Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V.

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Leibniz Centre for Agricultural Landscape Research

Cropping of legumes as a potential climate change mitigation strategy? Comparison of three different modelling approaches: CAPRI, MACC and MODAM

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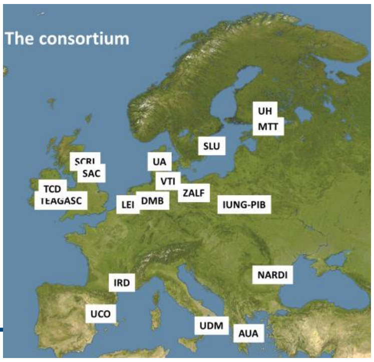
Legume Futures Project

- Legume-supported cropping systems for Europe (2000 to 2014)
- 18 partners, 18 field experimental sites (~ €4M)
- "to develop the use of legumes in cropping systems to improve the economic and environmental performance of European agriculture"
- Assess the agronomic & environmental role of legumes in farming systems
- Use of experimental and modelling approaches
- Design novel legume-based cropping systems for Europe
- Deliver productive, environmentally-friendly legume-based farming

➔ Potential cropping systems
➔ Environmental impacts
➔ Economic challenges



Advantages of legumes

N-fixation: no nitrogen fertiliser and reduced N demand in following crop

Break crop effect:

- Reduced crop diseases
- Improved soil conditions
- Improved soil fertility

EP study: role of protein crops within the CAP

15 - 25% yield increase in following crop yield

- Lower greenhouse gas emissions (nitrous oxide)
- Reduced fertiliser and fossil energy use
- Improved soil fertility
- Biodiversity
  - Mass flowering
  - Crop diversity
  - Soil organisms

Public intervention is justified

Protein crops contribute to different policy objectives and offer a unique combination of on-farm and public benefits

Protein Crops

- contribute to biodiversity
- reduce greenhouse gas emissions
- reduce fossil energy use
- provide high quality, high protein food and feed

On farm benefits

- N-fertiliser savings
- increased subsequent yields
- but low gross margins

CAP 2020

- Sustainability and Competitiveness of European Agriculture

Environmental policies

- Climate policy
- Water framework directive
- Nitrates directive
- Convention on Biological Diversity
- etc.

Reduced protein gap

- direct human consumption
- contribution to feed production
- may be adressed by EU protein strategy

Policy options within the CAP

- *More stringent crop diversification requirements (greening in Pillar 1)*

- *Classification of legume cropped areas as contribution to ecological focus areas (greening in Pillar 1)*

- *Voluntary coupled support schemes (direct support under Pillar 1)*
- ***What about a tax on GHG emissions?***

Focus

Objectives:

- show the influence of different modeling approaches
- investigate the potential of GHG mitigation through legumes

Policy scenarios

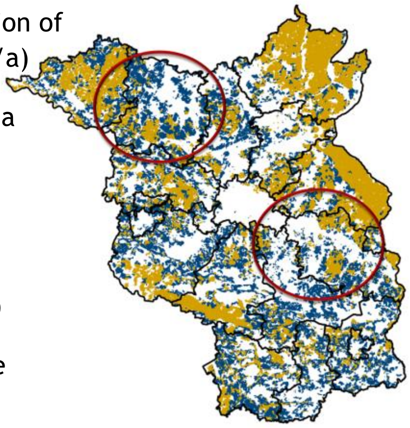
- carbon tax
- …

Three different modeling approaches

- CAPRI (LEI)
- MODAM (ZALF)
- MACC (SRUC)

Brandenburg

- sandy soils and relatively low precipitation of 554 mm/a (German average is 800 mm /a)
- large farm enterprises, average of 238 ha
- marginal areas cover 39% of arable area of Brandenburg (269 000 ha)
  - 81% of farms concerned (>2 600 farms with more than 10 ha)
- according to official and expert data the marginal areas are not profitable – but are actually cultivated



Methods

	CAPRI	MODAM	MACC
Name	Common Agricultural Policy Regionalised Impact Modelling System www.capri-model.org	Multi-Objective Decision support tool for Agroecosystem management www.modam.eu	Marginal abatement cost curve
General description	Partial equilibrium model - supply is built by few typical farms based on FADN data.	Supply model - LP whole farm models for typical farms. - Gross Margin maximization - Results are aggregated for a region by number of farms within a type	Supply model - Supply is modelled by Soil rent maximisation - for available arable land at regional level
Decision unit	Typical farms (from FADN typology)	Typical farms (from IACS typology)	Soil classes of arable land

data

	CAPRI	MODAM	MACC
Units of production	Farms – typology derived from FADN data	Farms – Typology derived from IACS data.	land area of the whole site class (only one rotation can be cultivated in a site class)
Crop production activities in Brandenburg	derived from FADN data and extended by for the introduction of legumes. - 7 Cereals, 3 Oilseed, pulses, potatoes, sugar beets, other - 7 horticultural crops - intensive &extensive grassland - fodder crops, Fallow land and set-aside (here the same thing)	Expert knowledge & literature based including set of rules to build rotations: arable crops and temporary grassland combined in 3000 rotations over 5 site classes, including feedstock productions crops: cereals (winter wheat, spring barley, winter barley, spring oat, winter rye, triticale), oilseeds (winter rape), pulses (faba bean, lupin, pea, seradel), fodder crops (glass-clover mixture, alfalfa, rye-vetch mixture, maize silage)	
Livestock production activities	○ 9 Cattle ○ 7 Pigs, ○ poultry and ○ other animals	○ dairy ○ suckler cows ○ fattening bulls ○ sows ○ fattening pigs	○ no livestock

Greenhouse gas impact of arable cropping

(IPCC coefficients 2006)

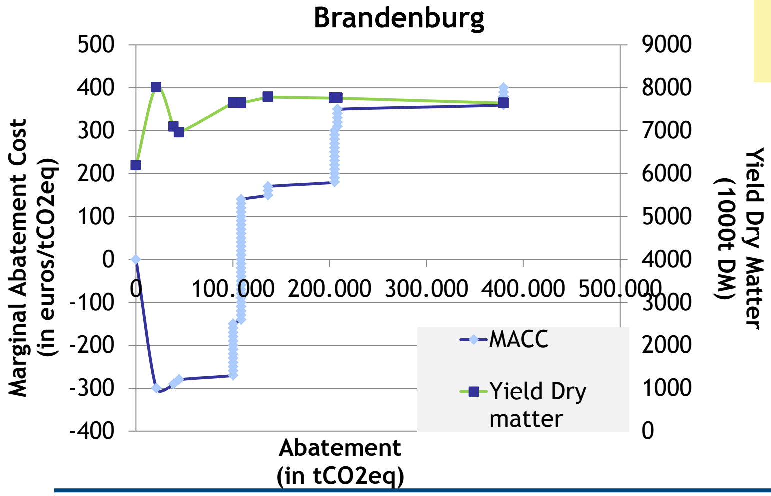
Crop	Average CO2 eq (t/ha)	Min CO2 eq (t/ha)	Max CO2 eq (t/ha)	CAPRI European average CO2 eq (t/ha)
lupin	0.07	0.06	0.07	
pea	0.19	0.15	0.21	0.16
fababea	0.35	0.34	0.38	
graclov	0.41	0.34	0.46	0.58
alfalfa	0.86	0.77	0.92	
wrye	1.06	0.41	1.57	
wbarley	1.12	0.97	1.56	
Wwheat	1.31	1.25	1.60	0.81
Wrape	1.72	1.42	1.92	
maize_s	2.73	2.05	3.11	

Climate Change 2007: Synthesis Report. Intergovernmental Panel on Climate Change, Geneva (available at www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html).

MACC

Results: Marginal abatement cost curve

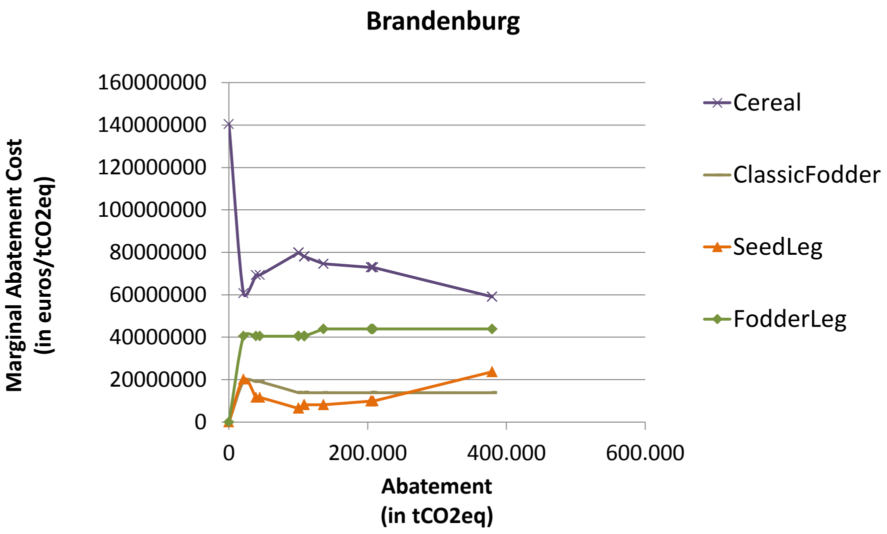
increasing CO_2 tax compared with a baseline scenario



- Neg. impact (win – win) caused by unrealisic baseline (one rotation)

MACC

Results land use



CAPRI

Scenarios

- Different ways to foster legumes were examined
- Premiums and taxes
- Model adaptations to allow „new“ legumes were neccessary

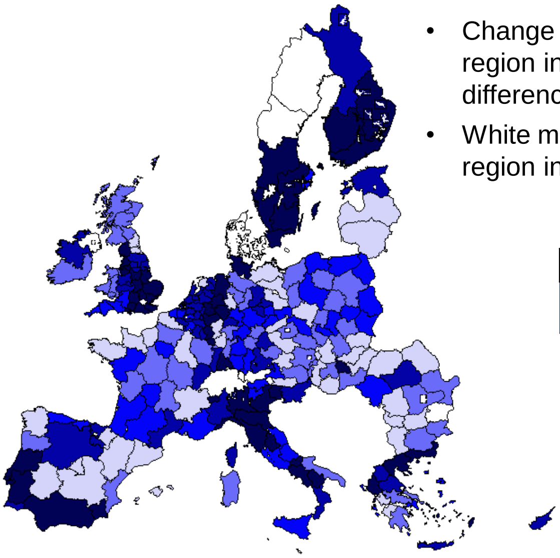
CAPRI

results

				Other arable crops				Fodder activities		
	Utilized agricul-tural area	Cereals	Oil-seeds		o.w. Pulses	o.w. Potat oes	o.w. Sugar Beet		o.w. Fodder maize	Set-aside and fallow land
CarbonA2 (18 € CO2 tax)	-0.4%	-1.1%	0.2%	3.5%	18.2%	-0.5%	-1.0%	-0.7%	0.8%	3.1%
CarbonB2 (72 € CO2 tax)	-1.6%	-4.3%	0.9%	14.5%	73.5%	-2.0%	-3.6%	-3.1%	-2.5%	12.1%

CAPRI

Carbon tax B2 (72€)

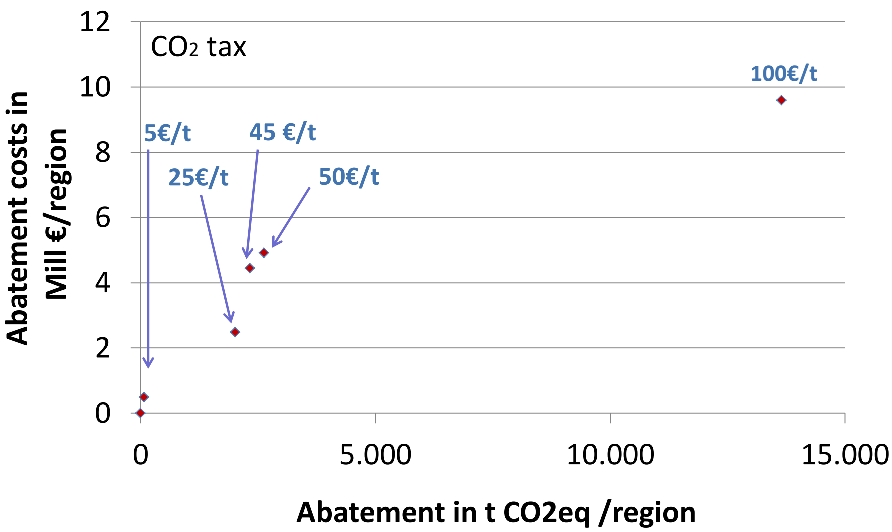


- Change in area under pulses per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference).
- White means that no pulses are grown in the region in the reference scenario)

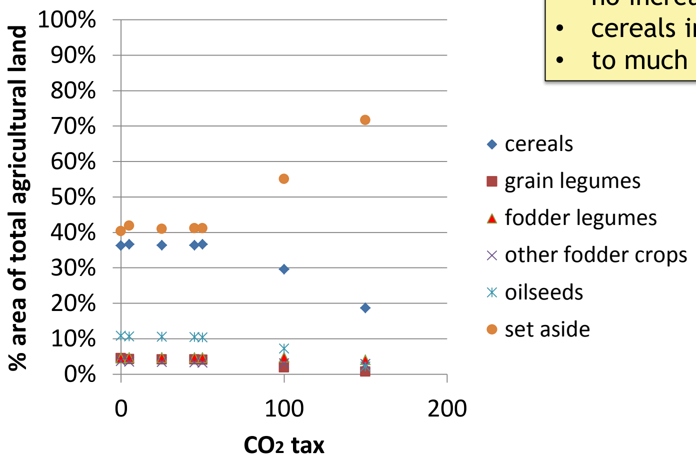
< 7.6	<15.3	<39.6	<120.5	>120.5

MODAM

GHG abatement cost



Development of the crop production area



- no increase in legumes
- cereals in realistic range
- to much set aside

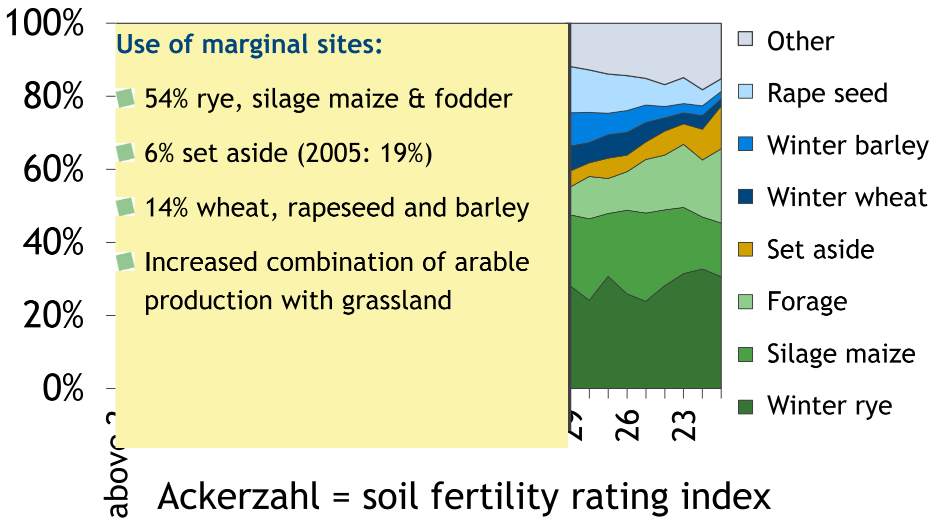
Land use according to IACS data 2010

	Crop group	area	% of agric.land
Arable land	forage arable	277104	20,9%
	protein crops	21086	1,6%
	cereals	514111	38,9%
	potatoe and sugar beet	17966	1,4%
	oil crops	143053	10,8%
Permanent	Grassland	281143	21,3%
Arable land	fallow	41557	3,1%

Land use according to IACS data 2011

Use of marginal sites:

- 54% rye, silage maize & fodder
- 6% set aside (2005: 19%)
- 14% wheat, rapeseed and barley
- Increased combination of arable production with grassland



Strategies in crop production
(qualitative survey among 7 farmers)

General: little unused arable land

Organic matter management (all farms)

- Organic manure (also purchased), biogas digestates, compost, cover crops

Cost minimization

- reduced fungicides, plant growth regulators, insecticides
- hardly reductions in herbicide, lime, fertilizer use

Yield maximization with investments in soil- and water management

- conservation tillage
- irrigation at sandy sites
- relatively intensive cop management

Comparison (CO_2 tax …€/t CO_{2eq})

MACC
- has impact on legumes

MODAM
- no impact on production of legumes
- More area set aside

CAPRI
- Has impact on legume production

Major advantages and disadvantages

	CAPRI	MODAM	MACC
Market	represents - Global market - EU-market	Only supply	Only supply
Data	FADN data are used and statistically evluated	Expert knowledge and local data is collected and organized for own gross margin calculation	See MODAM
Decision unit	Rough typology of farms	More detailed farm typology	No representation of farm structures
Calibration	PMP based on historical land use	No calibration, but - Plausibiltiy checks - Limits for crops typically under contract - based on historical land use	
Crop			

Major advantages and disadvantages - II

	CAPRI	MODAM	MACC
Crop production	Well presented due to PMP calibration	• More detailed through destinction of soil classes. • More sensible to errors and small differences in gross margins	ditto
Innovations / new crops …	Difficult to implement	Easy to implement	ditto
Single crops versus crop rotations		• rotations allow to work with pre crop effects, imply good agricultural practices • single crops allow more flexible response	

Outlook: Improved integrated modeling

- Closer cooperation has started with
  - crop modelling: to calculate yield and water shortage for climate scenarios, crops and soils in Brandenburg
  - hydrology: Water availability and potential hot spots of ground water recharge and water extraction for irrigation
- Simplification and elaboration of existing farm typology
  - **specific costs per farm size**
  - **Integrate different management strategies (irrigation, organic matter)**
- Addressing scale effects in production costs.