European Commission

Agriculture & carbon, nitrogen, water Research at the Joint Research Centre

www.jrc.ec.europa.eu

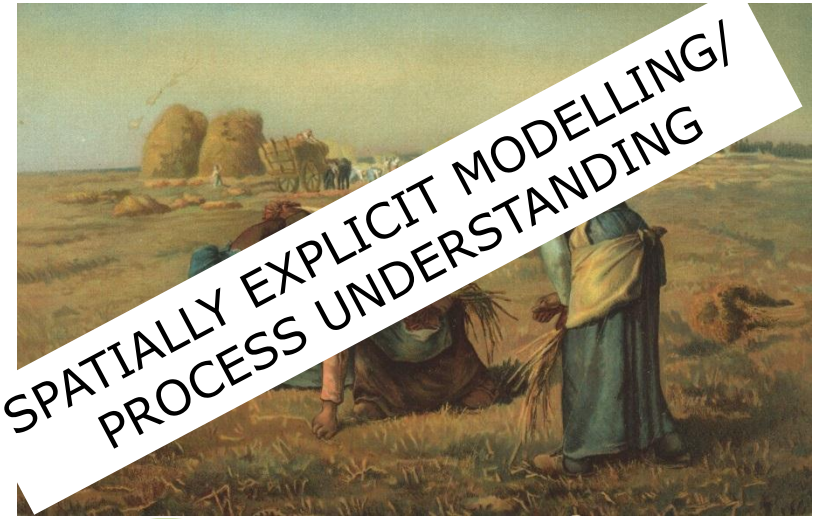
Adrian Leip
Stefan Niemeyer
+input from many colleagues

Horizon 2020 workshop on Climate Smart Agriculture

10-11 February 2014
Brussels

Joint Research Centre

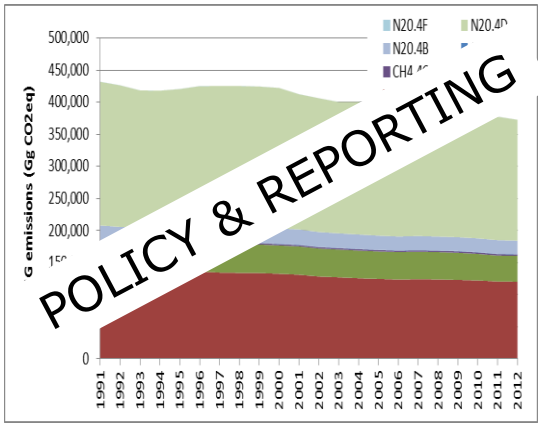
Outline

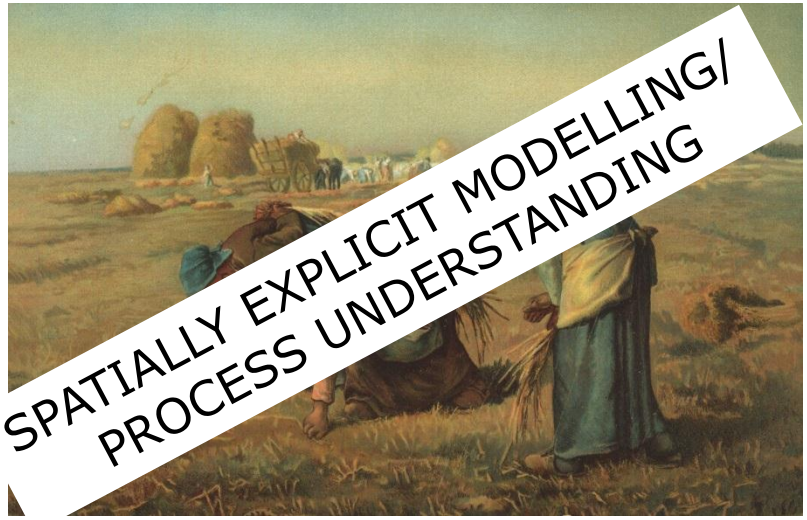

SPATIALLY EXPLICIT MODELLING/
PROCESS UNDERSTANDING

FARM LEVEL ASSESSMENT

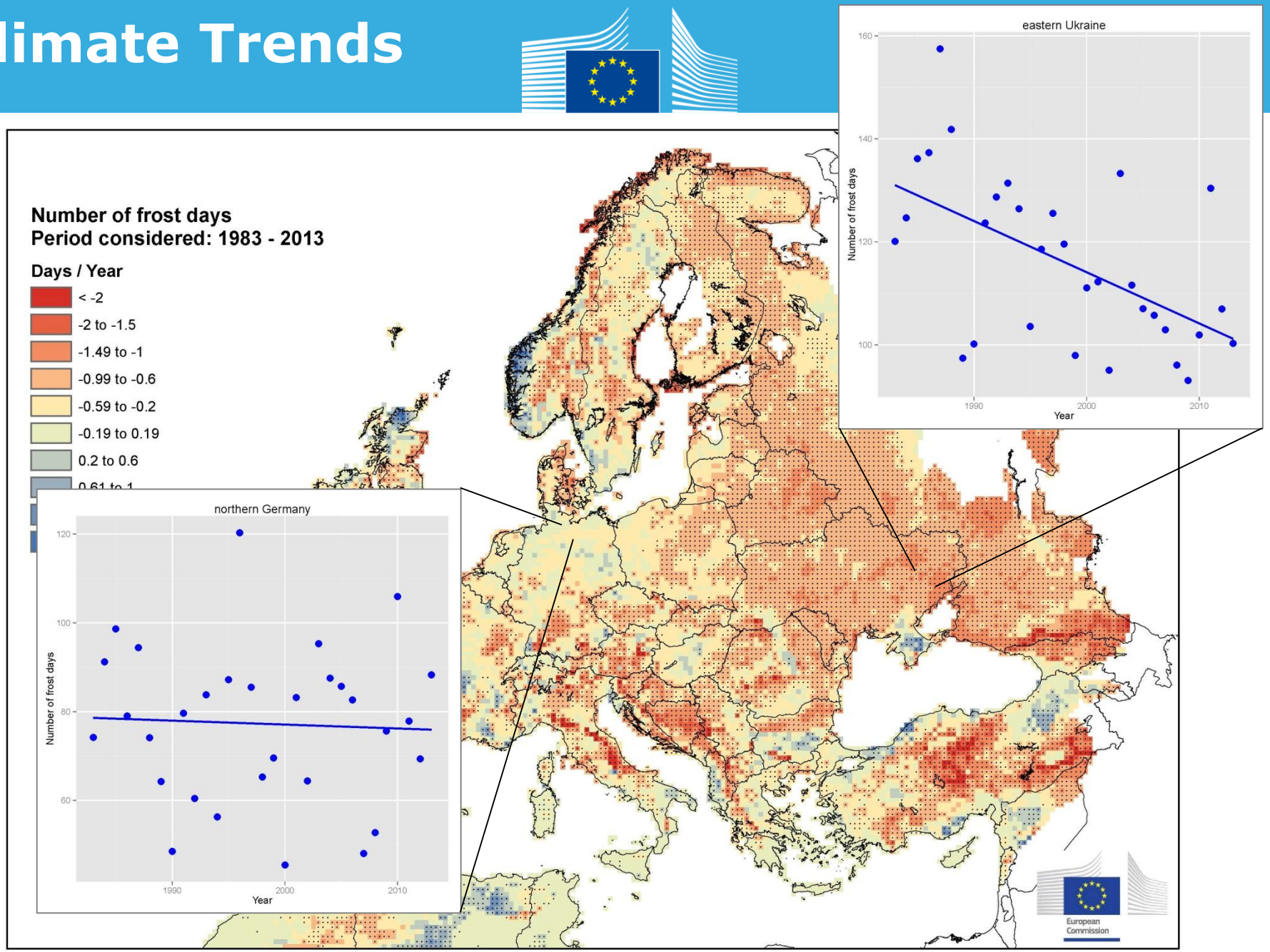
LIFE CYCLE THINKING

CONSUMER
ENGAGEMENT


POLICY & REPORTING
N2O.4F
N2O.4B
CH4
G emissions (Gg CO2eq)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

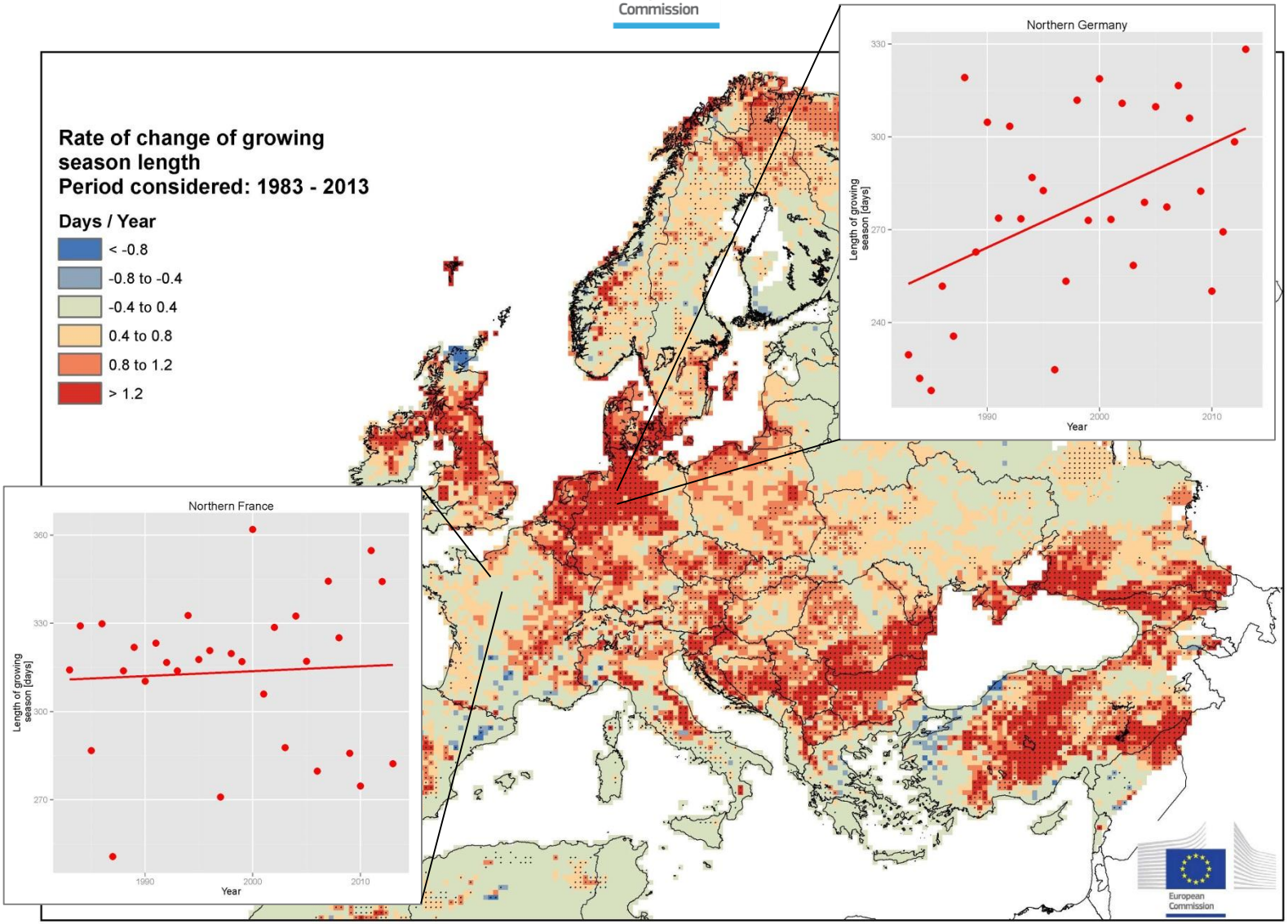

SPATIALLY EXPLICIT MODELLING/
PROCESS UNDERSTANDING

Climate Trends



JRC 2014, MARS meteorological database

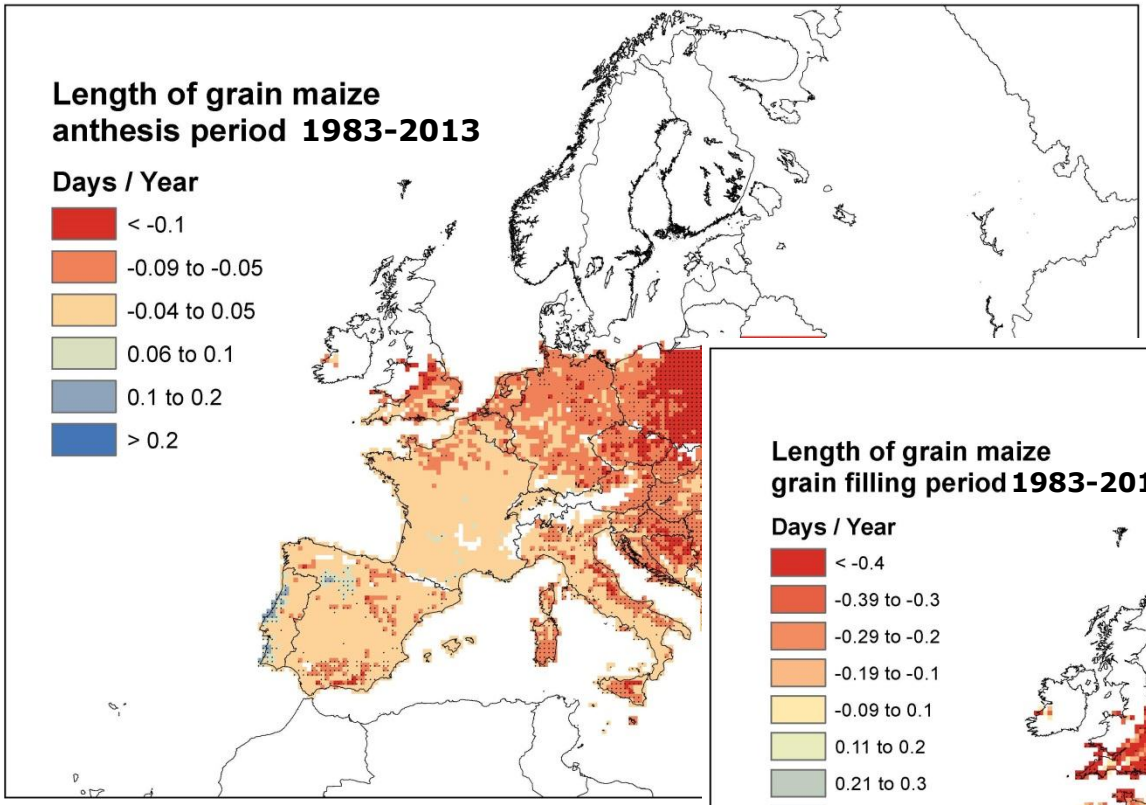
Climate Trends

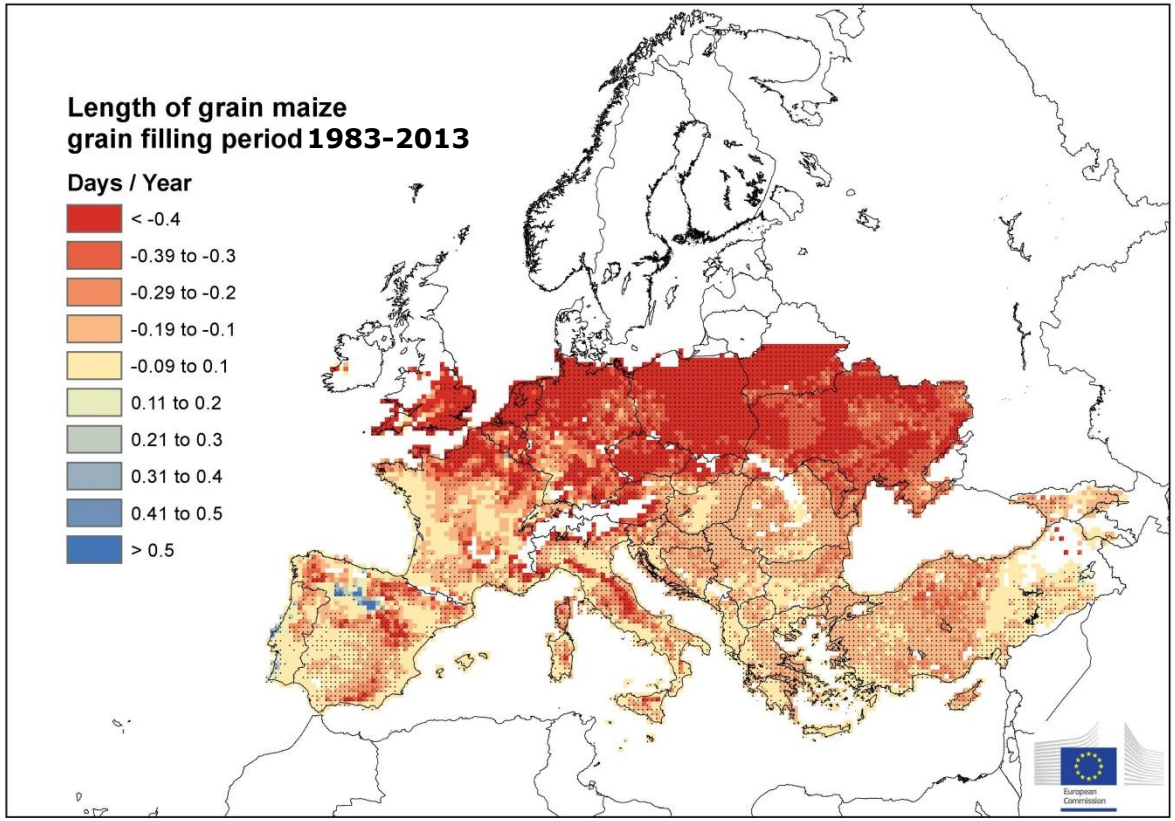


JRC 2014, MARS meteorological database

Research Centre

Model Simulations



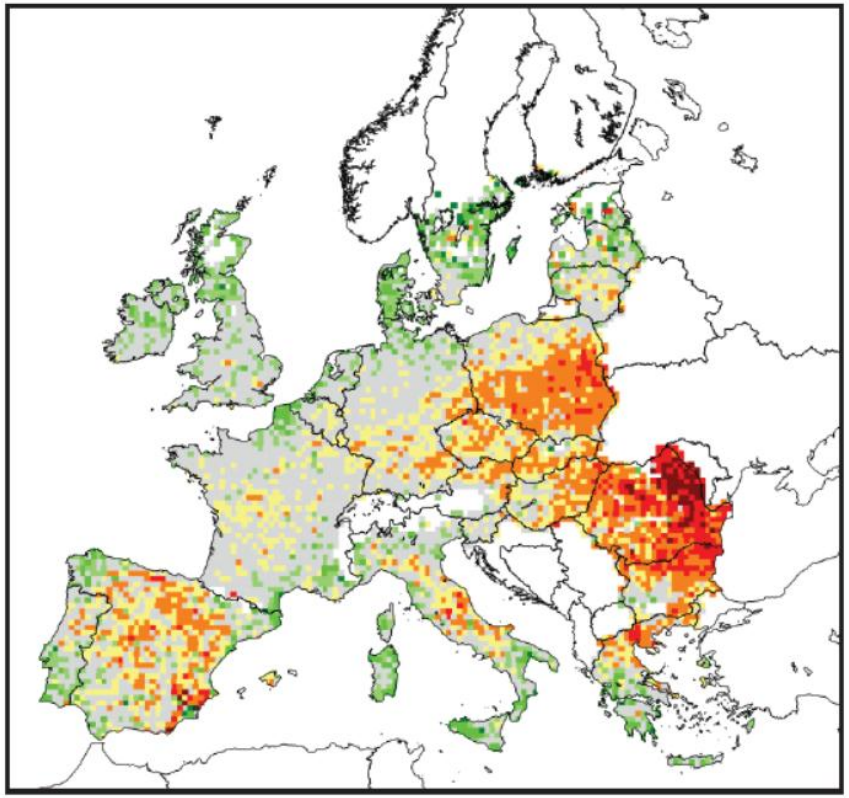


JRC 2014, MARS meteorological database

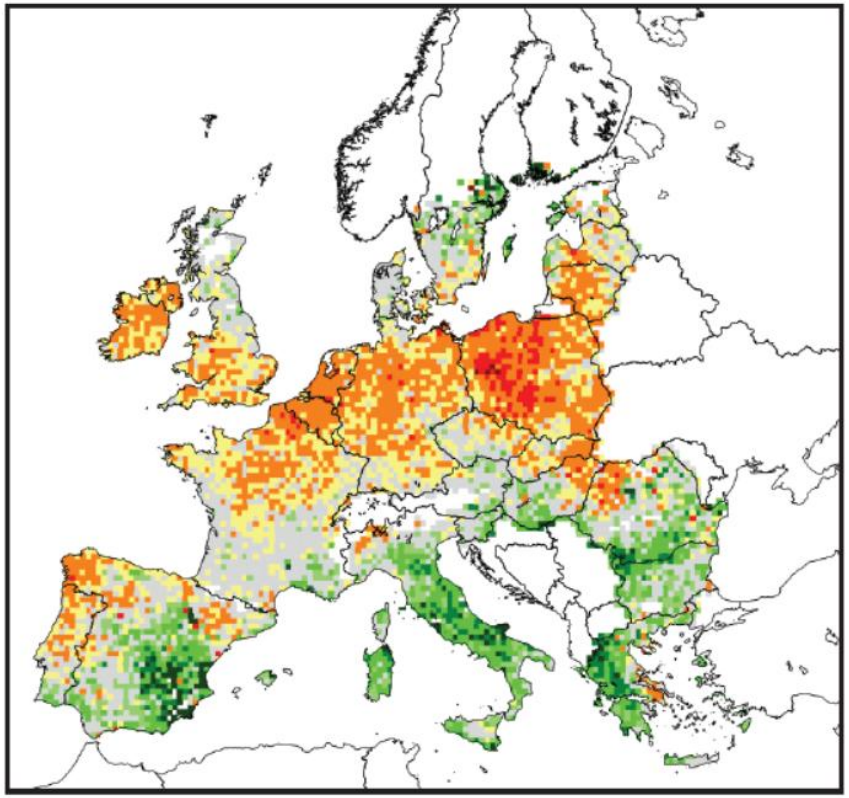
Projected impacts on crop yield

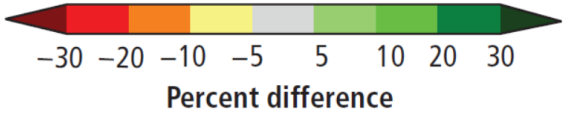
European Commission

Percent difference of water-limited yield for wheat
A1B scenario, ECHAM5, 2030–2000 (baseline)



Percent difference of water-limited yield for wheat
A1B scenario, HadCM3, 2030–2000 (baseline)





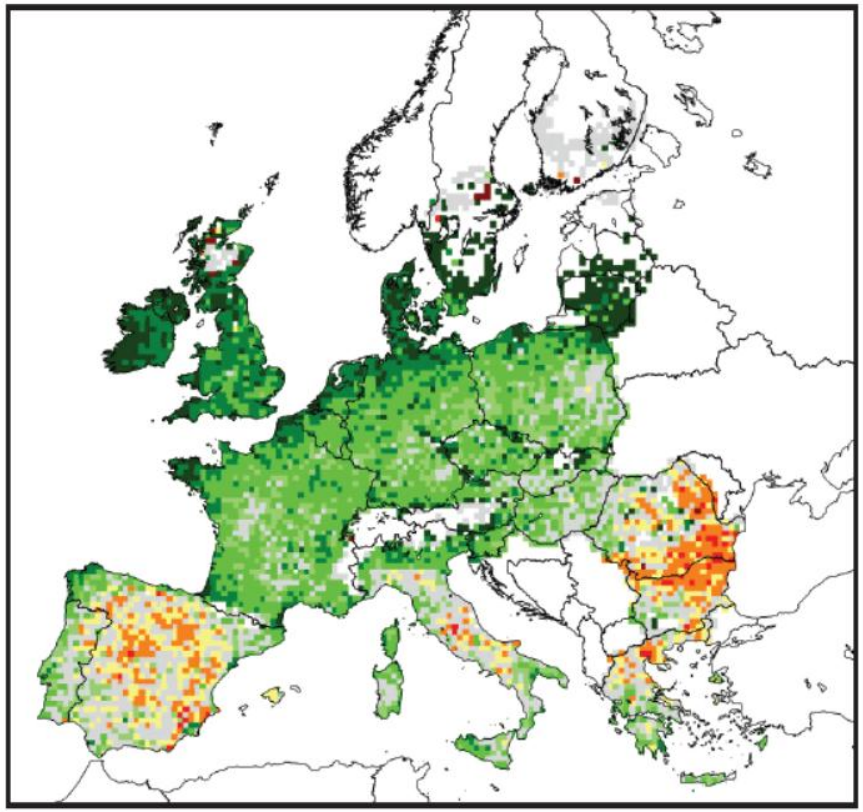
JRC 2013, crop model simulations

Joint Research Centre

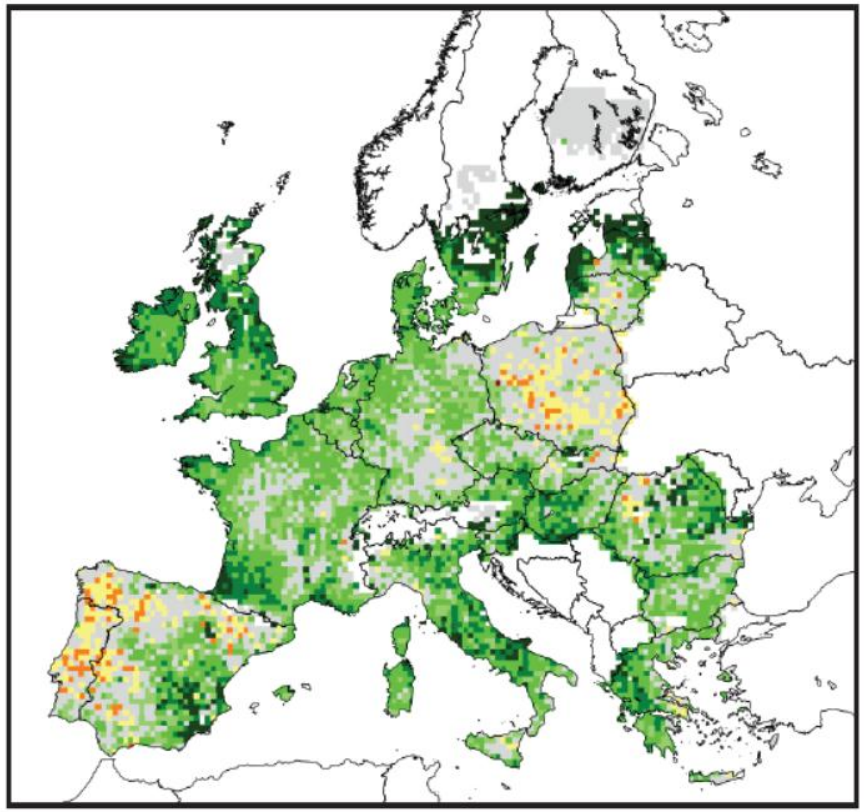
Projected impacts on crop yield incl. adaptation

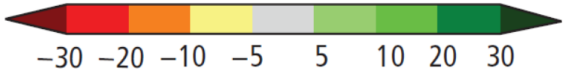
European Commission

Percent difference of water-limited yield for wheat with adaptation
A1B scenario, ECHAM5, 2030–2000 (baseline)



Percent difference of water-limited yield for wheat with adaptation
A1B scenario, HadCM3, 2030–2000 (baseline)





Percent difference

JRC 2013, crop model simulations

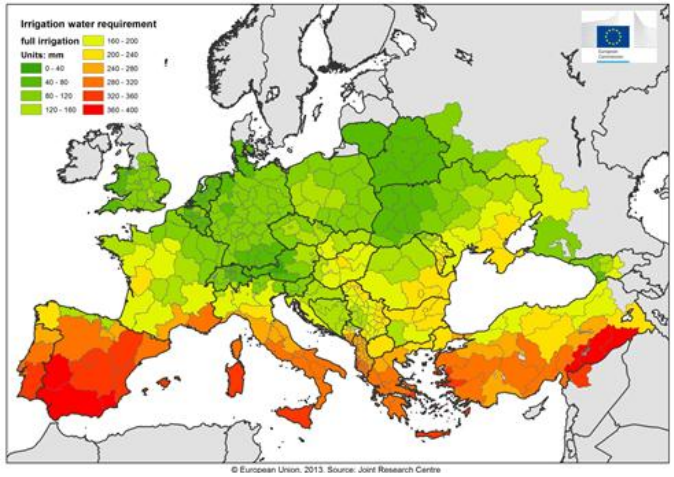
Joint Research Centre

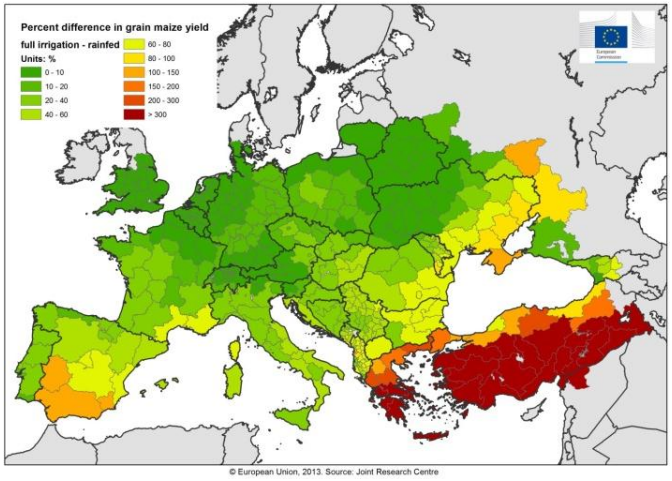
Analysis of different irrigation strategies for growing maize in Europe

Irrigation water requirement

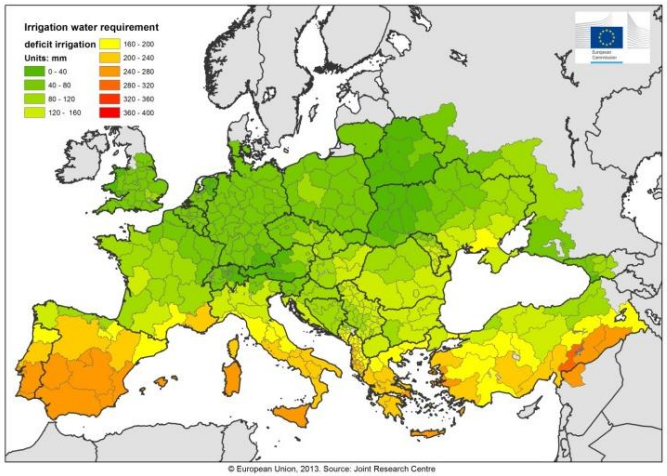
Relative difference in maize productivity

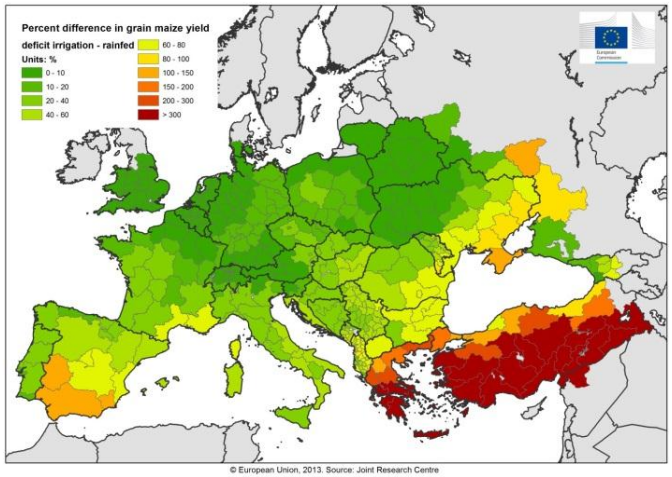
Full





Deficit





JRC, 2013

Joint Research Centre

Agro-Management Impacts

Tillage & Irrigation

European Commission

The impact of tillage and irrigation on simulated crop yield

Tillage

NUTS2	YN – NN (%)	NY – NN (%)	YY – NN (%)
Nord-Vest	13	14	17
Centru	15	15	19
Sud-Est	29	37	41
Nord-Est	12	13	15
Sud-Muntenia	22	33	34
Bucuresti-Ilfov	10	28	22
Sud-Vest Oltenia	10	20	22

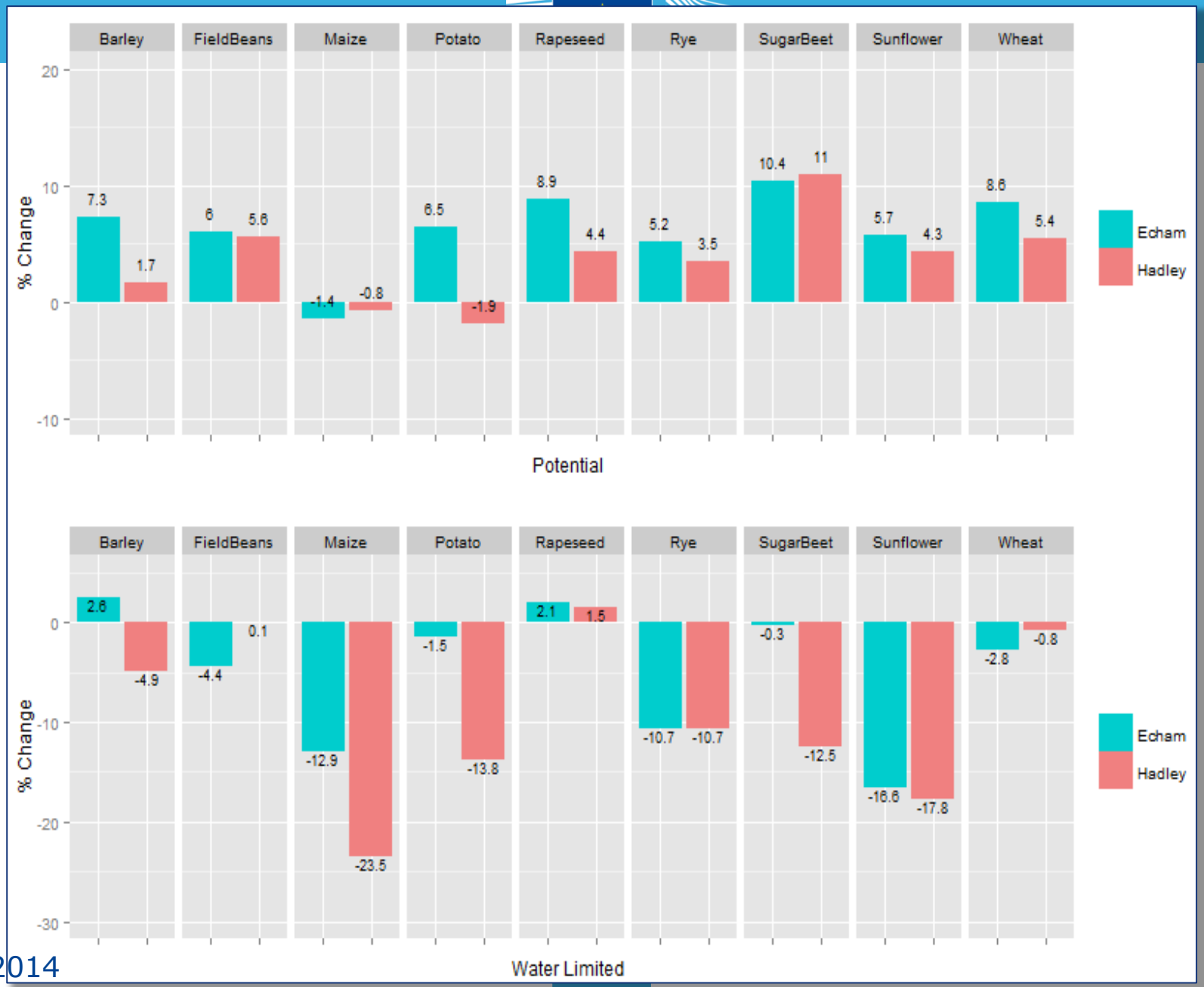
Relative change in productivity of sunflower when different management options were simulated (NY – without tillage, irrigation; YN – tillage, no irrigation; YY – tillage, irrigation; NN – without tillage, no irrigation).

JRC, 2013

©European Union, 2013. Source: Joint Research Centre

©European Union, 2013. Source: Joint Research Centre

Intercomparison Climate Scenarios



Intercomparison Crop Growth Models

European Commission

Change in Wheat Crop Yield (%)

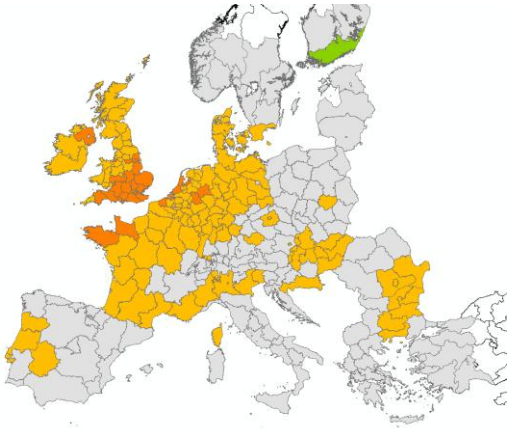
- < -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- > 30

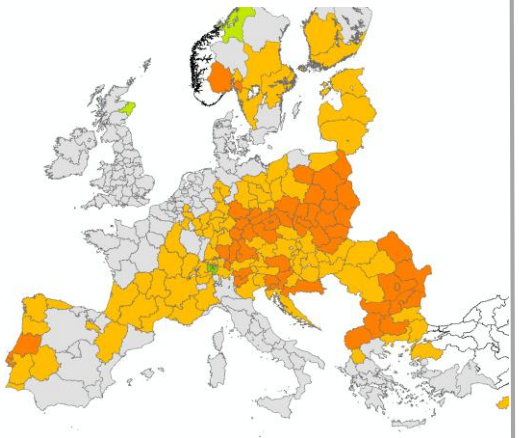
PESETA2 / CropSyst

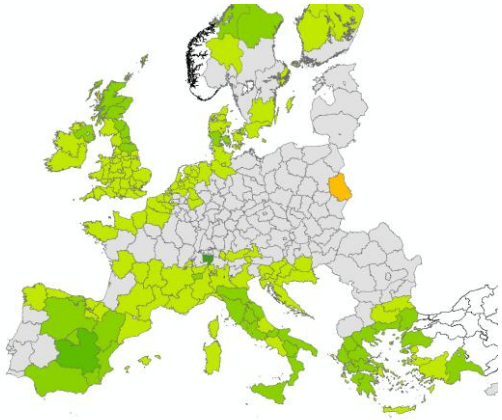
ULYSSES / WOFOST, no CO2

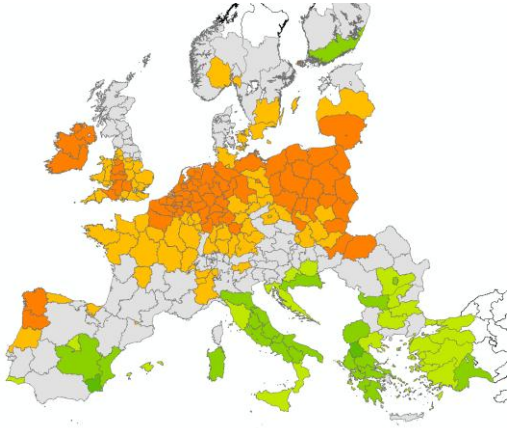
ULYSSES / WOFOST, with CO2

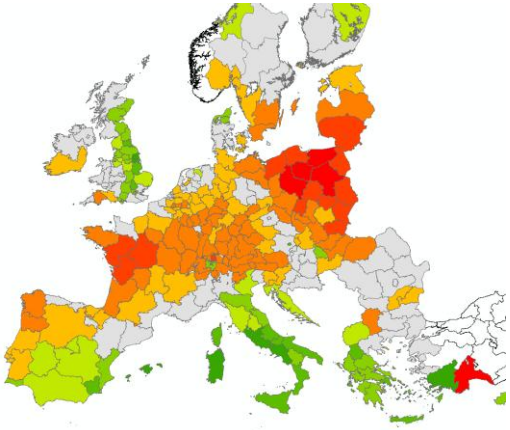
POTENTIAL

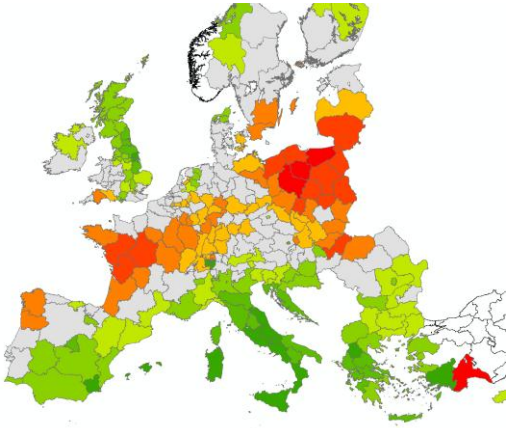








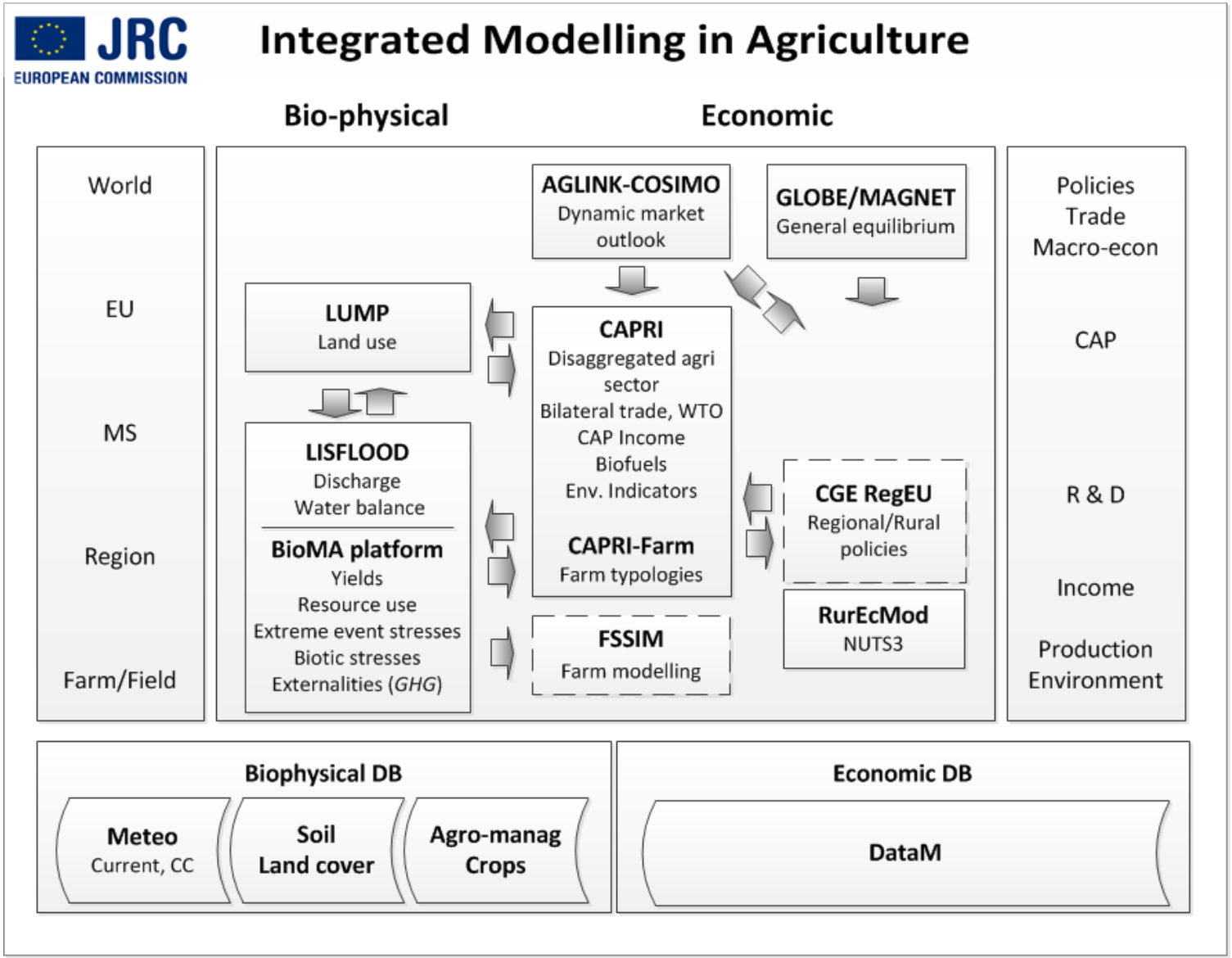




WATER LIMITED

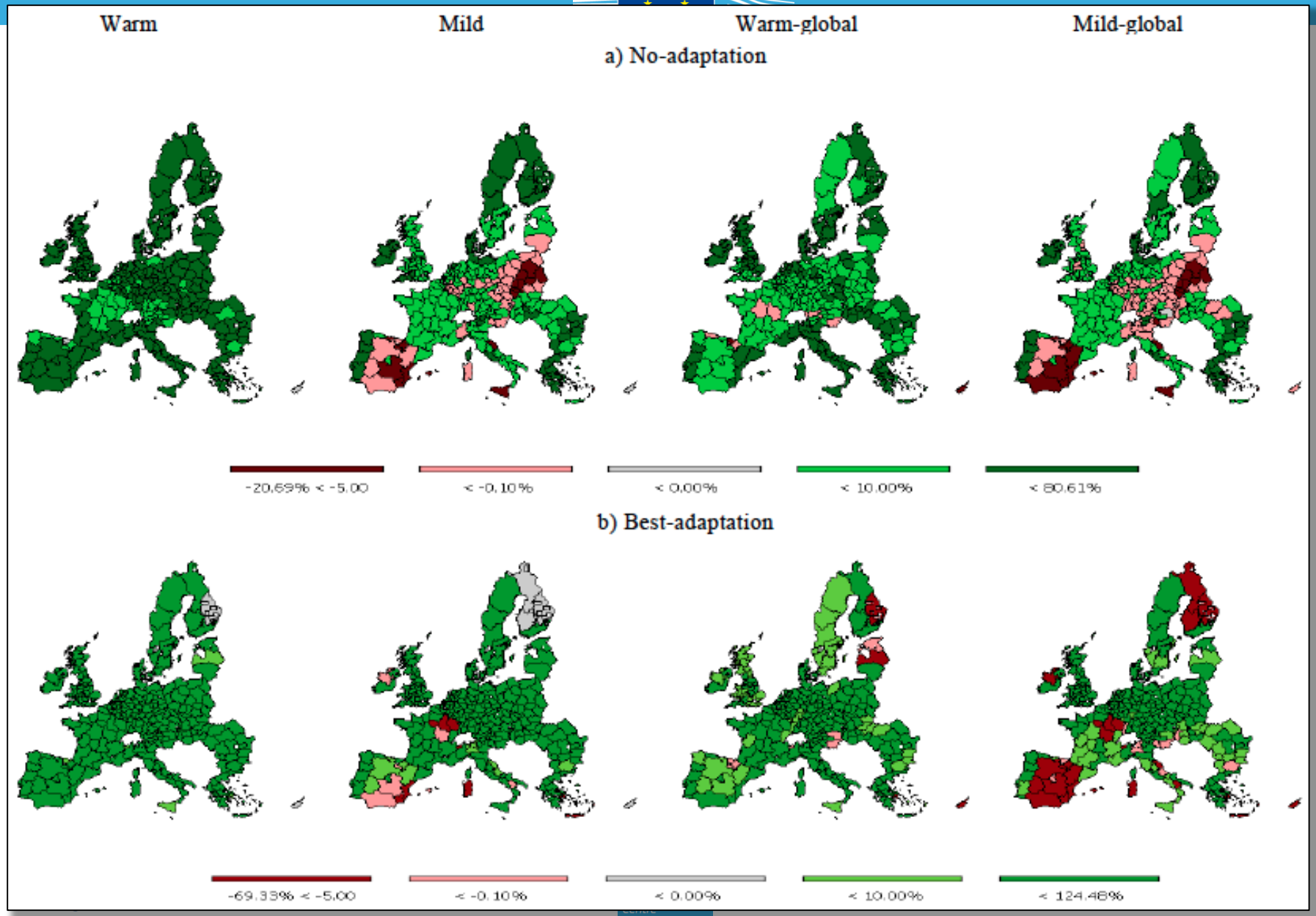
Joint Research Centre

Integrated Modelling in Agriculture



Integrated Modelling in Agriculture

Change Cereals Production



Change Producer Prices

European Commission

Table 3 Producer price changes in EU-27 (% change relative to baseline)

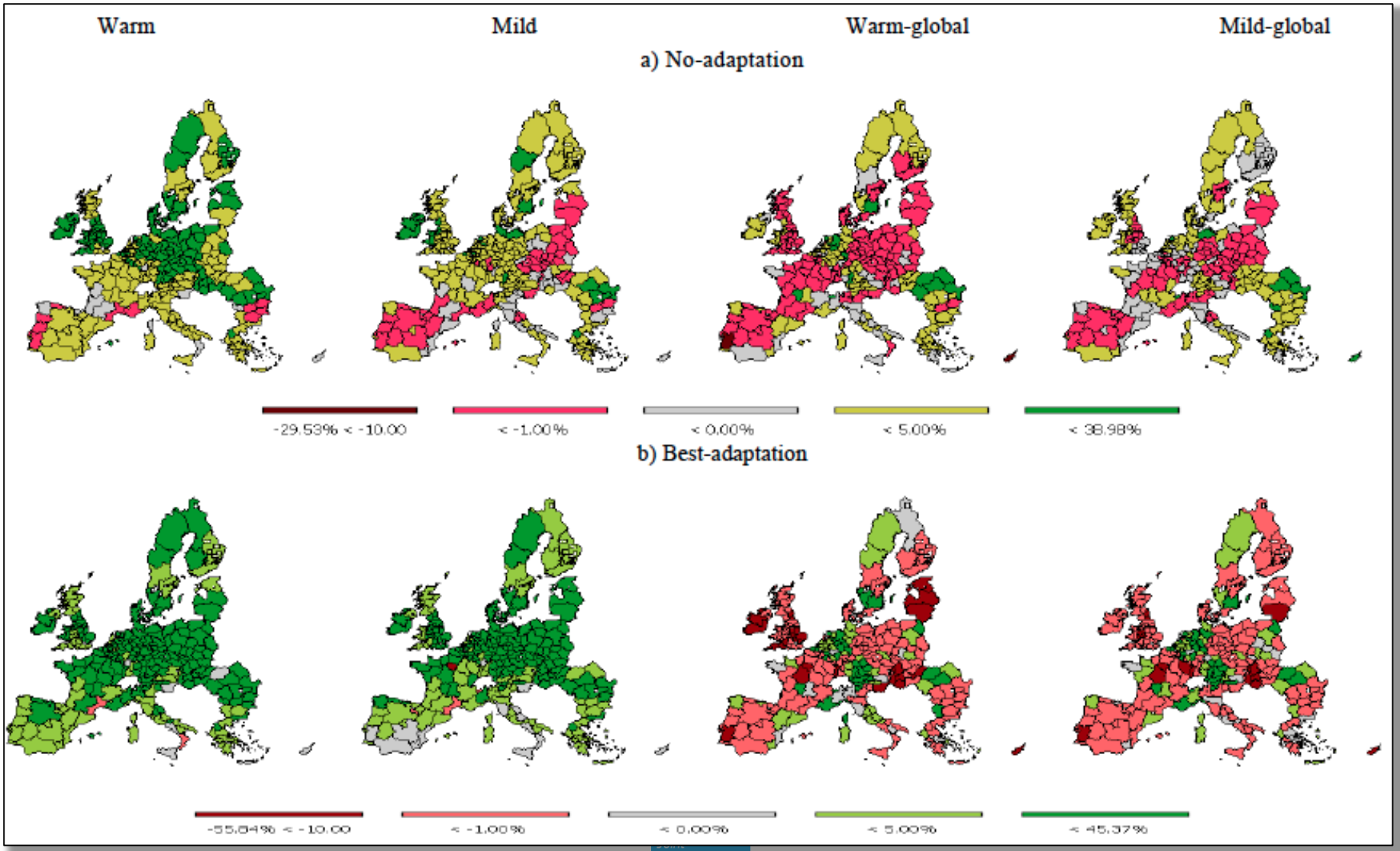
	Baseline (€/tonne)	Percentage change relative to the baseline scenario			
		No-Adaptation		Best-adaptation	
		Warm-global	Mild-global	Warm-global	Mild-global
Cereals	144.1	-10.2	-2.4	-19.2	-17.8
Soft wheat	139.6	-9.0	-2.2	-15.27	-14.9
Barley	147.3	-10.4	-2.1	-18.8	-16.7
Grain maize	155.6	-12.7	-4.0	-24.5	-21.8
Oilseeds	318.4	-6.7	2.9	-22.2	-18.9
Rape seed	318.6	-16.4	-4.1	-26.1	-23.1
Sunflower seed	313.5	37.8	34.6	-11.6	-6.6
Meat	1939.3	-2.9	-0.4	-6.1	-5.6
Beef	3223.2	-3.2	-0.3	-7.4	-6.8
Milk	265.1	-3.8	-0.2	-9.4	-8.7

Source: calculated

Shrestha et al. 2013, RAAE, 16 (2), 24-39

Integrated Modelling in Agriculture

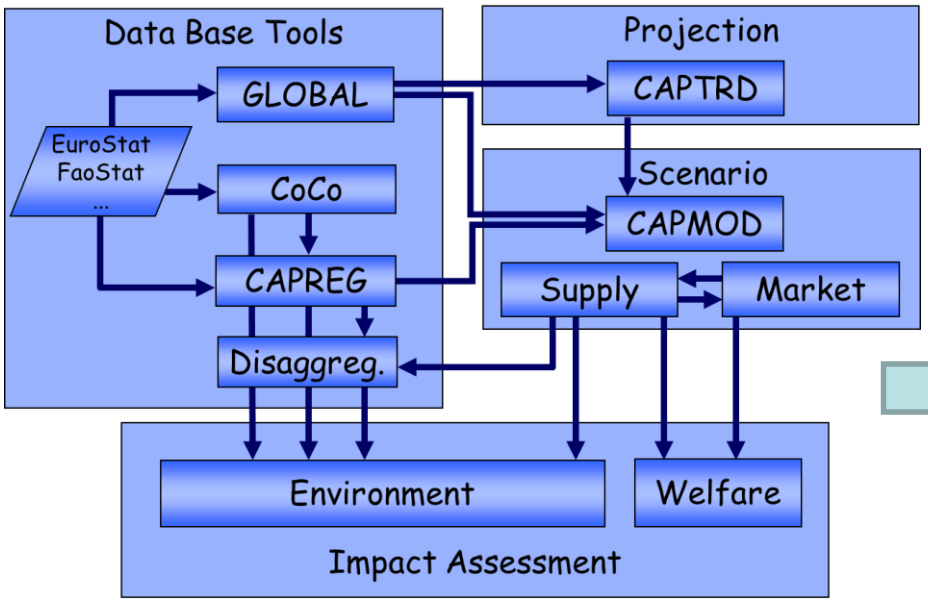
Change Farmers Income



CAPRI link to biophysical modelling

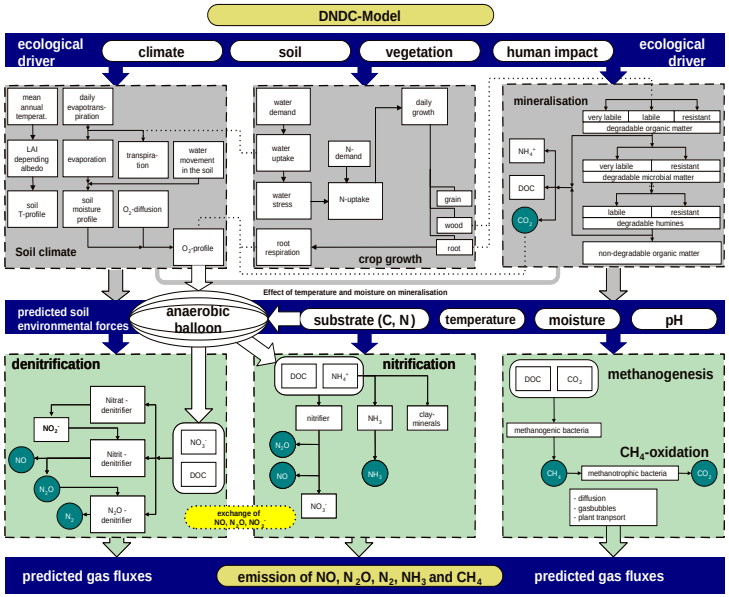
European Commission

CAPRI

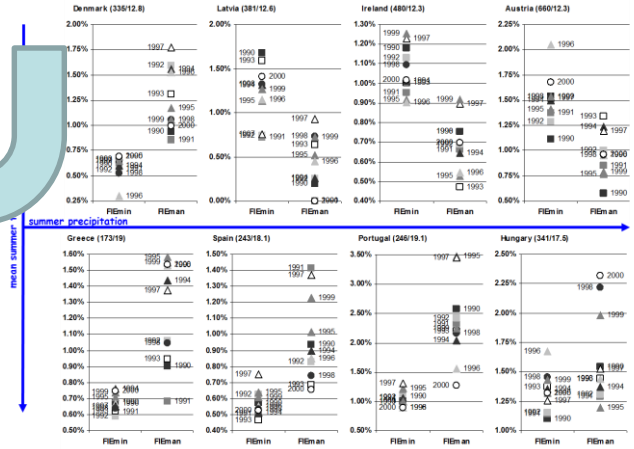


DISAGGREGATION

DNDC-EUROPE



	min	man	all
ave	1.4%	1.3%	1.3%
stdev	0.7%	0.8%	0.7%
min	0.5%	0.4%	0.4%
max	3.4%	4.1%	4.1%
EU25	1.15%	1.26%	1.17%



Leip, A., et al. 2011. Environmental pollution 159, 3223–32

Leip et al., 2011 ENVPOL 150: 3223-3232

Scale consistency: smart combining of data sources

European Commission

FSS/SAPM

FADN

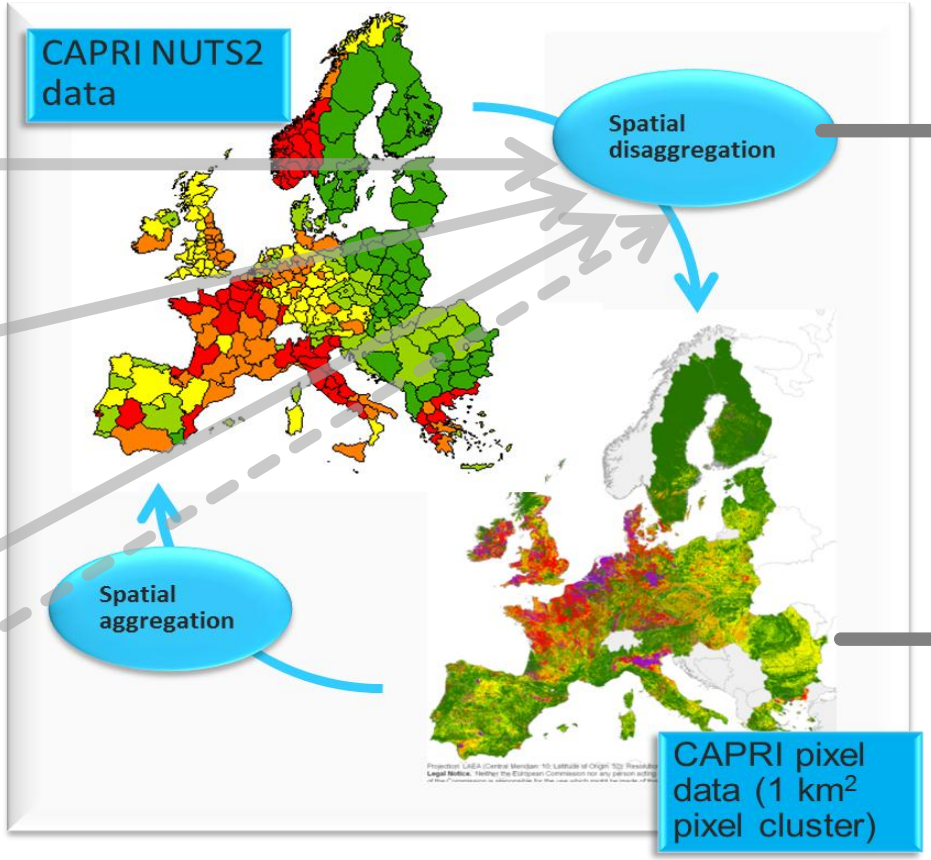
LUCAS

LPIS

IACS

Corine

…



Agri-environmental indicator at the country and province scale

Aggregation rules
Thresholds
Probability distributions

Agri-environmental indicator at the pixel scale

Available data: activities (areas by crop, yield, livestock number/density) and farm input (manure, mineral fertiliser, irrigation share), GHG and Nr flows

Assessment Greening measures The regional impact

Overall, no big changes in CAPRI between Baseline and Greening scenarios, however:

- ☺ N balance: limited positive impact (-0.2 kg ha^{-1} for EU27)
- ☺ Global Warming Potential: slightly lower GWP (-0.5% for EU27)
- ☺ Soil Erosion: very limited impact, more visible in SP (shift of land-use)
- ☺ Biodiversity: limited positive impact (again more contrasted in SP)

- ❑ Some results of greening measures should be seen at a more detailed spatial level (HSMU), as up-scaling may flatten them
- ❑ CAPRI-RD tool: allows quantitative environmental assessment (incl. CMEF indicators), fully consistent with economic modeling

Newly developed agri-environmental indicators

- Risk of Soil Erosion
- Biodiversity Friendly Farming Practices
- Agricultural Landscape Structure
- Environmental Compensation Zones
- Farmland Bird Index

Existing AEI

- N,P,K balances
- GHG emissions
- Energy use

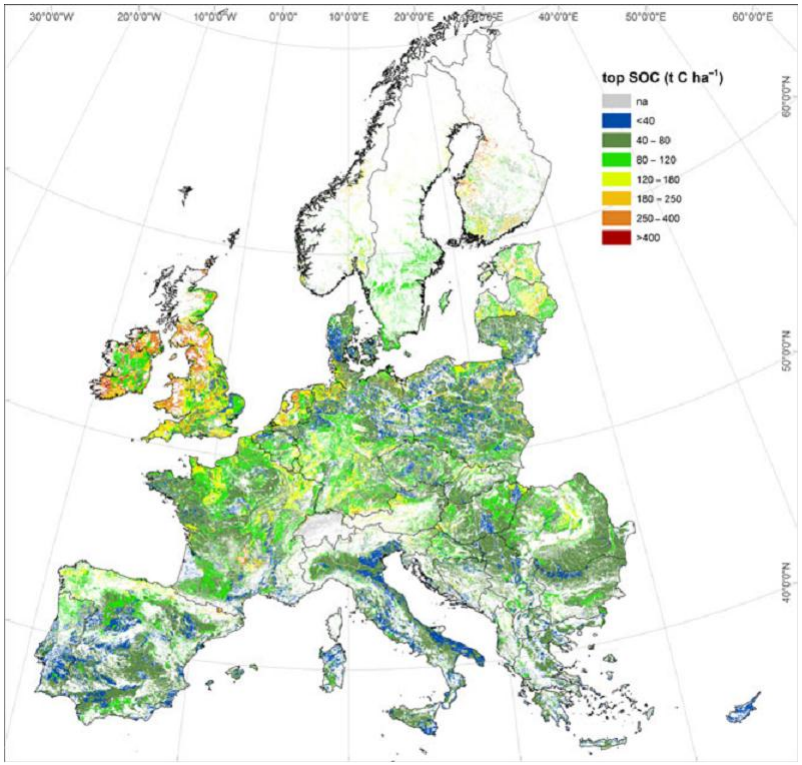
WARNING

Proxies – model results

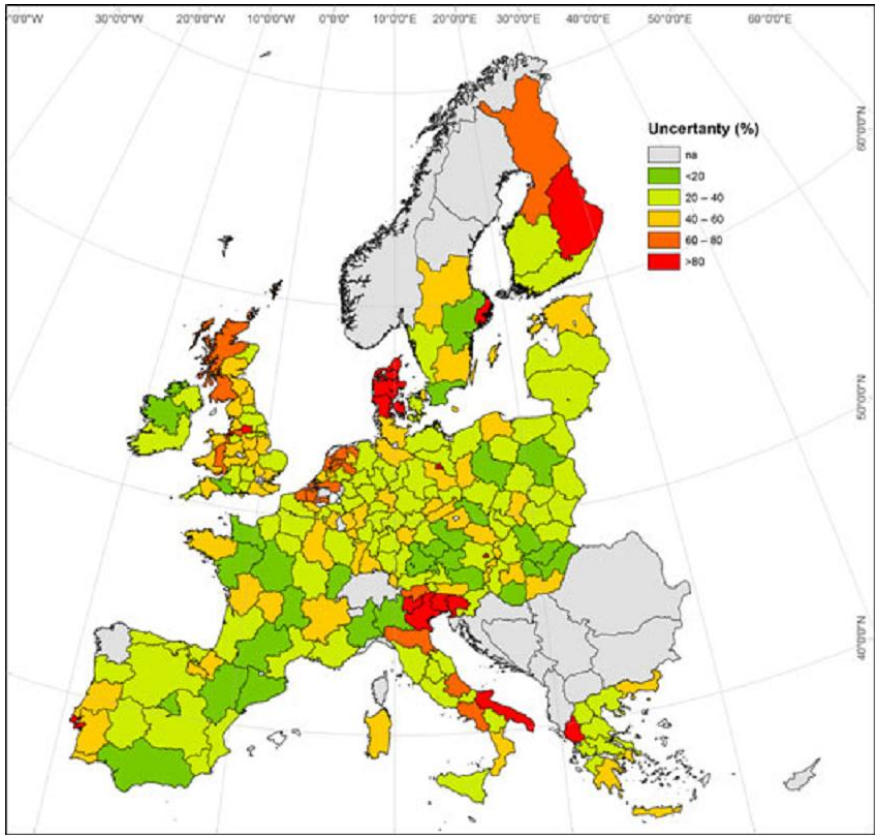
CAPRESE: Modelling quantitative effect of mitigation measures on soil organic carbon

European Commission

CENTURY process-based model estimates for 0-30 cm SOC stock 17.63 Gt C



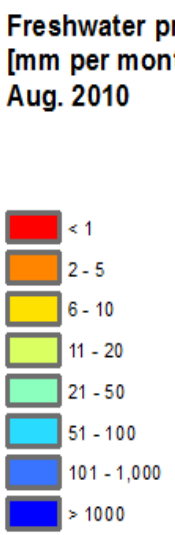
Simulated soil organic carbon (SOC) stock in the top-soil layer (0–30 cm) of European agricultural soils. (Lugato et al., 2014)

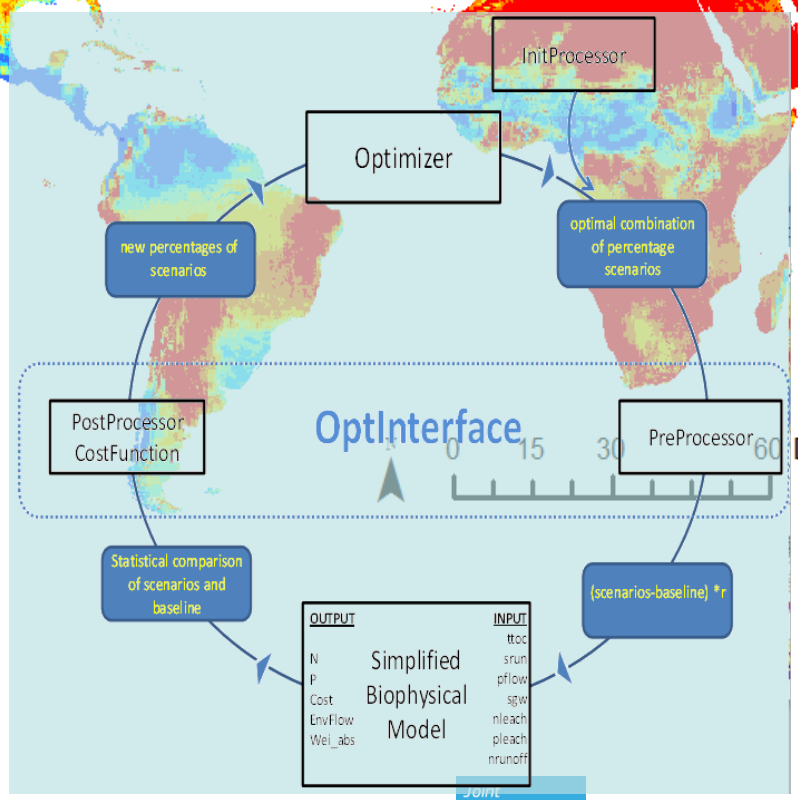


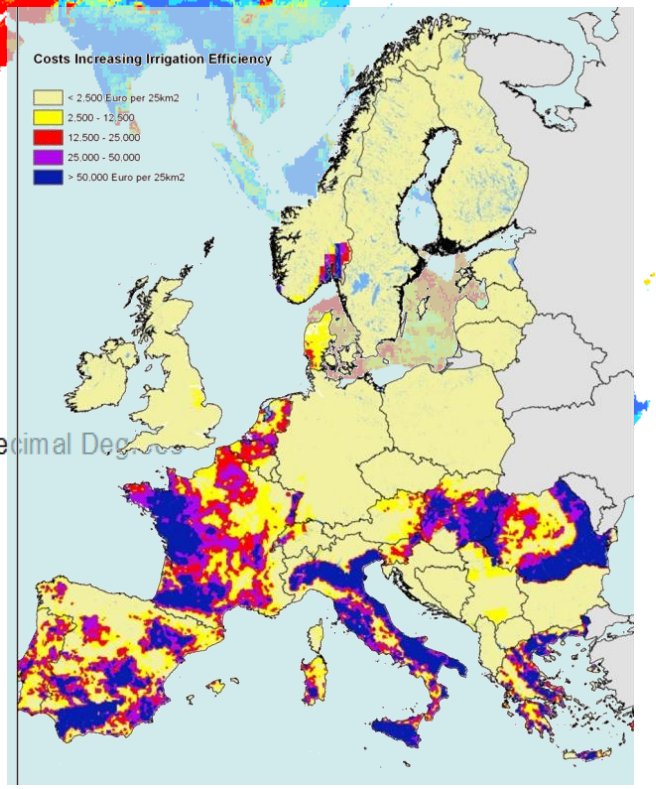
Percentage uncertainty in soil organic carbon (SOC) stock estimates across NUTS2 regions. (Lugato et al., 2014)

JRC's water resources model

- effects of various efficiency measures, climate and land use change
- on water resources, water availability
- to other sectors, including costs and benefits







Europe: 5x5 km spatial resolution
Global: 0.1 degree spatial resolution
daily time step

JRC activities 2015+

European Commission

- **Climate change impacts on crop yield & production**
  - Europe / neighbourhood / main producing regions worldwide
  - Extreme events, diseases
  - Adaptation options
- **Impact evaluation of agro-management options**
  - water, soil, tillage, rotation; nitrogen
  - Agri-environmental measures, CAP greening
- **Integrated modelling in agriculture**
  - bio-physical / agro-economic within agriculture (field, farm)
  - Multi-discipline: agriculture, water, forest, landuse, energy, ..
- **Robust modelling tools and results for policy support**
  - Model sensitivities, intercomparison, choice of scenarios

FARM LEVEL ASSESSMENT

European Commission: Low Carbon Farming project

Developed a farm level Carbon Calculator that:

- Assesses the carbon footprint of a farm and its products
- Recommends mitigation options to reduce GHG emissions
- Has been tested on 160 farms in the EU

- Assessed policy options for promoting low carbon farming practices in the EU
- Including certification schemes, incentive payments, legal obligations

- Surveyed farmers' willingness to use the carbon calculator

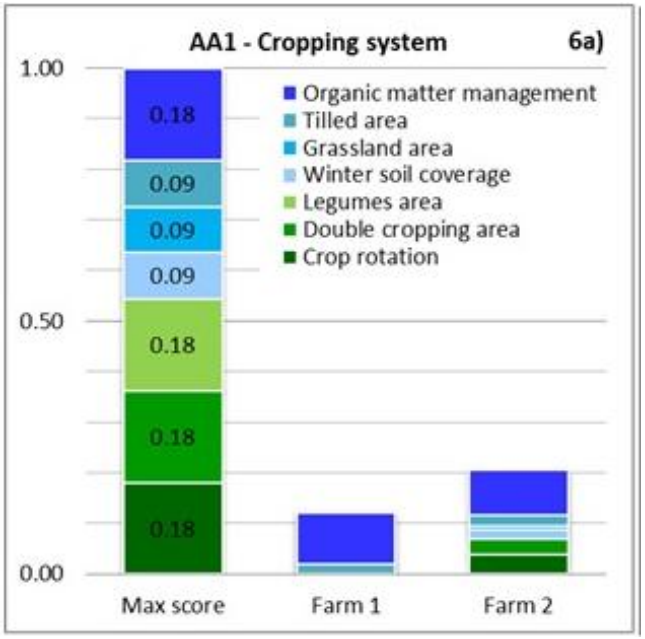
- The carbon calculator and publications available from: http://mars.jrc.ec.europa.eu/mars/Projects/LC-Farming
- Further information: palle.haastrup@jrc.ec.europa.eu

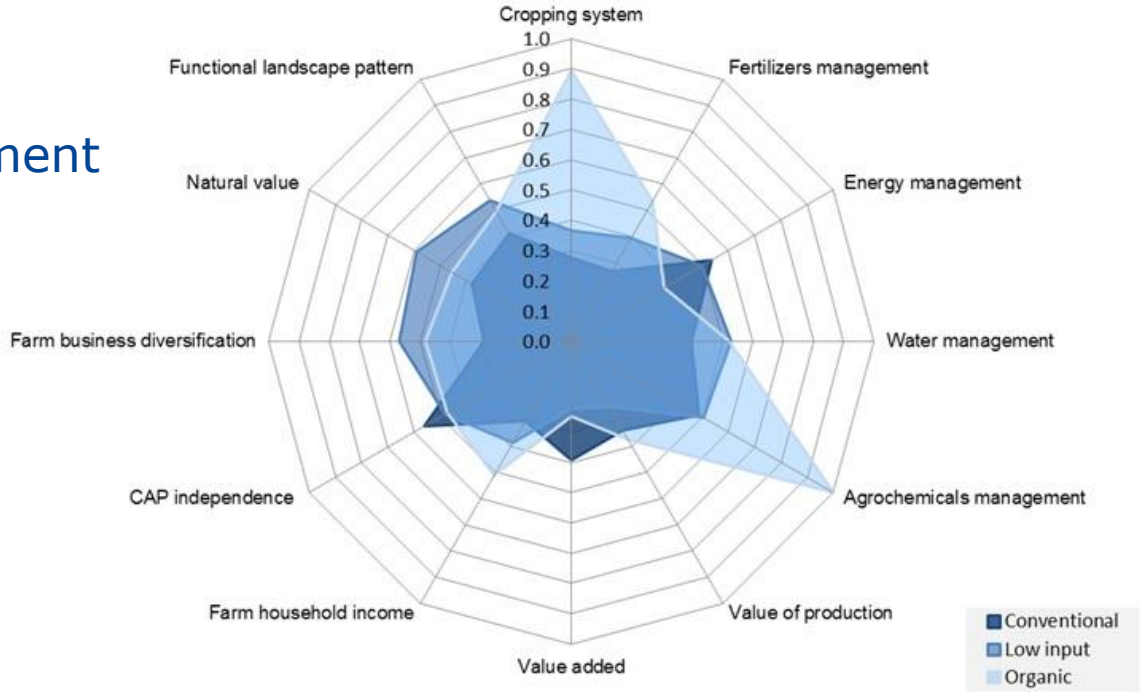
SOSTARE: A tool for sustainability assessment at farm level

European Commission

SOSTARE: integrated approach that analyses three farm management components:

- agronomic efficiency
- economic profitability
- protection of the environment

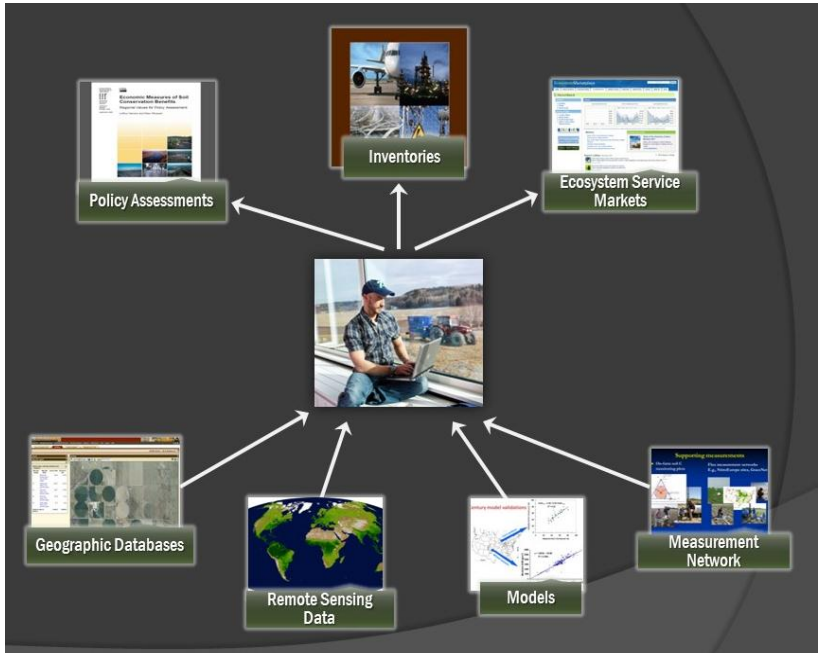


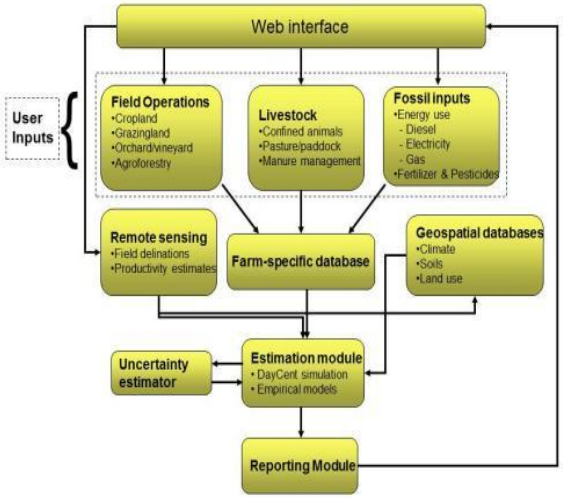


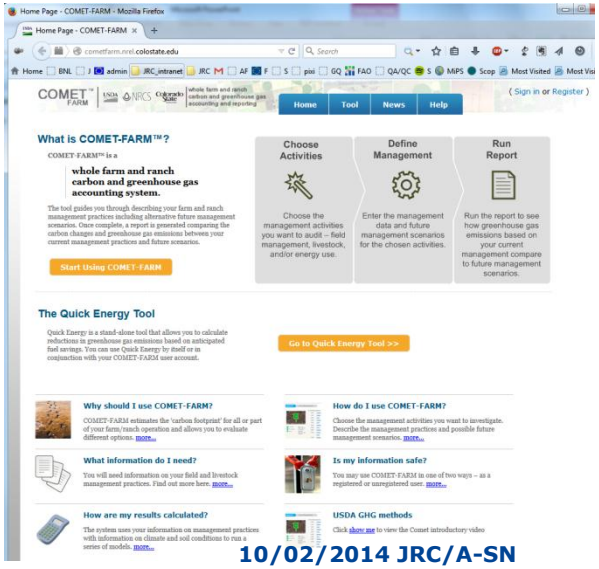
Regione Lombardia

COMÈTE-Mondiale: (FACCE-JPI support)
Farm-level Full GHG accounting

European Commission







Project PIs

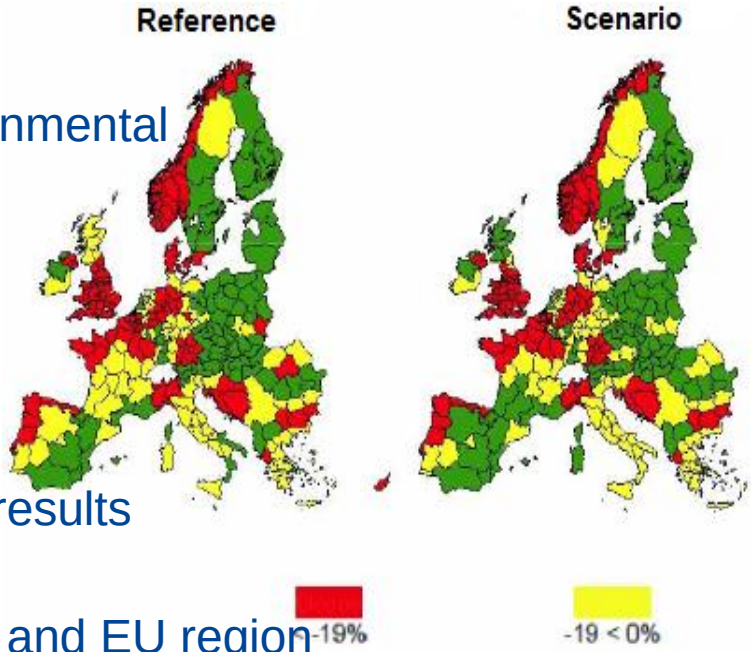
Keith Paustian, Stephen Ogle – Colo.St.Univ. (USA)
Jorge Alvaro-Fuentes – CSIC (Spain)
Martial Bernoux – IRD (France)
Peter Grace - QUT (Australia)
Emanuele Lugato – JRC (EC/EU)
Johan Six – ETH-Zurich (Switerland)
Pete Smith, Jo Smith – Univ. Aberdeen (UK)

EU wide farm level model for ex-ante assessment of new CAP

JRC-IPTS Seville

European Commission

IFM-CAP model



- More accurate analysis of welfare and environmental effects of CAP on rural farm community
- Modelling Pan-European individual farms
- Full farm heterogeneity in term of policy representation (e.g. CAP greening) and impacts (e.g. small versus big farms).
- Detailed socio-economic and environmental results (i.e. average and distribution)
- Flexibility in aggregating results by farm type and EU region (NUTS-2 & MS)

Model specifications

- **Individual** farm model running for every EU-FADN farm (≅ 60500 farms)
- **Static**, **deterministic** & **non-linear** optimisation model
- Calibrated for the **three-year** average around **2008**
- **Objective function**: max. farm level **profit function**:

  Revenues from selling products + Pillar I subsidies – Accounting costs – PMP terms
- **Constraints**: Land (arable & grassland), set-aside, quotas and animal feeding at farm level
- Modelling **compensation payments**: coupled and decoupling payments are calculated from FADN

Joint Research Centre

Research need: Farm level tools

Research Needs:

Farm level tools

- Acceptance
- Standardization
- Integration into current reporting and financing system

Assessing the food chain: from crade to farm gate

Product Environmental Footprint

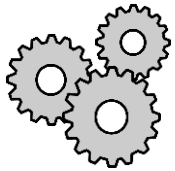
European Commission

Commenting EF WIKI
https://webgate.ec.europa.eu/fpfis/wikis/display/EUENVFP/

Minimise environmental impacts along the whole production chain

growing

transport


processing

sale

making

waste recycling

Impact categories

- Climate change
- Eco-toxicity
- Resource depletion
- Human toxicity
- Land transfor-mation
- Acidifi-cation
- Radiation
- Ozone depletion
- Water depletion
- Eutro-phication
- Particu-late matter

Food/Drink pilots

Beer Coffee Dairy Feed for food-producing animals

Fish for human consumption Packed fresh meat from bovine, pigs and sheep Uncooked pasta Packed water

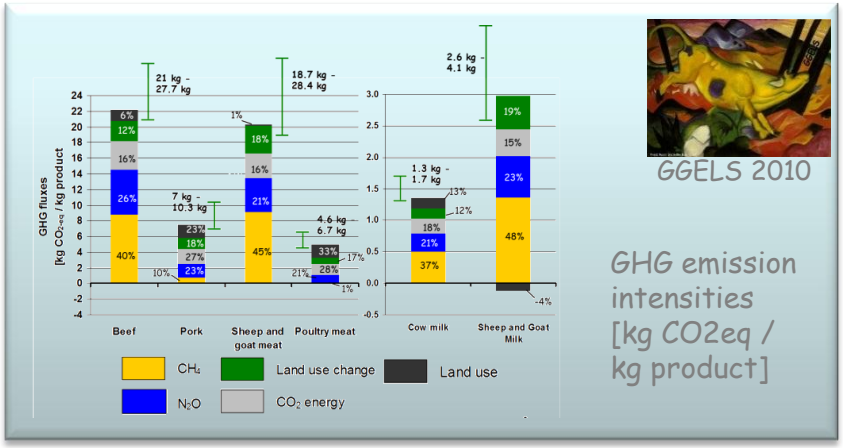
Pet food Olive oil Wine

Farm gate life cycle impact assessment

European Commission

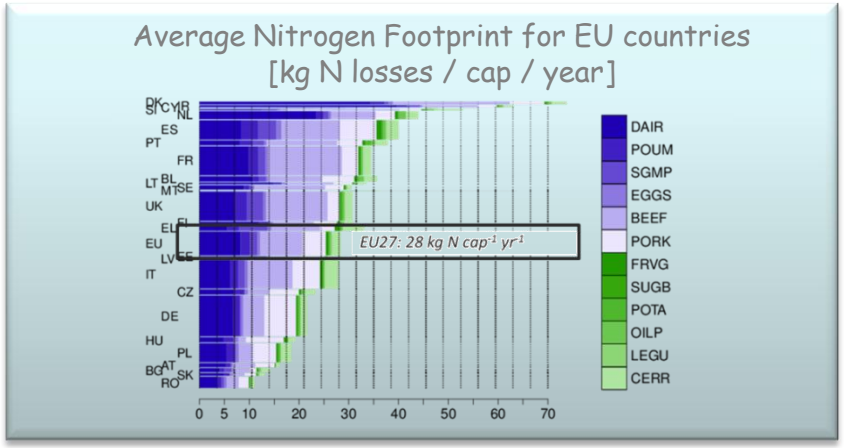
Resource-efficiency covers both domestic and imported production

- Linkage of (environmental) impact to (final) consumption
- Global dimension of sustainability
- Positive and negative effects of land use change (C-sequestration, iLUC)
- Comprehensive assessment of nutrient flows (C,N,P,…)

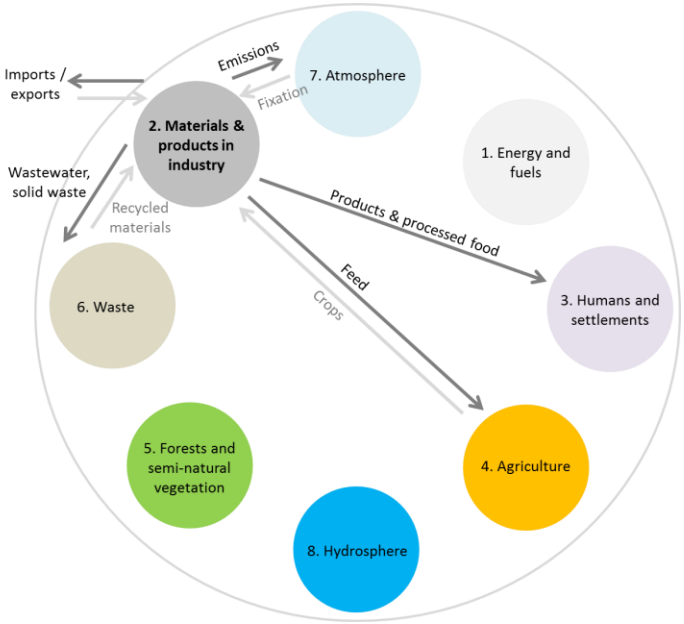


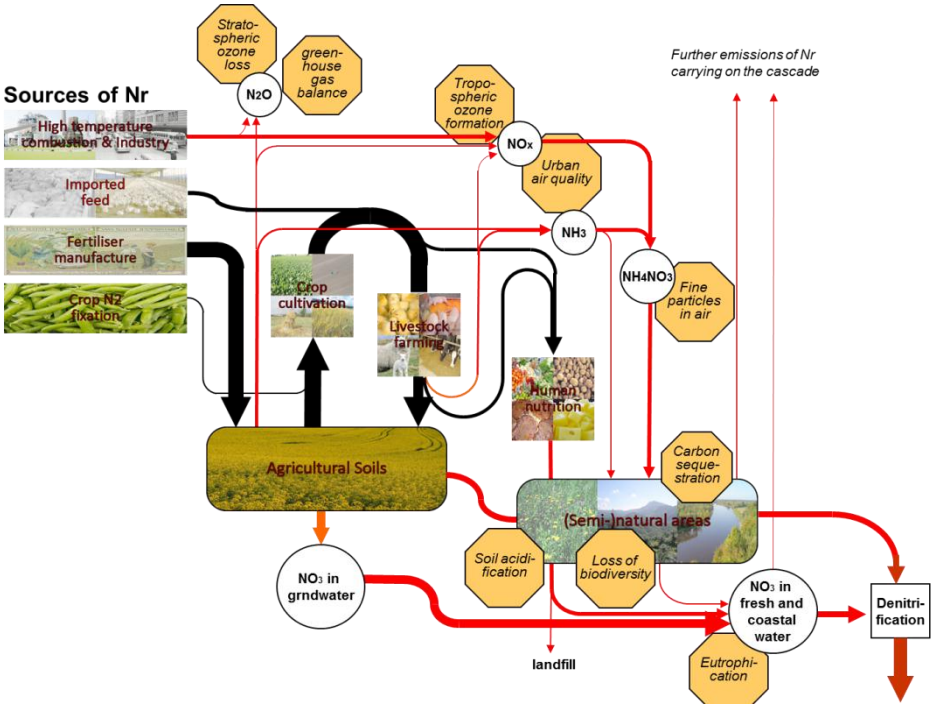
GGELS 2010

GHG emission intensities [kg CO2eq / kg product]



National Nitrogen Budgets



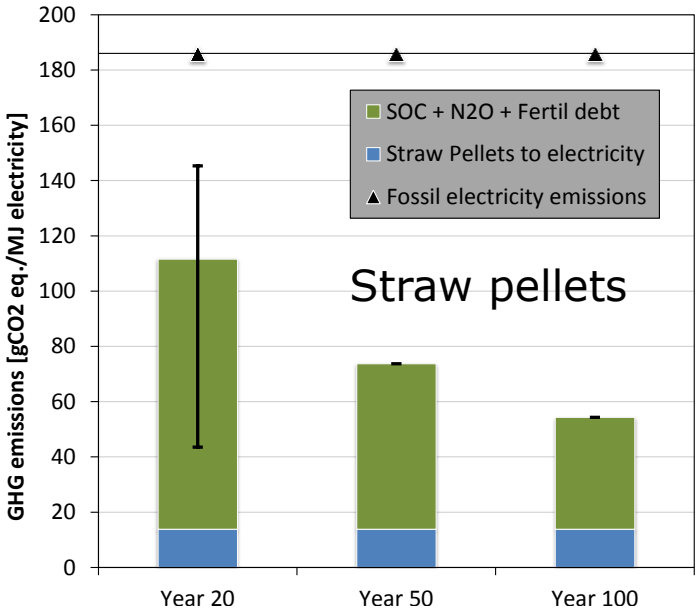


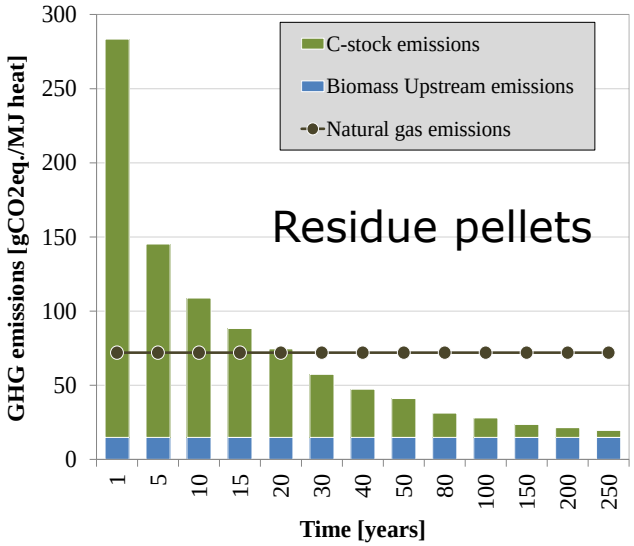
Member States shall establish a national nitrogen budget to monitor the changes in overall losses of reactive nitrogen from agriculture, including ammonia, nitrous oxide, ammonium, nitrates and nitrites, based on the principles set out in the UNECE Guidance Document on Nitrogen Budgets[4].

Waste and residues: direct and indirect effects

- Current JRC analysis focused on straw, manure, pruning residues and residues from forestry logging operations, considering:
  - Baseline ("non-bioenergy" uses)
  - Removal effects (from original environment)
  - Displacement effects (from existing uses/industries)
- **Main effects analysed**:

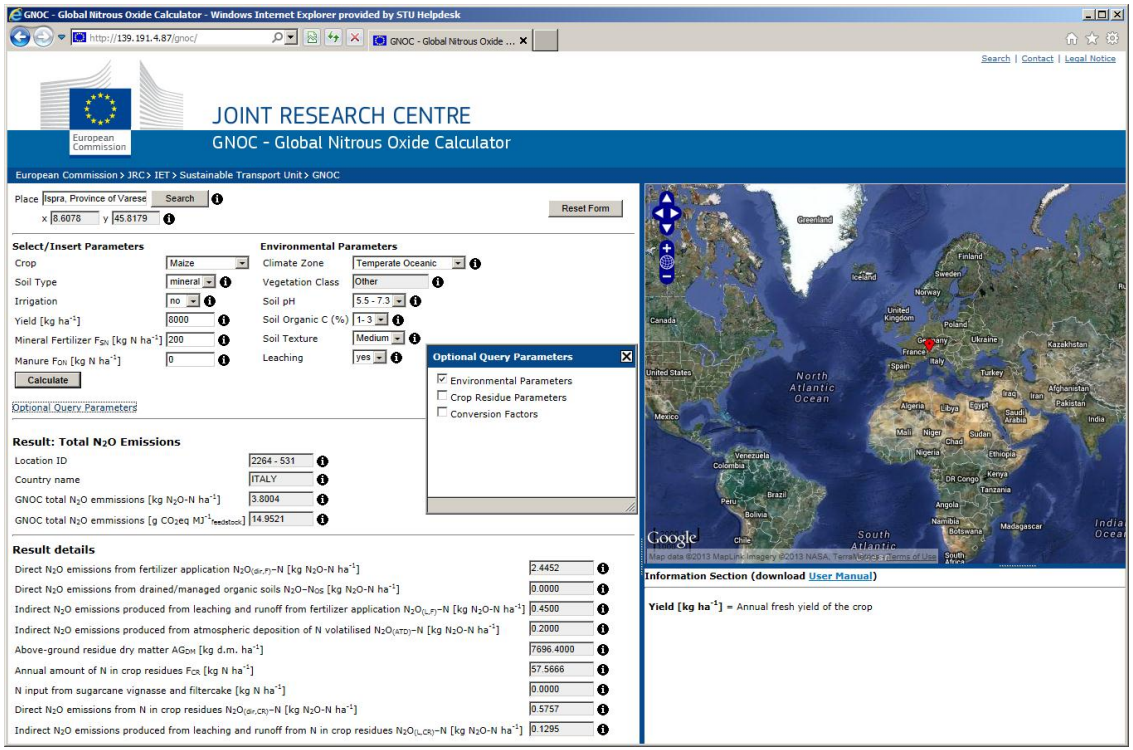
- Modeling of SOC and N_2O emissions changes due to the additional removal / change of management
- Effects on productivity
- Total "Direct" (LCA) GHG emissions and climate impacts
- Biodiversity/water (literature data)



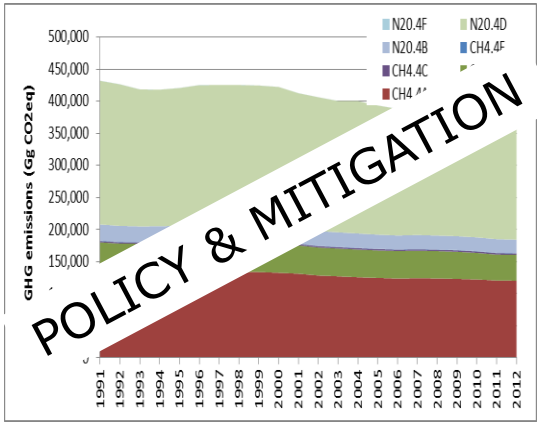


Development of guidelines for MS for the calculation of cultivation emissions: the Global Nitrous Oxide Calculator (GNOC)

- *Quantification of soil N_2O emissions from feedstock cultivation*
- *Combined "Stehfest&Bouwman- statistical model" with IPCC Tier1 Approach*
- *On-line tool to give local N2O emissions estimates based on soil properties and other variables (fertilizer, manure, crop, climate...) anywhere in the world*



Joint Research Centre


GHG emissions (Gg CO2eq)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
N2O.4F
N2O.4D
N2O.4B
CH4.4F
CH4.4C
POLICY & MITIGATION

European Commission

An economic assessment of GHG mitigation policy options for EU agriculture -EcAMPA-

JRC-IPTS, JRC-IES, EuroCare, SLU

Objectives:

- Improving CAPRI with respect to GHG emission accounting, implementation of endogenous technological mitigation options and representation of emission leakage
- Applying the model to assess illustrative GHG mitigation policy scenarios.

Joint Research Centre

European Commission

Main messages:

- Reference scenario: No change in total EU agricultural GHG emissions by 2030 compared to 2005; i.e. business as usual not enough to trigger reductions in aggregated EU agricultural GHG emissions in the medium-term.
- Policy scenarios: largest part of the GHG reduction realised by quantitative adjustments (herd size, yield and cultivated hectares), especially in the livestock sector.
- Emission leakage may considerably downsize any net effects of EU mandatory targets on global GHG reduction.

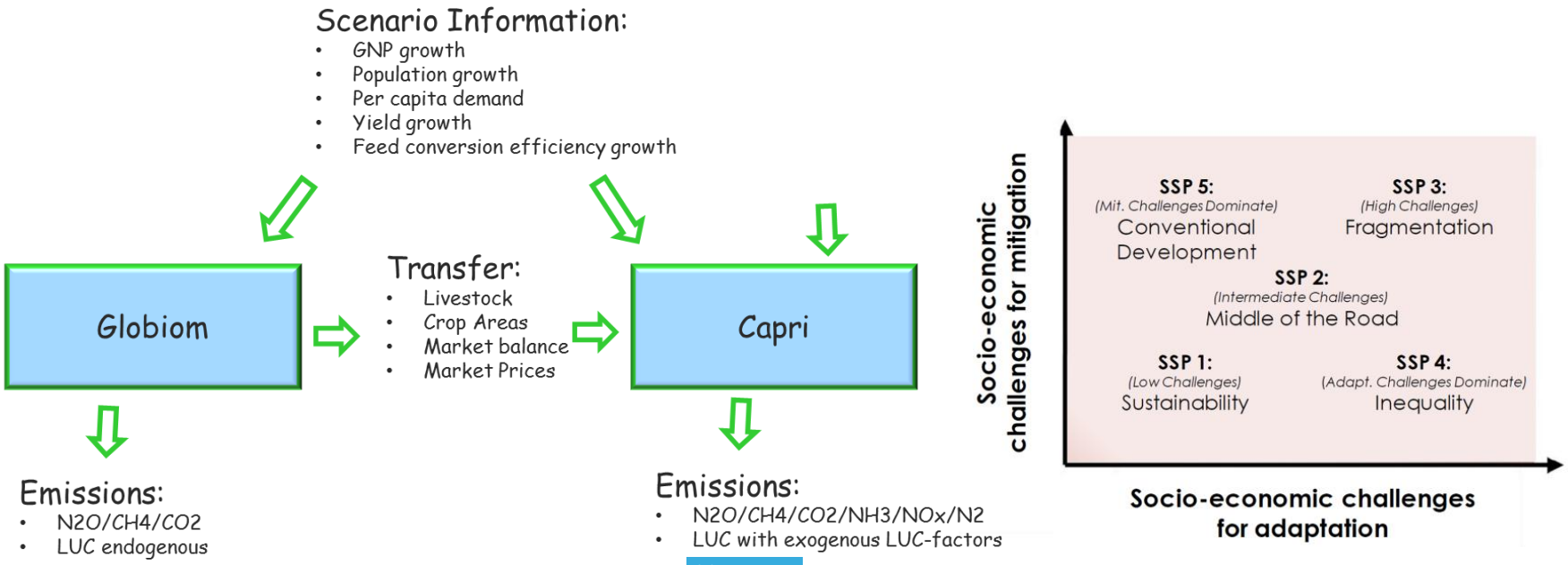
Follow-up: EcAMPA 2:

- Covering more technological mitigation options;
- Dynamic emission factors for calculating emission leakage;
- Design of more policy-relevant scenarios.

Joint Research Centre

Additional/improved mitigation technologies:

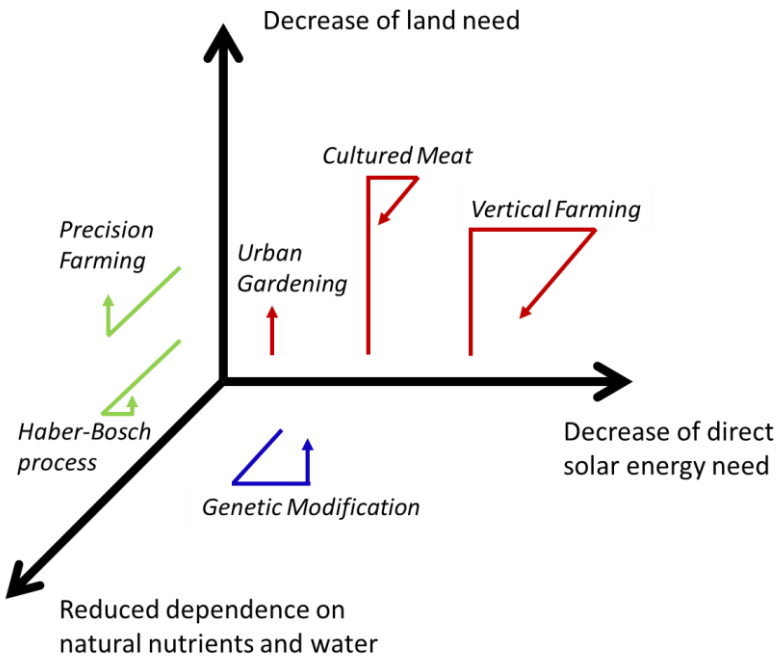
- Anaerobic digestion
- Feeding of extruded line seed
- Feeding of nitrate
- Low nitrogen feeding (reduced crude protein intake)
- Reduced fertilization on grassland
- Increase of legume share in temporary grassland



Long term N-innovations

European Commission

	Land need	Energy need	Costs	Nitrogen release	GHG emissions	Time to deployment
Precision farming	↓	↓	↓	↓	↓	★★
GMO's	↓	↓	↓	↓	↓	★★
Urban gardening	↓	↓	↓	—	—	★
Vertical farming	↓	↑	↑	↓	↓	★★★
Cultured meat	↓	↑	↑	↓	↓	★★★
Diet changes	↓	↓	↓	↓	↓	★
Industry and combustion	N/A	↓	↓	↓	↓	★★
	Land need	**Energy need**	**Costs**	**Nitrogen release**	**GHG emissions**	**Time to deployment**
COMBINATION	↓	↑	↑	↓	↓	Late 21st century



- "Soft" measures would only have a minor (positive) impact
- Socio-economic options seem less successful than high-tech options (rebound effects not considered)
- Massive reductions in environmental impacts entail
  - high energy demand
  - high costs

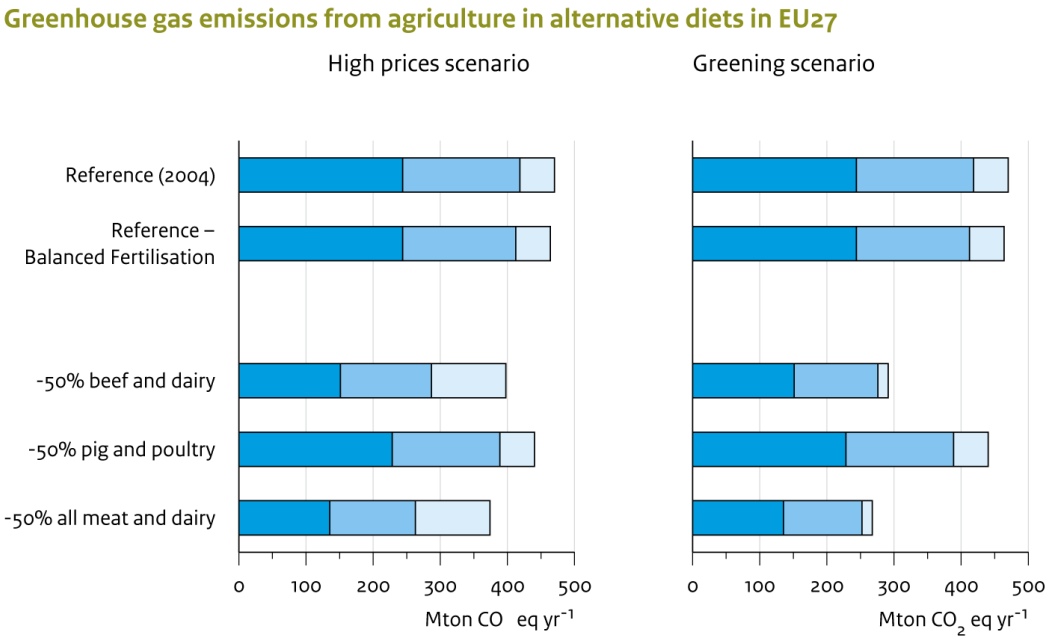
Winiwarter et al. 2014. COSUST 9-10, 37-45

CONSUMER
ENGAGEMENT

Nitrogen on the table (TFRN-ENA-EPNF)

European Commission

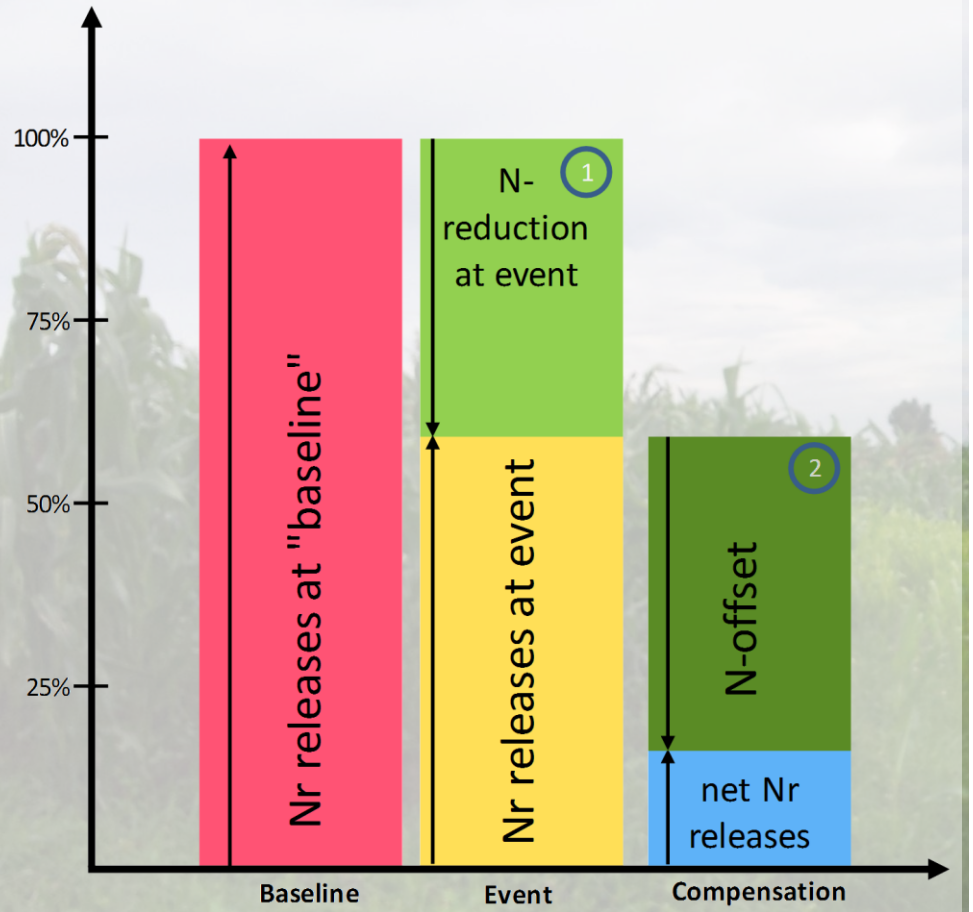
What would happen if Europe would reduce meat and dairy consumption by 50%?



- Food choices do matter, both for human health as well as for the environment
- Shift to plant-based products mean lower intake of saturated fats
- For the environment: multiple positive effects: lower nitrogen emissions (ammonia, nitrate, nitrous oxide), greenhouse gas emissions, land use savings
- With regard to the environment, more gains could be achieved by reducing food losses and by improving farm management

Westhoek H et al., 2014 Glob. Environ. Chang. ***26*** *196–205*

Nitrogen Neutrality



Box 1. Definition of N-neutrality and sustainable land management.

Definition of N-neutrality

To achieve N-neutrality,
(1) first decrease the release of reactive nitrogen (Nr) into the environment by
(a) reducing over-consumption of food and reducing food wastes and minimizing energy consumption, and
(b) choosing sustainable sources of energy and food,
(2) then, contribute to a measured compensation of the remaining Nr releases by a measured
(a) reduction of Nr releases elsewhere to balance the remaining releases,
(b) increased sustainability in the production of food where sustainable land management is not yet achieved.

Definition of sustainable land management

(3) With respect to N-neutrality, sustainable land management is a farming system which
(a) minimizes the ecological footprint of the farming products (incl. the C footprint, N footprint, water-footprint),
(b) keeps the farmed land in good environmental conditions,
(c) satisfies human food needs and enables the farm worker(s) and their families to a decent living standard.

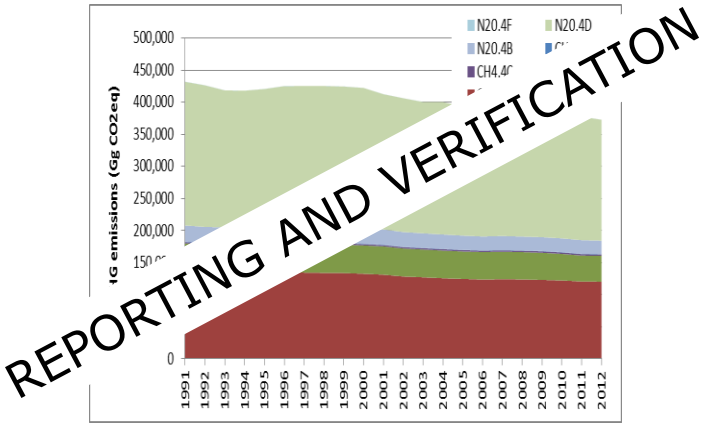
Leip A et al. 2014 Environ. Res. Lett. 9 115001

Research need: Consumer involvement

Research Needs:

Consumer engagement

- People's choices matter
- Information
- Responsibility
- Tools

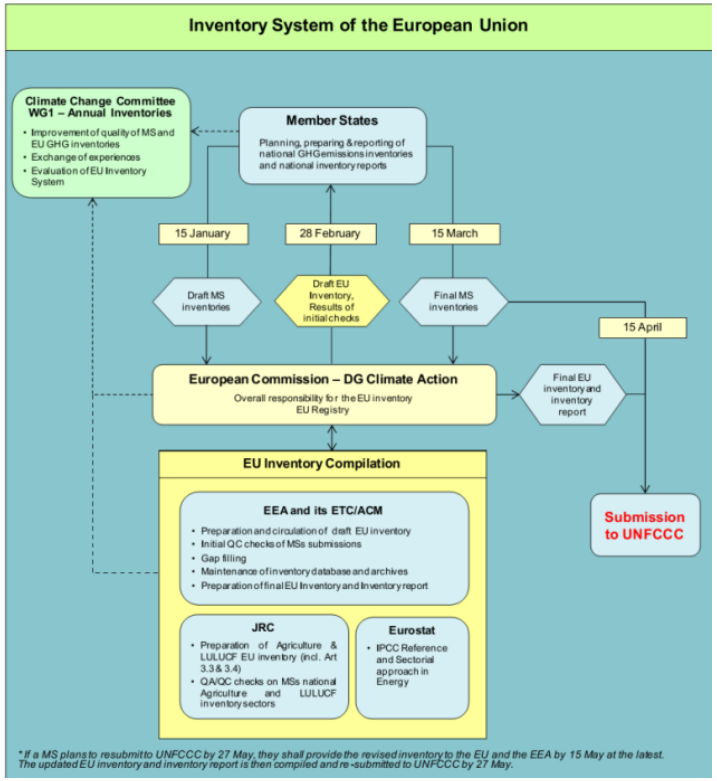


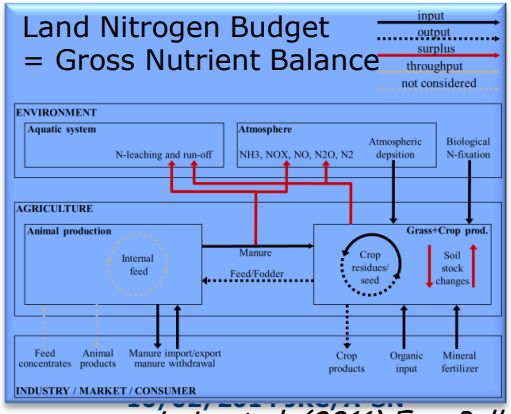
REPORTING AND VERIFICATION

Challenge of multi-reporting obligations Reporting of GHGs and N-indicators

European Commission

- Working Group on Annual Emission Inventories, GHG Monitoring Mechanism, CLIMA
  - QA/QC for agriculture and LULUCF
  - EU inventory chapter
  - Independent assessment of input data (e.g. soil map, activities, climate zones, …) and emissions (e.g. FAOstat, CAPRI, …)
- Working Group on Agri-Environmental Indicators, ESTAT
  - Cooperation with ESTAT (+ENV, AGRI, CLIMA, EEA) on improving data & methods
  - Pilot Project: using CAPRI for providing regionalized GNB estimates





Leip et al. (2011) Env. Poll.

JRC support for CM and GM reporting

European Commission

Context: Decision 529/2013/EU requires MS to report for carbon emissions/removals from cropland management (CM) and grazing land management (GM).

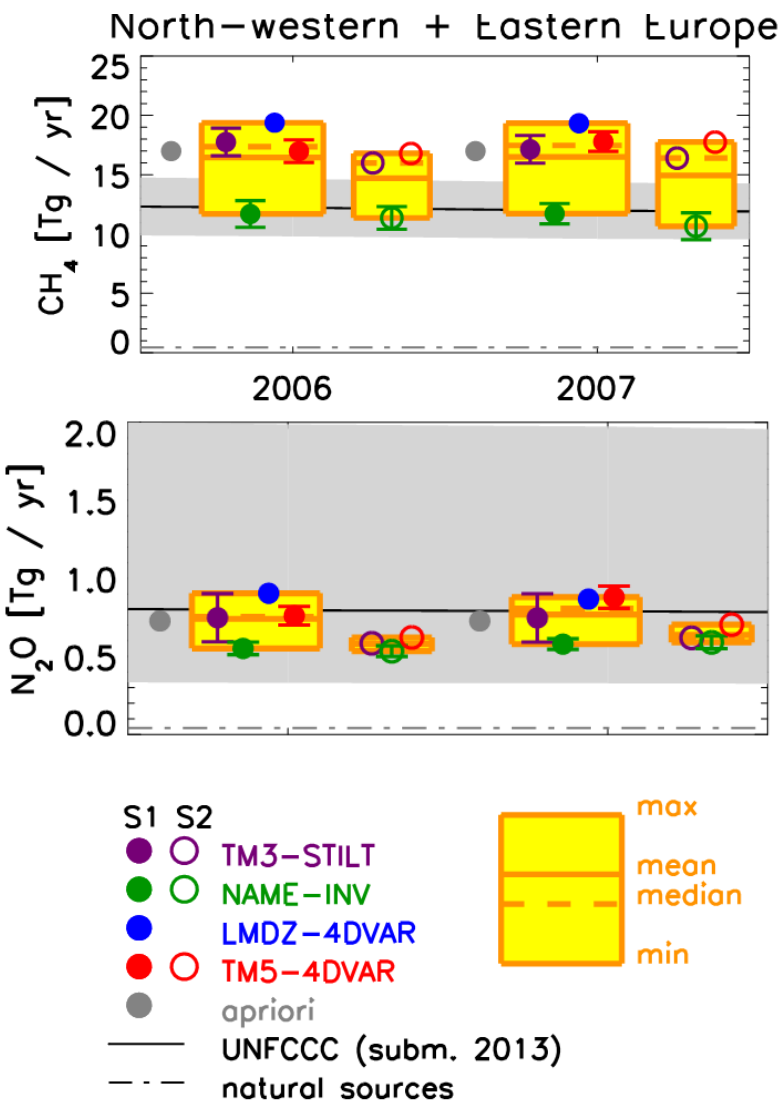
Areas of work

- Support to MS in reporting CM/GM following IPCC guidance (H03 leads), both using MS own data and exploring the usability of JRC estimates using IPCC Tier 1 (H05, H03)
- Planned AA with DG CLIMA to assess the impact at 2030 of specific policy scenarios, using Tier 1 and/or Tier 3 estimations (CENTURY model, H05)

Research on data needs/available sources for Land use and Management (H03, H04):

- EUROSTAT/LUCAS/SAPM/FSS: processing required (e.g. gap filling, interpolation)
- LPIS (analysis of the methods applied in Austria, Belgium, Denmark, Finland, Romania, Latvia, and Lithuania); testing in a new context: Italy.
- Stratification data (JRC datasets on Climate and Soil)
- EU CM/GM emission factor database to support MS' GHG reporting (planned activity)

Top-down estimates of CH4 and N2O emissions



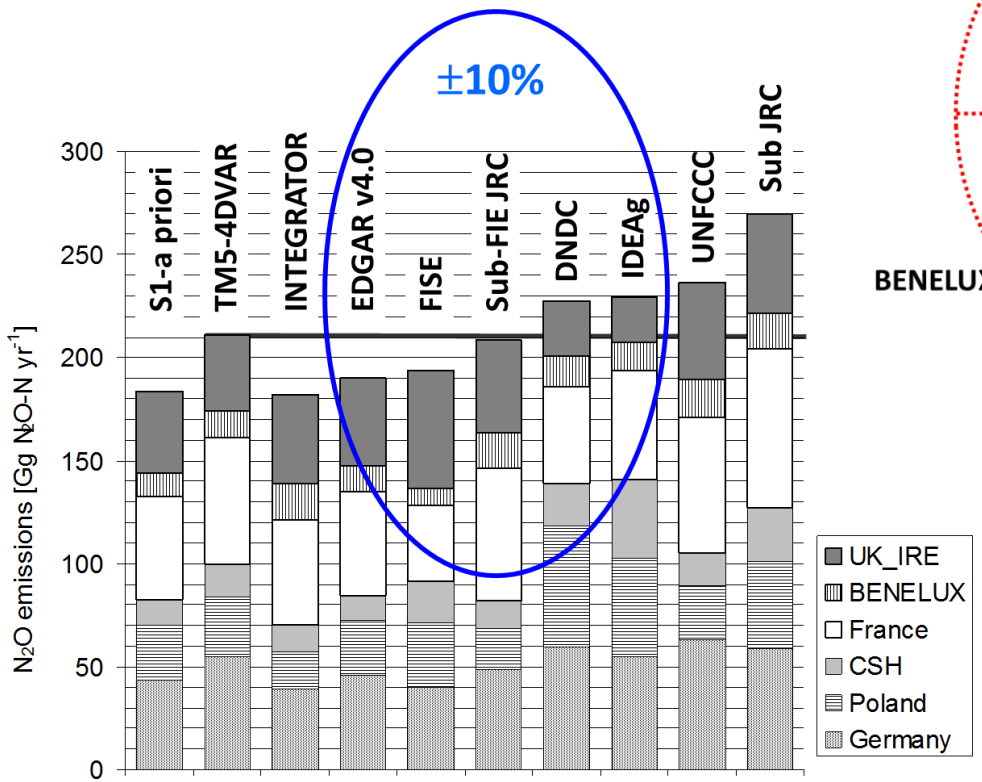
- Verification of bottom-up approaches possible for CH4 and N2O
- Inverse modelling can probably constrain N2O emissions better then bottom-up approaches and/or UNFCCC uncertainties are overestimated
- Requires: High-quality long-term monitoring of GHGs in the atmosphere with increased density of the monitoring stations, improved atmospheric transport models, and a realistic quantification of uncertainties, in both bottom-up and top-down emission estimates

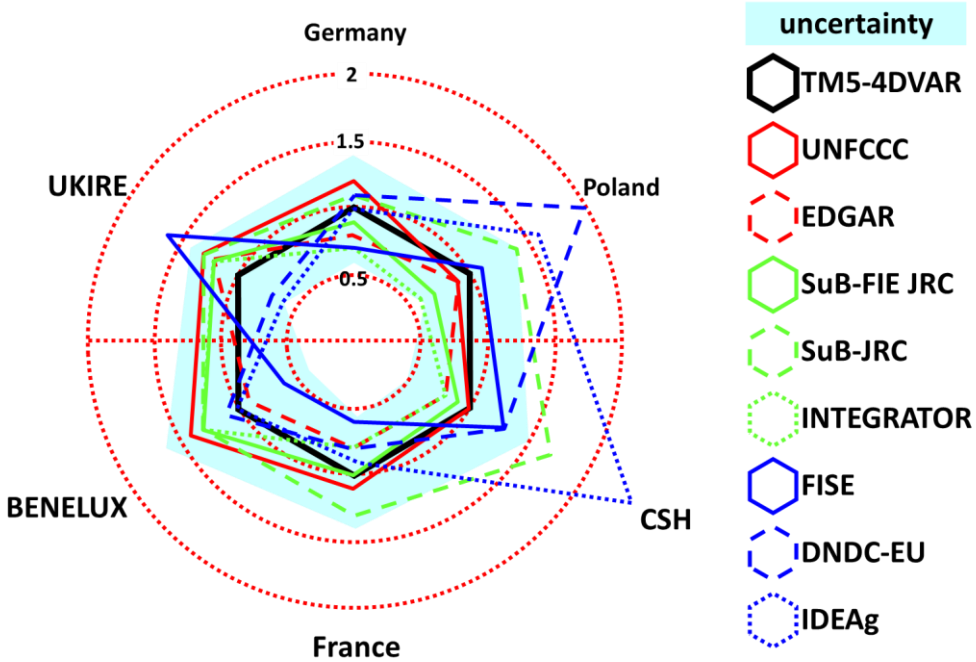
Bergamaschi et al, Atmos. Chem. Phys., 15, 715–736, 2015

Verification: *The true emissions are unknown*

European Commission

High variability in emissions & expensive measurements → high uncertainty





Accurate monitoring of emissions requires a combination of measurement programs at different scales and models that can <u>link the scales</u>

Leip et al. (2011) Cosust

Research needs: Innovative solution to adapt GHG reporting to scientific state of the art

Research Needs:

Inverse vs bottom up methodologies

- Integration
- Prioritisation
- De-compart-mentalization