GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Göttingen Campus

Adapting agriculture to a changing climate.

Challenges for agricultural systems modelling

Antrittsvorlesung /Inaugural address

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Tropical Plant Production and Agricultural Systems Modelling (TROPAGS)

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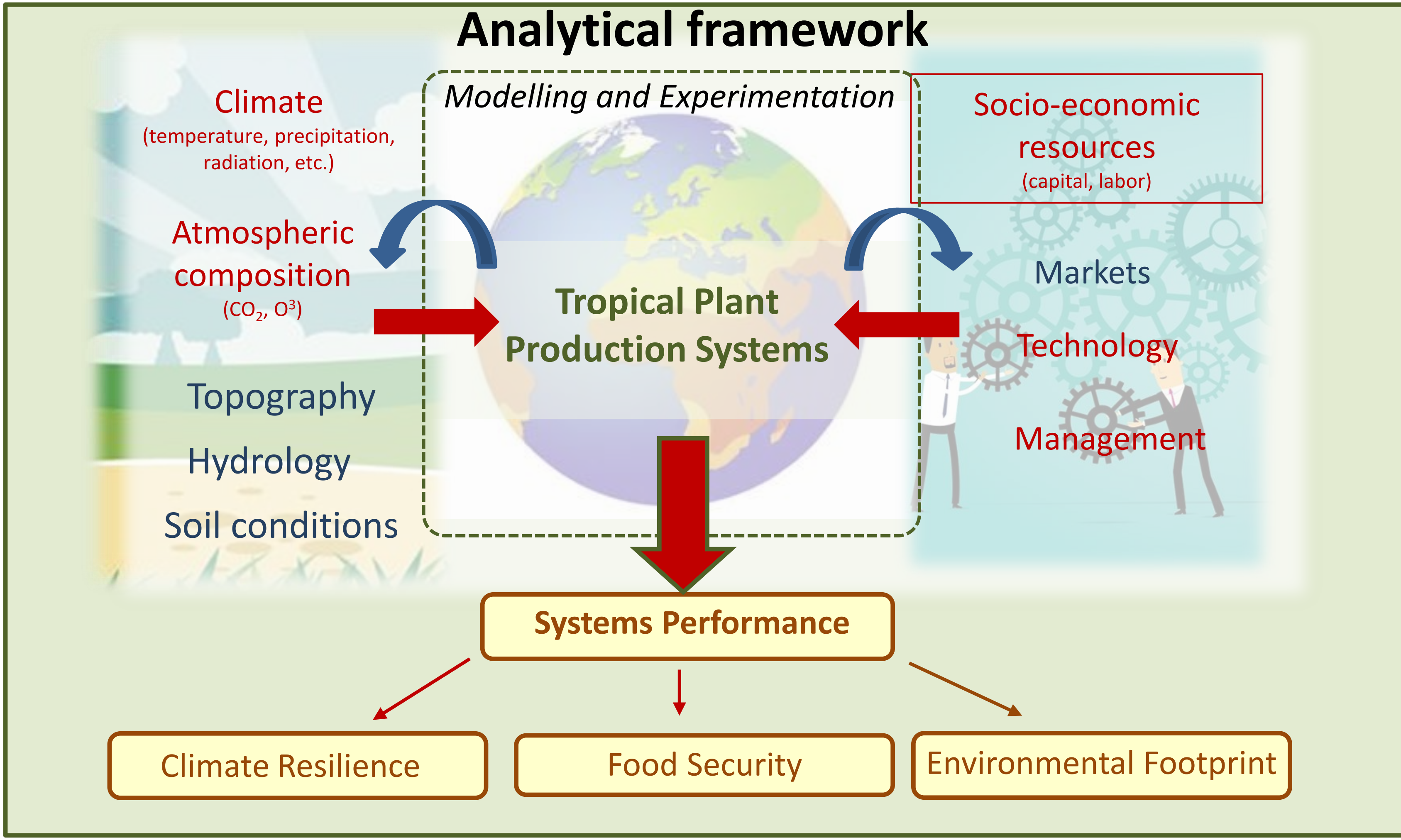
Göttingen, L01, 7 December 2016

CONTENTS

Tropical Plant Production and Agricultural Systems Modelling (TROPAGS)



1.1 Climate is changing…

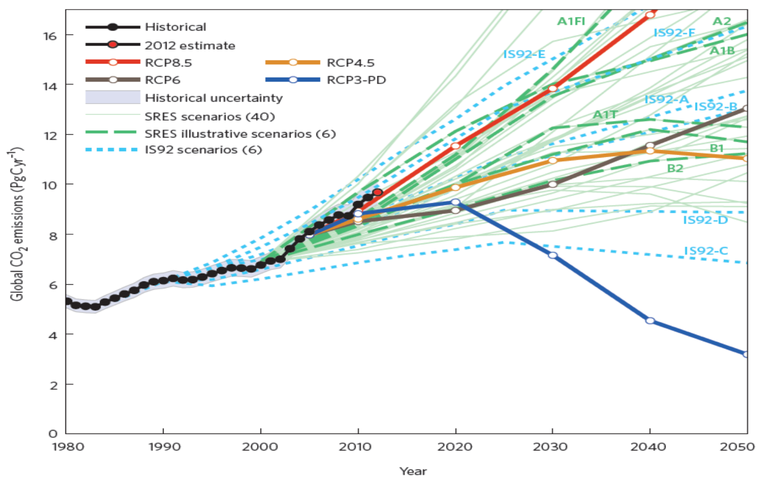
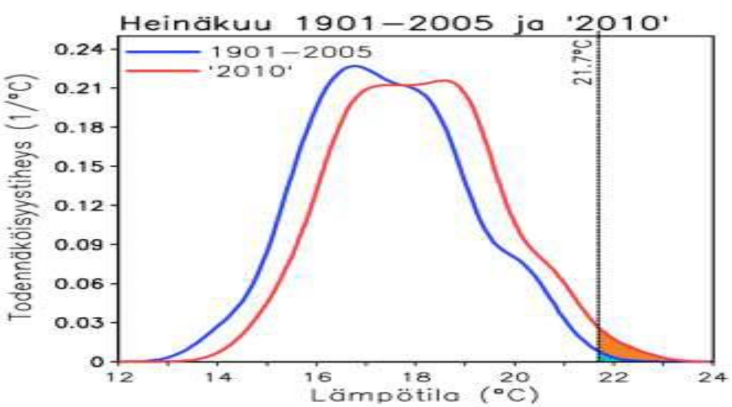
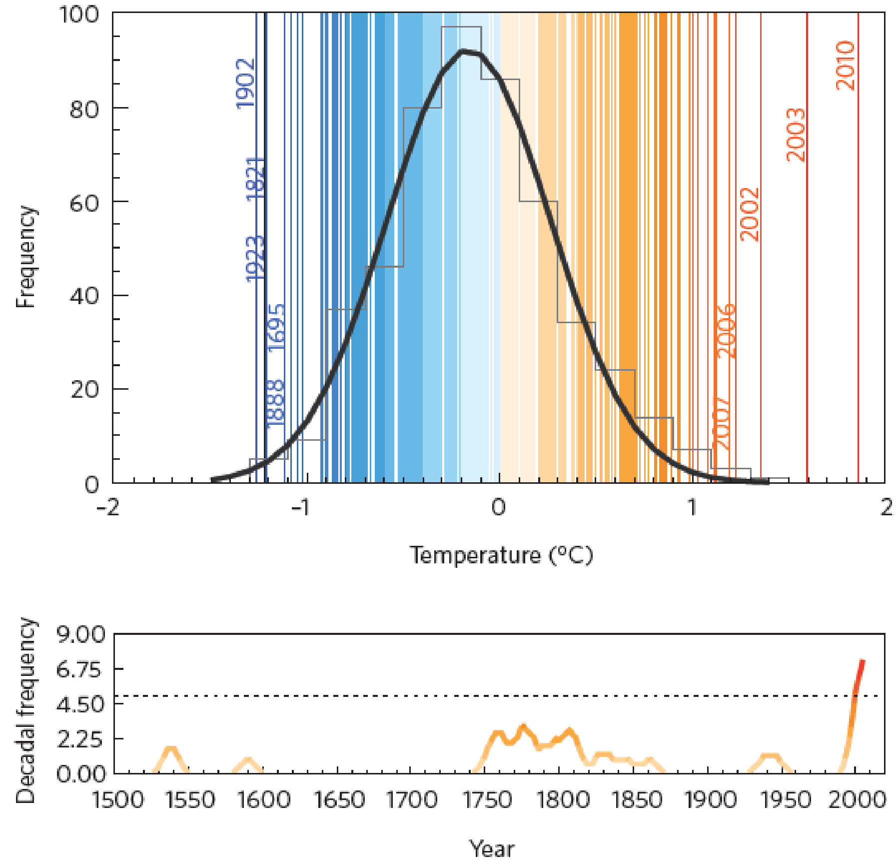


Figure 1 | Estimated CO_2 emissions over the past three decades compared with the IS92, SRES and the RCPs. The SA90 data are not shown, but the most relevant (SA90-A) is similar to IS92-A and IS92-F. The uncertainty in historical emissions is ±5% (one standard deviation). Scenario data is generally reported at decadal intervals and we use linear interpolation for intermediate years.

(*Source: Peters et al., 2013; Nat Clim Change*)



Shift in PDF of July temperatures S Finland
(*Source:* Räisänen 2010)

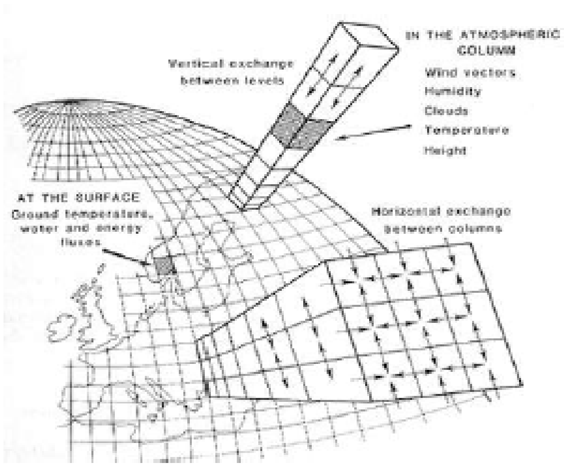


| European summer temperatures for 1500–2010. The upper panel shows the statistical frequency distribution of European (35° N, 70° N; 25° W, 40° E) summer land-temperature anomalies (relative to the 1970–1999 period) for the 1500–2010 period (vertical lines). The five warmest and coldest summers are highlighted. Grey bars represent the distribution for the 1500–2002 period with a Gaussian fit shown in black. The lower panel shows the running decadal frequency of extreme summers, defined as those with a temperature above the ninety-fifth percentile of the 1500–2002 distribution. A ten-year smoothing is applied. Reproduced with permission from ref. 69, © 2011 AAAS.

Source: Coumou & Rahmsdorf, 2012

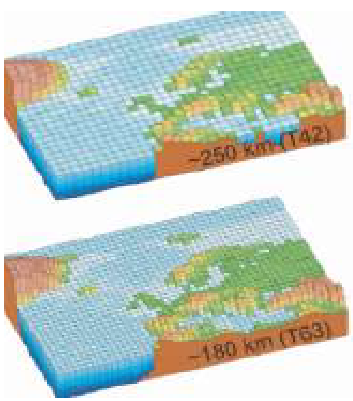
Climate change projections

General Circulation Models

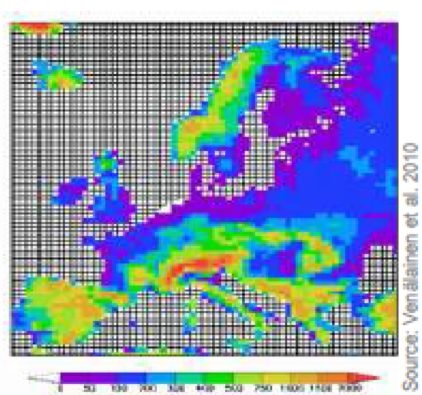


- General Circulation Models (GCM) = Numerical representation of the atmosphere and its phenomena over the entire Earth
- GCMs are the best tools available to address the likely impact of increasing atmospheric greenhouse gas concentrations on the climate system
- Spatial resolution of GCMs coarser than the driving processes of many impacts ➔ downscaling to finer resolution (e.g. with regional climate models (RCM))

Source: S. Fronzek et al, 2011



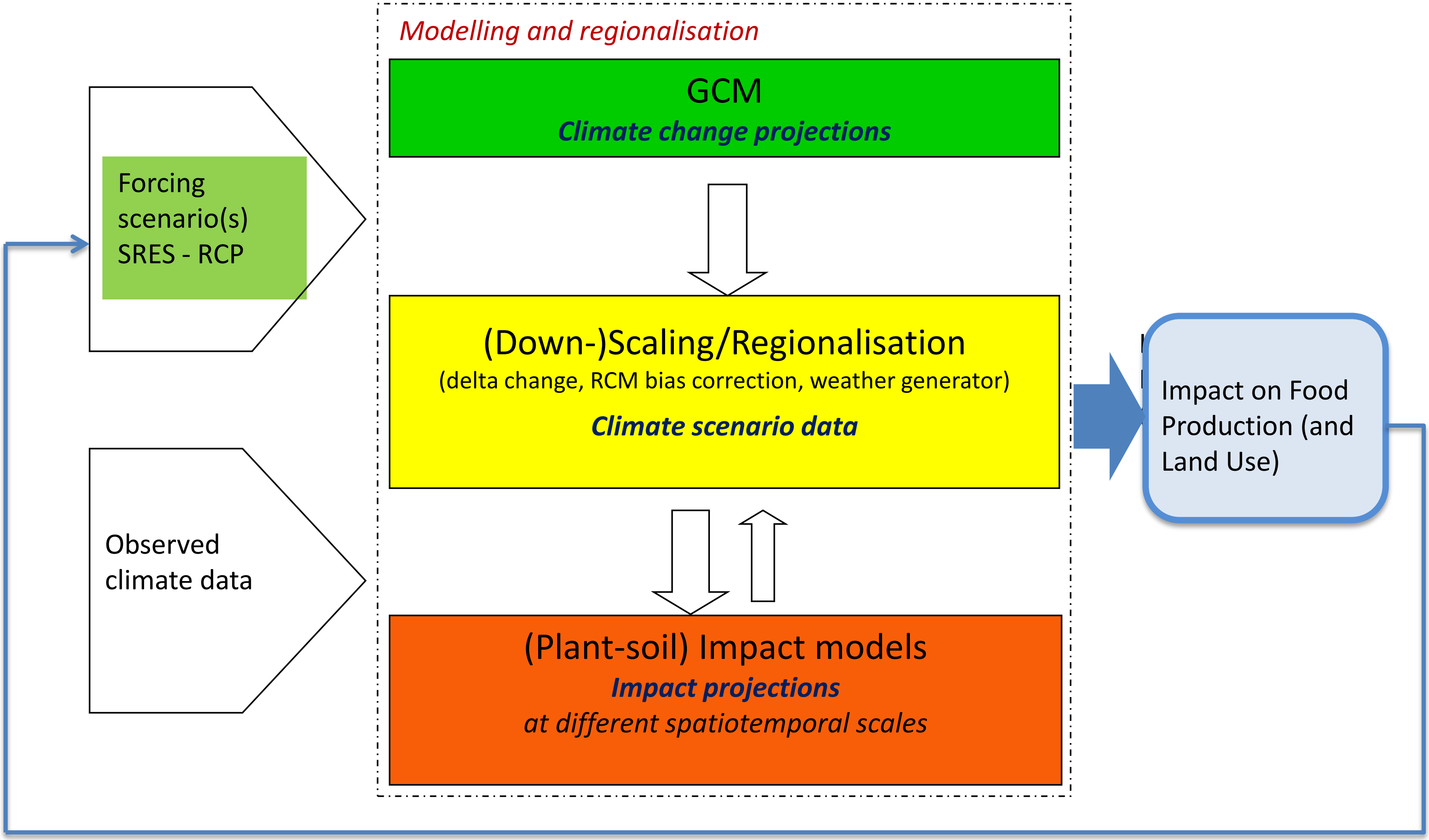
GCMs ~200 km



RCMs ~25-50 km

- Recently much progress regarding <u>integration</u> (Earth Syst Mod), <u>spatial resolution</u> (RCMs at 10 km) and <u>verification of projections</u> vs measurements (e.g. Fischer & Knutti, 2016)

Uncertainty chain in CC impact assessment



(source: Rötter et al. 2012, Acta Agric Scand. Section A, 62(4), 166-180).

Climatic Change (2011) 105:91–108 105

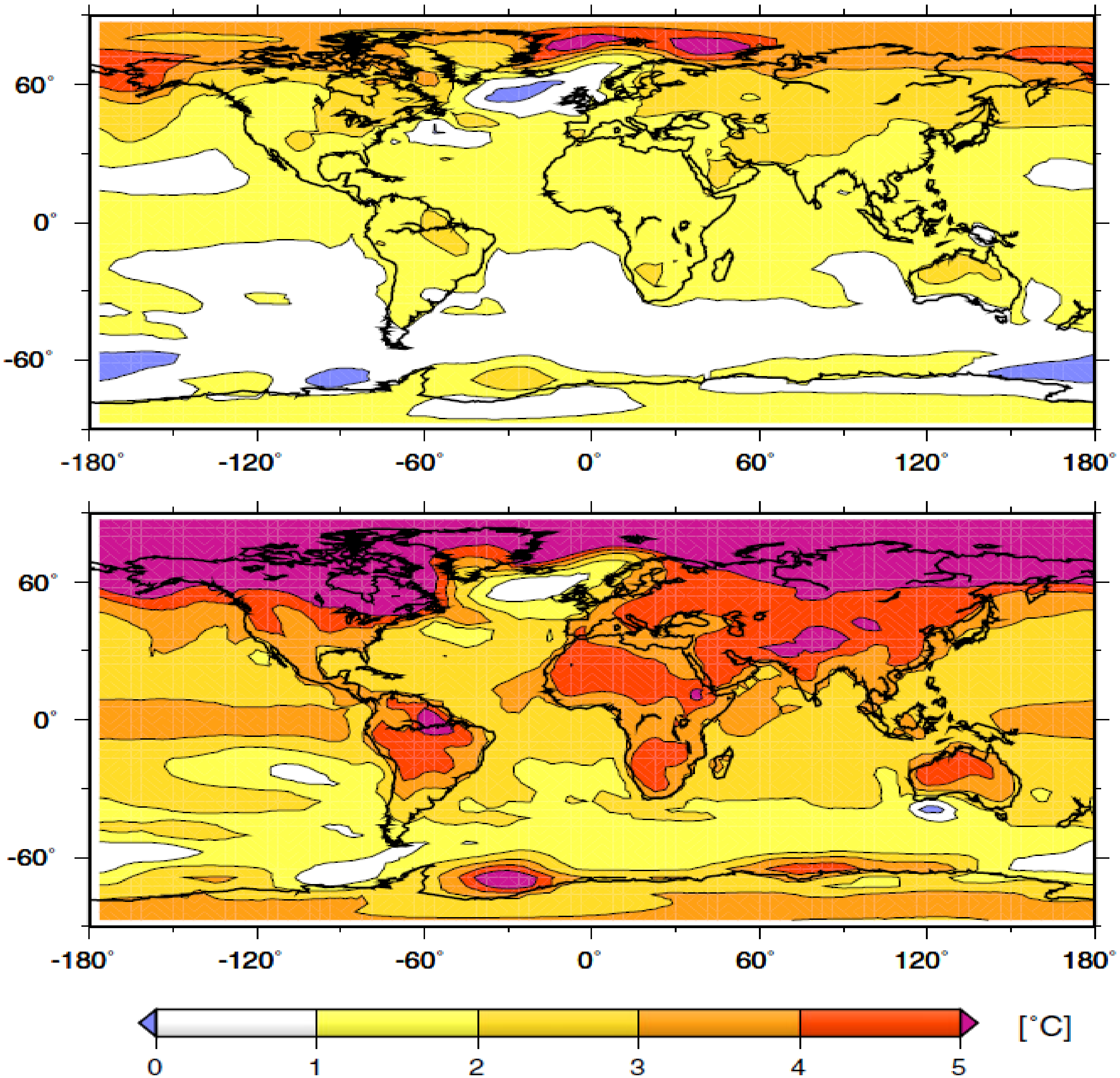


Fig. 11 Annual mean difference in surface air temperature (°C) between scenario (2080 to 2099) and present climate (1980 to 1999). *Top*: stabilization scenario E1; *bottom*: IPCC SRES scenario A1B

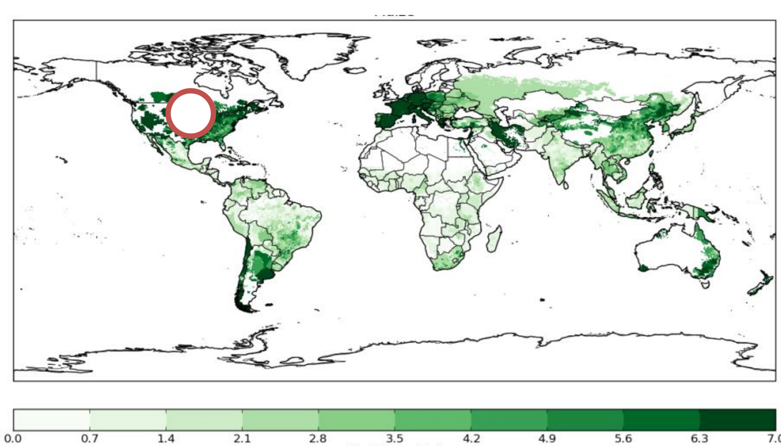
Shifts in annual mean surface air temperatures, 2080 to 2099 vs 1980 to 1999.

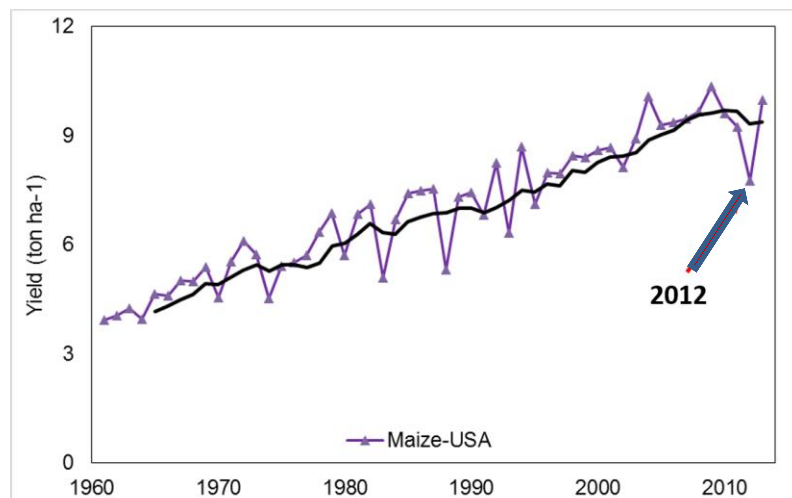
Top: stabilization scenario E1

Bottom: SRES A1B

Source: Roeckner et al 2011

Impact of extreme weather on maize Midwest/USA, 2012





2. Approaches to adaptation research

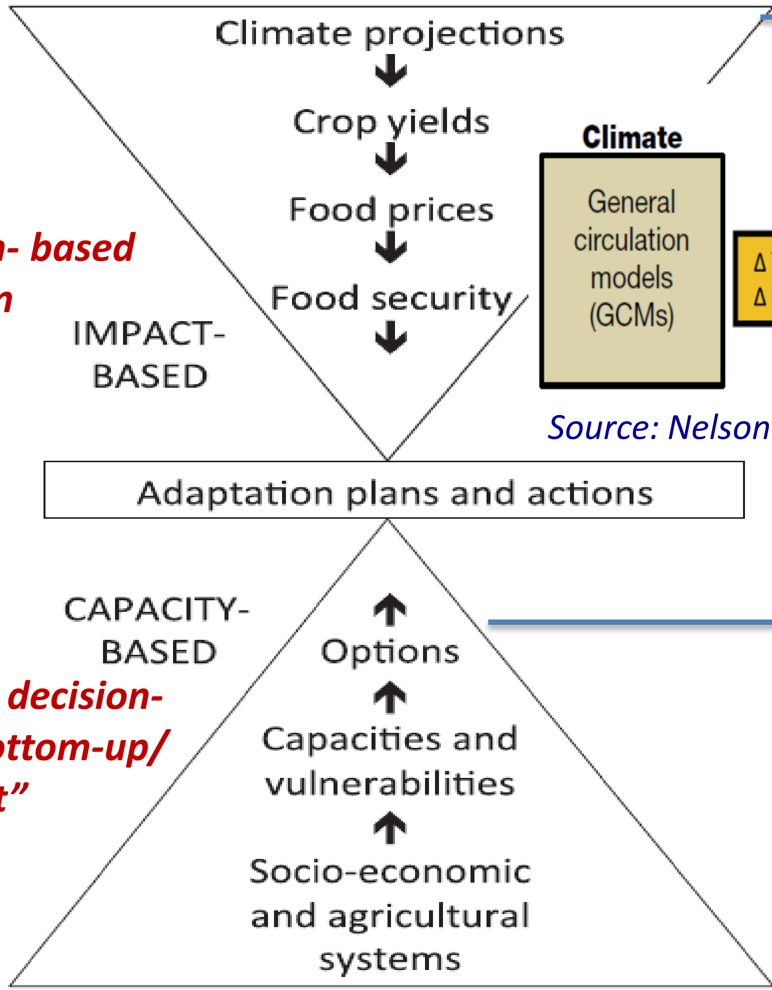
referring especially to research networks /programs:

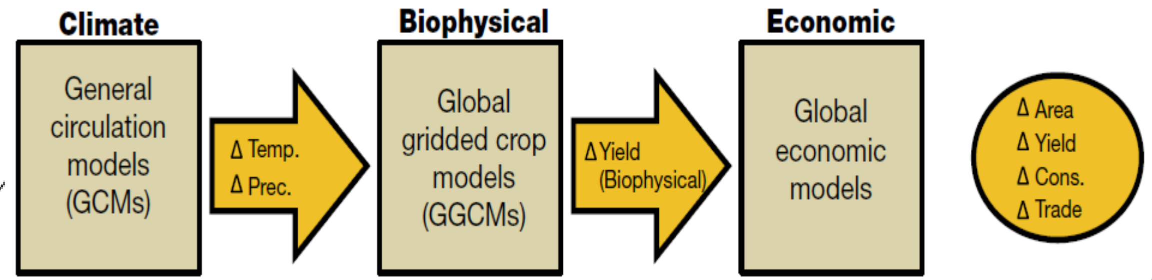
(1) AgMIP: the Agricultural Model Intercomparison and Improvement Project (www.agmip.org)
(2) CCAFS: Climate Change, Agriculture and Food Security (www.ccafs.cgiar.org)
(3) MACSUR: Modelling European agriculture with climate change for food security (www.macsur.eu)

Different approaches to adaptation analysis and planning

<u>AgMIP and MACSUR (EU-wide)</u>

Also called:
projection- based /top down





Source: Nelson et al., 2014 PNAS

<u>CCAFS and MACSUR (regional cases)</u>

Also called: ***decision-based /bottom-up/ ”no regret”***

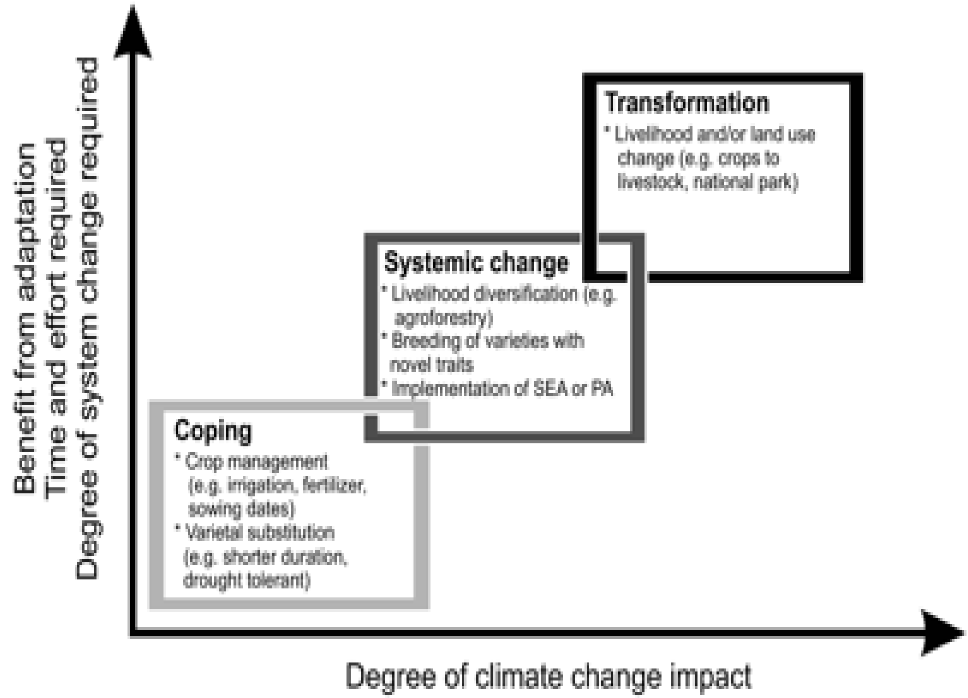
Fig. 1. Impact and capacity approaches to adaptation planning.

Source: Vermeulen et al, 2013, PNAS

Adaptation definition/ types of…

IPCC definition:

- **„the process of adjustment to actual or expected climate and its effects.**
- In human systems adaptation seeks to moderate harm or exploit beneficial opportunities (left and right tail of e.g. a yield distribution). In natural systems, human inter-vention may facilitate adjustment to expected changes.



Types of adaptations needed as degree of CC impact increases (three vars in y-axis: (i) benefit (ii) time and effort required (iii) degree of system change required);

(source: Rippke et al 2016)

Crop Simulation approach (G x E x M)

e.g. The CT de Wit Wageningen School of crop simulation models (SUCROS type - of moderate to high complexity; daily time step) (see, Bouman et al., 1996; van Ittersum et al 2003)

Different Cul
- early ↔ late
- current – futu

Different soil typ *(examples):*
- Fine sandy soil
- Clay loam
- Heavy clay
- Organic soil

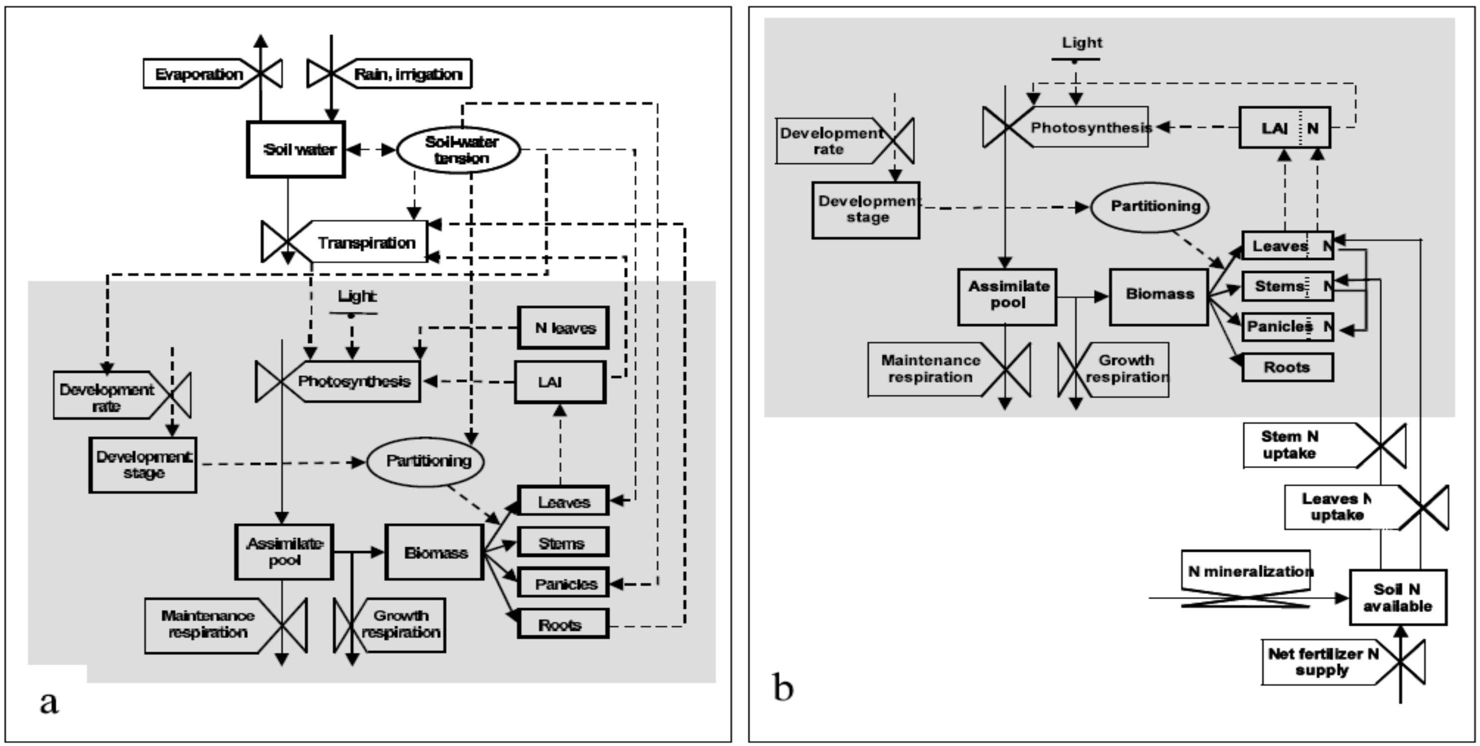
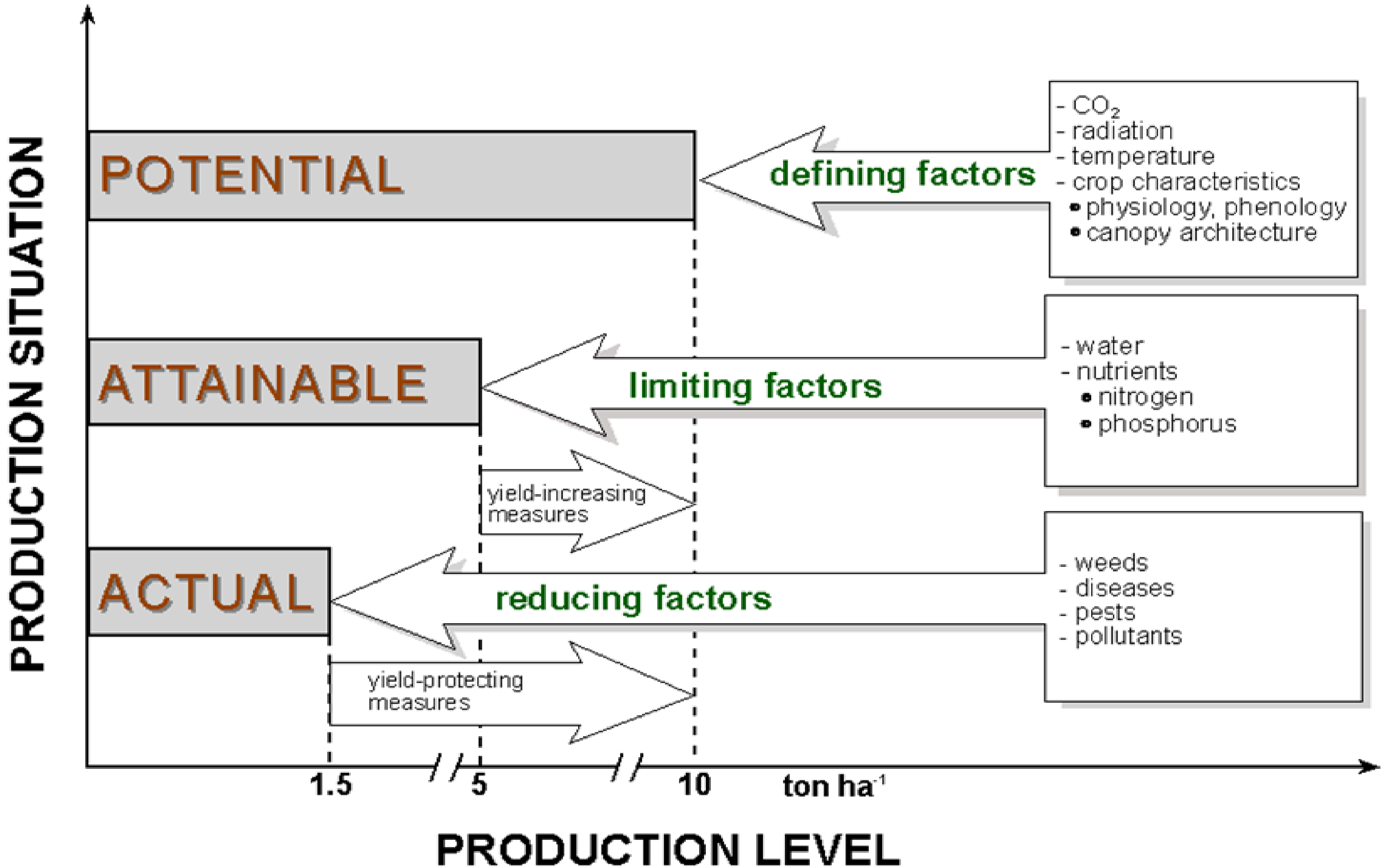


Fig. 2. A schematic representation of the photosynthesis module (in grey) for potential production, the module for water-limited production (a) and the dynamic N-approach for nutrient-limited production (b) for the ORYZA2000 model. Boxes are state variables, valves are rate variables, and circles are intermediate variables. Solid lines are flows of material and dotted lines are flows of information (Bouman et al., 2001). The same modules are used in many other models (Table 1).

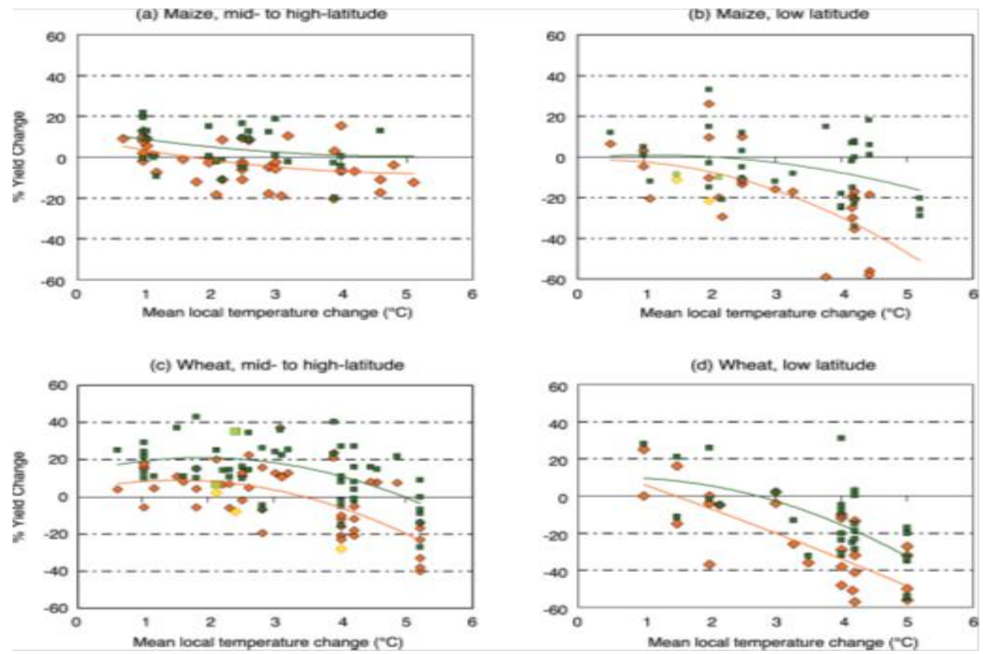
Production Situations & Crop model capabilities



(source: Van Ittersum& Rabbinge 1997)

Modelling adaptation of ag systems

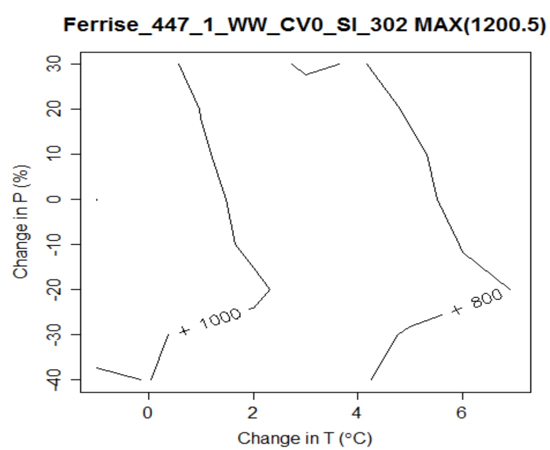
- IPCC WGII: **Easterling et al 2007;**
- **IPCC 2014: Challinor et al /Porter et al 2014; (IRS1-IRS2 – 2015ff)**
- **Van Wijk et al 2014** review paper bio-economic modelling studies



MACSUR -> a major driving force:

- CropM: Ruiz-Ramos et al. 2017 – Adaptation response surfaces

- TradeM: Integrated bio-economic analysis of adapt options (farm/region)



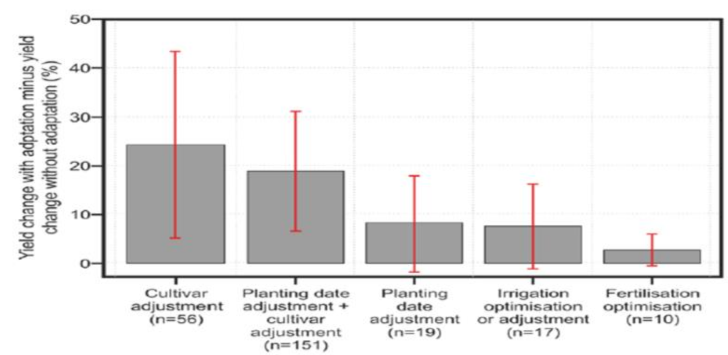


Figure 5 The benefit of different adaptation practices expressed as percentage change, from the baseline, in yield with adaptation minus that without adaptation, adapted from Challinor *et al.* (2014*b*). Data in this figure consists of yield changes from 32 simulation studies for various crops as described in Challinor *et al.* (2014*b*). Bars are means for each category and red lines indicate standard error. Note that the vast majority of data in the second category come from a single study (Deryng *et al.*, 2011).

3. Selected studies on CC impacts and agricultral adaptations

- **3.1 Potential impacts at global and regional scales**
- **3.2 Selected local case studies on crop-/region-specific impact and adaptation studies**

Global impacts of CC on crop productivity: 1994 and 2010

(source: Wheeler & von Braun, 2013)

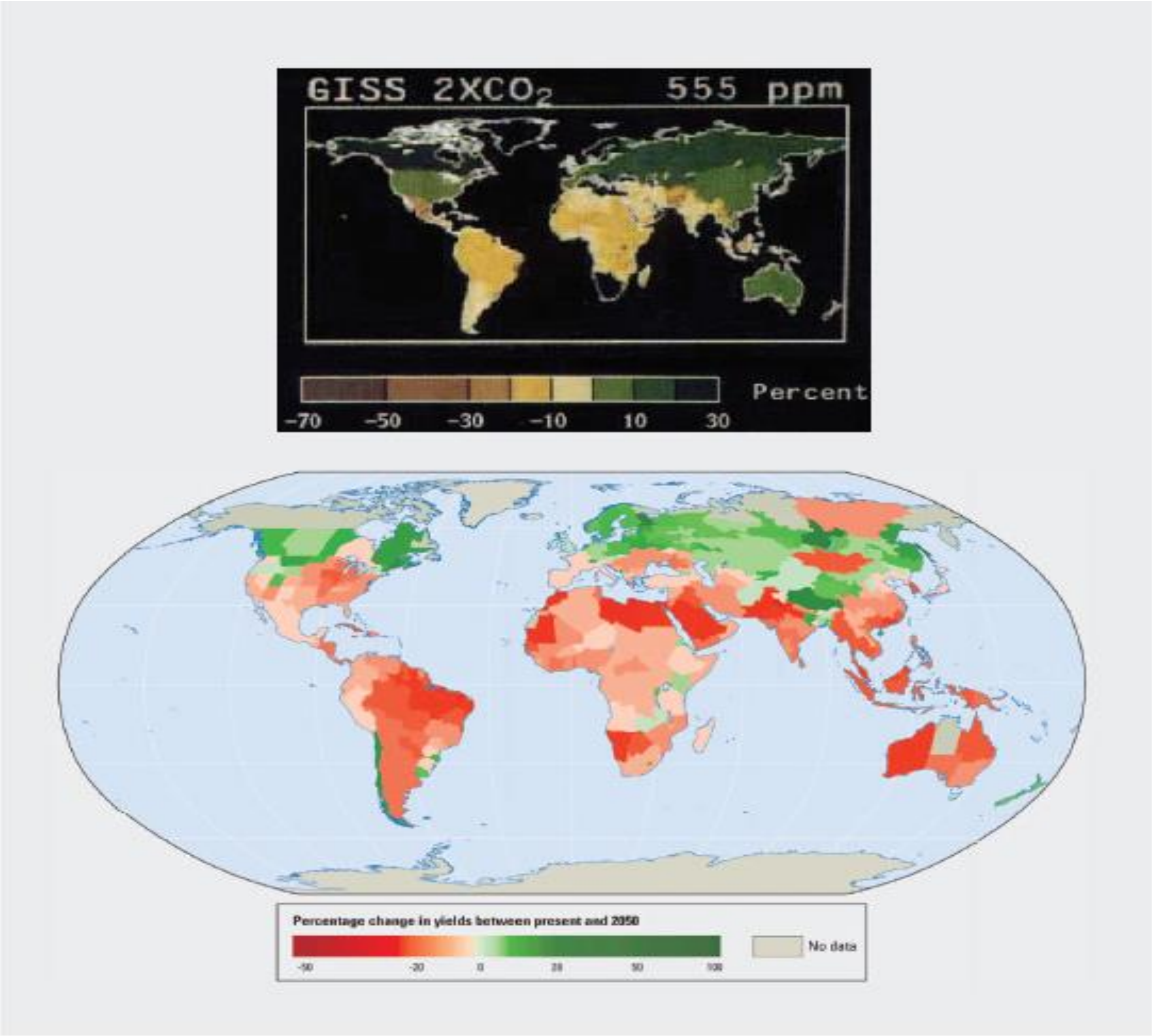


Fig. 2. Global impacts of climate change on crop productivity from simulations published in 1994 and 2010. (**Top**) The 1994 study (*22*) used output from the GISS GCM (in this example) with twice the baseline atmospheric CO_2 equivalent concentrations as input to crop models for wheat, maize, soybean, and rice that were run at 112 sites in 18 countries. Crop model outputs were aggregated to a national level using production statistics. (**Bottom**) The 2010 study (*27*) simulated changes in yields of 11 crops for the year 2050, averaged across three greenhouse emission scenarios and five GCMs. [Reprinted by permission from (top) Macmillan Publishers Ltd. (*22*); (bottom) World Bank Publishers (*27*)]

CC impact on wheat: Use of multi-model ensembles

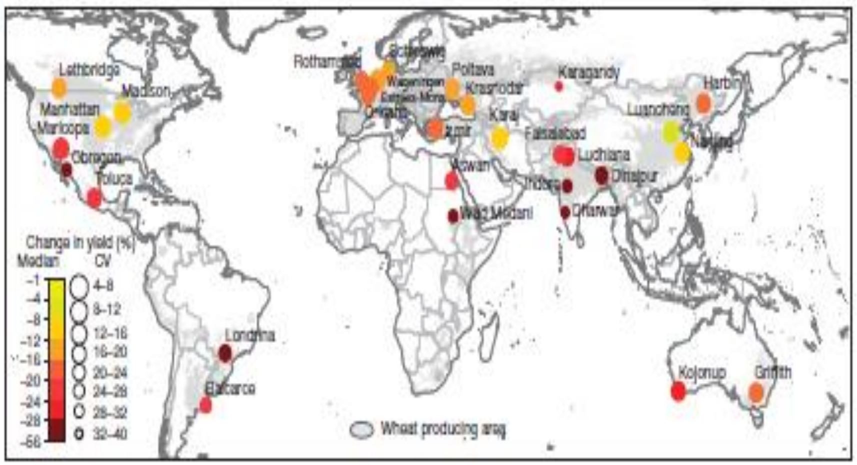
nature climate change

LETTERS

PUBLISHED ONLINE: 22 DECEMBER 2014 | DOI: 10.1038/NCLIMATE2470

Rising temperatures reduce global wheat production

S. Asseng *et al.*†



Application of ensemble modelling approach for bread wheat (AgMIP/Macsur) – map c shows: Relative median yield and CV for +4oC on top of 1981-2010 baseline

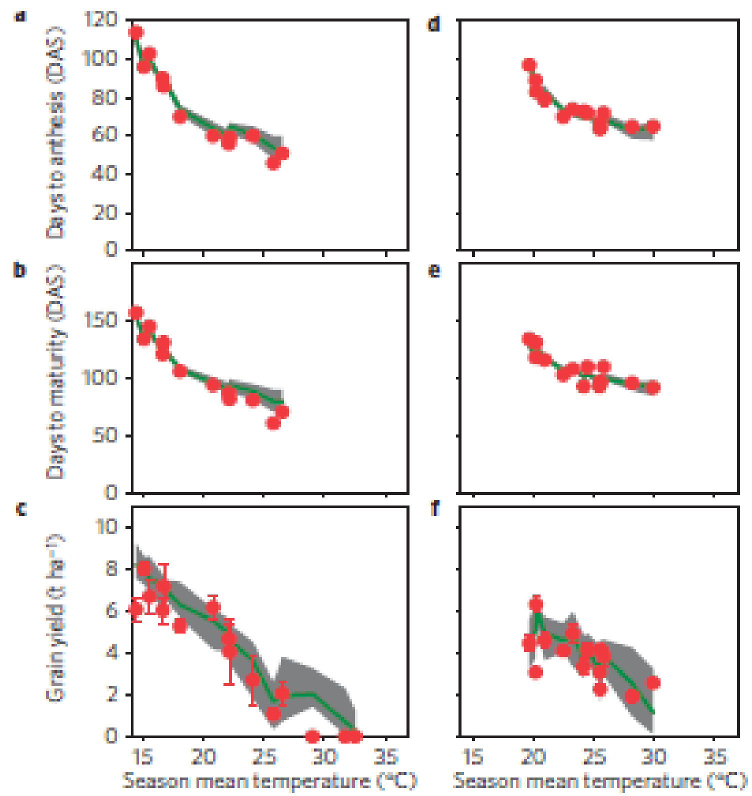
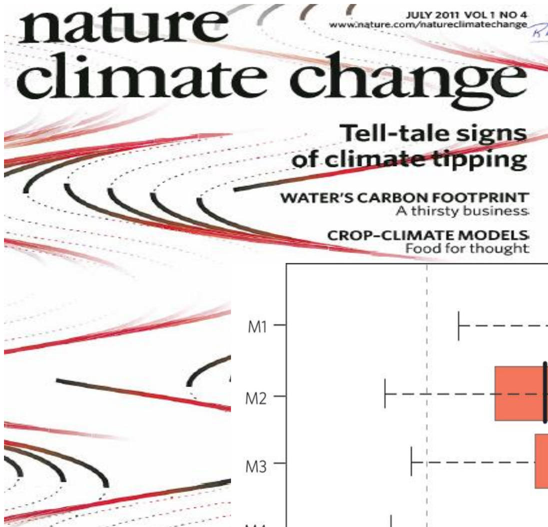
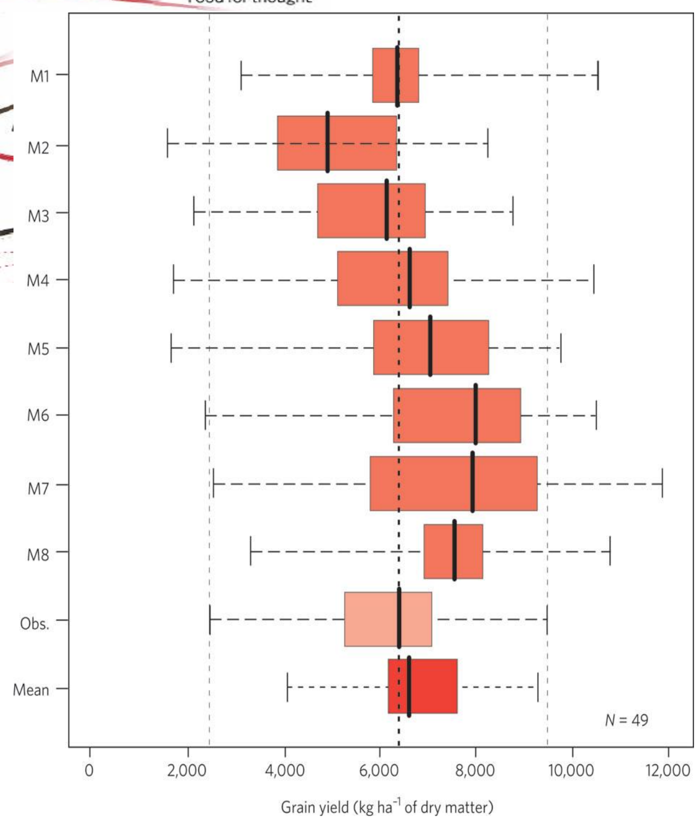


Figure 1 | Observations and multi-model simulations of wheat phenology and grain yields at different mean seasonal temperatures. a–f, Observed values ± 1 standard deviation (s.d.) are shown by red symbols. Multi-model ensemble medians (green lines) and intervals between the 25th and 75th percentiles (shaded grey) based on 30 simulation models are shown.

Model intercomparison and improvement

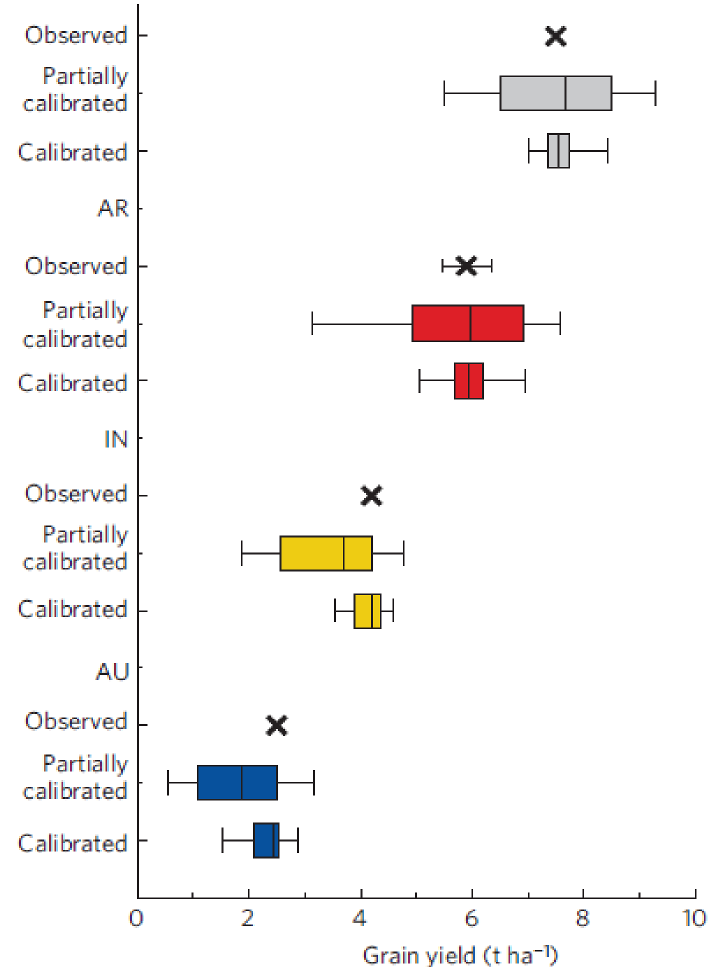
COST 734 (blind test, curr. climate); AgMIP wheat (partially & fully calibrated, curr. & future)





Source: Rötter et al., Nature Clim. Change 1, 175-177 (2011)

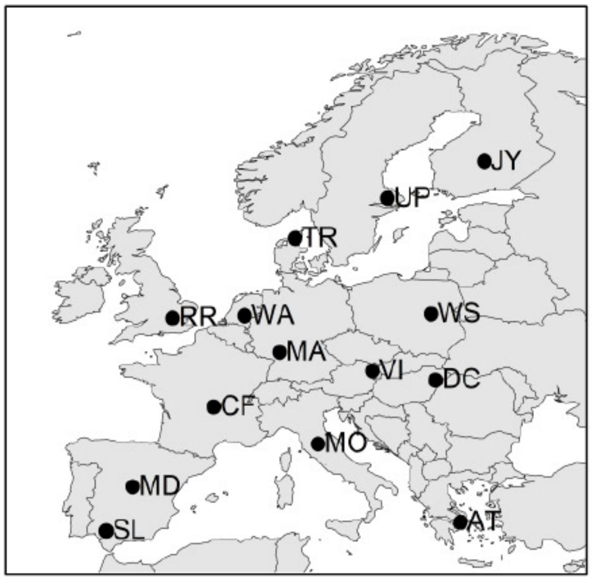
Use of multi-model ensembles

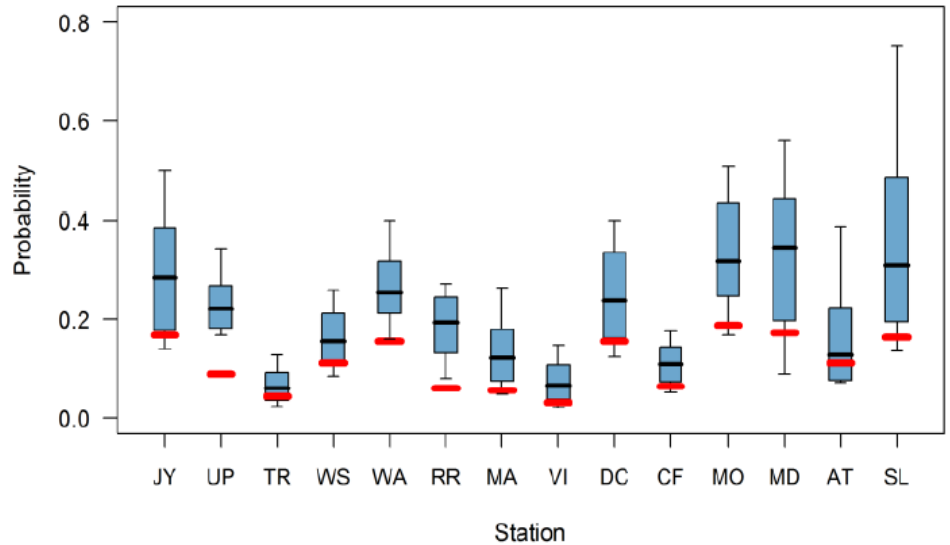


Source: Asseng et al., Nature Clim. Change 3, 827-832 (2013)

Assessing shifts in probabilities of multiple adverse events under CC

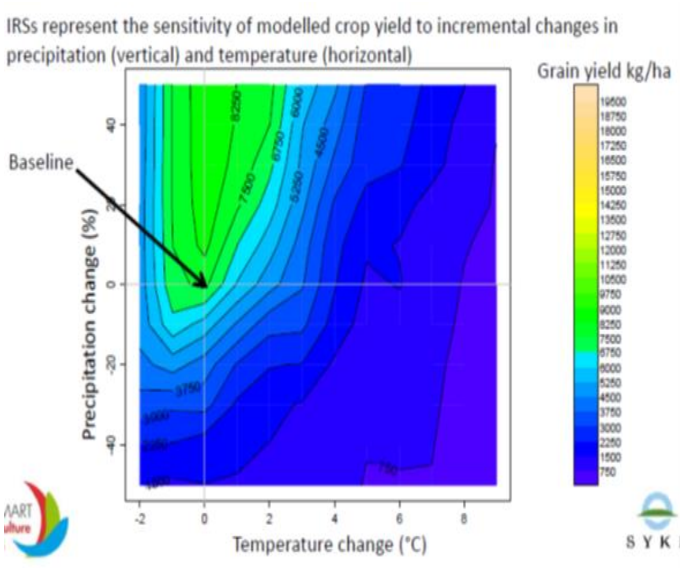
(Trnka, M., Rötter, RP, Ruiz-Ramos et al 2014)



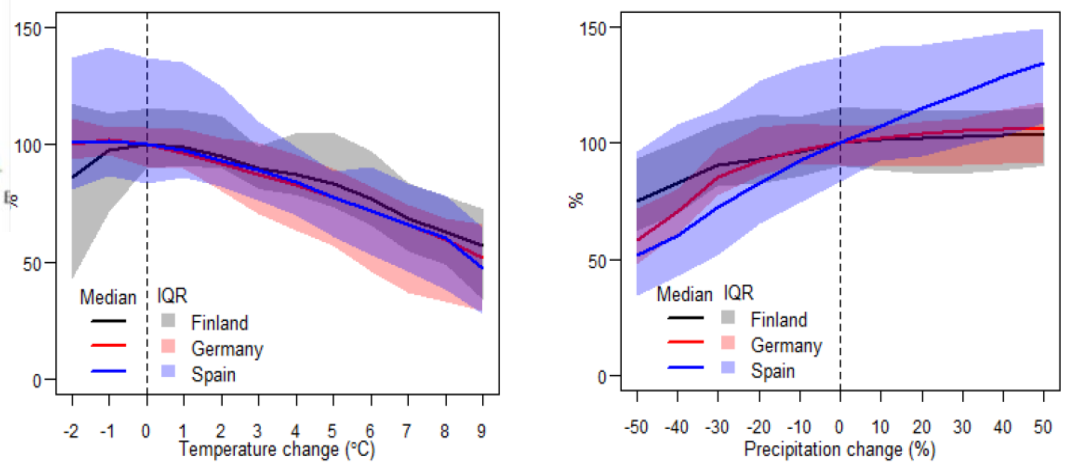


A MACSUR study shows that probabilities of occurrence of adverse events from sowing to maturity causing major threats for wheat production are projected to increase all over Europe under climate change (source: Trnka et al 2014, Fig 4). Red lines indicate the 1981–2010 baseline and box plots indicate the 2060 (RCP8.5) climate scenarios. The calculations consider a medium-ripening cultivar. The locations are ordered from north to south along the x axis.

Effects of local T change on wheat yields
(update of IPCC 2014 findings – by Macsur/Pirttioja et al.)



IRS1 - Results from single model: Spring wheat, Nossen/ Germany, year 2008



A MACSUR study shows that winter wheat yields are projected to decrease with increasing temperatures (a) and decrease with increasing precipitation (b) in different parts of Europe (sites in Finland, Germany and Spain). Changes are shown as relative (%) to yields during the baseline climate 1981-2010 with ensemble median responses of period-mean and interquartile ranges (IQR) across 26 crop models (source: Pirttioja et al 2015, Fig 8).

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Designing future barley ideotypes using a crop model ensemble

Fulu Tao[a,*], Reimund P. Rötter[a,b], Taru Palosuo[a], C.G.H. Díaz-Ambrona[c], M. Inés Mínguez[c], Mikhail A. Semenov[d], Kurt Christian Kersebaum[e], Claas Nendel[e], Davide Cammarano[f], Holger Hoffmann[g], Frank Ewert[g], Anaelle Dambreville[h], Pierre Martre[h], Lucía Rodríguez[c], Margarita Ruiz-Ramos[c], Thomas Gaiser[g], Jukka G. Höhn[a], Tapio Salo[a], Roberto Ferrise[i], Marco Bindi[i], Alan H. Schulman[a,j]

Objectives

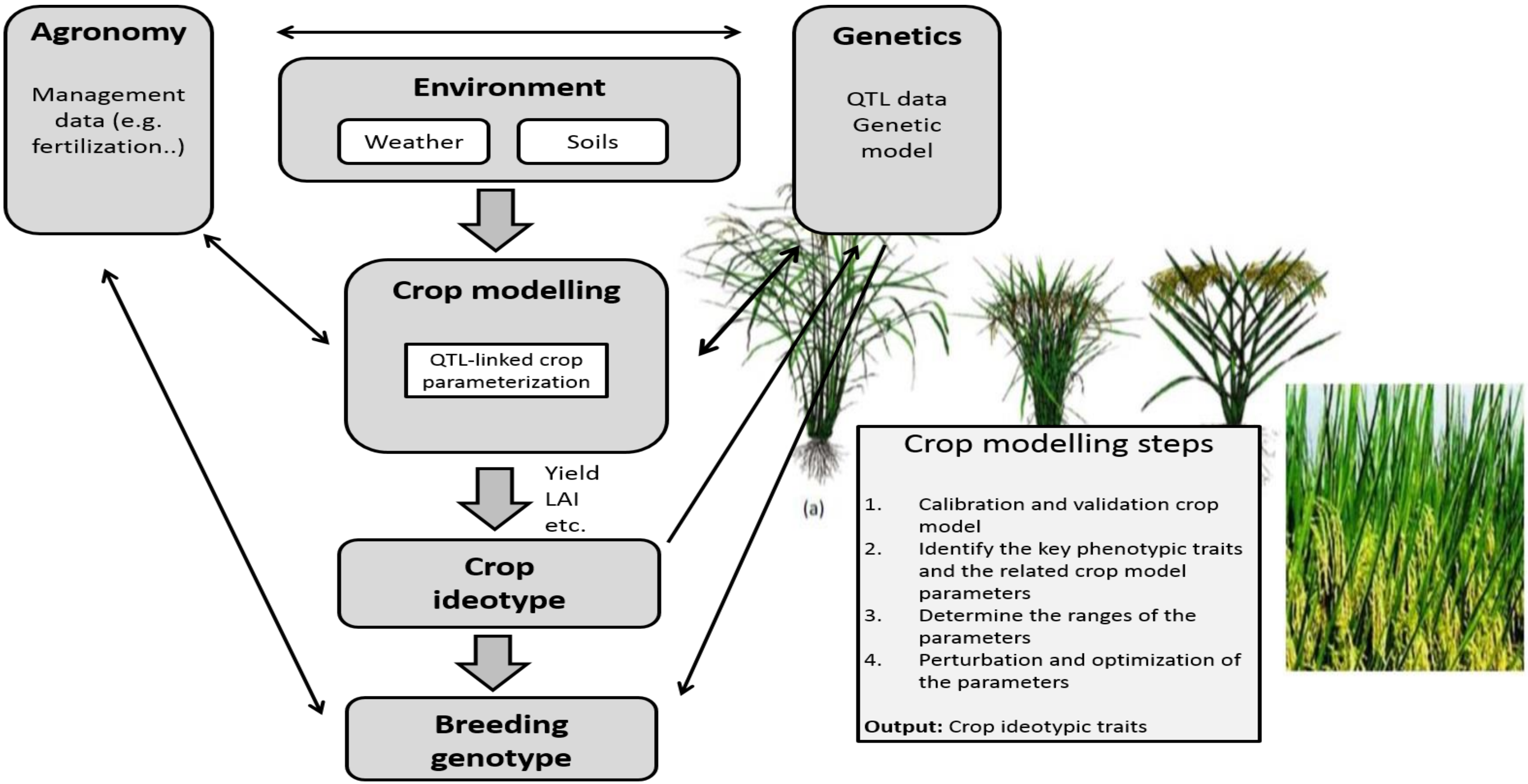
(1) To develop a new approach to design future crop ideotypes using a crop model ensemble

(2) To apply this approach to help design climate-resilient barley ideotypes for Boreal and Mediterranean (contrasting) climatic zones

4. What are future research challenges - and how to tackle them?

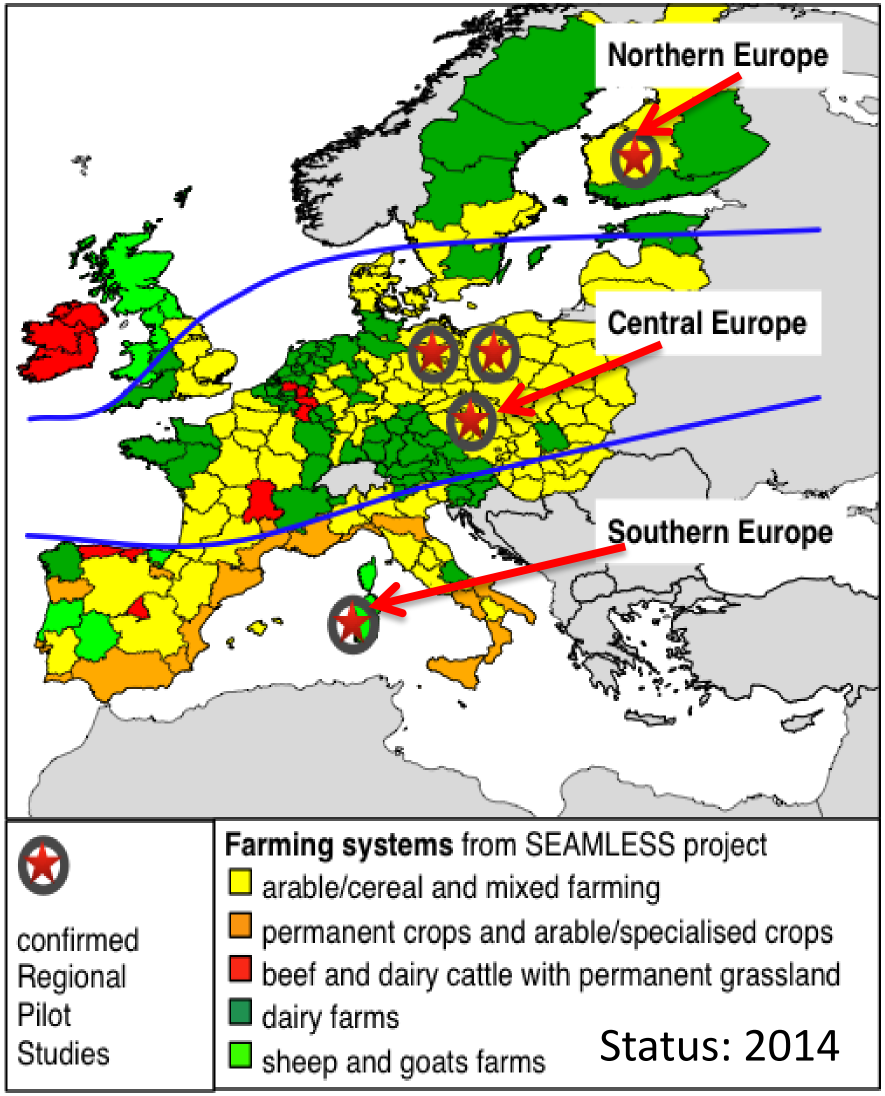
Experimentation to improve models for better quantifying extreme weather effects

Step towards robust method: Model-aided ideotyping of climate-resilient crop cultivars

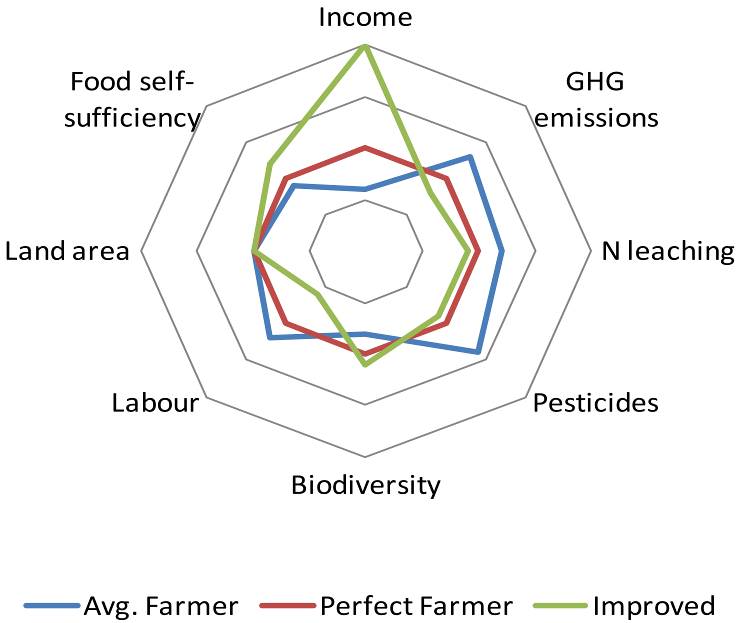


source: Rötter et al. 2015 (JEXBOT)

Integrated Regional Assessments (Macsur)



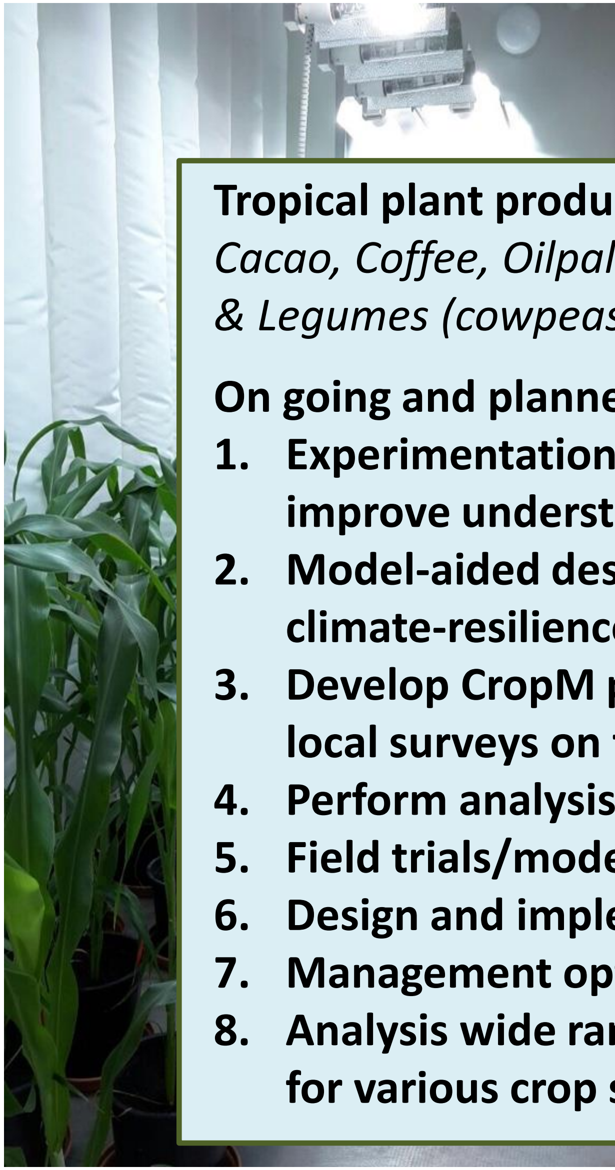
Multitude of appoaches for assessing **adaptation options** – one direction is upscaling from ***farm level*** (for typical farm types) of mitigative adaptation options via region/national to supra-national scales – also taking into account other Sustainable DevGoals (see, e.g. *www.mtt.fi/modags/*)

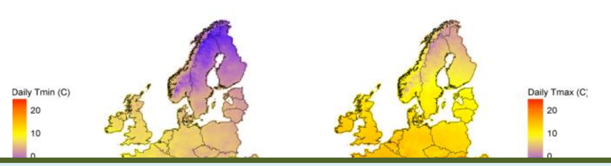


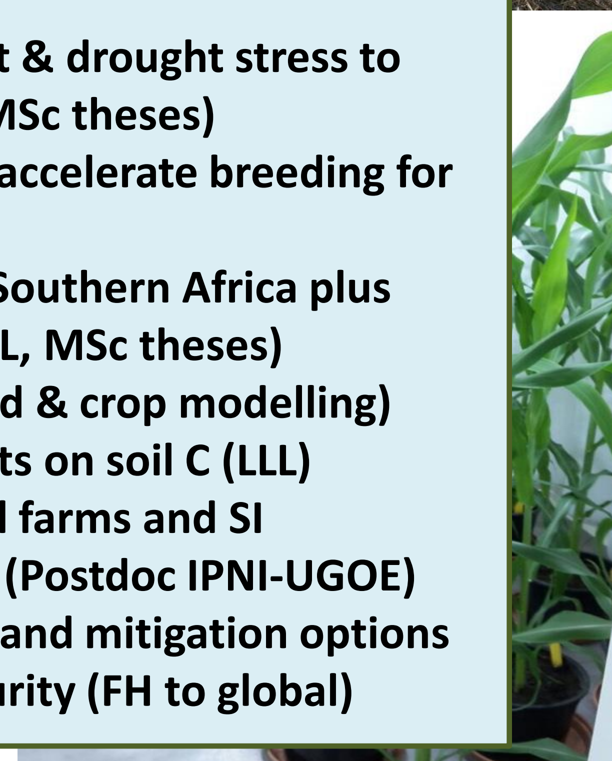
www.macsur.eu

Illustration multiple goal achievements under alternative management/ag-technologies

Challenges, on going & planned activities







Tropical plant production systems we are working on in Africa & Asia
Cacao, Coffee, Oilpalm, Maize/sorghum, Pearl millet, Rice, Wheat/ Barley & Legumes (cowpeas, groundnut, …)

On going and planned activities:

1. **Experimentation on effects of interactions heat & drought stress to improve understanding and models (2 CPs & MSc theses)**
2. **Model-aided design of future crop cultivars to accelerate breeding for climate-resilience (ClimBar /DE-IS….)**
3. **Develop CropM platform and Clim-Ewasys for Southern Africa plus local surveys on food and nutrition security (LLL, MSc theses)**
4. **Perform analysis of interactions (LLL - rangeland & crop modelling)**
5. **Field trials/modelling tillage and rotation effects on soil C (LLL)**
6. **Design and implementation of multi-functional farms and SI**
7. **Management options for oil palm in Indonesia (Postdoc IPNI-UGOE)**
8. **Analysis wide range of CC impacts, adaptation and mitigation options for various crop systems & effects on food security (FH to global)**

Citations /Further reading

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Homepage:

TROPAGS

https://www.uni-goettingen.de/en/106511.html

THANK YOU!