Modelling European Agriculture with Climate Change for Food Security

Challenges for CropM in integrated (regional) assessment of climate change risks to food production

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With contributions of Frank Ewert and CropM WP leaders

FACCE MACSUR: TradeM International Workshop

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CONTENTS

Background and Objectives

- □ More frequent extreme events, climatic variability and uncertainties in projections of future climate represent considerable risks for food production
- □ Adaptation could substantially reduce risks – analysis to be (i) local/regional and (ii) options are best evaluated in integrated assessment models (IAM)
- □ Crop models are fairly well able to simulate crop responses to climate factors – with some exceptions….
- □ Key limitations for crop models in IAM are low data availability & integration; insensitivity to some extremes
- □ Cross-scale nature of IAM might require to use novel modelling approaches

Climate is changing...

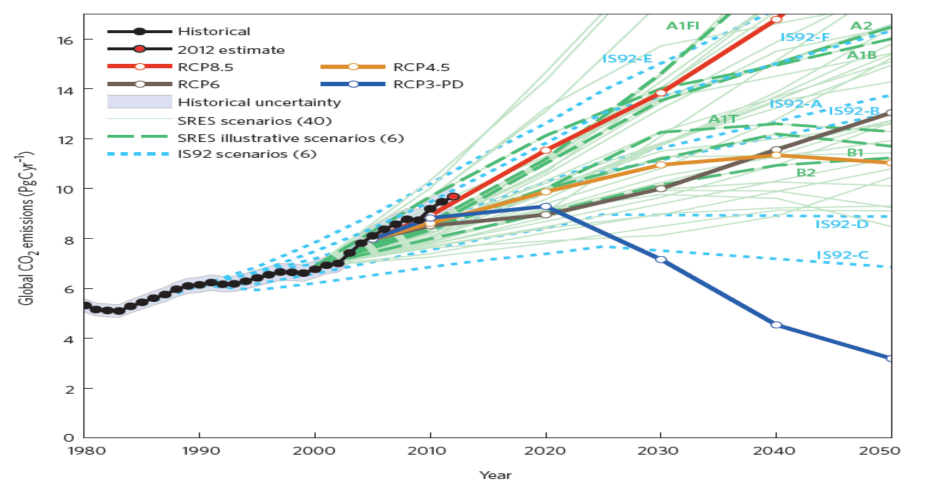


Figure 1 | Estimated CO_2 emissions over the past three decades compared with the IS92, SRES and the RCPs. The SA90 data are not shown, but the most relevant (SA90-A) is similar to IS92-A and IS92-F. The uncertainty in historical emissions is ±5% (one standard deviation). Scenario data is generally reported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

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

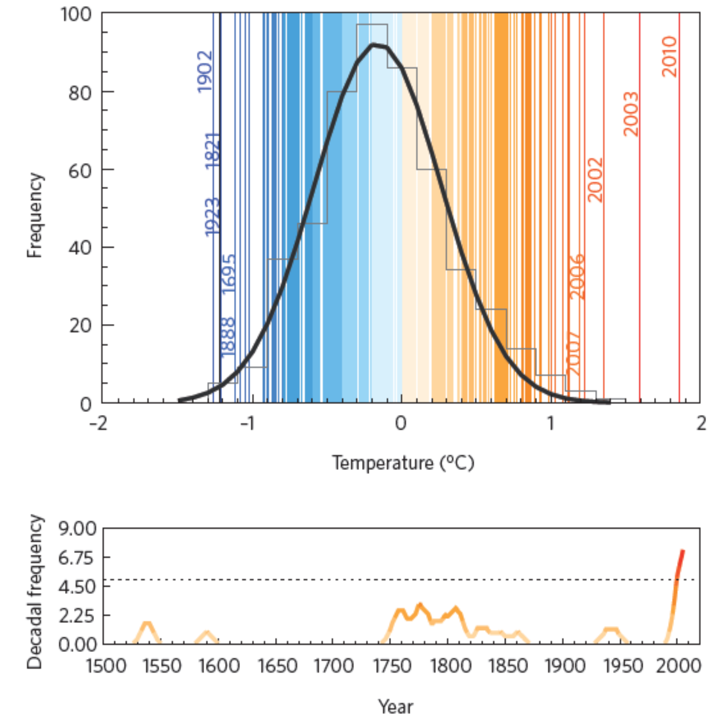
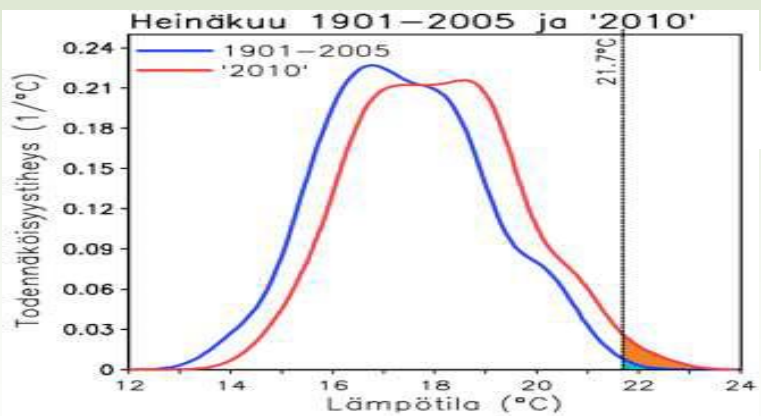


Figure 4 | European summer temperatures for 1500–2010. The upper panel shows the statistical frequency distribution of European (35° N, 70° N; 25° W, 40° E) summer land-temperature anomalies (relative to the 1970–1999 period) for the 1500–2010 period (vertical lines). The five warmest and coldest summers 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.

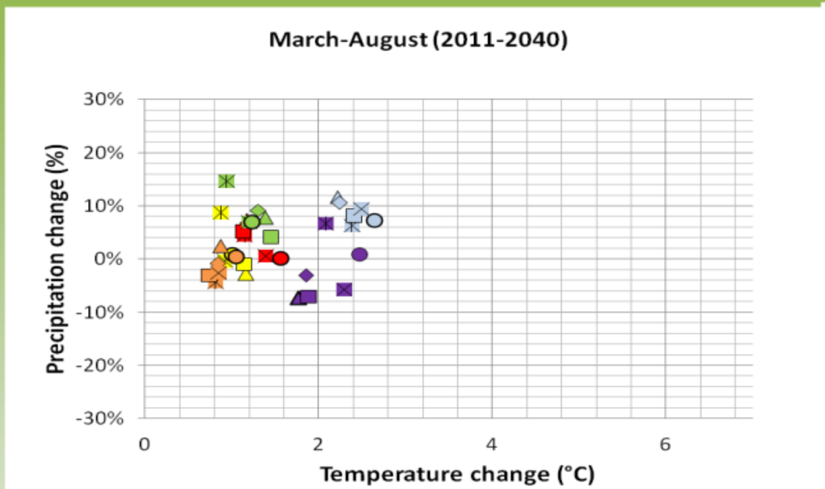


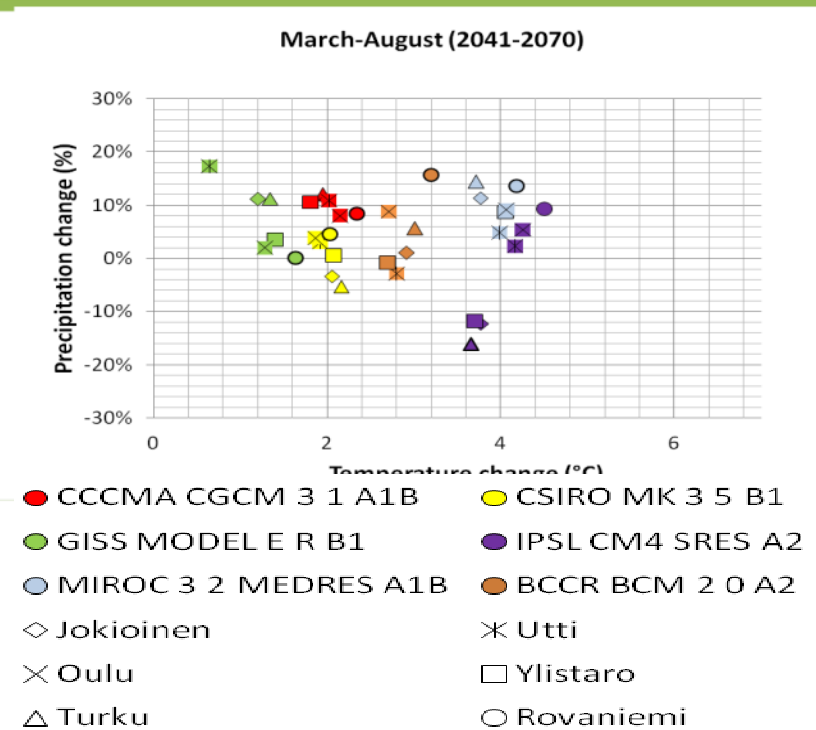
Shift in PDF of July temperatures
S Finland (*Source:* Räisänen 2010)

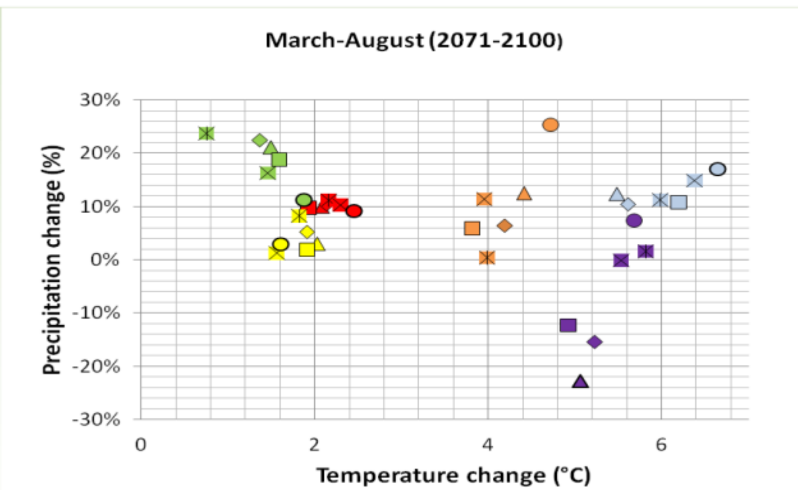
Source: Coumou & Rahmsdorf, 2012

Projected changes in Tmean & Precipitation during March-August

(3 time slices, 6 climate scenarios and 6 stations in Finland)



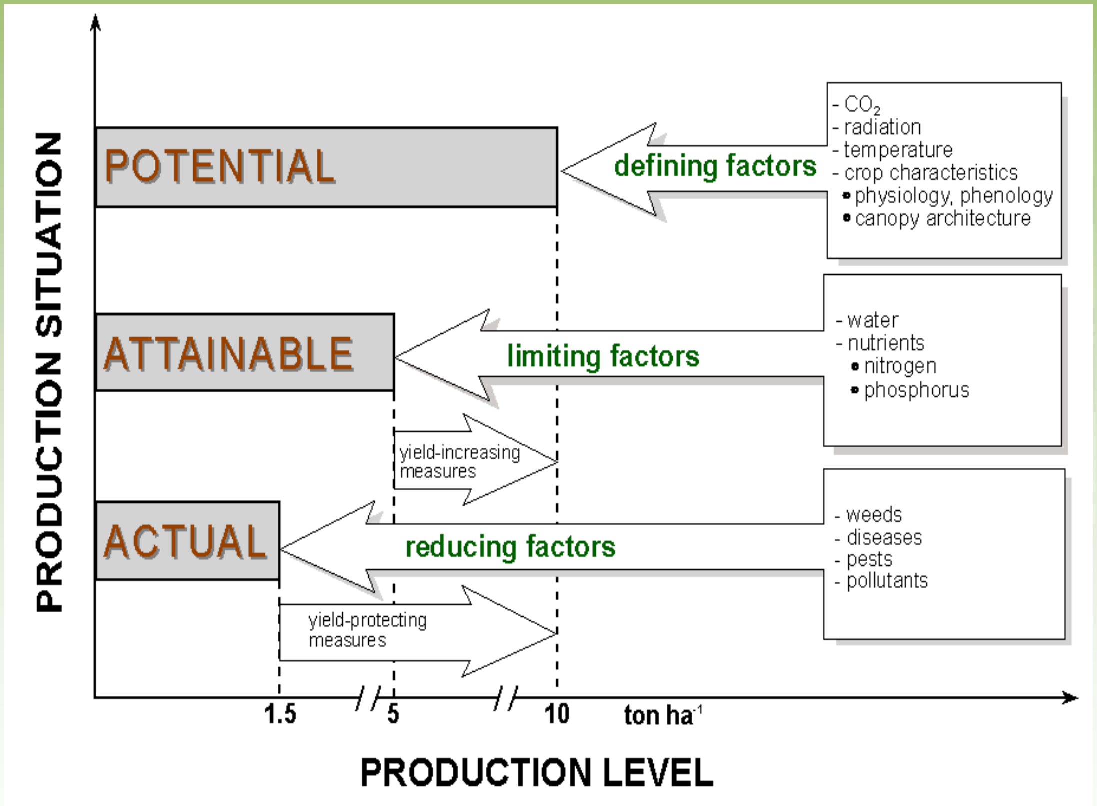




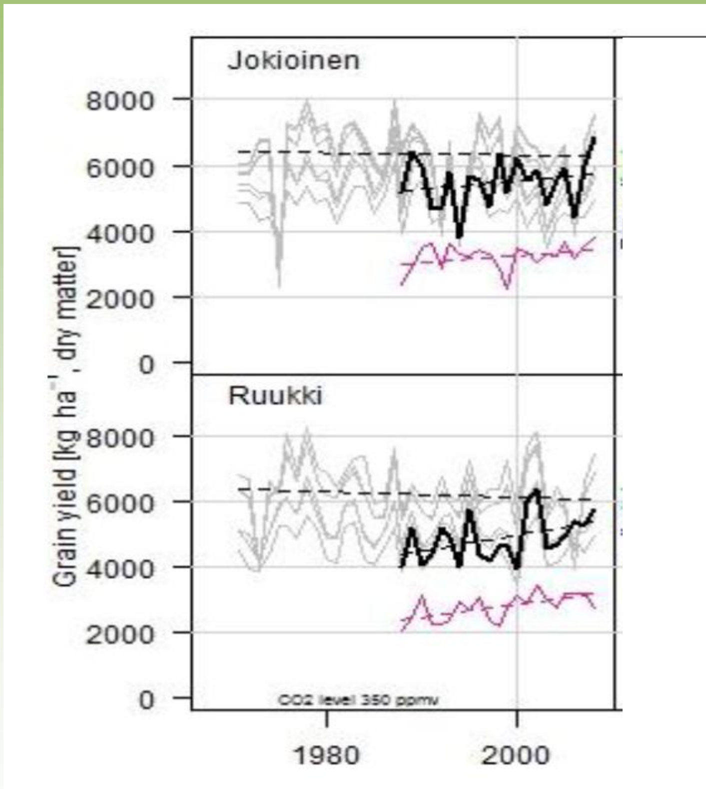
Changes in T and PRECIP for time periods 2011-2040, 2041-2070 and 2071-2100 compared with 1971–2000 for six representative locations relevant for agricultural production in Finland (see Fig.). Six GCMs (CCCMA CGCM 3 1, CSIRO MK 3 5, GISS MODEL E R, IPSL CM4, MIROC 3 2 MEDRES and BCCR BCM 2 0) are presented.

(Source: Rötter et al. 2013)

Model/production situations & levels
(e.g. for YG analysis with examples from HAM study/Finland)

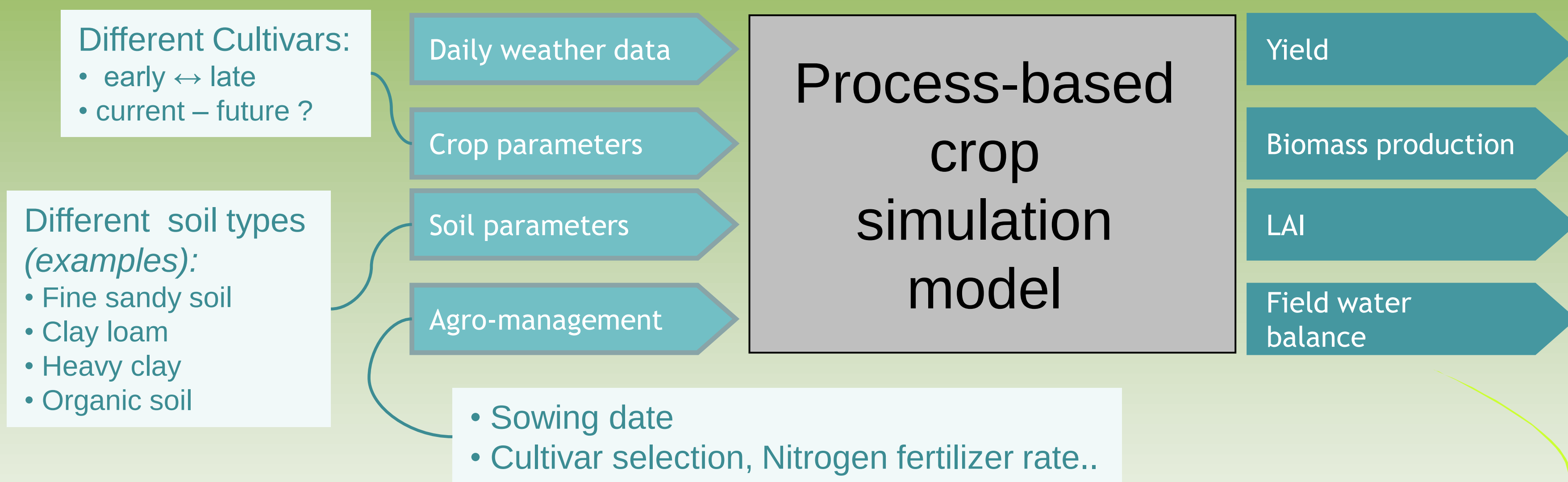


(Source: Van Ittersum & Rabbinge, 1997)



Palosuo et al. 2013. modelling historical adaptation/cultivar choice Proceed Impacts World 2013

Prevailing Crop modelling approach (GxExM) and Objectives of this Review



Objectives of this review

1. **Identify challenges and how CropM has addressed them to date**
2. **Examine IAM demands and implications for CropM /MACSUR2**

CropM Work Packages (www.macsur.eu)

NO.	WORK PACKAGE TITLE	COORDINATION
WP1	Model intercomparison (develop protocols; extend sites, crops)	Christian Kersebaum (GER) Marco Bindi (IT)
WP2	Model improvements through generating and compiling data	Jorgen Olesen (DK) Mirek Trnka (CZ)
WP3	Scaling methods and model linking	Frank Ewert (GER), Sander Janssen (NL) Martin van Ittersum (NL)
WP4	Scenario development and impact uncertainty analysis	Reimund Rötter (FI), Daniel Wallach (FR), M Semenov (UK), Mike Rivington (UK)
WP5	Capacity building	John R Porter (DK)
WP6	Case studies on impact assessment (cross cutting theme package and linkage to decision-making)	Jan Verhagen (NL) Derek Stewart (UK) Pier Paolo Roggero (IT)

2. MAIN ACCOMPLISHMENTS & ACTIVITIES 2012-14 *(A SELECTION):*

Specific outputs	Responsible WP/persons	Partners involved	Timeline
Data set evaluation and classification for model testing (software/paper)	**WP1:** C. Kersebaum C. Nendel	Olesen, Bindi, Boote, Kollas, Rötter, Gaiser, Ruget, Frühauf, Trnka..	Paper submitted on 5.2.2014 to EMS Software ready
Analysis of first runs on crop rotations	**WP1:** C. Kersebaum C. Kollas	18 modelling teams	1. March first run, June second finalised; Paper in prep.
Overview of experimental data for modelling	**WP2:** J.E. Olesen M. Trnka		Finished; report
Analysis of extremes for wheat in Europe	**WP2 and WP4**: M. Trnka	Ruiz-Ramos, Rötter, Kersebaum, Olesen, Semenov	Published in Nature CC
Effect of scaling methods for simulating crop yield	**WP3** H Hoffmann F Ewert	Bussel van, Constantin, Dechow, Eckersten, Ewert, Gaiser, Grosz, Haas, Hoffmann, Kuhnert, Kiese et al.	Submitted book chapter and paper; autumn 2014

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

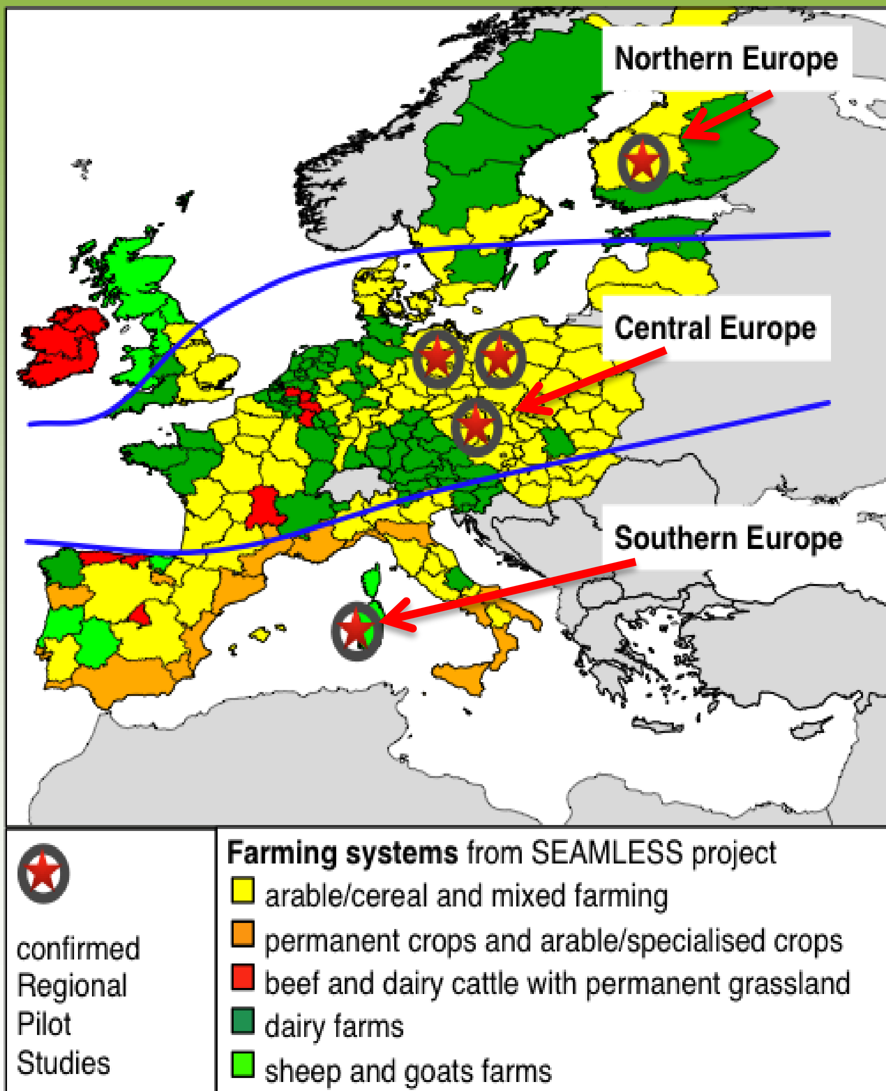
Miroslav Trnka[1,2*], Reimund P. Rötter[3], Margarita Ruiz-Ramos[4], Kurt Christian Kersebaum[5], Jørgen E. Olesen[6], Zdeněk Žalud[1,2] and Mikhail A. Semenov[7]

Part1 of EXTREMES study of WP4 of CropM /MACSUR
for more info, see: **www.macsur.eu**

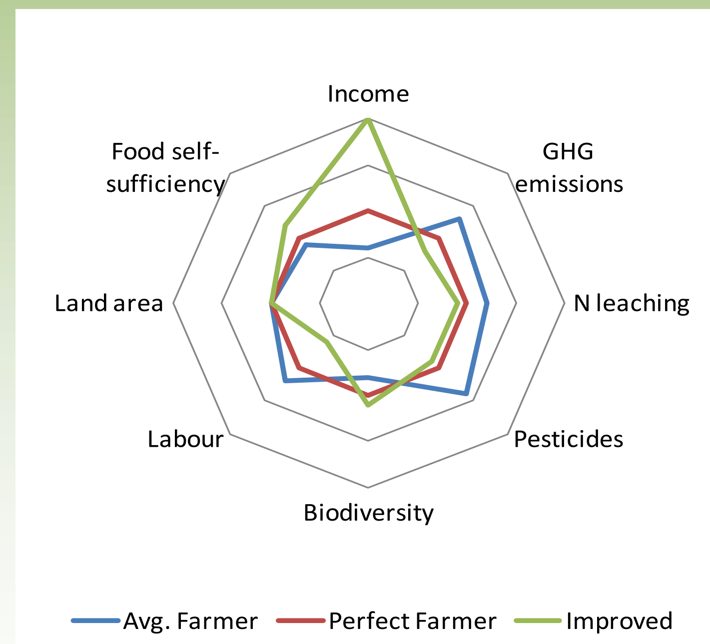
2. MAIN ACCOMPLISHMENTS & ACTIVITIES 2012-14 *(A SELECTION):*

Specific outputs	Responsible WP/persons	Partners involved	Timeline
Delivery of local-scale CMP5-based scenarios..	**WP4:** M Semenov	P Stratonovicv, PL Calanca	Paper published; still some RCPs..
Designing high-yielding wheat ideotypes	**WP4:** M Semenov	P Stratonovic	Paper published
IRS1: Basic impact response surface method; applied to wheat (3 sites/EU Transect)	**WP4:** N Pirttioja, S Fronzek, T Carter, R Rötter	26 modelling groups: WP4 members and AgMIP partners (Asseng, Wang, Ruane)	Simulations done; paper in prep. – Nov. 2014
Well-attended PhD courses (5) on art of crop modelling	**WP5:** JR Porter & collbaorators/local hosts	HEL/FI (DW); WUR/NL (MvI); AH/DK (JEO); ZALF(CN); FI/IT (MB)	08/12; 03/13; 10/13; 05/14; 11/14
Identification and support (joint learning) on three integrated regional pilots -	**WP6:** D Stewart, J Verhagen, PP Roggero & TradeM task Leaders	AT-Mostviertel (Schönhart) FI-North Savo (Lehtonen), IT Sassari (Dono)	Presentation prelim. results at Sassari/ April 2014

Contributions to MACSUR Regional Pilot Studies



Multitude of appoaches – 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 – e.g. NORFASYS *www.mtt.fi/modags/*)



Qualitative illustration goal achievement under alternative management

3. Demands on CropM for IAM

TWO APPROACHES to assessing effects of "adaptation" (top down/bottom-up) *(acc. to Vermeulen et al 2013)*:

- I) Decision-based -> robust ("no-regret") under known uncertainties
- II) Projection-based -> predict & act (model-based, data high) /ensemble treatm. of known uncertainties; adaptation as P.S.

Towards true regional IAM; Novelties of 3 MACSUR pilots:

- ❑ **Flexible (i.t. of req. Output variables & modelling approaches)**
- ❑ **Truly multi-scale (field-farm-(sub-)national-continental-global)**
- ❑ **Truly interactive (key stakeholders part of the research process)**

Different approaches to adaptation analysis and planning

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

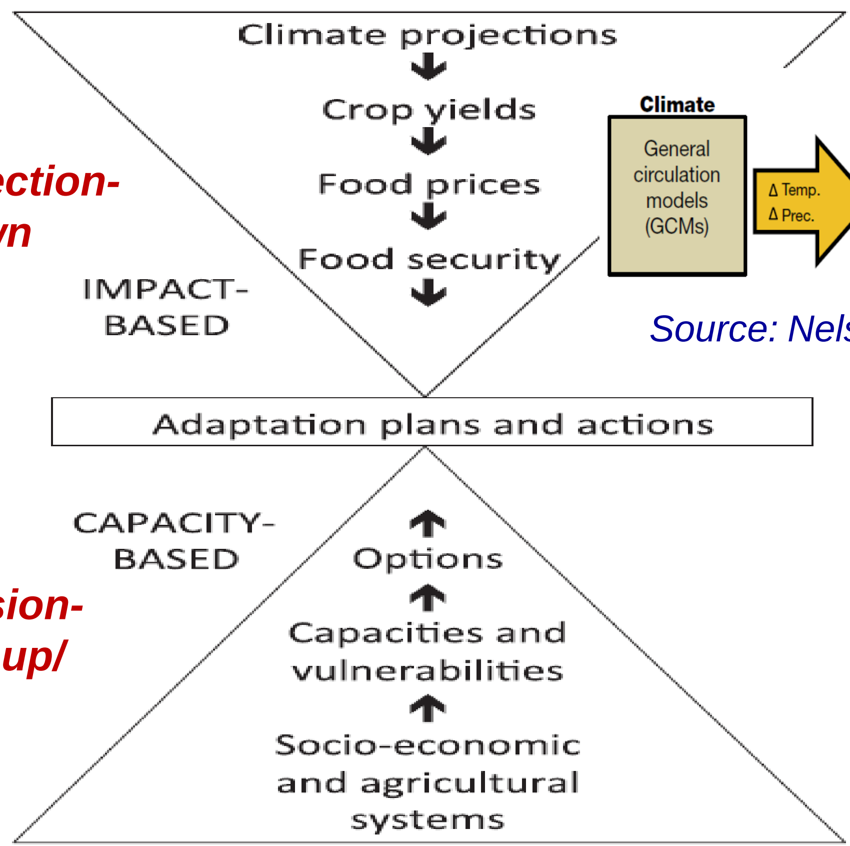
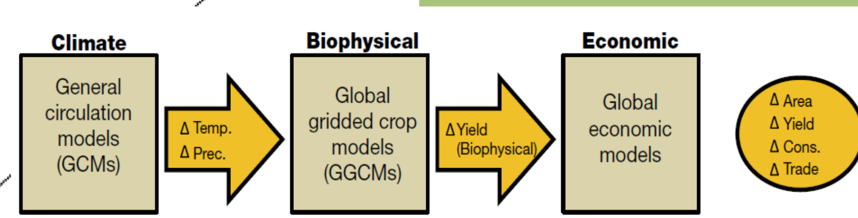


Fig. 1. Impact and capacity approaches to adaptation planning.



Source: Nelson et al., 2014 PNAS (example AgMIP)

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

Source: Vermeulen et al, 2013, PNAS

Three major sources of this review /overview

- **Rötter, R.P.,** Ewert, F., Palosuo, T., Bindi, M., Kersebaum, K.C., Olesen, J. E., and 14 others (2013). Challenges for agro-ecosystem modelling in climate change risk assessment for major European crops and farming systems. Proceedings of the Impacts World 2013 conference at Potsdam, Germany, May 2013, 555-564. DOI: 10.2312/pik.2013.001.

- **Ewert, F.**, Rötter, R.P., Bindi, M., Webber, H., Trnka, M., Kersebaum, K.C. and 16 others (accepted). Crop modelling for integrated assessment of risk to food production from climate change. (EMS Special Issue).

- www.mtt.fi/modags/ (MTT strategic project on multi-scale and integrated analysis of agricultural systems (MODAGS) with NORFASYS as Finnish IAM application)

Agro-ecosystem models as part of integrated modelling systems

Climate scenarios
Crop and variety information
Soil data
Agronomic practices

Market and policy drivers

Modelling framework

Field level
Plant-soil models

Farm level
Static and dynamic farm level models

Sector level
Dynamic regional sector model

Environmental and economic impacts and land-use

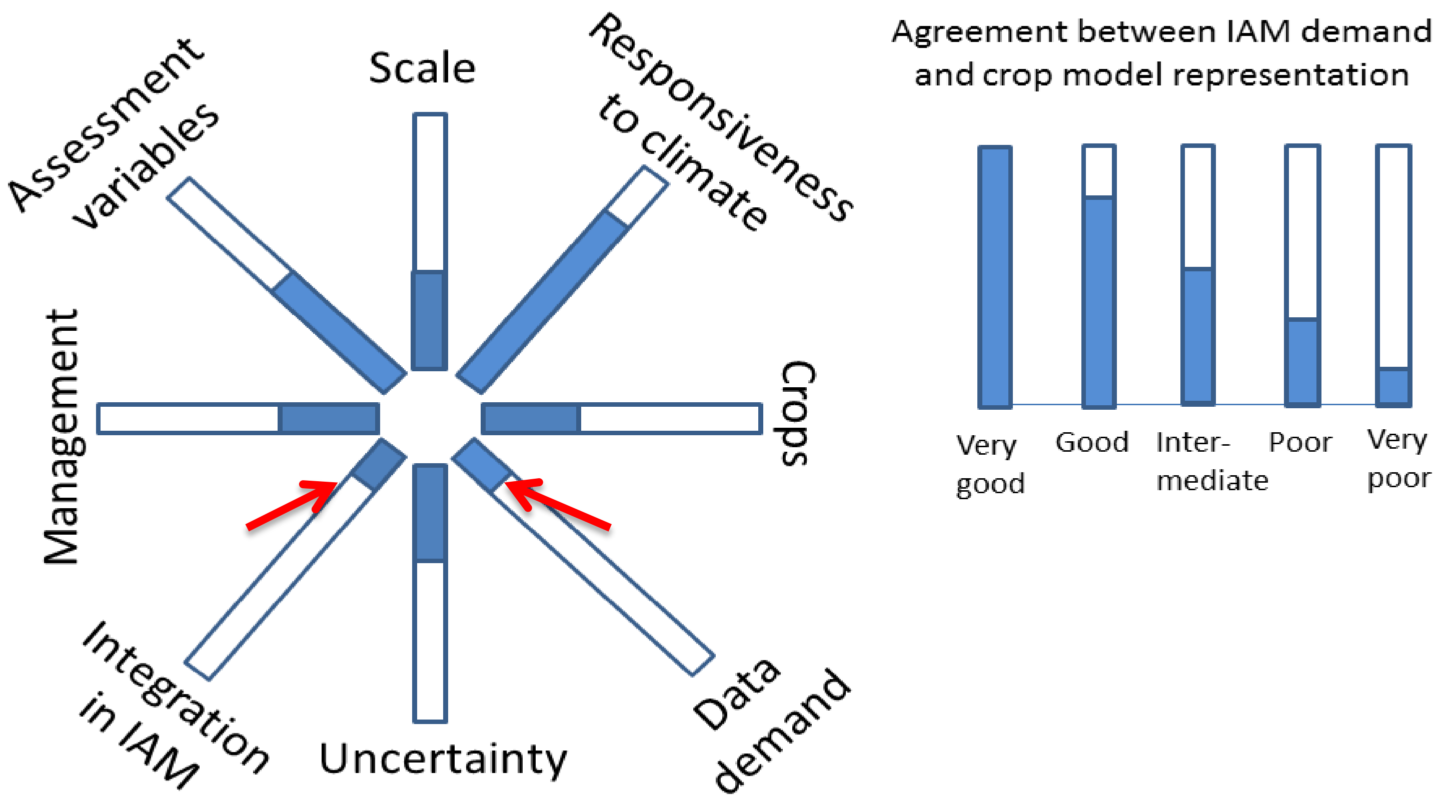
Lehtonen et al. 2010. JAS

3. Important Demands on CropM for IAM.../

(extending on White et al 2011 review in FCR)

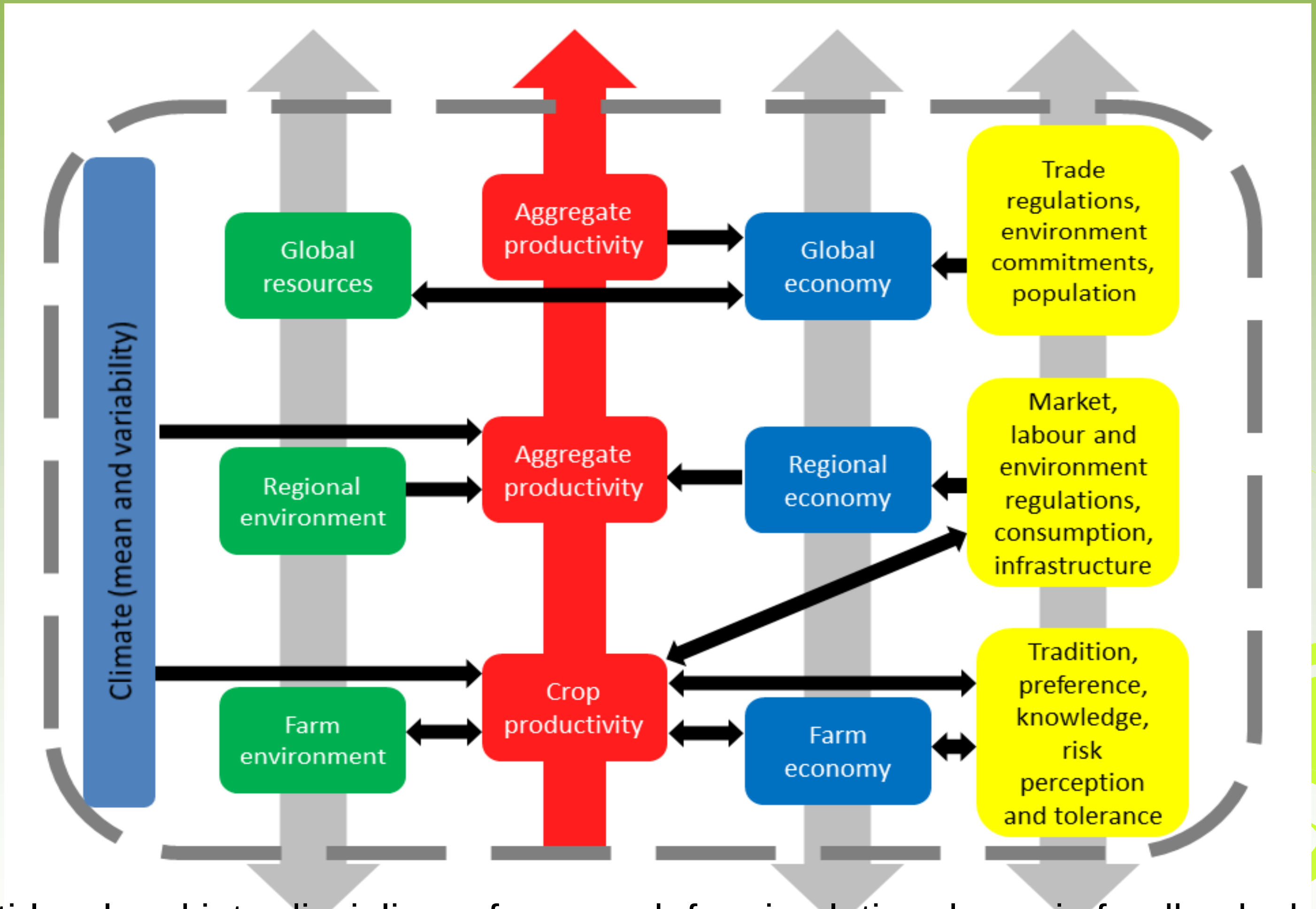
- Scale and regional coverage
- Number of crops
- Model response (sensitivity) to climate variables
- Model output (assessment) variables generated
- Crop management practices /Adaptation options
- Uncertainty and error analysis and reporting
- Data demand and availability
- (Model) Integration

4. Status quo and key challenges .../1



Source: *Ewert, F, Rötter, RP et al (accepted) Fig. 4*

4. Status quo and key challenges .../2



IAM: multi-level and interdisciplinary framework for simulating dynamic feedbacks between crop, soil, management, and other factors (*Source: Ewert et al , accepted*)

5. Plans of CropM for MACSUR 2 (a selection)

Bottom-line Macsur1: **limitations are substantial;**

=>advance crop modelling as integrated part of IAM

Neglected areas to be addressed by WPs 1, 2, 3 and 4:

- ways of improving models to better capture variability and extremes **(WP1),**
- empirical crop-weather analysis to complement CSM results **(WP2)**
- management variables in the scaling exercises **(WP3)**
- full range of methods for analysing uncertainty & error propagation in CC impact and risk assessments **(WP4)**

5. Plans of CropM for MACSUR 2 (a selection)

- **In WP5 (capacity bulding) and WP6 (XC activities):**

  => more emphasis on **multi-scale and integrated analysis of adapting to CC by** alternative genotypes **(G)**, management practices **(M) -** *but also:* structural changes /transformations of agrifood systems at farm and regional scales

- **Concerted effort by MACSUR partners for goal:**

  => robust European-wide impact assessments and evaluations of adaptation options as part of a global analysis on CC and food security

Reversal of rice yield decline at LTCCE at IRRI

(source: Dobermann, A., Daw, D, Rötter R, Cassman, K. 2000.)

DOBERMANN ET AL.: REVERSAL OF YIELD

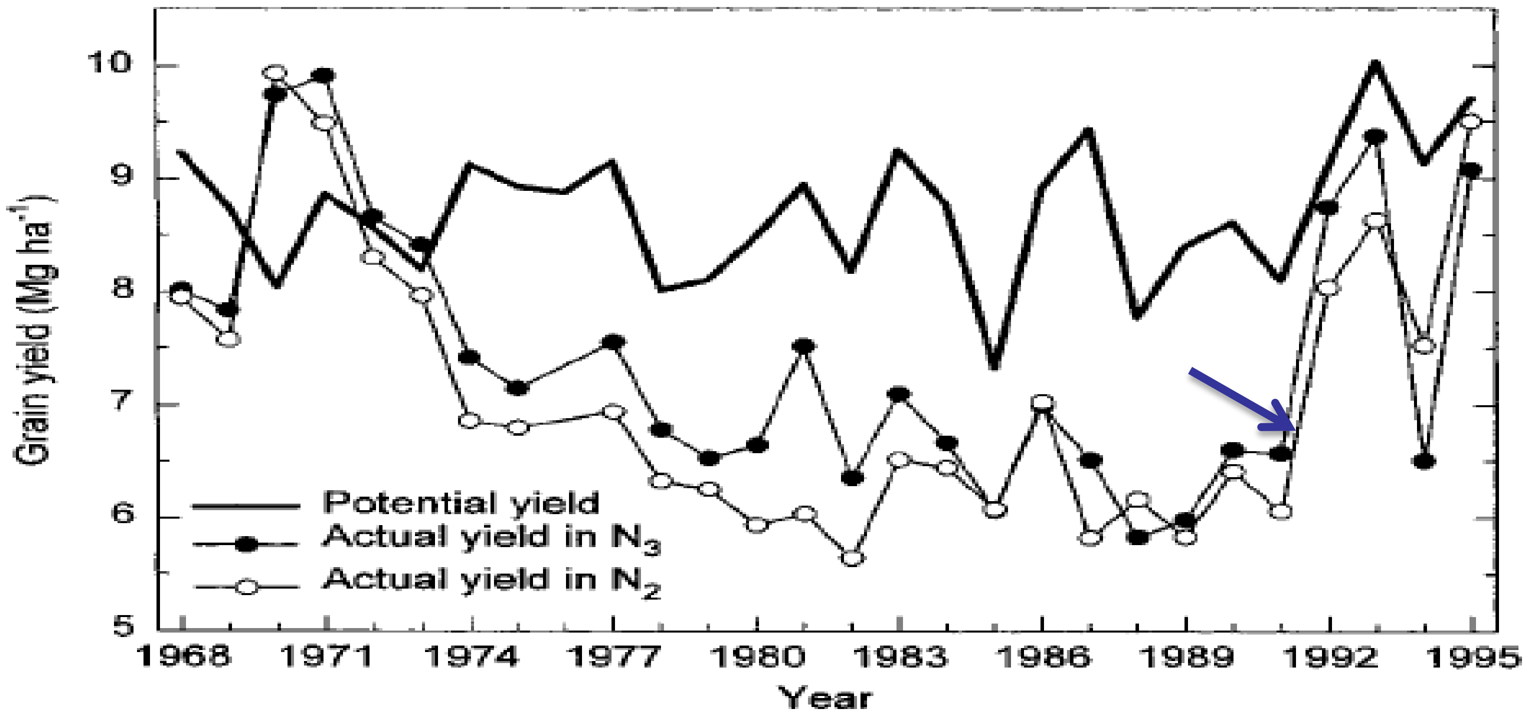


Fig. 3. Simulated potential dry season rice yield of IR72 and actual yields of the highest-yielding variety in each year at Los Baños, Philippines. Simulated potential yields are means of potential yields predicted by ORYZA1 and WOFOST 7.1.

Model-aided crop ideotyping for CC adaptation

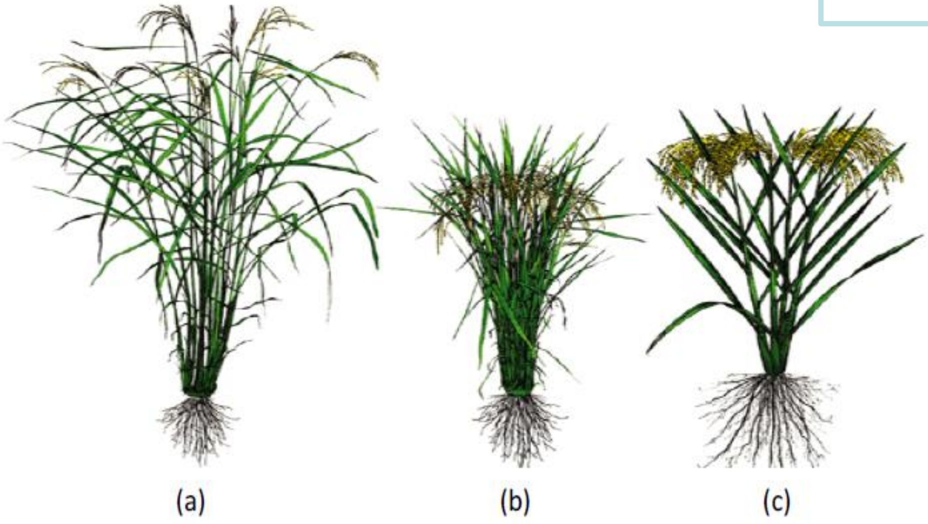


Figure 1. Suggested ideotype changes for continued improvement of rice yield. (a) Traditional plant type; (b) Semi dwarf plant type (Present varieties); (c) New plant type.

Source: Kush et al 1995

Further Reading /literature cited

IAM, climate change risks, adaptation, weather -crop yields; crop ideotyping, uncertainties

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