Complexity and Integrated Resources Management Transactions of the 2nd Biennial Meeting of the International Environmental Modelling and Software Society

Vol. 2

14-17 June 2004
Complexity and Integrated Resources Management

Transactions of the 2nd Biennial Meeting of the
International Environmental Modelling
and Software Society

Editors
Claudia Pahl-Wostl
Sonja Schmidt
Andrea E. Rizzoli
Anthony J. Jakeman

IEMSs 2004 – 14-17 June 2004,
University of Osnabrück, Germany
Complexity and Integrated Resources Management - Transactions of the 2nd Biennial Meeting of the International Environmental Modelling and Software Society

Volume Editors

Claudia Pahl-Wostl
Sonja Schmidt
Institut für Umweltsystemforschung
Universität Osnabrück
Artilleriestr. 34
D 49076 Osnabrück, Germany

Andrea E. Rizzoli
IDSIA Istituto Dalle Molle di studi sull'intelligenza artificiale
Galleria 2
CH 6928 Manno, Switzerland

Anthony J. Jakeman
The Centre for Resource and Environmental Studies (Bldg 43)
The Australian National University
ACT 0200, Canberra, Australia

Each paper in this volume was refereed by an Editor, a member of the Editorial Board and two anonymous referees.

The copyright of all papers is an exclusive right of the authors. No work can be reproduced without written permission of the authors.

Responsibility for the contents of these papers rests upon the authors and not on the International Environmental Modelling and Software Society.

ISBN 88-900787-1-5

iEMSSs 2004
Published by the International Environmental Modelling and Software Society (iEMSS)
President: Anthony J. Jakeman.
Address: IEMSS, c/- IDSIA, Galleria 2, 6928 Manno, Switzerland
Email: secretary@iemss.org
Website: http://www.iemss.org
Complexity and Integrated Resources
Management Transactions of the 2nd Biennial
Meeting of the International Environmental
Modelling and Software Society

Claudia Pahl-Wostl, Sonja Schmidt, Andrea
E. Rizzoli, Anthony J. Jakeman (Editors)

Co-editors

David Batten, Keith Jeffery, Dale S. Rothman
Michel Blind, Kostas Karatzas, Miquel Sánchez-Marrè
Felix Chan, Markus Knoflacher, Dragan Savic
Barry Croke, Peter Krause, Huub Scholten
Wolfgang-Albert Flügel, Christine Lim, Boris Schröder
Carlo Giupponi, Ian Littlewood, Jan Sendzimir
Romy Greiner, Michael Matthies, Ralf Seppelt
Carlo Gualtieri, Michael McAleer, Achim Sydow
Nigel Hall, Dragutin T. Mihailovic, Hilde Passier
Matt Hare, Les Oxley, David Post
Reinout Heijungs, Jens C. Refsgaard, Peter Vanrolleghem
Stefanie Hellweg, Otto Richter
Suheja Hoti, Michela Robba

Organizers

The conference has been organized by iEMSs
(the International Environmental Modelling and Software Society) in cooperation with:

Harmoni-CA (Concerted Action on Harmonizing Modelling Tools for River Basin Management)
TIAS (Integrated Assessment Society)
IAHS (International Association of Hydrological Sciences)
BESAI (Binding Environmental Sciences and Artificial Intelligence)
MODSS International Conference on Multi-objective Decision Support Systems for Land,
Water and Environmental Management
ISESS International Symposium on Environmental Software Systems
ERCIM the European Research Consortium for Informatics and Mathematics

Local Organizers

The local organization of the conference has been managed by:

DBU (German Environmental Foundation)
USF (Institute of Environmental Systems Research, University of Osnabrück)
Editorial

Dear Reader,

The 2nd Biennial Meeting of the International Environmental Modelling and Software Society (iEMSS 2004) was dedicated to the theme: Complexity and Integrated Resources Management”, a very topical theme given the increasing complexity of contemporary resource management problems and the increasing uncertainties from global change. The meeting assembled nearly 300 researchers from all over the globe and from a wide range of disciplines. Presentations discussed latest developments in modelling methodologies and software tools applied to different areas of resources management. Contributions provided evidence of the important role of models to improve our understanding of the complexity of socio-ecological systems and to develop appropriate management strategies. Increasing attention was paid to the role of stakeholders in model development and application and to a new role for models in processes of social learning in participatory resources management.

The conference took place in the facilities of the German Environmental Foundation in Osnabrück. The ambience of these low-energy buildings, designed to minimise their impact on the environment, was well suited to the conference theme and their open and flexible structure facilitated intense discussions and exchange not only during but also between sessions.

I hope that readers will share the excitement of conference participants when browsing through the conference proceedings and reading some of the papers in more detail. Interested readers are advised to consult the journals Environmental Modelling and Software and Ecological Modelling and Advances in Geosciences where special issues emanating from this conference will be published. We also look forward to the third biennial meeting, iEMSs 2006, which will be held in Burlington, Vermont, USA (see http://www.iemss.org/iemss2006).

October 2004

The International Environmental Modelling and Software Society acknowledges gratefully the assistance of the following people in realizing the iEMSs 2004 conference:

- Claudia Pahl-Wostl for convening the conference
- Sonja Schmidt for organising the conference
- Andrea Rizzoli for the web-based conference management tool, creating and updating the conference website and for expert and technical advice
- all session organizers and reviewers
- Antje Braeuer and Georg Johann for supporting the organisation whenever and wherever necessary
- all members of the Institute of Environmental Systems Research and the department of resource flow management for supporting iEMSs 2004, especially Ilke Borowski, Frank Hilker, Maja Schlüter and Dominik Reusser
- all members of ZUK “Zentrum für Umweltkommunikation” of the German Environmental Foundation
## Environmental Informatics Towards Citizen-centred Electronic Information Services: the Urban Environment Example

Using FLOSS towards Building Environmentale Information
K. Karatzas, A. Masouras ................................................................. p. 525

Applying agent technologyin Environmental Management Systems underreal-time constraints
I.N. Athanasiadis, P.A. Mitkas ................................................................. p. 531

Supporting the Strategic Objectives of Participative Water Resources Management; an Evaluation of the Performance of Four ICT Tools
A. Swinford, B. McIntosh, P. Jeffrey ................................................................. p. 537

Web Services for Environmental Informatics
E. Arauco, L. Sommaruga ................................................................. p. 543

## Environmental Decision Support Systems

Concepts of Decision Support for River Rehabilitation  P. Reichert, M. Borsuk, M. Hostmann,
S. Schweizer, C. Spörr, K. Tochker, B. Truffer ................................................................. p. 550

Decision Making under Uncertainty in a Decision Support System for the Red River Inge
A.T. de Kort, M.J. Boij ................................................................. p. 556

M. Märker, K.Bongartz, W.A. Flügel ................................................................. p. 562

Possible Courses: Multi-Objective Modelling and Decision Support Using a Bayesian Network Approximation to a Nonpoint Source Pollution Model
D. Swayne, J. Shi ................................................................. p. 568
A Spatial DSS for South Australia’s Prawn Fisheries. Using Historic Knowledge Towards Environmental and Economical Sustainability
B. Ostendorf, N. Carrick ................................................................. p. 574

Optimum Sustainable Water Management in an Urbanizing River Basin in Japan, Based on Integrated Modelling Techniques
E. Kudo, M. Ostrowski ................................................................. p. 580

Application of a GIS-based Simulation Tool to Analyze and Communicate Uncertainties in Future Water Availability in the Amudarya River Delta
M. Schlüter, N. Rüger ................................................................. p. 586

Integration of MONERIS and GREAT-ER in the Decision Support System for the German Elbe River Basin
J. Berlekamp, N. Graf, O. Hess, S. Lautenbach, S. Reimer, M. Matthes ........................................... p. 593

An integrated tool for water policy in agriculture
G.M. Bazzana ................................................................. p. 599

Towards a Decision Support System for Real Time Risk Assessment of Hazardous Material Transport on Road

Appropriate Modelling in DSSs for River Basin Management
Y. Xu, M.J. Boolj ................................................................. p. 611

Water Management, Public Participation and Decision Support Systems: the MULINO Approach
J. Feás, C. Giupponi, P. Rosato .................................................... p. 617

A Dual-scale Modelling approach to Integrated Resource Management in East and South-east Asia: Challenges and Potential solutions
R. Rötter, M. van den Berg, H. Hengsdijk, J. Wolf, M. van Ittersum, H. van Keulen, E.O. Agustin, T.T. Son,
N.X. Lai, W. Guanghuo, A.G. Laborte ........................................... p. 623

The role of Multi-Criteria Decision Analysis in a DEcision Support sYstem for REhabilitation of contaminated sites (the DESYRE software)
C. Carlon, S. Giove, P. Agostini, A. Critto, A. Marcomini ........................................... p. 629

ICT Requirements for an ‘evolutionary’ development of WFD compliant River Basin Management Plans
M. Blind ................................................................. p. 635

DAWN:A platform for evaluating water-pricing policies using a software agent society
I.N. Athanasiadis, P. Vartalas, P.A. Mitkasa ........................................... p. 643

R.S. Sojda ................................................................. p. 649

An integrated modelling approach to conduct multi-factorial analyses on the impacts of climate change on whole-farm systems
M. Rivington, G. Belloccchi, K.B. Matthews, K. Buchan, M. Donatelli ........................................... p. 656
Some Methodological Concepts to Analyse the Role of ICT-tools in Social Learning Processes  
P. Maurel, F. Cernesson, N. Ferrand, M. Craps, P. Valkering .................................................. p. 662

Tools to Think With? Towards Understanding the Use and Impact of Model-Based Support Tools  
B.S. McIntosh, R.A.F. Seaton, P. Jeffrey ................................................................. p. 668

Uncertainty in the Water Framework Directive: Implications for Economic Analysis  
J. Mysiak, K. Sigel ........................................................................................................ p. 674

An Interactive Spatial Optimisation Tool for Systematic Landscape Restoration  
B.A. Bryana, L.M. Perryb, D. Gerne, B. Ostendorf, N.D. Crossman ........................................... p. 680

Assessing the Feasibility of Using Radar Satellite Data to Detect Flood Extent and Floodplain Structures  
Edith Stabel ............................................................................................................... p. 686

Optimal Groundwater Exploitation and Pollution Control  
A. Bagnera, M. Massabò, R. Minciardi, L. Molini, M. Robba, R. Sacile .................................... p. 693

Towards an Environmental DSS based on Spatio-Temporal Markov Chain Approximation  
G. Balent, M. Deconchat, S. Ladet, R. Martin-Clouaire, R. Sabbadin ..................................... p. 699

---

**Regional Dynamic Modelling**

Land Use and Hydrological Management: ICHAM, an Integrated Model at a Regional Scale in Northeastern Thailand  
N. Hall, R. Lertsirivorakul, R. Greiner, S. Yongvanit, A. Yuvaniyama, R. Lastf, W. Milne-Homef ........ p. 705

Forecasting Municipal Solid Waste Generation in Major European Cities  
P. Beigl, G. Wassermann, F. Schneider, S. Salhofer ................................................................. p. 711

Real Time Optimal Resource Allocation in Natural Hazard Management  

Combining Dynamic Economic Analysis and Environmental Impact Modelling: Addressing Uncertainty and Complexity of Agricultural Development  
H. Lehtonen, I. Bärlund, S. Tattari, M. Hilden ........................................................................ p. 723

Simulation of Water and Carbon Fluxes in Agro- and Forest Ecosystems at the Regional Scale  
J. Post, V. Krysanova, F. Suckow ............................................................................. p. 730

C. de Jong, R. Machauer, B. Reichert, S. Cappy, R. Viger, G. Leavesley ................................ p. 736

Anticipated Effects of Re-Allocation of Intensive Livestock in Sandy Areas in the Netherlands  
A. van Wezel, J.D. van Dam, P. Cleij ............................................................................ p. 742

An Integrated System for the Forest Fires Dynamic Hazard Assessment Over a Wide Area  
P. Fiorucci, F. Gaetani, R. Minciardi .............................................................................. p. 748
Scenario Development and Integrated Scenario Modelling

Linking Narrative Storylines and Quantitative Models to Combat Desertification in the Guadalentín, Spain
K. Kok, H. Van Delden ................................................................. p. 754

Integrated Assessment of Water Stress in Ceará, Brazil, under Climate Change Forcing
M.S. Krol, P. van Oel ................................................................. p. 760

From Narrative to Number: A Role for Quantitative Models in Scenario Analysis
E. Kemp-Benedict ................................................................. p. 765

Scenario Reoptimization under Data Uncertainty
P. Zuddas, G.M. Sechi, A. Manca ......................................... p. 771

Reliable and Valid Identification of a Small Number of Global Emission Scenarios
O. Tietje ..................................................................................... p. 777

Simulating Global Feedbacks Between Sea Level Rise, Water for Agriculture and the Complex Socio-Economic Development of the IPCC Scenarios
S. Werners, R. Boumans, L. Bouwer ....................................... p. 783

Biocomplexity and Adaptive Ecosystem Management

Principles of Human-Environment Systems (HES) Research
R. Scholz, C. Binder ................................................................. p. 791

Addressing Sustainability, HIV-AIDS, and Water Resource Questions in Botswana

Modelling Biocomplexity in the Tisza River Basin within a Participatory Adaptive Framework
J. Sendzimir, P. Balogh, A. Vári ..................................................... p. 803

Linking Hydrologic Modeling and Ecologic Modeling: An Application of Adaptive Ecosystem Management in the Everglades Mangrove Zone of Florida Bay
J.C. Cline, J. Lorenz, E. Swain ..................................................... p. 810

On the Local Coexistence of Species in Plant Communities

Ecosystems as Evolutionary Complex Systems: A Synthesis of Two System-Theoretic Approaches Based on Boolean Networks
B. Fath, W. Grant ................................................................. p. 822

Benthic Macroinvertebrates Modelling Using Artificial Neural Networks (ANN): Case Study of a Subtropical Brazilian River

Interspecific Segregation and Phase Transition in a Lattice Ecosystem with Intraspecific Competition
K. Tainaka, M. Kushida, Y. Itoh, J. Yoshimura ................................................................. p. 834
A Model of the Biocomplexity of Deforestation in Tropical Forest: Caparo Case Study
R. Quintero, R. Barros, J. Dàvila, N. Moreno, G. Tonella, M. Ablan ........................................... p. 840

D. Eisenhuth, J.B. Abad, A. Bonnet ................................................................. p. 846

---

Ecological Modelling

Stability Analyses of the 50/50 Sex Ratio Using Lattice Simulation
Y. Itoh, J. Yoshimura, K. Tainaka ................................................................. p. 852

Reproductive Strategies of Marine Green Algae: the Evolution of Slight Anisogamy and Environmental Conditions of Habitat
T. Togashi, T. Miyazaki, J. Yoshimura, J.L. Bartelt, P.A. Cox ........................................... p. 858

Predicting Predation Efficiency of Biocontrol Agents: Linking Behavior of Individuals and Population Dynamics
B. Tenhumberg .................................................................................................... p. 864

The Coexistence of Plankton Species with Various Nutrient Conditions: nutrient conditions: A Lattice Simulation Model

Mathematical Modelling of Harmful Algal Blooms
R.R. Sarkar .......................................................................................................... p. 876

---

Landscape Patterns: Simulating Changes, Identifying Driving Forces and Calibrating Models

Implications of Processing Spatial Data from a Forested Catchment for a Hillslope Hydrological Model
T. Kokkonen, H. Koivusalo, A. Laurén, S. Penttinen, S. Plirainen, M. Starr, L. Finér ............ p. 783

Generic Process-Based Plant Models for the Analysis of Landscape Change
B. Reineking, A. Huth, C. Wissel ........................................................................ p. 889

The Role of Local Spatial Heterogeneity in the Maintenance of Parapatric Boundaries: Agent Based Models of Competition Between two Parasitic Ticks
A. Tyre, B. Tenhumberg, C.M. Bull ........................................................................ p. 895

How to Compare Different Conceptual Approaches to Metapopulation Modelling
F.M. Hilker, M. Hinsch, H.J. Poethke ........................................................................ p. 902

Simulation of Dynamic Tree Species Patterns in the Alpine region of Valais (Switzerland) during the Holocene
H. Lischke .............................................................................................................. p. 908

Aphid Population Dynamics in Agricultural Landscapes: An Agent-based Simulation Model
H. Parry, A.J. Evans, D. Morgan ............................................................................. p. 914
# Integrating Wetlands and Riparian Zones in Regional Hydrological Modeling

*F.F. Hattermann, V. Krysanova, A. Habeck* ................................................................. p. 920

# Ecoregion Classification Using a Bayesian Approach and Centre-Focused Clusters

*D. Pullar, S. Low Choy, W. Rochester* ................................................................. p. 927

# Assessing Management Systems for the Conservation of Open Landscapes Using an Integrated Landscape Model Approach

*M. Rudner, R. Biedermann, B. Schröder, M. Kleyer* ................................................................. p. 933

# Physics and Modelling of Transport and Transformation Processes at Environmental Interfaces

**Forecasting UV Index by NEOPLANTA Model: Methodology and Validation**

*S. Malinovic, D. Mihailovic, D. Kapor, Z. Mijatovic, I. Arsenic* ................................................................. p. 939

**Mathematical Models for Gene Flow from GM Crops in the Environment**

*O. Richter, K. Foit, R. Seppelt* ................................................................. p. 945

**Simulation of Herbicide Transport in an Alluvial Plain**

*K. Meiwirth, A. Mermoud* ................................................................. p. 951

**The Influence of the Averaging Period on Calculation of Air Pollution Using a Puff Model**

*B. Rajkovic, G. Zoran, P. Zlatica, D. Vladimir* ................................................................. p. 956

**Interaction Between Hydrodynamics and Mass-Transfer at the Sediment-Water Interface**

*C. Gualtieri* ................................................................. p. 962

**A Spatially-Distributed Conceptual Model for Reactive Transport of Phosphorus from Diffuse Sources: an Object-Oriented Approach**

*B. Koo, S. Dunn, R. Ferrier* ................................................................. p. 970

**A Probabilistic Modelling Concept for the Quantification of Flood Risks and Associated Uncertainties**

*H. Apel, A. Thieken, B. Merz, G. Blöschl* ................................................................. p. 977

**Parameters Estimation Using Some Analytical Solutions of the Anisotropic Advection-Dispersion Model**

*F. Catania, M. Massabo, O. Paladino* ................................................................. p. 984

**Soil Hydraulics Properties Estimation by using Pedotransfer Functions in a Northeastern Semiarid Zone Catchment, Brazil**

*L. Moreira, A. Marozzi Righetto, V. Medeiros* ................................................................. p. 990

**An Approach for Calculating the Turbulent Transfer Coefficient Inside the Sparse Tall Vegetation**

*D. Mihailovic, M. Budincevic, B. Lalic, D. Kapor* ................................................................. p. 996
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Basin Management</td>
<td></td>
</tr>
<tr>
<td>T. Goodwin, M. Fry, M. Holmes, A. Young</td>
<td></td>
</tr>
<tr>
<td>A Tool for Evaluating Risk to Surface Water Quality Status</td>
<td>p.1008</td>
</tr>
<tr>
<td>N. McIntyre</td>
<td></td>
</tr>
<tr>
<td>Spatially Distributed Investment Prioritization for Sediment Control over the Murray Darling Basin, Australia</td>
<td>p.1014</td>
</tr>
<tr>
<td>H. Lu, C. Moran, I. Prosser, R. DeRose</td>
<td></td>
</tr>
<tr>
<td>Appropriate Accuracy of Models for Decision-Support Systems: Case Example for the Elbe River Basin</td>
<td>p.1021</td>
</tr>
<tr>
<td>J.L. de Kok, K.U. van der Wal, M.J. Booij</td>
<td></td>
</tr>
<tr>
<td>River Basin Management Plans and Decision Support</td>
<td>p.1027</td>
</tr>
<tr>
<td>C. Giupponi, R. Camara, V. Cogan, F. Anita</td>
<td></td>
</tr>
<tr>
<td>Introducing River Modelling in the Implementation of the DPSIR Scheme in the Water Framework Directive</td>
<td>p.1033</td>
</tr>
<tr>
<td>S. Marsili-Libelli, S. Cavalieri, F. Betti</td>
<td></td>
</tr>
<tr>
<td>Sensitivity analysis of a network-based, catchment scale water quality model</td>
<td>p.1039</td>
</tr>
<tr>
<td>Dealing with Unidentifiable Sources of Uncertainty within Environmental Models</td>
<td>p.1045</td>
</tr>
<tr>
<td>A. van Griensven, T. Meixner</td>
<td></td>
</tr>
<tr>
<td>I. Bärlund, T. Kirkkala, O. Malve, J. Kämäri</td>
<td></td>
</tr>
<tr>
<td>Assessing the Effects of Agricultural Change on Nitrogen Fluxes Using the Integrated Nitrogen CATchment (INCA) Model</td>
<td>p.1057</td>
</tr>
<tr>
<td>K. Rankinen, H. Lehtonen, K. Granlund, I. Bärlund</td>
<td></td>
</tr>
<tr>
<td>Implications of Complexity and Uncertainty for Integrated Modelling and Impact Assessment in River Basins</td>
<td>p.1064</td>
</tr>
<tr>
<td>V. Krysanova, F.F. Hattermann, F. Wechsung</td>
<td></td>
</tr>
<tr>
<td>Coupling Surface and Ground Water Processes For Water Resources Simulation in Irrigated Alluvial Basins</td>
<td>p.1069</td>
</tr>
<tr>
<td>C. Gandolfi, A. Facchi, D. Maggi, B. Ortuani</td>
<td></td>
</tr>
<tr>
<td>Investigating Spatial Pattern Comparison Methods for Distributed Hydrological Model Assessment</td>
<td>p.1075</td>
</tr>
<tr>
<td>S. Wealands, R. Grayson, J. Walker</td>
<td></td>
</tr>
<tr>
<td>Reduced Models of the Retention of Nitrogen in Catchments</td>
<td>p.1081</td>
</tr>
<tr>
<td>K. Wahlin, D. Shahsavani, A. Grimval, A. Wade, D. Butterfield, H.P. Jarvie</td>
<td></td>
</tr>
<tr>
<td>The Evaluation of Uncertainty Propagation into River Water Quality Predictions to Guide Future Monitoring Campaigns</td>
<td>p.1087</td>
</tr>
<tr>
<td>V. Vandenbergh, W. Bauwens, P.A. Vanrolleghem</td>
<td></td>
</tr>
</tbody>
</table>
A Model of the biocomplexity of deforestation in tropical forest: Caparo case study

Raquel Quintero¹, Rodrigo Barros¹ ², Jacinto Dávila¹, Niandry Moreno¹, Giorgio Tonella¹ ² ³, Magdiel Ablan¹.
¹Centro de Simulación y Modelos (CESIMO).
²Grupo de Investigación BIODESUS.
³University of Lugano, Switzerland.
Universidad de los Andes. Facultad de Ingeniería. Av. Don Tulio Febres Cordero. Mérida, Venezuela.5101
raquelq@ula.ve, rbarros@ula.ve, jacinto@ula.ve, morenos@ula.ve, tonella@ieee.org, mablan@ula.ve

Abstract: This paper presents some preliminary results with a multi-agents modeling approach to understand the complexity of deforestation in tropical forests. The approach was applied to the study of the deforestation of the Caparo Forest Reserve, in the western part of Venezuela. The model includes, among others, the following types of agents: several instances of settlers, government and lumber concessionaries. Settler agents represent people of limited economical resources that occupied land of the reserve with the aims of improving their socio-economical status and obtaining in the future the property of the occupied land. They use subsistence agriculture and they try to maximize the benefits from the land occupation, without knowing that they could generate ecological or environmental problems such as soil exhaustion, due to inexistent or poor management practices. The lumber concessionaires are represented by companies that are constantly supervised by the State; their work is to exploit the forest using management plans previously approved in agreement with the Government. In addition to the dynamical interactions of the agents, the used approach includes also a cellular automata model for the simulation of the dynamic of the natural system. Both aspects use representational tools developed in house: Galatea [Uzcátegui, 2002] for the multi-agents aspects, Actilog [Dávila, 2003] a logic language for the description of rules, and SpaSim [Moreno, 2001, 2003] for the Cellular automata aspects.

Keywords: Biocomplexity, Spatio-Temporal models, Multi-agents modeling and simulation.

1. INTRODUCTION
This study is a subproject of “Biocomplexity: Integrating Models of Natural and Human Dynamics in Forest Landscapes Across Scales and Cultures” [http://www.geog.unt.edu/biocomplexity]
It is carried out at the Caparo Forest Reserve in Venezuela with the aim to model and simulate land-use processes and changes in vegetation cover as a consequence of human actions and the effects of the changes in subsequent human decision-making.

Human behavior affecting forest sustainability is simulated using multi-agent models, there are rules to generate dynamics similar to what is observed at the forest reserve; meanwhile, forest dynamic is represented by a Cellular Automata.

Explicit modeling of human actions and their interaction with ecosystems will give policymakers information about the impact of their decisions on the future composition, structure, and functionality of local ecosystems. It will also facilitate a more informed analysis of the long-term consequences of private choices and public policies on the natural systems in which human systems are embedded and with which they interact [Acevedo et al. 2003].

The structure of this paper includes: a brief description of the Caparo Forest Reserve and the agents considered; models’ description; implementation details; and finally, the conclusions and comments about future work.

1.1 Case Study
The Caparo Forest Reserve, CFR, was created in 1961 and its original purpose was to support the development of the logging industry in the zone, while preserving one of the finest forests of Venezuela [CESIMO, 1998]. It is located southeast of the Barinas State, in the Venezuelan western plains region. Its extension is of 176,434
hectares, and it has been divided on three units to facilitate its management (Figure 1). The study takes place in Unit I, an area of 53,358 hectares, which itself includes a special area called the Experimental Unit, that is used by the University of Los Andes for research and educational activities.

Currently, only 7,000 ha. survived (all in the Experimental Unit). Nevertheless, this area is still not exempted from deforestation due to agrarian settlement process.

Many factors have contributed to forest disappearing in the CFR: unsuitable forest management of some lumber concessionaires, contradictions between different governmental organisms, poverty and the demand of lands for agricultural activities, and the existence of political interests in favor of settlements, among others factors [Ablan et al., 2003].

The following is a description of the most important characteristics of the agents implemented in the models.

1.2 Settler Agent
According to Rojas [1993], the first settlers took possession of a certain area at the reserve and practiced subsistence (i.e. slash and burn) agriculture. This surface could be an uncultivated land (previously deforested and unoccupied). Before five years, the soils are exhausted, and the harvests are no longer enough to sustain the settler and his family. Some settlers try to expand their farms at the expense of new deforestation. However, sooner or later, they will end facing the same situation. The alternative is to seed pasture for cattle (which gives value to the land) so that later, they will be able to sell its improvements to landlords or other settlers.

At this stage, pasture retailers and landlords acquire the improvements of primary settlers.

Extensive cattle ranch dominates the land-use. After some years, the property of the parcels is transferred to the settlers, by application of the Agrarian Reform. Then the parcels are sold at very low prices, to landlords, politicians and cattle dealers who urged and supported the original settlements [Centeno, 1997]. This process, characterized by the concentration of the property, forces the initial group of settlers to move towards primary cycle settlements or to wage-earning work (as workers for landlords) [Sánchez, 1989].

There is in the model a settlement function that considers those places that are more attractive for this agent: land-uses without supervision, such as plantations, secondary bushes and prairies. At the same time, this function model the movement of the settlers using weighted distance buffers around rivers, borders and roads.

1.3 Concessionary Agent
The lumber concessionaires are represented by private companies that have the function to carry out the forest exploitation and management plans in the reserve areas under the supervision of the Government.

The lumber concessionary agent implemented, makes a very simplistic and hypothetical forest management within the reserve: the lumber concessionaire exploits the forest and proceeds to plant commercial valuable species; furthermore, the concessionaire is in charge of forest plantations supervision during the first two years [Ablan et al., 2003].

In case that the concessionaire finds a settler on its assigned zone, there are two behaviors implemented: -the first one implies that the concessionary agent ignores the settler and continues the work at another place that is not occupied by settlers; - the second one implies that the concessionary agent informs to the Government about the settlements.

The implemented concessionary agent has a 30 year cycle and it is allowed to harvest 1,200 ha of “Forest” annually (Figure 2); after the concessionary acts on the site, the use of land is changed to “Logged Forest”. Once the 30 year cycle is over, the concessionary could harvest the first compartment again (the concessionary area is divided in “compartments”).

1.4 Government Agent
Three different behaviors or scenarios were implemented for the Government agent. These behaviors represent different ways of the role of the government at the CFR. Their specification is as follows:

Figure 1. Caparo Forest Reserve Units [Jurgenson, 1994].
1. The Government neither interacts nor interferes with the activities of the others agents. It does not have any monitoring activity. This is called the “Hands-off” government model.

2. The Government has a “strong” policy to keep settlers away from protected forest areas (called at our models as the “Pro-Forestry Government”). This agent has a monitoring process where any settler founded at the CFR area is evacuated. Furthermore, if the concessionary agent, on its exploitation process, finds a settler in the zone, the government agent receives the settlement’s information from the concessionary and the indicated settlers will be removed from the CFR area in the next government’s monitoring process.

3. The Government has an “agroforestry” policy, which means that this agent monitors the forest area trying to protect it, but when he finds a settler, the settler will be relocated to a special area for agricultural activities. At the same time, the government agent receives settlements’ information from the concessionary and then the indicated settlers are relocated. The “Pro-forestry” and the “Agroforestry” governments evaluate the concessionary's exploitation and plantation quotas. The concessionary will be punished by the government in case the concessionary has failed the agreed quotas.

Monitoring is based on a function that considers the places that are more attractive for settlements (buffers around rivers, CFR borders, roads...).

2. THE MODELS

On the above specification, three computational models have been developed. They differ only in the implemented behavior of the Government agent.

Each model counts with a hundred settler agent instances (identified from 1 to 100), and one concessionary agent.

Land-use change is modeled as cellular automata. State transition rules are simplifications of the ecological dynamic of forest succession at the CFR. Other characteristics of the model are:

- Number of layers: 6.
  1. Land-uses Layer: each cell can be in any of the fifteen states described on the Figure 2.
  2. Time in Use Layer: used as a time count layer that indicates the time that a cell has spent remaining at a determined state.
  3. Population Layer: each cell can be in some of the following states: - 0 represents an unoccupied cell; - 1, there is a settler occupying the cell; - 2, there is a landowner occupying the cell.
  4. Supervision Layer: each cell can be in some of the following states: - 0, that represents a no watched over cell, - 1, that indicates a watched cell.
  5. Settler Identification layer: if the cell is occupied by a settler the cell in this layer will have the identification number of the settler.
  6. Compartment layer: it indicates the compartment’s sequence to be followed by the agent concessionary in his exploitation process.

<table>
<thead>
<tr>
<th>TYPES OF CHANGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>X years</td>
</tr>
<tr>
<td>Environment natural evolution.</td>
</tr>
<tr>
<td>The settler agent establishes agricultural activities in the place.</td>
</tr>
<tr>
<td>The settler abandons the place due to the lack of fertility.</td>
</tr>
<tr>
<td>Action performed by concessionaire agent (to exploit the forest).</td>
</tr>
<tr>
<td>Reforesting actions performed by the concessionaire agent.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LAND USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm</td>
</tr>
<tr>
<td>This state changes only if the settler agent abandon the place.</td>
</tr>
<tr>
<td>Land uses that never change.</td>
</tr>
<tr>
<td>Land uses.</td>
</tr>
</tbody>
</table>

Figure 2 Land-uses Transition Graph
• Moore Neighborhood (Zeigler et al., 2000) for every cell (this neighborhood includes the eight adjacent cells).
• State Transition Rules:
  o Each land-use can stay in that state until the cell remaining time in that states achieves the transition time indicated at Figure 2.
  o Permanent states are: Flood River Bank, Seasonal Wetland used for stockbreeding, Rivers, Roads, Livestock, and Farming.

2.1 Agent’s Interactions with the environment
The interaction between the settler agent and the environment is described as follows:
1. A settler agent can establish a farm in a cell that is unoccupied and without supervision. Certain land-uses are preferred for the initial settlements, and once the settler is established, they will change the land usage to adapt it to its agricultural activities.
2. A settler agent can expand its funds at neighboring unoccupied and without surveillance cells.
3. Before five years, the soils are exhausted, and then the settler agent moves to another place inside the CFR. Once the place is left by the settler, the land usage is changed to prairie.

The concessionary agent interacts with the environment in the following ways:
1. To exploit the forest, the concessionary agent needs and unoccupied cell with a land usage equals to forest. Then, the land usage is changed to Logged Forest.
2. To reforest, the concessionary agent needs an unoccupied cell with a land usage equals to prairie or secondary bushes. Then the land usage is changed to plantations.

2.2 Sample of Agent’s Rules
To detail settler agent’s rules we use Actilog Language, which is a language to write generalized, (condition --> action), activation rules. The semantics of the language is based on the assumption that implications (conditional goals) can be used to state integrity constraints for an agent. These integrity constraints describe conditions under which the agent’s goals must be reduced to plans that can be executed. See Dávila, [2003] for more details.

Here is a simplified example of the implemented rules:
FARMS EXPANSION: It is carried out whenever the settler finds a neighboring unoccupied land without supervision. The next Actilog language code line indicates the only way to farm expansion:

```
if thinking_on expansion, not (occupied_land), not (supervision) then funds_expansion.
```

3. IMPLEMENTATION
The implemented model is a multi-agent spatial explicit model, where agents are codified using GALATEA agents’ library, while the space is modeled as cellular automata representing a simplified account of the dynamics of the environmental system. The cellular automata is implemented by means of the SpaSim-lib library. Both the libraries and the model are encoded in Java.

The simulation theory that explains the way we combined the simulator (SpaSim) with the tool that implements the agents (GALATEA) is presented in Moreno, [2002].

Galatea [Uzcátegui, 2002] is a multi-agent simulation platform that nicely fits with SpaSim [Moreno, 2002] for the sake of an integrated spatial, agent-based simulation model. Galatea provides for a collection of classes to model reactive and rational agents, with a scalable, logic-based, inference engine which will eventually allow the agents to perform meta-reasoning, of the kind required to reason about other agents’ reasoning. For the time being, however, the agents are more of a reactive kind, with behaviors that can be modeled by means of generalized condition-action rules [Dávila, 2003].

The methodological path used here tries to embed as much behavior as possible with simpler agent models in such a way that extensions, such as those required for meta-reasoning, remain computationally feasible. This is why the research has developed these simplified agent models, testing for their expressiveness and evaluating their validity progressively. In this respect, it coincides with the work done in Monticino et al. [2004], also reported in this congress volume. However, these models are not attached to decision theory. The reason for this is that, even though, decision-theoretical approaches have the advantage of their straightforward psychological interpretation, the same advantage can be achieved with logic based models, without having to pre-encode, in numerical values of the potential consequences, all the qualitative information about agents’ preferences and assumptions for meta-reasoning.

SpaSim is software that allows the specification, simulation, visualization and analysis of spatial models in the same environment, using a friendly user interface while at the same time providing considerable flexibility. Square cells were used for the cellular automata to keep compatibility with most raster GIS systems in use. Also the
software integrates simulation techniques (like cellular automata), spatial analysis, spatio-temporal analysis, and maps visualization [Ablan et al., 2003].

The implementation includes former processes that affect the evolution of the land-use cover, which are carried out by the already implemented agents. There are some other agents that have not been implemented yet, like politicians, Los Andes University, among others...

4. RESULTS
For each one of the government scenarios implemented, the model was run for 65 years, because this is the estimated time required to observe a transformation from a Logged Forest into a Forest. The initial state of the CFR corresponds to the land-use reported in Pozzobón [1996] et al. for the year 1987. Simulation results are portrayed as maps that show the spatial distribution of land-use types obtained in each of the scenarios.

In the Hands-off Government Model, at the end of the simulation the forest have been replaced by other types of land-uses, the dominant land-use being cattle and ranching activities.

On the other hand, in the pro-forestry government model, the settlers are finally removed from the CFR area, and the forest has the opportunity to achieve its original state.

The agroforestry government, at the end of the simulation the forest has the opportunity to achieve its original state, but the settlers have left the special place for agricultural activities and the landlords has occupied that zone for cattle and ranching activities.

5. CONCLUSIONS
Simulation results agree qualitatively well with what is now known about land-use change, tropical forest succession and forest management in the area. On the contrary to what was believed a few decades ago, it takes vegetal succession in tropical forests relatively long periods to fully recuperate its original state, both in volumes of wood and in floristic diversity. For example, Guariguata & Ostertag [2002] and Gómez-Pompa & Vázquez-Yanez [1985] say that the process leading to the reappearance of the initial forest species in the way they were found at the moment of deforestation could take even around a hundred (100) years. Our results corroborate that the way in which the forests were managed, with a 30 year cycle, would end up compromising the availability of the forest’s resources in the future, just as Martinez-Angulo (1955), Lamprecht (1956: cited by Kammescheidt et al. 2001) and Veillón (1971) had warned.

Some points to be improved at our future works:
- Population growth of settlers will be represented at future models representing the influence of government policies.
- The landlords will be implemented explicitly as agents. This will enhance agents’ interactions as they would be able to expand their properties, acquire other settler improvements, etc.
- The government agent will implement a more detailed evaluation of the concessionary performance; measuring beyond exploitation and reforestation quotas.
- The ecological realism of the cellular automata will be improved by estimating its parameters from detailed gap-model simulations (as in Acevedo, et al. [2001], and Monticino, et al. [2002]).

Details of the work and future developments can be found at the www page of the project: http://chue.ing.ula.ve/INVESTIGACION/PROYECTOS/BIOCOMPLEXITY/

5. ACKNOWLEDGMENTS
SpaSim software is a product of the research activities developed by Niandry Moreno as a part of a researcher development program (Programa de Desarrollo del Investigador Novel) at Los Andes University (ULA-FONACIT). Galatea was originally developed under project ULA CDCHT 199-667 and it uses the GLIDER simulation language, also developed at Los Andes University.

This material is based upon work supported by the US National Science Foundation under Grant CNH BCS-0216722. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

We would like to thank Miguel Acevedo, Armando Torres, Hirma Ramirez and Emilio Vilanova for many valuable discussions and feedback.

6. REFERENCES

Acevedo M.F., S. Pamarti, M. Ablan, D.L. Urban and A. Mikler, Modeling forest landscapes:


Lamprecht, H. Unos apuntes sobre el principio del rendimiento sostenido en la ley forestal y de aguas venezolanas. Boletín de la Facultad de Ingeniería Forestal 10. 9 34, Mérida, Venezuela, 1956.


Moreno N., Diseño e Implementación de una estructura para el soporte de simulación espacial en Glider. Master Theses. Graduate Computer Program Universidad de los Andes, Mérida, Venezuela, 2001


845