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science for global insight

Crop calorie supply under climate change and vulnerability to drought events at +2°C of global warming threshold in Europe

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IIASA, BOKU, CRI, JRC

Outline

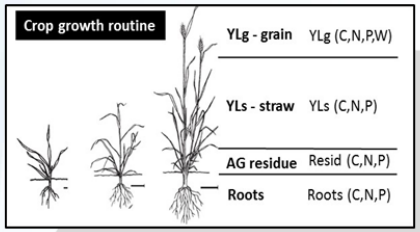
- **Methods**
- Tools validation
- Vulnerability to drought events
- Impact of a +2°C global warming
- Bracketing uncertainties

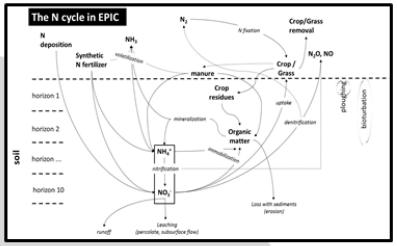
Environmental Policy Integrated Climate (EPIC) model

The EPIC model (Williams et al. 1996)

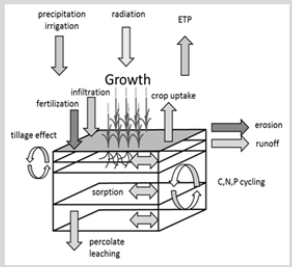
Production
Embedded C,N,P
Emb. energy

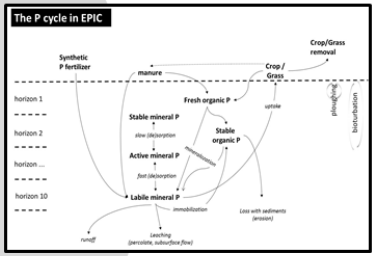
Climate change
- T,PRCP distr. patterns
- extremity
- atm. CO2 effect



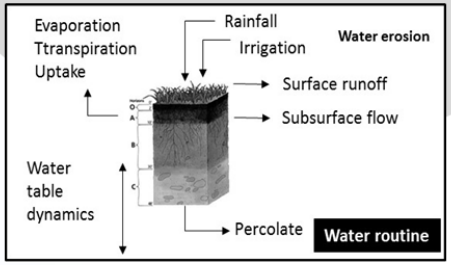


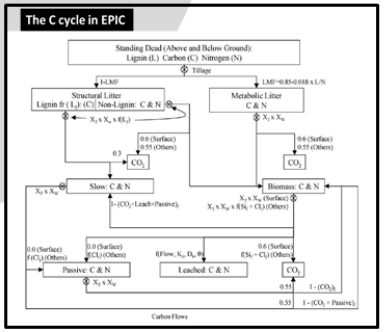
Weather
- daily T, PRCP, RAD, wind, RHUM
- Weather generator
- CO2 fertilization / WU efficiency
- PET
- Temperature stress





Management
- N,P,K and manure fertilization
- irrigation
- tillage
- crop rotation, inter-cropping,...
- drainage
- pesticide fate
- grazing/mowing
- residue management



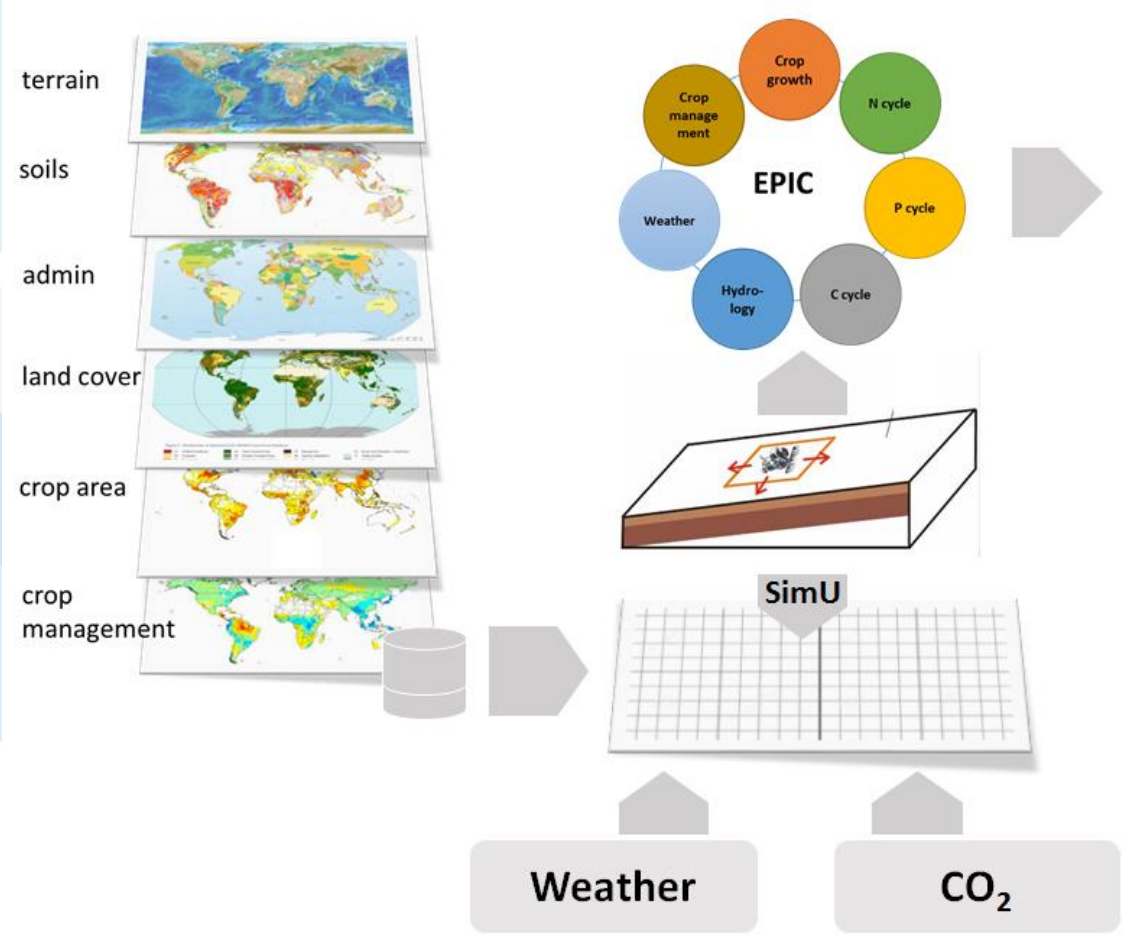


Management interventions

Environmental externalities
CO2,N-emissions, N,P, C leaching & erosion, water use

EPIC-IIASA GGCM to simulate agricultural systems at large scale

- EU-version gridded at 1-km resolution (Balkovič et al. 2013)



Potential yield biomass
Actual yield/biomass
Water use
Nutrient Uptake
Growth constraints
Runoff
Subsurface flow
Percolation
ETP
CO_2,N-emissions
N,P,C leaching
Water erosion
Soil organic carbon
Irrigation
Fertilization
Tillage
Drainage
Pesticides
Crop residue management
Grazing/mowing

EPIC-IIASA GGCM Agricultural crop calorie yield

$$y_{t,p,s,c} = (1 - f_{c,p}) \cdot y(r)_{t,p,s,c} + f_{c,p} \cdot y(i)_{t,p,s,c}$$

$$Y_{t,p,s} = \sum_{c=1}^{k} g_c \cdot y_{t,p,s,c}$$

$y_{t,p,s,c}$ – simulated crop yield (in t ha^{-1})
- *c – crop (maize, wheat, rye, barley, rapeseed, sunflower, sugar beet, potato, soya, rice)*
- *p – grid cell*,
- s – climate change scenario
- *t* – year

y(r), y(i) – simulated crop yield under rainfed (r) and irrigated conditions (i)

$f_{c,p}$ – fraction of irrigated area of the *c*-th crop in the *p*-th grid,

$Y_{t,p,s}$ – aggregated calorie yield (in Gcal ha^{-1})
- *k* – number of crops
- g_c – calorie content in the unit yield

BAU: BAU-fertilization and irrigation (Balkovič et al. 2013; Wriedt et al. 2009)

POT-RF: yield potential for rainfed systems

POT-IR: yield potential for irrigated systems and environments not limited by water

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- Methods
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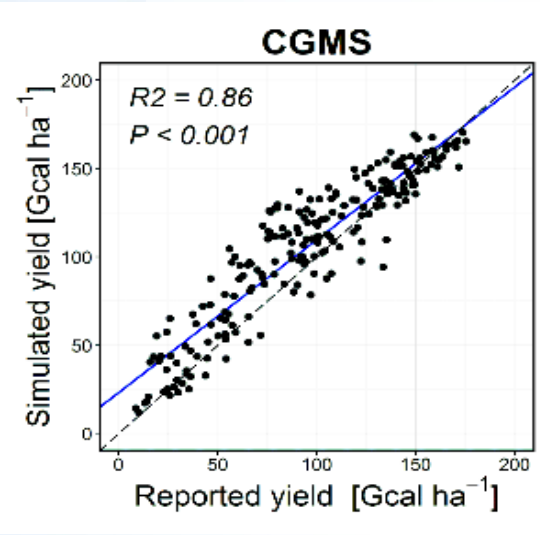
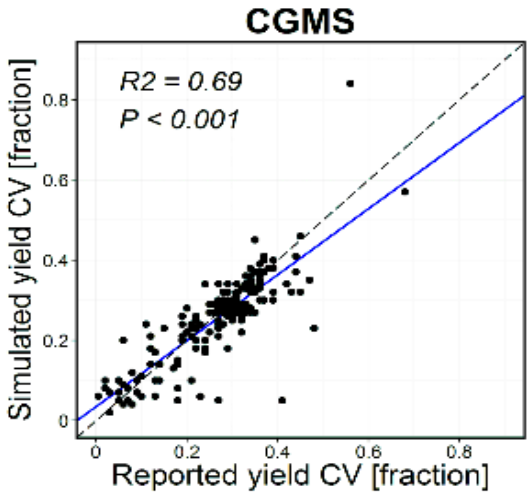
MODEL VALIDATION Long-term historical crop calorie yields

- CGMS weather data from 1990 to 2000
- Aggregated at EU NUTS2 regions (EPIC vs EUROSTAT)

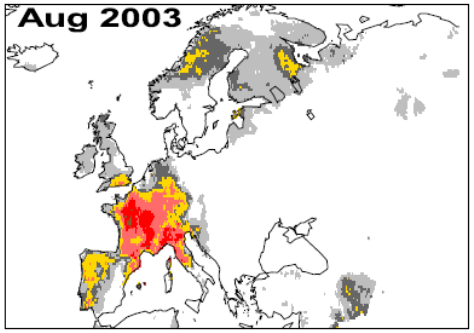


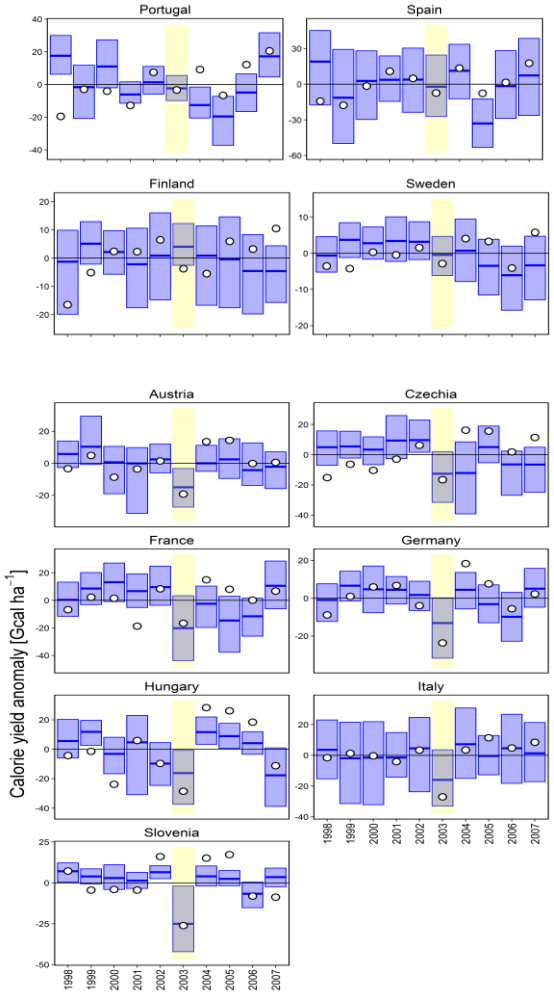


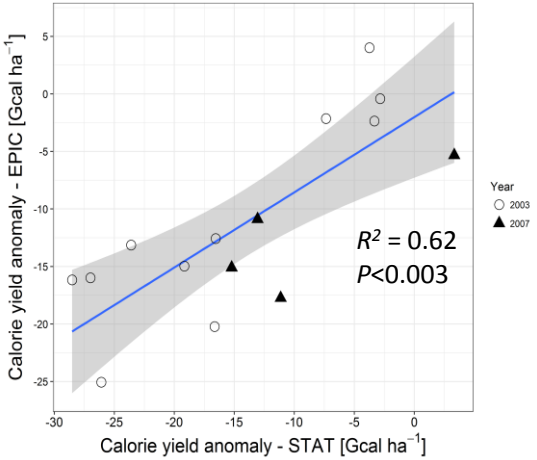
MODEL VALIDATION Anomalies in crop calorie yields due to drought events

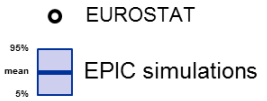
- Heat wave and drought 2003

Russo et al. (2015, ERL 10)









EPIC-IIASA VALIDATION Anomalies in crop calorie yields due to drought events

- Heat wave and drought 2007

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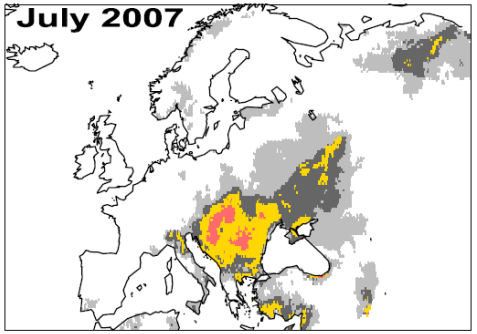

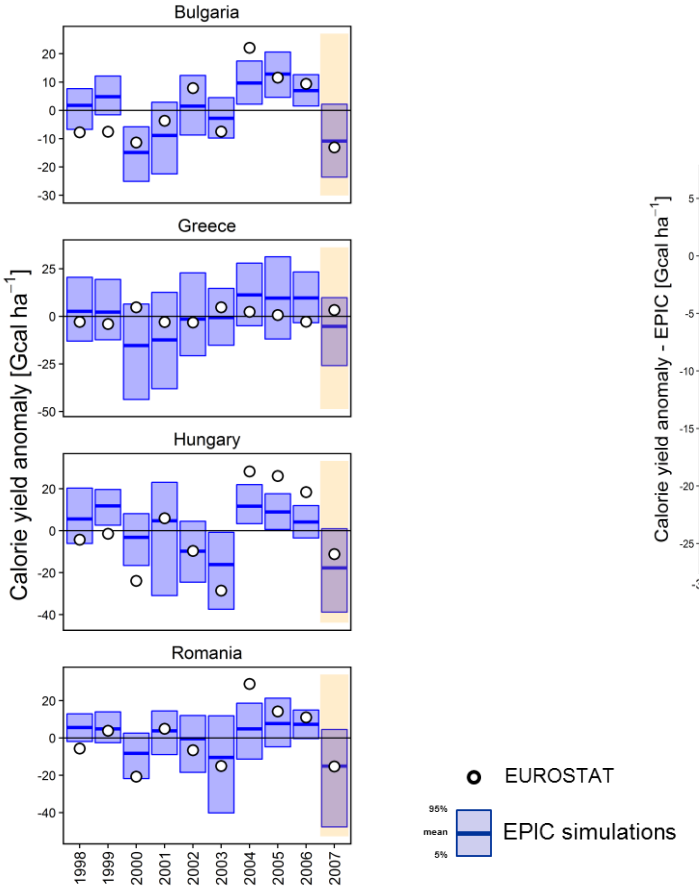

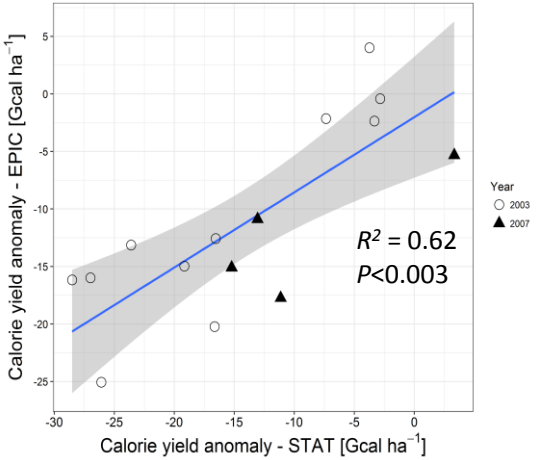

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VULNERABILITY Concept of vulnerablity to drought events

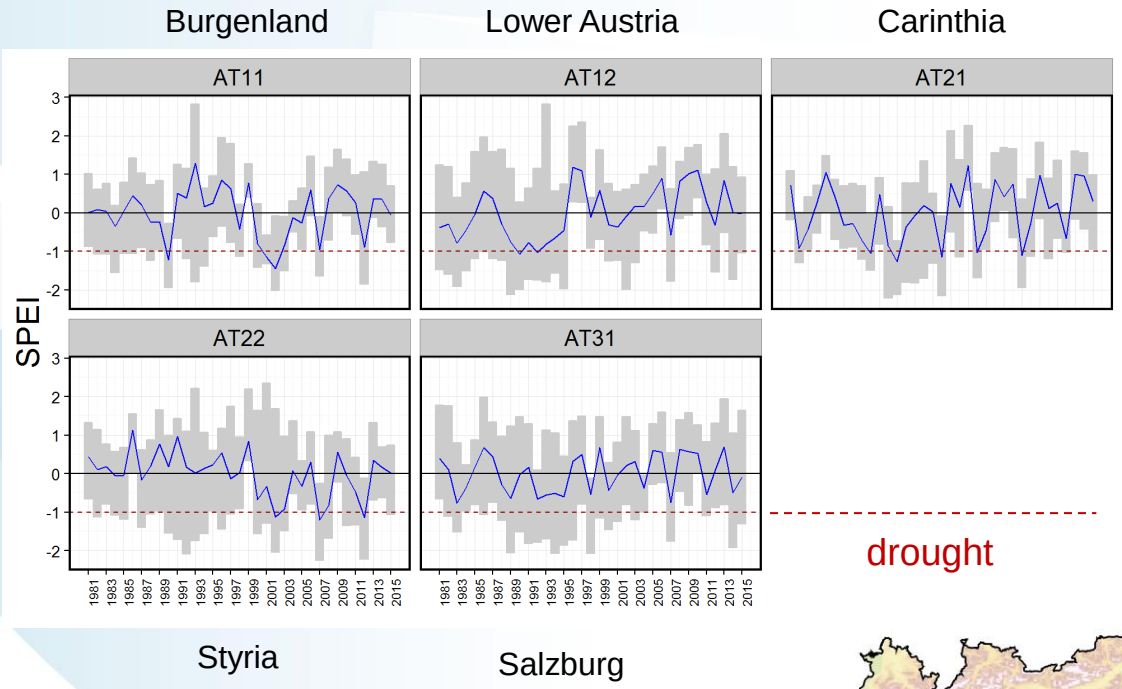
- **Yield vulnerability (V)** is quantified as a fraction of crop yield that may be lost due to harmful effects of climate
- The meteorological drought was identified using SPEI (Vicente-Serrano et al. 2010) calculted monthly
- Drought: mean SPEI over the growing season < -1 (Van Oijen et al. 2014)
- Vulnerability to meteorological drought (Vd):

$$Vd_p = \sum_{c=1}^{k} \left(\frac{1}{n} \sum_{t=1,s=1}^{n} g_c \cdot y_{t,p,s,c} \right) - \sum_{c=1}^{k} \left(\frac{1}{m} \sum_{t=1,s=1}^{m} g_c \cdot y_{t,p,s,c} \right)$$

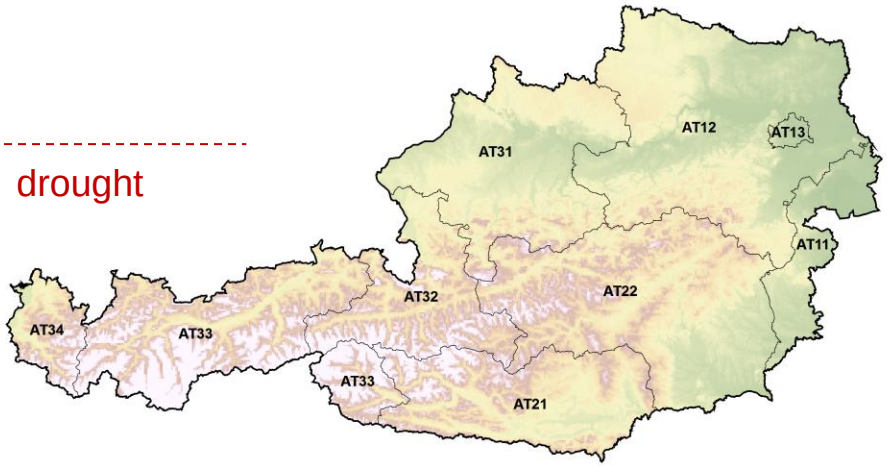
m years with SPEI < -1
n years with SPEI ≥ -1

VULNERABILITY Proof Of Concept

- mean SPEI of crop growing season
- regionalized index of drought

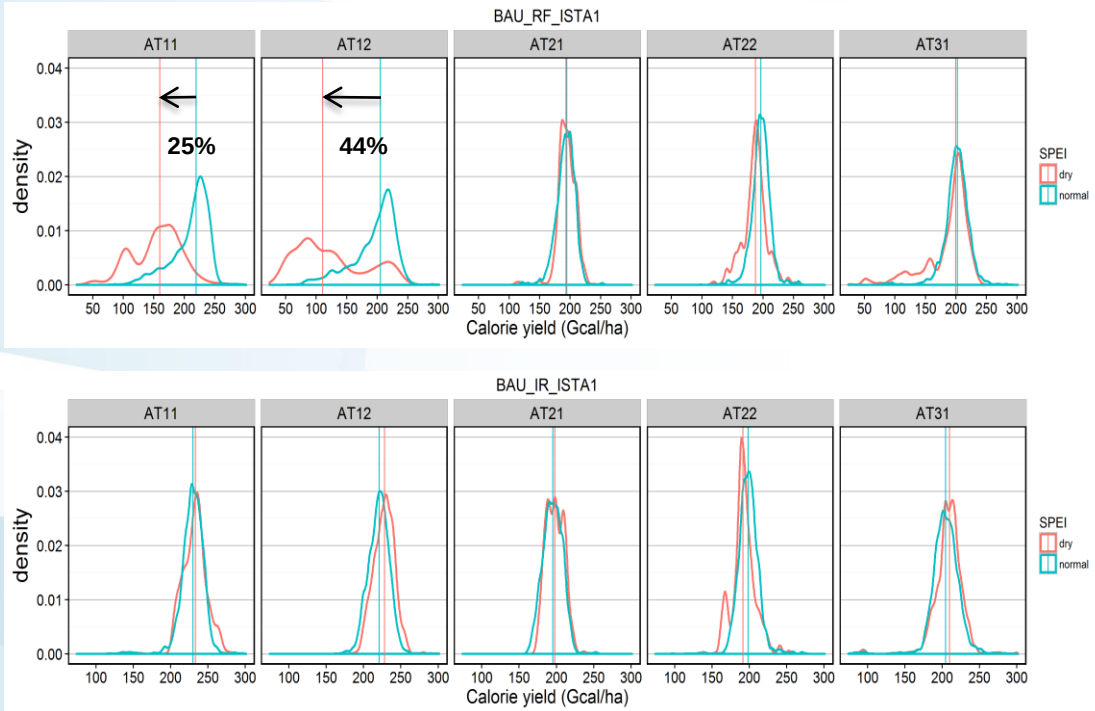


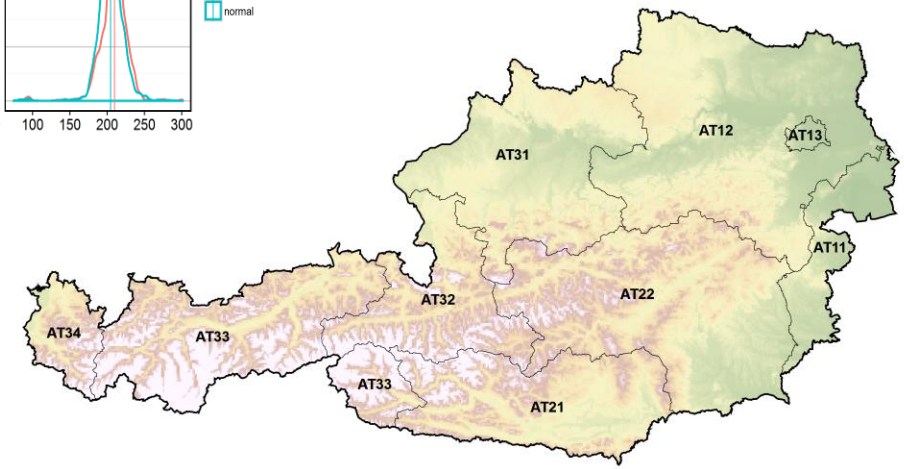
drought



FARM (ACRP 8th Call Project)

VULNERABILITY SPEI to determine yield vulnerability





FARM (ACRP 8th Call Project)

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- **Impact of a +2°C global warming**
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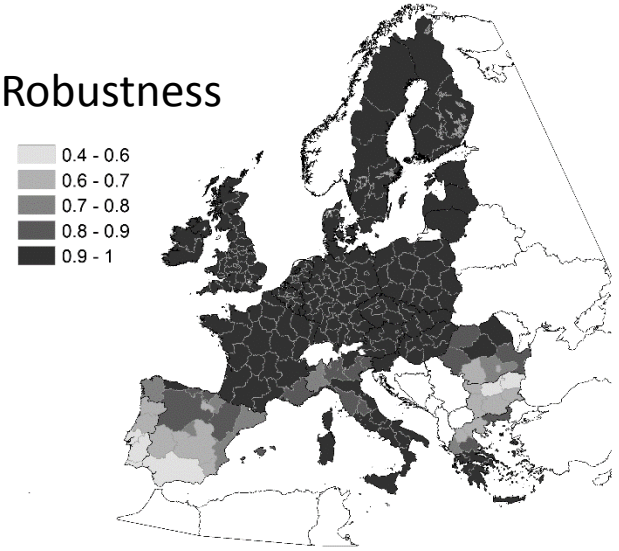
+2°C WARMING Background

- The Quantifying Projected Impacts Under 2°C Warming (IMPACT2C) Project (http://impact2c.hzg.de)
- Bias-corrected data from EURO-CORDEX database form IMPACT2C

  - CSC-REMO/MPI-ESM-LR (RCP 4.5)
  - SMHI-RCA4/EC-EARTH (RCP 4.5)
  - KNMI-RACMO22E/EC-EARTH (RCP 4.5)
  - SMHI-RCA4/HadGEM2-ES (RCP 4.5)
  - IPSL-WRF331F/IPSL-CM5A-MR (RCP 4.5)

- +2°C period when the 30-year running mean temperature calculated from the base period 1971–2000 exceeds the +2°C threshold globally (Vautard et al., 2014)

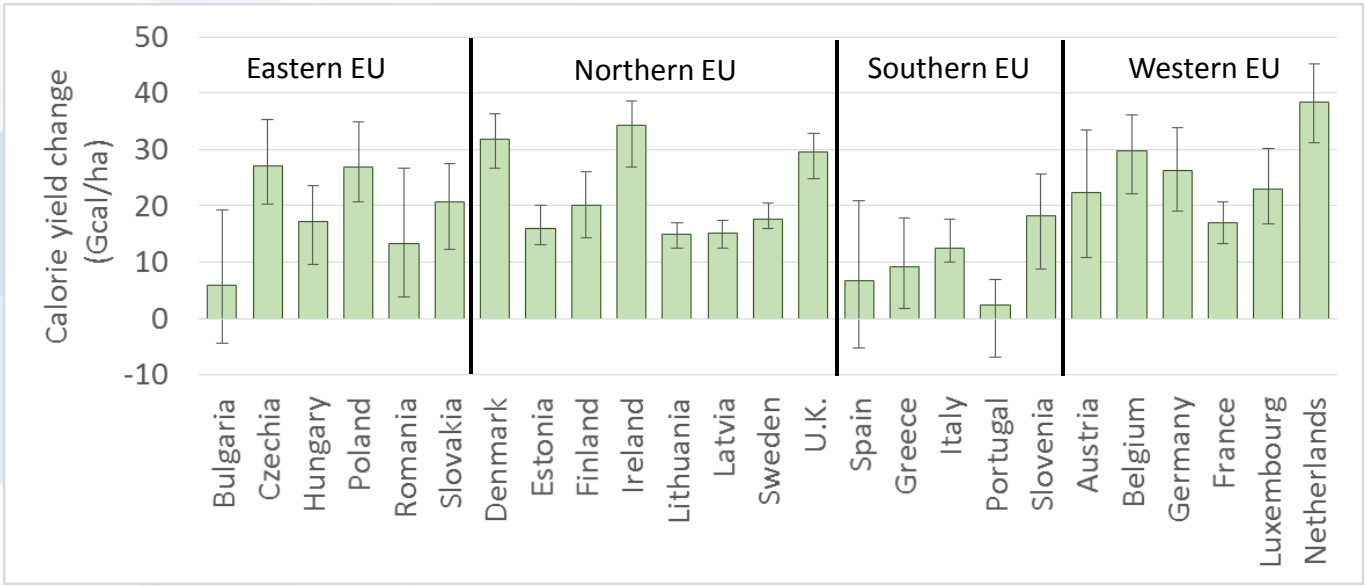
+2°C WARMING Mean impact



- EURO-CORDEX-mean calories change
- Robustness across CC projections

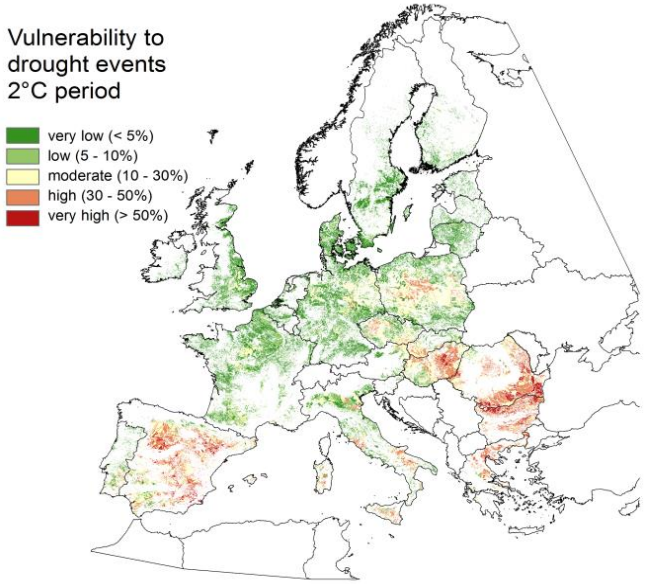
<u>Conventional impact approach:</u>

- BAU-scenario, all availbale cropland
- Full physiological impact of elevated atm. CO_2



+2°C WARMING Drought vulnerability

- high vulnerability (> 40 Gcal/ha) in the Pannonian zone, namely Bulgaria, Romania, and Hungary
- followed by Greece and Spain (> 30 Gcal/ha)



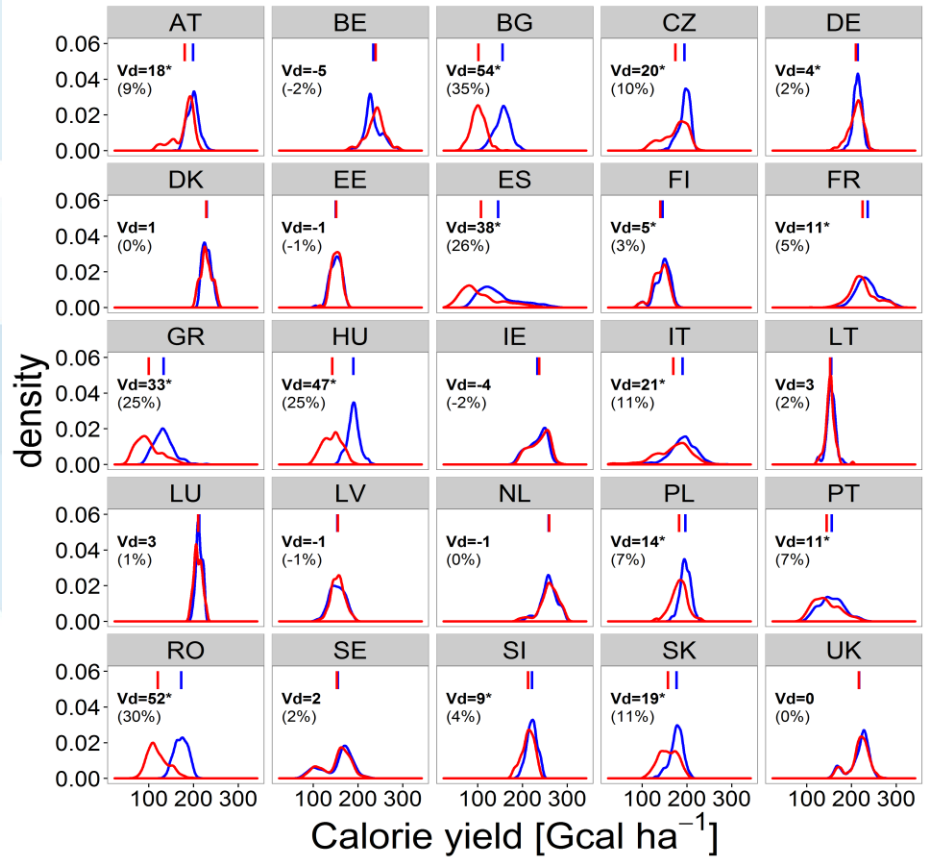


Figure. Crop calorie yield distribution under +2°C (red: years with dry GS, blue: years with normal GS)

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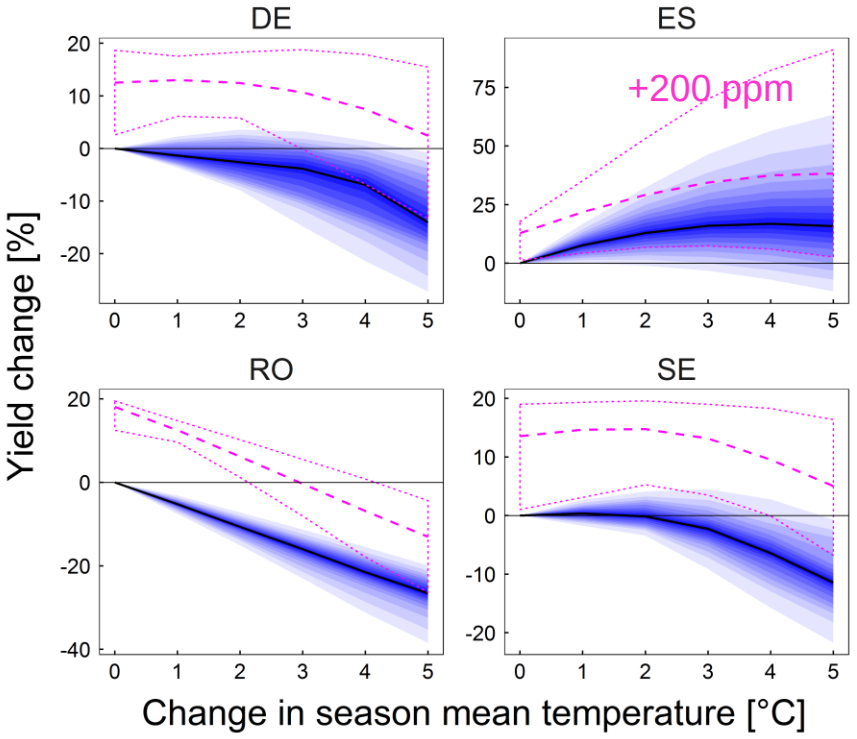
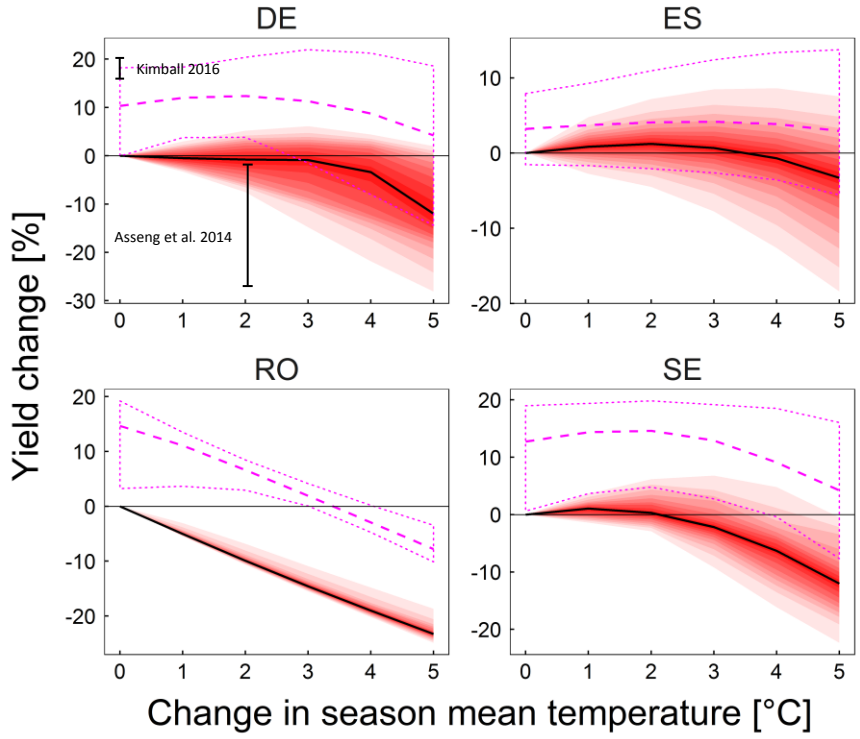
+2°C WARMING Projection uncertainty (T and CO_2)

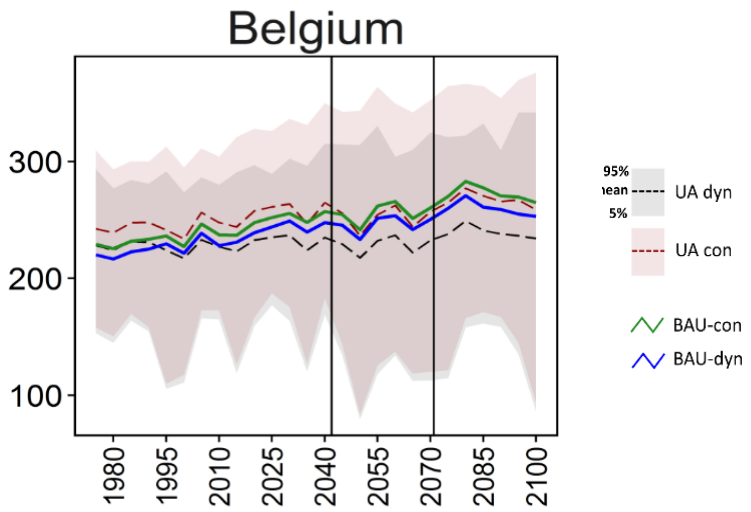
- Uncertainty analysis of elevated CO_2 and temperature impacts (wheat example)
- KNMI projection
- Ample nutrients; rainfed and irrigated

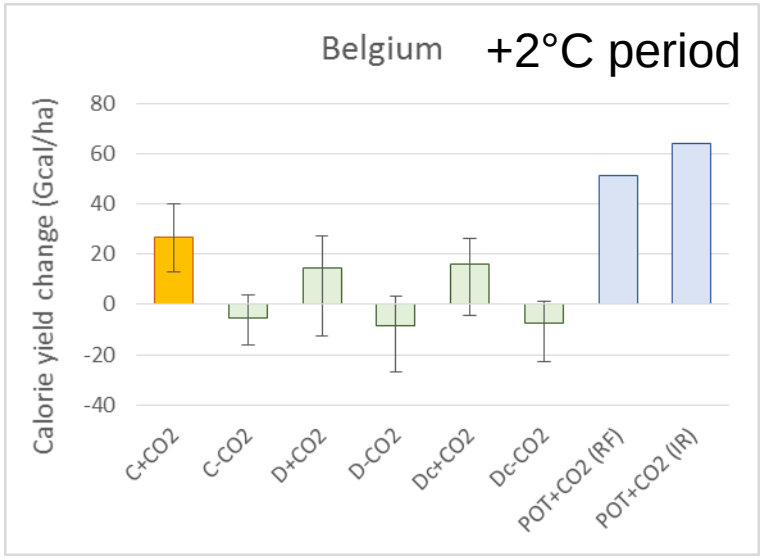


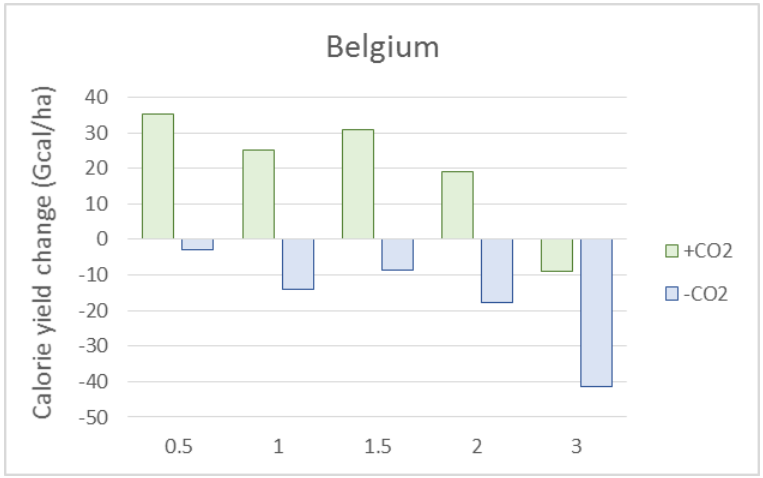


+2°C WARMING Bracketing projection-specific uncertainties

- Soil degradation (D)
- Soil degradation with conservation practic. (Dc)
- Crop intensification (POT)
- Elevated CO_2 impact (+/- CO_2)
- Temperature impact







Thank you for your attention!