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# **Proceedings of the Second Meeting of the EURO Working group on Operational Research (OR) in Agriculture and Forest Management**

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EDITED BY

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*(First published online 7 September 2006)*

This working group, which is concerned with operational research methods and applications to agricultural science in its broad meaning (i.e. including Forest Management and Fisheries), was formed in 2003 within the European Association of Operational Research Societies (EURO). The first meeting of the group was held at the former Silsoe Research Institute two years ago. The next meeting will be held in 2007 within the XXII EURO Conference in Prague. The group intends to start regular meetings at approximately yearly intervals in association with the EURO Conferences. The second meeting of the working group, chaired by Dr. L. M. Plà of the University of Lleida and organized as a stream within the XXI EURO Conference, was held at the University of Iceland in Reykjavík from 3rd–5th July 2006 where the following papers were read.

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## ABSTRACTS OF COMMUNICATIONS

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**The ‘curse of animal disease’ and the ‘curse of dimensionality’: A new decision support framework for the control of foot-and-mouth disease epidemics.**

L. GE<sup>1</sup>, A. KRISTENSEN<sup>2</sup>, M. MOURITS<sup>1</sup> AND R. HUIRNE<sup>1</sup>. <sup>1</sup>*Business Economics, Wageningen University, Hollandseweg 1, 6708CT Wageningen, The Netherlands,* <sup>2</sup>*Department of Large Animal Sciences, Royal Veterinary and Agricultural University, Groenegaardsvej 2, Frederiksberg C, DK-1870 Copenhagen, Denmark*

Epidemics of foot-and-mouth disease (FMD) pose a recurrent threat to countries with a large population of susceptible animals and intensive livestock production. The decision problem in FMD control is fraught with uncertainty and complexity. This paper presents a new decision-support framework for the control of FMD epidemics based on dynamic models and the Multi-level hierarchic Markov process (MLHMP). While providing a formal structure of dynamic decision process, the MLHMP formulation facilitates simultaneous optimization of strategic decisions and operational decisions.

**Keywords:** System Dynamics and Theory, Risk Analysis and Management, Economic Modelling

**An approach to the optimal design of a pig production chain.**

L. M. PLA. *Department of Mathematics, University of Lleida, 73 Jaume II, 25001 Lleida, Spain*

In this work the author presents a tactical Supply Chain model of pig production. The model is a first approach to a wider Supply Chain model. It intends to structure the chain in terms of number of farms per stage required to satisfy a weekly pre-stated demand, and therefore is formulated for tactical purposes. The chain includes commercial herds integrated vertically and demand is represented by the number of heads processed by a slaughterhouse. Seasonal effects on production are taken into account. The objective function is to maximize revenues keeping an optimal herd structure.

**Keywords:** Supply Chain Management, Optimization Modelling, Linear Programming

**Optimization of delivery strategies for slaughter pigs.**

M. S. HANSEN AND A. R. KRISTENSEN. *Department of Large Animal Sciences, Royal Veterinary and Agricultural University, Groenegaardsvej 2, Frederiksberg C, DK-1870 Copenhagen, Denmark*

Automatic weighing equipment for slaughter pigs, is currently being investigated and a Decision Support System (DSS) for slaughter pig marketing has been created. The DSS is based on a recent development of Bayesian Networks termed Limited Memory Influence Diagrams (LIMID). A LIMID is represented graphically as a directed acyclic graph consisting of variables represented as chance, decision and utility nodes connected by directed edges. The model constructed here assumes that individual weight data are available from all pigs during the finishing period.

**Keywords:** Decision Support Systems, Optimization Modelling, Graphs and Networks

**OR in the management planning of forest-industry (UPM-Kymmene Ltd) owned forests in Finland.**

J. KANGAS. *Forest Finland, UPM-Kymmene Ltd, P.O. Box 32, FIN-37601 Valkeakoksi, Finland*

Simulation of forest development is needed in describing management alternatives and in forecasting their consequences. Combined use of simulation and optimization enables analyses of timber production possibilities and production of efficient forest plan alternatives. Multicriteria decision aid (MCDA) methods can then be used for holistic comparison of these plans so that other information available is also utilized. At the firm UPM-Kymmene Ltd, simulation, optimisation, and MCDA are frequently applied, and their applications are under continuous development. A general problem in applying advanced OR tools is the poor quality of input data.

**Keywords:** Forestry Management, Large Scale Optimization, Strategic Planning and Management

**Integrated production and distribution planning for Södra Cell AB.**

H. GUNNARSSON<sup>1</sup>, M. RÖNNQVIST<sup>2</sup> AND D. CARLSSON<sup>3</sup>. <sup>1</sup>*Department of Mathematics, University of Linköping, Division of Optimization, 581 83 Linköping, Sweden,* <sup>2</sup>*Department of Finance and Management Science, Norwegian School of Economics and Business Administration, NO-5045 Bergen, Norway,* <sup>3</sup>*Logistics Manager, Södra Cell AB, Växjö, Sweden*

In this paper the present authors consider integrated planning of transportation of raw material, production and distribution of products of the supply

chain at Södra Cell AB. Decisions included in the planning are transportation of raw materials from harvest areas to pulp mills, production mix and contents at pulp mills, distribution of pulp products from mills to customers via terminals or directly and selection of potential orders and their levels at customers. The authors propose a mathematical model for the entire supply chain. Five different alternatives in a case study are analysed and evaluated.

**Keywords:** Forestry Management, Optimization Modelling, Production and Inventory Systems

**Production planning and use of material flow simulation in sawmilling industries.** M. GRONALT. *Institute of Production and Logistics, University of Natural Resources and Applied Life Sciences, Feistmantelstr. 4, A-1180 Vienna, Austria*

The sawmilling industry is faced with strong competition. To improve their operation, advanced planning methods are suggested. In sawmilling, a number of by-products are generated automatically. Customer orders and inventory figures of both timber and round wood must be considered to select the optimal cutting patterns. The authors' approach starts with the solution of a loading problem, which combines cutting pattern selection and inventory management. The selected orders are used as input for the simulation model which provides a detailed resource scheduling. The author's approach is tested with real data.

**Keywords:** Production and Inventory Systems, Decision Support Systems, Enterprise Resource Planning Systems

**Optimal continuous cover forest management in an uneven-aged forest in the north of Iran.** S. M. LIMAEI AND P. LOHMANDER. *Forest Economics, Swedish University of Agricultural Sciences, 901 83 Umeå, Sweden*

In this paper a growth function was estimated for an Iranian uneven-aged forest. Then the optimal harvest decisions were calculated via stochastic dynamic programming. The harvest decisions which maximize the expected present value of all profits over time are made adaptively, conditional on the latest available price and stock level information. It is possible to determine the optimal harvesting level under different price and stock level states. The results show that one may increase the expected present value by more than 26% via optimal adaptive decisions.

**Keywords:** Forestry Management, Optimization Modelling, Stochastic Models

**A graph markov decision process model for harvest planning under risk of wind throw.** N. FORSELL<sup>1,2</sup>, F. GARCIA<sup>2</sup>, L. O. ERIKSSON<sup>1</sup>, R. SABBADIN<sup>2</sup> AND P. SIKSTRÖM<sup>1</sup>. <sup>1</sup>*Department of Forest Resource Management and Geomatics, Sveriges lantbruksuniversitet (SLU) Inst. skoglig resurshushållning och geomatik, 901 83 Umeå, Sweden,* <sup>2</sup>*Unite de Biometrie et Intelligence Artificielle, INRA, Castanet-Tolosan, France*

An approach is presented for taking the risk of wind throw into account when optimizing the management policy of a forest. The ensuing problem is a spatial problem and the authors assume that the risk of a stand being wind thrown is dependent on the state of the stand itself, as well as the states of the neighbouring stands. The problem is modelled as a Graph-Based Markov Decision Process and solved with an approximate linear programming algorithm. The approach is demonstrated on a sample problem, consisting of about 5000 stands.

**Keywords:** Forestry Management

**Substitution between clearcutting and thinning decisions in private forestry.** J. UUSIVUORI AND J. LATURI. *Finnish Forest Research Institute Metla, Unioninkatu 40 A, FIN-00170 Helsinki, Finland*

A two-period intertemporal model describing the behaviour of a non-industrial private forest owner facing a dual management problem of clear-cut harvesting and thinning of an even-aged forest is solved rigorously. The two decisions are interdependent and solved simultaneously. A sequential solution is also demonstrated. Under general conditions, saving for more old-growth forest and reducing the thinning intensity are shown to be substitutes. Comparative statistics methodology and numerical examples are used to show that a timber price change may affect the two harvesting decisions in opposite ways.

**Keywords:** Forestry Management, Economic Modelling, Natural Resources

**Fuzzy multicriteria approval method and its application to forest planning.** A. KANGAS<sup>1</sup>, J. KANGAS<sup>2</sup> AND S. LAUKKANEN<sup>3</sup>. <sup>1</sup>*Department of Forest Resources Management, University of Helsinki, P.O. Box 27, 00014 Helsinki, Finland,* <sup>2</sup>*Forest Finland, UPM-Kymmene Ltd, P.O. Box 32, FIN-37601 Valkeakoski, Valkeakoski, Finland,* <sup>3</sup>*University of Joensuu, Joensuu, Finland*

One Multi-Criteria Decision Aid (MCDA) method used in forest planning is Multicriteria Approval (MA). It is based on approval voting, where the voters have been replaced by criteria. Alternatives are

approved or rejected with respect to each criterion, using a crisp approval threshold defined by the system. The importance order is provided by the decision maker, and it is accounted for using the concept of ordinal dominance. The authors present a new version of MA method using a concept of fuzzy approval. It can also be extended to group decision-making problems. Its application to forest planning is presented.

Keywords: Multi-Criteria Decision Aids, Forestry Management, Fuzzy Sets and Systems

**Operations Research in Agroindustrial Supply Chains in Colombia.** R. G. GARCÍA<sup>1</sup>, E. GUTIERREZ<sup>2</sup>, M. E. MARTINEZ<sup>2</sup> AND M. M. CERVANTES<sup>2</sup>. <sup>1</sup>*Productive Processes, Pontificia Universidad Javeriana, Carrera 7 No. 40-62, Facultad de Ingeniería, 1 Bogotá, Colombia,* <sup>2</sup>*Facultad de Ingeniería, Centro de Investigación en Tecnologías Avanzadas de Decisión, Universidad de La Sabana, Autop Norte de Bogota Km 21 Campus Univesitario Puente del Comun. Cll 163 b No 48-68, 571 Bogota, Colombia*

The purpose of the project is to strengthen the planning research and programming of operations in agroindustrial supply chains and to concentrate that knowledge in mathematical models. These models support the decision-making that structures the enterprises of the agroindustrial Colombian sector to increase it competitively. A case study of the supply chain of palm oil is presented.

Keywords: Supply Chain Management, Optimization Modelling

**A multiobjective simulation-based method for optimizing irrigation strategies.** F. GARCIA, O. CRESPO AND J.-E. BERGEZ. *Unite de Biometrie et Intelligence Artificielle, INRA, Chemin de Borde Rouge, 31320 Castanet-Tolosan, France*

The present authors consider the problem of designing new agricultural strategies by taking into account multicriteria evaluation under uncertainties. An approach combining multiobjective optimization and simulation is proposed. The method is based on a stochastic simulation optimization algorithm that consists of a hierarchical decomposition of the parameter space. Partitioning is iterated on the promising regions that are selected through a multiobjective evaluation. First results obtained on an irrigation management problem by using the MODERATO simulation tool are presented.

Keywords: Multi-Objective Decision Making, Stochastic Models, Simulation

**Dynamic resource allocation in agricultural production systems.** R. MARTIN-CLOUAIRE AND J.-P. RELIER. *Unite de Biometrie et Intelligence Artificielle, INRA, Auzeville BP52627, 31320 Castanet Tolosan, France*

Typical agricultural production processes generally consist of a number of interrelated activities that are undertaken to achieve goals. Their successful completion depends on the availability of required resources such as labour, machinery or energy. The activities are scheduled flexibly to cope with uncertainty, and resources must be allocated dynamically. The paper presents an algorithm of dynamic resource allocation used in the simulation of a plan execution process. The focus is on the incremental search mechanism that operates on various kinds of resources.

Keywords: Simulation, Scheduling, Artificial Intelligence

**An advanced architecture to provide open agricultural planning services.** F. RUBIO<sup>1</sup> AND M. SUAREZ DE CEPEDA<sup>2</sup>. <sup>1</sup>*Matematica Aplicada a la Ingeniería Agronómica, UPM, ETSI Agrónomos, 28040 Madrid, Spain,* <sup>2</sup>*Mecanica Aplicada e Ingeniería de Proyectos, Universidad de Castilla La Mancha, Albacete, Spain*

The objective of the Project AgriMec is to implant an open service of machinery park management centred in Castilla-La Mancha but applicable to any zone. To solve it, the AgriSupport system has been used in a three tier architecture: internet server, database and model, each of them executing in separated computers. The system has an acceptable response time and guarantees that the proposed solution is optimal in terms of cost of machinery on the basis of the farms the users have, their crops and the agricultural tasks to perform.

Keywords: Decision Support Systems, Mathematical Programming, Scheduling

**A Mixed Integer Programming flow model for crop rotation planning in the context of sustainable development of the Madagascan forest.** L. ALFANDARI<sup>1</sup>, J.-L. LEMALADE<sup>2</sup>, A. NAGIH<sup>2</sup> AND G. PLATEAU<sup>2</sup>. <sup>1</sup>*SID, ESSEC, Avenue B. Hirsch BP 05105, 95021 Cergy-Pontoise Cedex, France,* <sup>2</sup>*LIPN-UMR 7030, Université Paris 13, Villetaneuse, France*

The present authors propose a Mixed Integer Programming (MIP) model for a generic crop rotation planning problem. This work is part of a French-Madagascan project to reduce deforestation.

The objective is to help farmers to cover seasonal needs while minimizing total space. The main originality of the model lies in the combinatorial choice of cultivating or leaving a plot fallow, as well as innovative production variables. Complexity, upper bound computation and cutting planes are presented. Computational experiments on Eastern Madagascar real cases show the positive impact of land division.

Keywords: Sustainable Development, Programming, Integer, Optimization Modelling

**Methodological approach to develop an overall sustainability function for dairy farming by using stakeholder perceptions.** K. J. VAN CALKER<sup>1</sup>, P. BERENTSEN<sup>2</sup>, G. GIESEN<sup>2</sup> AND R. HUIRNE<sup>2</sup>. <sup>1</sup>*Agricultural Economics Research Institute (LEI), Wageningen University and Reserach centre, Postal code 29703, 2502 LS Den Haag, The Netherlands,* <sup>2</sup>*Business Economics, Wageningen University, Hollandseweg 1, 6708CT Wageningen, The Netherlands*

One difficulty in determining the sustainability of farming systems is the combination of the different attribute measures into one overall sustainability function. The Multi-Attribute Utility Theory (MAUT) is used to develop an overall sustainability function for Dutch dairy farming. A goal programming approach is used to aggregate preferences of experts and stakeholders into a single collective sustainability function. This collective sustainability function is applied in Dutch dairy farming.

Keywords: Sustainable Development, Multi-Objective Decision Making, Mathematical Programming

**A model for calculating the environmental burdens of livestock production.** D. SANDARS, A. WILLIAMS AND E. AUDSLEY. *Institute of Water and Environment, Cranfield University at Silsoe, Barton Road, MK45 4DT Silsoe, Bedfordshire, UK*

The present authors produced a mathematical model to calculate the environmental burdens and resource use in the production of agricultural commodities and to enable the impact of changes to be assessed. The model is a set of simultaneous linear equations. The solution represents the level of activity of all the subsystems that yields the desired unit of production. Lamb meat (1 t) required 44 GJ of fossil energy and involved 6.7, 20 and 18 non-organic ewes in various hill, upland and lowland systems,

respectively, as well as 5.2 organic upland/ lowland ewes.

Keywords: Environmental Management, Sustainable Development, Research and Development

**Analytical approaches for obtaining consensus solutions among stakeholders within an environmental context.** J. GONZÁLEZ-PACHÓN<sup>1</sup>, C. ROMERO<sup>2</sup> AND L. DIAZ-BALTEIRO<sup>2</sup>. <sup>1</sup>*Department of Artificial Intelligence, Technical University of Madrid, Campus de Montegancedo s/n, Boadilla del Monte, 28660 Madrid,* <sup>2</sup>*Department of Forest Economics and Management, Technical University of Madrid, ETS Ingenieros de Montes-Avda Complutense s/n, 28040 Madrid, Spain*

It is widely accepted currently that the sustainable management of the environment implies the recognition of the existence of several criteria, as well as the participation of several stakeholders with different perceptions towards these criteria. Hence, the aggregation of these preferences into a single collective one is a crucial issue in this context. This paper aims to review different systems of aggregation of preferences that seem especially suitable within an environmental context. To illustrate the potentiality of these methods, they will be applied to simple but realistic examples.

Keywords: Environmental Management, Group Decision Making and Negotiation, Multi-Objective Decision Making

**A new mixed integer programming model for harvest scheduling subject to maximum area restrictions.** I. MARTINS<sup>1</sup>, M. CONSTANTINO<sup>2</sup> AND J. BORGES<sup>1</sup>. <sup>1</sup>*Department of Mathematics, Instituto Superior de Agronomia, Tapada da Ajuda, 1349-017 Lisbon, Portugal,* <sup>2</sup>*University of Lisbon, FCUL-DEIO-CIO, Bloco C2 Piso 2 Campo Grande, 1749-016 Lisbon, Portugal*

Research on exact methods has been done in order to solve forest management problems with constraints on the clear-cut size. Each clear-cut may have more than one stand if its area does not exceed the maximum clear-cut size. Two main basic integer programming models have been discussed, each one with an exponential number of variables or constraints. In the present work, the authors describe a new integer programming model with a polynomial number of variables and constraints. Branch-and-bound is used to solve it and computational experience with real life and test instances is reported.

Keywords: Forestry Management, Programming, Integer, Optimization Modelling



**Heuristic for bilevel olive harvest and olive oil production planning problem.** K. SORIC<sup>1</sup>, V. V. ROSENZWEIG<sup>1</sup> AND O. KOPRIVNJAK<sup>2</sup>. <sup>1</sup>*Faculty of Economics, Dept. of Mathematics, University of Zagreb, Trg J.F. Kennedy 6, 10000 Zagreb, Croatia,* <sup>2</sup>*Department of Food Technology and Control, Faculty of Medicine, B. Branchetta 20, 51000 Rijeka, Croatia*

The problem considered here is a practical problem of a Croatian olive oil producer. The aim is to schedule the harvest of olives and the production of olive oil minimizing overtime cost and setup, storage, waiting and production cost. The problem is modelled as a bilevel integer programming production planning problem and solved using heuristic based on tabu search, Lagrangean and some other relaxations.

Keywords: Metaheuristics, Production and Inventory Systems, Scheduling

**An experiment with non-industrial private forest owners' preferences in interval and ratio scales.** T. HUJALA<sup>1</sup> AND P. LESKINEN<sup>2</sup>. <sup>1</sup>*Department of Forest Research Management, University of Helsinki, P.O. Box 27, FI-00014 Helsinki, Finland,* <sup>2</sup>*Joensuu Research Centre, Finnish Forest Research Institute, Joensuu, Finland*

The present authors tested direct capturing of preferences in different measurement scales. Altogether 30 non-industrial private forest owners were asked to set importance of six predefined forestry goals. The interval scale values were set graphically in a vertical line, and the ratio scale values were elicited numerically as percentages. Those percentages were transformed and compared with the original interval scale values. Interestingly, the ratio scale showed significantly greater contrast than interval scale. In this presentation, the results are discussed and the alternative methods of capturing of decision makers' subjective preferences assessed.

Keywords: Multi-Objective Decision Making, Forestry Management, Decision Theory and Analysis

**Manure management and spreading land use by using a shortage function.** I. PIOT-LEPETIT. *Economie, INRA, 4 allée Adolphe Bobierre, CS 61103, 35011 Rennes cedex, France*

The shortage function (Luenberger 1992) provides a useful framework to implement theoretical models. It allows study of the impact of various environmental policy instruments on the partial equilibrium costs borne by regulated entities (firms, households, government), including both pecuniary and non-pecuniary expenses, when the market price system is held constant. It is illustrated in the particular case of manure management in European countries. It provides information on the optimal land allocation for manure spreading. It is implemented by using Data Envelopment Analysis (DEA) techniques.

Keywords: Data Envelopment Analysis, Environmental Management, Economic Modelling

LUENBERGER, D. G. (1992). New optimality principles for economic efficiency and equilibrium. *Journal of Optimization Theory and Applications* **75**, 221–264.

**Consolidation of farming by means of quadratic optimization.** A. BRIEDEN. *Bundeswehr University, Munich, Werner-Heisenberg-Weg 39, 85579 Neubiberg, Germany*

For various reasons, currently, farmers may cultivate a number of small lots distributed over a wide area, leading to high production costs. Due to a high percentage of leased land, classical forms of land consolidation based on change of ownership become increasingly less suitable for the farmers. The voluntary lend-lease based exchange of agricultural acreage might be an alternative. In order to fully exploit the potential of the method, a mathematical optimization model is required and presented in this talk. The author also reports on the method's application in practice.

Keywords: Optimization Modelling, Convex Optimization, Programming, Quadratic