MAS as Component of Integrated Modeling Systems

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Challenges of Land Use Science

- Exploring possible adaptation strategies and improving land use planning
  - Better understanding of human-environment interactions
  - Capturing decision making at land user level
- Moving from pixels to agents
  - Unpredictability of socioeconomic processes
  - Descriptions of system components combined with assumptions about their relationships

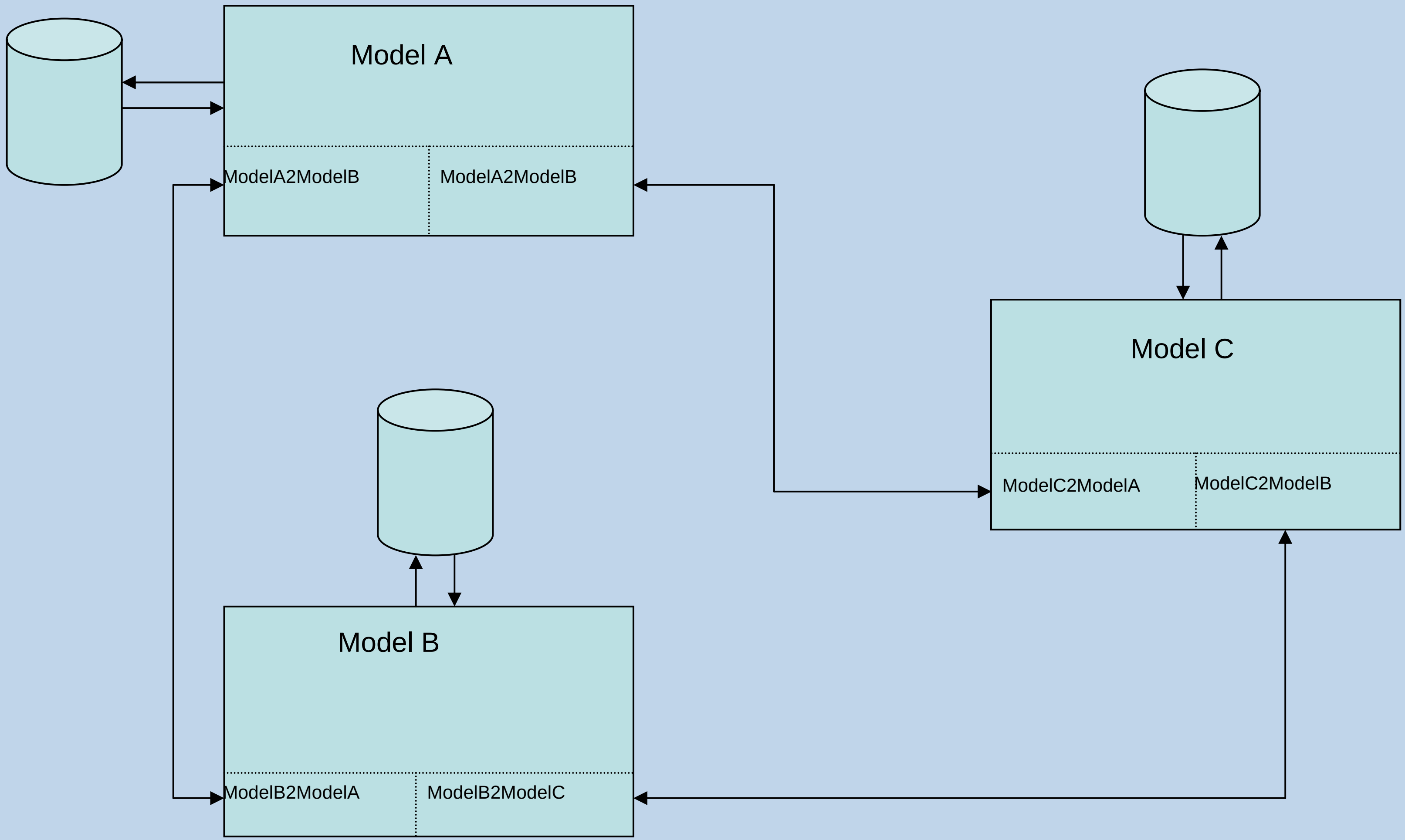
Why Integrative Modeling?

- "Value Added" when integrating and communicating across knowledge domains
  - Feedback loops, thresholds, irreversibility
- Unexploited data sets, both biophysical/socioeconomic aspects
  - Merging possible through spatial data models
- Participatory planning tools, new governance concepts
  - Integrated River Basin Management
  - EU Water Framework Directive
- "Frontier" of applied research
  - Funding by DFG, Volkswagen, NSF, ...
  - Funding by CGIAR, EU Commission, ...

Why is Integration so Difficult?

- Demanding process in terms of communication
  - **Institutional integration**: involving resource users and managers
  - **Knowledge integration**: scientific conceptualization and discourse of stakeholders
  - **Technical integration**: coupling of computer models
- Although a hot topic, there are few methods and tools available up to now
  - Knowledge representation and knowledge modeling
  - Component-based software engineering

How Integration is Often Done ...



Thanks to M. Huigen

Integration of Knowledge Domains

- Difficulties at conceptual level
  - Different objectives of scientists and stakeholders
  - Various semantics (ontologies)
  - Spatial, temporal and social scales not identical
  - Issues and entities do not necessarily overlap
  - Different approaches and methods in data gathering and data analysis
  - Various approaches to interpretation of results
- Difficulties at program/code level
  - *"Good knowledge bound in outdated code"* (Argent, 2004)
  - *Legacy-code* cannot be re-used easily

Use of Legacy Models #1

1. Representation of legacy-model through meta-model approach (transfer- or production functions)
   - Bioeconomic household models (Ruben/van Ruijven, 2001)
   - Holistic water allocation models (Rosegrant et al., 2000; Ringler, 2001; Cai, 2004)
2. Reprogramming and implementing in one code (*Brute Force Merger*)
   - MAS & Edic-Cedec & CropWat (Berger, 2001)
   - MAS & TSPC (Berger/Schreinemachers, 2006)

Use of Legacy-Models #2

3. Communication-oriented coupling of models
   - Data exchange in specific format, shell scripts for modular management
   - Examples in environmental modeling: GIBSI, RAISON (see for overview Argent, 2004)
4. Component-oriented implementation with framework (.NET or J2EE)
   - Re-usable model components, connected with *Plug-And-Play*
   - Examples: OpenMI (Gregersen et al., 2005), SeamFrame (Van der Wal et al., 2006)
   - Vision: web-based open environment for environmental modeling (Rizzoli et al., 2007)

Challenges for Land System Models

- Linking various biophysical and socioeconomic process models at high resolution
  - Results from subsystem models cannot simply be matched or aggregated
  - Interpretation difficult because boundary conditions under which results were generated are too restrictive
- Model integration must be achieved at several levels
  - Conceptualization, modeling, programming
  - Experimental frame to ensure transparency and traceability in execution of simulation scenarios

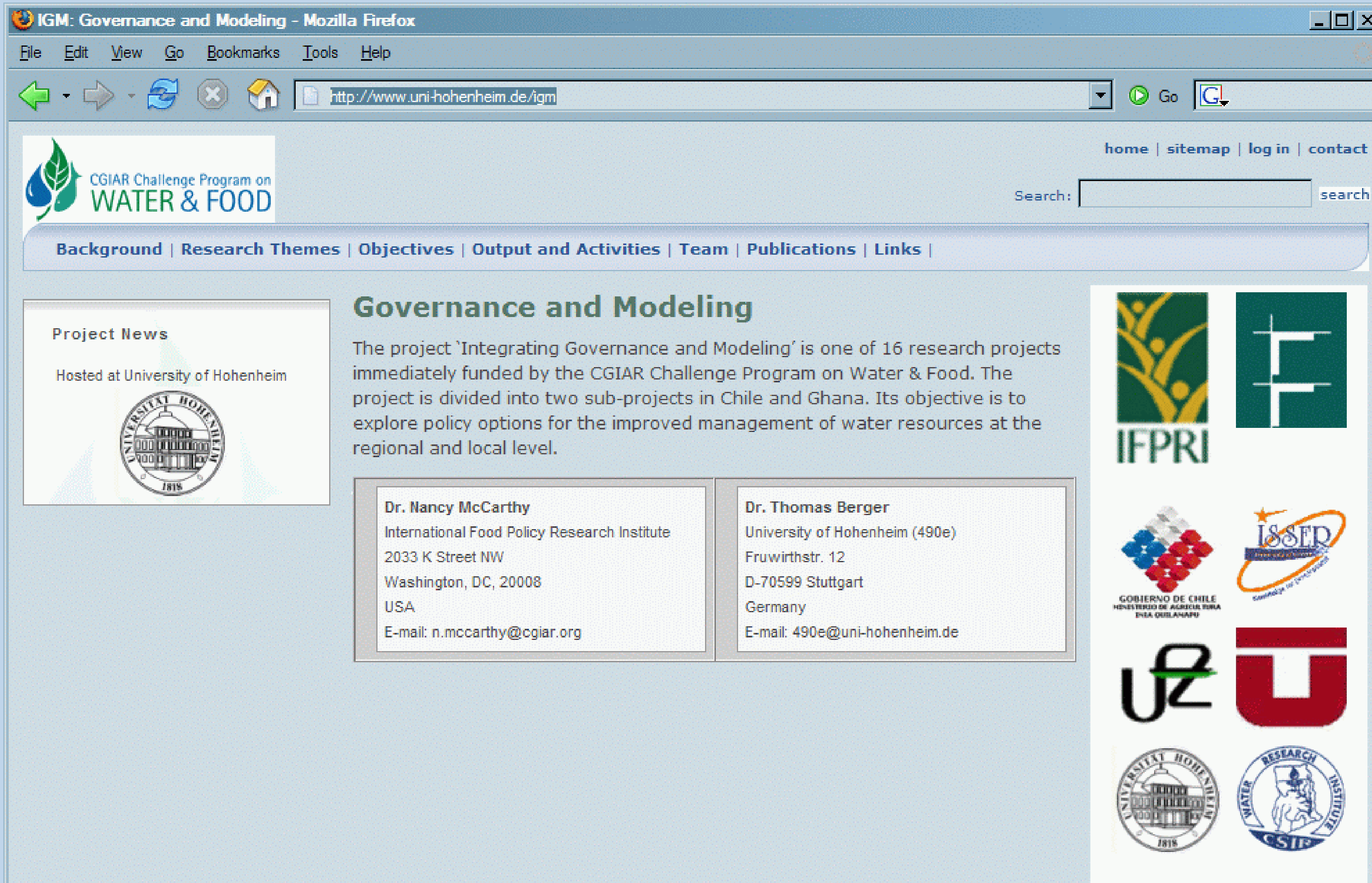
The Better Way: "Integration-on-Demand"

- Common Sampling Frame
  - Methods for integrative data collection and parameterization (Berger et al., 2002; Berger and Schreinemachers, 2006)
- *Use-Case Analyses* and *Workflow Protocols*
  - Methods/tools for guiding the process from research questions to technical implementation
- Component-based modeling system
  - Re-usable, linkable model components
  - Standard interfaces and data models

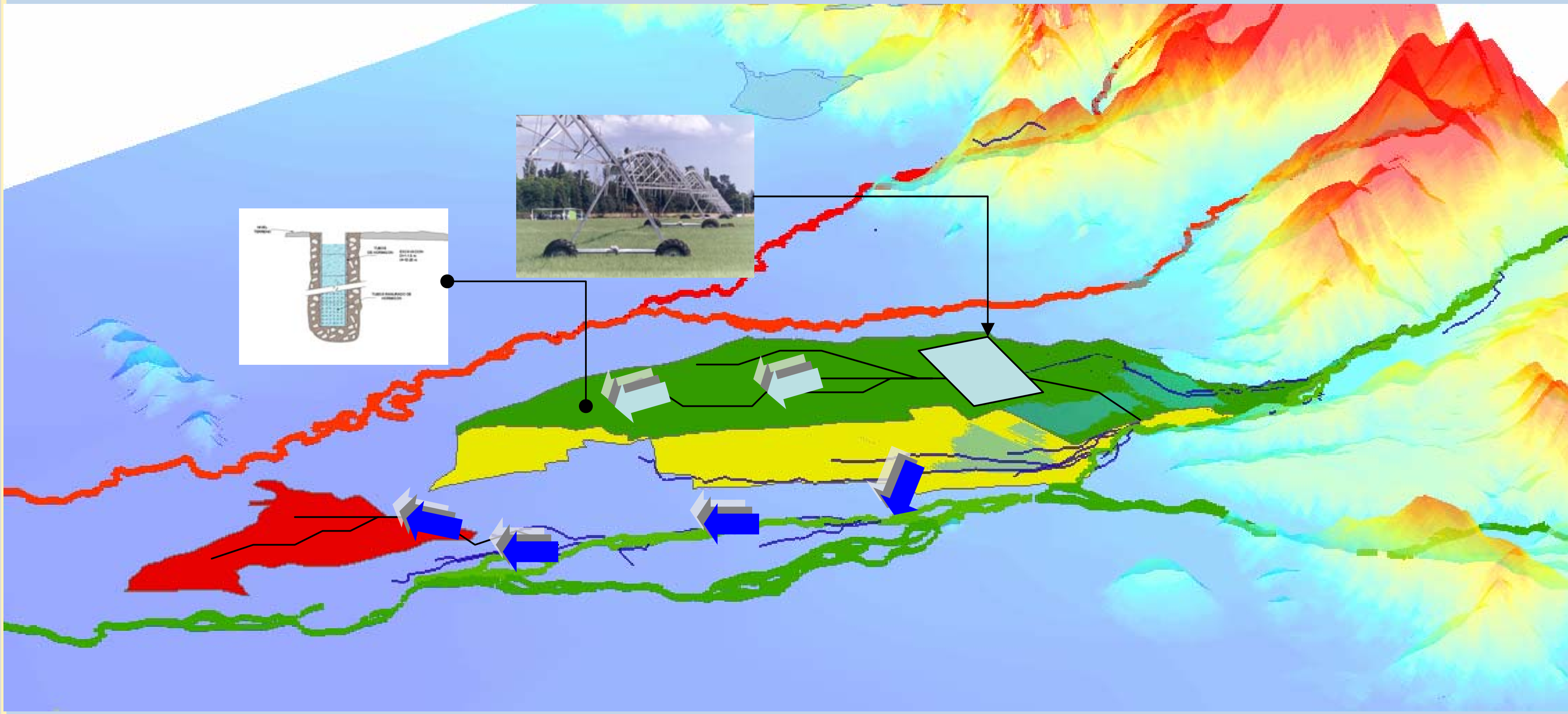
Multi-Agent Systems (MAS/LUCC)

- Representation of agents and landscapes building on various sources of knowledge
  - Measurements, observations, expert opinions and stakeholder insights
- One-to-one correspondence of human actors and computational agents
  - Straightforward interpretation of simulation results
- Direct involvement of stakeholders in model specification and evaluation
  - Collaborative learning, teaching and education

CGIAR Challenge Program Water & Food



Land Use: Interactions of Actors



Berger et al. (2007)

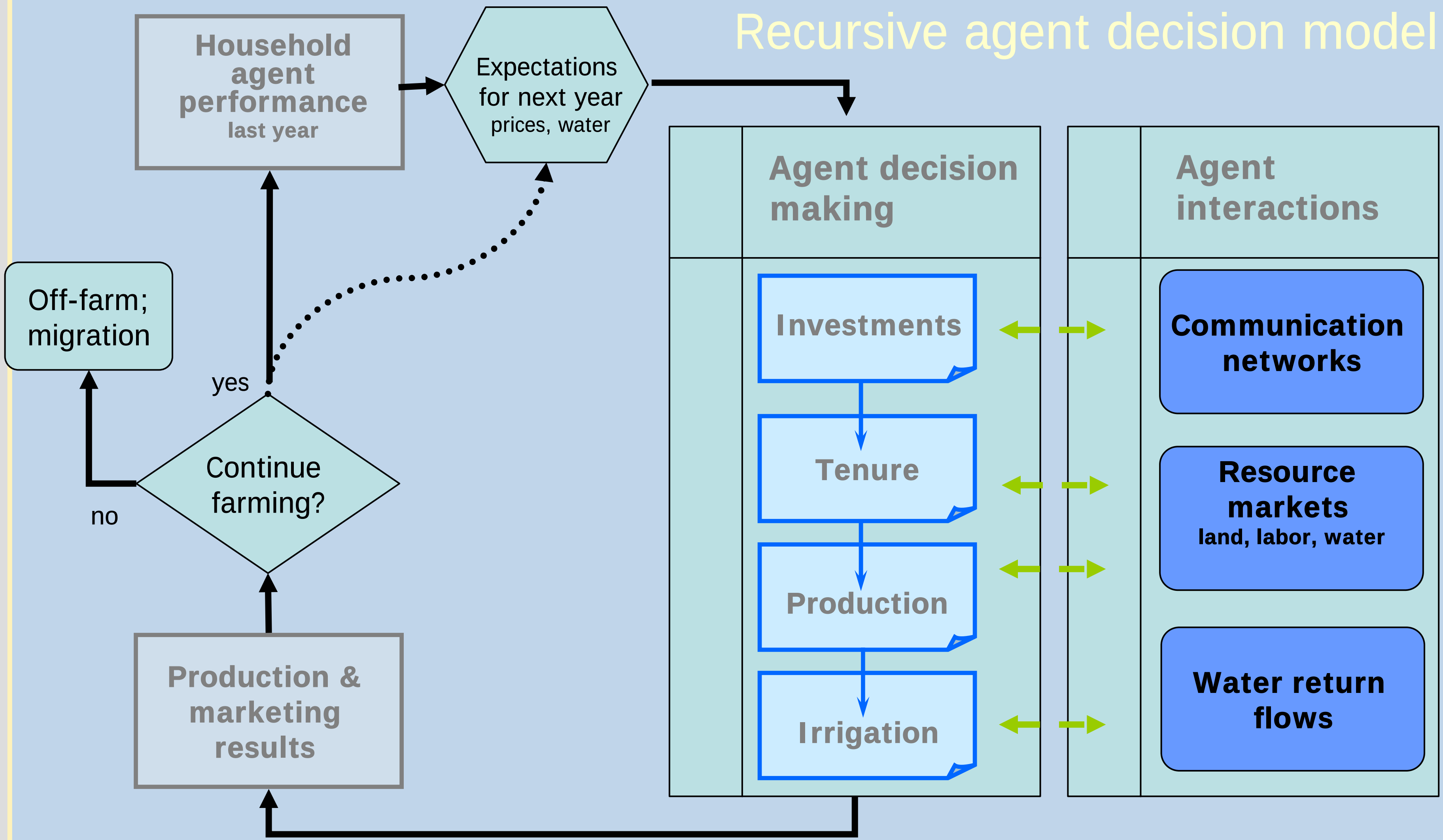
CGIAR Challenge Program on
WATER & FOOD

Here: Class of Problems

- Land use in small to medium size watersheds
  - 1,500 km^2 (Chile) and 3,700 km^2 (Ghana)
- Spatial externalities, property rights, distributional effects
  - Social ecological systems
- Compensation mechanisms, viability, implementation
  - Policy-relevant information, corrective measures
- Potential for collective action, participation of resource users and managers
  - Collaborative learning, teaching, education
- Application of MP-MAS software
  - Component of Integrated Modeling System

Agent Behavior in MP-MAS

Recursive agent decision model



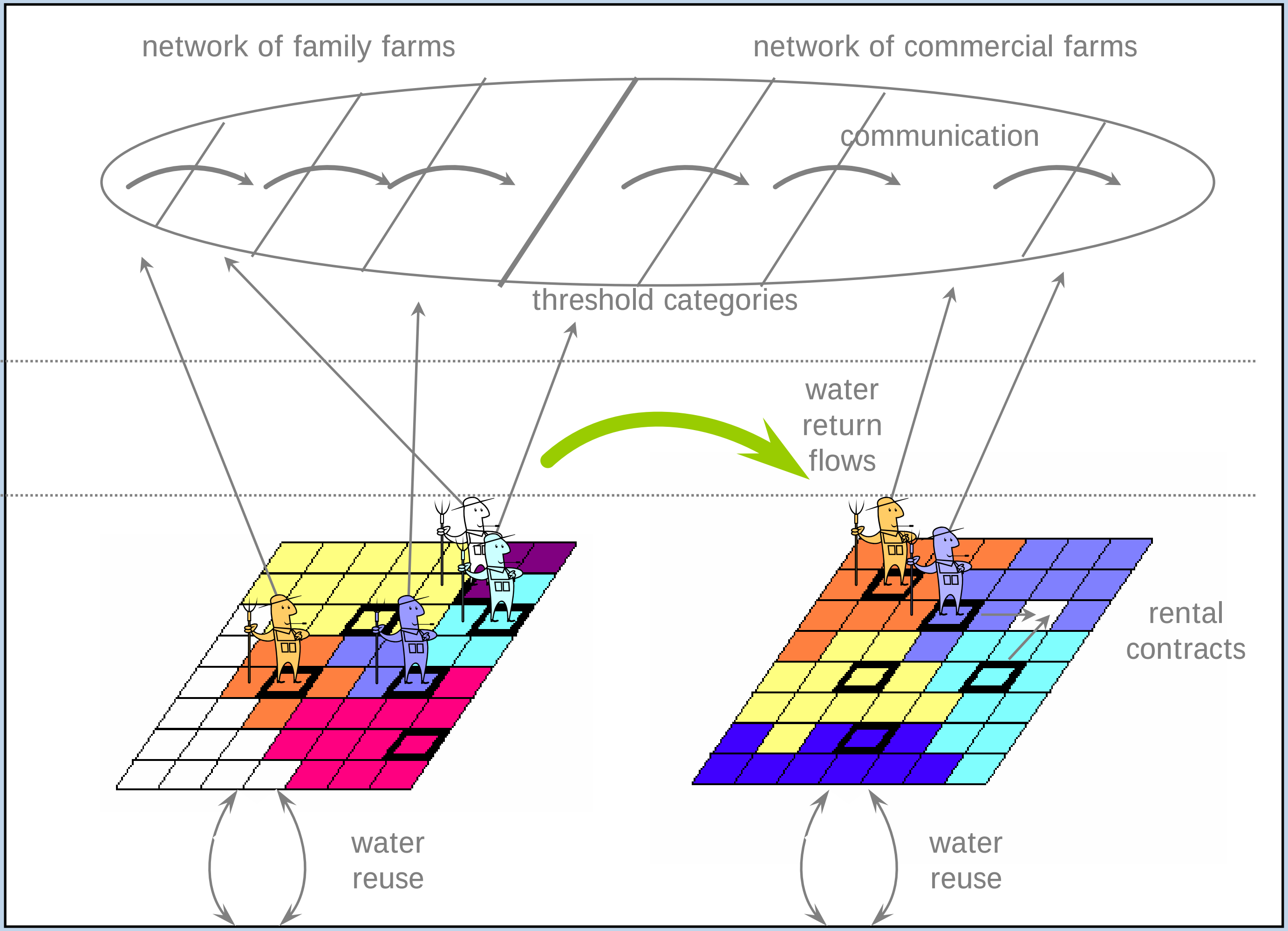
Agent Interactions in MP-MAS

level and type of interaction

regional:
- information

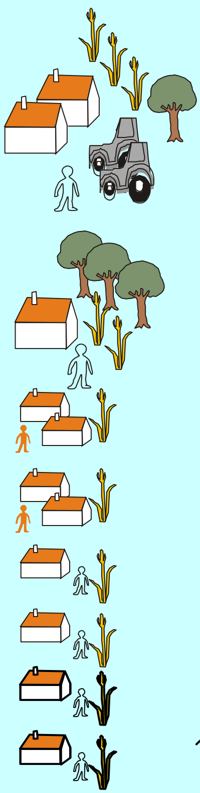
inter-group:
- return flows

intra-group:
- rental contracts
- reuse of water



Empirical Parameterization of MP-MAS

Actors



N = 5400

Data processing

- Estimate distribution functions
- Apply *Monte Carlo*-approach
- Assign characteristics to computational agents
- Validate statistical consistency

n = 250

Agents

11 1111 11

01 0011 10

11 0101 01

01 0101 01

01 0110 00

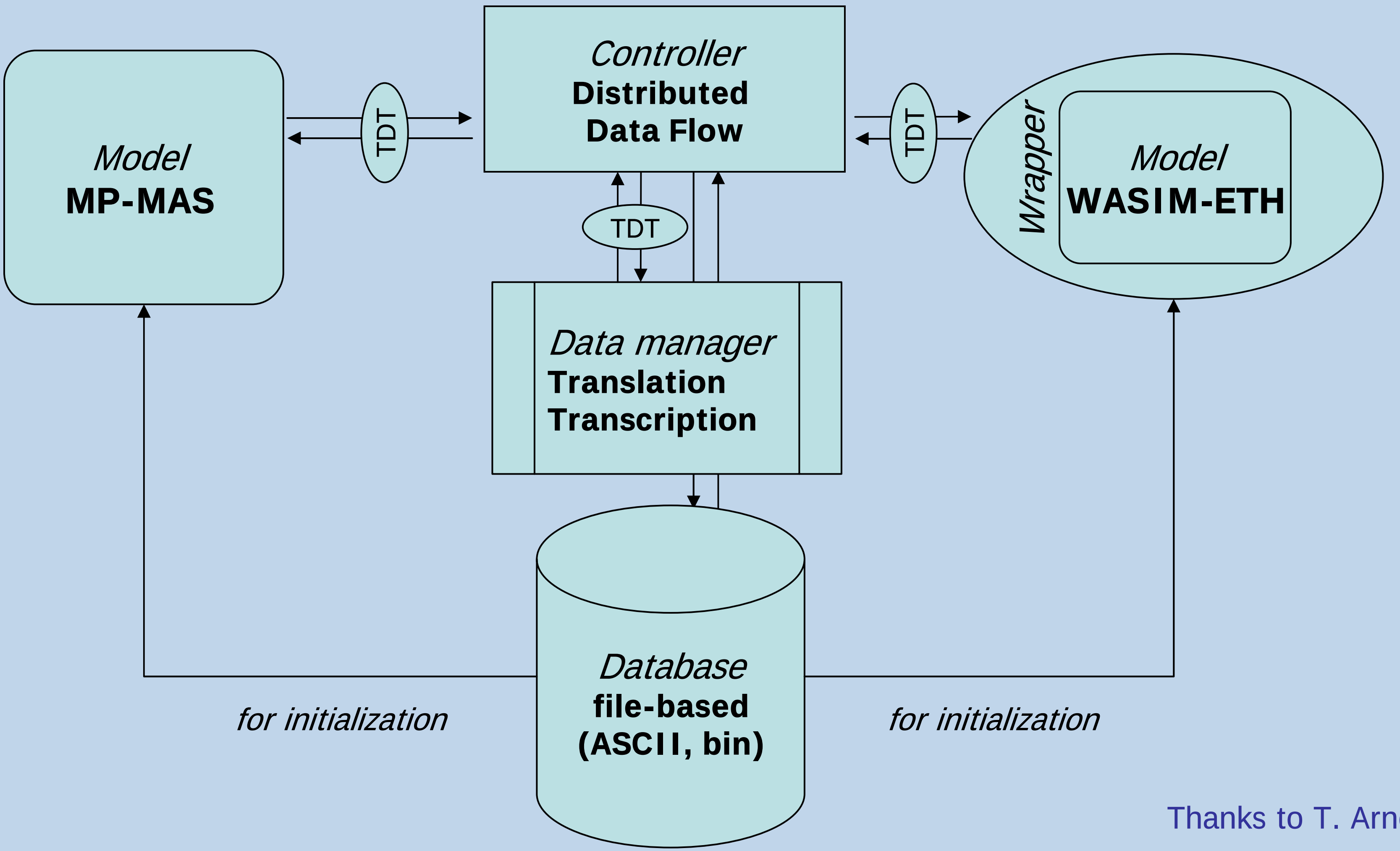
11 0111 11

01 0111 11

01 0011 11

N = 5400

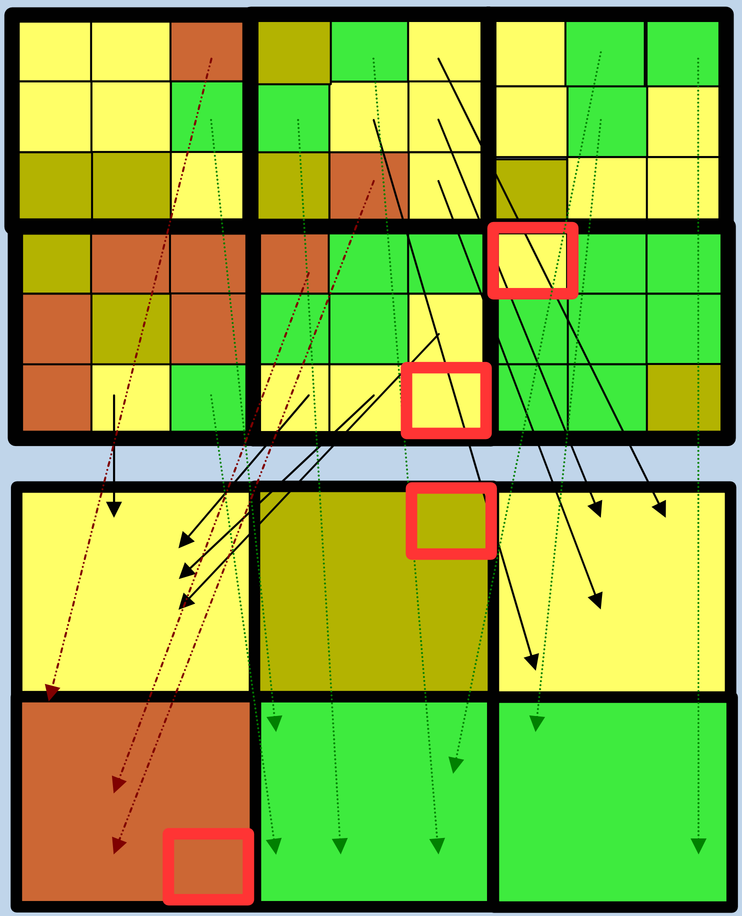
Integrated Modeling System (UHOH)



Thanks to T. Arnold

Transfer of Data between Components

- Data of various spatial, temporal and social scales
- Transfer requires transformation and translation
- Sometimes straightforward, sometimes challenging



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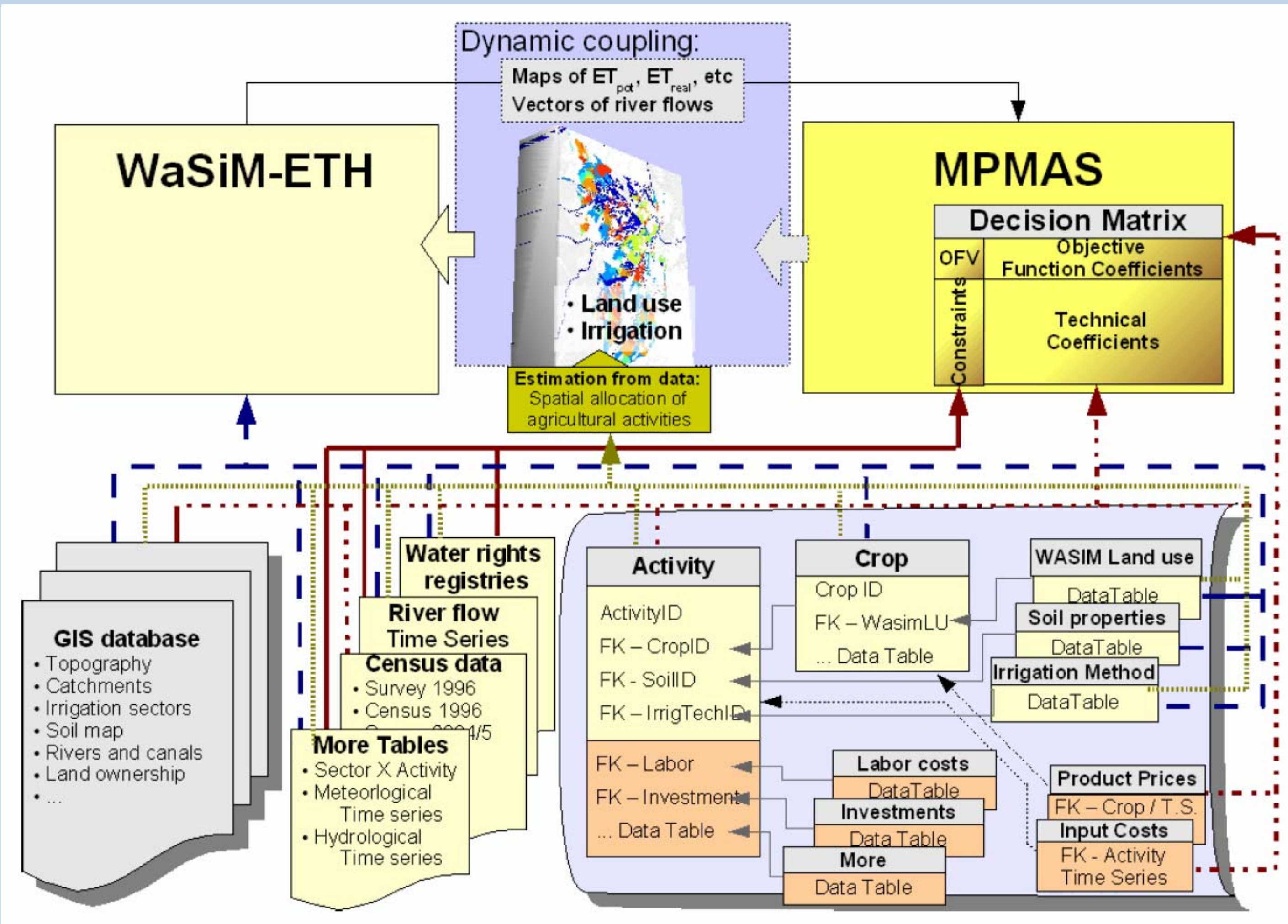
Flow of Data



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Thanks to T. Arnold

Collaborative Research & Learning Framework

1. First round contacts, introductions

   Inform stakeholders, contribute to understanding governance structures

2. Demonstrations of the model

   Elicit feed-back on problems, needs and potential solutions and evaluation criteria (use cases, scenarios); may involve another workshop

3. Organizing feed-back, esp. regarding front-end

   More workshops and evaluation of workshops, may also involve smaller working groups/interviews

4. Practical use of the model by stakeholders

   Identification of people who to train, training courses with teaching version of the model

5. Monitoring/evaluating the use of models by stakeholders

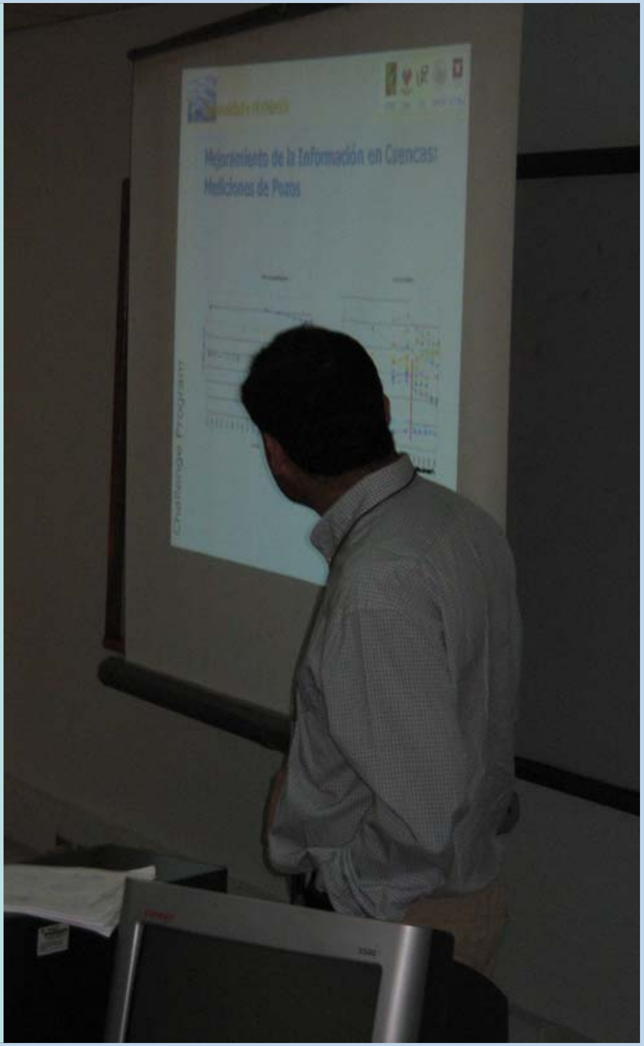
   Establishing the use potential of the model

Wittmer et al. (2006)

Options Perceived by Stakeholders

Stakeholder Workshop, Casa Pehuenche, Chile
22-23 Nov. 2005

Advanced Model User Training



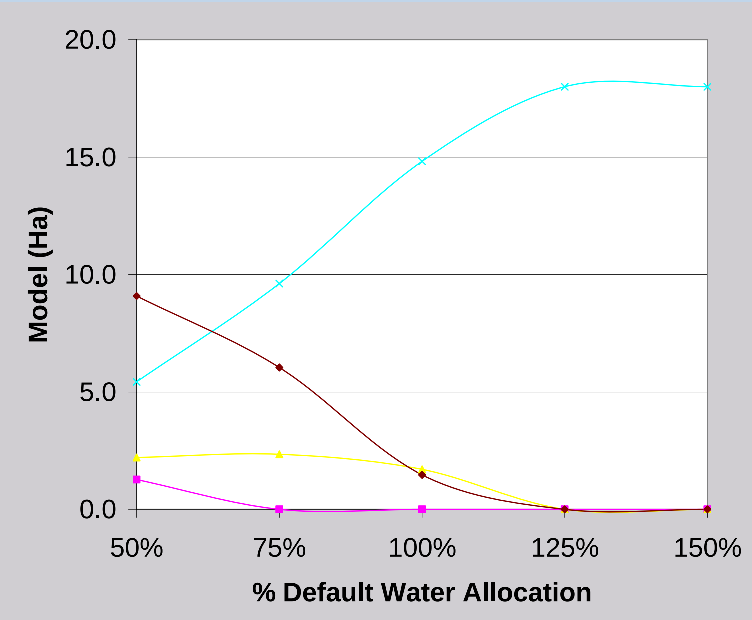
Interactive Modeling Session

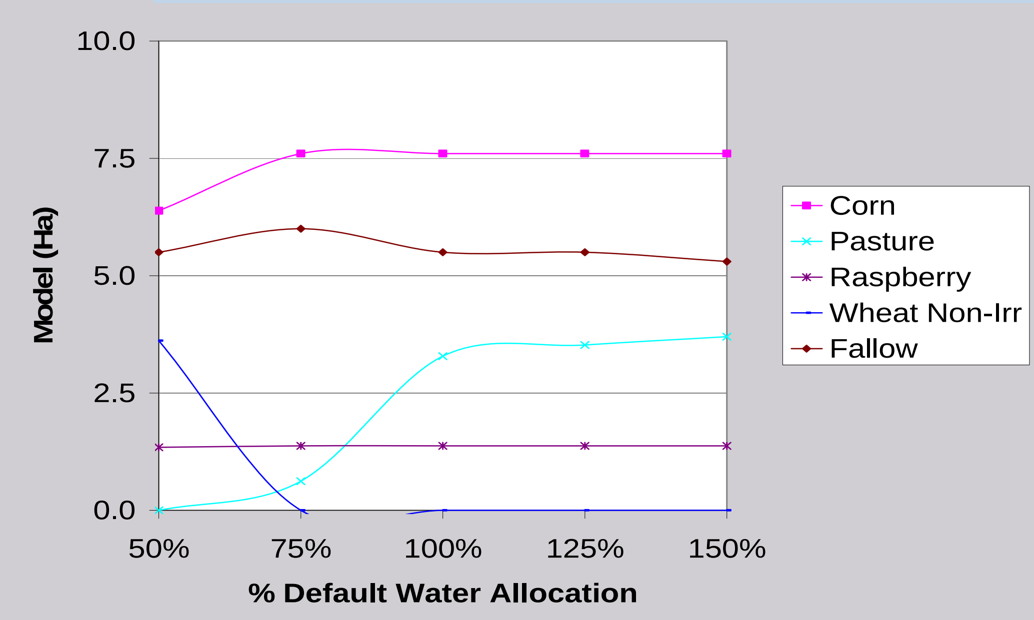
Interactive Modeling, Club Social Linares, Chile
28 March 2007

Interactive Modeling Validation

- Surveys of 10 Sample Farms used to capture
  - Farm endowment levels (land, machinery, labor, water)
  - Farm crop production schedule
  - Farm response to water variation; water trading
- Farm endowments from surveys are used as input for single-agent simulations
- Modeling Sessions (Feedback loops)
  - Model discrepancies are discussed
  - Model revisions are suggested (e.g. new constraints)

Interactive Validation: Water Sensitivity





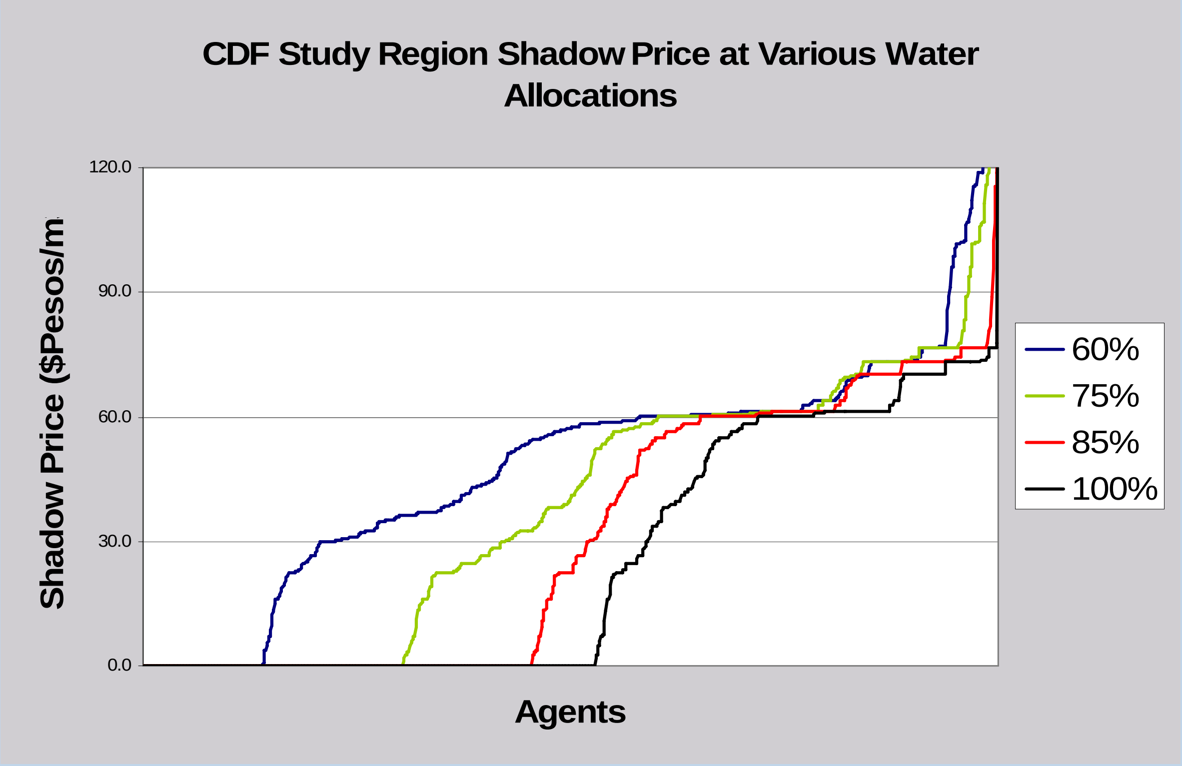
Notes: Farmer Verbatim to reduced water allocation

– Farm 1 (Left): Prioritize staples and reduce pasture

– Farm 2 (Right): Prioritize raspberry first, then staples, then pasture

Thanks to C. Schilling

Simulation Results: Water Shadow Prices



Notes: Distribution of shadow prices for irrigation water

- Variation of "irrigation security" from 60% to 100%
- Substantial number of farmers has shadow prices of zero

Thanks to C. Schilling

Specific Applications of MP-MAS

- Single-agent specification (“fine grained”)
  - Farm income analysis
  - Farm investment analysis
  - Water rental analysis
  - Contribution to large-scale irrigation projects
- Multi-agent specification (“coarse grained”)
  - Dynamics of water rental markets
  - Provision of small-scale infrastructure
  - Provision of large-scale infrastructure
  - Policy evaluation (ex post, ex ante)

Ongoing Work ...

- Arrive at guidelines for setting up the scene for stakeholder involvement and integration
  - Identify scope for model-enhanced learning
  - Intermediate products of MAS should prove useful for stakeholders
- Improve methods for knowledge sharing and knowledge bridging
  - Better model interfaces need to be developed
  - Iterative modeling/learning sessions
- Need to assess impacts of using MAS on individual and collective decision-making
  - Later on, suggest appropriate institutional solutions for using tools ("advanced model user groups")

Applications of MP-MAS

Uganda	Yield gaps, nutrient mining, HIV-AIDS	IFPRI-GMU (BMZ, RBS)
Ghana	Sustainable water and land use in Volta sub-basin	Challenge Program on Water and Food (CP 40)
Chile	Sustainable water and land use in Maule sub-basin	Challenge Program on Water and Food (CP 40)
Thailand / Vietnam	Sustainable development in mountainous regions	Deutsche Forschungsgemeinschaft (SFB 564)
Germany	Landscape structures and functions under climate change	Deutsche Forschungsgemeinschaft

http://www.uni-hohenheim.de/mas/software

L I FE SCIENCE CENTER

Integrated Project Funded by DFG

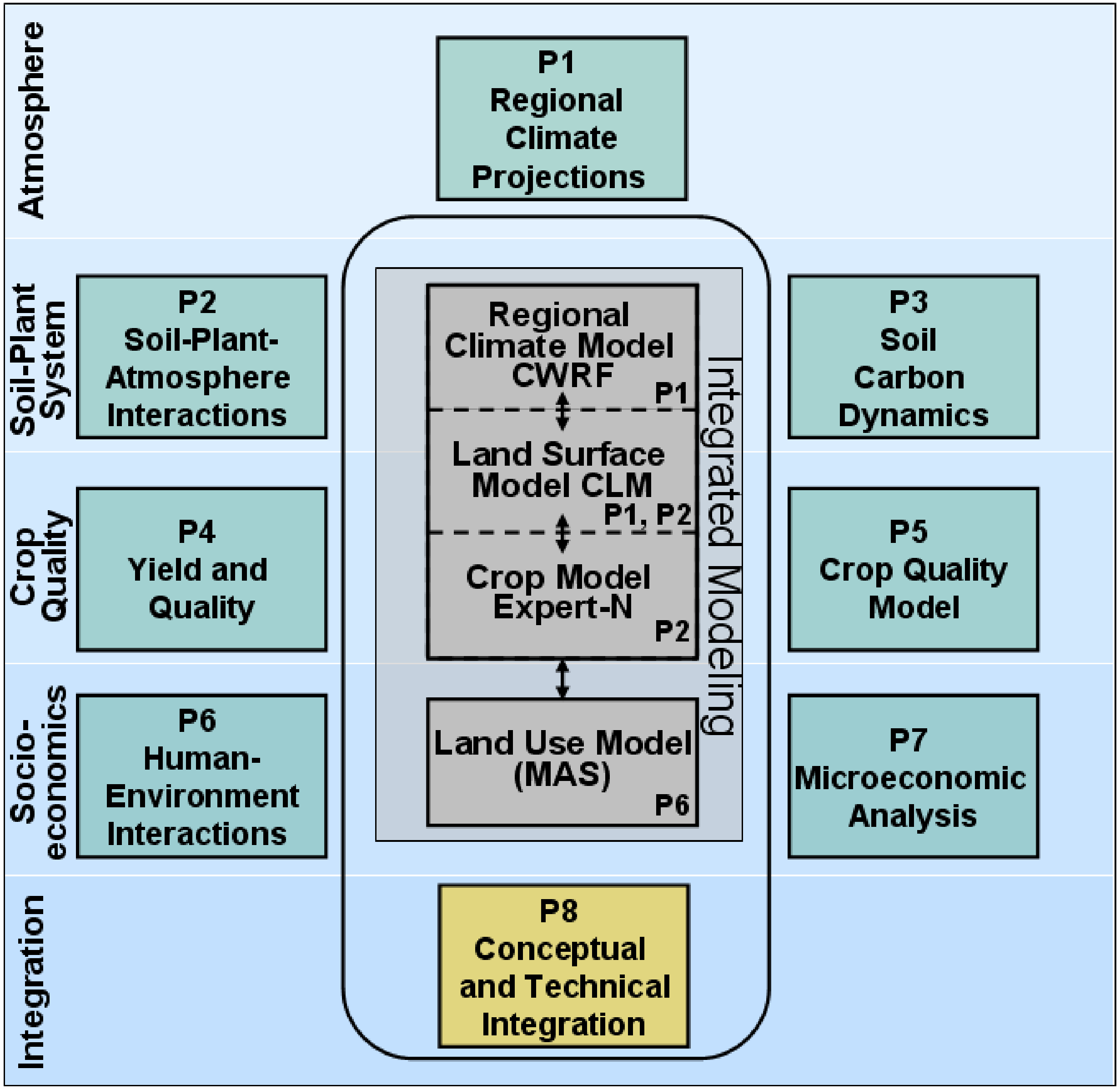
UNIVERSITÄT HOHENHEIM

STRUCTURE AND FUNCTIONS OF AGRICULTURAL LANDSCAPES UNDER GLOBAL CLIMATE CHANGE

Processes and Projections on a Regional Scale




Structure of Integrated Project



Modeling Team at UHOH

Alexandra Theune	Groundwater and Water Quality
Arnélida Gorrín	Satellite imagery, remote sensing, classification of land use change in Chile
Carlos Padilla	Compilation of model input data in Chile
Chris Schilling	Gross Margin Analysis, calibration of MIP, interactive modeling in Chile
Christian Troost	Database and spatial model input in Chile
Constanze Leemhuis	WASIM calibration in Chile; Extension of WASIM model in Ghana (Atankwidi+)
Florian Bruns	Programming of GIS structure and TDT for MAS-WASIM model coupling
Hamil Uribe	WASIM irrigarion sections, GIS input data in Chile; Use-Case Analysis
Hannes König	WASIM (Top Soil model) in Chile plus Gross Margin Calculations
Marco Huigen	Use-Case Analysis; Advice on options for model coupling
Markus Mast	Coupling of MAS and WASIM; programming of WASIM interface
Nedumaran S.	Agent-based component in Ghana
Pepijn Schreinemachers	MAS Teaching Module; Visual Basic Macros for MAS input data set (front end)
Sascha Holzauer	MAS Teaching Module; Project Website
Thomas Berger	Programming of MAS source code
Thorsten Arnold	Coupling of MAS and WASIM; User Front End, data processing routines

Funding by Robert Bosch Foundation, CPW&F and Dr. Hermann Eiselen

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