The Finnish MELA system, JLP and DemoMELA

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Outline

- Background
- What is MELA?
- What is JLP?
- What is DemoMELA?
- Guided Tour of DemoMELA
- DemoMELA Exercise

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Conventional forest planning based on standwise inventory

In conventional forest planning, suggestions for forest management operations for stands are made in the field – as a part of forest inventory

- based on characteristics of stand
- following laws, recommendations and silvicultural guidelines (e.g. instructions related to thinning or rotation periods)
- taking into account interests of the decision-maker.

Problems in conventional forest planning

- Standwise proposals consider each stand independent.
- The assumptions behind silvicultural recommendations may not be relevant for the particular decision situation.
  - the utility to a forest owner from an individual stand may not equal the net present value of the future revenues (cf. Faustmann formula)
  - even if it in theory did, the parameters in the calculation when recommendations where prepared may not be relevant anymore (new income sources excluded, changes in the product markets related to assortments and their price, changes in technology etc.)
- Standwise proposals – based on exogeneously given regimes - often become outdated due to changes in, for example
  - forest stand
  - laws, recommendations and silvicultural guidelines
  - market situation
  - the interests of the decision-maker.

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Traditional forest level considerations

- The principle of maximum sustainable yield:
  - forest resource as a whole should be managed in such a way that the current generation gets as much benefit as possible without decreasing what future generations can get from it.
- The practical aim is ”normal forest” or ”fully regulated forest”:
  - an idealistic model of a multi-stand forest consisting of even-aged stands with even age-class distribution
  - from which the same amount of products can be harvested in the current and all the future periods.
- Maximum sustained yield (MSY) is achieved by adopting rotation age and the desired age-class structure.
  - Different methods and calculation procedures for the preparation of cutting budget and harvesting scheduling
    - iterative methods (”trial-and-error”) and heuristics
    - mathematical programming
  - Conversion of non-regulated forests into regulated is a challenge!
    - mathematical modelling applied widely.

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Operation research – ”science and art”

- Seeks for the best (optimal) solution under limited resources.
- Definition of the decision problem:
  - mathematical model
  - aspects and issues which cannot be included into the mathematical model
- Construction of the decision model:
  - integrates decision alternatives and their description for the systematic evaluation and/or the selection of best alternative based on evaluation criteria
  - goal function to be optimised (minimised or maximised) and constraints defined using decision variables (alternatives) in the decision problem
- Solving the model:
  - optimisation techniques such as linear programming (LP), non-linear programming, integer programming, dynamic programming(-> optimal solution) or heuristics and simulation
  - in addition to seeking optimum solution, sensitivity analysis to study the behaviour of the optimal solution in respect of model parameters
- Validation of the model
- Implementation of the model i.e. ”translating” the results for operational use

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What is MELA?

For more information:

http://www.metla.fi/metinfo/mela

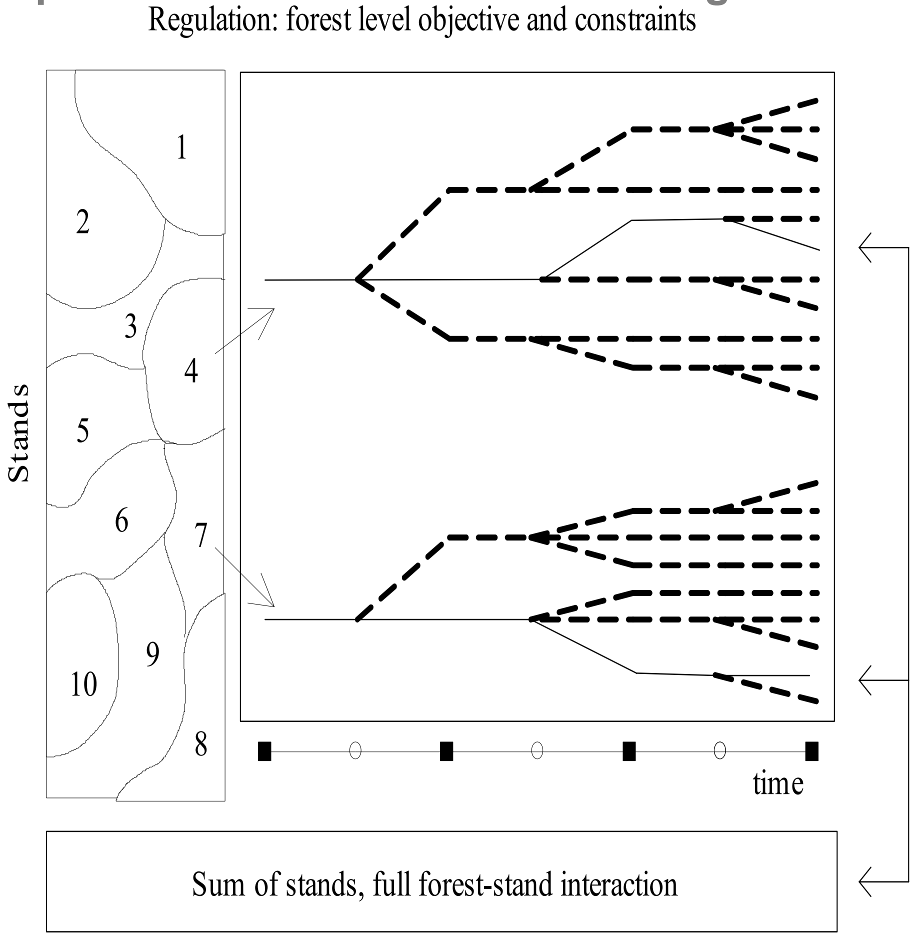
Siitonen, M., Härkönen, K., Hirvelä, H., Jämsä, J., Kilpeläinen, H., Salminen, O. & Teuri, M. 1996. MELA Handbook - 1996 Edition . The Finnish Forest Research Institute. Research Papers 622. 452 p.

Redsven, V., Anola-Pukkila, A., Haara, A,. Hirvelä, H., Härkönen, K., Kettunen, L., Kiiskinen, A., Kärkkäinen, L., Lempinen, R., Muinonen, E., Nuutinen, T., Salminen, O., Siitonen, M. 2004. MELA2002 Reference Manual (2nd edition). The Finnish Forest Research Institute. 606 p.

Integrated stand and forest level optimisation

- facilitates endogeneous solving of stand management in Model I context based on potential variation of stand management

Simulation:
Prediction of forest development using tree-level models under different treatment alternatives. Feasible treatments are identified based on forest data and user-supplied parameters.



Optimisation:
Simultaneous selection of forest-level production program and corresponding management of stands based on forest-level objective and constraints.

Integrated stand and forest level optimisation

- The potential range of management over space (in stands) and in time is compiled into the input data of optimisation as management schedules.
- Each schedule is associated with a vector of input and output variables over time.
- The management of stands is solved endogeneously based on forest level objective(s) and constraints.
  - In practice, a combination of schedules for stands within a forest area that fulfills the defined objective(s) and constraints, is selected.
  - Constraints may deal with inputs (resources available, e.g. machines or workers available) or outputs (targets set by decision maker, e.g. income expectations).

The Finnish MELA system

- The Finnish MELA system was designed in the 1970s for regional and national timber production analyses in Finland.
- MELA consists of two principal parts:
  - an automated stand simulator based on individual trees in Finnish conditions (the MELASIM)
    - individual trees for taking into account
      - changes in environment
      - changes in the definition of timber assortments
  - the JLP software as the integrated stand and forest level optimiser with hierarchical domain constraints (the MELAOPT),

  both wrapped into an interface module.
- Interface allows user to define his/her own analysis using a large set of simulation, optimisation and reporting parameters (including thousands of variables describing forest state, management and products).
- Currently, MELA is
  - a forestry model used for regional and national level analysis and
  - an operational decision support system used as a planning component of forest information systems in practical forestry.

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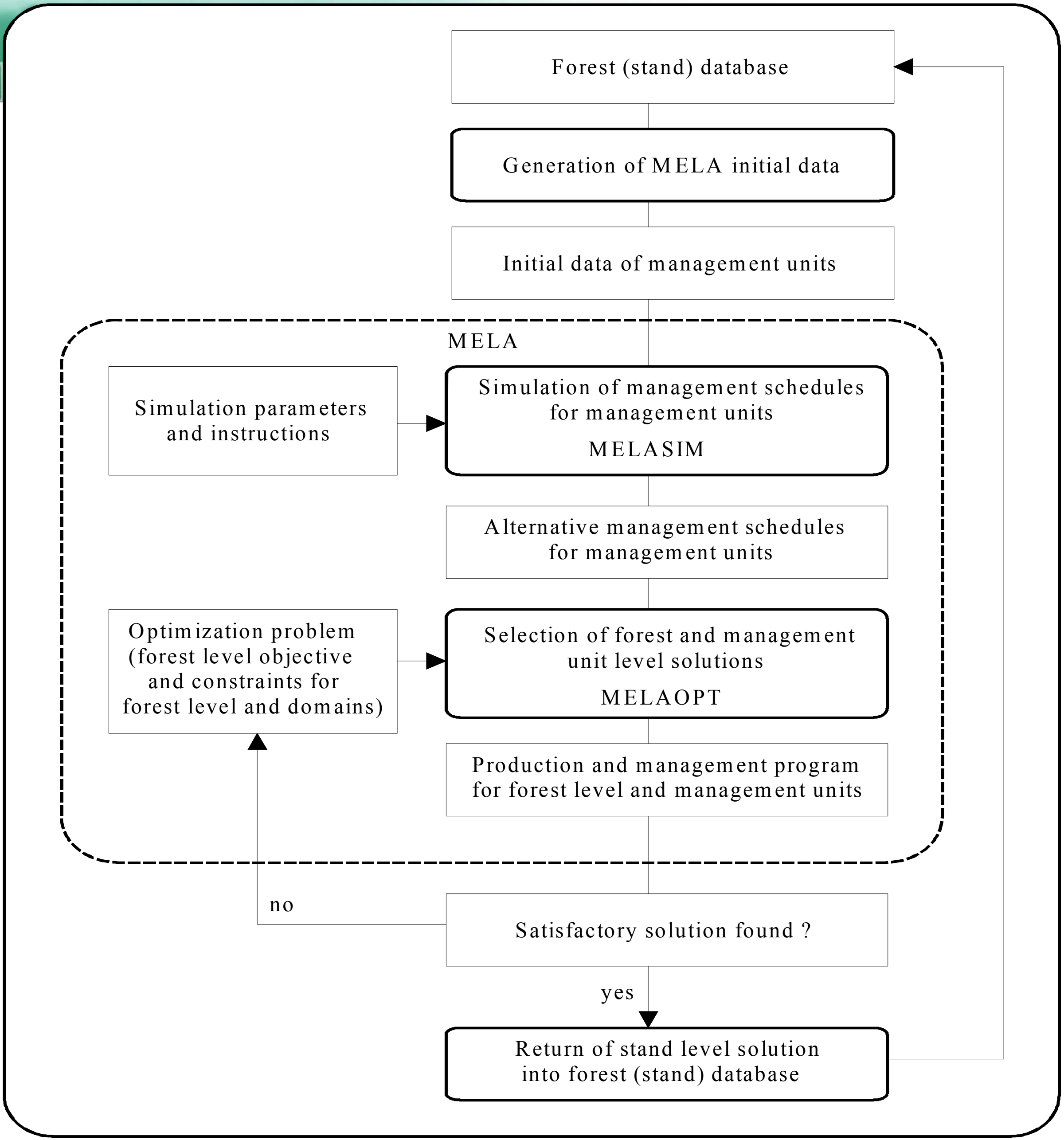
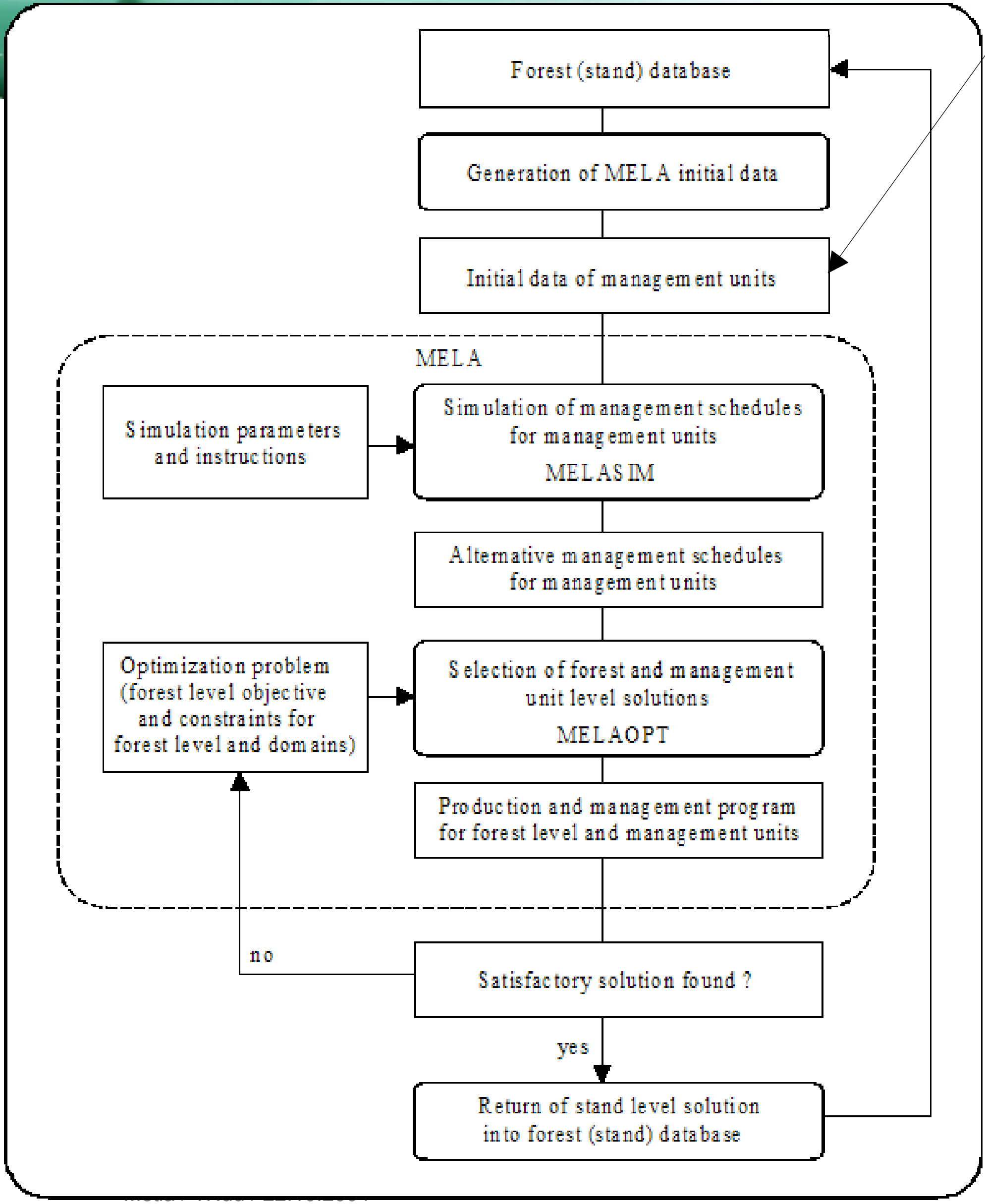
A brief history of MELA

- Kilkki, Pekka, 1968. Income oriented cutting budget. Tiivistelmä: Tulotavoitteeseen perustuvaa hakkuulaskelma. Acta Forestalia Fennica. Vol. 91. 54 p.
- Kilkki, P. & Siitonen, M. 1976. Principles of a forest information system, XVI IUFRO World Congress, Division IV, Proceedings: 154-163.
- Siitonen, Markku, 1983. A long term forestry planning system based on data from the Finnish national forest inventory. In: Forest Inventory for Improved Management. Proceedings of the IUFRO. Subject Group 4.02. Meeting in Finland, September 5-9, 1983. Helsingin yliopiston metsänarvioimistieteen laitoksen tiedonantoja 17: 195-207.
- Lappi, J. 1992. JLP: A linear programming package for management planning. Metsäntutkimuslaitoksen tiedonantoja 414. The Finnish Forest Research Institute. Research Papers 414. 134 p.
- Siitonen, M., Härkönen, K., Hirvelä, H., Jämsä, J. Kilpeläinen, H. Salminen, O. & Teuri, M. 1996. MELA Handbook 1996 Edition. Metsäntutkimuslaitoksen tiedonantoja 622. 452 p.
- Experiments in Baltic countries in the beginning of 1990s.
- MELA services and products since 1996.
- DemoMELA since 2002.


Forest (stand) database
Generation of MELA initial data
Initial data of management units
MELA
Simulation parameters and instructions
Simulation of management schedules for management units
MELASIM
Alternative management schedules for management units
Optimization problem (forest level objective and constraints for forest level and domains)
Selection of forest and management unit level solutions
MELAOPT
Production and management program for forest level and management units
no
Satisfactory solution found ?
yes
Return of stand level solution into forest (stand) database



MELA Initial data

Management unit/Sample plot data:

ID

Inventory year

Area

X, Y coordinates -> Height above sea, dd

Owner category

Land-use category

Soil and peatland category

Site type category

Drainage category

Year from last treatment (by treatments)

Forestry board district

Forest management category

Sample tree data:

Number of stems/ha

Tree species

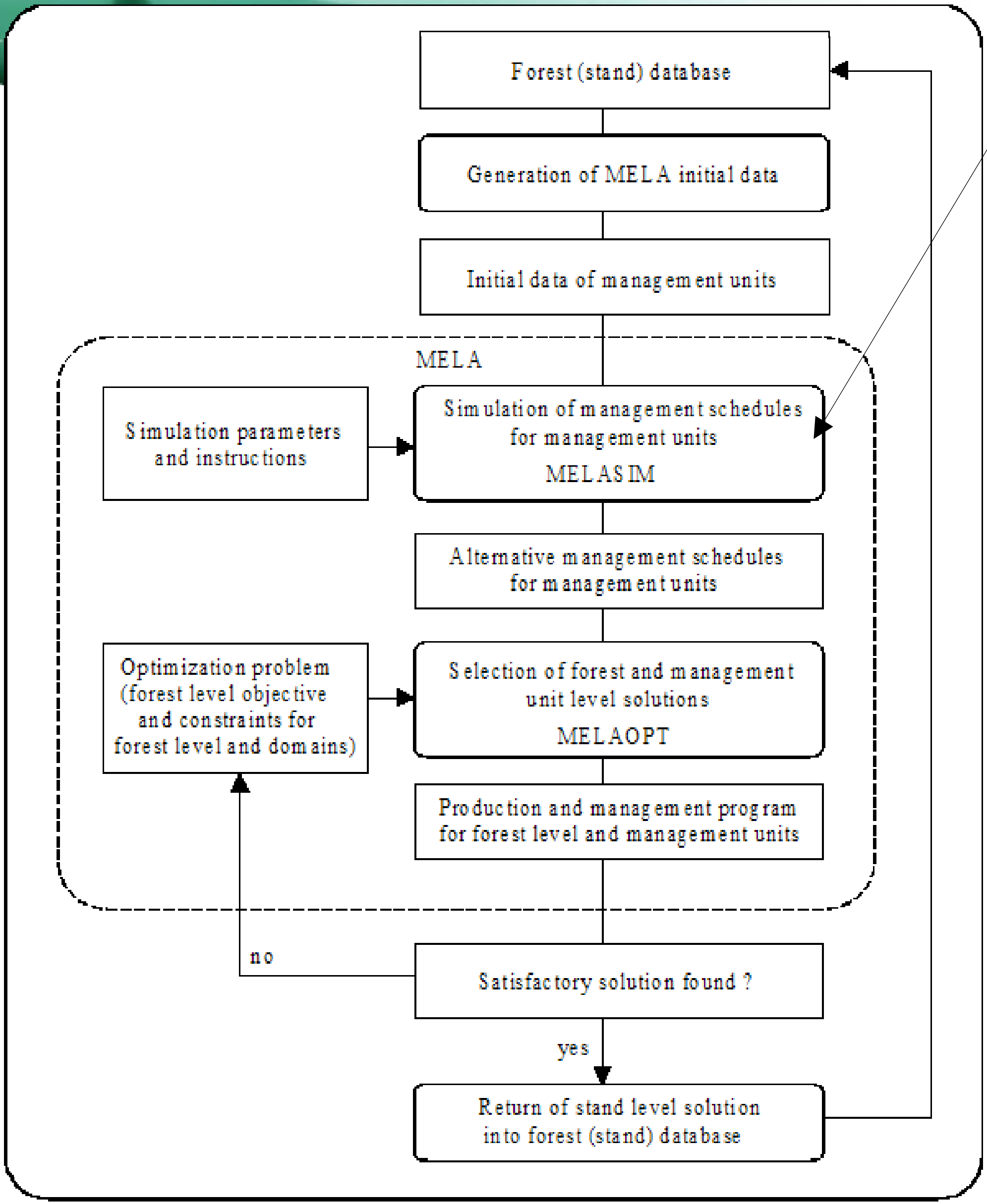
d1.3

Height

Age (both d1.3 and biological)

Reduction to model-based saw log volume

Origin



MELASIM

Models for stand development
on mineral soils and peatlands
(Hynynen et al. 2000)

Built-in simulation routines for treatments

Calculation of physical variables for trees and stand
- e.g. timber volume by assortments

Calculation of economic variables
- income from timber
- costs of treatments
- net present value

- user interface based on commands
- a parameter manager
- a report generator

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Models for stand development (Hynynen et al. 2002)

both model sets were tested and calibrated against NFI8 data before they were applied within MELA

On mineral soils

- distance-independent models for basal-area growth and height growth of trees (> 1.3 m), as a function of

1) climate, site and stand characteristics such as stand density and stage of stand development

2) dimensions of trees such as diameter, height, crown ratio, relative size of a tree

- regeneration models for juvenile development of trees (<1.3 m), as well as natural regeneration and ingrowth
- individual-tree survival model and stand-level self-thinning model for mortality of trees

On peatlands

- a model for growth of the basal area of a tree
- the level of growth was adjusted in simulations with respect to the time elapsed since draining.
- a categorical stand-level variable indicating the need for ditch network maintenance was utilised in growth predictions
- a static height model

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MELASIM

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Built-in simulation routines for treatments

Silvicultural practices
- obligatory silvicultural events whose timing the model is able to choose (clearing of regeneration area, site preparation, artificial regeneration after clear cutting and tending of a young stand)
- feasible for the MELA model but not generally used: fertilisation, pruning or ditching
- thinning combined with maintenance of the ditch network

Cuttings
- thinning instructions based on basal area can be regulated using the parameters thinning intensity, selection of tree size, selection of tree species and minimum cutting removal per hectare
- thinning instructions based on number of stems
- clear cuttings
- removal of over-storey
- seed-tree cutting (pine, birch and populus) and shelterwood cutting (spruce).
- regeneration criteria age or diameter.

MELASIM

Models for stand development
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Built-in simulation routines for treatments

Calculation of physical variables for trees and stand

- e.g. timber volume by assortments

Calculation of economic variables

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- user interface based on commands
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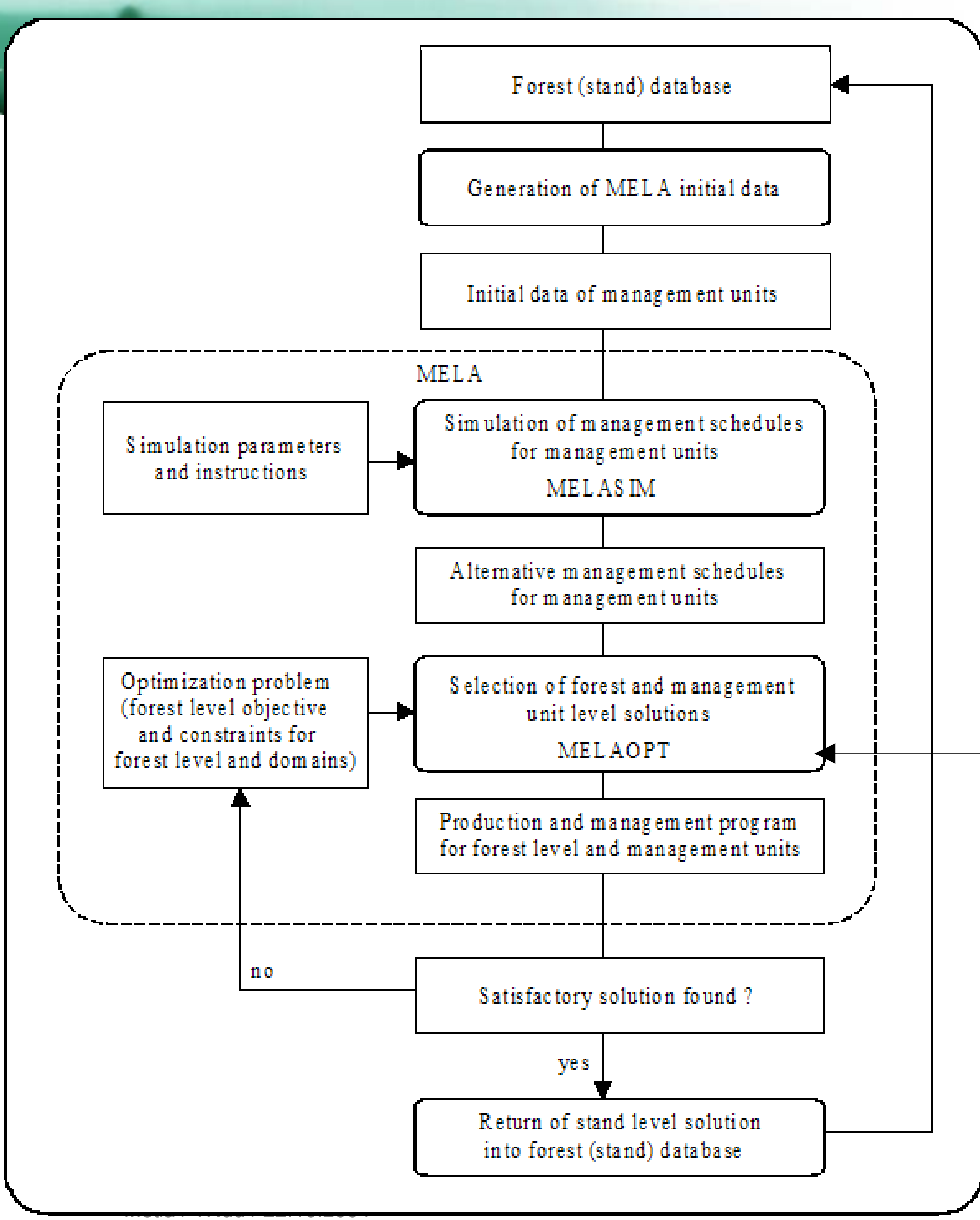
Calculation of physical variables for trees and stand

- Stem volume and wood assortments are stored in a table where the cells are the values predicted with the stem curve models as a function of tree species, diameter and height (Laasasenaho 1982).
- The model for log-reduction.

The economy models

- The value of the stems is calculated from the wood assortments and unit prices on the roadside or at stumpage.
- The net income = revenues – (costs of logging, silvicultural and forest improvement work).
- The costs are based on time expenditure (Rummukainen et al. 1995 and Kuitto et al. 1994) and unit prices. The most important factors affecting time consumption in logging are size of a stem, number of removed stems, harvesting type, the cutting drain and the off-road distance.
- The prices in the MELA model are constant and exogenous and the capital markets are assumed to be perfect, i.e. money can be saved and borrowed in unlimited quantities at the same price (interest rate).



MELAOPT

JLP

- JLP is a general LP package (Lappi 1992).
- JLP is characterized by its easy problem definition and its outstanding capasity and speed in solving large scale multilevel LP problems. The efficient optimization algorithm is based on generalized upper bound technique for built-in area constraints
- Domains for multilevel optimization: simultaneous constraints for any group of management units defined by such management unit level variables as location, owner group, management category, site type, and administrational district

- user interface based on commands

- a parameter manager

- a report generator

What is JLP?

For more information:

http://www.metla.fi/products/J

Lappi, J. 1992. JLP: A linear programming package for management planning. Metsäntutkimuslaitoksen tiedonantoja 414. The Finnish Forest Research Institute. Research Papers 414. 134 p.

Background

- New multi-objective, site-specific and hierarchical problems have been identified.

=> Requirements for methods:

- multiple goals
- subsets/domains.

- Sampling, aggregation and simulation of feasible alternatives are simplified ways to deal with large-scale problems.
- Current tools are poorly integrated.

=> Requirements for tools:

- efficiency (large-scale, fast)
- flexibility, modularity and portability (components of DSS)

Method

- JLP is a general linear programming package by Juha Lappi for solving Model I type forest management planning and conventional LP problems.
- JLP is characterized by its easy problem definition and its outstanding capasity and speed in solving large scale multilevel LP problems.
- Efficient optimization algorithm
  - Generalized upper bound (GUB) technique for built-in area constraints
- Domains for multilevel optimization
  - simultaneous constraints for any group of management units defined by such management unit level variables as location, owner group, management category, site type, and administrational district

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[1] Max or Min $z_0 = \sum_{k=1}^{p} a_{0k} x_k + \sum_{k=1}^{q} b_{0k} z_k$

subject to the following constraints:

[2] $c_t \le \sum_{k=1}^{p} a_{tk} x_k + \sum_{k=1}^{q} b_{tk} z_k \le C_t, t = 1, \ldots, r$

[3] $x_k - \sum_{i=1}^{m} \sum_{j=1}^{n_i} x_k^{ij} w_{ij} = 0, k = 1, \ldots, p$

[4] $\sum_{j=1}^{n_i} w_{ij} = 1, i = 1, \ldots, m$

[5] $w_{ij} \ge 0$ for all i and j

[6] $z_k \ge 0$ for $k = 1, \ldots, q$,

where

m	=	number of treatment units
n_i	=	number of treatment schedules for unit i
w_{ij}	=	the weight (proportion) of the treatment unit i managed according to treatment schedule j
x_k^{ij}	=	amount of item k produced or consumed by unit i if schedule j is applied, constants provided by the simulation system
x_k	=	obtained amount of output variable k, k=1,...,p
z_k	=	an additional decision variable, k=1,...,q
a_{tk}	=	fixed real constants for t=1,...,r, k=1,...,p
b_{tk}	=	fixed real constants for t=1,...,r, k=1,...,q
c_t	=	the lower bound for utility constraint t, t=1,...,r
C_t	=	the upper bound for utility constraint t, t=1,...,r
r	=	number of utility constraints
p	=	number of output variables
q	=	number of z-variables

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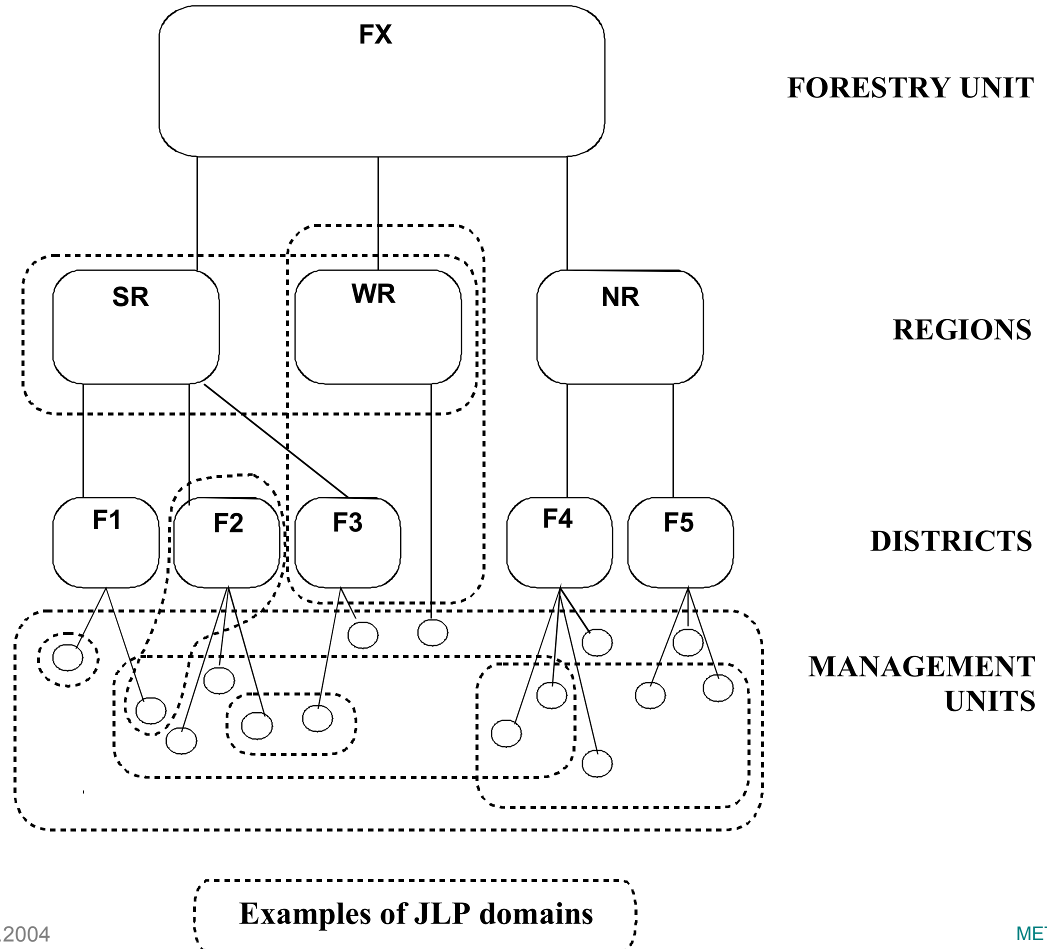
JLP Domains



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Implementation

- command language as a user interface and a transformation compiler (flexible)
  - generation of new variables
  - generation of new management schedules
  - rejection of management schedules
  - splitting of management units
- mode of operation
  - more than 50 commands with options for problem definition and job control
  - interactive or batch
  - nested command files
  - macros
  - support for user-supplied user interface
    - templates for input and report modules (modular and portable)

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The benefits of JLP

- LP
  - is an efficient way of analysing production possibilities
  - provides marginal information
- Specialized software
  - makes it easy to solve large-scale, multi-objective, site-specific, and hierarchical problems
  - can be used to overcome assumptions of LP
  - can be extended for goal programming
  - can be integrated into a DSS
- Capacity/efficiency
  - the largest problems so far solved on UNIX servers have contained more than 100000 management units and 2 mill. management schedules with 10 forest-wide constraints
- Portability
  - portable FORTRAN 77 code running on DOS, Windows, OS/2, Macintosh, Unix and VMS
  - precompiler for system-dependent parameters and options, incl. problem size

JLP References

- MELA in Finland since 1989.
- GAYA-JLP in Norway since 1991.
- Users in Sweden.

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What is DemoMELA?

For more information:

http://www.metla.fi/metinfo/mela -> DemoMELA

mela@metla.fi

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Requirements for the planning system

- Preparation of the plan:
  - whenever needed due to e.g. changes
    - in forest resources (growth, death, consequences of treatments and damages)
    - in environment (laws, recommendations, incentives, wood markets/prices and assortments, knowledge such as research) and/or
    - in the needs of decision maker.
- Forest data:
  - collection of forest data separate process from planning
  - computational updating of forest resource information
- Alternatives:
  - predict and illustrate the consequences due to changes in environment or own decisions (management strategy, income needs,…)
- Output:
  - integrated (syncronized) solution at stand and at forest level

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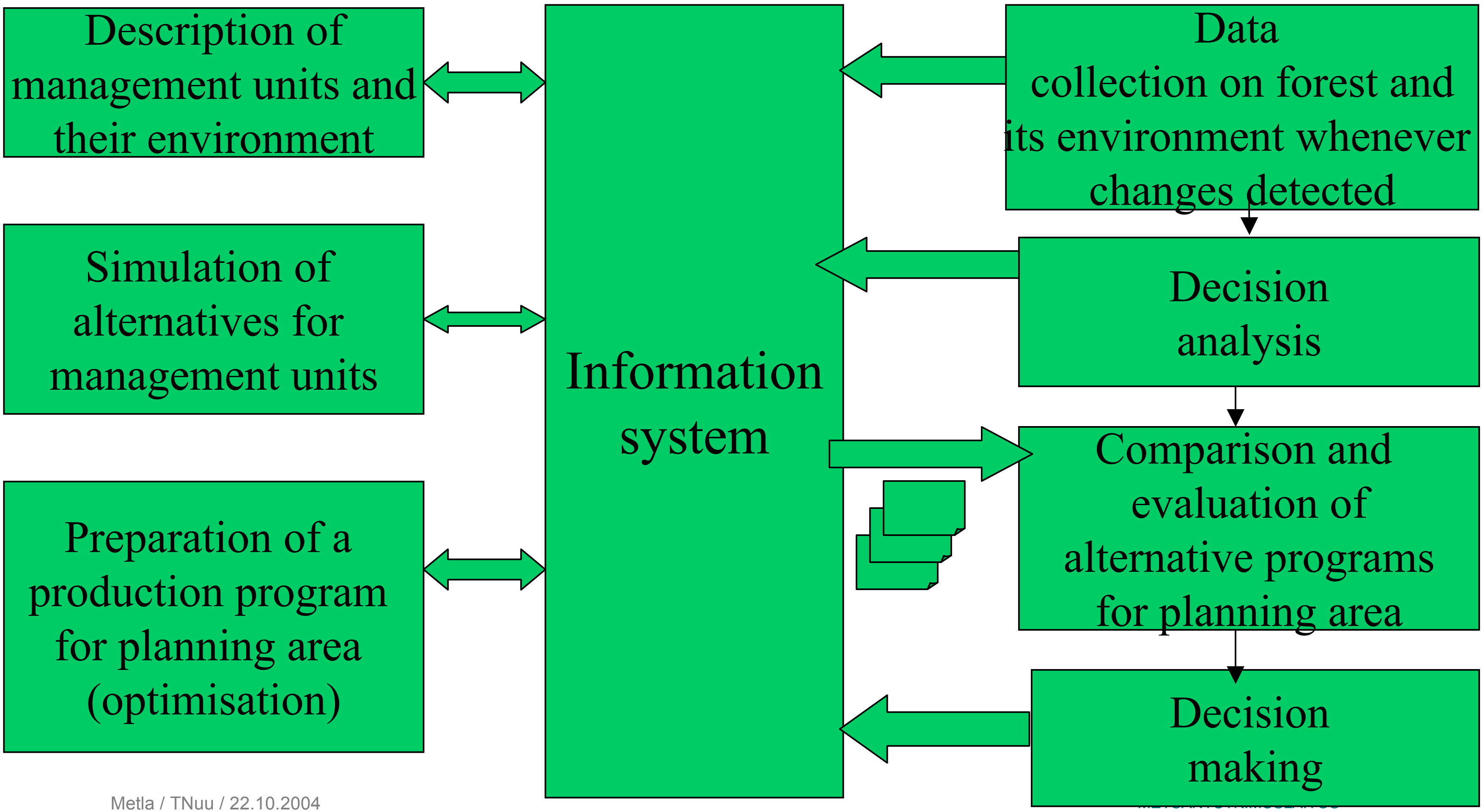
Continuous (adaptive) forest planning based on up-to-date information system



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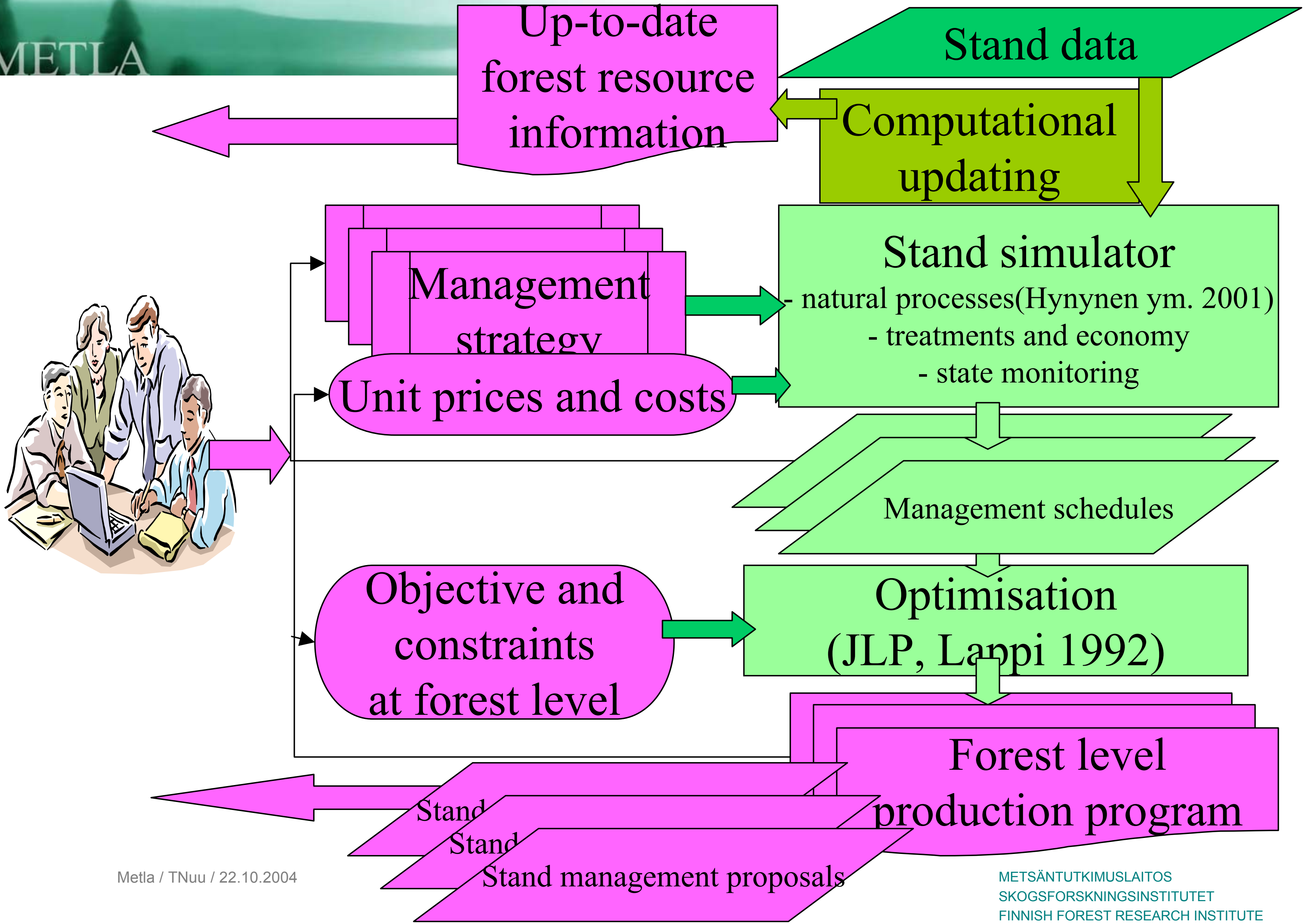
Why DemoMELA?

- Installation, tailoring and use of the MELA system in different organisations/decision situations requires expertise and time.
- Positive experiences on internet technology:
  - software distribution (extranet)
  - browsers work in different user/system environments => possibilities to improve user-friendliness of applications
  - Application service providers (ASP) more common
- The objectives of DemoMELA project:
  - To develop a simple browser interface to control MELA applications running at a server
  - To collect experience from the development and use of an internet application
    - A browser and a MELA server
    - User management/registration
    - Control and starting of MELA applications
    - Processing and transfer of initial data and outputs
    - Monitoring the use of disk space and computing capacity / Pricing
- At the moment DemoMELA is a demonstration and teaching package for registered users illustrating the principle of integrated stand and forest level optimisation as well as potential of MELA software.
- Experiments with the MELA application service via internet are on-going with some companies.

Currently, DemoMELA has

- three analysis tasks:
  - update of forest resource data (if needed)
  - simulation of optional management schedules for the stands
  - solving integrated forest and stand level optimisation problem.
- three types of phases in each step:
  - setting values for step-specific definitions
  - executing the MELA task in question
  - evaluation of task-specific results (both task accomplishment and the contents of the results)
- three sections in the user interface:
  - Projects (initial data set available)
  - Results (links to the files related to the prior MELA tasks, if any)
  - MELA tasks (access to the three MELA analysis steps and user-specific settings)



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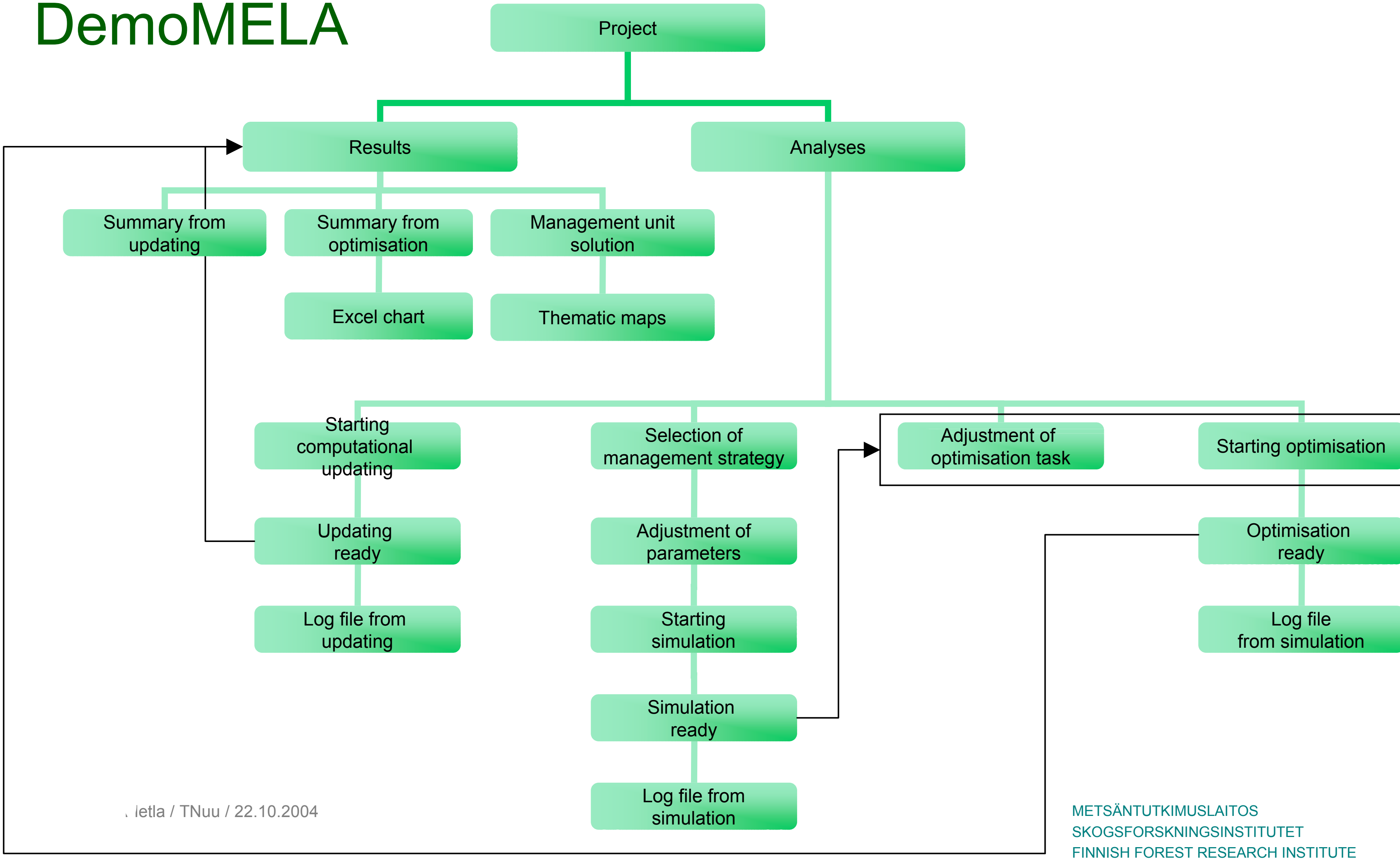
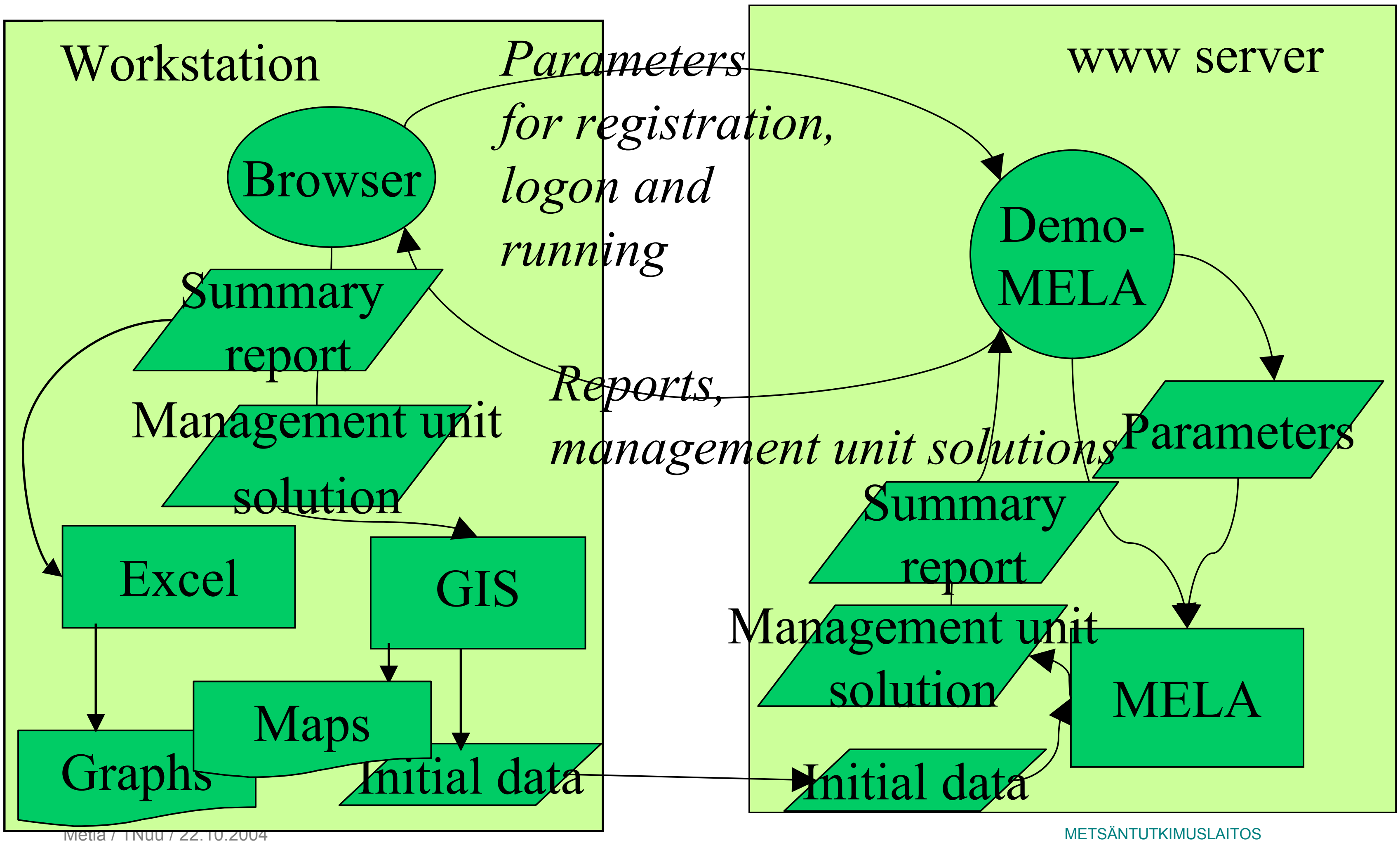
DemoMELA



Project
Results
Analyses
Summary from updating
Summary from optimisation
Management unit solution
Excel chart
Thematic maps
Starting computational updating
Updating ready
Log file from updating
Selection of management strategy
Adjustment of parameters
Starting simulation
Simulation ready
Log file from simulation
Adjustment of optimisation task
Starting optimisation
Optimisation ready
Log file from simulation

DemoMELA



Workstation
Parameters
for registration,
logon and
running
www server
Browser
Demo-
MELA
Summary
report
Reports,
management unit solutions
Management unit
solution
Parameters
Summary
report
Excel
GIS
Management unit
solution
MELA
Maps
Graphs
Initial data
Initial data

Section III: MELA-exercises

Tuula Nuutinen, Aimo Anola-Pukkila, Reetta Lempinen, Visa Redsven and Markku Siitonen

NOVA-BOVA Course

Lithuanian University of Agriculture, Kaunas

October 18-22, 2004

Background

- A family has inherited a forest holding. The family has 4 members: Father (60 years, 50 % share of forest), Mother (50 years, 25 % share), Daughter (25 years, 12,5 % share) and Son (30 years, with 12,5 % share). The members have different interests:
  - father is interested in even income from forest, increasing the total value of their ownership to be left for the childen and doing silvicultural work as a hobby during the summer months
  - mother is interested in berry and mushroom picking and wants to avoid all financial risks
  - daughter is interested in nature protection
  - son is interested in getting money immediately for a new apartment (the real interest rate of loan is 4 %).
- You are a forest consultant. The family has asked your advice what to do with the forest holding.
- You have access to DemoMELA and their forest data.

Task

- First, identify variables that would present the interests of family members.
- Second, define analyses mapping the production possibilities in fulfilling interests of different family members separately.
  - management strategy * optimisation tasks (utility variables and constraints)
  - sensitivity analysis using utility variables (interest rate) or constraints (RHS) or simulation settings (prices)
- Third, define three alternative management plans which would best reconcile the differing interests of the family members.
- Fourth, prepare a presentation covering three plans and showing how they contribute to the interests for different family members.

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