GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Göttingen Campus

How might the potential for food production change in the major agricultural regions?

Reimund P Rötter

Professor and Head of Division Tropical Plant Production and Agrosystems Modelling

Georg-August Universität Göttingen, Department of Crop Sciences, Grisebachstr. 6

(Coordinator CropM theme, EU FACCE-MACSUR knowledge hub)

Seminar: „Klimaatanpassninsäkrad livsmedelsproduktion-globalt och nationellt"

Kungl. Skogs- och Lantbruksakademien, Stockholm, 29 September 2016

AgMIP The Agricultural Model Intercomparison and Improvement Project

MACSUR a FACCE JPI Knowledge Hub

Motivation

„Since reliable and affordable food is central to human well-being and stability of societies [1], it will be paramount to assess potential impacts, effectively adapt agricultural systems to climate change, and, *at the same time,* develop and utilize the considerable mitigation potential of the agricultural sector [2]“

(source: Rötter, Höhn & Fronzek, 2012)

[1] von Braun, 2008. Nature 456, 701-02.

[2] Smith, P., Olesen, J.E., 2010. Journal of Agricultural Sciences, 148. 543-552

CONTENTS

1. Climate change (CC) projections: global, Europe /selected agricultural regions
2. Review of methods for CC impact projections & integrated assessments for agriculture
3. Projected CC impacts on food crop production in different world regions
4. Outlook on future research

Climate change projections – global perspective

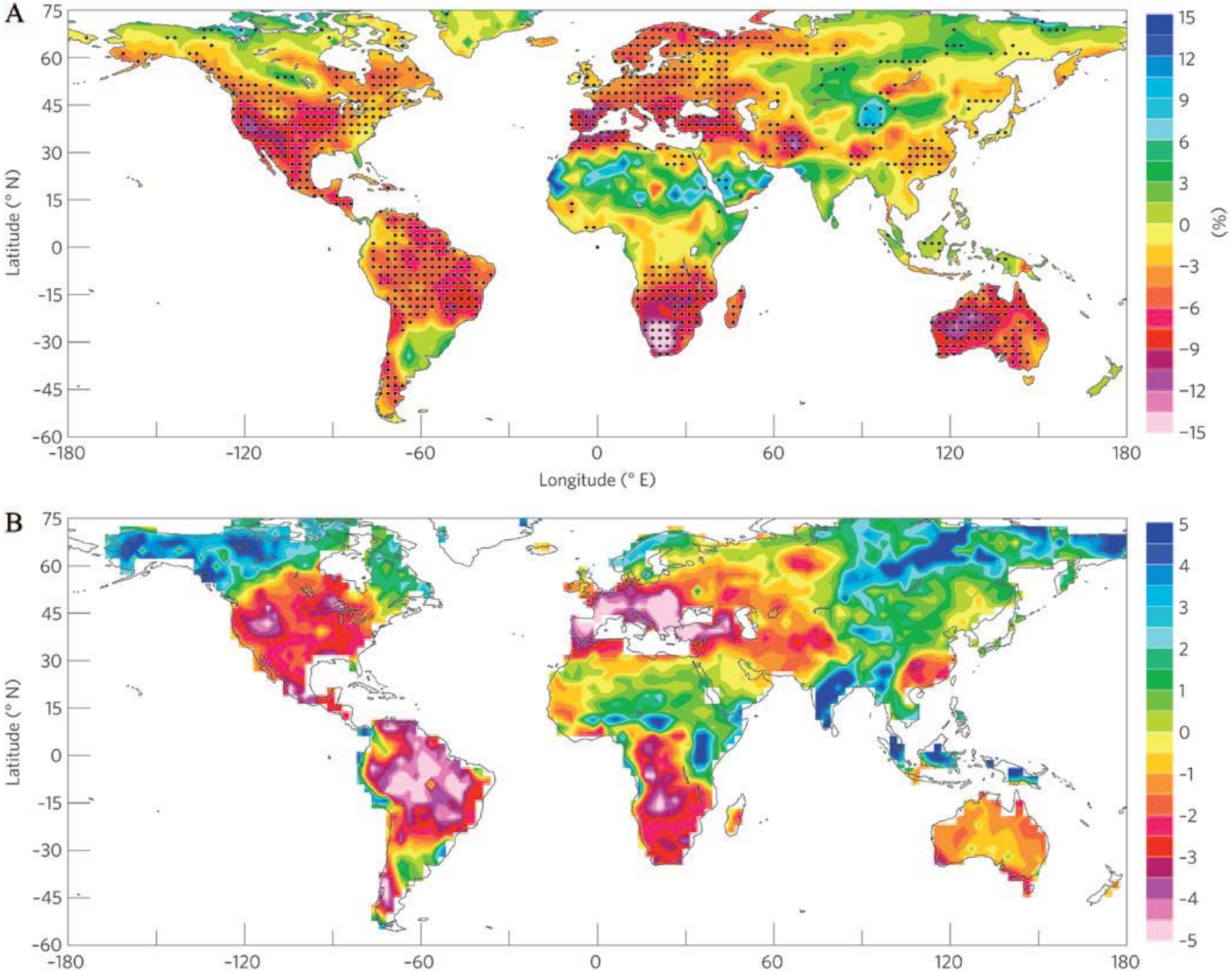


Fig. 3. **Future changes in soil moisture and the self-calibrated Palmer drought severity index (PDSI)** with potential evapotranspiration estimated using the Penman-Monteith equation (sc_PDSI_pm)**. (A) Percentage changes from 1980–1999 to 2080–2099 in the multi-model ensemble mean soil-moisture content in the top 10 cm layer (broadly similar for the whole soil layer) simulated by 11 Coupled Model Intercomparison Project Phase 5 (CMIP5) models under the representative concentration pathway 4.5 (RCP4.5) emissions scenario**. Stippling indicates at least 82% (9 out of 11) of the models agree on the sign of change. **(B) Mean sc_PDSI_pm averaged over 2090–2099 computed using the 14-model ensemble mean climate** (including surface air temperature, precipitation, wind speed, specific humidity, and net radiation) **from the CMIP5 simulations under the RCP4.5 scenario.** A sc_PDSI_pm value of −3.0 or below indicates severe to extreme droughts for the present climate, but its quantitative interpretation for future values in B may require modification. From **Dai. 2013**. Increasing drought under global warming in observations and models. ***Nature Climate Change, 3, 54. Reprinted with permission from Macmillan Publishers Ltd: Nature Climate Change, copyright 2013.***

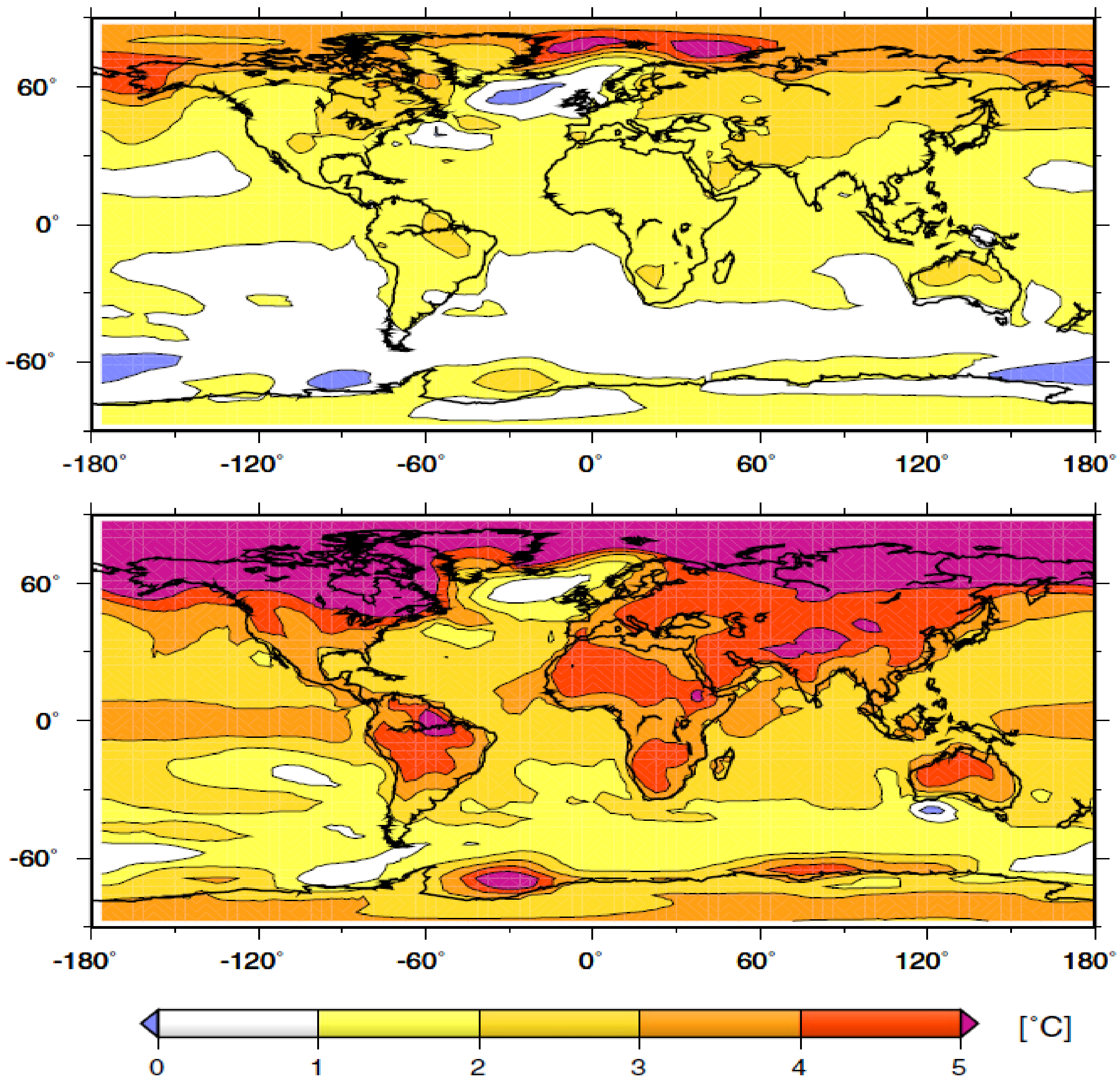


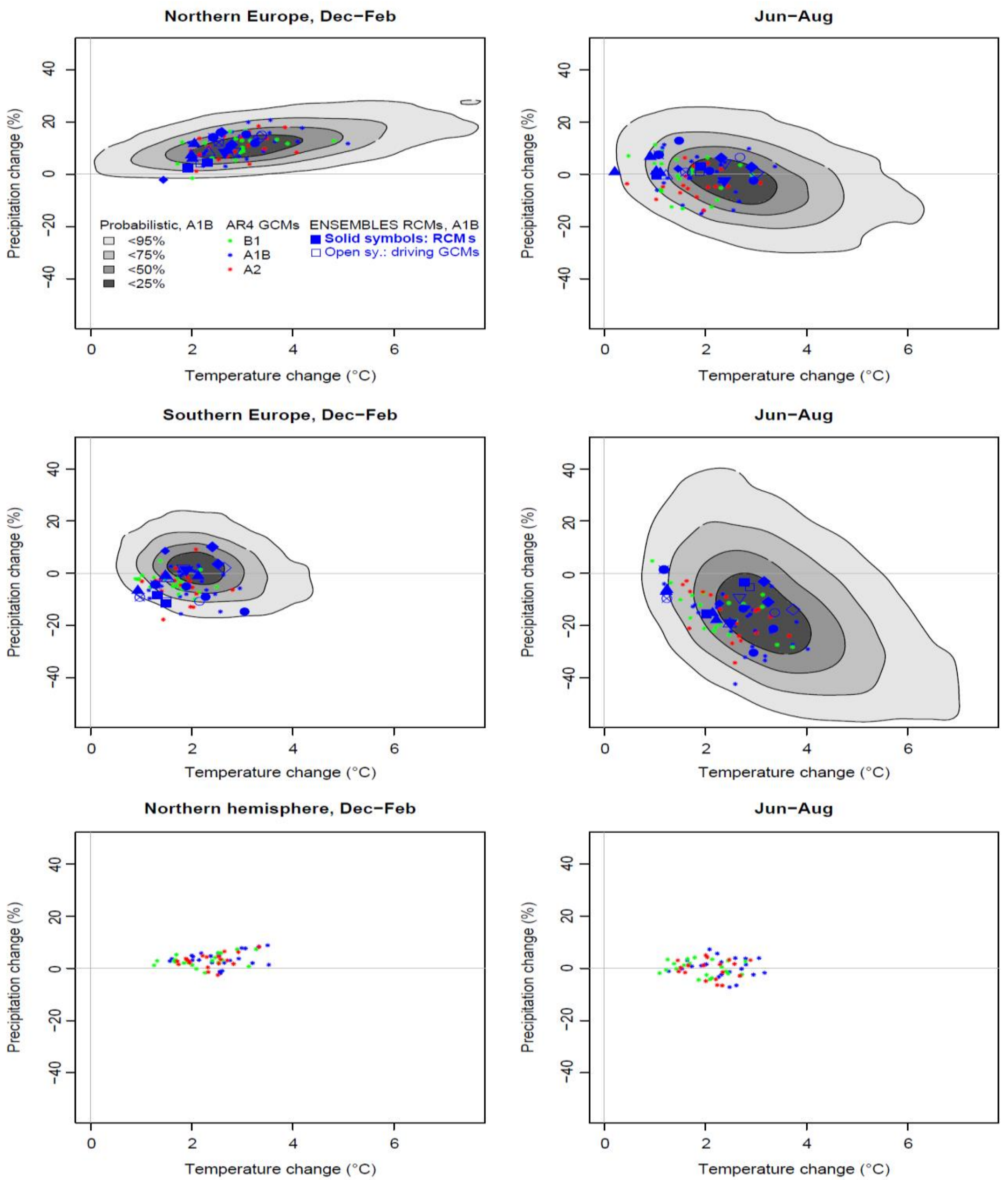
Fig. 11 Annual mean difference in surface air temperature (°C) between scenario (2080 to 2099) and present climate (1980 to 1999). *Top*: stabilization scenario E1; *bottom*: IPCC SRES scenario A1B

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

Top: stabilization scenario E1

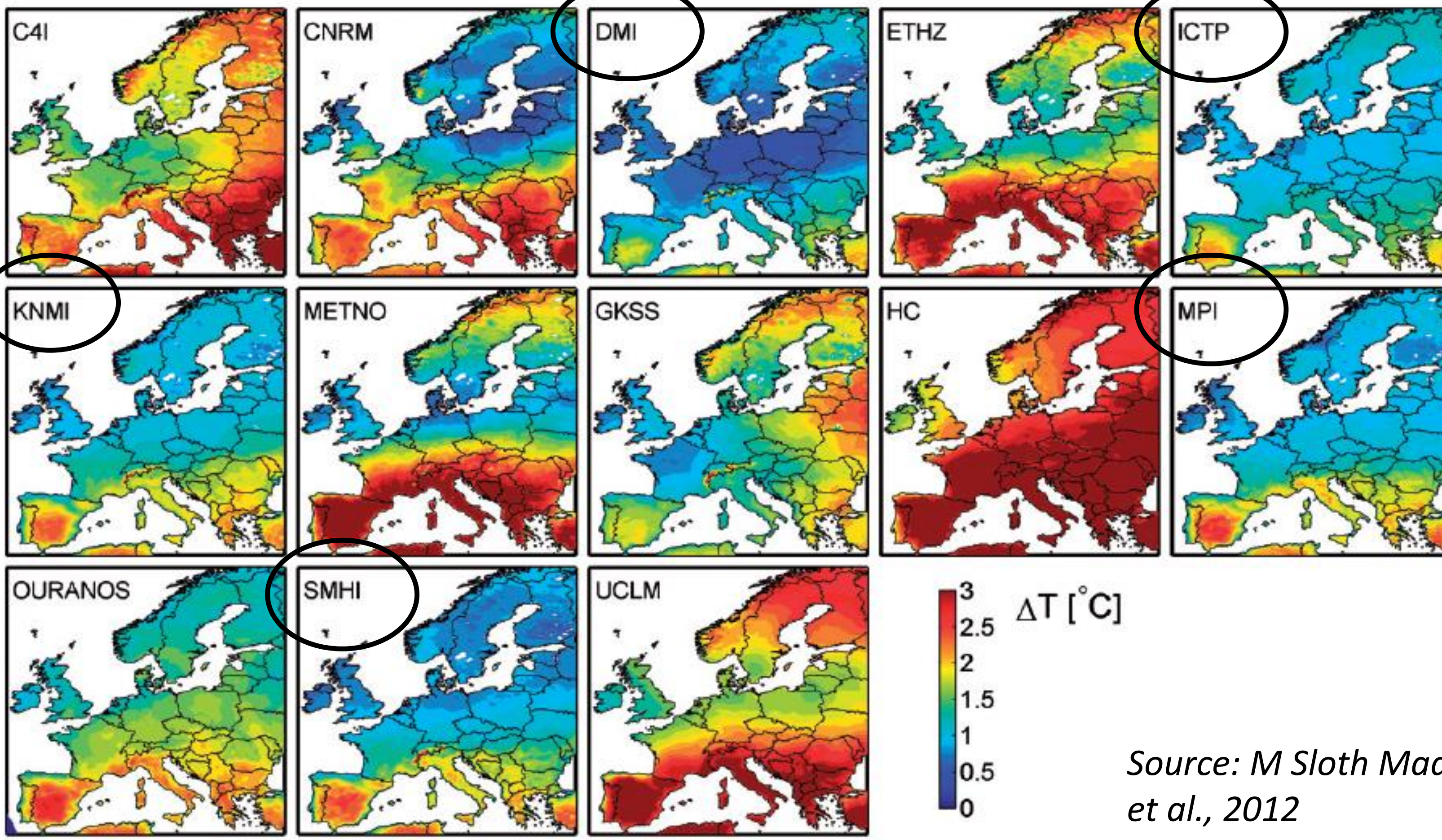
Bottom: SRES A1B

Source: Roeckner et al 2011



Changes in winter (December-February) and summer (June-August) temperature and precipitation in northern Europe (10W-40E, 48-75N; top panels), southern Europe (10W-40E, 30-48N; middle panels) and northern hemisphere land areas (bottom panels) for the period 2030-2049 relative to 1961-1990 from three datasets of climate model projections: the "Grand ensemble" probabilistic projection for the A1B scenario (Harris *et al.*, 2010), ENSEMBLES RCMs and their driving GCM simulations (Deque *et al.*, 2011) and

Regional climate model (RCM) projections and their uncertainties



Source: M Sloth Madsen et al., 2012

Figure 2. (Colour online). Projected changes in mean summer (June–August) temperature for the scenario period 2031–2050 as compared with the reference period 1975–1994. Note that similar patterns are seen for the five models using the ECHAM5 GCM.

Climate is changing...

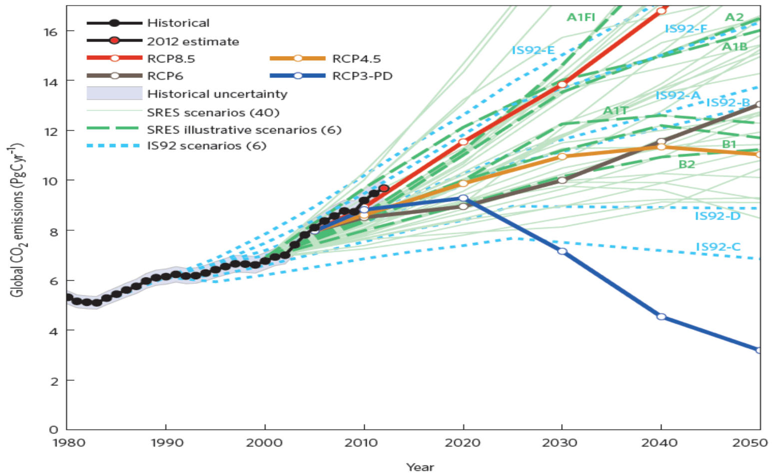
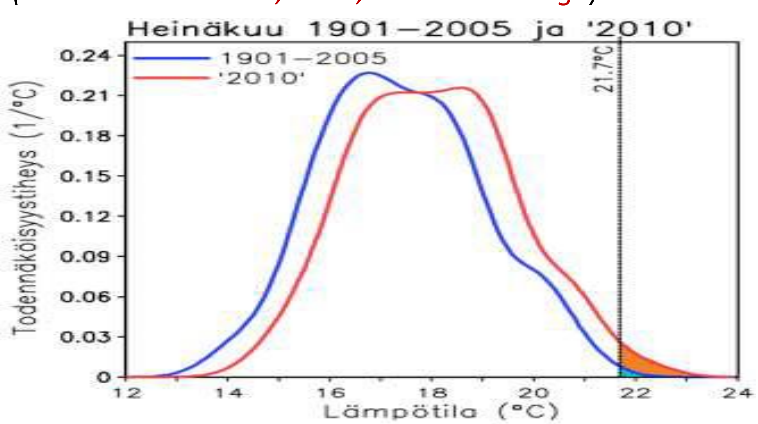
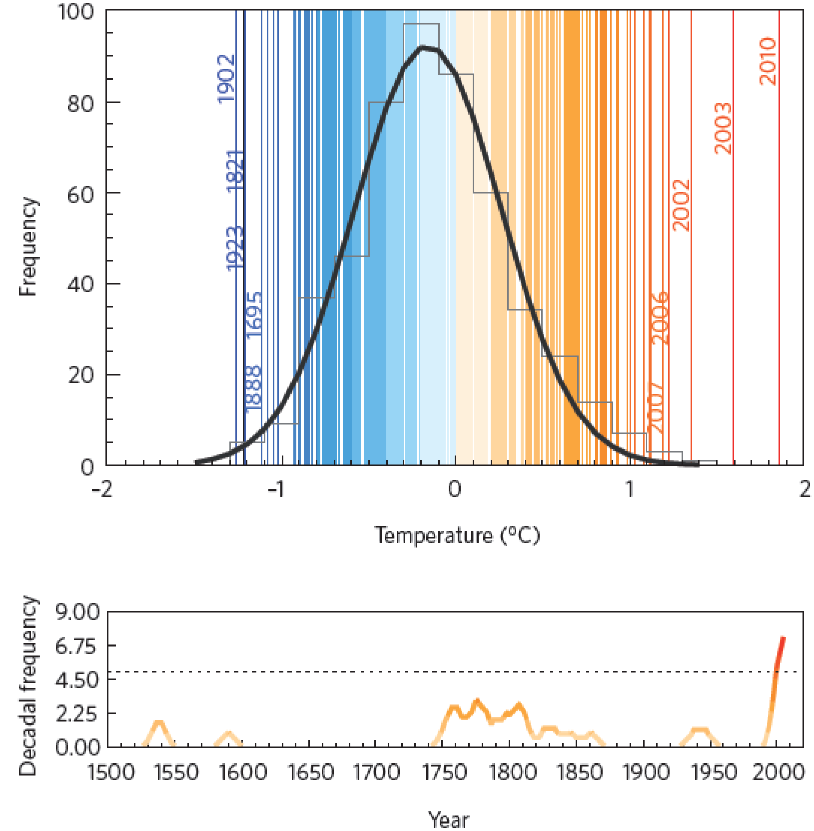


Figure 1 | Estimated CO_2 emissions over the past three decades compared with the IS92, SRES and the RCPs. The SA90 data are not shown, but the most relevant (SA90-A) is similar to IS92-A and IS92-F. The uncertainty in historical emissions is ±5% (one standard deviation). Scenario data is generally reported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

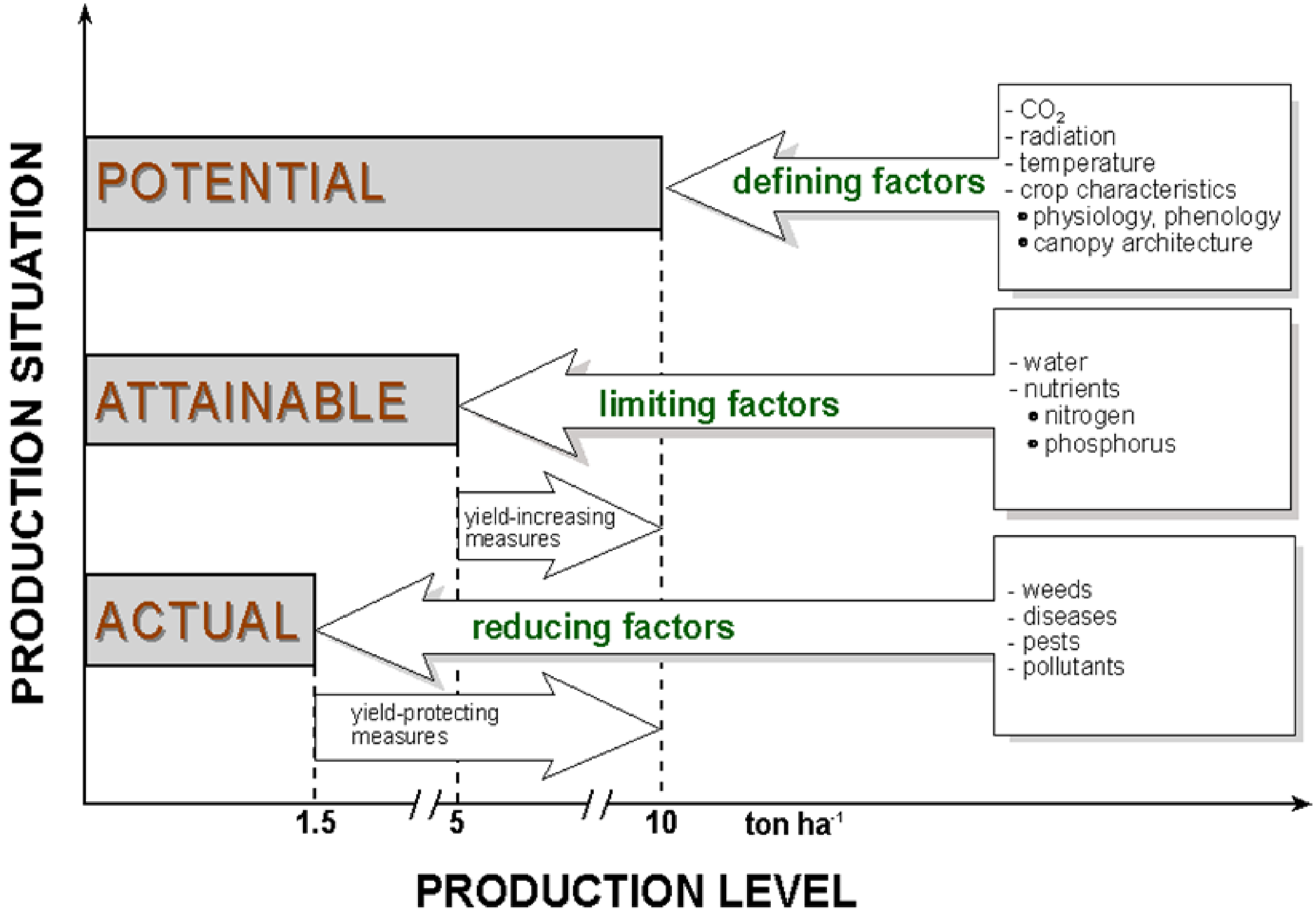


European summer temperatures for 1500–2010. The upper panel shows the statistical frequency distribution of European (35° N, 70° N; 25° W, 40° E) summer land-temperature anomalies (relative to the 1970–1999 period) for the 1500–2010 period (vertical lines). The five warmest and coldest summers are highlighted. 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

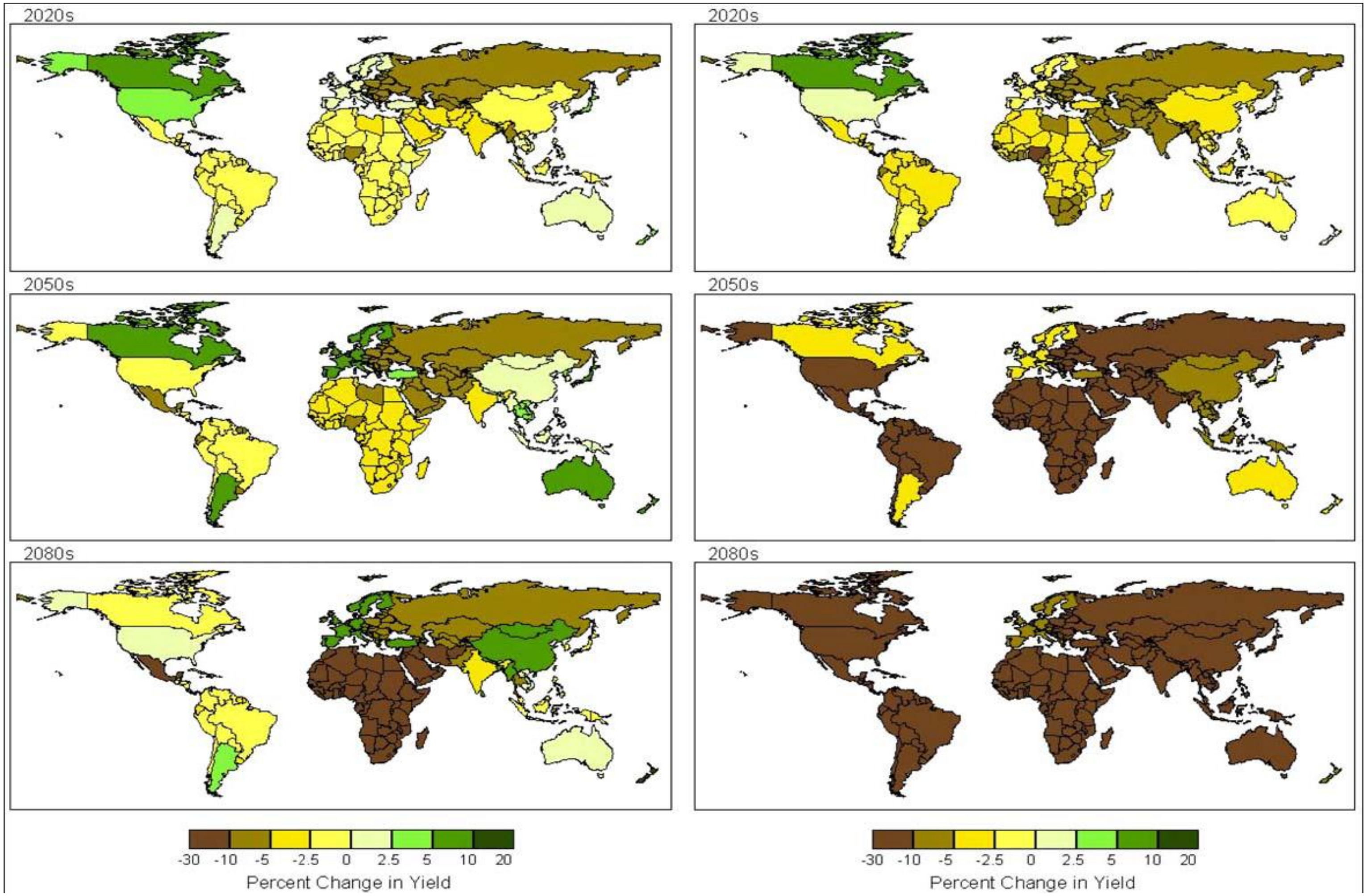
2. Brief review of methodology for climate impact projections in agriculture

Yield gap analysis/ Production Situations 1-4



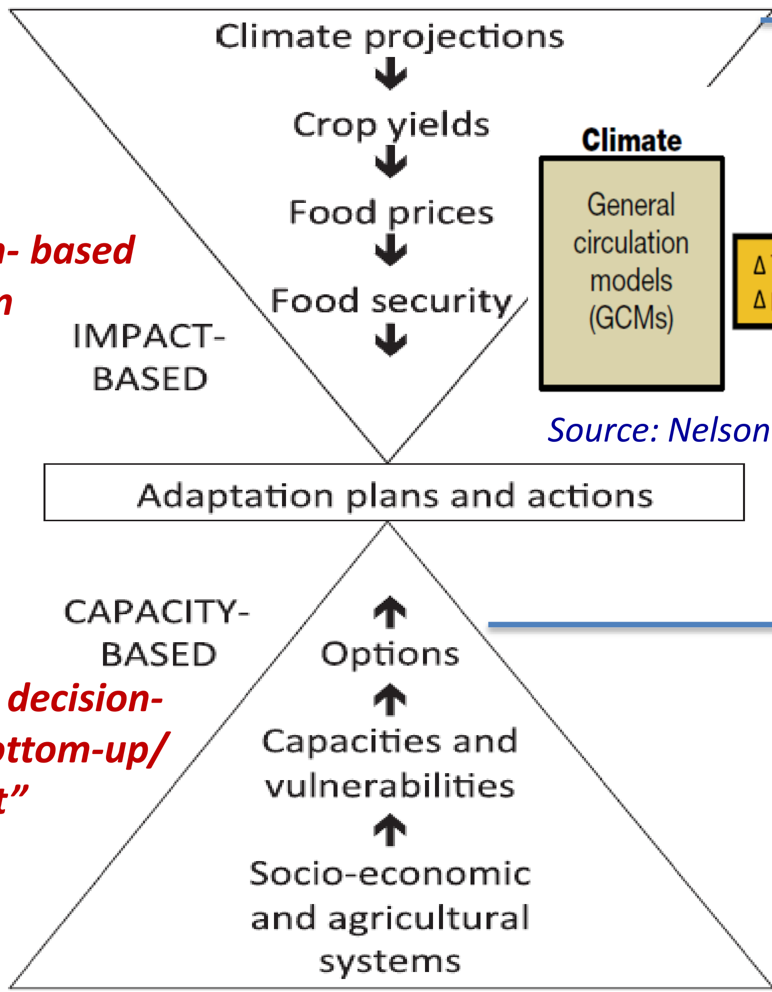
(source: Van Ittersum& Rabbinge 1997)

Conv. CC IA methodology/so-called "Winners /Loosers", IPCC TAR- changes in climatic means; *Potential changes in cereal yields, SRES A2*

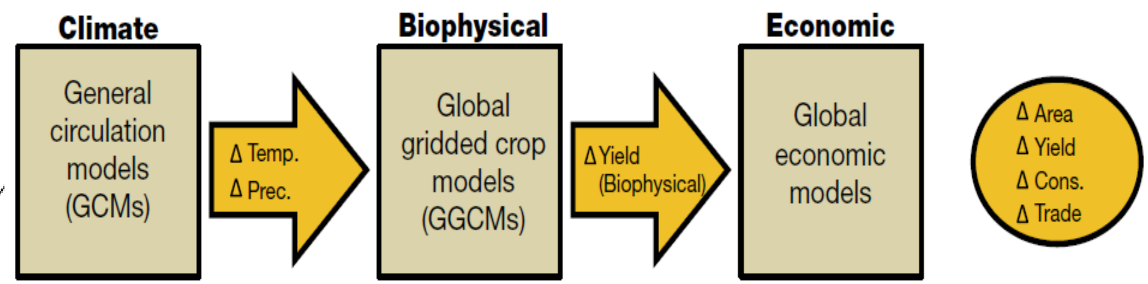


(Source: Parry et al., 2004)

Different approaches to adaptation analysis and planning



AgMIP and MACSUR (EU-wide)



Source: Nelson et al., 2014 PNAS

Also called: ***projection- based /top down***

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

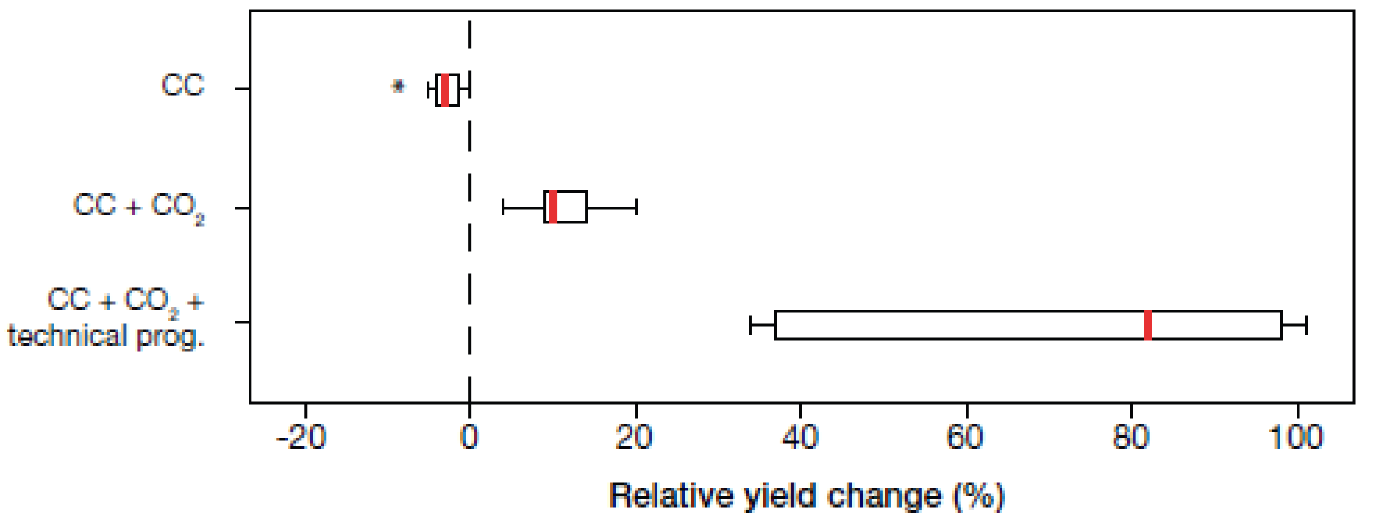
CCAFS and MACSUR (regional pilots)

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

Source: Vermeulen et al, 2013, PNAS

3. Projected CC impacts on food crop production in different world regions

Impacts of climate change (CC) on European wheat yields at mid-century (2050s) with/without taking CO_2 effects (CO_2) and progress in technology (technical progr.) into account. (Compiled from results of the following studies: Angulo *et al.*, 2013; Hermans *et al.*, 2010; Ewert *et al.*, 2005; Harrison and Butterfield, 1996



Global impacts of CC on crop productivity: 1994 and 2010

(source: Wheeler & von Braun, 2013)

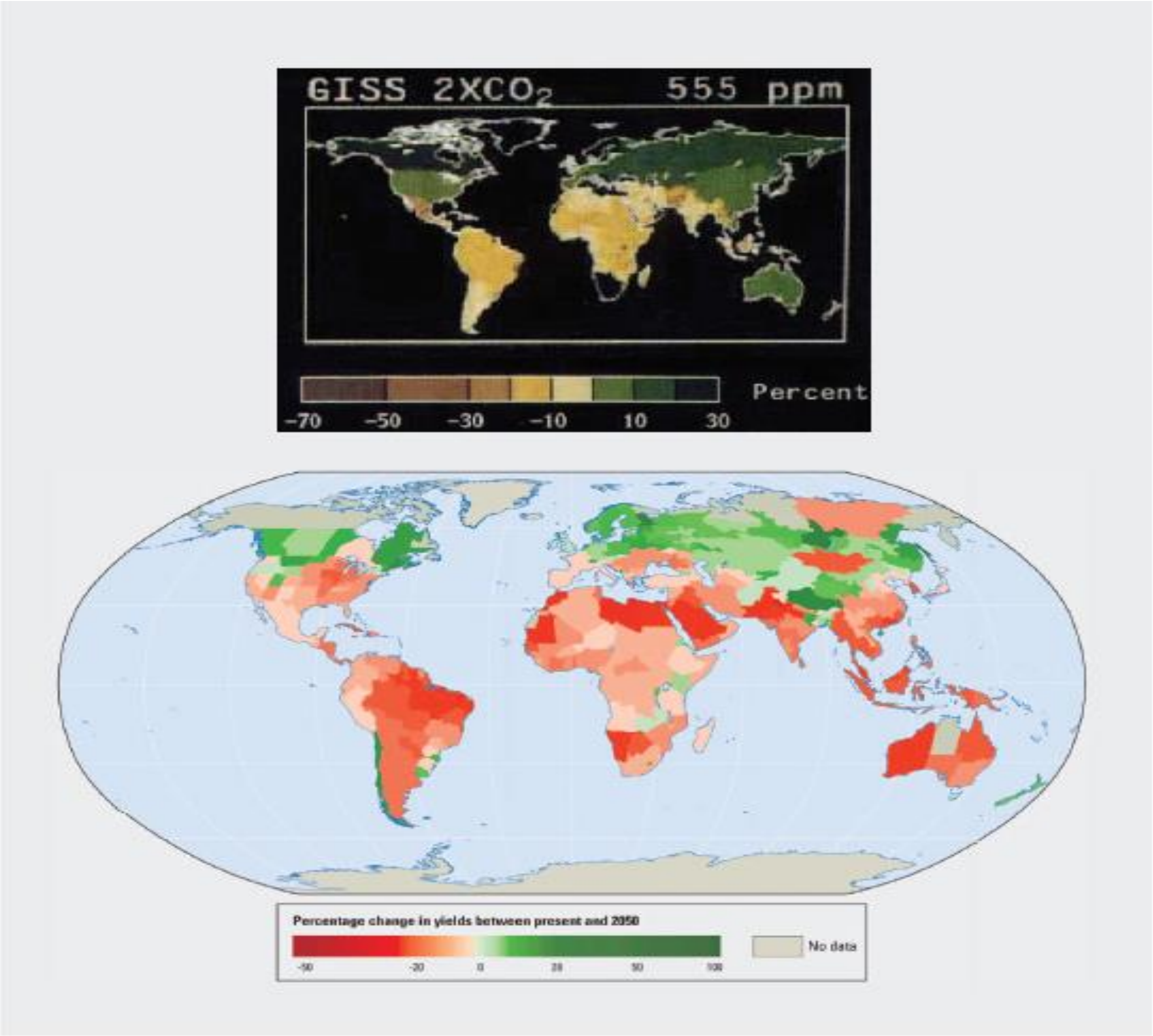


Fig. 2. Global impacts of climate change on crop productivity from simulations published in 1994 and 2010. (**Top**) The 1994 study (*22*) used output from the GISS GCM (in this example) with twice the baseline atmospheric CO_2 equivalent concentrations as input to crop models for wheat, maize, soybean, 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*)]

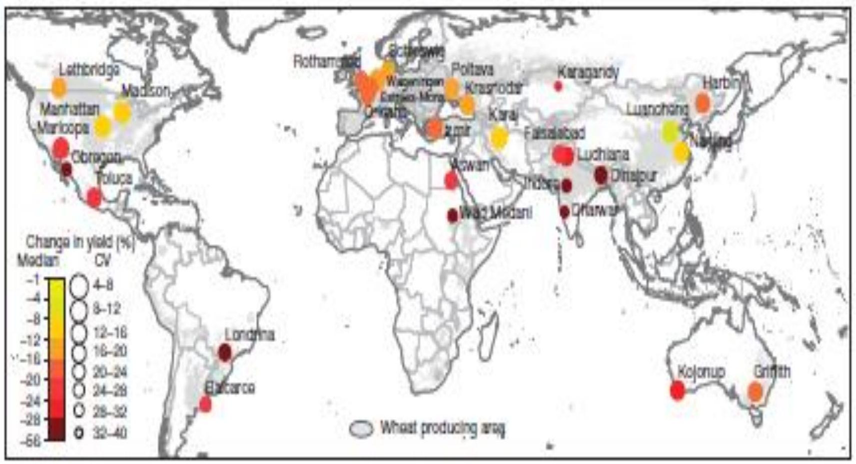
State-of-the-art: using model ensembles for wheat

nature climate change
LETTERS
PUBLISHED ONLINE: 22 DECEMBER 2014 | DOI: 10.1038/NCLIMATE2470

Rising temperatures reduce global wheat production

S. Asseng *et al.*†

c



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

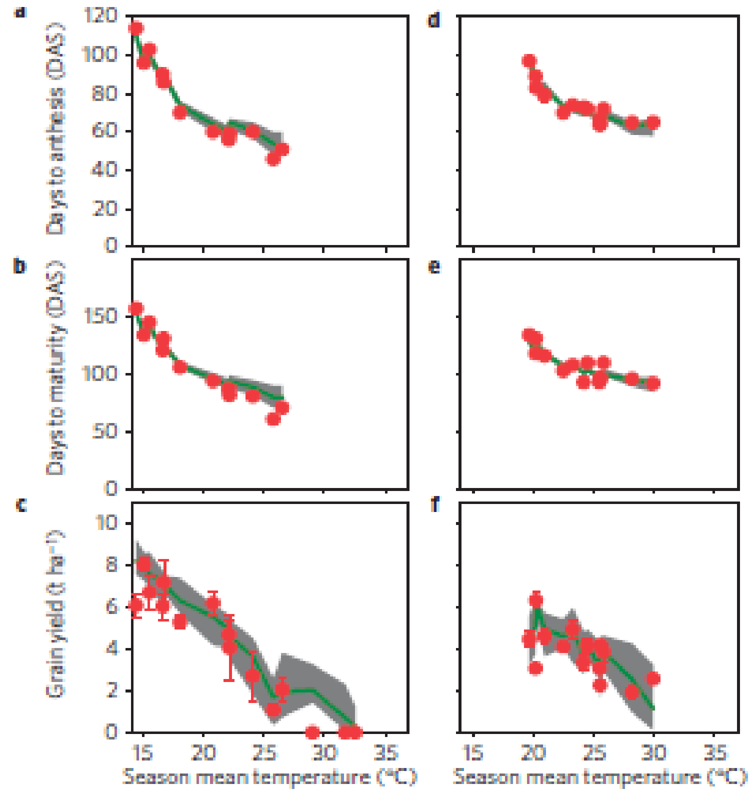


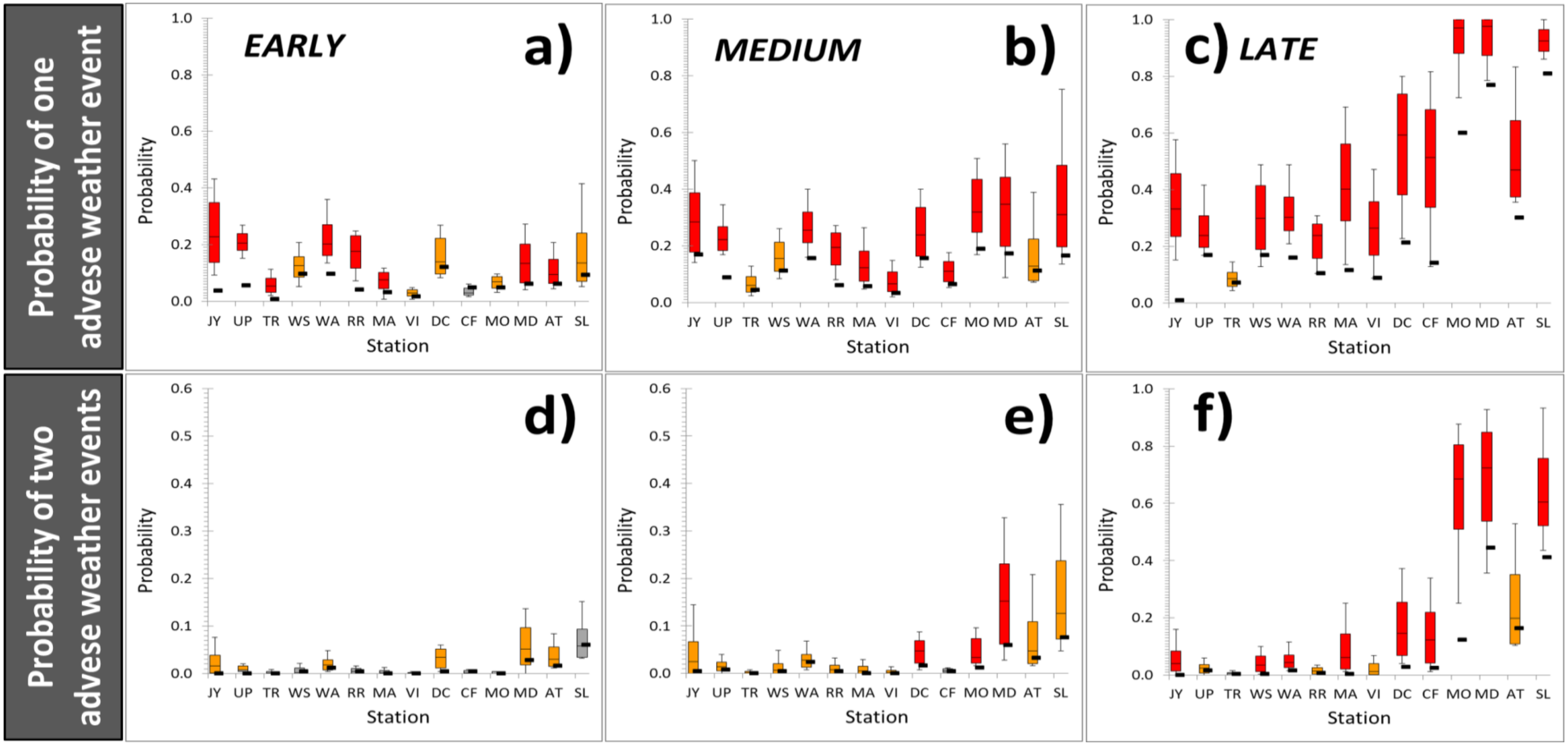
Figure 1 | Observations and multi-model simulations of wheat phenology and grain yields at different mean seasonal temperatures. a–f, Observed values ± 1 standard deviation (s.d.) are shown by red symbols. Multi-model ensemble medians (green lines) and intervals between the 25th and 75th percentiles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

nature climate change

ARTICLES
PUBLISHED ONLINE: 25 MAY 2014 | DOI: 10.1038/NCLIMATE2242

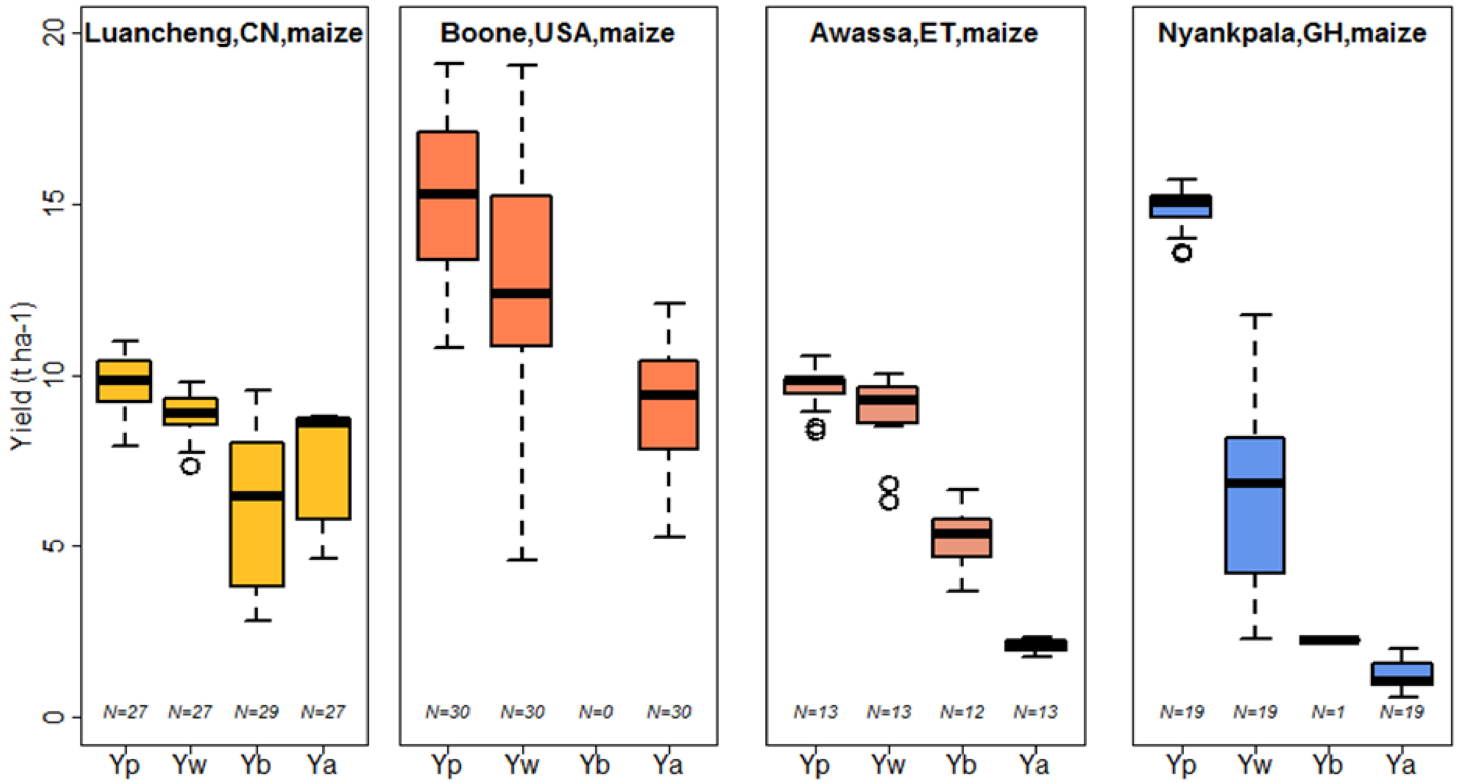
Adverse weather conditions for European wheat production will become more frequent with climate change

Miroslav Trnka[1,2]*, Reimund P. Rötter[3], Margarita Ruiz-Ramos[4], Kurt Christian Kersebaum[5], Jørgen E. Olesen[6], Zdeněk Žalud[1,2] and Mikhail A. Semenov[7]



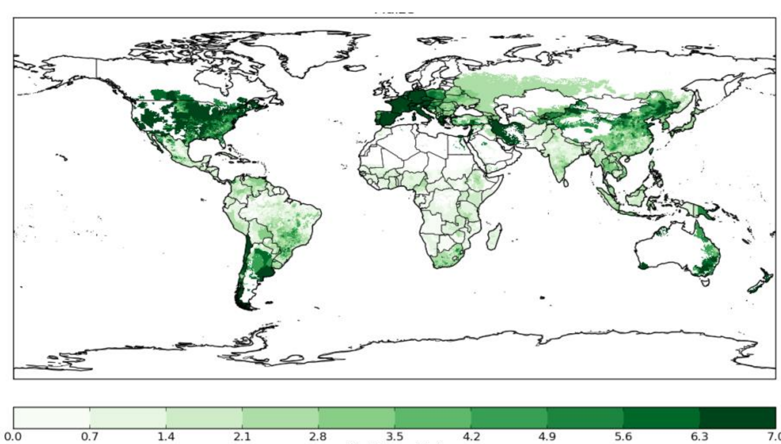
 (Trnka et al., 2014)

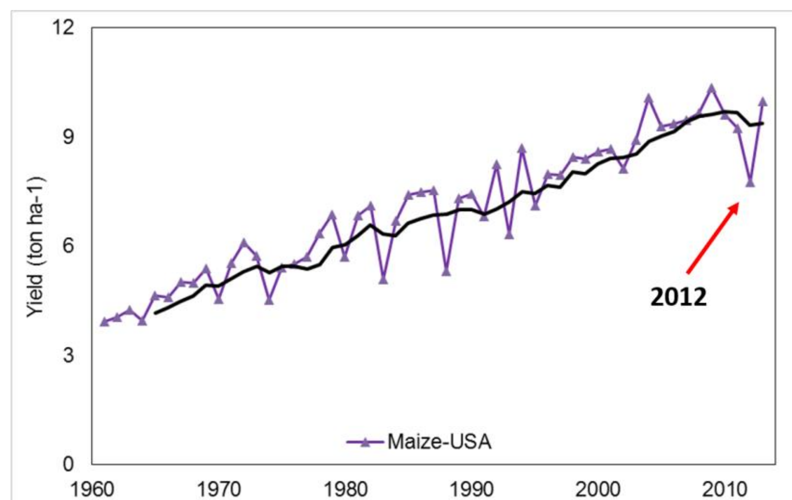
Yield gap and variability study (Macsur/AgMIP) – example maize



Yield gaps and variability for maize in the different production situations for four selected locations. Error bars represent ± 1 σ (standard deviation). Yields are reported at standard commercial moisture content with maize=15.5%. (source: Hoffmann et al., submitted).

Impact of extreme weather on maize Midwest/USA, 2012





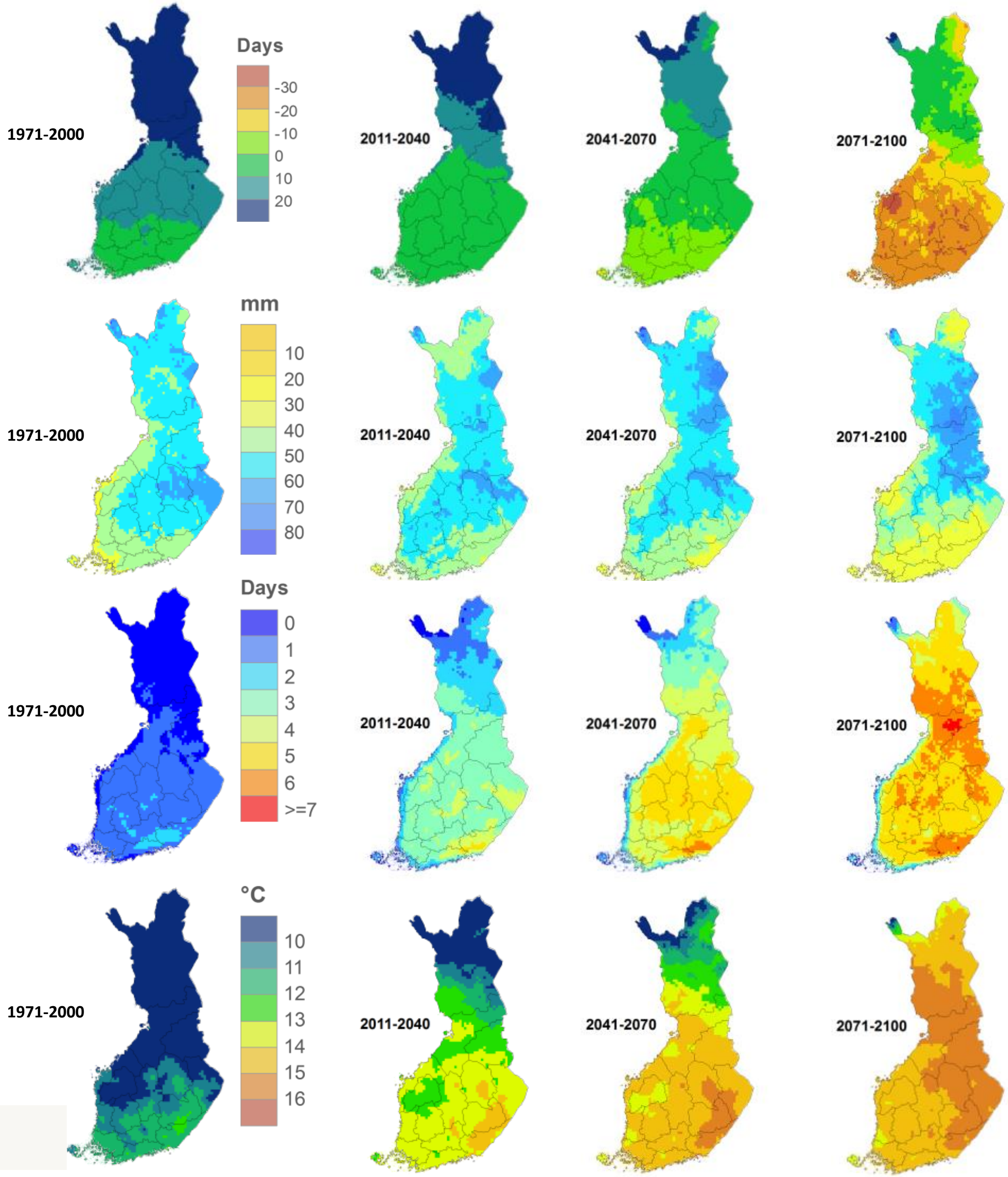
MIROC 3_2 Medres A1B

Sowing date deviation
(relative to May 1st)

Rain 3-7 weeks after sowing
(early drought stress)

No. of days with Tmax >=28°C around heading
(specific heat stress)

Temperature sum accumulation rate per day at grain filling
(yield potential reduction risk)



Source: Rötter et al., 2013b

An application for barley in Finland: Yield response to changes in climatic means & variability using WG M & Rfi

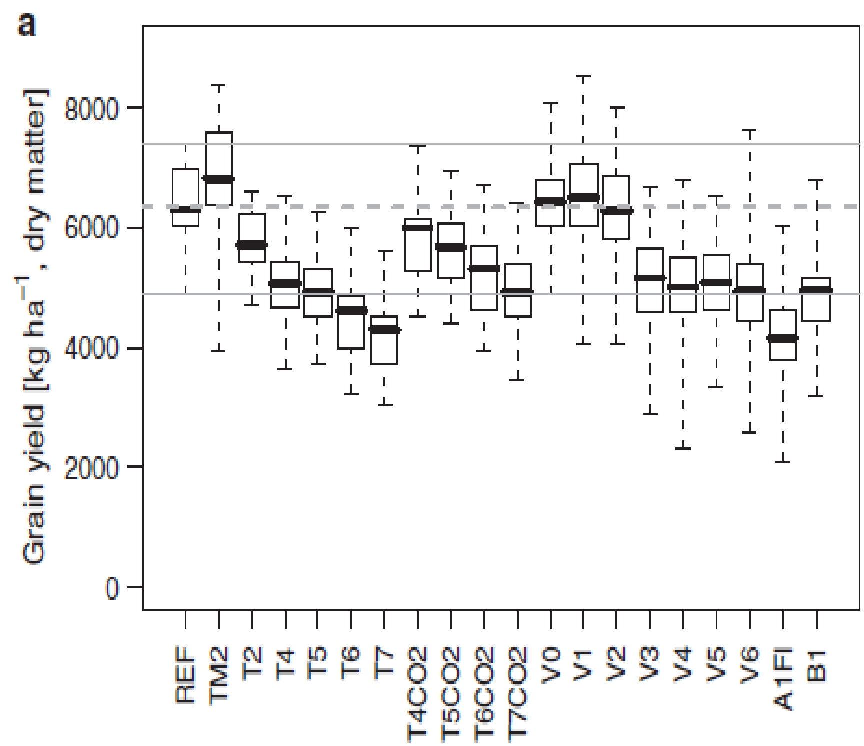
Contents lists available at ScienceDirect
European Journal of Agronomy
journal homepage: www.elsevier.com/locate/eja

What would happen to barley production in Finland if global warming exceeded 4 °C? A model-based assessment

R.P. Rötter[a,*], T. Palosuo[a], N.K. Pirttioja[b], M. Dubrovsky[c,d], T. Salo[e], S. Fronzek[b], R. Aikasalo[f], M. Trnka[d], A. Ristolainen[e], T.R. Carter[b]

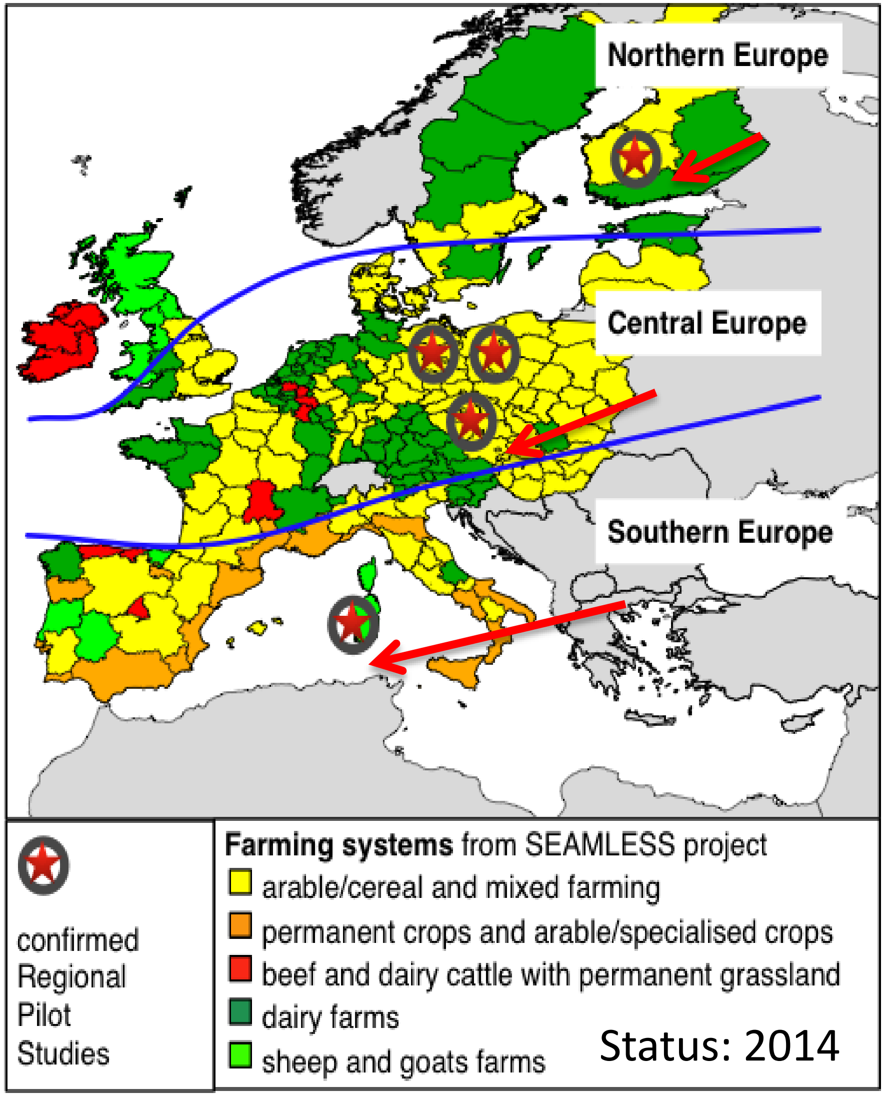
Set-up of model runs.

Scenario acronym	Scenario description	Simulation period
REF	Model runs based on observed weather	30 years, 1971–2000
TM2	Daily temperatures decreased by 2 degrees	30 years, based on adjustments to REF
T2	Daily temperatures increased by 2 degrees	-"-
T4	Daily temperatures increased by 4 degrees	-"-
T5	Daily temperatures increased by 5 degrees	-"-
T6	Daily temperatures increased by 6 degrees	-"-
T7	Daily temperatures increased by 7 degrees	-"-
T4CO2	Daily temperatures increased by 4 degrees and increased CO_2 level (560 ppmv) implemented by changing the crop parameters	-"-
T5CO2	Daily temperatures increased by 5 degrees and increased CO_2 level (560 ppmv)	-"-
T6CO2	Daily temperatures increased by 6 degrees and increased CO_2 level (560 ppmv)	-"-
T7CO2	Daily temperatures increased by 7 degrees and increased CO_2 level (560 ppmv)	-"-
V0	Weather generated based on the statistical characteristics of observed weather from the reference period	200 simulated years
V1	Changes in daily temperature variability 1.5 times standard deviation	-"-
V2	Probability of wet day following dry day (Pdw) is only 25% compared to present	-"-
V3	Daily temperatures increased by 4 degrees combined with decreased probability of wet days (Pdw: = 0.50*Pdw whole year)	-"-
V4	Daily temperatures increased by 4 degrees combined with V4, i.e. (Pdw: = 0.25*Pdw whole year)	-"-
V5	Daily temperatures increased by 4 degrees combined with decreased probability of wet days by 50% in summer (Pdw: = 0.50*Pdw summer) AND −20% of summer precipitation	-"-
V6	Daily temperatures increased by 4 degrees combined with decreased probability of wet days in summer (Pdw: = 0.25*Pdw summer) AND (−20% summer PREC)	-"-
A1FI	High emission variant of SRES (A1) scenario using HadCM3 model and CO_2 840 ppmv	2071–2100 time slice
B1	Low emission SRES (B1) scenario using HadCM3 model and CO_2 560 ppmv	-"-



Jokioinen, clay soil

MACSUR Integrated Regional Assessments



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

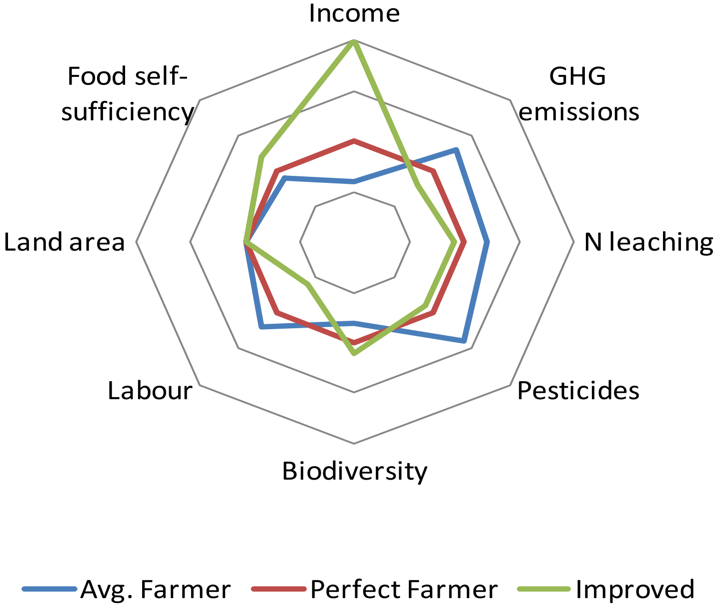


Illustration multiple goal achievements under alternative management/ag-technologies

www.macsur.eu

4. OUTLOOK ON FUTURE RESEARCH

Related to work of UGOE/DNPW:

- Improving models to quantify effects of alternative adaptation and mitigation options (utilizing unique experim.data: (i) heat & drought wheat cvs, (ii) LT field data M effects on soil C))
- Model-aided design of climate resilient cultivars (barley)
- Explore effects of shifts in climate variability (including extremes) and anticipated ag-technology packages

A. (SPACES LLL S Africa) Seasonal climate forcasting to inform adaptation – develop Early Warning System with RFS

B. (MACSUR Europe): Integrated regional assessement of CC impacts informed by SH platforms

C. (IMPAC Asia & Europe): utilizing field experimental data and modelling to quantify e.g. effects of management on soil carbon)

Impact assessments by process-based crop models

REVIEW *(summer 2011)*: CSMs need an overhaul...

nature climate change

JULY 2011 VOL 1 NO 4
www.nature.com/natureclimatechange

Tell-tale signs of climate tipping

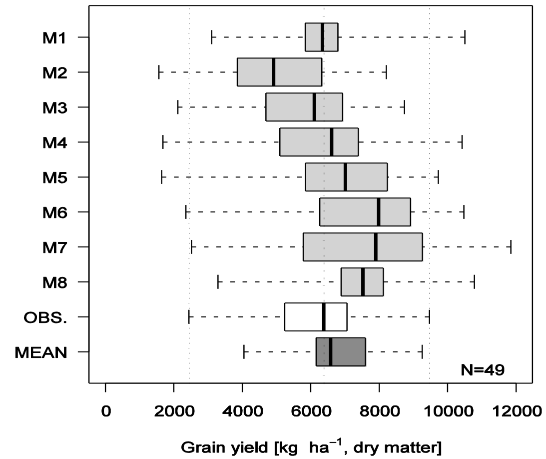
ATER'S CARBON FOOTPRINT
A thirsty business

CROP-CLIMATE MODELS
Food for thought

ARCTIC CARBON BALANCE
Push from pathogens

in this issue

Towards competent crop models
To meet the world's growing demand for food, it may be necessary to boost agricultural productivity by as much as 70% by 2050. The extent to which large yield gains can be achieved in a changing climate remain unknown, but estimates depend heavily on crop models. Reimund Rötter and colleagues argue that current crop modelling tools are out of date and not fit for purpose. They argue strongly that researchers need to switch to more rigorous multi-model approaches to better quantify inherent uncertainties. Only then will model estimates of crop yields under climate change provide a firm basis for delivering robust and usable information, for everyone from farmers to policymakers.
[Commentary p175]



Source: Palosuo et al. 2011, EJA

Based on results of three companion studies within COST 734, we suggested

1) **=> test use multi-model ensemble approach mean/median as predictor – *(-> AgMIP)***
2) ***need for improved scaling methods (MACSUR jointly with AgMIP)***
3) ***better reporting uncertainties in impact projections (MACSUR jointly with AgMIP)***
4) ***Reduce model deficiencies to better capture climatic variability and extremes***

How well do CropMs currently simulate effects of CO_2 extremes, adaptation & mitigation options?

- Considerable improvements for extreme heat
- Gradual improved for CO2/better (tapped some FACE)
- Interactions heat x drought x CO2 still rather poor data
- Little attention to effects of heavy rainfall/flooding
- Still too few crops covered by data for these interrelations (Macsur and AgMIP to improve that ....)
- Simulation of adaptations still fairly simplistic- e.g. mono-crops, Pl-date, irrig., limited cultivars; **=> model-aided ideotyping /advanced breeding; utilize SCF and response diversity; integrated assessment approaches in Macsur**
- **Simulation of (adaptive) mitigation options** neglected -> **requires urgent attention** (e.g. minimum tillage effect on carbon sequestration and improved water retention…)

THANK YOU!

Further reading

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