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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Content

- 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

Introduction

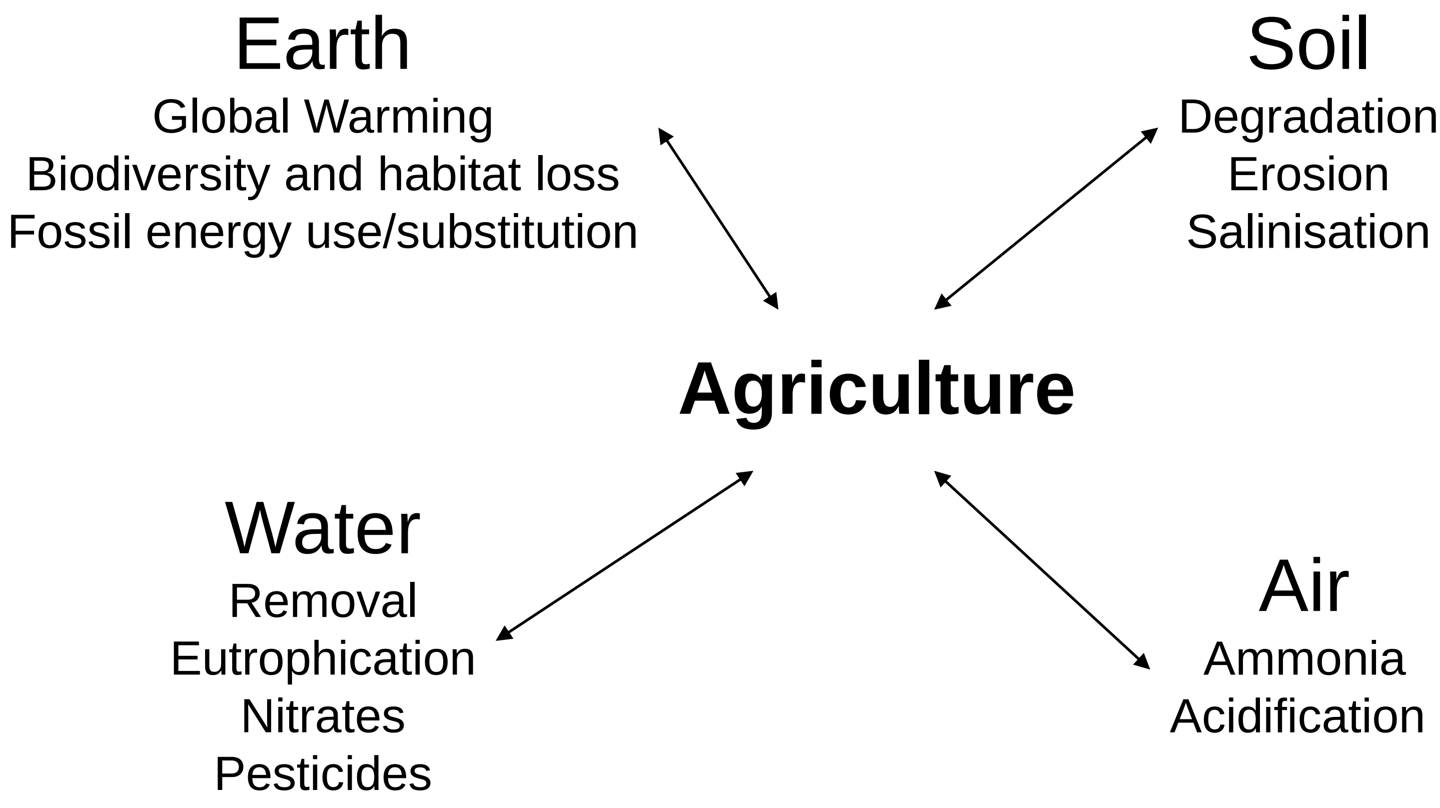
- Some words of caution:
  - Presentation due to “surprise effect” based on own research agenda and not on systematic literature review
  - Research field certainly broader, but cannot be covered in sufficient detail in one presentation
  - Bio-physical components without behavioral model excluded if not directly linked to economic tools
  - Certain “Henrichsmeyer” bias by focusing an approaches covering all agricultural activities and including market feedbacks

Background

- 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

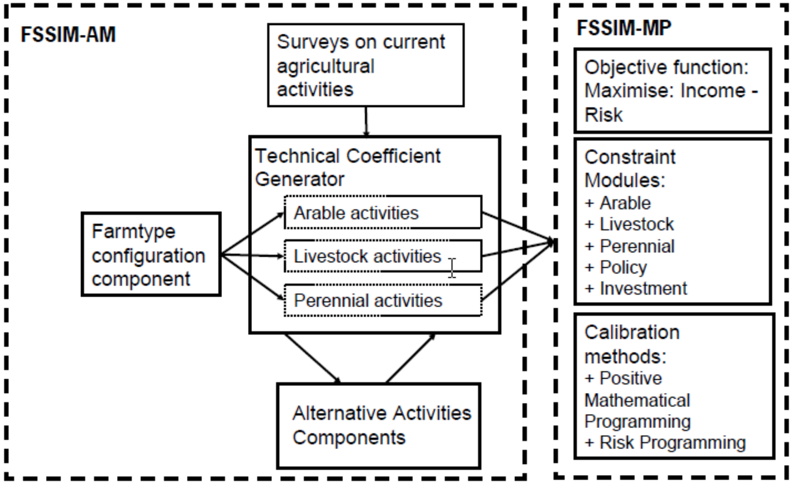
  ⇒ Agricultural, energy and environmental policies interact
  ⇒ Need for quantitative impact assessment (tools)

Agri-Environmental Interactions



Bio-Economic Modelling

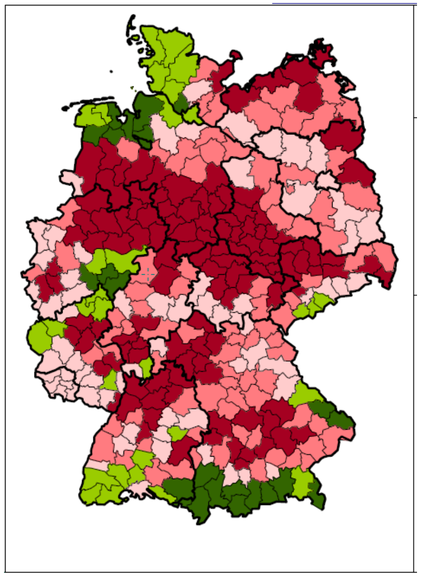
- Typical example: FFSIM in SEAMLESS (Louhichi et.al. 2010)
- (N)LP based programming models with exogenous prices
- Risk behaviour can be integrated
- Highly detailed technology description, covering variants of relevant processes such as tillage, including not adopted ones
- Distinction by soil types, 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

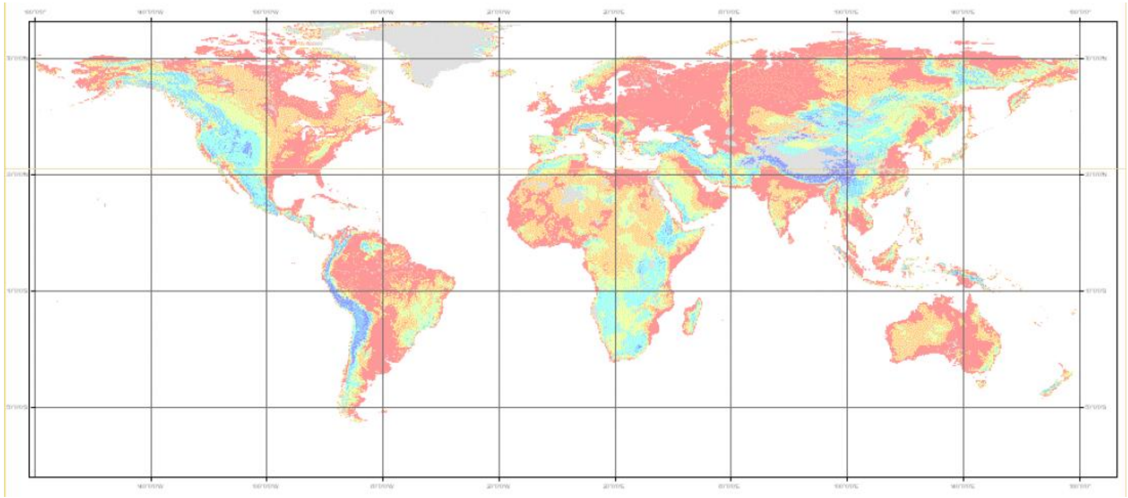


Regional/Farm type Programming Models

- 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

National/Global Land Use Models

- 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



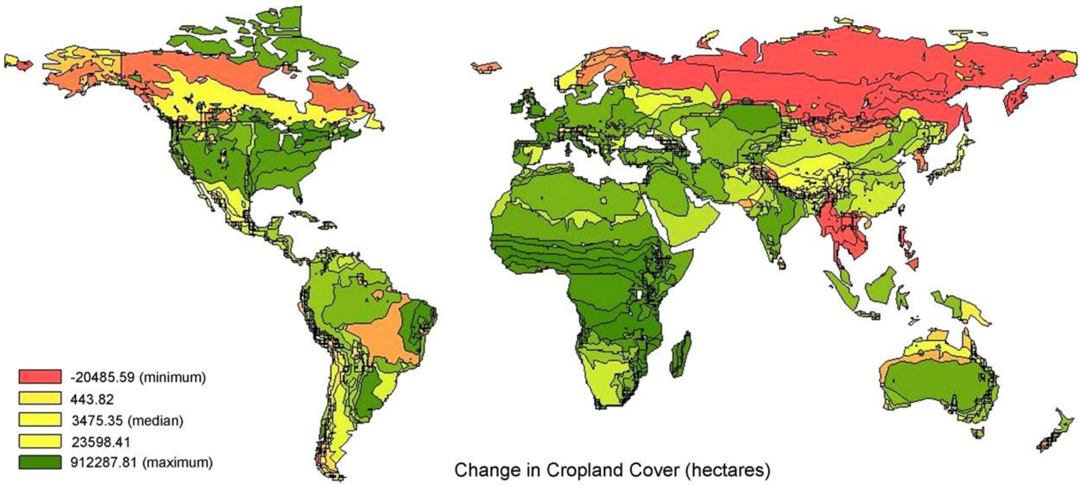
Homogenous reponse units underlying GLOBIOM, Skalský et.al. (2008)

National/Global Land Use Models

- 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 CO_2 (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)

Market models with „Environmental Satellites“

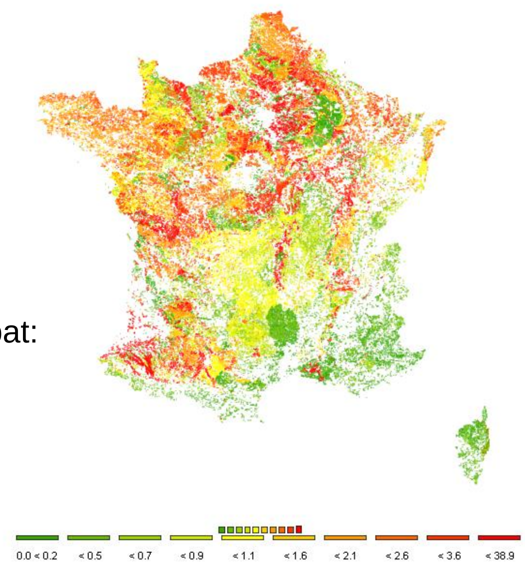
- Extensions of existing (market) models with new endogenous modules
- Examples:
  - Integration of a land-use module in GTAP (GTAP-AEZ, Lee 2005)
  - Integration of 126 river basins in IMPACT (IMPACT-Water Rosegrant et.al. 2008)
- Advantages:
  - Global perspective
  - Market feedback
- Dis-advantages:
  - Highly stylized technology and policy description
  - Regional aggregation quite high



Example from GTAP-AEZ (Britz & Hertel 2009)

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

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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

Intermediate conclusions

- 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)

Model chains

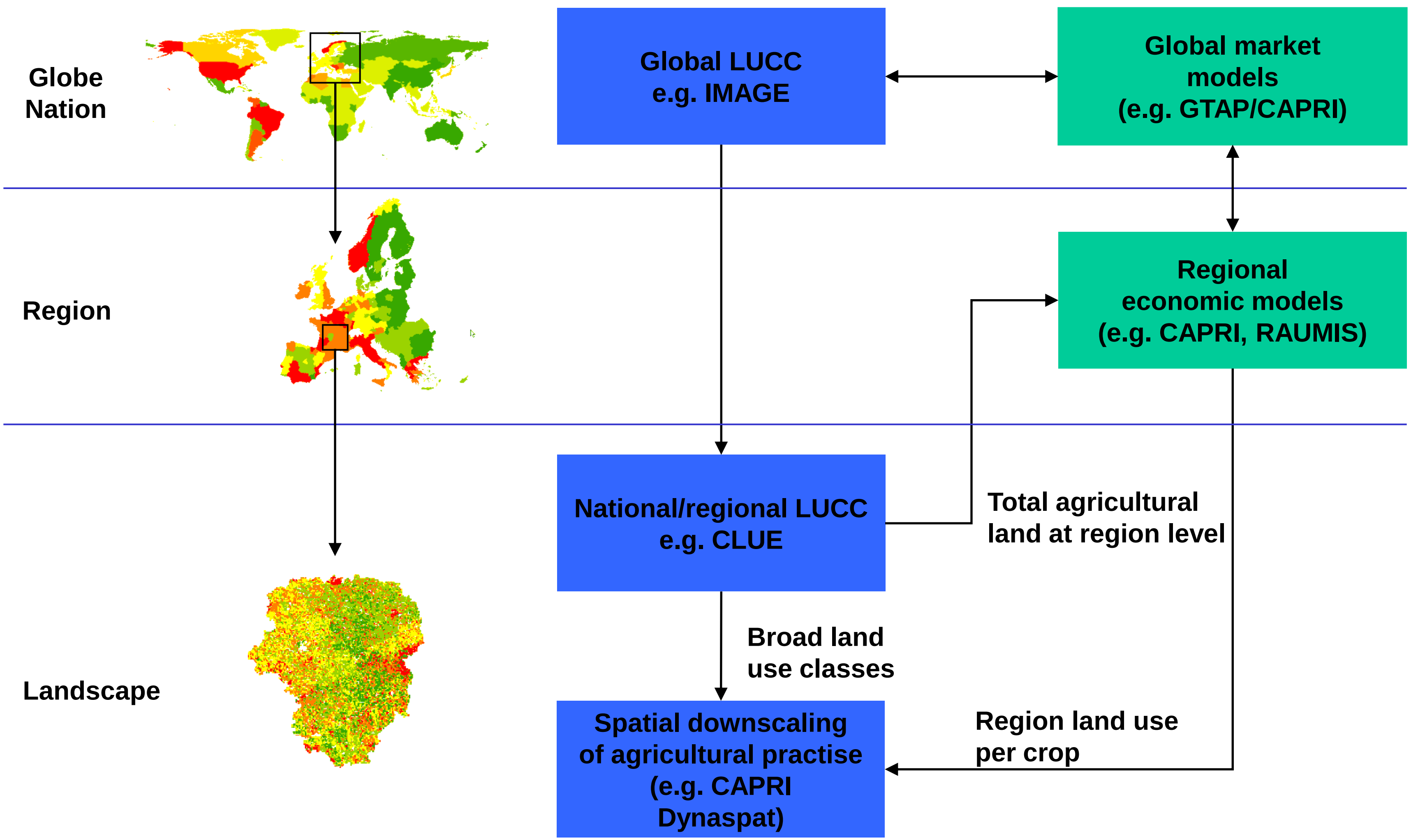
- Exploit comparative advantages by combining tools, e.g.
  - Integration of bio-economic or regional models with market models to allow for price feedback while keeping technological detail and spatial resolution
  - Integration of land-use models with agricultural/forestry models to capture land-use 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?

Model chains

- 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



Summary

- 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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