Agriculture and food production challenges

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Climate change – food, agriculture and land use

Complex problem

- Increasing wealth and consumption
- Very large differences in productivity and efficiency
- Large differences in waste and use of side streams
- Agriculture delivers food, materials and bioenergy

Many causes of greenhouse gases

- Food consumption
- Agricultural production
- Land use (including iLUC – indirect land use change)

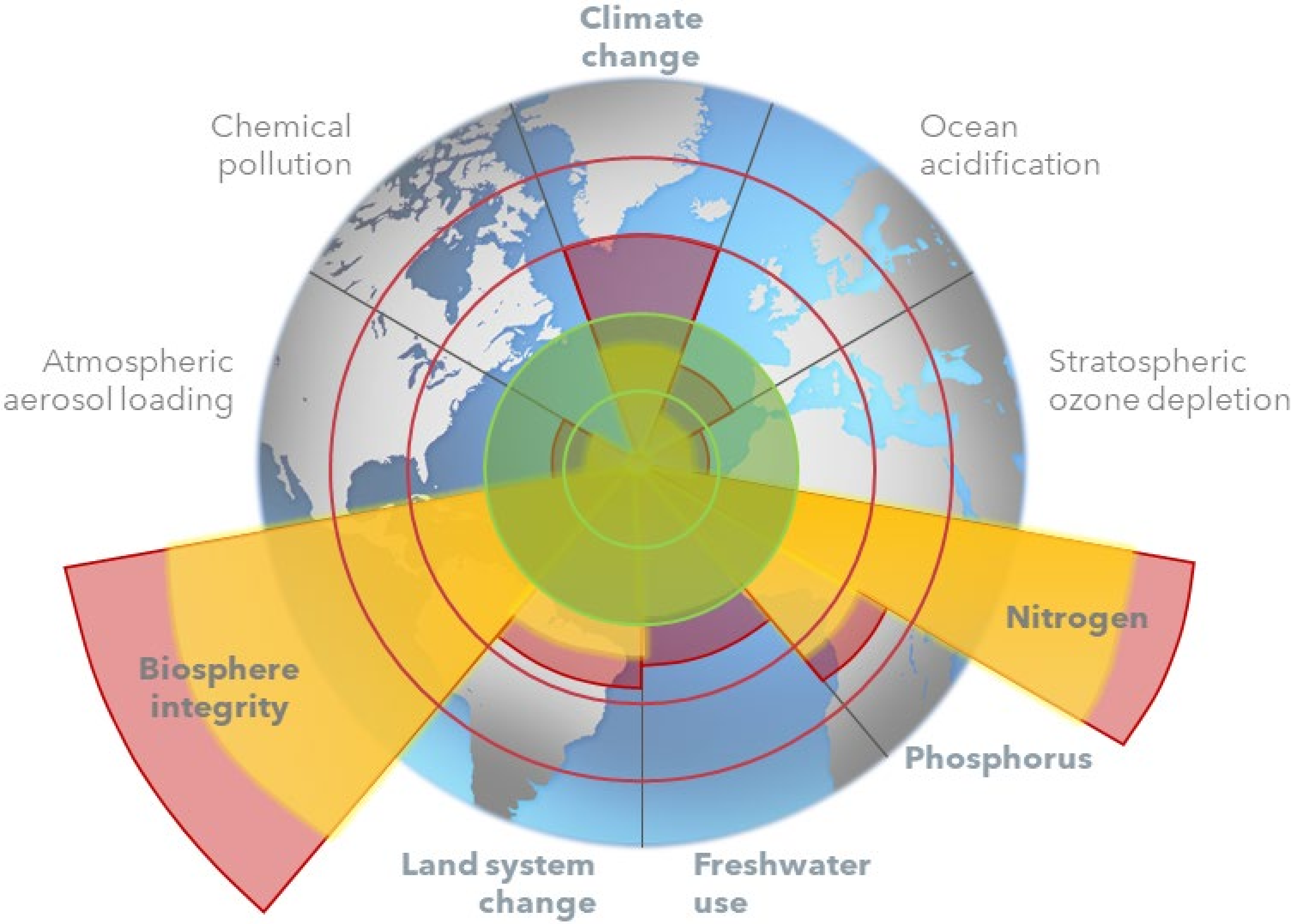
Climate change and adaptation is also important

- Climate change will happen even with mitigation
- Warmer climate, more extremes, droughts, floods
- World food supply will be threatened

Agriculture is critical to planetary boundaries

Agriculture contributes to
- Food
- Bioenergy
- Biomaterials

Agriculture also contributes to
- Nutrient pollution
- Greenhouse gases
- Biodiversity decline
- Declining freshwater
- Soil degradation



Global food consumption

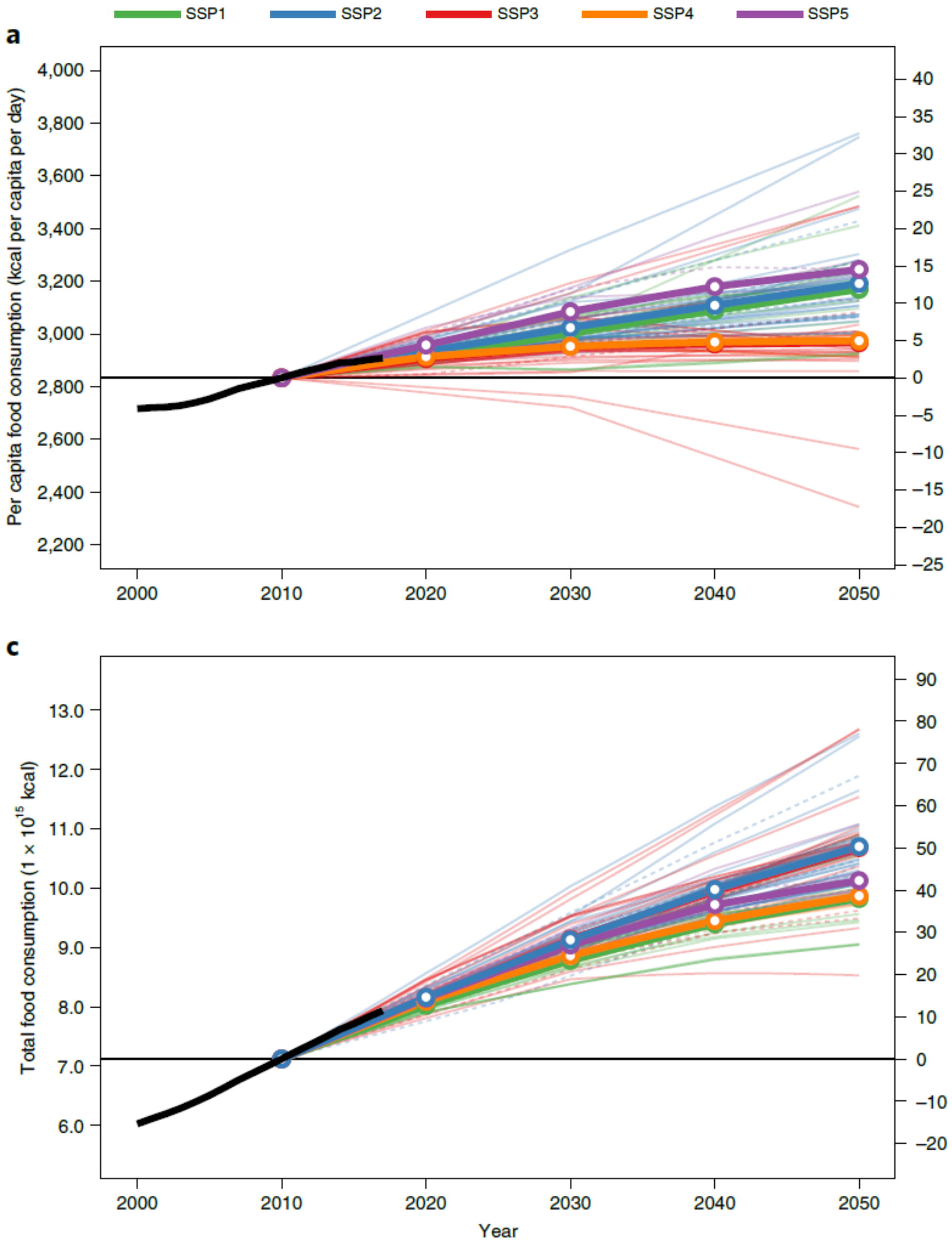
- Food consumption er capita is increasing
- Global population also increases
- Total food consumption is expected to increase by about 45% until 2050

- Global meat and milk production increases more than grain production thus worsening impacts

A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050

Michiel van Dijk[1,2], Tom Morley[1], Marie Luise Rau[1] and Yashar Saghai[3,4]

NATURE FOOD | VOL 2 | JULY 2021 | 494–501 |



Food systems are responsible for a third of global anthropogenic GHG emissions

ARTICLES
https://doi.org/10.1038/s43016-021-00225-9
nature food

M. Crippa[1]✉, E. Solazzo[1], D. Guizzardi[1], F. Monforti-Ferrario[1], F. N. Tubiello[2] and A. Leip[1]✉

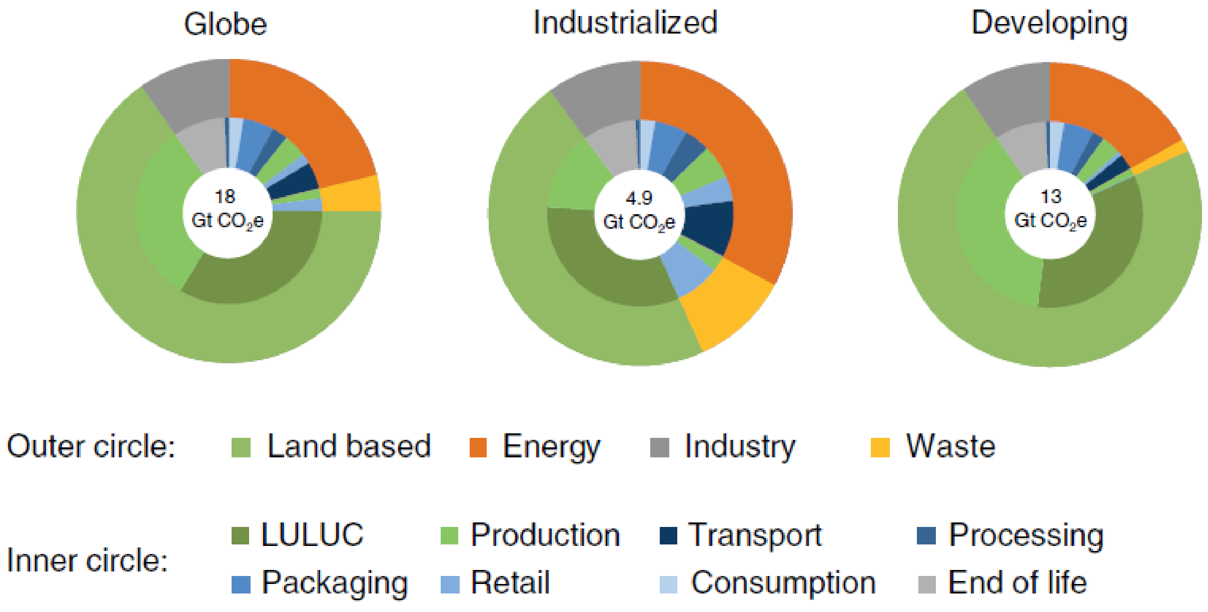


Fig. 1 | GHG emissions from the food system in different sectors in 2015. Total GHG emissions (including CO_2, CH_4, N_2O and F-gases) are expressed as CO_2e calculated using the GWP100 values used in the IPCC AR5, with a value of 28 for CH_4 and 265 for N_2O.

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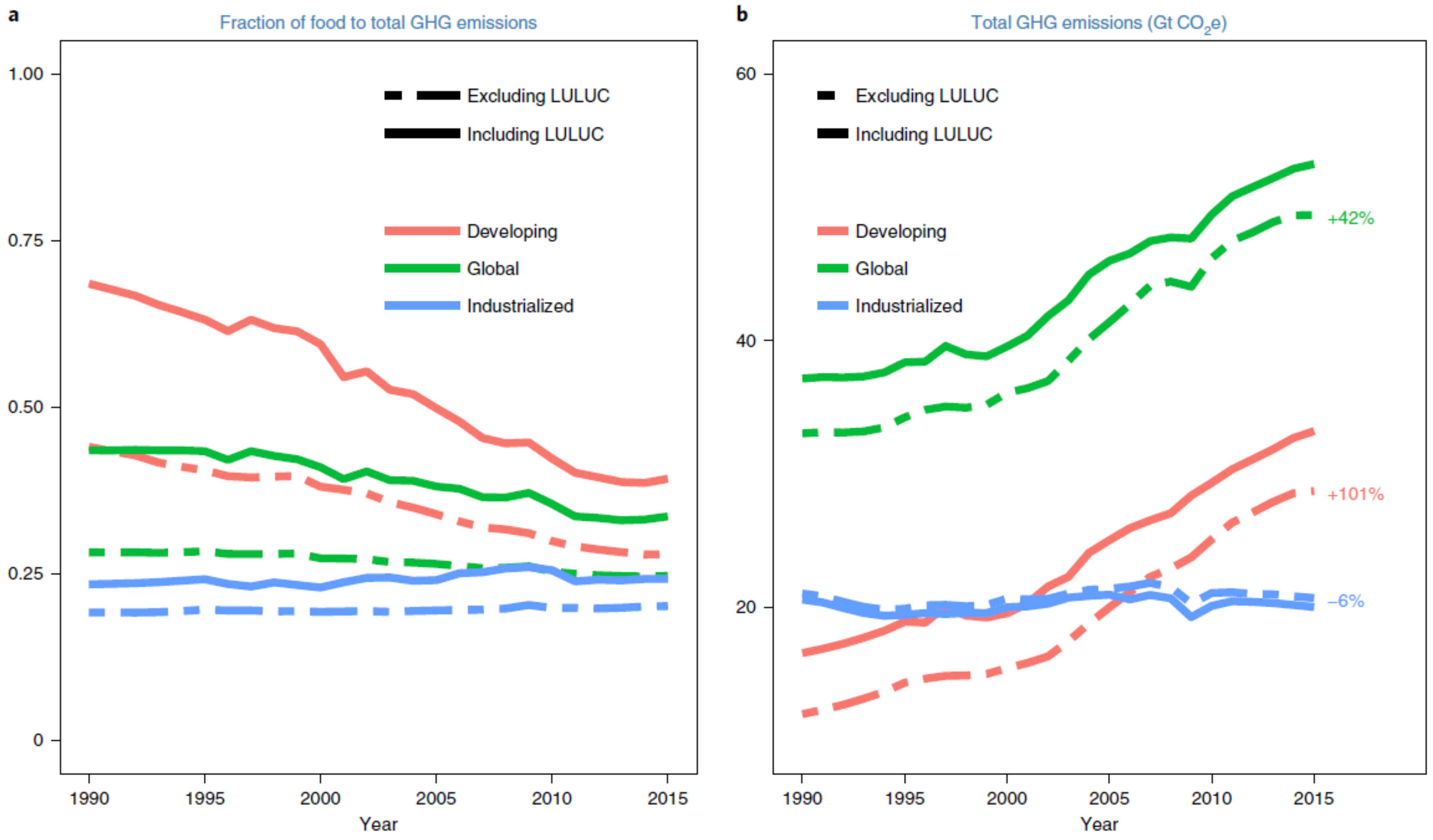

Fig. 2 | Total GHG emissions and food-system data globally, and in developing and industrialized countries. a,b Fraction of food to total GHG emissions (**a**) and total GHG emissions from the food system (**b**) globally, in developing and industrialized countries. Non-CO_2 GHG emissions (CH_4, N_2O and F-gases) are expressed as CO_2 equivalent (CO_2e) calculated using the GWP100 values used in the IPCC AR5, with a value of 28 for CH_4 and 265 for N_2O.

Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods

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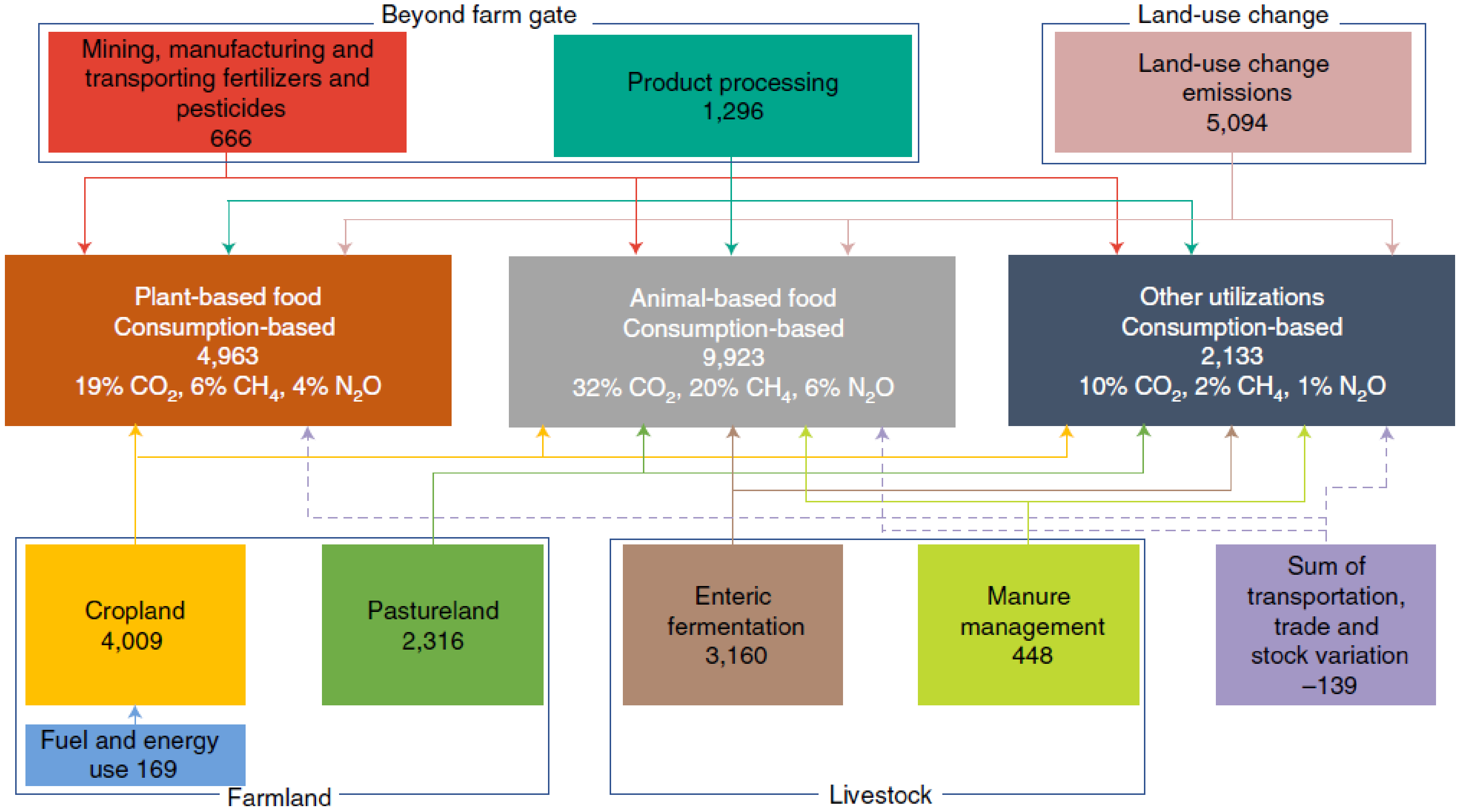

Fig. 1 | GHG emissions from different subsectors of plant- and animal-based food production/consumption. The contributions of individual GHGs provided are the percentage of the total emissions. Solid arrows indicate production-based emissions, and solid and dashed arrows combined are consumption-based emissions. The values in the boxes are mean values for 2007–2013, which may slightly differ from the median values of 10,000 Monte Carlo simulations in the text. Values are expressed in $TgCO_2eq$.

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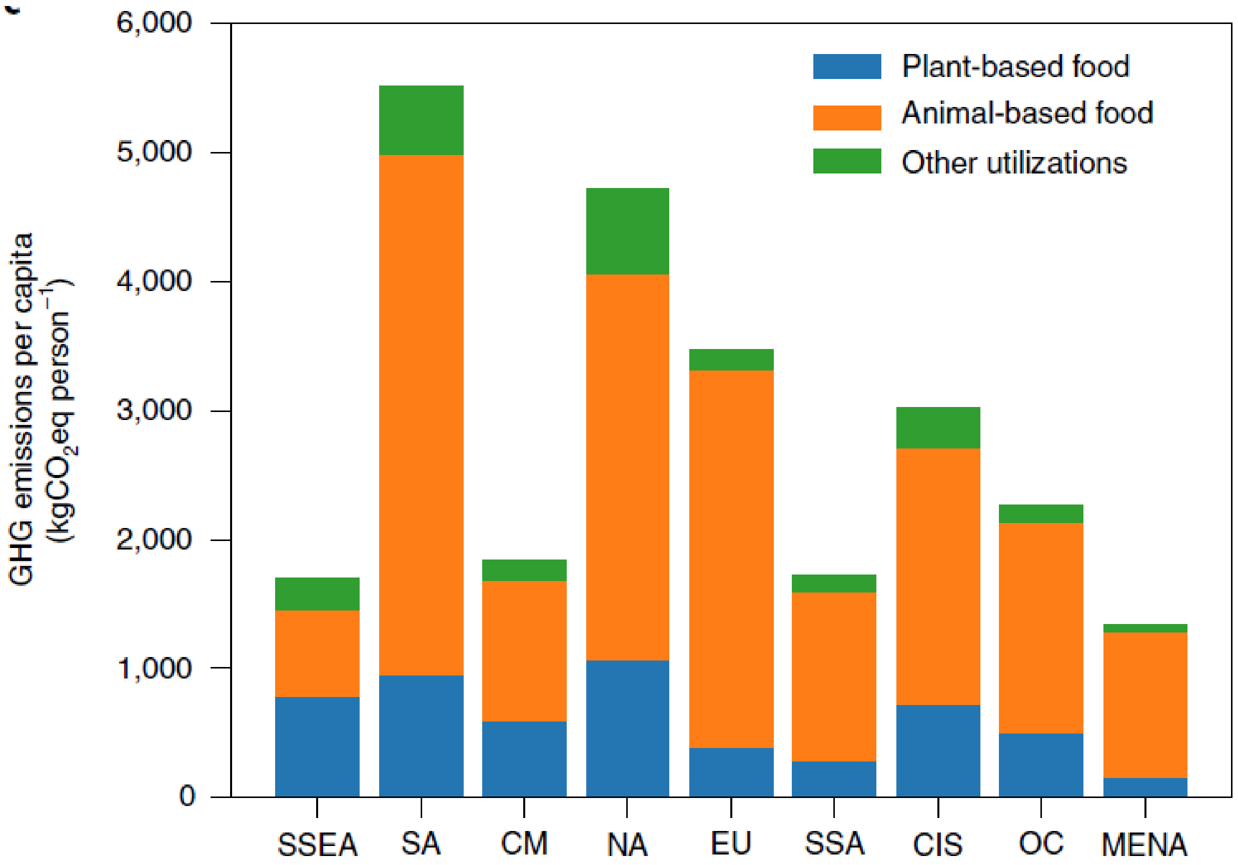
GHG per person



NA, North America; SA, South America; EU, European Union; MENA, Middle East and North Africa; SSA, sub-Saharan Africa; CIS, Commonwealth of Independent States; CM, China and Mongolia; SSEA, South and Southeast Asia; OC, Oceania and other East Asia

Food system changes are required to constrain climate change

- Food systems currently contribute one-third to global warming
- Many different changes in both food demand, production and processing are required to meet targets

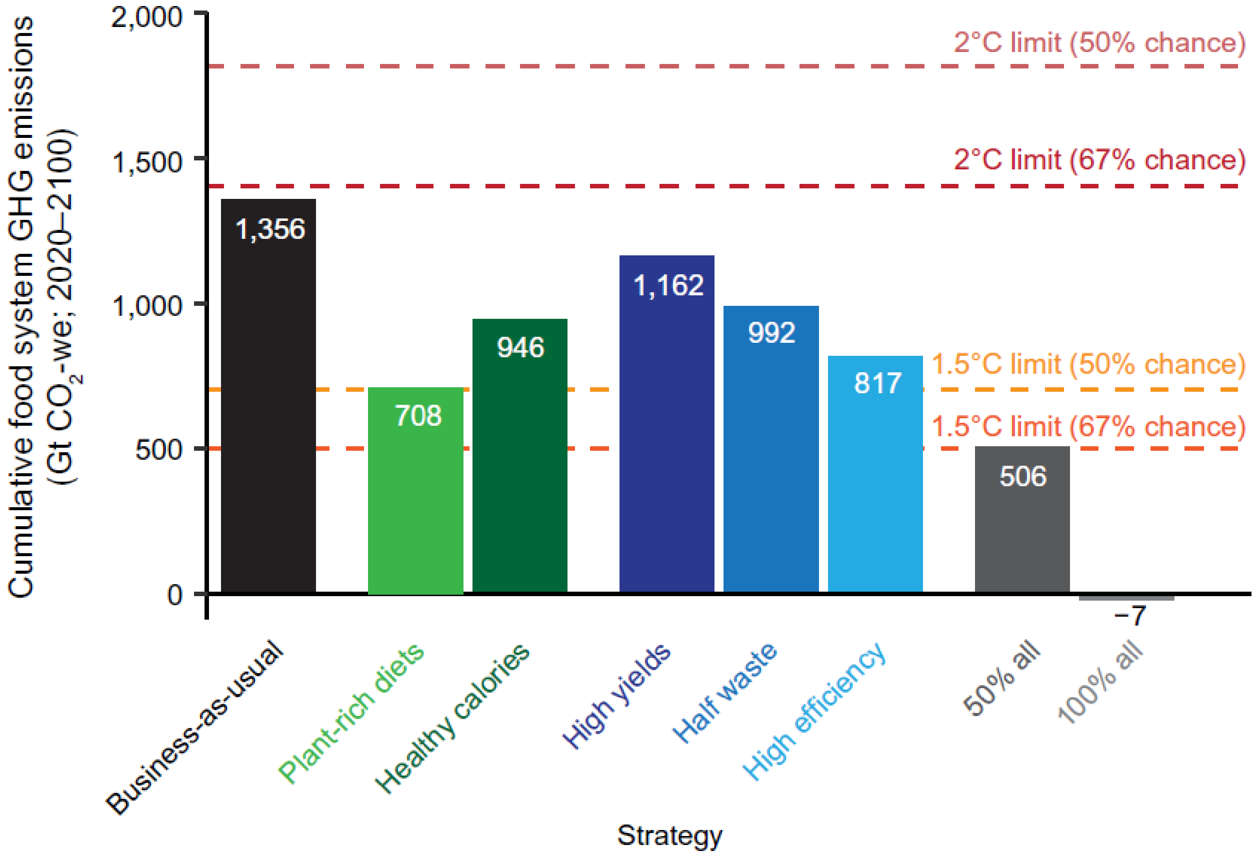
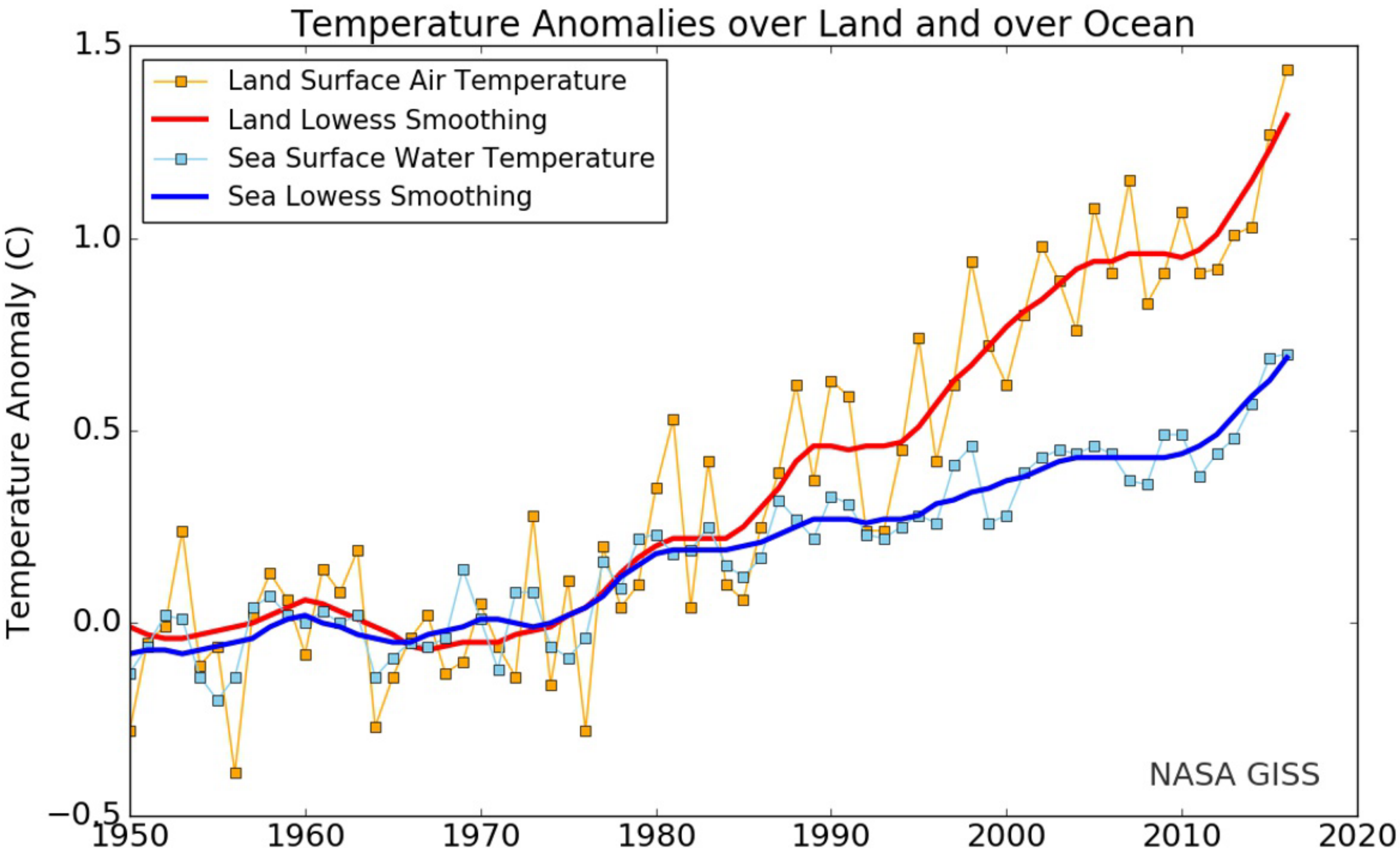


Fig. 1. Projected cumulative 2020 to 2100 GHG emissions solely from the global food system for business-as-usual emissions and for various food system changes that lead to emission reductions.

Clark et al. (2020) Science

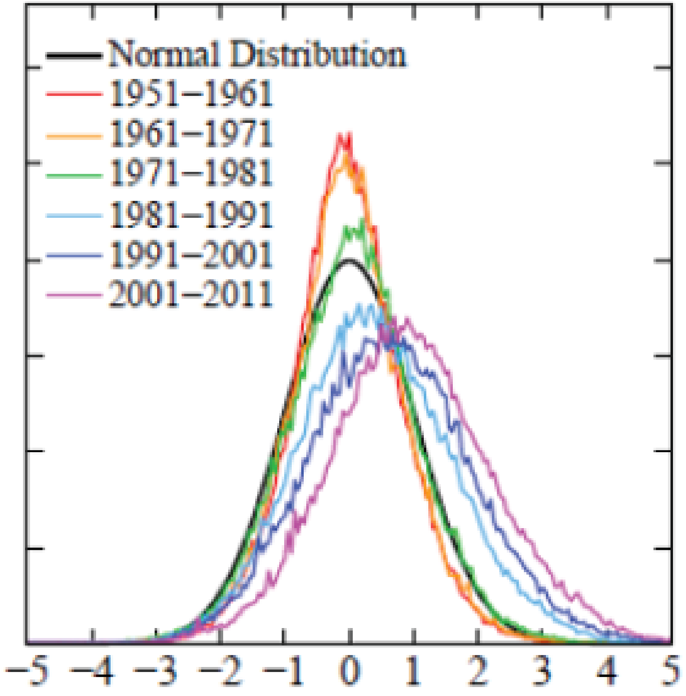
Temperature over land increase more over land than oceans

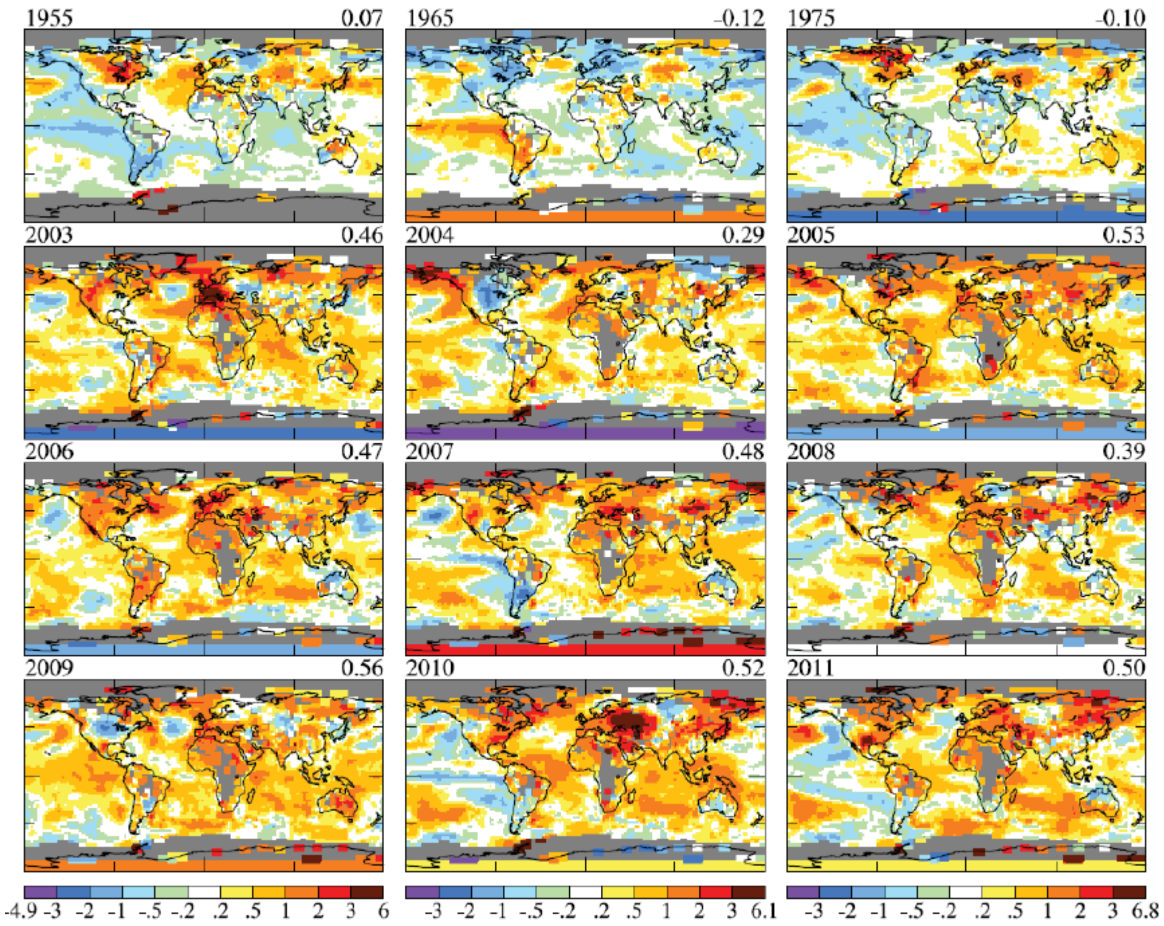


EEA (2017)

Summer temperatures are getting more extreme

- Global mean temperature increases
- But so does the interannual variation

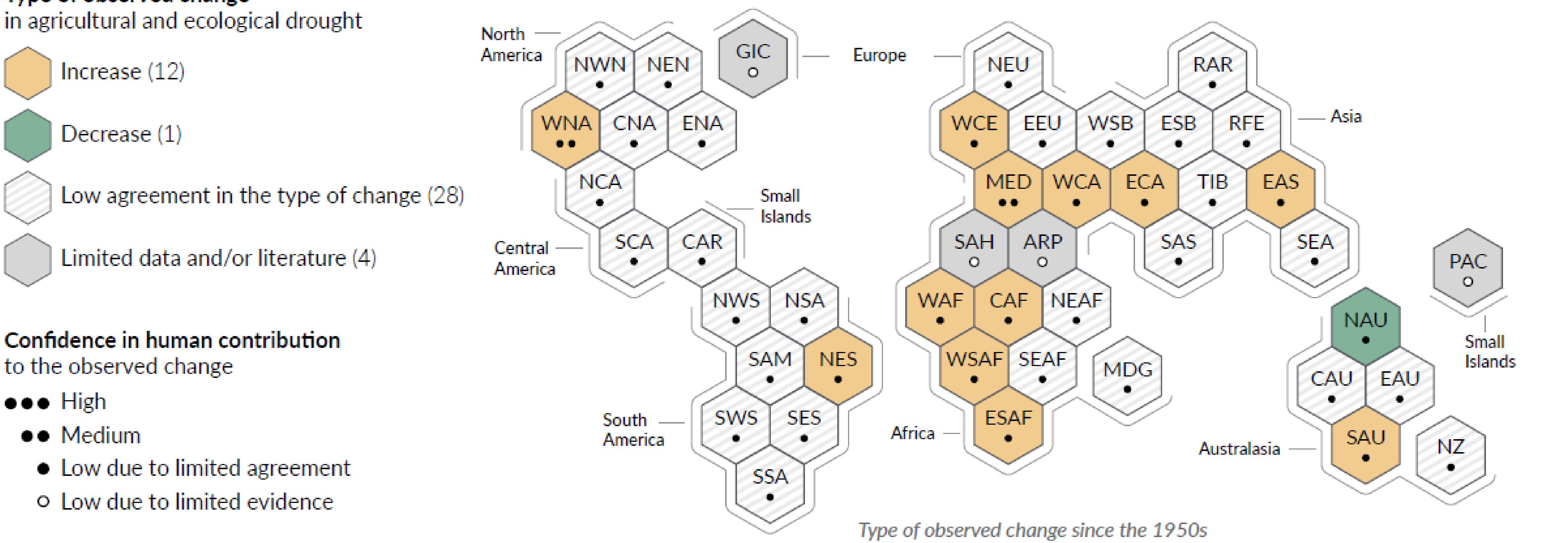




Hansen et al. (2012), PNAS 109 E2415-E2423

The climate is getting more extreme

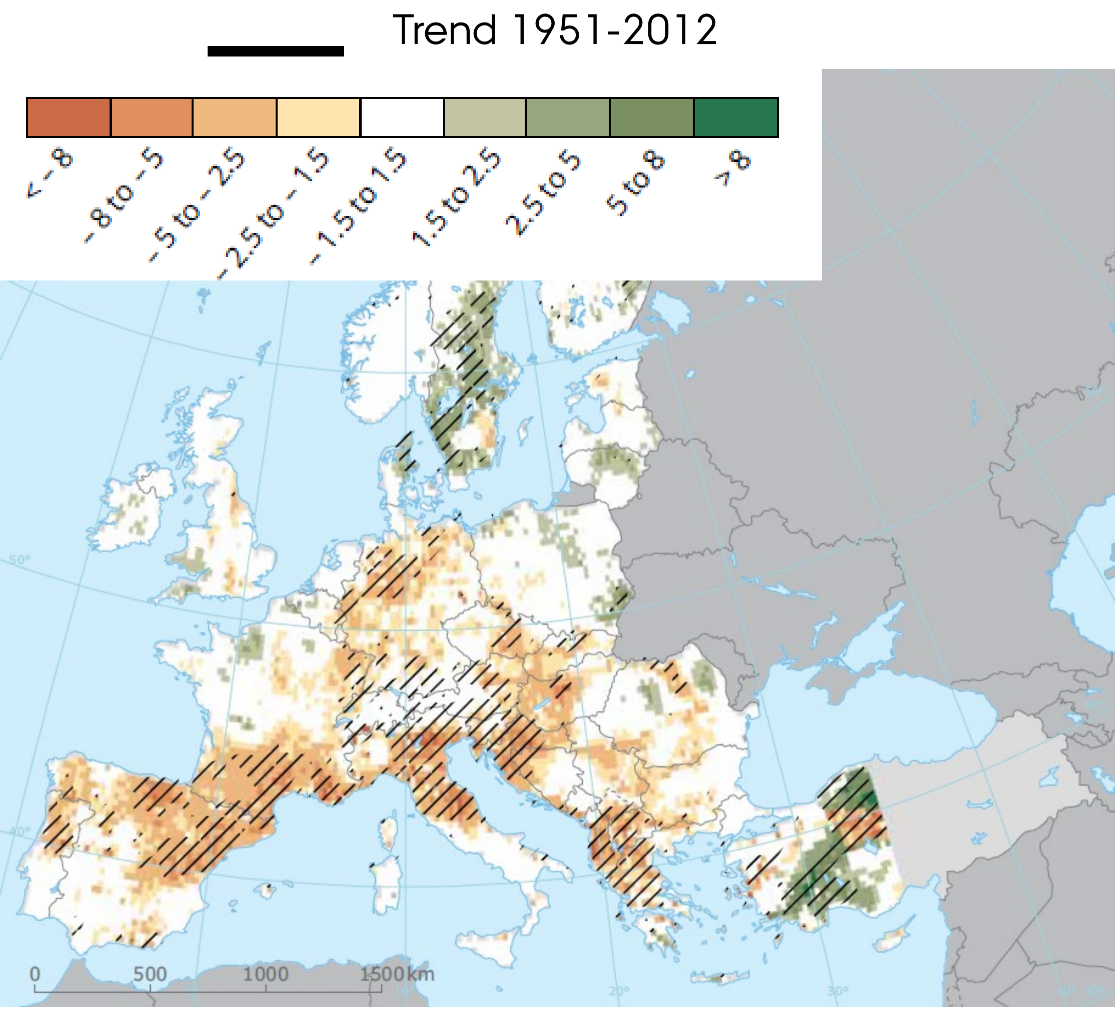
c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions

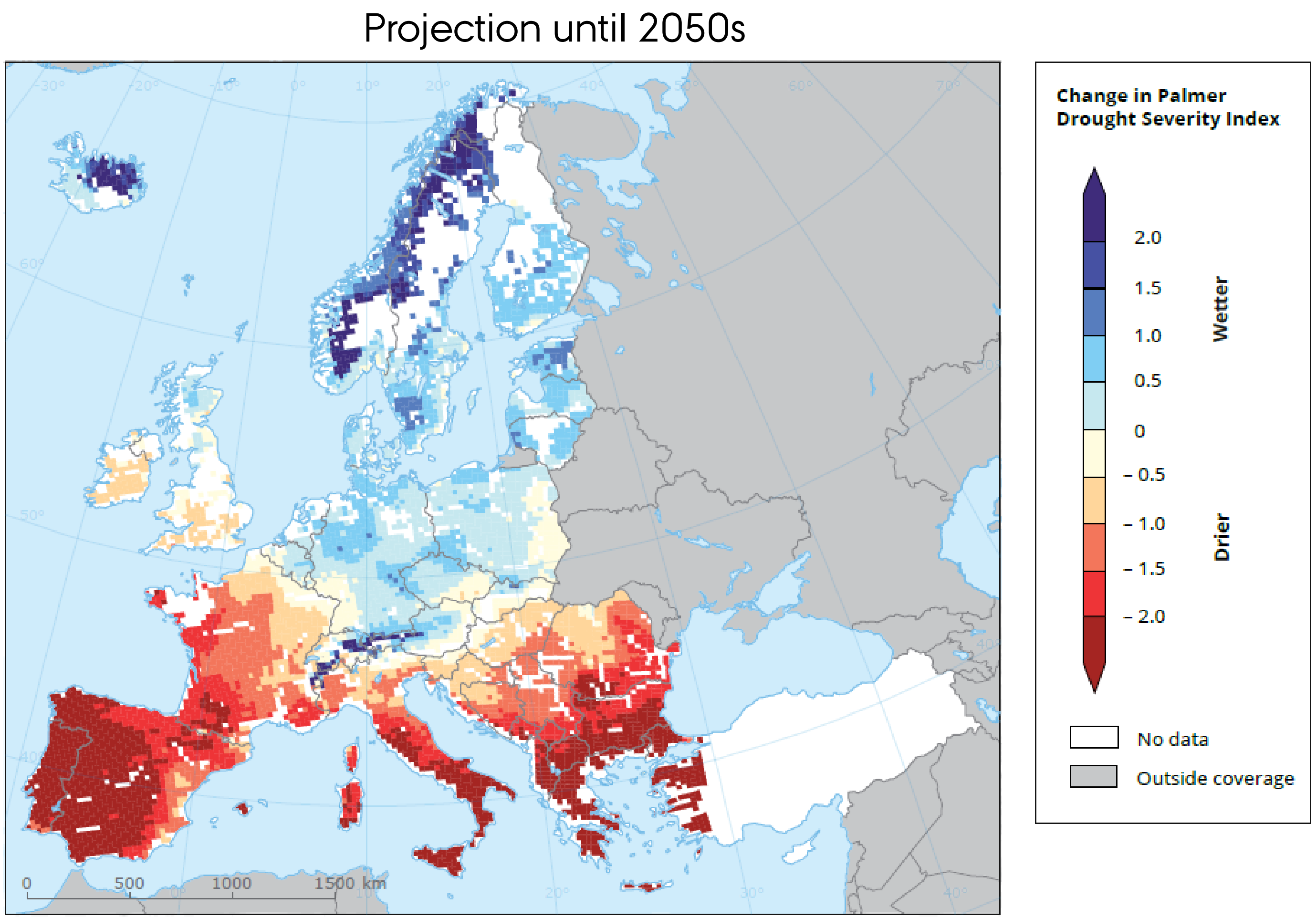


Type of observed change since the 1950s

IPCC (2021)

Trends in summer soil moisture





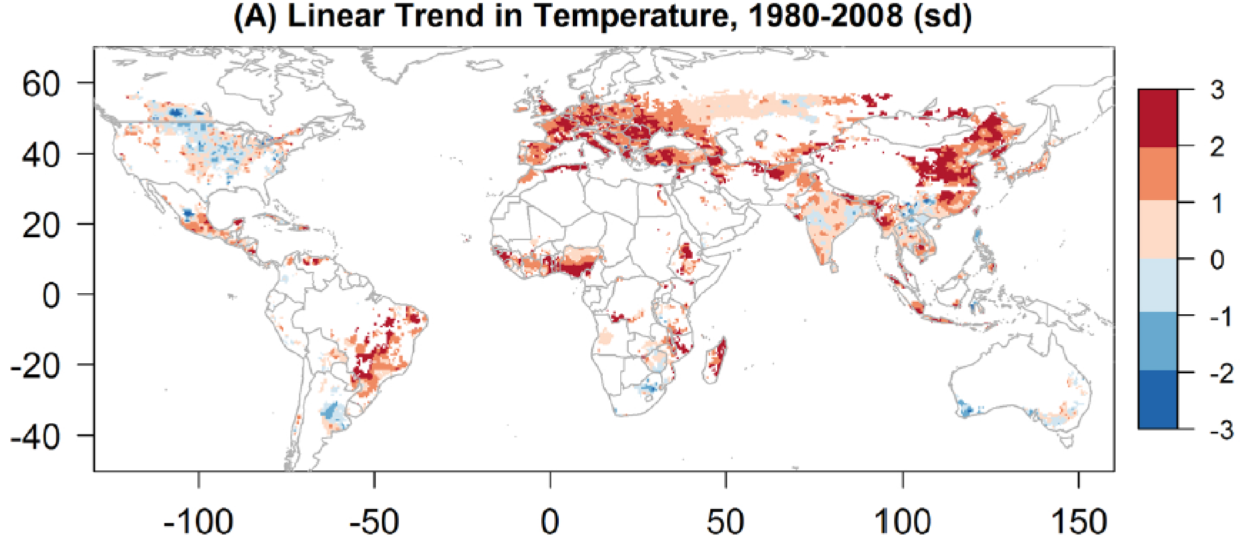
EEA (2017)

Climate change poses risks to current systems

- Risks to production systems are mostly related to extreme events and new biotic interactions
  - Heat waves
  - Frost, snow, ice
  - Droughts
  - Intense or long lasting rainfall (floods)
  - Storms
  - Pest and diseases
- Climate change increases
  - Frequency of extreme events
  - Inter-annual variability

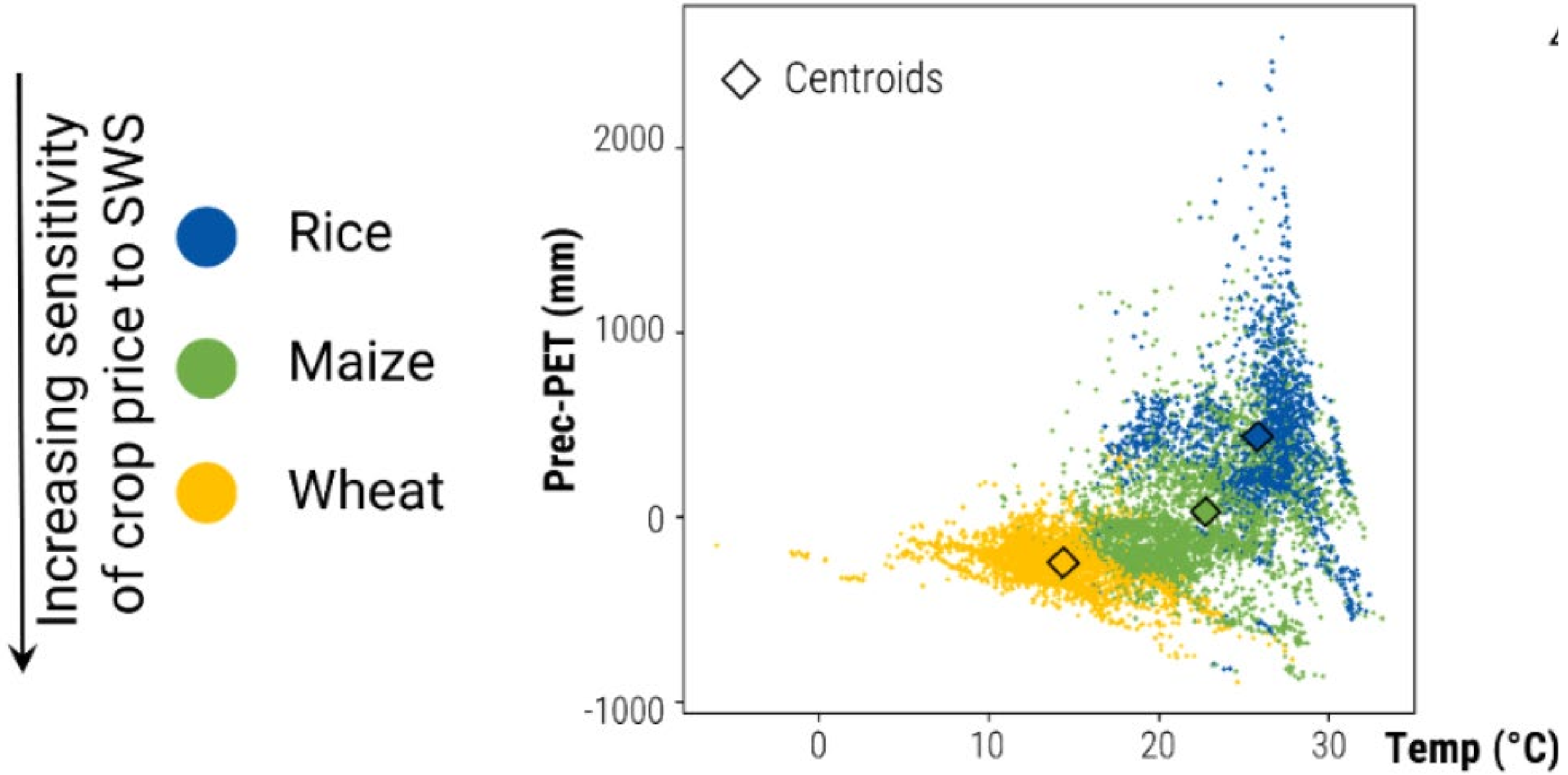
Observed impacts on crop yield of climate change globally

Crop	Global production (1998-2002 average, million metric tons)	Global yield impact of temperature trends (%)	Global yield impact of precipitation trends (%)	Subtotal	Global yield impact of CO_2 trends (%)	Total
Maize	607	–3.1 (–4.9, –1.4)	–0.7 (–1.2, 0.2)	–3.8 (–5.8, –1.9)	0.0	–3.8
Rice	591	0.1 (–0.9, 1.2)	–0.2 (–1.0, 0.5)	–0.1 (–1.6, 1.4)	3.0	2.9
Wheat	586	–4.9 (–7.2, –2.8)	–0.6 (–1.3, 0.1)	–5.5 (–8.0, –3.3)	3.0	–2.5
Soybean	168	–0.8 (–3.8,1.9)	–0.9 (–1.5, –0.2)	–1.7 (–4.9, 1.2)	3.0	1.3



Lobell et al. (2011)

Wheat, maize and rice are grown in different environments



Plant and animal responses to temperature

Development (phenology)

- Timing of events, in particular reproduction

Growth

- Assimilation of energy and nutrients
- Respiration

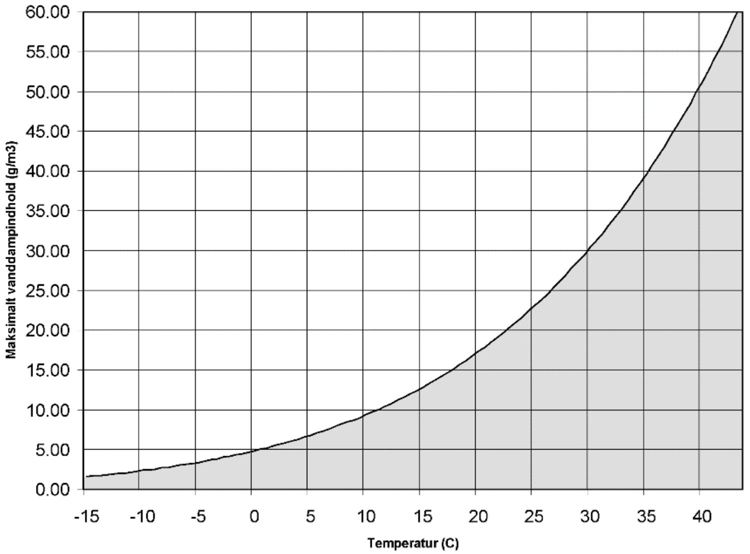
Animal body temperatures

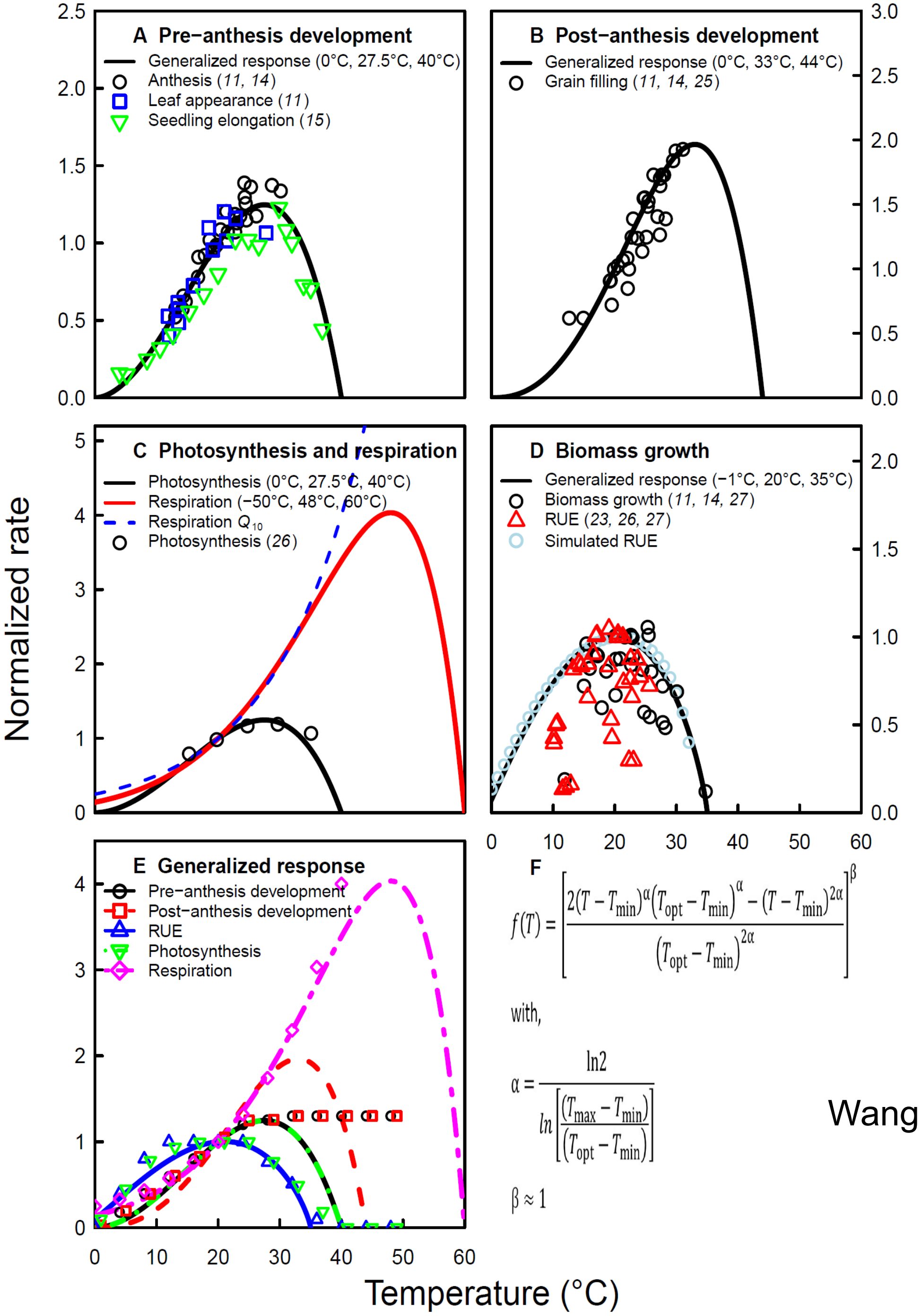
- Endotherms (constant body temperature)
- Poikilotherms (facultative endotherms)
- Ectotherms (body temperature depends on external temperature)

Temperature responses

Evapotranspiration increases with increase temperature due to the vapour pressure curve that increases vapour pressure deficit with increasing temperature.

Saturated water vapour – temperature curve





Wang et al. (2016)

Projected yield change

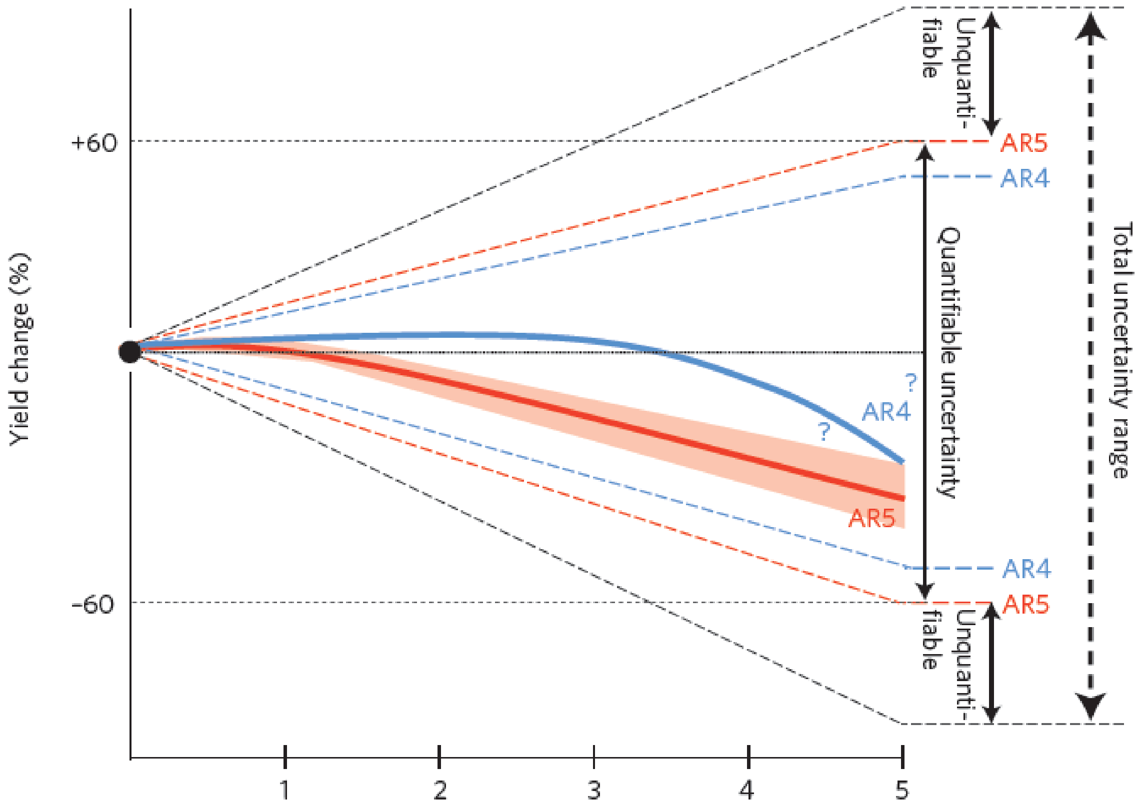
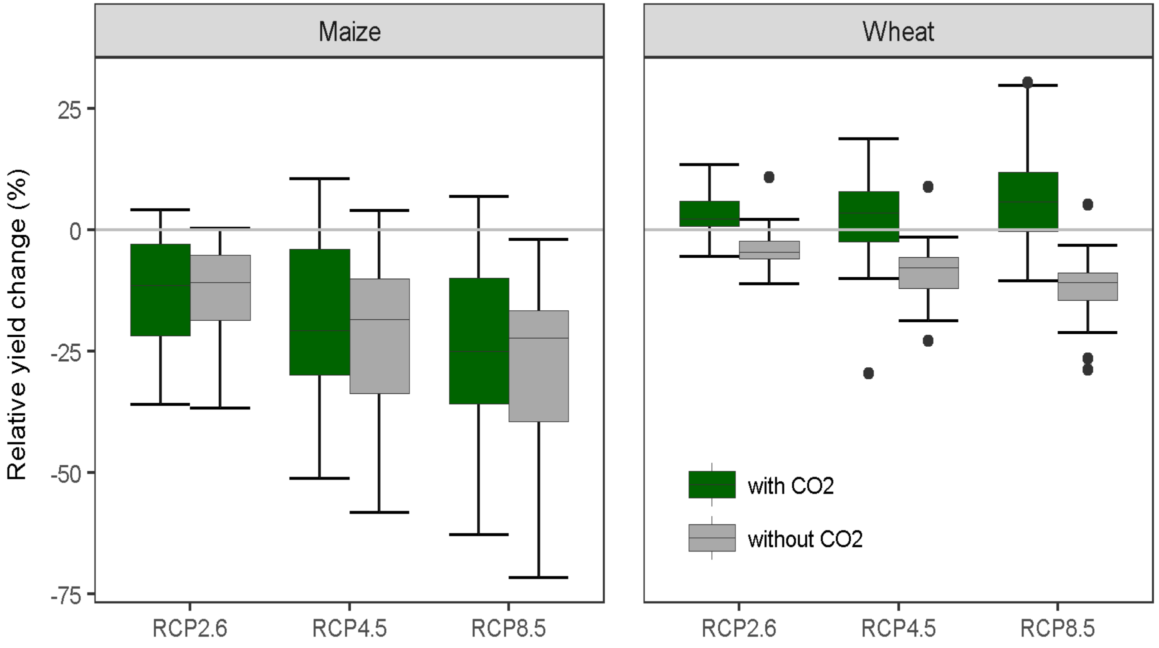
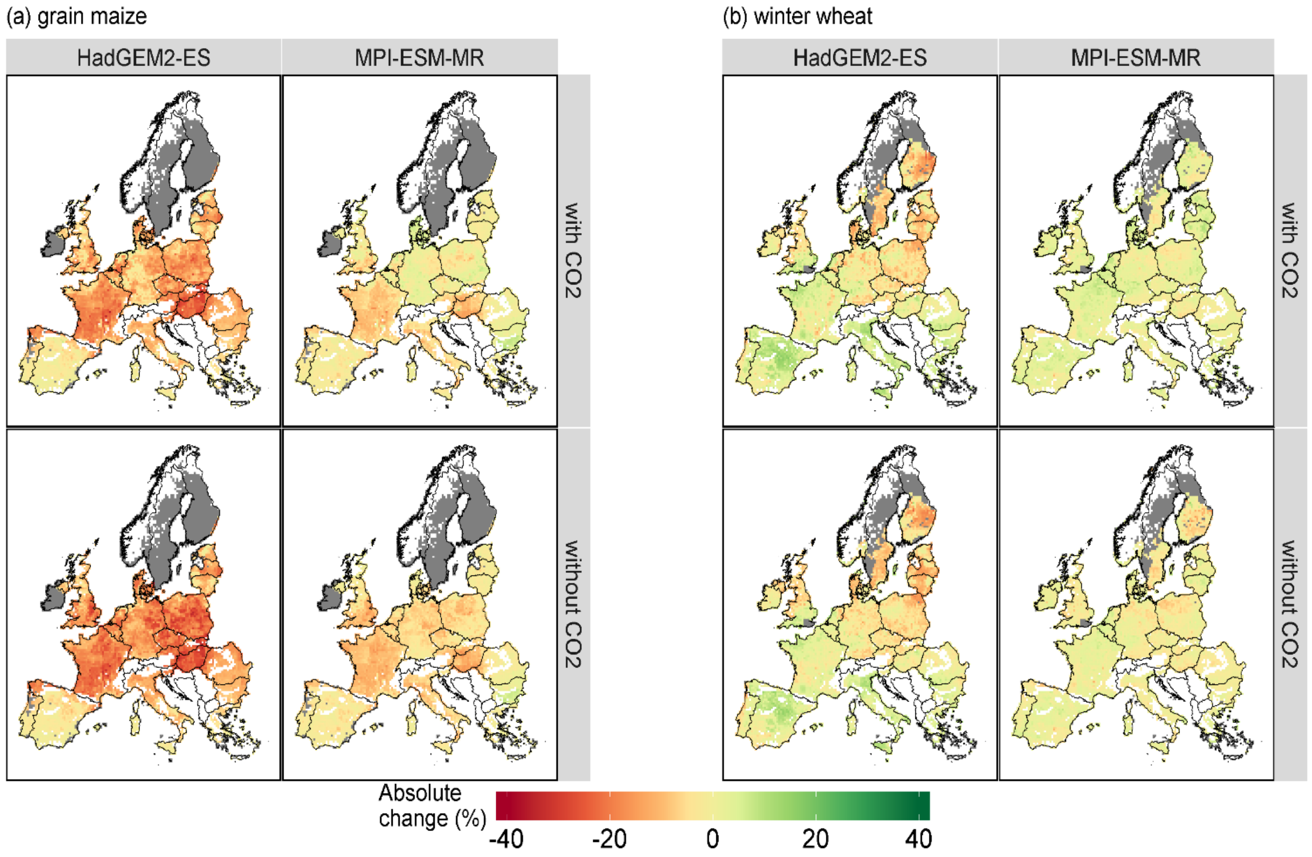


Figure 1 | Schematic illustration of the relationship between total uncertainty, projected ranges of relative yield changes and best fits of aggregate yield changes. The figure refers to model-based results from AR4 (ref. 5) and AR5 (WGII chapter 'Food security and food production systems') and indicatively depicts the main message and novelties of this study[4]. Figure modified from ref. 6.

Rötter et al. (2014)

Drought is the major threat for cereals under climate change in Europe (2050s)

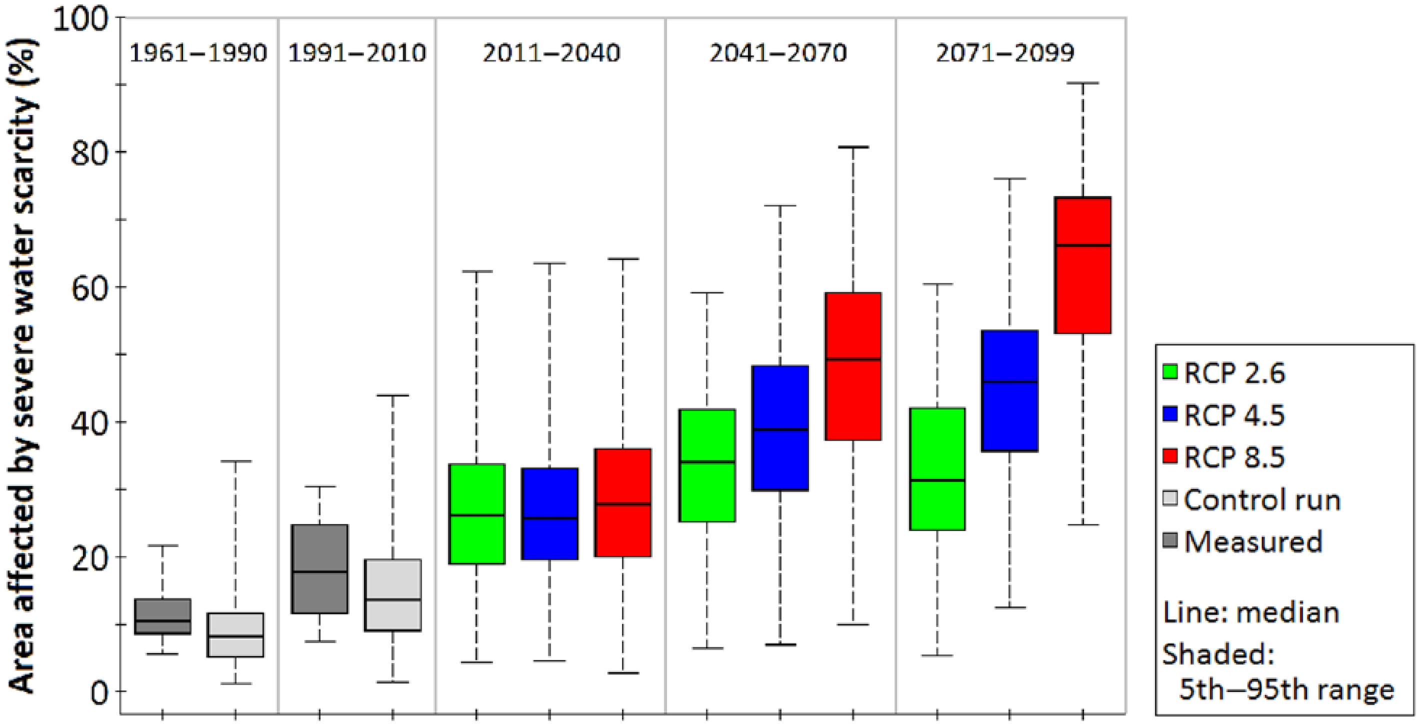




Webber et al. (2018) Nature Com. 9, 4249

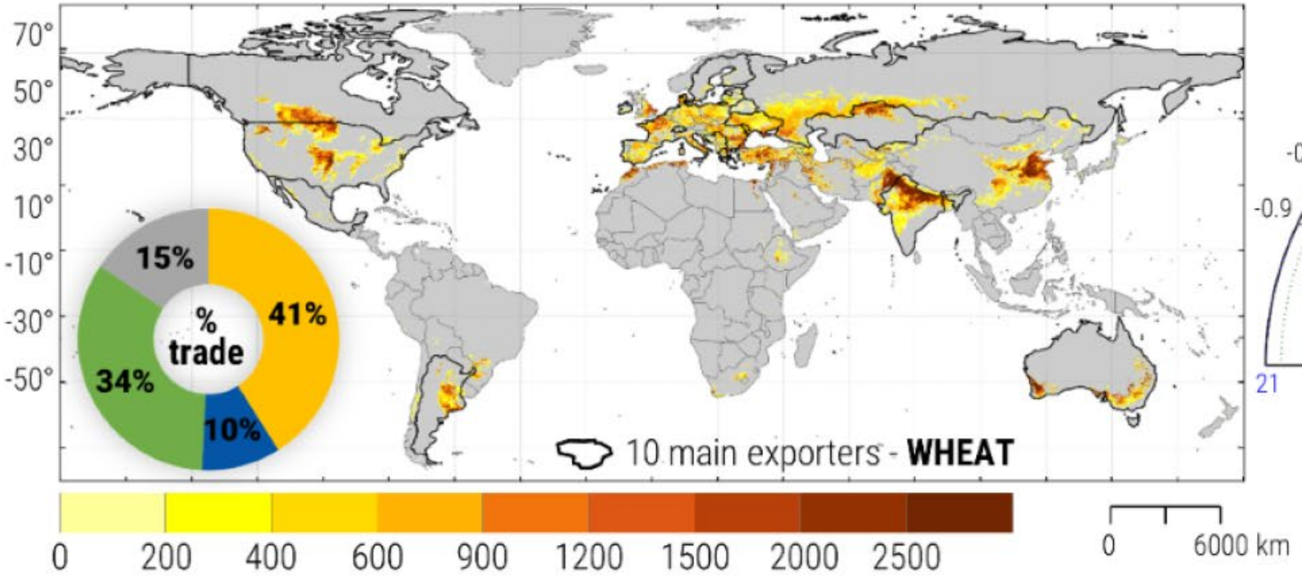
Future severe drought in wheat

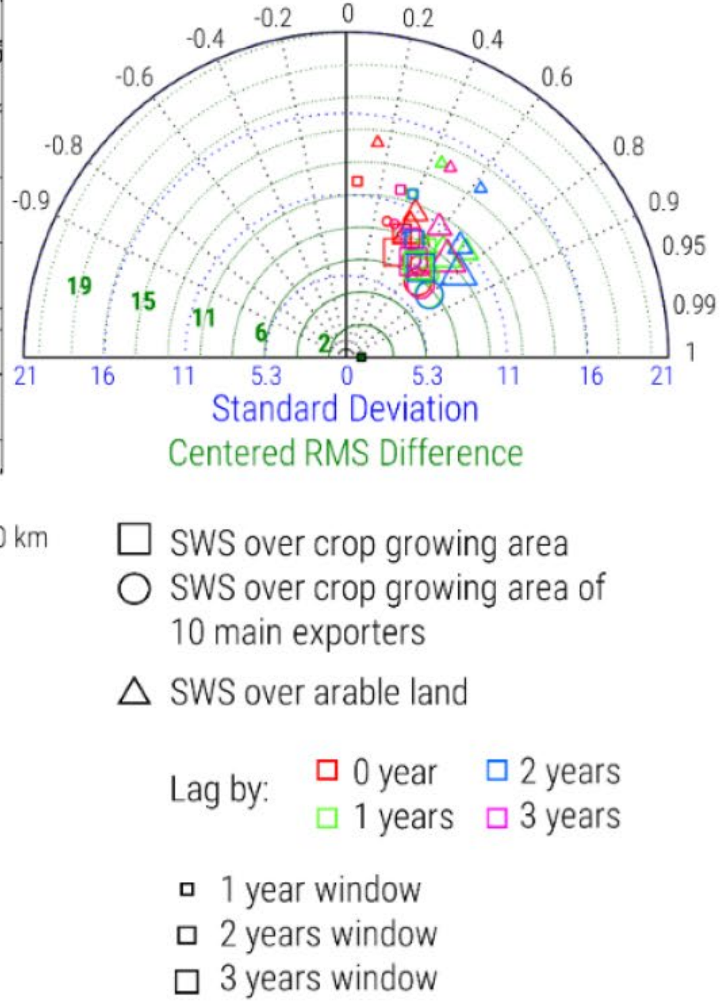
- Calculated area with severe drought for the world wheat area over the growing period for wheat
- The area with severe drought has increased by 50 % relative to 1961-1990
- Under moderate climate change the area with severe drought will quadruple by mid century
- This increase in severe drought also happens in the world wheat exporting countries, affecting grain price



Trnka et al. (2019) Sci. Adv. 5, eaau2406

World wheat price (WPI) is primarily driven by variation in drought





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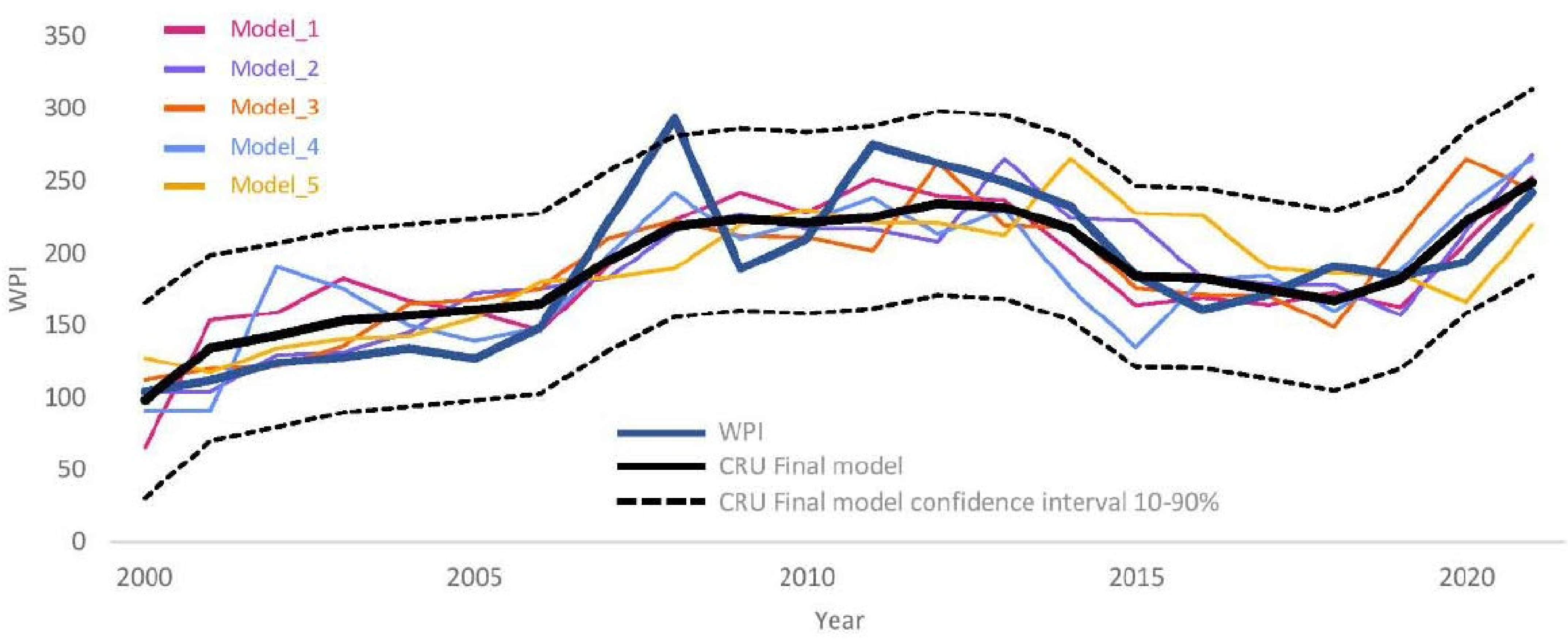
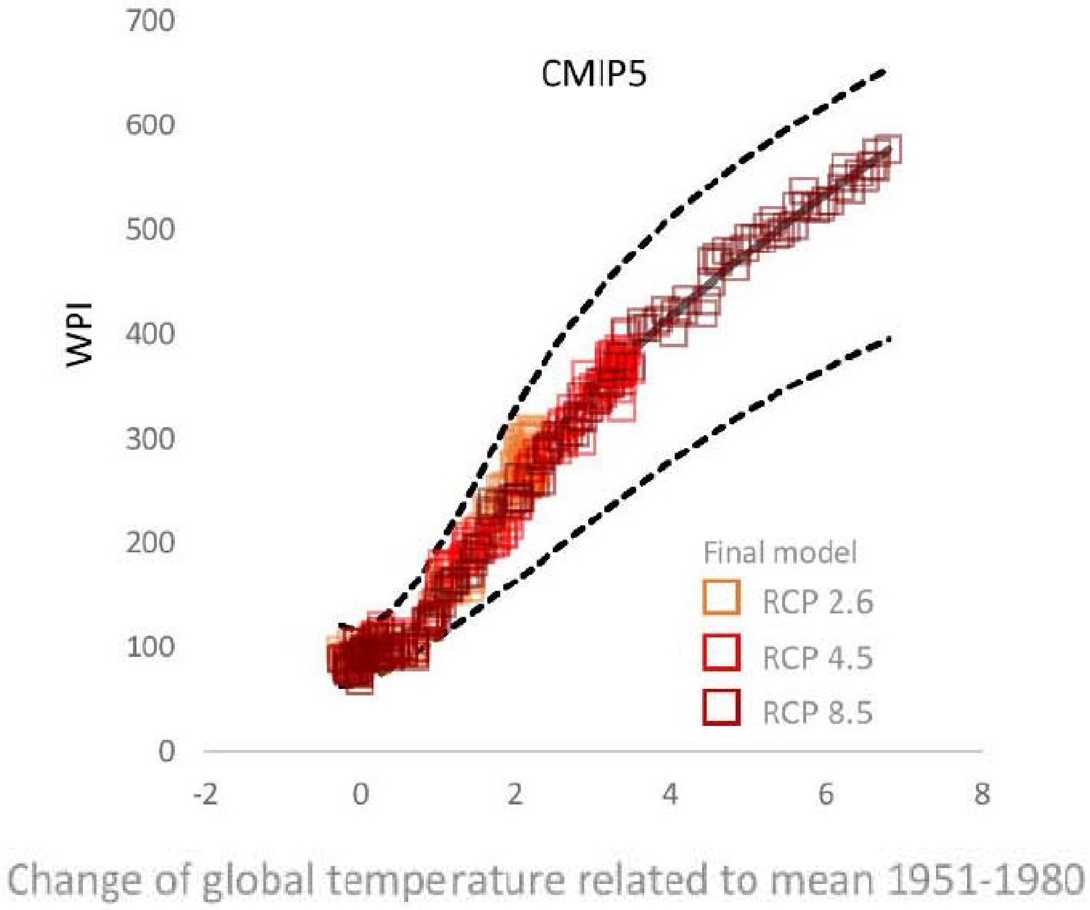


Climate change is projected to increase wheat price (WPI)



Response of agriculture to climate change

- The ongoing climate change with higher temperatures, increased variability and extremes will challenge most agricultural systems and often make mitigation efforts more challenging
- Globally, climate change will increase extent and frequency of drought, negatively affecting food supply and food security
- This necessitates development of technologies and agricultural systems that emphasize both low GHG emissions as well as resilience to climatic stresses

Satellite image showing drought in 2018 over West Zealand

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