# Uncertainties from Climate Change on Farms and Ecosystem Services of a Grassland Dominated Austrian Landscape

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**TradeM International Workshop 2016**
**Assessing climate change adaptation and mitigation options: The regional and policy dimension**
*Somewhere along Norway, October 9-12, 2016*

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# Problem statement

*„There have been harsh winters in the past. And there have been winters with only little [snow] in the past. And there were (…) wet summers, there were dry summers. (…) So I cannot asses in my 60 years, if this has changed".*

Farmer, 2016 (Survey by Magdalena Stöttinger, upublished)

*"I do not think that somebody is capable of telling us with guarantee how it will be in the next 5 or 10 years. […] There are tendencies but nobody knows about the rate of change."*

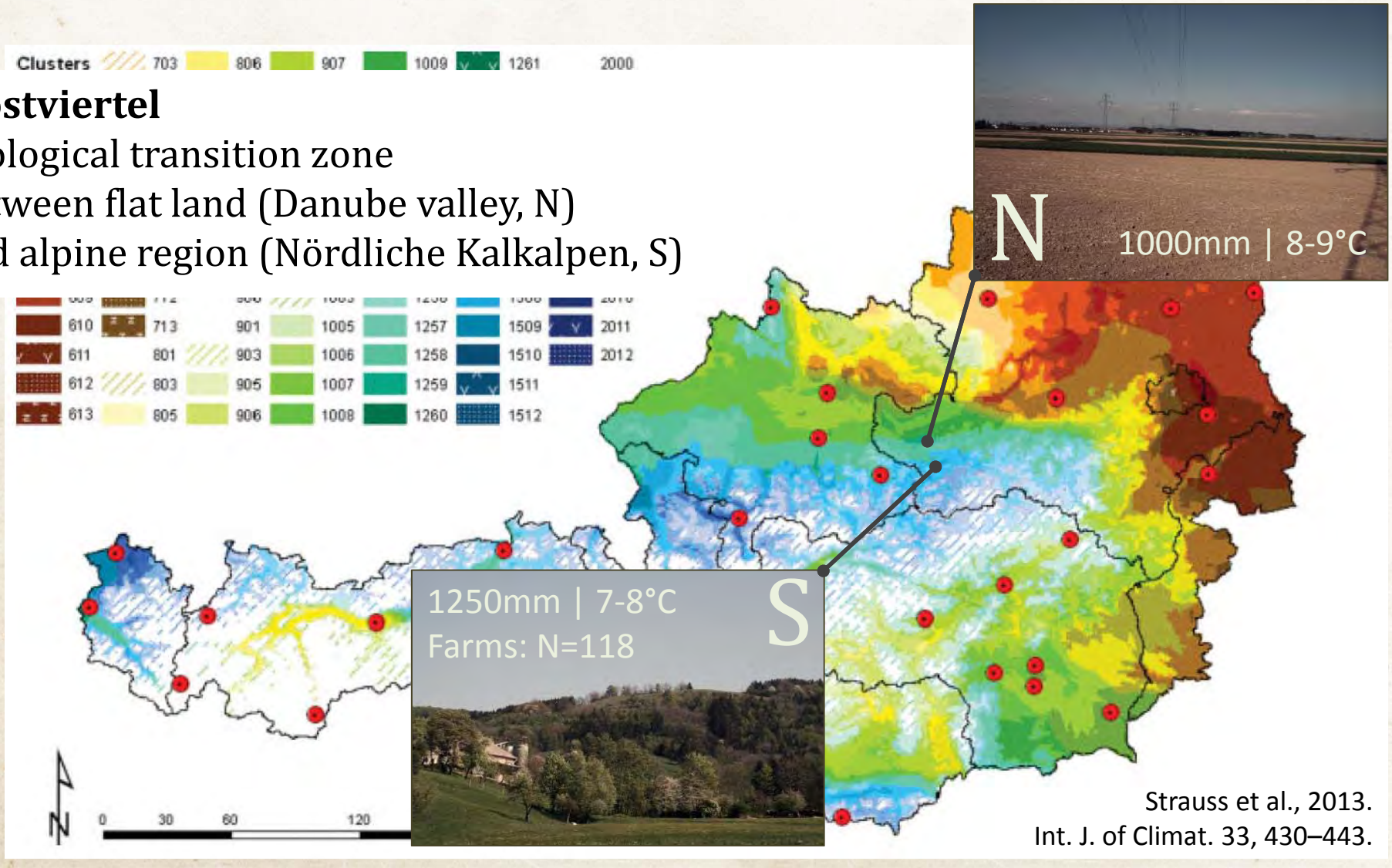
Farm advisor, 2016 (Survey by Hermine Mitter, unpublished)

# Problem statement

- MACSUR 1: development of a method to analyse farm and landscape scale impacts of CC, mitigation and adaptation effects
  - cropland dominated landscape, crop choice and soil management
  - climate model uncertainty
- Now: test and improve the robustness of the method
  - grassland landscape, cropland expansion and livestock
  - uncertainty analysis
  - variability of weather conditions

# Case study landscape

**Mostviertel**
geological transition zone
between flat land (Danube valley, N)
and alpine region (Nördliche Kalkalpen, S)




Strauss et al., 2013.
Int. J. of Climat. 33, 430–443.

# Methods and Data

## Input

natural & socio-economic data

input and output prices
CAP
production functions
farm labor supply
livestock – herd sizes
observed land use
spatially explicit field data
landscape elements
climate scenarios
topography
soil characteristics

## Models

CropRota[1]

EPIC[2]

CALDIS VÂTIS[4]

FAMOS[space][3]

## Output

socio-economic & RD indicators

farm gross margin
public budget spending
farm labor demand
landscape diversity & appearance

agri-environmental indicators

agric. & forestry land use change
biodiversity
SOC
soil sediment loss
N & P nutrient balances
GHG emissions

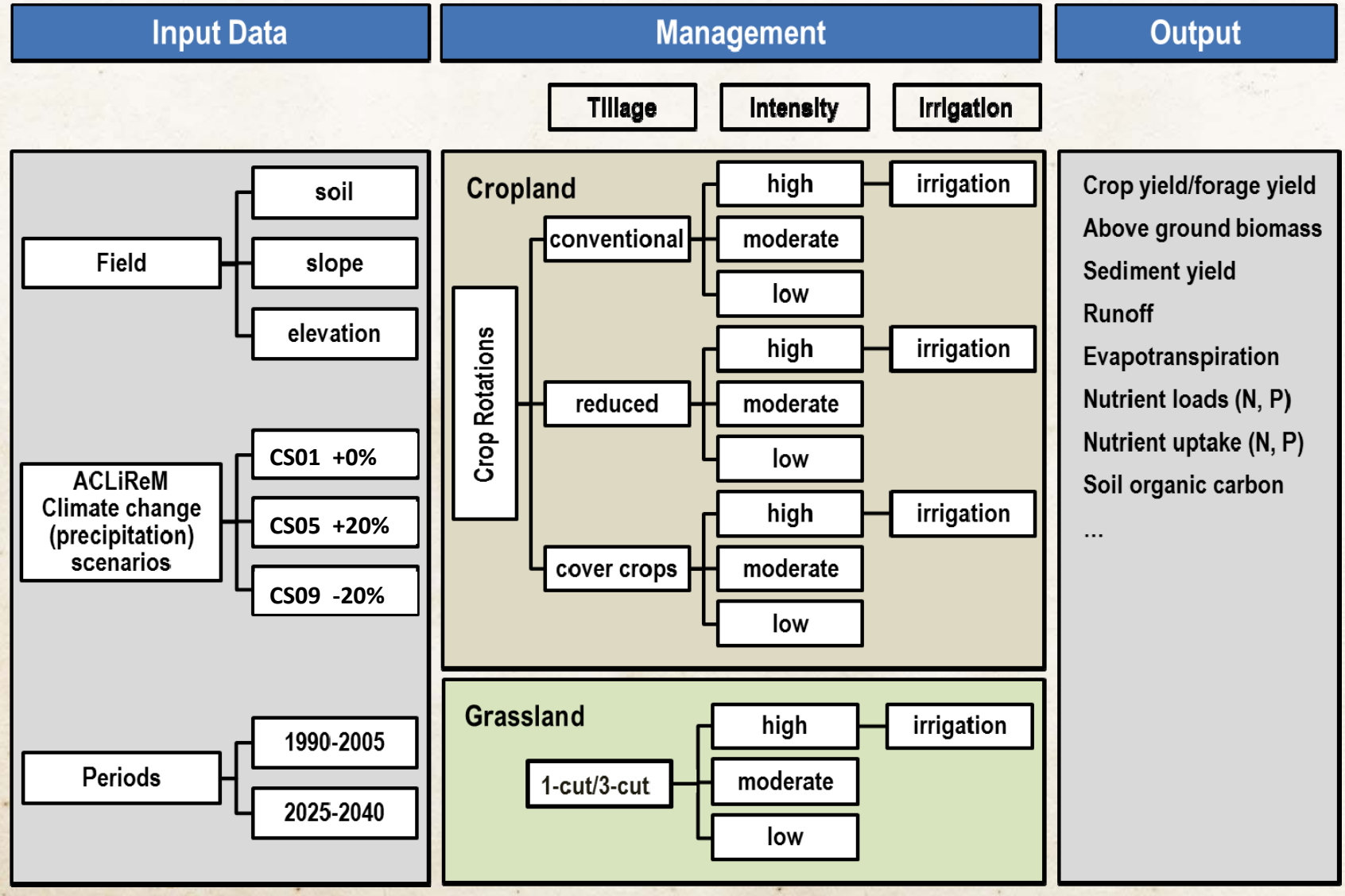
food production indicators

crop & livestock production

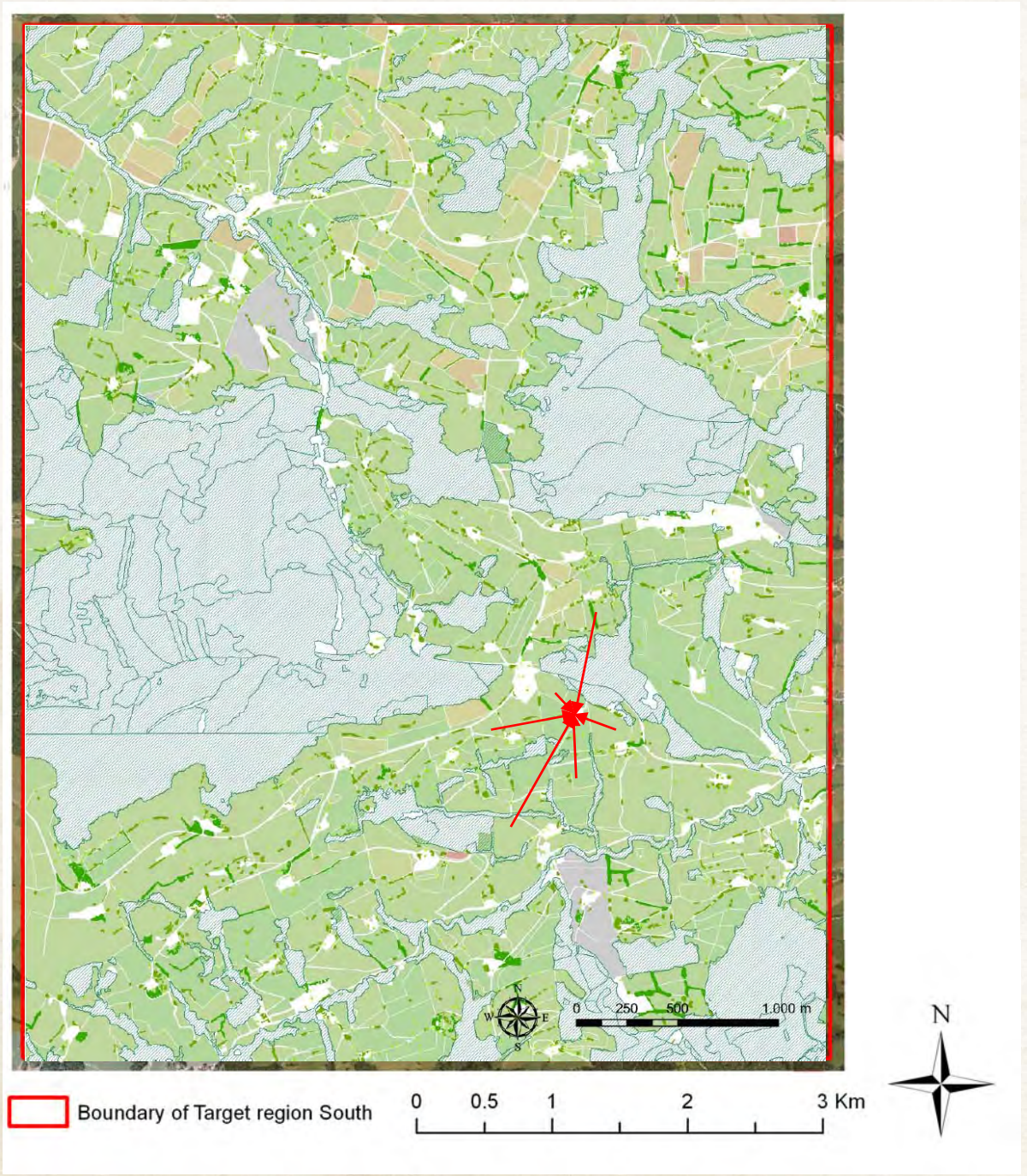
[1]Schönhart et al. (2011). Eur J Agron 34, 263-277.
[2]e.g. Izaurralde et al. (2006). Ecol Modell 192, 362-384.
[3]Schönhart et al. (2011). J Environ Plann Manage 54, 115-143.
[4]Georg Kindermann, BFW (see Kirchner et al., (2015). Ecol Econ 109, 161-174).

See also Schönhart et al. 2016. Agric Syst 145, 39–50.

# EPIC – model run settings



# Field level data



# Impact, mitigation & adaptation scenarios

| Name | CC* | AEP* | CAP reform | Mitigation policies | Adaptation policies |
|---|---|---|---|---|---|
| REF_2040 | No | No | no dairy quota; no livestock premiums; regional farm payment; greening; LFA payments from 2008 | | |
| CS[CC]_i | Yes | No | like REF_2040 | | |
| CS[CC]_m | Yes | No | like REF_2040 | energy crops on set aside; subsidies for: landsc. elements, SRF, afforestation, cover crops, min. tillage and extensive land use | |
| CS[CC]_a | Yes | No | like REF_2040 | | no greening, subsidies for maintenance of steep slope grass land and irrigation |
| CS[CC]_ma | Yes | No | like REF_2040 | like CS[CC]_m | like CS[CC]_a |

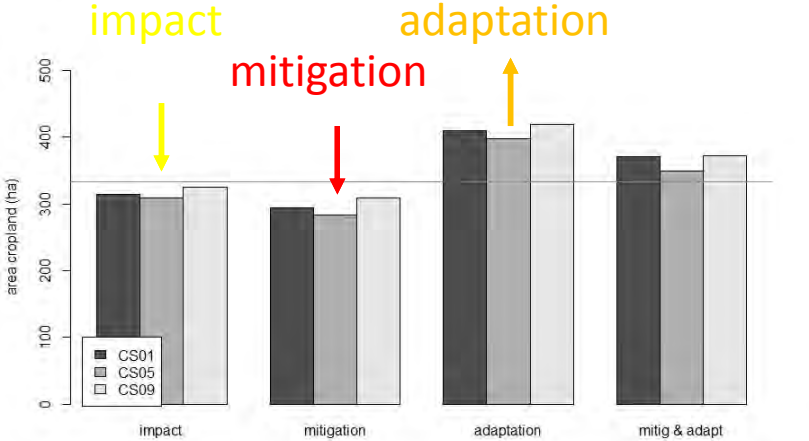
| Climate Change [CC] Scenario Name | Climate change in 2040 | |
|---|---|---|
| | Δ temperature (°C) | Δ precipitation (%) |
| CS01 | + 1.5 | 0% |
| CS05 | + 1.5 | +20% |
| CS09 | + 1.5 | -20% |

* CC…climate change, AEP…agri-environmental program

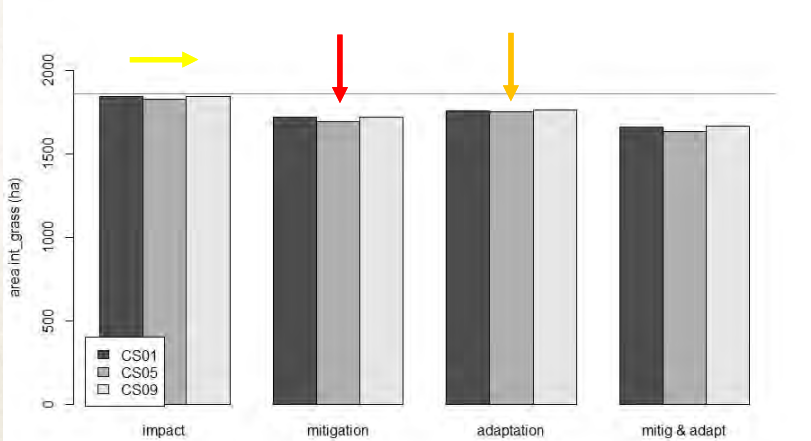
# Results – land use impacts (ha)

## from climate change and policies

### Cropland

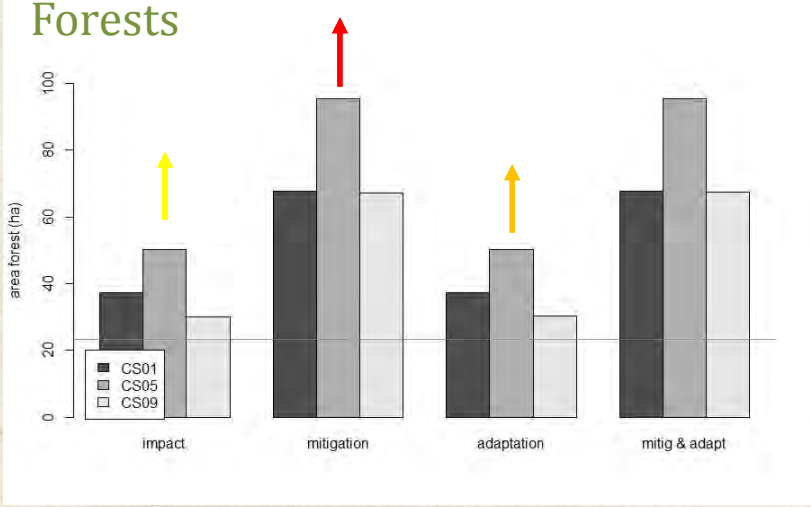



### Intensively managed permanent grassland

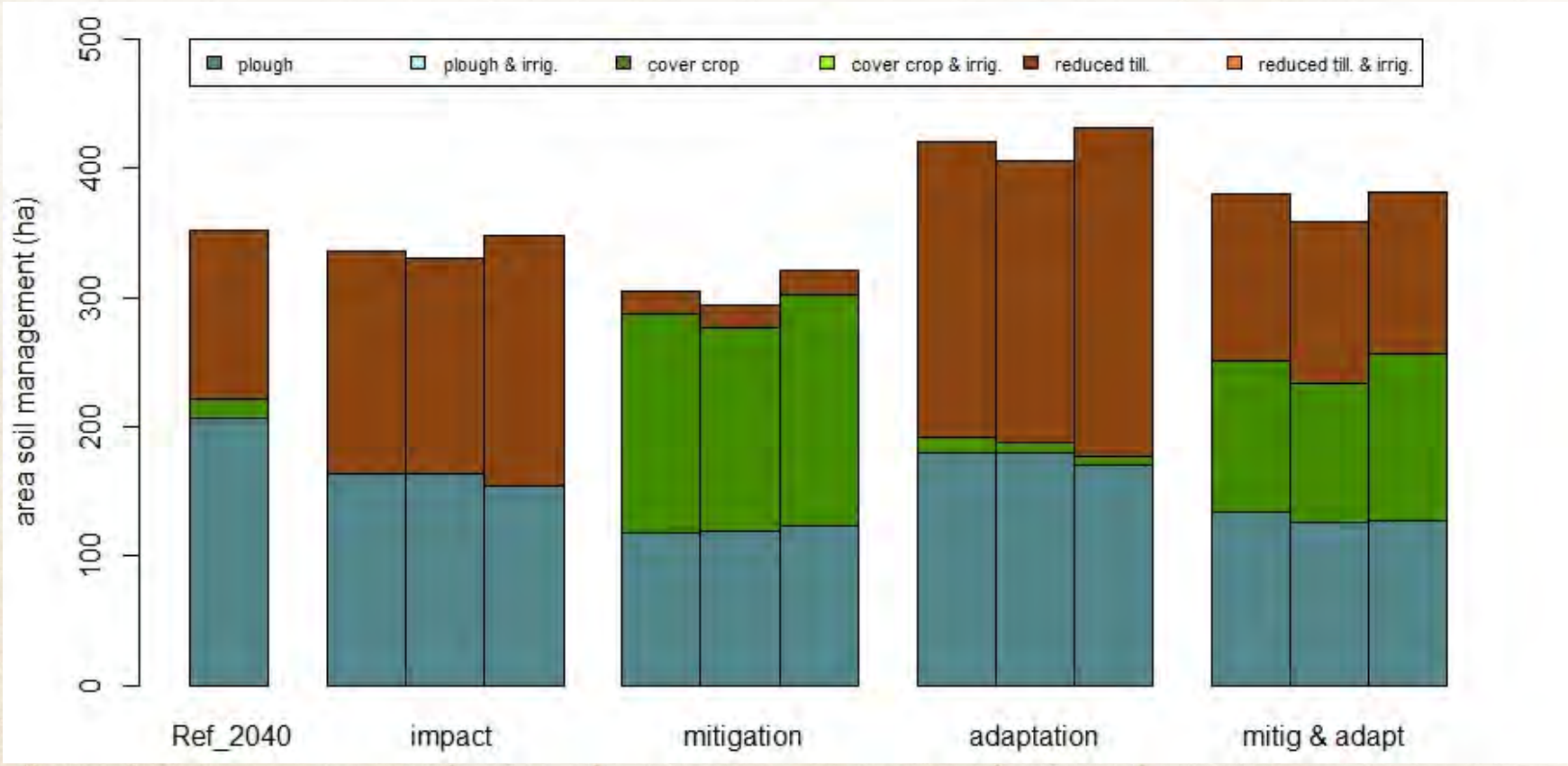



### Orchard meadows


### Forests



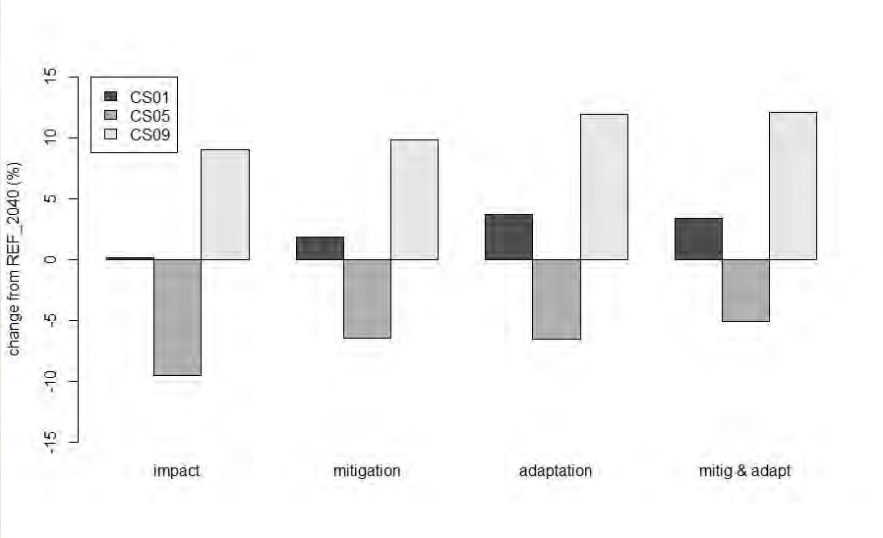
# Results – soil management (ha)



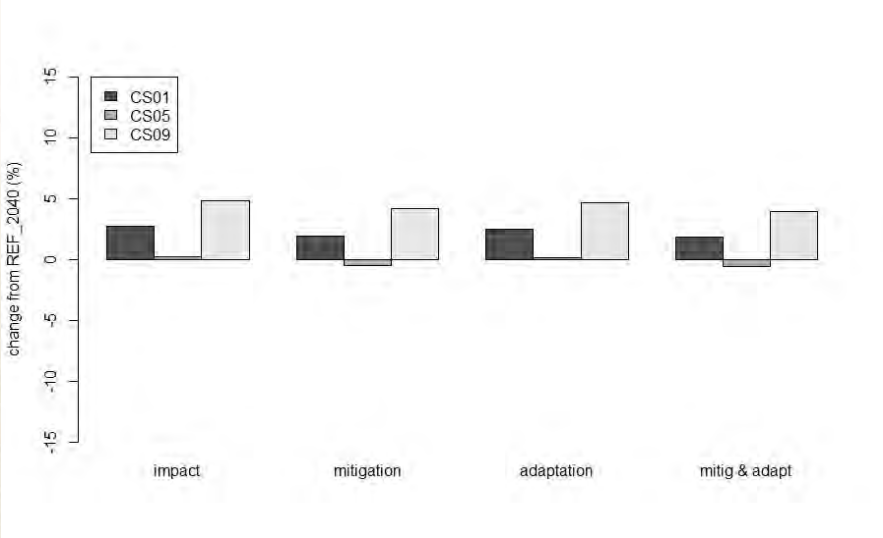
# Results – changes in soil organic carbon

## from climate change and policies

### Cropland



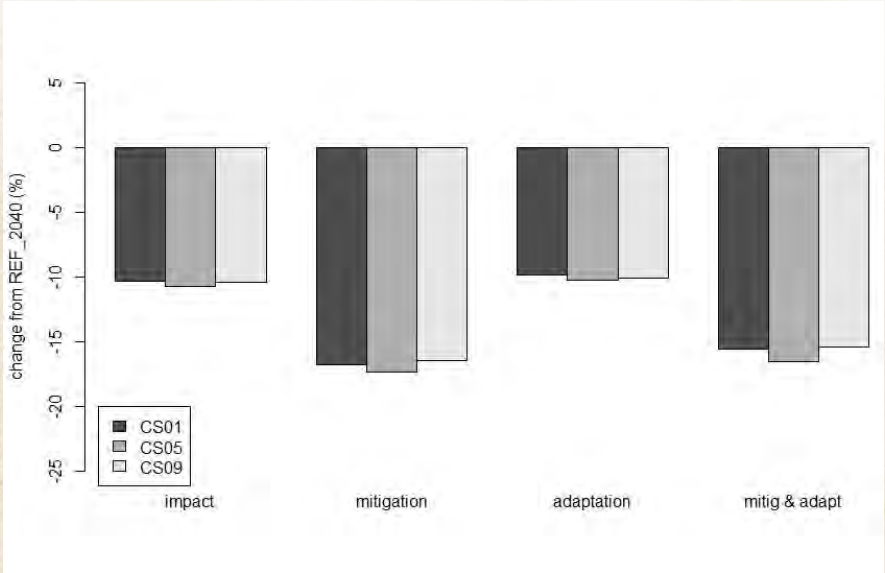

### Permanent grassland



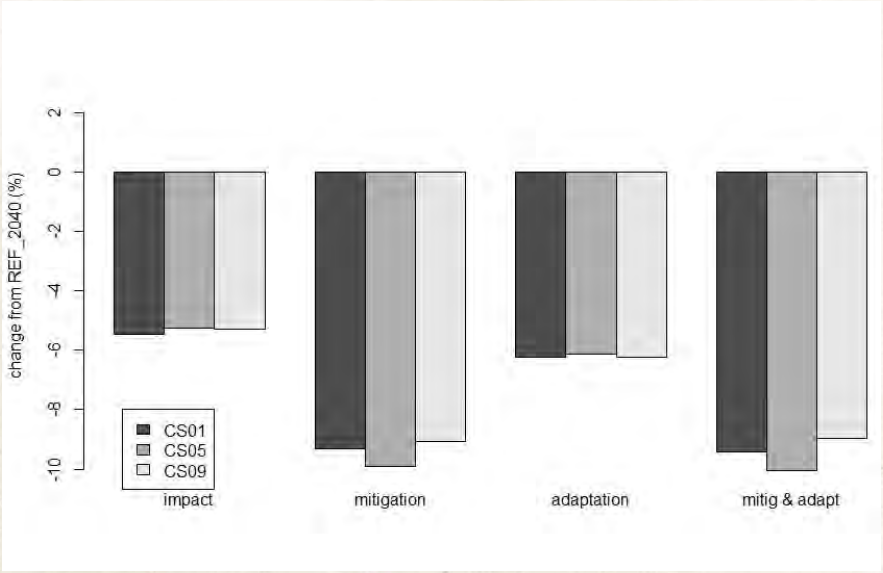
# Results – changes in nitrogen fertilization and GHG emissions

## from climate change and policies

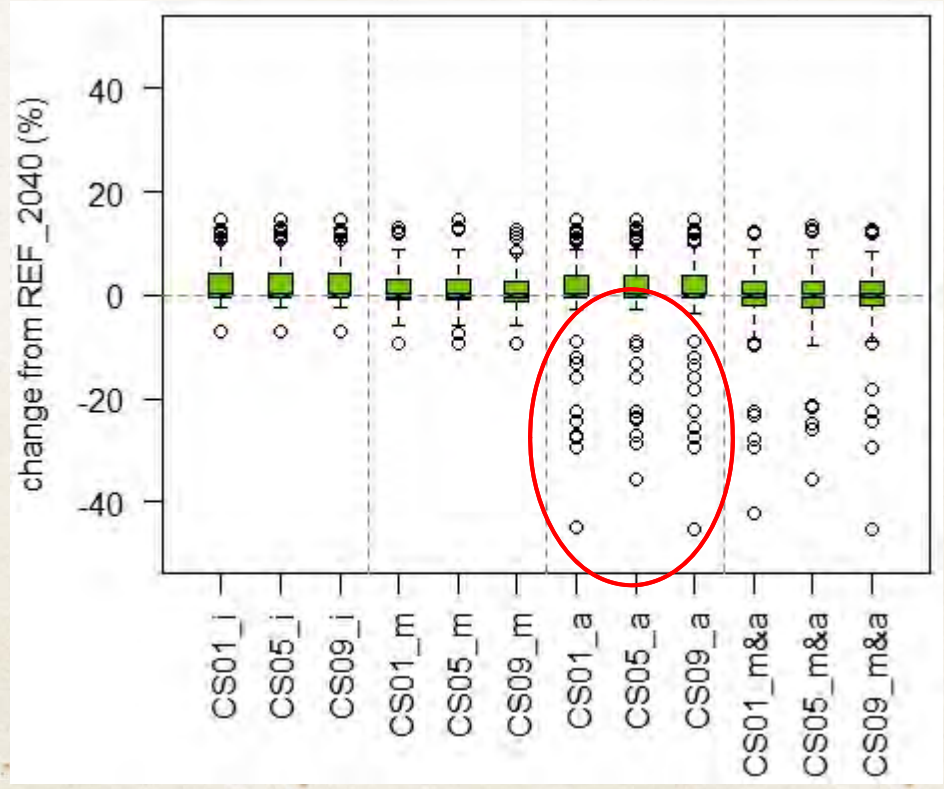
### Nitrogen fertilization




### GHG emissions

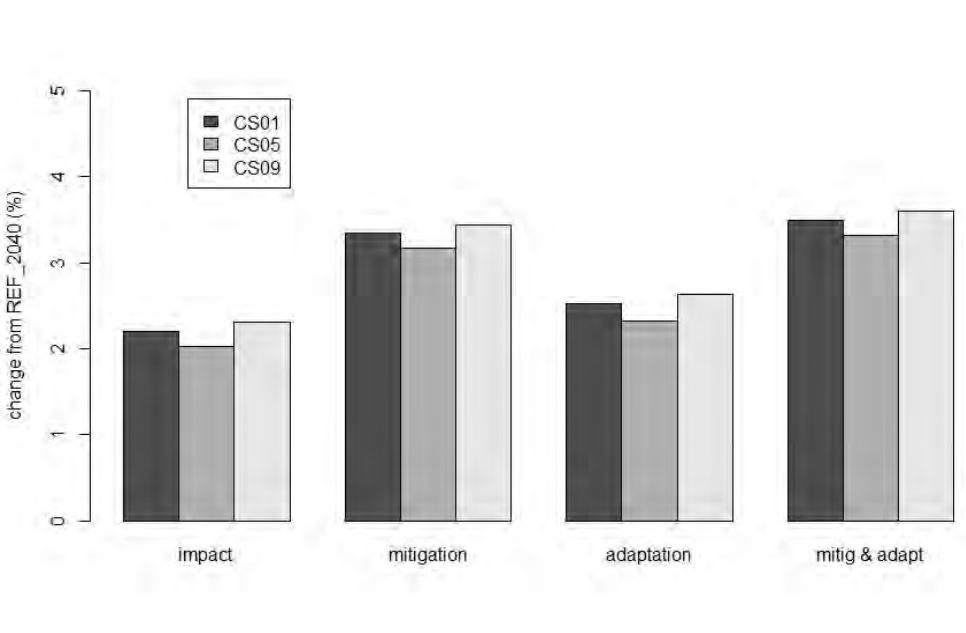


# Results –
# changes in vascular plant species richness on farms
## from climate change and policies

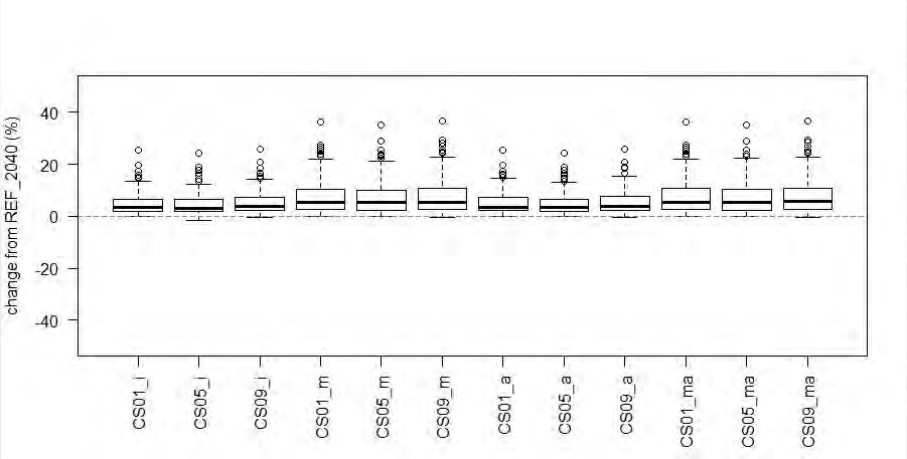


# Results – changes in farm gross margins
## from climate change and policies

Average aggregated at landscape level




Farm gross margins at landscape level




**Gross margin:** + product sales (plant, livestock) + subsidies + annuities for long-term investment
- variable costs (machinery, inputs and services, off-farm labor)

# Uncertainty analysis

- Climate change uncertainty
  - average precipitation levels
  - weather variability and extremes
- Crop model uncertainty
  - field vs. grid level analysis
  - ensemble results
- Livestock model uncertainty
- Economic model uncertainty
  - aggregation bias: value of farm level analysis
  - socio-economic base line assumptions (SSPs, RAPs)

# Field vs. grid level analysis

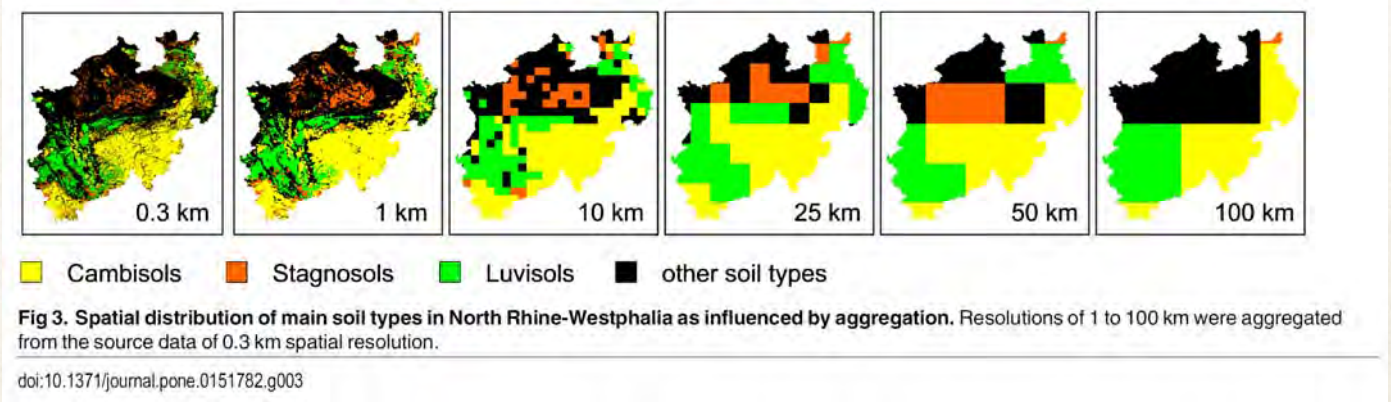



**Fig 3. Spatial distribution of main soil types in North Rhine-Westphalia as influenced by aggregation.** Resolutions of 1 to 100 km were aggregated from the source data of 0.3 km spatial resolution.

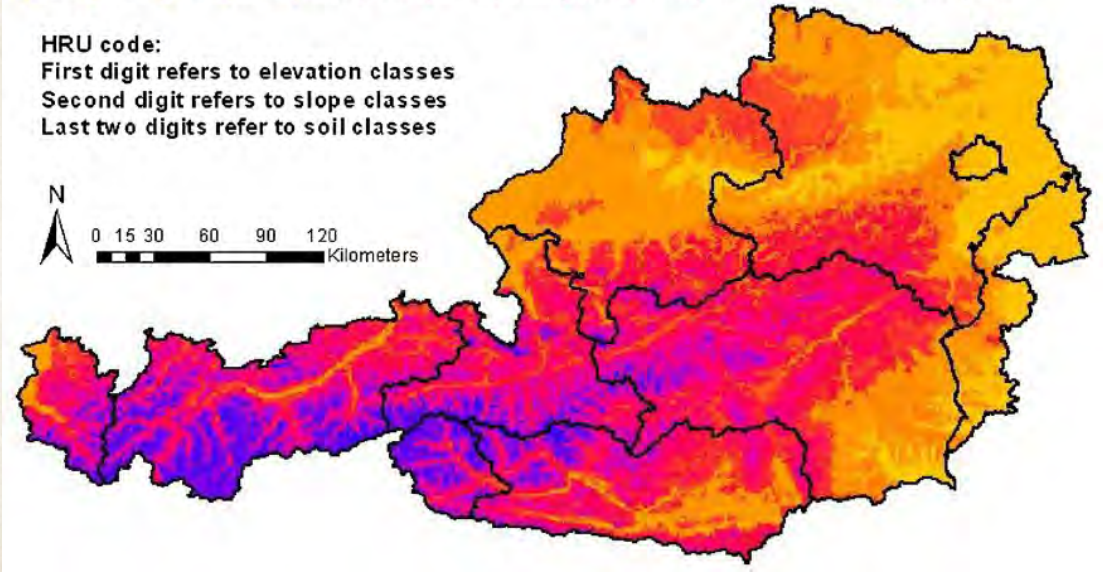
doi:10.1371/journal.pone.0151782.g003

"We conclude that, when simulating regional water-limited average yields in a temperate humid region, most models are little affected by aggregating soil and/or climate data up to 100 km resolution. However, …"

Hoffmann et al. 2016. PLoS 1 11: e0151782-e0151782

# EPIC results with HRU resolution

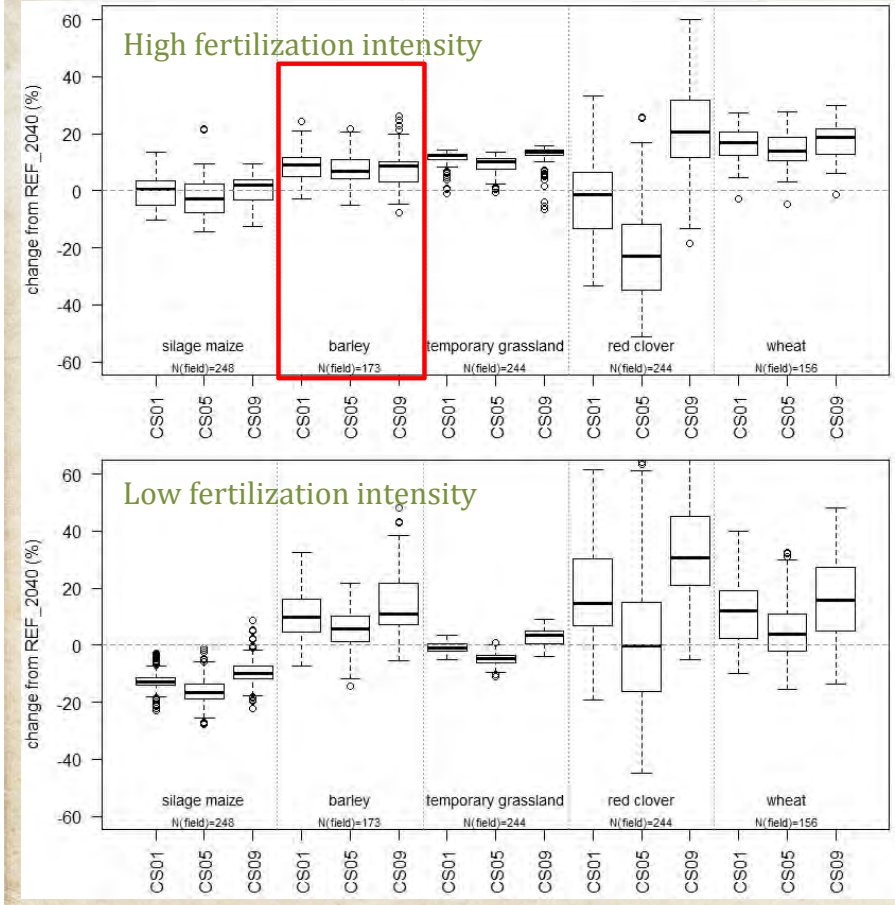
| HRU | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1101 | 1301 | 2104 | 2306 | 2509 | 3115 | 3403 | 3602 | 4199 | 4401 | 4599 | 5108 | 5406 | 5607 | 6302 | 6510 |
| 1102 | 1302 | 2105 | 2307 | 2510 | 3199 | 3404 | 3603 | 4201 | 4402 | 4601 | 5110 | 5408 | 5608 | 6303 | 6511 |
| 1103 | 1303 | 2106 | 2308 | 2511 | 3201 | 3405 | 3604 | 4202 | 4403 | 4602 | 5114 | 5409 | 5609 | 6304 | 6514 |
| 1104 | 1304 | 2107 | 2309 | 2599 | 3202 | 3406 | 3605 | 4203 | 4404 | 4603 | 5199 | 5410 | 5610 | 6308 | 6515 |
| 1105 | 1306 | 2108 | 2310 | 2601 | 3203 | 3407 | 3606 | 4204 | 4405 | 4604 | 5201 | 5411 | 5611 | 6309 | 6599 |
| 1106 | 1307 | 2109 | 2311 | 2602 | 3204 | 3408 | 3607 | 4205 | 4406 | 4605 | 5202 | 5414 | 5614 | 6310 | 6601 |
| 1107 | 1308 | 2110 | 2314 | 2603 | 3205 | 3409 | 3608 | 4206 | 4407 | 4606 | 5203 | 5415 | 5615 | 6311 | 6602 |
| 1108 | 1309 | 2111 | 2399 | 2604 | 3206 | 3410 | 3609 | 4207 | 4408 | 4607 | 5204 | 5499 | 5699 | 6314 | 6603 |
| 1109 | 1310 | 2114 | 2401 | 2607 | 3207 | 3411 | 3610 | 4208 | 4409 | 4608 | 5205 | 5501 | 5701 | 6399 | 6604 |
| 1110 | 1311 | 2199 | 2402 | 2608 | 3208 | 3413 | 3611 | 4209 | 4410 | 4609 | 5208 | 5502 | 5702 | 6401 | 6605 |
| 1111 | 1399 | 2201 | 2403 | 2609 | 3209 | 3414 | 3614 | 4210 | 4411 | 4610 | 5209 | 5503 | 5704 | 6402 | 6606 |
| 1112 | 1401 | 2202 | 2404 | 2610 | 3210 | 3415 | 3699 | 4211 | 4414 | 4611 | 5210 | 5504 | 5708 | 6403 | 6607 |
| 1113 | 1402 | 2203 | 2405 | 2611 | 3211 | 3499 | 3702 | 4214 | 4415 | 4614 | 5214 | 5505 | 5711 | 6404 | 6608 |
| 1114 | 1403 | 2204 | 2406 | 2699 | 3299 | 3501 | 3705 | 4299 | 4499 | 4615 | 5299 | 5506 | 5799 | 6406 | 6609 |
| 1199 | 1404 | 2205 | 2407 | 2701 | 3301 | 3502 | 3708 | 4301 | 4501 | 4699 | 5301 | 5507 | 6101 | 6408 | 6610 |
| 1201 | 1407 | 2206 | 2408 | 2799 | 3302 | 3503 | 3799 | 4302 | 4502 | 4701 | 5302 | 5508 | 6102 | 6409 | 6611 |
| 1202 | 1408 | 2207 | 2409 | 3101 | 3303 | 3504 | 4101 | 4303 | 4503 | 4702 | 5303 | 5509 | 6103 | 6410 | 6614 |
| 1203 | 1409 | 2208 | 2410 | 3102 | 3304 | 3505 | 4102 | 4304 | 4504 | 4703 | 5304 | 5510 | 6108 | 6411 | 6615 |
| 1204 | 1410 | 2209 | 2411 | 3103 | 3305 | 3506 | 4103 | 4305 | 4505 | 4707 | 5308 | 5511 | 6109 | 6415 | 6699 |
| 1206 | 1411 | 2210 | 2499 | 3104 | 3306 | 3507 | 4104 | 4306 | 4506 | 4708 | 5309 | 5514 | 6110 | 6499 | 6701 |
| 1207 | 1499 | 2211 | 2501 | 3105 | 3307 | 3508 | 4105 | 4307 | 4507 | 4709 | 5310 | 5515 | 6199 | 6501 | 6702 |
| 1208 | 1502 | 2214 | 2502 | 3106 | 3308 | 3509 | 4106 | 4308 | 4508 | 4799 | 5311 | 5599 | 6201 | 6502 | 6703 |
| 1209 | 1508 | 2299 | 2503 | 3107 | 3309 | 3510 | 4107 | 4309 | 4509 | 5101 | 5399 | 5601 | 6202 | 6503 | 6708 |
| 1210 | 1599 | 2301 | 2504 | 3108 | 3310 | 3511 | 4108 | 4310 | 4510 | 5102 | 5401 | 5602 | 6203 | 6504 | 6799 |
| 1211 | 1602 | 2302 | 2505 | 3109 | 3311 | 3514 | 4109 | 4313 | 4511 | 5103 | 5402 | 5603 | 6204 | 6505 | |
| 1214 | 2101 | 2303 | 2506 | 3110 | 3399 | 3515 | 4110 | 4314 | 4513 | 5104 | 5403 | 5604 | 6208 | 6507 | |
| 1299 | 2102 | 2304 | 2507 | 3111 | 3401 | 3599 | 4111 | 4315 | 4514 | 5105 | 5404 | 5605 | 6299 | 6508 | |
| | 2103 | 2305 | 2508 | 3114 | 3402 | 3601 | 4114 | 4399 | 4515 | 5107 | 5405 | 5606 | 6301 | 6509 | |



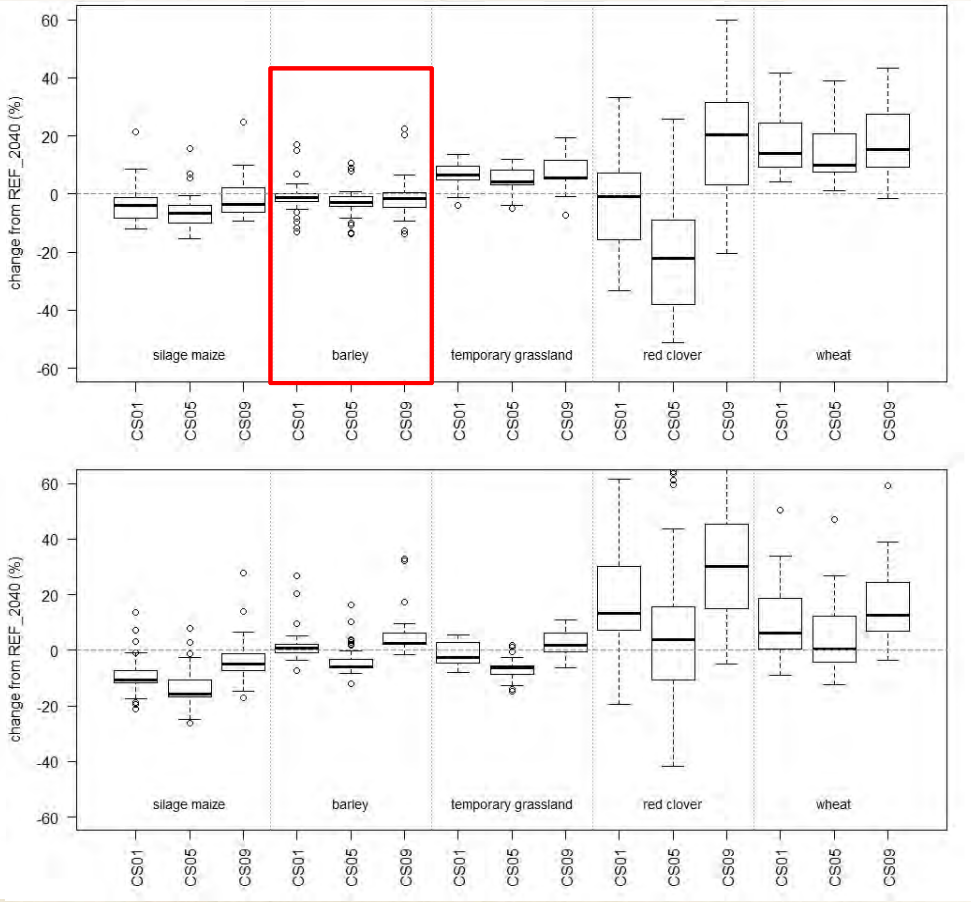

Stürmer et al. 2013. Land Use Policy 30, 570–581.

# EPIC results for fields

## Field level EPIC runs

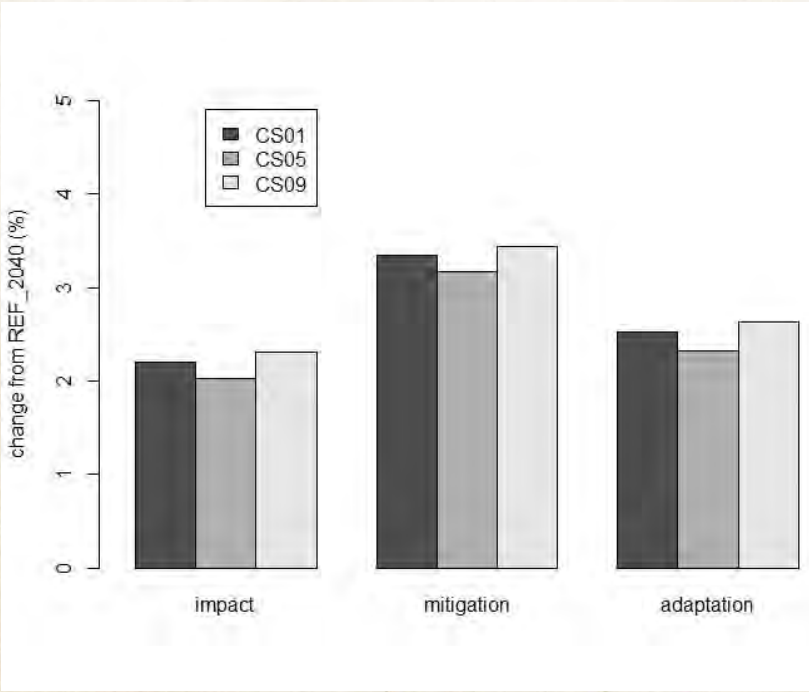



## Grid level EPIC runs

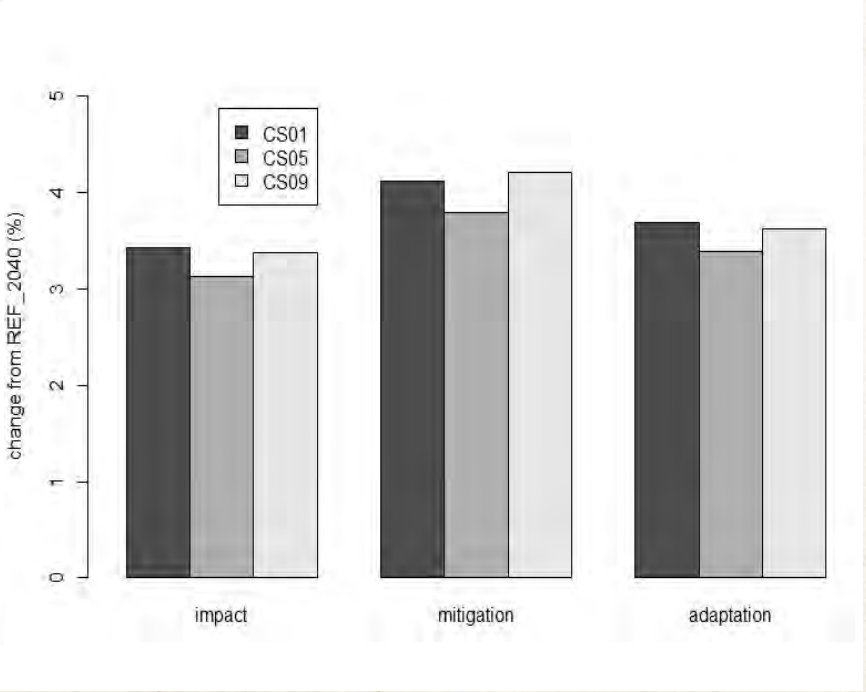


# Results – changes in farm gross margins

Field level EPIC runs

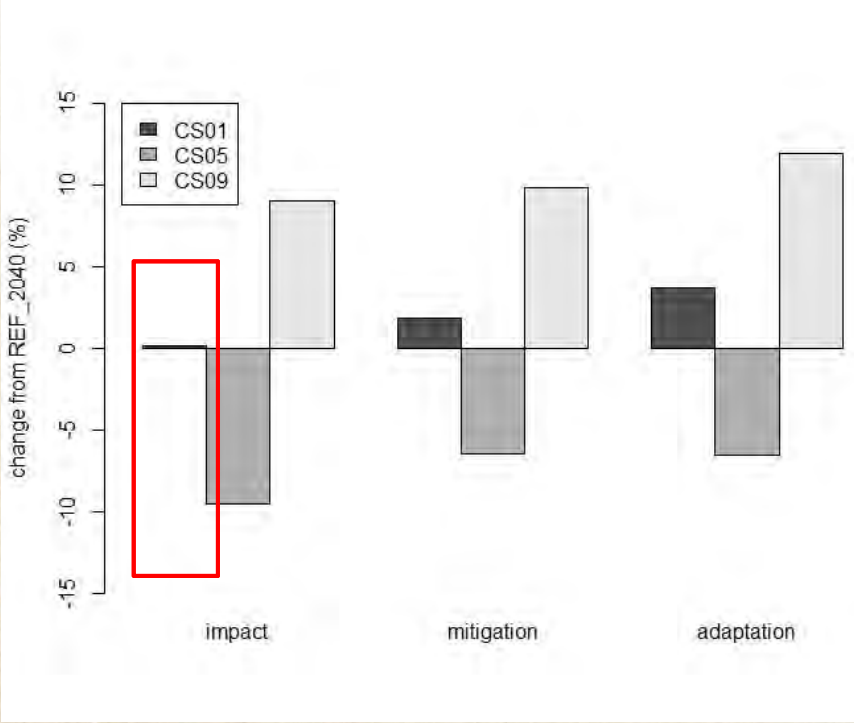



Grid level EPIC runs



# Results – changes in soil organic carbon

Field level EPIC runs

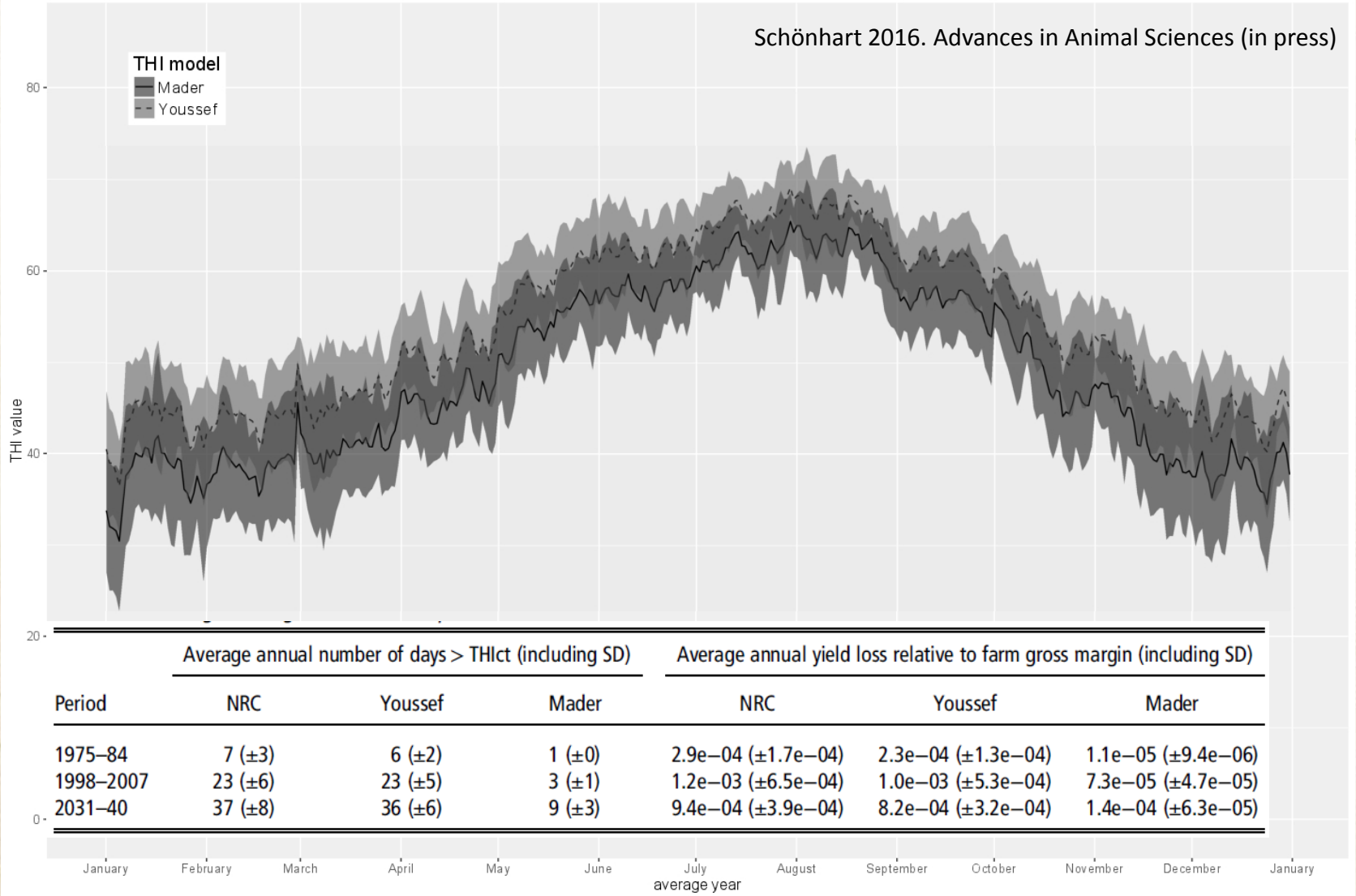



Grid level EPIC runs

# Temperature Humidity Index

## THI value, days above threshold & economic loss

Schönhart 2016. Advances in Animal Sciences (in press)




| | Average annual number of days > THIct (including SD) | | | Average annual yield loss relative to farm gross margin (including SD) | | |
|---|---|---|---|---|---|---|
| Period | NRC | Youssef | Mader | NRC | Youssef | Mader |
| 1975–84 | 7 (±3) | 6 (±2) | 1 (±0) | 2.9e−04 (±1.7e−04) | 2.3e−04 (±1.3e−04) | 1.1e−05 (±9.4e−06) |
| 1998–2007 | 23 (±6) | 23 (±5) | 3 (±1) | 1.2e−03 (±6.5e−04) | 1.0e−03 (±5.3e−04) | 7.3e−05 (±4.7e−05) |
| 2031–40 | 37 (±8) | 36 (±6) | 9 (±3) | 9.4e−04 (±3.9e−04) | 8.2e−04 (±3.2e−04) | 1.4e−04 (±6.3e−05) |

# Discussion – case study results

- Increasing productivity from climate change on average in the landscape
  - In line with some of the literature, but not all
  - What about extreme weather events?
  - Declining intensity on grasslands on average
    - counter-intuitive to economic reasoning – may indicate rigidity (in the model) for forage markets and livestock expansion
- Increasing farm incomes on average from assumed mitigation and adaptation policies
  - Mitigation policy increases environmental quality at the cost of public budgets and agricultural production
  - Flexibility from adaptation shows trade-offs between ag. production and env. protection
- Location determines impacts
  - Heterogeneous climate change impacts among regions and farms
  - Not only latitude but altitude to be considered as well in impact studies

# Discussion – uncertainty management

- Climate change uncertainty from precipitation
  - of minor importance in the model
- Crop model resolution
  - determines levels of major results &
  - occasionally also direction of changes
- Climate change impacts on cattle
  - unimportant

# Conclusions & Outlook

- High spatial resolution creates interfaces to disciplinary models and indicators
  - Challenging data & modelling demand
- Increasing productivity can increase intensification pressures
  - Threatened permanent (extensive) grasslands and landscape elements, but
  - subject to resource constraints, costs and prices
  - Future RDP and environmental policy design (e.g. WFD) may need to take changing productivity into account
- Future research: analyze uncertainties & environmental impacts
  - Ensembles of crop and grassland models
  - Sensitivity analysis on economic input parameters
  - Qualitative surveys with agricultural experts and farmers

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