L | FE SCIENCE CENTER

UNIVERSITÄT HOHENHEIM

Insights for Climate Change Policy from Agent-Based Modeling of Land-Use

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Climate Impacts on Agriculture

- Crop growth affected by temperature, precipitation, CO_2
- Risk of crop losses due to extreme weather events and potential pest pressure
- Time slots for sowing and harvesting
- Policy, trade, and other changes in economic environment

Adaptation and Feedbacks

- Climate adaptation in agriculture
  - → Crop growth ↔ Crop choice & management
  - → Technical and structural change
  - → Learning and adaptation of land users
  - → Risk management
  - → Feedback loops: land surface – atmosphere
- Considering other relevant drivers
  - → Policy changes, urban-rural linkages, non-agricultural development

Agent-Based Models (e.g. MP-MAS*)

- One-to-one correspondence of human actors and computational agents
  - → Straightforward interpretation of simulation results
- Direct involvement of stakeholders possible
  - → Model specification and evaluation
- Explicit interactions
  - → Information, resource markets, external effects, …
- Explicit decision-making
  - → Learning, risk management, multiple goals

* Mathematical Programming based Multi-Agent System, *Berger 2001*

Architecture of MP-MAS

Layers

Networks

Property rights

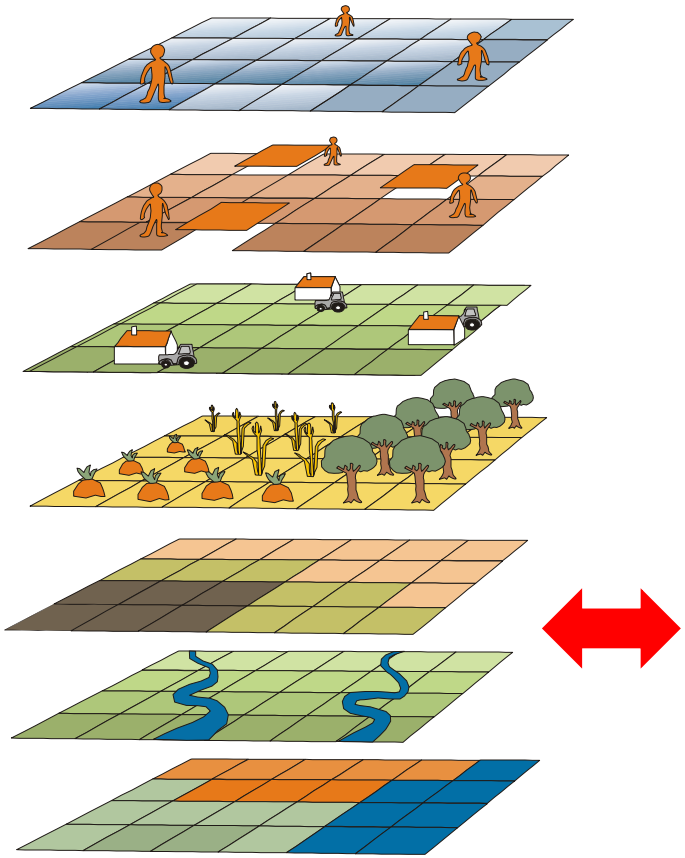
Factor endowment

Land use

Soil quality

Water run-off

Weather



Components

Communication model
Collective decisions

Land markets

Asset registry

Agent decision model

Crop growth model

Soil nutrient model

Hydrology model

Climate data/model

Model integration

Options for Model Integration

1. Holistic models
   - → Crop models in simplified form, often in spatial equilibrium approaches
2. Integrated modeling frameworks
   - → Existing frameworks (e.g. SEAMLESS, OpenMI, DANUBIA)
3. **Lightweight software coupling**
   - → Lightweight model-linking tools (e.g. TDT*)

Application of MP-MAS

Uganda	**Yield gaps and nutrient mining**	**IFPRI-ZEF (BMZ)**
Ghana	**Sustainable water and land use in Volta basin**	**Challenge Program on Water and Food (CGIAR)**
Chile	**Sustainable water and land use in Maule basin**	**Challenge Program on Water and Food (CGIAR)**
Thailand Vietnam	**Sustainable development in mountainous regions**	**Deutsche Forschungs-gemeinschaft (DFG-SFB)**
Germany	**Landscape structures and functions under climate change**	**Deutsche Forschungs-gemeinschaft (DFG-PAK)**
Uganda	**Rural producer organizations**	**IFPRI-UHOH (BMZ)**
Brasil	**Land use and carbon management**	**Uni Göttingen (BMZ-EMBRAPA)**

http://mp-mas.uni-hohenheim.de

Modelling Mitigation & Adaptation

Global Level

- mitigation
- trade
- migration

Regional Level

- adaptation & mitigation
- local markets
- resource management
- technology adoption
- collective risk management
- rural-urban migration
- local external effects

→ vulnerability & resilience

Household Level

- adaptation
- production & consumption
- individual learning and risk management

→ vulnerability & resilience

CGE

RFM

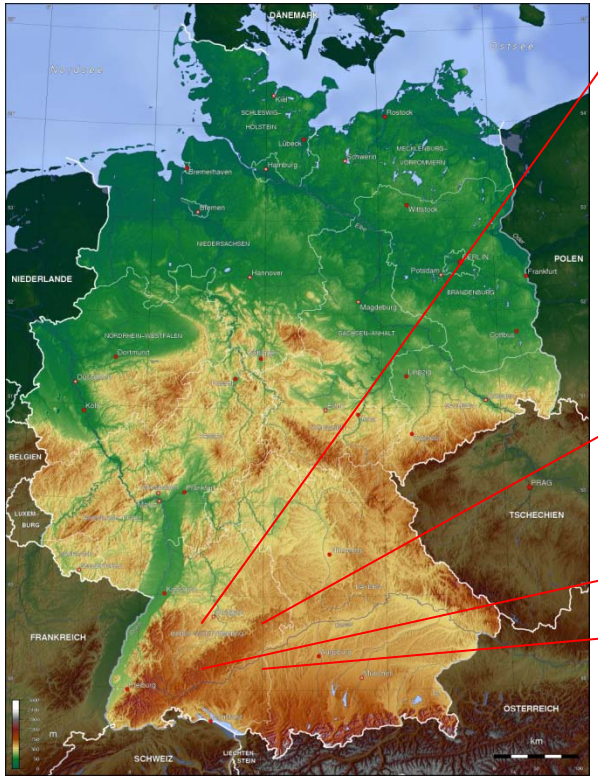
ABM

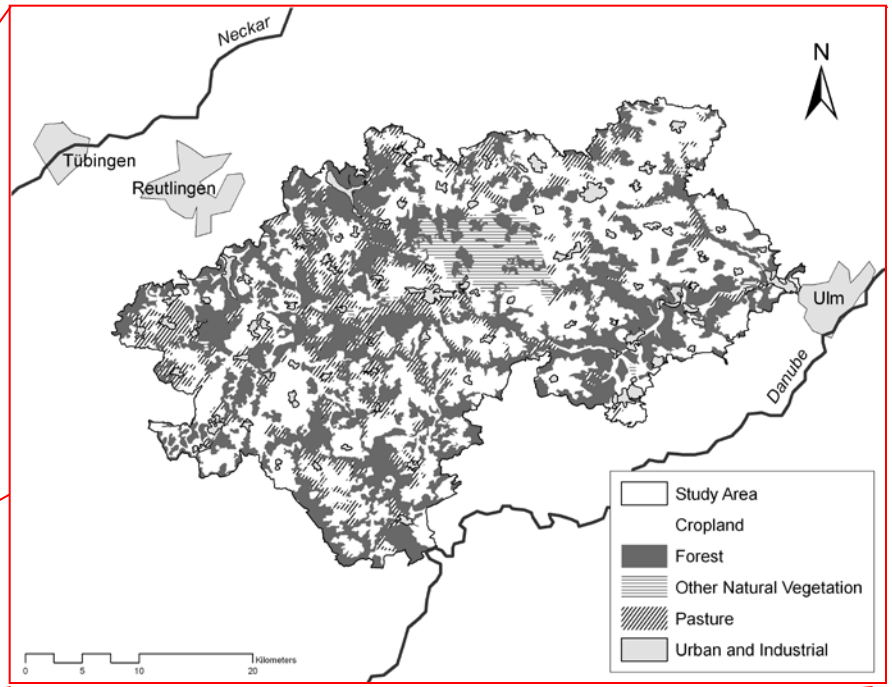
SFM

Types of Analysis

1. Predicting land use change and supply response of a regional agricultural sector
   - → Considering structural change, speed of learning, technology diffusion, risk management
2. Stress tests for existing or proposed risk coping strategies/insurance systems
3. Evaluation of policy interventions to facilitate adaptation

1. Predicting adaptation ...

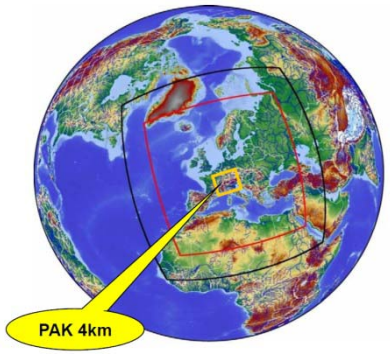


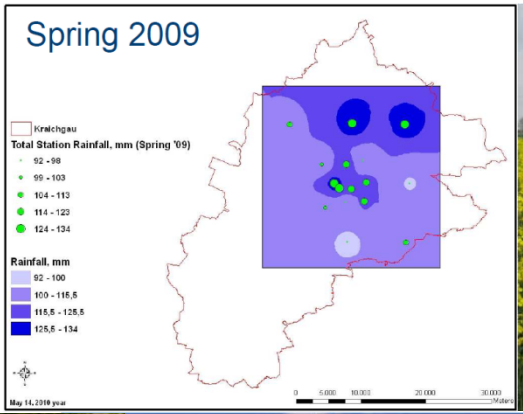


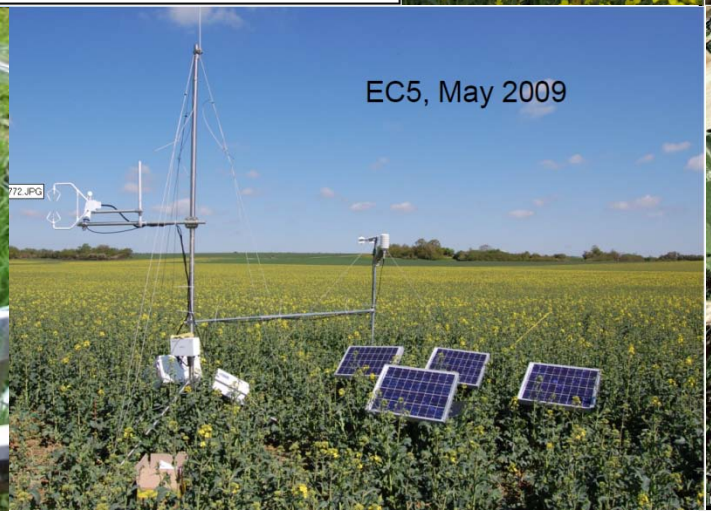
MP-MAS 'Central Swabian Alb'

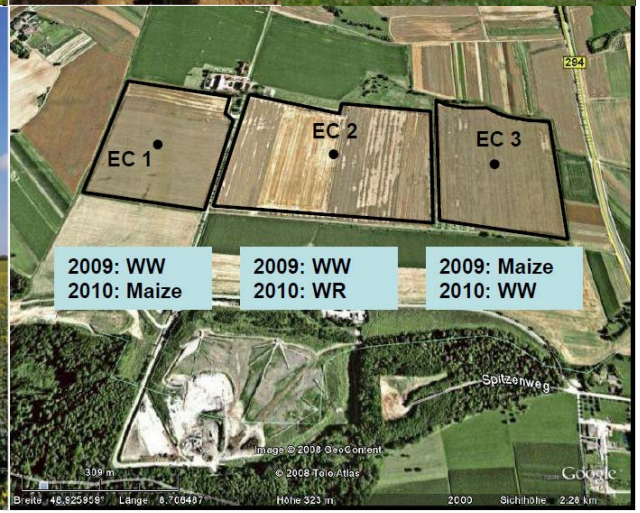
51,000 ha crop area,
770 farms (> 20 ha)

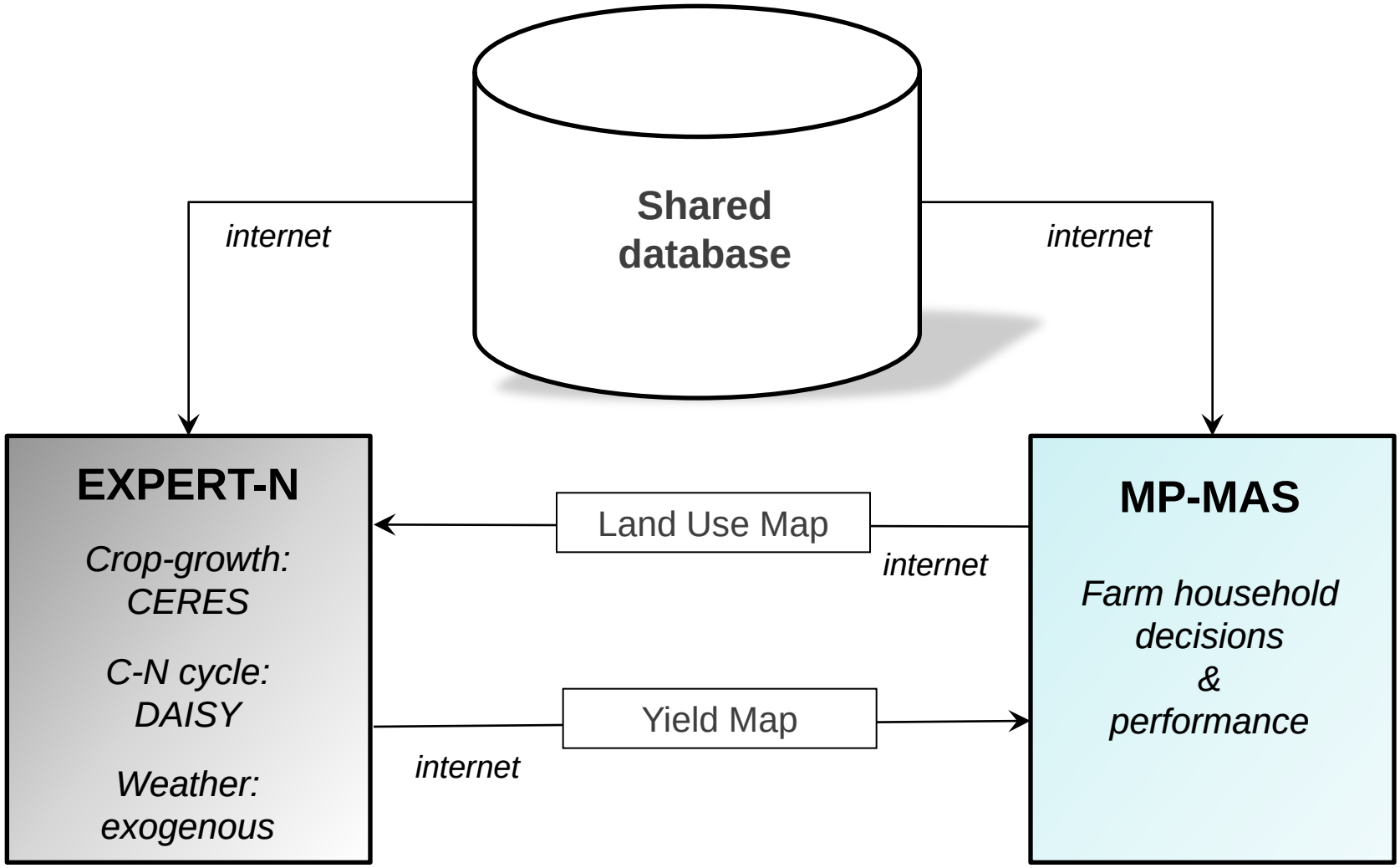
Integrated Project “Climate Change” (DFG)





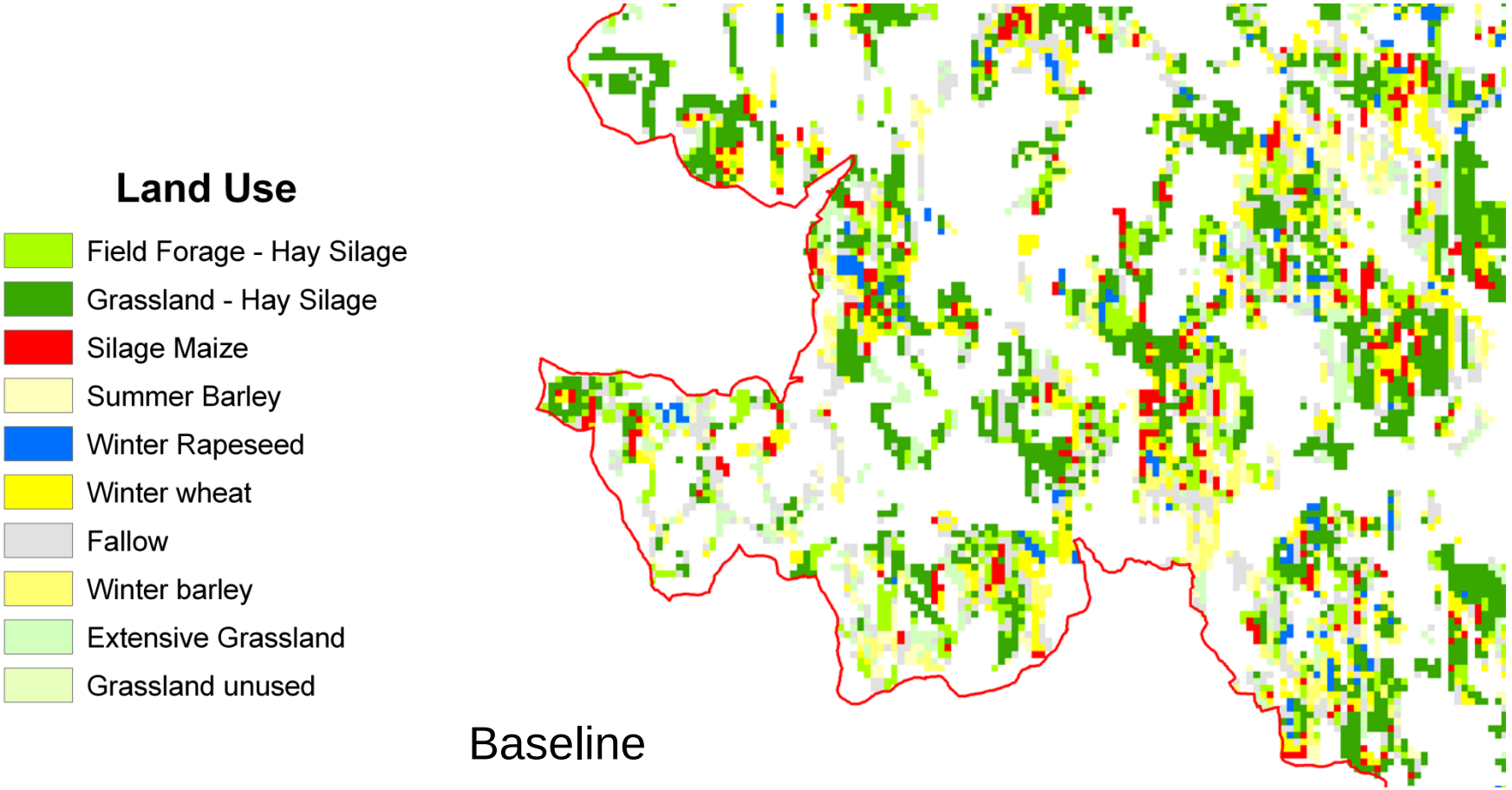




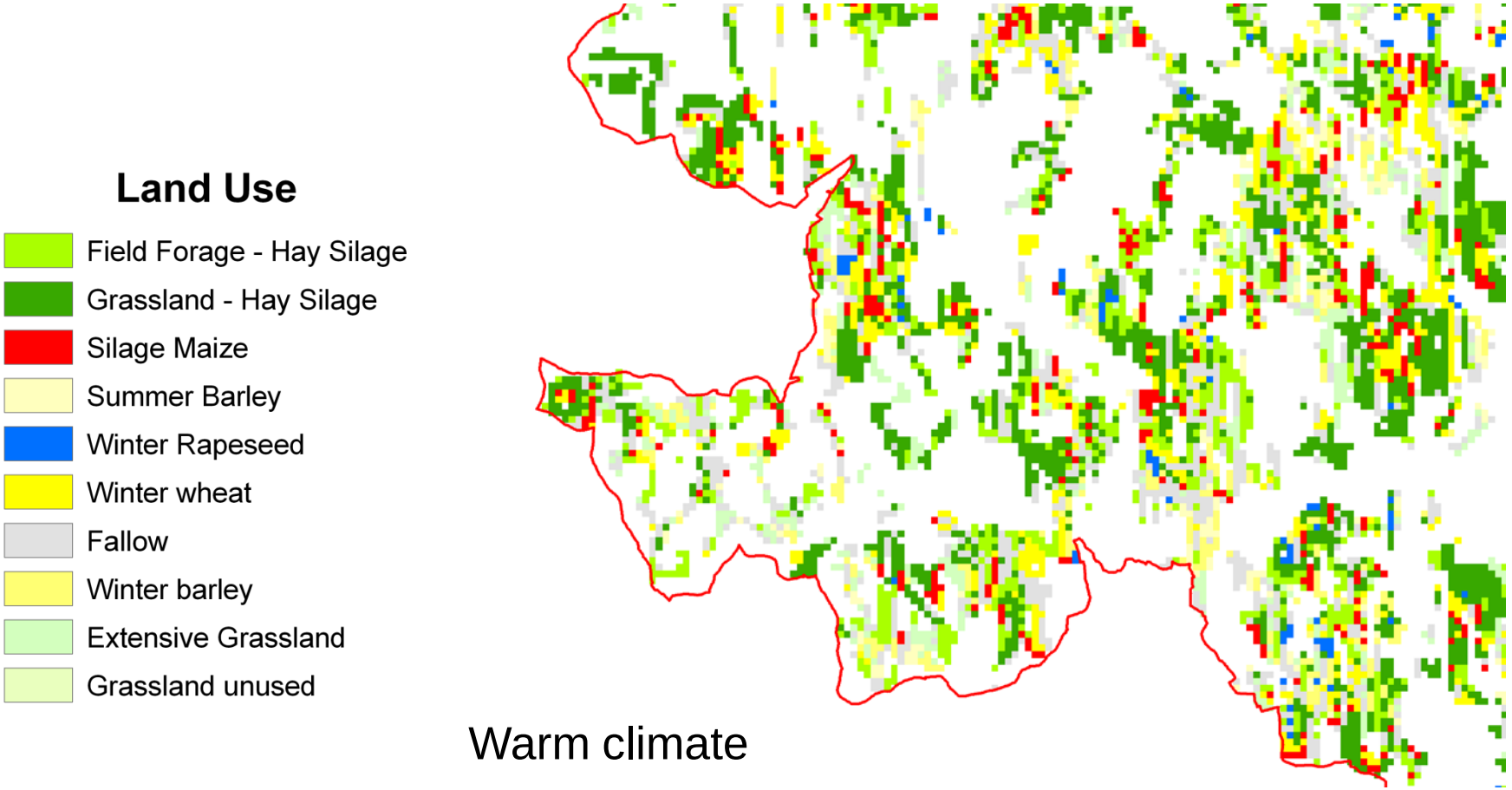

Shared database
internet
internet
EXPERT-N
Crop-growth: CERES
C-N cycle: DAISY
Weather: exogenous
Land Use Map
internet
Yield Map
internet
MP-MAS
Farm household decisions & performance

First Scenarios

- Weather
  - → Historical weather of 1995/1996 (‘normal‘)
  - → Historical weather of 2002/2003 (‘warm‘)
- Prices
  - → Average prices 1999-2006 (‘average‘)
  - → Peak prices 2007 (‘high‘)
- Adaptation of farmers
  - → None
  - → Short-term (changes in crop mix, herd size)
  - → Long-term (investment into stables, machinery)

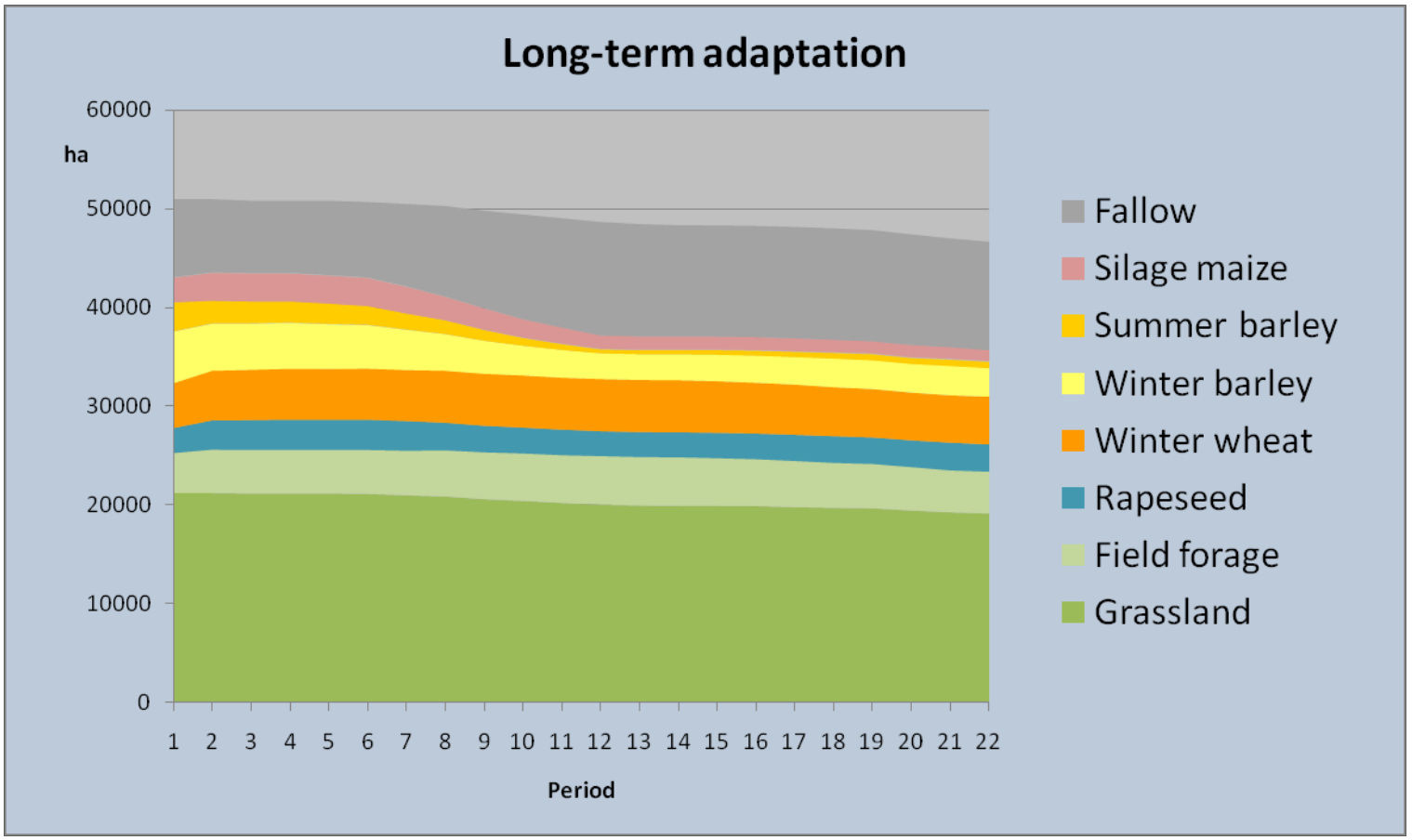

Land Use
Field Forage - Hay Silage
Grassland - Hay Silage
Silage Maize
Summer Barley
Winter Rapeseed
Winter wheat
Fallow
Winter barley
Extensive Grassland
Grassland unused

Baseline

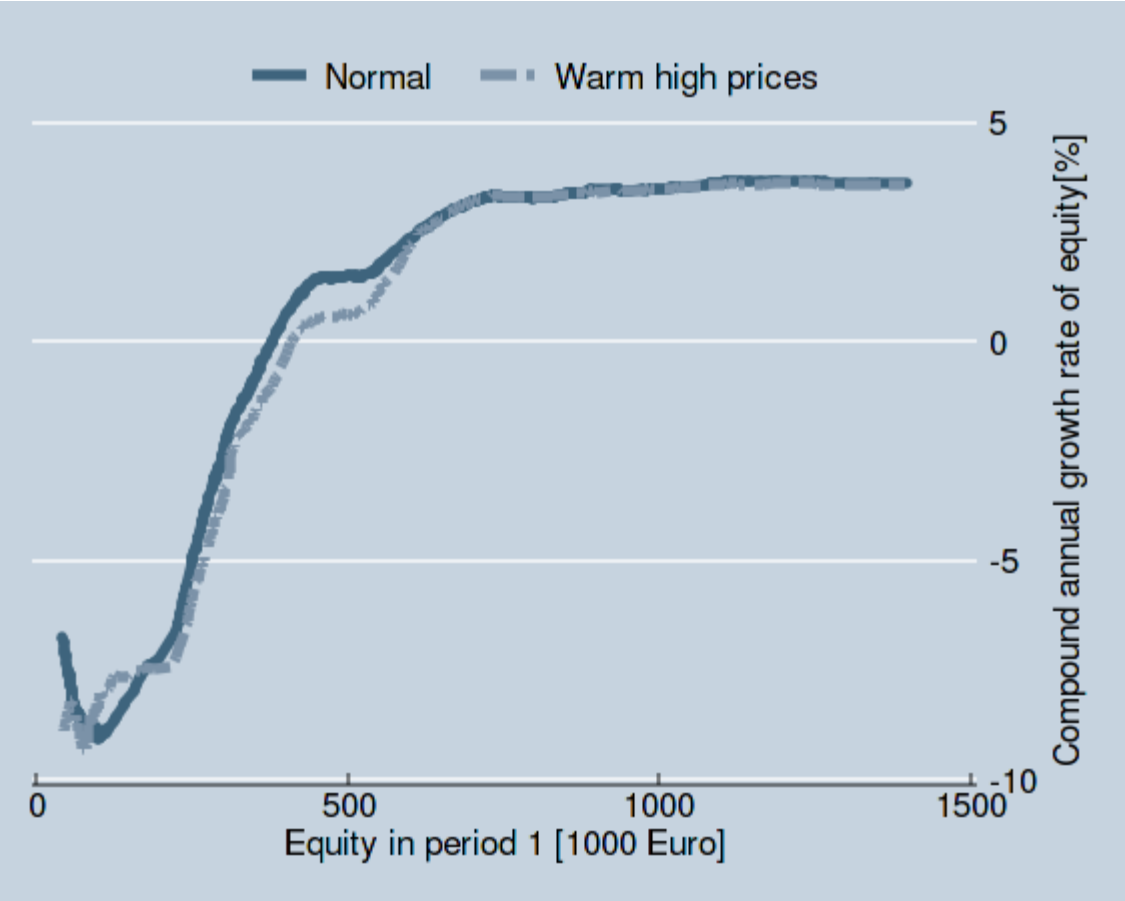


Warm climate

Simulation: Land Use



Disaggregation: Farm Equity



Preliminary results

- → Similar magnitude of climate and price effects
- → EU policy not yet considered
- → Constant weather, no learning, no risk

2. Testing risk coping strategies

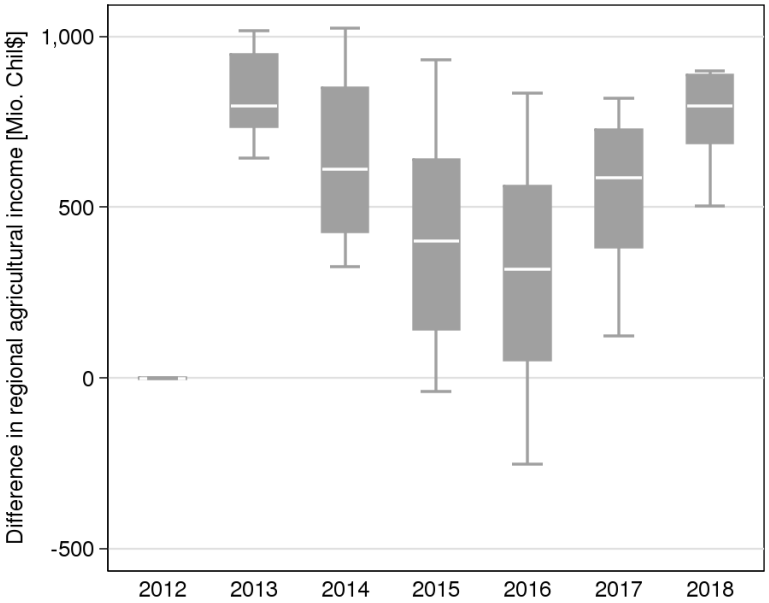
- Assess vulnerability & resilience of invididual strategies and collective insurance mechanisms
  - → Which individual risk management strategy proves most robust and should be recommended to farmers?
  - → What‘s the effect of individual diversification/ specialization upon crop/income insurance schemes?
  - → What is the effect of an increased probability of having several drought years in a row?
  - → Are established irrigation water management schemes still efficient with an increased probability of severe droughts?

3. Policy evaluation

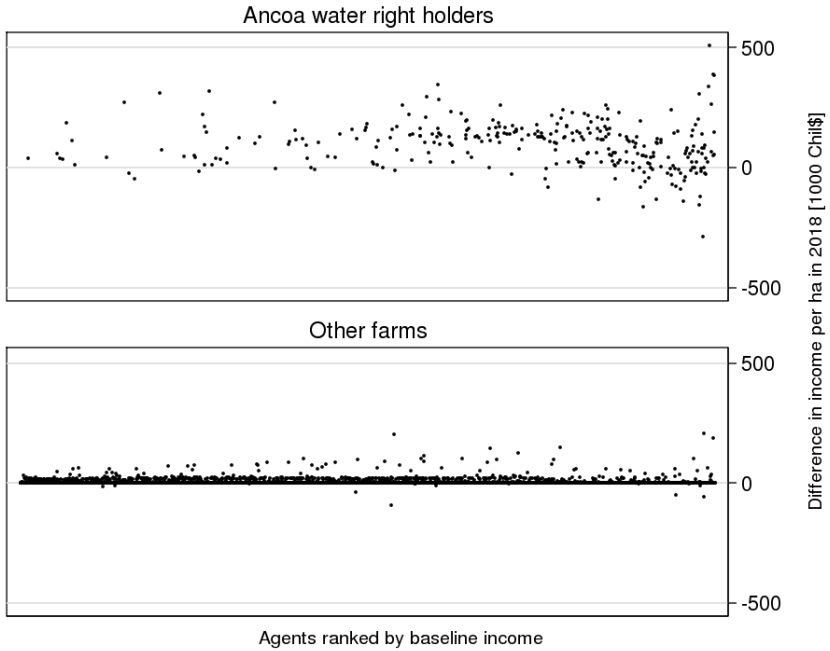
- Assess the effectiveness, distribution of benefits and feed backs of policy interventions
  - → Insurance schemes, weather derivatives, income transfers
  - → Response to agri-environmental incentives schemes
  - → Construction of infrastructure (e.g. water reservoirs)
  - → Diffusion of improved technologies (tolerant varieties, efficient irrigation)
  - → Seasonal weather forecasts (cf. *Ziervogel et al. 2005*)

Disaggregate policy evaluation

Chile: Construction of a reservoir for irrigation purposes



Aggregate effect of reservoir on regional agricultural income in the first seven years after the inauguration. (distribution over LHS sample of uncertain parameters)



Income effect of reservoir on farm households as the median of a latin-hypercube sample over the uncertain parameter space

Challenges

- Make theories of learning and collective action usable for empirical modelling
- Find a balance between holism and simplicity
- Challenges of model integration and interdisciplinary research

Summary

- Adaptation buffers effects of climate change
- Agent-based models allow detailed analysis:
  - → Structural change, disaggregation
  - → Learning, risk, individual strategies
- ABM complement information provided by other types of models
- Market forces and policies are as important as climate change (input from CGE)