Modeling
Agri-Environmental Interactions
for Policy Analysis

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Model based Policy Analysis
in memoriam Prof. Dr. Wilhelm Henrichsmeyer
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Background: Interactions between agriculture and the environment

Tools:
- Bio-Economic Modelling
- Regional / Farm Type aggregate programming models
- National / Global land use models
- Global market models with environmental satellites
- Spatial down-scaling and post modelling processing

Pros and cons, challenges of combined tool usage

Summary and conclusions
Some words of caution:

- Presentation due to “surprise effect” based on own research agenda and not on systematic literature review
- Research field certainly broader, but cannot be covered in sufficient detail in one presentation
- Bio-physical components without behavioral model excluded if not directly linked to economic tools
- Certain “Henrichsmeyer” bias by focusing on approaches covering all agricultural activities and including market feedbacks
Growing awareness of limited global resources (soil, water, fossil energy, bio-diversity and habitat loss)

Agriculture, despite small GDP share in developed nations, still a dominating land use activity, with important positive and negative environmental externalities

Interaction between (fossil) energy markets and agriculture, contribution of agriculture to climate change and its mitigation

⇒ Agricultural, energy and environmental policies interact
⇒ Need for quantitative impact assessment (tools)
Agri-Environmental Interactions

Earth
- Global Warming
- Biodiversity and habitat loss
- Fossil energy use/substitution

Soil
- Degradation
- Erosion
- Salinisation

Water
- Removal
- Eutrophication
- Nitrates
- Pesticides

Air
- Ammonia
- Acidification

Agriculture
- Typical example: FFSIM in SEAMLESS (Louhichi et.al. 2010)
- (N)LP based programming models with exogenous prices
- Risk behaviour can be integrated
- Highly detailed technology description, covering variants of relevant processes such as tillage, including not adopted ones
- Distinction by soil types, farming system etc.
- Parameterization partly based on simulations with crop-growth models
- Many applied in case-studies (data availability, resources needed for parameterization/calibration/validation)
Advantages

- Resource specificity (soil, climate, farm endowments)
- Excellent interfacing to agri-environmental policy instruments (opt-in measures, taxes, regulatory approaches)
- Rich set of environment related results from crop growth models

Dis-advantages

- Often rather normative – necessary observations for calibration/validation scarce
- Expensive survey based data acquisition
- Generalization of results challenging
- Missing price feedback
Regional/Farm type Programming Models

- Typical examples: RAUMIS (Henrichsmeyer et.al. 1996)
- Sub-national resolution based on administrative regions
- Calibrated to observed farming practise, based on Positive Mathematical Programming and extensions
- Cover all of agriculture (Economic Accounts for Agriculture, Land use, Herds)
- Some major environmental processes/indicators e.g. N/P/K balancing, GHG emissions integrated as constraints
Advantages

- Key farm practise data such as crop areas, herd sizes & yields readily available from official statistics as time series
- Typically higher resource specificity and improved description of farm level processes compared to market level models

Dis-advantages

- Less technological detail and resource specificity compared to Bio-Economic modelling, regions assumed to be homogenous
- Input allocation to processes/regions challenging and labour intensive due to data limitations
- Missing price feedback
- Typical example: GLOBIOM (Havlik et al. 2008)
- Builds on FASOM (Adams et al. 1996) model family: LP based supply, spatial, endogenous prices via welfare maximisation, recursive-dynamic, agriculture and forestry covered
- Land and water as fixed resources
- Sourced by EPIC

Homogenous response units underlying GLOBIOM, Skalský et al. (2008)
Advantages:

- Some resource specificity combined with global coverage
- Major competing land uses included
- Link to bio-physical model allows e.g. to capture mitigation options for CO2 (equivalents)

Dis-advantages:

- Only own-price demand elasticities
- Parameterization, calibration/validation
- Higher spatial resolutions lead to very large LP frameworks (solution time, debugging, quality control)
Extensions of existing (market) models with new endogenous modules

Examples:
- Integration of a land-use module in GTAP (GTAP-AEZ, Lee 2005)
- Integration of 126 river basins in IMPACT (IMPACT-Water Rosegrant et.al. 2008)

Advantages:
- Global perspective
- Market feedback

Dis-advantages:
- Highly stylized technology and policy description
- Regional aggregation quite high
Spatial downscaling

- Examples: Land-Use Cover Change (LUCC) modelling (e.g. Verburg and Overmars 2009), CAPRI-Dynaspat (Leip et.al. 2008)

- General approach:
  - Estimate quantitative relations between local factors (soil, climate, topography, existing land cover) and land use resp. agricultural management (crop shares, stocking densities, yields, input use)
  - Dis-aggregate given results on higher regional scale based on estimated relations

Example from CAPRI-Dynaspat: Ruminants in livestock units per ha fodder area, France, 2001-2003
Spatial downscaling

- **Advantages:**
  - Economic models operate on established regional scale (data availability, estimation of behavioural parameters, response time, model size and complexity)
  - Independent down-scaling tool can apply different methodology (e.g. cellular automaton) and software
  - Serves as input into bio-physical models, e.g. FATE (Baraoui and Grizetti 2008, CAPRI-DNDC link (Leip et.al. 2008))

- **Disadvantages:**
  - Post-model step – indicator calculators and underlying processes are not integrated in economic models
  - Linked bio-physical models may contradict aggregate relationships in economic models
For any policy instrument where aggregate perspective matters (price feedback, indirect land use change, GE):

- Tension between required level of detail to capture environmental impacts and policy instruments – spatial resolution, process detail – and enormous data and processing need
- Stand-alone use of one specific tool often not promising – tools with the required detail are not sufficiently encompassing, global tools (PE or GE) can hardly be dis-aggregated to appropriate scale

⇒ Increasing interest in combined tool use
⇒ Large-scale EU framework projects (SEAMLESS, SENSOR)
Exploit **comparative advantages** by **combining** tools, e.g.

- Integration of bio-economic or regional models with market models to allow for price feedback while keeping technological detail and spatial resolution
- Integration of land-use models with agricultural/forestry models to capture land-use dynamics
- Combination of agricultural and bio-physical models for detailed impact assessment, e.g. on different N-Compartments

=> Major research question: how to ensure matching response e.g. to price/policy changes in different tools?
Improved consistency in combined tool use:

- **Sequential calibration:**
  - Models updated and solved iteratively till convergence (CAPRI e.g. Britz 2008, Jansson et.al. 2009 for CAPRI and GTAP)

- **Response surfaces:**
  - Britz & Hertel 2009 linking CAPRI supply models and GTAP
  - Perez et.al. 2010 extrapolate supply response from bio-economic models FFSIM to regional scale, Adenäuer et.al. calibrate CAPRI regional models to the upscaled response of FFSIM
Example for top-down model chain

**Global market models** (e.g. GTAP/CAPRI)

**Regional economic models** (e.g. CAPRI, RAUMIS)

**Total agricultural land at region level**

**Broad land use classes**

**Region land use per crop**

**Spatial downscaling of agricultural practice** (e.g. CAPRI Dynaspat)

**National/regional LUCC** e.g. CLUE

**Global LUCC** e.g. IMAGE

**Globe Nation**

**Region**

**Landscape**

Britz: Modelling Agri-Environmental Interactions for Policy Analysis
Modelling agri-environmental interactions:

- currently a **dynamic scientific field** which competing approaches
- requires data and tools capturing relevant **farm management processes** (tillage, fertilizing and irrigation practise, use of pesticides ..)
- remains **challenging**, especially if tools operating at appropriate spatial / temporal / process resolution are combined with global models
Future research

- Weakly covered bits such as appropriate indicators for bio-diversity or landscape assessment
- Robust behavioural models for
  - Participation rates for opt-in measures or cheating rates
  - Adaption of new farm management practises
- Appropriate communication of multiple indicators and multiple scales (space, time) – upscaling, indices, choice of social discount rates?
- How to deal with uncertainty and stochastics, e.g. the question of possible catastrophic events?
Thanks for your attention!


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Henrichsmeyer, W. et.al. (1996): Entwicklung eines gesamtdeutschen Agrarsektormodells RAUMIS96. Endbericht zum Kooperationsprojekt. Forschungsbericht für das BML (94 HS 021)


