Modeling GHG emissions and carbon sequestration in Swiss agriculture

an integrated economic approach

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A modeling approach developed at ETH Zurich together with Simon Peter and Michael Hartmann

Background and motivation

Original research questions

(Swiss Farmers Union & Federal Office for Agriculture)**:**

- Economic appraisal of soil carbon sequestration potentials
- Monetary assessment of the economic value of GHG mitigation by Swiss agriculture
- Estimation of the supply (marginal cost) for further GHG reductions by Swiss agriculture

Further research issues:

- Assessment of agricultural Nitrogen losses in Switzerland
- Assessment of bioenergy potentials in Swiss Agriculture
- “GHG 2020” with longer time horizon, technological mitigation options, and evaluation of different policy options

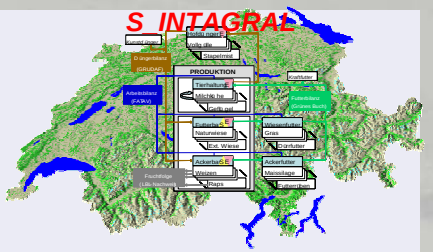
Methodology

An integrated economic modeling approach:

- Develop a new model that is
  a) as simple as possible and as comprehensive as necessary, and
  b) designed to answer a specific set of research questions.

- A model that allows us
  - to fully represent the agricultural GHG emissions & mitigation options (→ national GHG inventory + IPCC guidelines + scientific studies), and to assess the cost of GHG mitigation;
  - to project the development of the Swiss agricultural production system and its major environmental impacts (GHG emissions, Nitrogen losses, land use patterns).

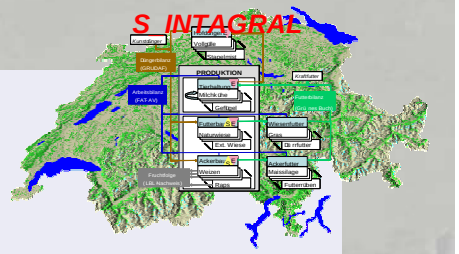
S_INTAGRAL:
Swiss INTegrated AGricultural ALocation model



- **A tool for the economic evaluation of agri-environmental problems:**
  1. Carbon sequestration in agricultural soils
  2. Agricultural GHG emissions and mitigation
  3. Nitrogen losses from agricultural systems
  4. Land allocation and structural adjustment
  5. Bioenergy production

- **A recursive-dynamic tool which represents all economically and environmentally relevant agricultural activities on the aggregate level of Swiss agricultural production system.**

The concept of the model



A sectoral production model of Swiss agriculture:

- **a regulated system in a small open economy which is in transition to EU/world market prices**
  → step-wise demand function with 2 different price levels

An activity-analytic approach with myopic behavior:

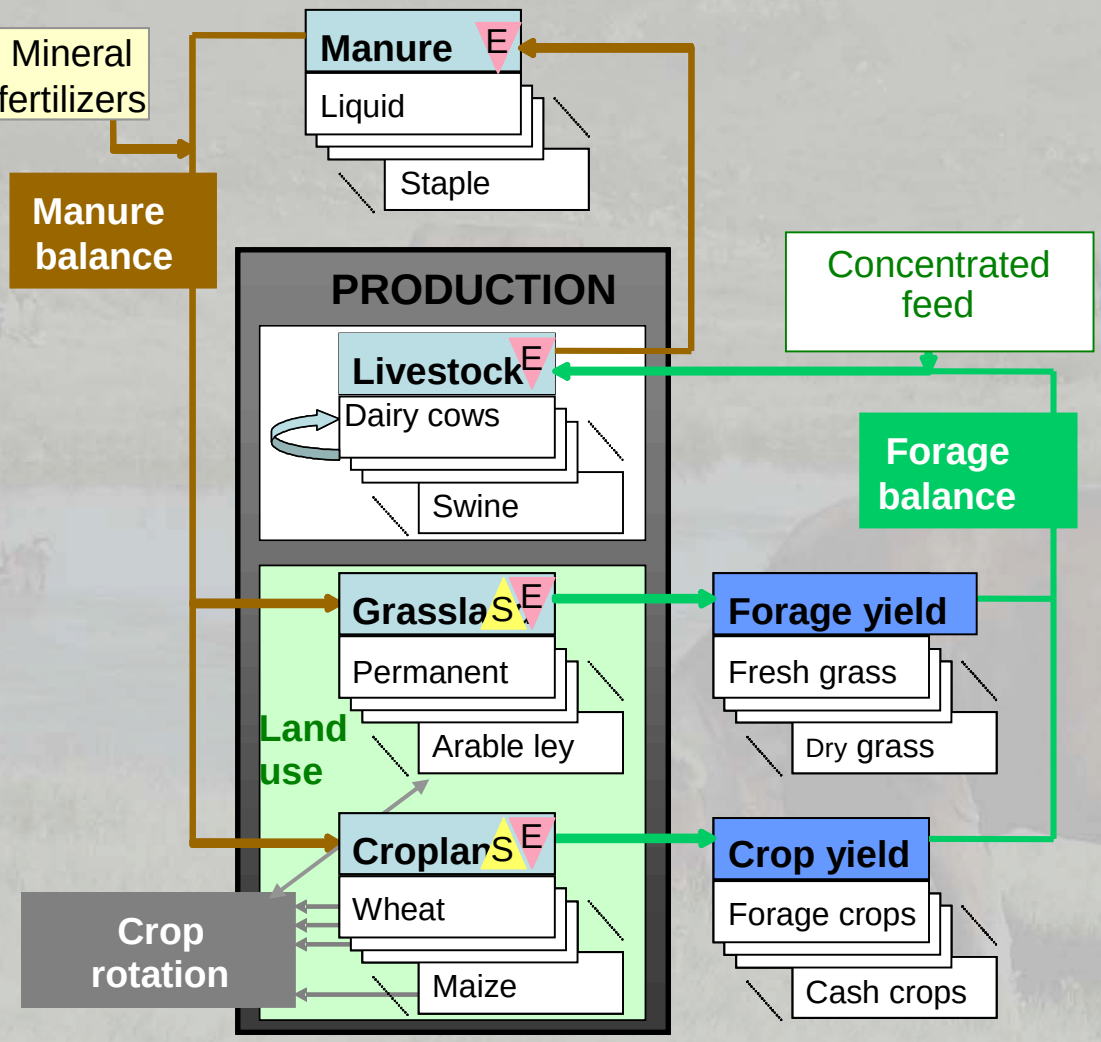
- **A linear programming (LP) model**

  with short-term maximization of the aggregate farm income (labour income + land rents)

  under consideration of production related constraints (integrated land use and livestock production system)

  as well as structural costs and path dependence through a recursive-dynamic integration

The structure of the model

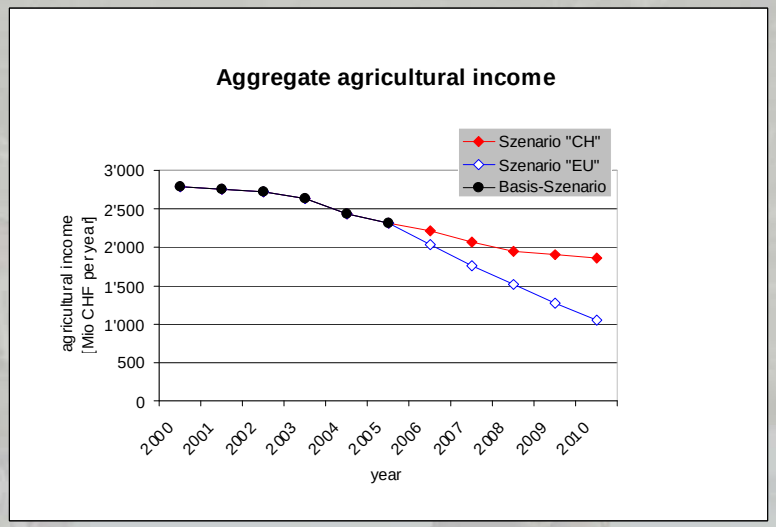


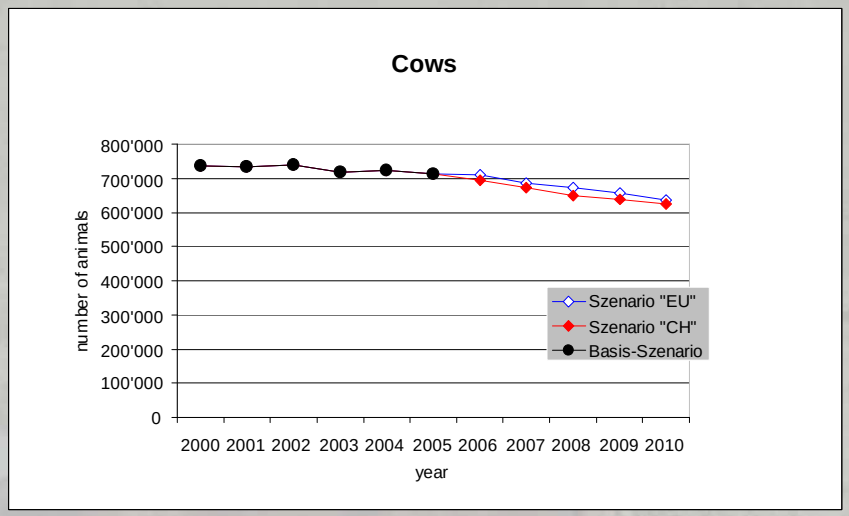
S = **Carbon sinks:**
- **no-till**
- **cropland → permanent pasture**

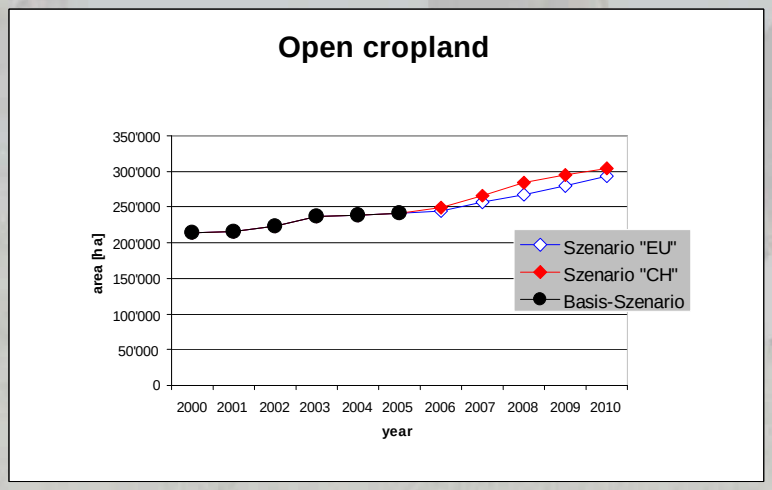
E = **GHG emissions:**
- **Fossil energy use**
- **Enteric fermentation**
- **Manure management**
- **Manure and fertilizer use**

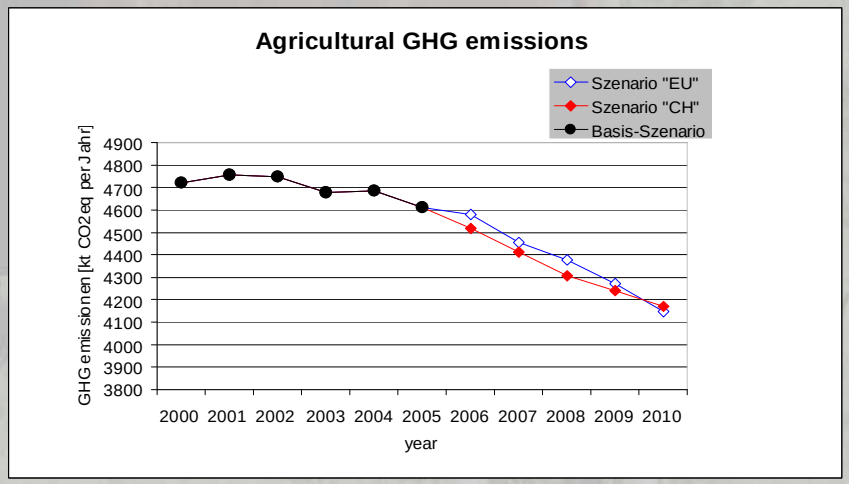
Structural dynamics:
- Stable capacities and population dynamics as constraints for livestock production.
- Dynamic adjustment of stable capacities, livestock and machinery.

Characteristic model results (base-runs)



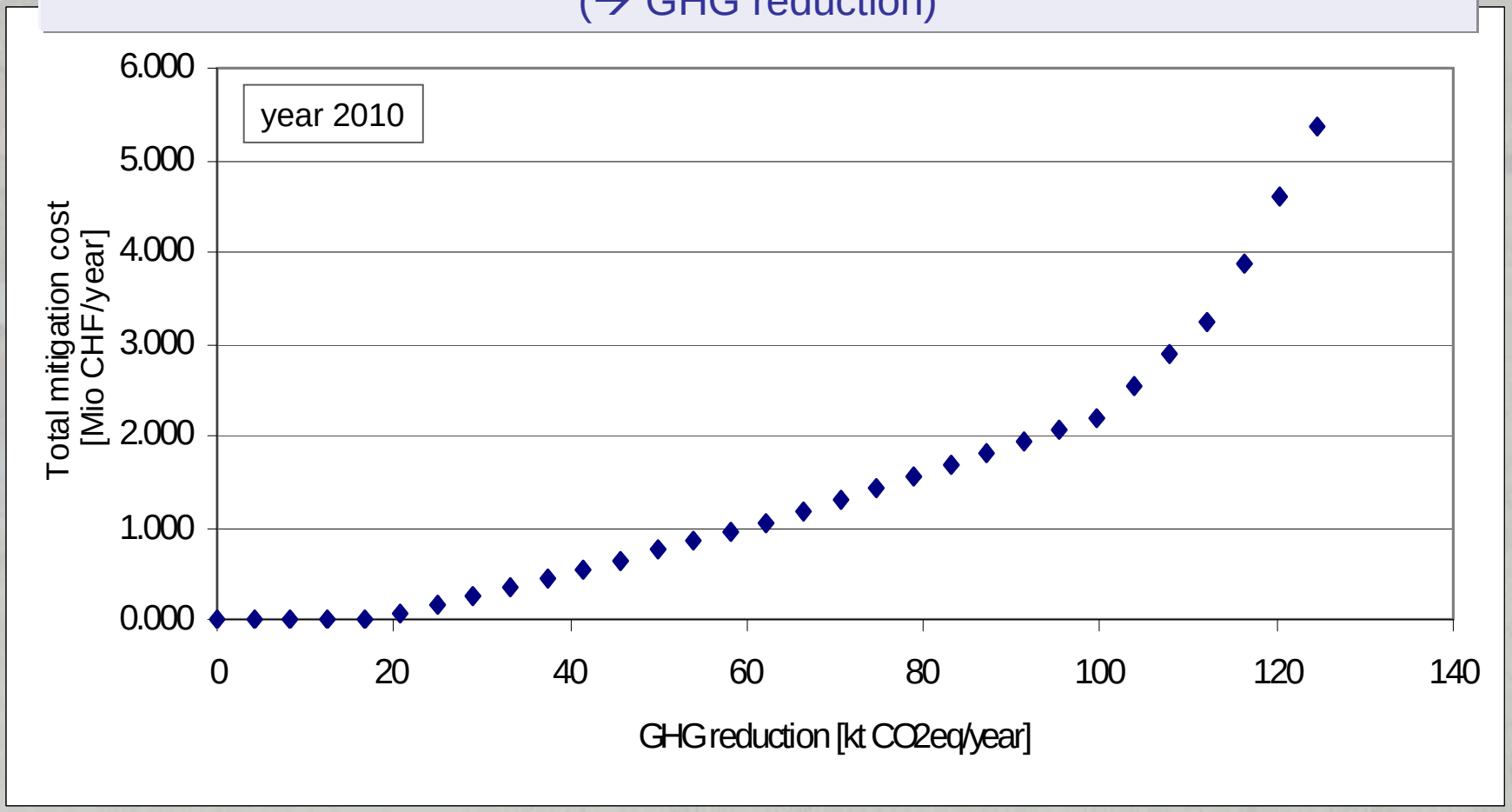


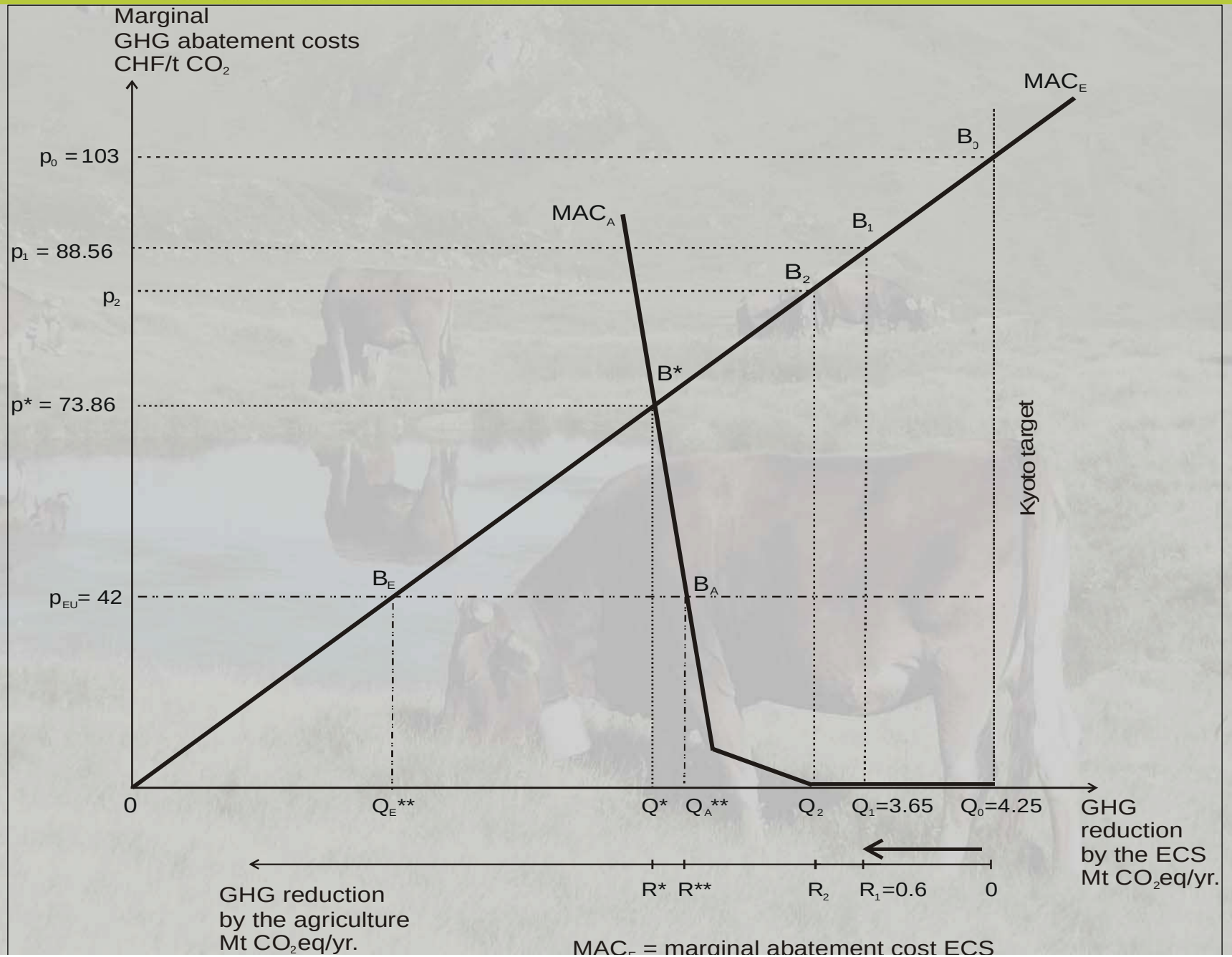




Estimation of GHG mitigation costs

Mitigation cost = Δ income resulting from an increase in the GHG constraint (→ GHG reduction)




Marginal
GHG abatement costs
CHF/t CO_2
MAC_E
B_0
$p_0 = 103$
MAC_A
B_1
$p_1 = 88.56$
B_2
p_2
B*
$p^* = 73.86$
Kyoto target
B_E
B_A
$p_{EU} = 42$
0
Q_E**
Q*
Q_A**
Q_2
Q_1=3.65
Q_0=4.25
GHG reduction by the ECS Mt CO_2eq/yr.
R*
R**
R_2
R_1=0.6
0
GHG reduction by the agriculture Mt CO_2eq/yr.
MAC_E = marginal abatement cost ECS

Conclusion & remarks for modelers

- ✓ The **economic evaluation** of agricultural GHG mitigation options must be based on an **integrated modeling** approach that adequately takes into account the interdependencies and interactions of **crop and livestock production** and the **structural dynamics** of the system, such as the model *S_INTAGRAL*.
- ✓ **Sensitivity** of the system (the results of the optimisation) to (critical) changes in **relative prices** (producer prices & factor prices/calculated costs).
- ✓ The rigidity of the system is determined by the integrated nutrient cycles (**manure + forage**) and the structural dynamics and costs (**path dependence**) in the agricultural system.

Thank you for your attention.

Selected references (in English & available on the internet):

Hediger W.: “Modeling GHG emissions and carbon sequestration in Swiss agriculture: an integrated economic approach”, *International Congress Series* 1293, 2006, pp. 86-95.

Hartmann M., Hediger W., Peter S.: “How Much Should Swiss Farmers Contribute to Greenhouse Gas Reduction? A Meta-Analytical Approach”, *Yearbook of Socioeconomics in Agriculture* 2008, pp. 183-218.

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