the behavior towards its employees and the social stakeholders of the company and provides the basis for the efficiency of management.

The *Bayerische Staatsforsten* conducts periodically forest inventories based on forest management units. A systematic sampling is applied to derive growing stocks and increment. Measured tree heights and stem diameters at the sampling points allow further detailed analysis. Every decade a forest management plan is established in each forest district, which summarizes the results of the forest inventory, the performance of the past operations, the present condition of the forest district, and the forest planning for the following decade.

Currently, the forests of the *Bayerische Staatsforsten* have a growing stock of around 203 million cubic meters under bark and an annual increment of about 6 million cubic meters under bark. In the year 2006 approximately 5.4 million cubic meters under bark of timber were harvested. In the fiscal year 2006, a profit of 25 million € was achieved. Of these, 15 million € were transferred to the government of Bavaria and 10 million € were retained as a reserve in the *Bayerische Staatsforsten*.

The State Forest District of Munich

Organization and geographical situation

The forest district is located in the south of the provincial capital of Munich (Figure 1). The operating area is 18362 hectares, of which 18015 hectares are forest land (Figure 2). A large proportion of the area is covered by protective and recreational forest functions. In particular, recreation, the protection against pollution, and the protection of the local climate play a prominent role (Table 1). The coincidence of a service oriented society and primary production takes influence on the management of the forest district.

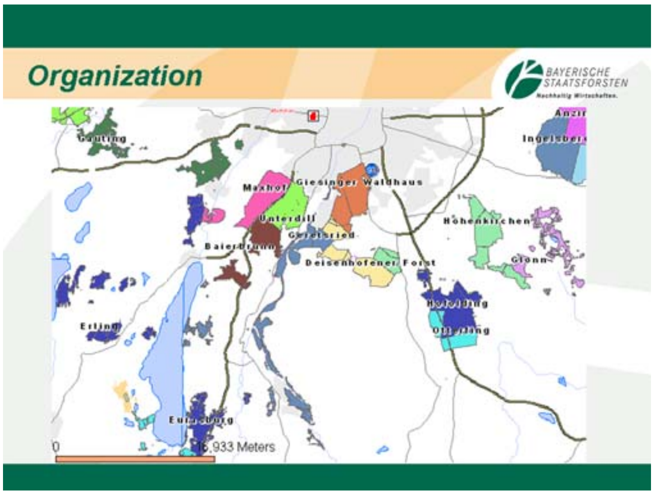

Figure 1 Left: Organization of the forest district, Right: The "Forstenrieder Park" (Field trip)

Areas

Land use	Area [ha]
Productive forest land	**17207,0**
Non-productive forest land	808,0
Forest land	18015,0
Other areas	437,3
Total area	**18452,3**

Commercial forest	
• regular management	16523,9
• non-regular management	683,1
Forest according Art. 2 BayWaldG	17877,3

Figure 2 Left: Classification of the operating area, Right: Present structure of large areas of productive forest land

Function	Percentage of total area
Protection of biotopes	6%
Protection of soil	3%
Recreation	76%
Protection of ecology	1%
Protection of landscape	9%
Protection against imissions	63%
Protection of local climate	70%
Protection against noise	3%
Protection of infrastructure	2%
Protection of water resources	18%

Table 1 Recreational and protective functions

History

The Forest District of Munich was founded in the 2005 from the former forestry offices in Munich and Starnberg, as well as parts of the former forestry offices Sauerlach, Wolfratshausen, Fürstenfeldbruck and Anzing.

Since the 14th century, the hunting area of the Wittelsbach dynasty was located in the south of Munich, and therefore the forest area enjoyed a special protection for centuries ("Forstrieder Park"). Since 1805, a large proportion of the forest between the rivers Isar and Würm were fenced and used for royal hunting. The most important data of the forest history are shown in Table 2.

50	Construction of the Roman road from Augsburg to Salzburg
1399	Duke *Ludwig der Gebartete* buys the "Forstenrieder Park", which was used as a favorite hunting area of the Bavarian royal dynasties until 1918.
1640/50	Wolf menace.
17th/18th century	Period of coursing ("Parforce Jagden").
1734/1735	The Yellow, Blue, Green and Red House are be built.
1806	Royal hunting with Napoleon I, on the occasion of the appointment of the Kingdom of Bavaria.
1809/10	First forest management plan. Establishment of the logging road system.
1837	Beginning of the systematic artificial regeneration with pine and spruce.

1889/92	Insect outbreak, 550000 cubic meters salvage felling.
1918	King Ludwig III shoots his last deer. End of royal hunting area.
1945/47	Destruction of 400 hectares of land by bombing and bark beetles, afterwards reforestation.
1961/62	Exploitation of water resources for provincial capital of Munich
1988	Control of game, to enable the realization of silvicultural objectives (e.g. natural forest regeneration).

Table 2 History of the forests in the south of the provincial capital of Munich

Site conditions and forest composition

The forests stock on limestone moraines of the last ice ages and post glaciations gravel deposits, which are partly covered by loess. The climatic site conditions enable high forest yields (Table 3). Nevertheless there exist limitations of the water supply: Two third of the sites have only a moderate water storage capacity and about one tenth of the area consists of dry sites. The natural vegetation is dominated by deciduous tree species. Today, two third of the forest area is covered by conifers, mainly spruce (Table 4). Spruce was formerly preferred because of the low costs for artificial regeneration, good timber quality and high increment.

Mean annual temperature	7 - 8 ^{o}C
Mean temperature during vegetation period	14,5 - 15,5 ^{o}C
Number of days with a mean daily temperature above 10 ^{o}C	150 – 165 days
Range of temperature	18 - 19,5 ^{o}C
Annual precipitation	750 – 1220 mm
Precipitation during vegetation period	450 – 750 mm

Table 3 Climate conditions in the forest district

Tree Species	**Percentage**
Spruce	60%
Pine	6%
Fir	1%
Larch	2%
Douglas Fir	<1%
Total Conifers	68%
Beech	13%
Oak	4%
Other Broadleaved	15%
Total Broadleaved	32%

Table 4 Tree species composition of the forest district

Silviculture

Today the forest district consists of extensive areas of pure spruce stands, with a low structural diversity and stand ages between 60 and 90 years. Due to its low resistance against insects, storms, and dryness (Figure 3), forest damages appear frequently and salvage felling play a dominant role in the management of the forest district.

Figure 3 Risk factors for spruce stands: Dryness, wind and bark beetle

The silvicultural concept consists of following steps:

- Spatial sequences
- Preparatory cutting
- Advance planting of mixed species
- Overhead release felling
- Final harvest of spruce

Special focus is given to the introduction of mixed species (Figure 4) – especially beech (*Fagus sylvatica* L.). This requires a detailed strategy of preparatory cuttings to enable the regeneration of beech and to harvest spruce stands without causing extended damages. Therefore following treatment is applied in spruce stands of the final harvest area:

- Final improvement cutting in spruce
- Cautious opening of the crown layer
- Creation of sufficient light conditions for beech
- Acceleration of humus formation
- Short-log assortments to protect the remaining stand during harvest
- Operation of harvesters

The prescribed yield amounts 166700 cubic meters under bark for the next decade, whereby 1/4 is produced by improvement cuttings.

Figure 4 Conversion of spruce stands into mixed forests

Forest Planning

Introduction

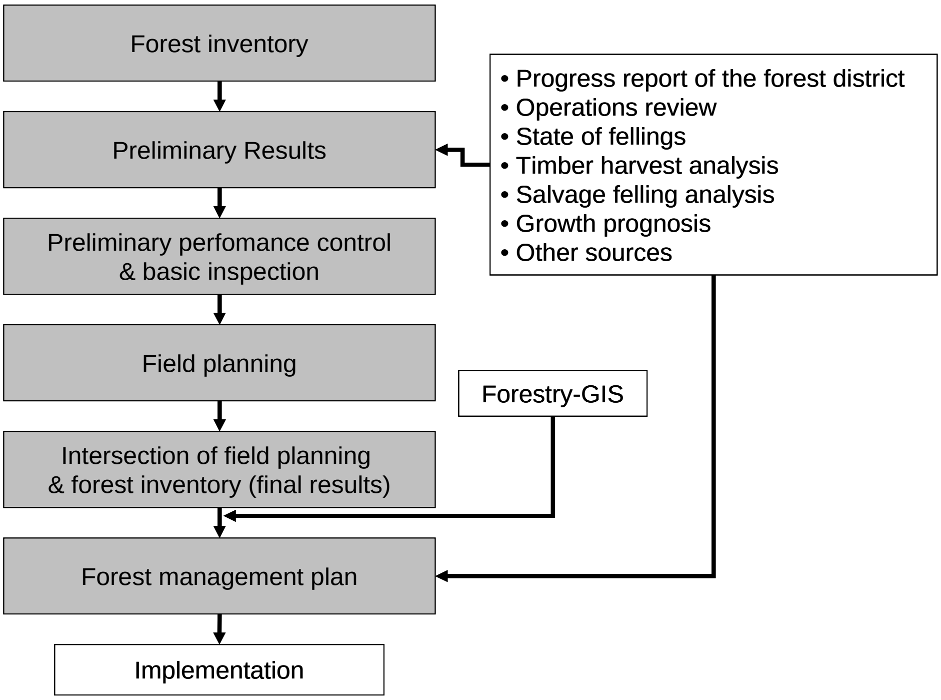

Figure 5 Development of the forest management plan

Jungbestandspflege (JP):
Tending during the pre-thicket and thicket stages

Jungdurchforstung (JD):
Selective thinning (selection in regard to quality, beginning improvement of diameter increment)

Altdurchforstung (AD):
Promotion of crown development and improvement of diameter increment

Verjüngungsnutzung (VJ):
Start of regeneration, establishment of mixed species, harvesting of mature trees

Langfristige Behandlung (LB):
Small-scale regeneration and tending treatments to improve and conserve structural diversity. Permanent forest.

Wirtschaftswald außer regelmäßigen Betrieb (a..r.B.):
Sustainable cuts below 1 cubic meter per hectare and year

Nichtholzboden (NHB) / Sonstige Flächen (SF):
All other areas, which are not used for timber production

Figure 6 Definition of management types

Procedure of the forest inventory (Field trip POINT A)

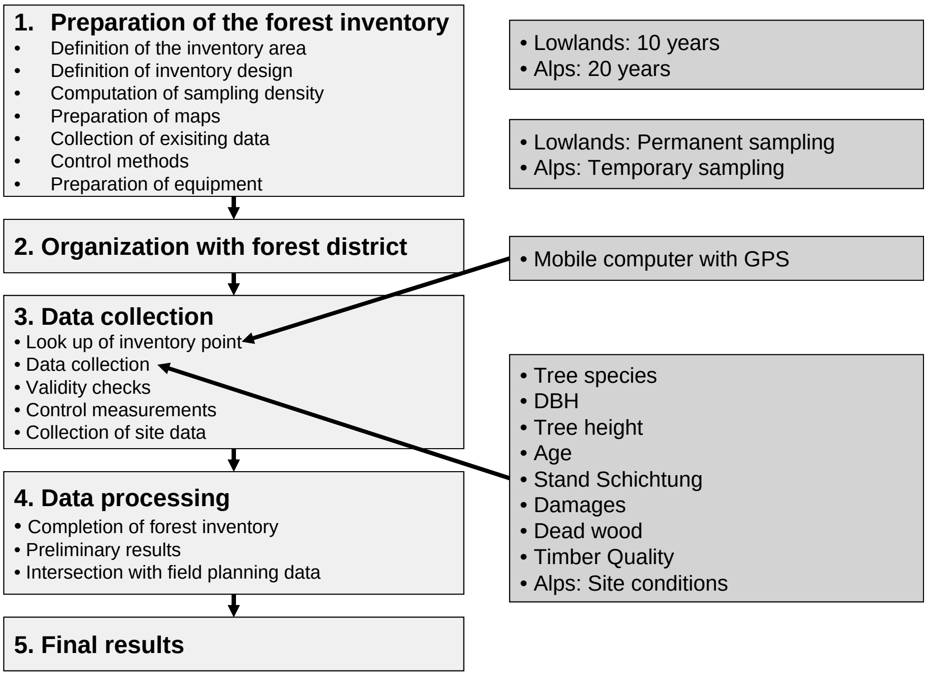

Figure 7 Procedure of the forest inventory

Data analysis, preparation of the forest management plan (Field trip POINT B)

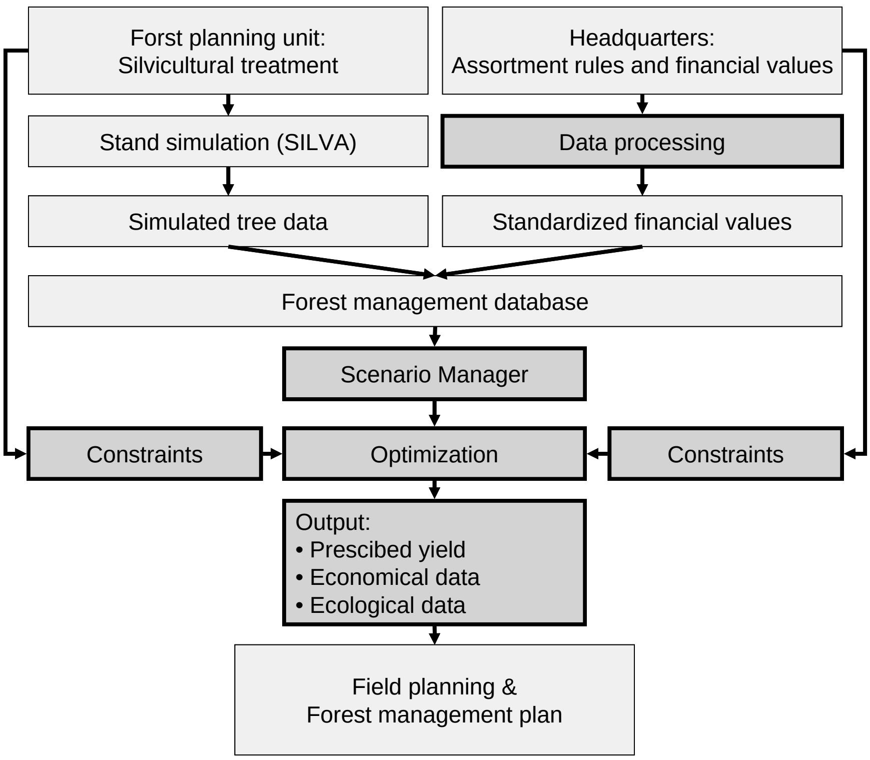

Figure 8 Role of optimization in the forest management planning (bold marked boxes contain the components of the optimization package)

Procedure of the forest management planning and implementation

(Field trip POINT C)

- Update of information on forest areas and organisation
- Forest inventory, planning, performance control

↓

- Interpretation and verification of inventory data
- Classification of management types and development stages, respectively
- Classification of stands and stand description
- Silvicultural planning for single stands (final harvest) or stand classes
- Special plannings (wilderness areas …)
- Control / completion of the seed harvesting register
- Alps: Control of protection forest redevelopment plannings
- Alps: Definition of business segments

↓

- Validy checks, calculation of areas
- Definition of prescribed yield
- Prognosis of stand growth (simulation modell SILVA)
- Optimization
- Forest management plan and definition of objectives
- Preparation of the forest range handbook
- Production of maps

Figure 9 Procedure of the forest management planning

Optimization of the sustainable prescribed cut: A case study for the forest management planning in the state forest district of Munich

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In future the forest management planning must consider higher financial expectations for the forestry operations and extended requirements for the sustainable development. Therefore it is necessary to enhance the existing methods of forest management planning: Complex target systems must be processed, the use of existing operational information must be improved, and the deviation of the prescribed cut must lead to optimal financial results under the given restrictions.

Therefore, the objective of the presented study is to investigate whether novel planning procedures can be developed on the basis of modern optimization methods, which meet the objectives of a future-oriented forestry company and can be applied by the forest managers in practice. In a case study at the state forest district of Munich the opportunities of the application for these systems are demonstrated. The area is characterized by artificial spruce stands of low stability and various target conflicts caused by high recreational use of the forests. Applying various restrictions, which result from variations of the target preferences, the consequences are calculated for the prescribed cut and thus the financial results of the forest management unit. Finally, it is explained how these results can be introduced into the forest management process.

KEYWORDS: forest management planning, optimization, risk

Session 4

Sustainability Assurance: Lessons from Time Series (C&I) and Cross-national Comparison Methods

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Two emerging streams of research and analysis are focusing on very different ways of conceptualizing and measuring attainment of society's sustainability goals for forests. The first stream is the concept of Criteria and Indicators, which involves developing indicators of sustainability and then applying measurements to those indicators to assess performance. This could be thought of as "time series analysis", as the focus is on identifying whether trends over time are favorable. The other is the approach of cross –national comparisons, which could be thought of as a "cross-section" approach, under which different nations are ranked in comparison to one another on a list of variables, which may further be combined into complex indices. In both cases, the discipline of "environmetrics" is at work.

Why is this a concern for forest inventory? The reason is that for roughly 80% of the world's nations, and perhaps a similar share of the forest area, field-based inventory data simply do not exist to provide a basis for assessing current status, much less trend. We can expect that in nations with strong inventory systems, there will be a tighter integration between both time series and cross section indicators, and the variables measured in the field, and how analytical reports are prepared. For the globe as a whole we may hope for – and should actively support with our efforts – a substantial, fully funded, and state-of the art remote sensing and inventory component for the FAO's 2010 Global Forest Resources Assessment.

Sustainable forest ecosystem with consideration to Medicinal plants products, case study: North-West of Iran, Arasbaran forest, Mardanaghomchay watershed

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Arasbaran forests is one of the important ecosystems in Iran with 168000 ha area that is located in North West of Iran and was known as the one of more important biosphere reserve. It represent valuable and often unique genetic resources which currently face both challenges and opportunities for it conservation and use. Major challenges include rural people destructions and structure changes due to forest fragmentation, weak management forestry practices, that is expected to severely affect the Arasbaran forest. The need for action to conserve forest ecosystem necessitous to improve none woody products of it especially medicinal plants. Research showed that the study area has remarkable medicinal plant species. Consideration to the medicinal plants and developing of cultivation and rural people occupation can be decreased the unsuitable pressures to the ecosystem. Rich biodiversity of medicinal plants in the region can be increased the practicability developing of related industrial. Sustainable forest ecosystem needs more consideration and good management of forest products.

KEYWORDS: biosphere reserve**,** none woody products**,** biodiversity

Multiple-Use forest planning model for second-growht forests of Roble-Raulí-Coihue

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This work deals with the development of a multiple-use forest management model for second-growth natural forests of Roble-Raulí-Coihue to be used in thinning and harvest scheduling with a profit maximizing objective while maintaining forest areas with minimum levels of biodiversity and landscape protection. The value of biodiversity is derived from a land use allocation and management model based on a linear programming approach which incorporates constraints regarding timber production and biodiversity levels as well as clearcutting regulation in high visibility landscape.

Forests of the case study are located in the commune of Lanco (Los Ríos Region, Chile).The methodology involves the calculation of biodiversity indicators such as Richness index, Shannon – Wiener index, a Shannon vertical structure index and horizontal structure index based on dbh standard deviation. A 100-year planning horizon divided into 5-year periods has been considered. The model considers several forest management options like a non-intervention regime and a number of thinning-based management schemes, with different intensity levels. Thinnings considered in this work conform to the management rules in force for this kind of forest.

The results obtained point to the optimal management strategies for these stands when management goals include fulfilment of biodiversity and landscape levels. The model leads to consistent results and perfectly understandable and reflects the existence of conflicting goals. For example, a search for high values of the indices of species diversity promotes staggering the clearcutting, thus penalizing the objective of maximizing the NPV regard to non constrained scenario. The scenarios that

consider constraints of biodiversity structural are those with a greater decline in the objective function with respect to a scenario without constraints. In the case of constraints associated with the landscape, it is interesting to see that it is possible to control the harvested area with high visual impact without causing major reductions in the objective function.

The developed methodology has an important flexibility degree, allowing the representation of several planning scenarios based on the inclusion or exclusion of each of those subsets of constraints.

Towards sustainable forest management: How to implement the precautionary approach

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The term of sustainability was once used to secure the delivery of the salt and mining industry with timber resources. Today, at least since the Brundlandt-report had been published and the Earth Summit of Rio de Janeiro had taken place, sustainability is defined much broader. Since that time, the idea of a sustainable development has become a leading idea for global, national and regional policy and politics.

While forestry science brought up tools to fulfil the former sustainability approaches, solutions are rare to fit the current and more complex idea of a sustainable forest management. Although it is common sense in management science that sustainable decisions have to keep a big number of options for future actors, it is not much known about how this precautionary approach could be integrated in an optimization algorithm.

Therefore the presented project focuses the topic of risk integration in strategic planning. It is our thesis that every forestry enterprise acts sustainable, if full and symmetric information would be available and rational decisions were drawn. As this very often is not the case, integration of uncertainty could help to find a sustainable path as a surrogate for complete information. To test this thesis, techniques for the integration of uncertainty will be adapted in an optimization algorithm on forest management considering a horizon of 200 years.

KEYWORDS: strategic planning, risk integration, sustainable forest management

Authors

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FS	12/13	Freising Ⓢ R	2.44		3.24		4.04		4.44	5.04	5.24	5.44	6.04	6.24	6.44	7.04	7.24	7.44	8.04	8.24
FS	12/13	- Schlüterstraße	2.48		3.28		4.08		4.48	5.08	5.28	5.48	6.08	6.28	6.48	7.08	7.28	7.48	8.08	8.28
			Y		Y		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	13	Flughafen, Briefzentrum	2.53		3.33		4.13		4.53	5.13	5.33	5.53	6.13	6.33	6.53	7.13	7.33	7.53	8.13	8.33
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	13	Flughafen, Terminalbereich A/B	8.59	9.19	9.39	9.59	10.19	10.39	10.59	11.19	11.39	11.59	12.19	12.39	12.59	13.19	13.39	13.59	14.19	14.39
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	13	Flughafen, Urlauber-Parkpl.P41	20.55	21.15	21.35	21.55	22.15	22.35	22.55	23.15	23.35	23.55	0.15	0.35
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	13	Flughafen, Terminalbereich A/B	20.59	21.19	21.39	21.59	22.19	22.39	22.59	23.19	23.39	23.59	0.19	0.39
	13	Flughafen, Terminal 1 Ⓢ	21.01	21.21	21.41	22.01	22.21	22.41	23.01	23.21	23.41	0.01	0.21	0.41
	13	Flughafen, Terminal 2 Ankunft	21.05	21.25	21.45	22.05	22.25	22.45	23.05	23.25	23.45	0.05	0.25	0.45

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	13	Flughafen, Urlauber-Parkpl.P41	3.13	3.45	3.59	4.25	4.33	5.05	5.25	5.45	6.05	6.25	6.45	7.05	7.25	7.45	8.05	8.25	8.45	9.05
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				Y		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
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FS	12/13	Freising Ⓢ Ⓡ		3.58		4.38		5.18	5.38	5.58	6.18	6.38	6.58	7.18	7.38	7.58	8.18	8.38	8.58	9.18

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	13	Flughafen, Briefzentrum	9.27	9.47	10.07	10.27	10.47	11.07	11.27	11.47	12.07	12.27	12.47	13.07	13.27	13.47	14.07	14.27	14.47	15.07
			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
FS	12/13	Freising, Schlüterstraße	9.32	9.52	10.12	10.32	10.52	11.12	11.32	11.52	12.12	12.32	12.52	13.12	13.32	13.52	14.12	14.32	14.52	15.12
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	®		täglich																	
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			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
FS	12/13	Freising, Schlüterstraße	15.32	15.52	16.12	16.32	16.52	17.12	17.32	17.52	18.12	18.32	18.52	19.12	19.32	19.52	20.12	20.32	20.52	21.12
FS	12/13	Freising Ⓢ Ⓡ	15.38	15.58	16.18	16.38	16.58	17.18	17.38	17.58	18.18	18.38	18.58	19.18	19.38	19.58	20.18	20.38	20.58	21.18

Y = keine Kurzstrecke

	®		täglich											
	13	Flughafen, Terminal 2 Ankunft	21.14	21.34	21.54	22.14	22.34	22.54	23.14	23.34	23.54	0.14	0.34	0.54
	13	Flughafen, Terminalbereich A/B	21.18	21.38	21.58	22.18	22.38	22.58	23.18	23.38	23.58	0.18	0.38	0.58
	13	Flughafen, Terminal 1 Ⓢ	21.20	21.40	22.00	22.20	22.40	23.00	23.20	23.40	0.00	0.20	0.40	1.00
	13	Flughafen, Terminalbereich D/E	21.21	21.41	22.01	22.21	22.41	23.01	23.21	23.41	0.01	0.21	0.41	1.01
	13	Flughafen Besucherpark Ri Fr. Ⓢ	21.24	21.44	22.04	22.24	22.44	23.04	23.24	23.44	0.04	0.24	0.44	1.04
	13	Flughafen, Urlauber-Parkpl.P41	21.25	21.45	22.05	22.25	22.45	23.05	23.25	23.45	0.05	0.25	0.45	1.05
	13	Flughafen, Bauzentrale	21.26	21.46	22.06	22.26	22.46	23.06	23.26	23.46	0.06	0.26	0.46	1.06
	13	Flughafen, Briefzentrum	21.27	21.47	22.07	22.27	22.47	23.07	23.27	23.47	0.07	0.27	0.47	1.07
			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
FS	12/13	Freising, Schlüterstraße	21.32	21.52	22.12	22.32	22.52	23.12	23.32	23.52	0.12	0.32	0.52	1.12
FS	12/13	Freising Ⓢ Ⓡ	21.38	21.58	22.18	22.38	22.58	23.18	23.38	23.58	0.18	0.38	0.58	1.18

Y = keine Kurzstrecke

® = Angabe der Zeitkartenringe

Busfahrten innerhalb einer Gemeinde gelten als Kurzstrecke:
FS = Gde. Freising

In Freising Anschluss zu Regionalzügen in Richtung Regensburg/Passau - Landshut (Bay)
In den Fahrzeugen dieser MVV-Regionalbuslinie werden - soweit betrieblich möglich - auch Tages-, Wochen- und Monatskarten verkauft.

From Freising (Railway Station) to Munich (Central Station)

	Freising ab	München Hbf an	
S 1	00:13	00:56	
S 1	01:33	02:16	Nacht Fr/Sa Sa/So u. vor Feiertagen
S 1	04:53	05:36	
RB	05:18	05:48	Mo.-Fr.
S 1	05:33	06:16	
ALX	05:49	06:15	Mo.-Sa.
S 1	05:53	06:36	Mo.-Sa.
RB	06:07	06:38	
S 1	06:13	06:56	
RE	06:29	07:01	Mo.-Sa., nicht 22.05, 15.08, 01.11.08
S 1	06:33	07:16	
S 1	06:41	nur bis Moosach an Schultagen	
ALX	06:49	07:16	
S 1	06:53	07:36	Mo.-Sa.
RB	07:03	07:41	Mo.-Fr.
RE	07:09	07:37	Mo.-Fr.
S 1	07:13	07:56	
RB	07:28	07:59	Mo.-Sa.
S 1	07:33	08:16	Mo.-Sa.
RE	07:49	08:20	Mo.-Fr.
RE	07:51	08:20	Sa./So./Feiertage
S 1	07:53	08:36	
RE	08:09	08:36	
S 1	08:13	08:56	
S 1	08:33	09:16	Mo.-Fr.
ALX	08:48	09:16	
S 1	08:53	09:36	
S 1	09:13	09:56	
RB	09:28	09:59	
S 1	09:32	10:15	Sa, auch 01.11.08
S 1	09:33	10:16	Sa. an Feiertagen
RE	09:37	10:04	Sa. nicht 01.11.08
RE	09:53	10:20	
RE	10:09	10:36	
S 1	10:13	10:56	
S 1	10:33	11:16	
ALX	10:49	11:16	
S 1	11:13	11:56	
RB	11:28	11:59	
S 1	11:33	12:16	
RE	11:53	12:21	
RE	12:09	12:36	
S 1	12:13	12:56	
S 1	12:33	13:16	
ALX	12:48	13:16	
S 1	12:53	13:36	Mo.-Fr.
S 1	13:13	13:56	
RB	13:28	13:59	Sa/So/Feiertage

	Freising ab	München Hbf an	
S 1	13:33	14:16	Mo.-Fr.
RE	13:51	14:21	
S 1	13:53	14:36	
RE	14:10	14:36	
S 1	14:13	14:56	
S 1	14:33	15:16	
ALX	14:48	15:19	
S 1	15:13	15:56	
RB	15:28	15:59	
S 1	15:33	16:16	Mo.-Fr.
RE	15:50	16:20	
S 1	15:53	16:36	
RE	16:09	16:41	
S 1	16:13	16:56	
RB	16:28	17:00	Mo.-Fr.
S 1	16:33	17:16	
ALX	16:49	17:19	
S 1	16:53	17:36	Mo.-Fr.
S 1	17:13	17:56	
RB	17:28	17:59	Sa/So/Feiertage
S 1	17:33	18:16	Mo.-Fr.
RE	17:50	18:20	
S 1	17:53	18:36	
RE	18:09	18:40	
S 1	18:13	18:56	
S 1	18:33	19:16	
ALX	18:49	19:19	
S 1	18:53	19:36	Mo.-Fr.
S 1	19:13	19:56	
RB	19:28	19:59	
S 1	19:33	20:16	Mo.-Fr.
RE	19:51	20:17	
S 1	19:53	20:36	
RE	20:09	20:40	
S 1	20:13	20:56	
S 1	20:33	21:16	Mo.-Fr.
ALX	20:48	21:16	
S 1	20:53	21:36	
S 1	21:13	21:56	
RB	21:28	21:56	
S 1	21:33	22:16	
RE	21:56	22:21	Fr/Sa/So/Feiertag
RE	22:09	22:36	
S 1	22:13	22:56	
S 1	22:33	23:16	
ALX	22:57	23:21	
S 1	23:13	23:56	
RE	23:56	00:21	

From Munich (Central Station) to Freising (Railway Station)

	München Hbf ab	Freising an	
S 1	00:05	00:44	
S 1	00:45	01:24	
S 1	02:25	03:04	Fr/Sa Sa/So
S 1	04:25	05:04	
S 1	05:05	05:44	Sa.+So.
S 1	05:25	06:04	Mo.-Fr.
RE	05:36	06:03	Sa/So/Feiertage
RE	05:44	06:08	Mo.-Fr.
S 1	05:45	06:24	
RE	06:12	06:47	Sa., auch 24.12.+ 31.12.07
S 1	06:05	06:44	Mo.-Sa.
S 1	06:25	07:04	
ALX	06:44	07:07	
S 1	06:45	07:24	Mo.-Sa.
S 1	07:05	07:44	
RE	07:17	07:48	
S 1	07:25	08:04	
RE	07:43	08:07	
S 1	07:45	08:24	Mo.-Fr.
RB	08:05	08:32	
S 1	08:05	08:44	
S 1	08:25	09:04	
ALX	08:44	09:07	
S 1	08:45	09:24	
RE	09:24	09:48	
S 1	09:25	10:04	
RE	09:43	10:07	
S 1	09:45	10:24	
RB	10:05	10:32	
S 1	10:25	11:04	
ALX	10:44	11:07	
S 1	10:45	11:24	
RE	11:24	11:48	
S 1	11:25	12:04	
RE	11:43	12:07	
S 1	11:45	12:24	
RB	12:05	12:32	
S 1	12:05	12:44	Mo.-Fr.
S 1	12:25	13:04	
ALX	12:44	13:07	
S 1	12:45	13:24	Mo.-Fr.
S 1	13:05	13:44	
RE	13:23	13:46	
S 1	13:25	14:04	
RE	13:43	14:07	
S 1	13:45	14:24	
RB	14:05	14:32	Fr/Sa/So/Feiertag
S 1	14:25	15:04	
ALX	14:44	15:07	
S 1	14:45	15:24	Mo.-Fr.
RB	15:03	15:32	Mo.-Fr.
S 1	15:05	15:44	
RE	15:24	15:48	
S 1	15:25	16:04	
RE	15:43	16:07	
S 1	15:45	16:24	
RB	16:03	16:30	Mo.-Fr.
RB	16:05	16:30	Sa/So/Feiertage
S 1	16:05	16:44	Mo.-Fr.
RE	16:23	16:47	Mo.-Fr.
S 1	16:25	17:04	
ALX	16:44	17:07	
S 1	16:45	17:24	Mo.-Fr.
RB	17:03	17:32	Mo.-Fr.
S 1	17:05	17:44	
RE	17:24	17:48	
S 1	17:25	18:04	
RE	17:43	18:07	
S 1	17:45	18:24	
RE	18:03	18:31	Mo.-Fr.
RB	18:05	18:31	Sa/So/Feiertage
S 1	18:05	18:44	Mo.-Fr.
RB	18:23	18:52	Mo.-Fr.
S 1	18:25	19:04	
ALX	18:44	19:07	
S 1	18:45	19:24	Mo.-Fr.
RE	19:04	19:28	Sa., nicht 01.11.08
S 1	19:05	19:44	
RE	19:24	19:48	
S 1	19:25	20:04	
RE	19:43	20:07	
S 1	19:45	20:24	Mo.-Fr.
S 1	20:05	20:44	
RB	20:24	20:51	
S 1	20:25	21:04	
ALX	20:44	21:07	
S 1	20:45	21:24	
S 1	21:05	21:44	
RE	21:24	21:48	
S 1	21:45	22:24	
ALX	22:15	22:42	Sa.
S 1	22:25	23:04	
RE	22:44	23:09	Sa.+feiertags
S 1	22:45	23:24	
RB	23:04	23:32	
S 1	23:25	00:04	
ALX	23:55	00:18	

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