ICTP Workshop on Climate Information for Risk
Assessment and Regional Adaptation from Global Scale
Climate Projections to Local Scale Climate Hazards
Trieste, Italy – June 9th, 2021

Climate information for Agricultural Impact and Risk Assessment

Alex Ruane
NASA Goddard Institute for Space Studies, New York, USA
IPCC Working Group 1 Chapter 12 Coordinating Lead Author
IPCC AR6 Synthesis Report Core Writing Team Member
Science Coordinator and Climate Team Leader, AgMIP

A Quadruple Challenge for Agriculture

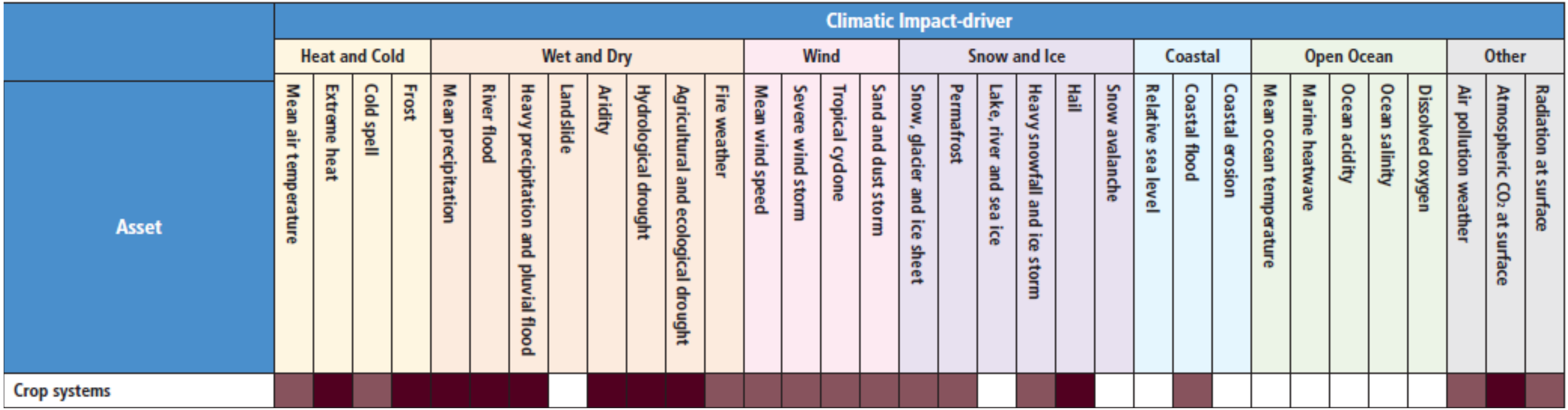
1. **Sustainably increase production** to provide healthy food for growing and developing populations
2. **Adapt to climate change** and ongoing climate extremes
3. **Mitigate emissions** from agricultural lands
4. **Maintain financial incentives** for agriculture

Outline

- Inventory of agricultural responses to climatic impact-drivers
- CIDs as a core element of AgMIP approaches
- Building scenarios of future agricultural systems
- Key priorities for agricultural risk information development

Climate Information Connected to Agriculture

For each important aspect of climate change



Asset	Climatic Impact-driver																																
	Heat and Cold				Wet and Dry								Wind				Snow and Ice						Coastal			Open Ocean					Other		
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Crop systems	▨	■	▨	■	■	■	■	□	■	■	■	▨	▨	▨	▨	▨	▨	▨	□	▨	■	□	□	▨	□	□	□	□	□	□	▨	■	▨

□ None/low confidence ▨ Low/moderate ■ High

Impacts and risk relevance

IPCC AR6 WGI Table 12.2

The Agricultural Model Intercomparison and Improvement Project (AgMIP)

Coordinated Climate-Crop Modeling Project
C3MP

Global Economics Assessments
Integrated National Assessments

AgGRID
GGCMI
pSIMS

Key Interactions
Water Resources
Livestock/Pastures
Soils and Crop Rotation
Pests/Diseases
Ozone
Adaptation / Mitigation

Data and Tools
Data Translators
ACE Database
AgMIP Tools
FACE-IT
Climate Scenarios
AgMERRA
Impacts Explorer
Remote Sensing

Regional Integrated Assessments
Sub-Saharan Africa
South Asia
Latin America and Caribbean
North America
East Asia
Europe
Australia
North Africa
Vietnam

Experiment-Model Interface
Crop-Water ET
Maize / ET
Soybean / ET

Crop Model Intercomparison and Improvement
Wheat
Maize
Rice
Potato
Millet/Sorghum
Soybean
Sugarcane
Peanut
Biofuels
Canola
Barley
Tomato

Cross-Cutting Themes
Uncertainty
Aggregation and Scaling
Representative Agricultural Pathways
Forecasting and Disaster Risk

AgMIP

AgMIP is an international community of 1200+ **climate scientists**, **agronomists**, **economists**, and **IT experts** working to improve assessments of **current and future risks to food security** in order to **build a more productive, sustainable, and resilient future**

- **Launched in 2010**
- **AgMIP is like CMIP for agricultural sector models**
- **50+ MIPs**

Visit www.agmip.org for more information and to sign up for AgMIP listserv

2022 World Food Prize Awarded to NASA Climate Scientist

05/05/2022

Leading climatologist, agronomist and former farmer Dr. Cynthia Rosenzweig has been named the 2022 World Food Prize Laureate for her pioneering work in modeling the impact of climate change on food production worldwide. She was recognized for leading the global scientific collaboration that produced the methodology and data used by decision-makers around the world.

Awarded by the World Food Prize Foundation, the $250,000 prize honors Dr. Rosenzweig's achievements as the founder of the Agricultural Model Intercomparison and Improvement Project (AgMIP), a globally integrated transdisciplinary network of climate and food system modelers. AgMIP is dedicated to advancing methods for improving predictions of the future performance of agricultural and food systems in the face of climate change, providing the evidence base for effective food system transformation. Her

Dr. Cynthia Rosenzweig

WORLD FOOD PRIZE FOUNDATION

https://www.worldfoodprize.org/index.cfm/87428/48752/2022_world_food_prize_awarded_to_nasa_climate_scientist

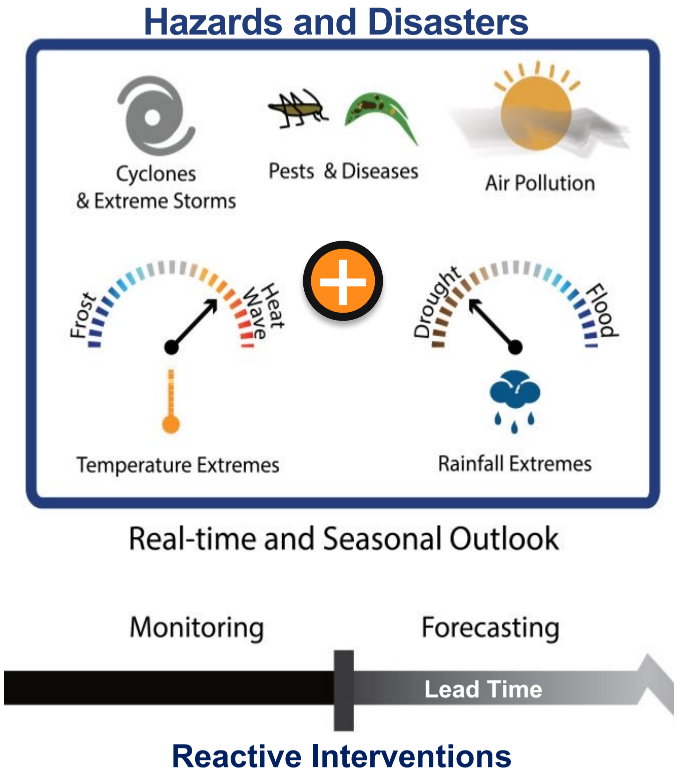
AgMIP Connections to Decision Making across Complex Food Systems

Models aim to capture interactions between Genotype, Environment, Management, and Value Chains

G x E x M x VC

AgMIP Applications across Time Horizons

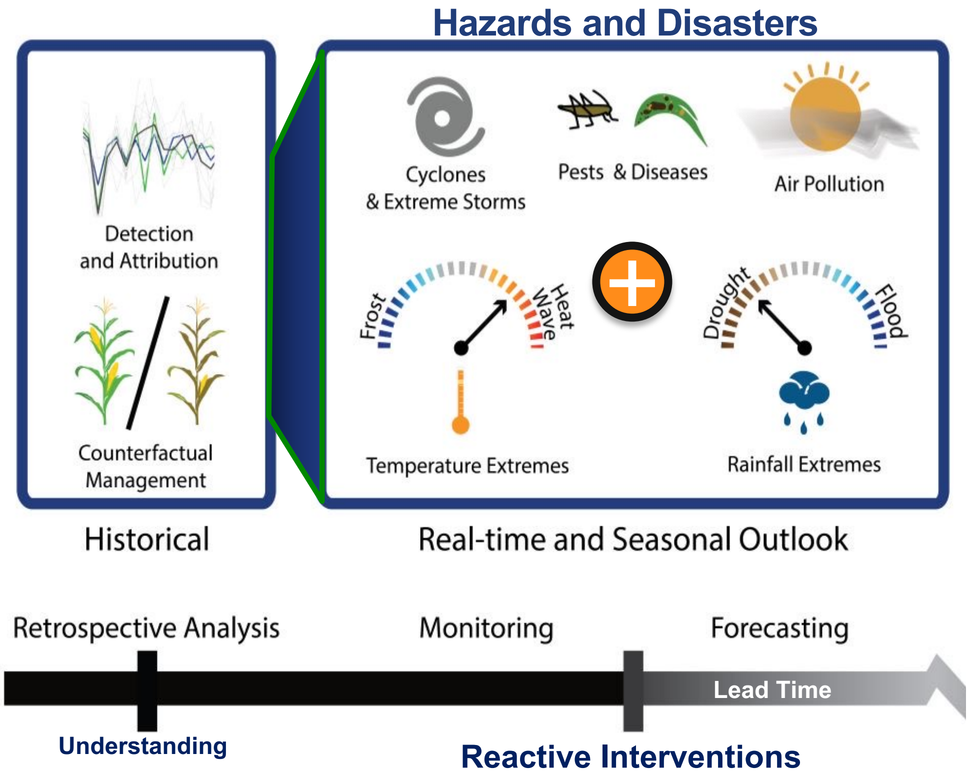
Understanding, projecting, and preparing for shocks



Ruane et al., in prep

AgMIP Applications across Time Horizons

Understanding, projecting, and preparing for shocks



Hazards and Disasters

Detection and Attribution

Counterfactual Management

Cyclones & Extreme Storms

Pests & Diseases

Air Pollution

Temperature Extremes

Rainfall Extremes

Historical

Real-time and Seasonal Outlook

Retrospective Analysis

Monitoring

Forecasting

Understanding

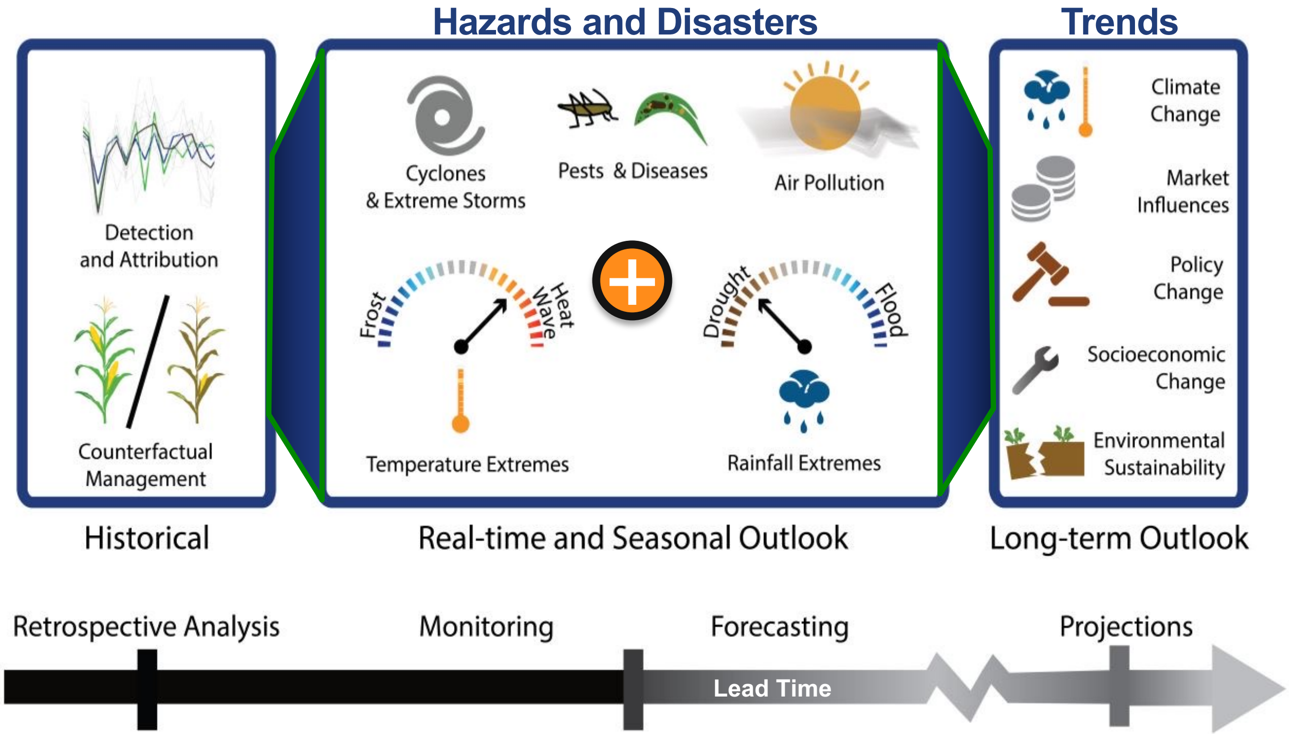
Reactive Interventions

Ruane et al., in prep

AgMIP The Agricultural Model Intercomparison and Improvement Project

AgMIP Applications across Time Horizons

Understanding, projecting, and preparing for shocks



Hazards and Disasters

Trends

Detection and Attribution

Counterfactual Management

Cyclones & Extreme Storms

Pests & Diseases

Air Pollution

Temperature Extremes

Rainfall Extremes

Climate Change

Market Influences

Policy Change

Socioeconomic Change

Environmental Sustainability

Historical

Real-time and Seasonal Outlook

Long-term Outlook

Retrospective Analysis

Monitoring

Forecasting

Projections

Understanding

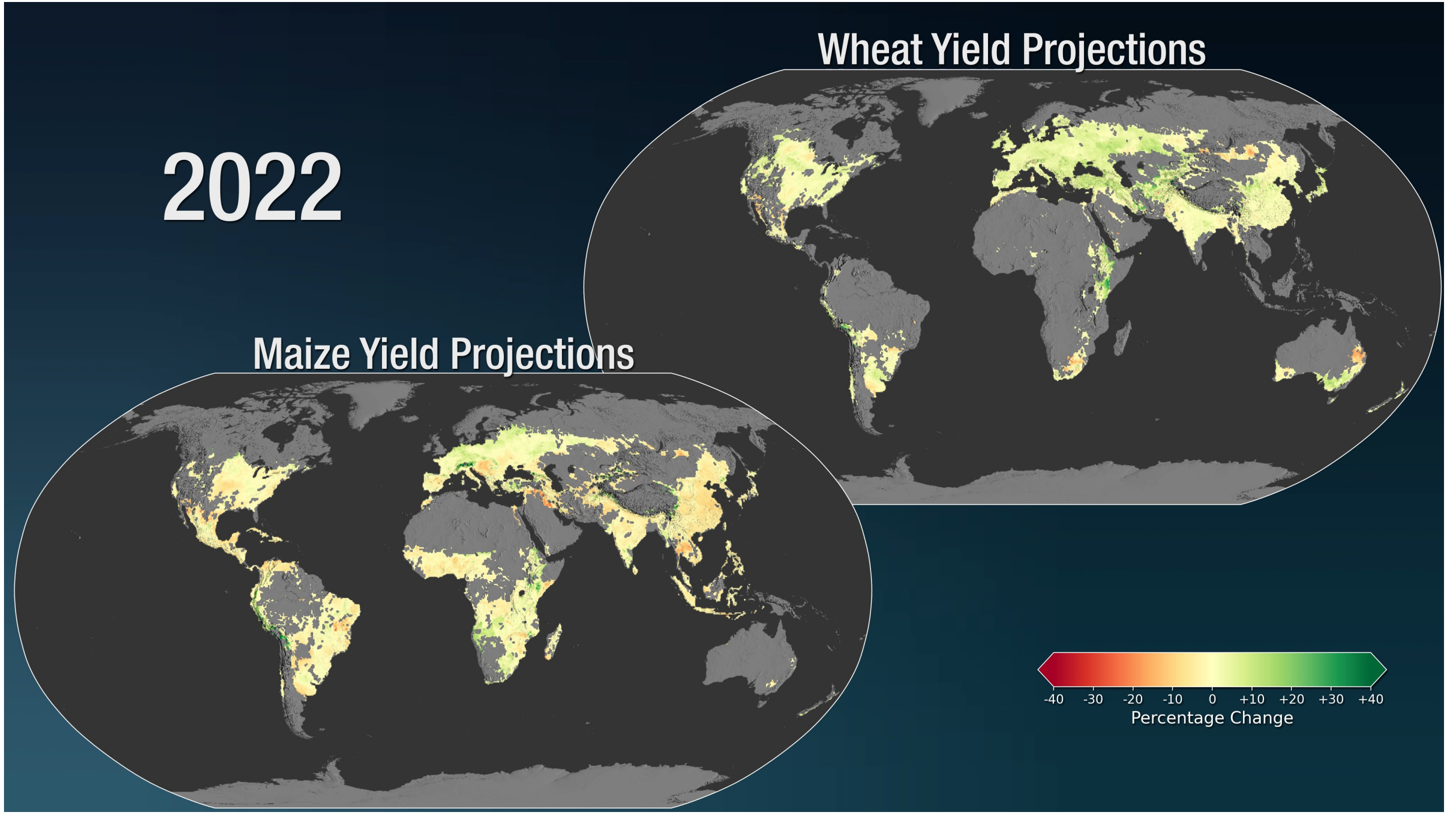
Reactive Interventions

Proactive Interventions

[non-stationarity & emerging challenges]

Ruane et al., in prep

Global Yield Projections



Ensemble of climate and crop models under high-emissions scenario

12 Crop Models and 5 Climate Models – No adaptation

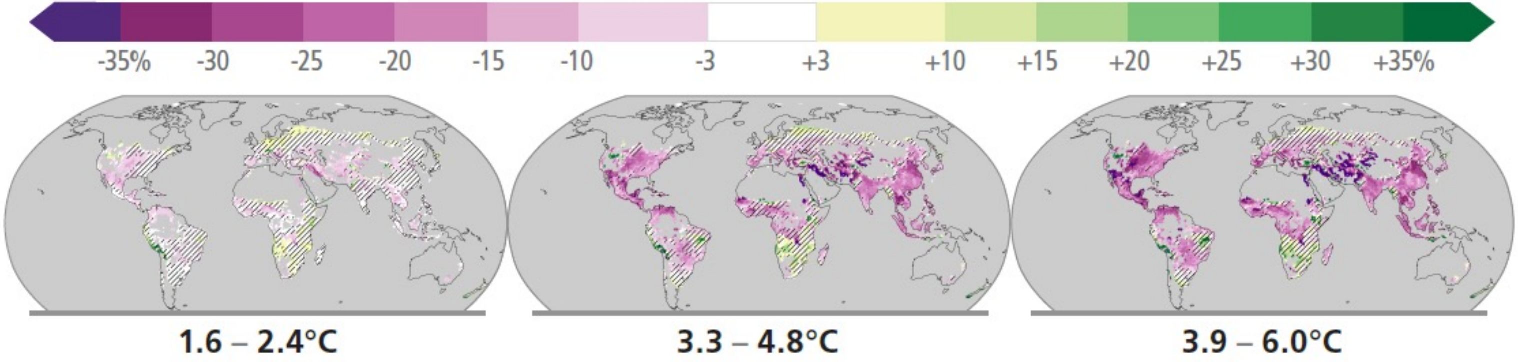
Jägermeyr et al., 2021

Synthesis Report Figure SPM.3c

c) **Food production impacts**

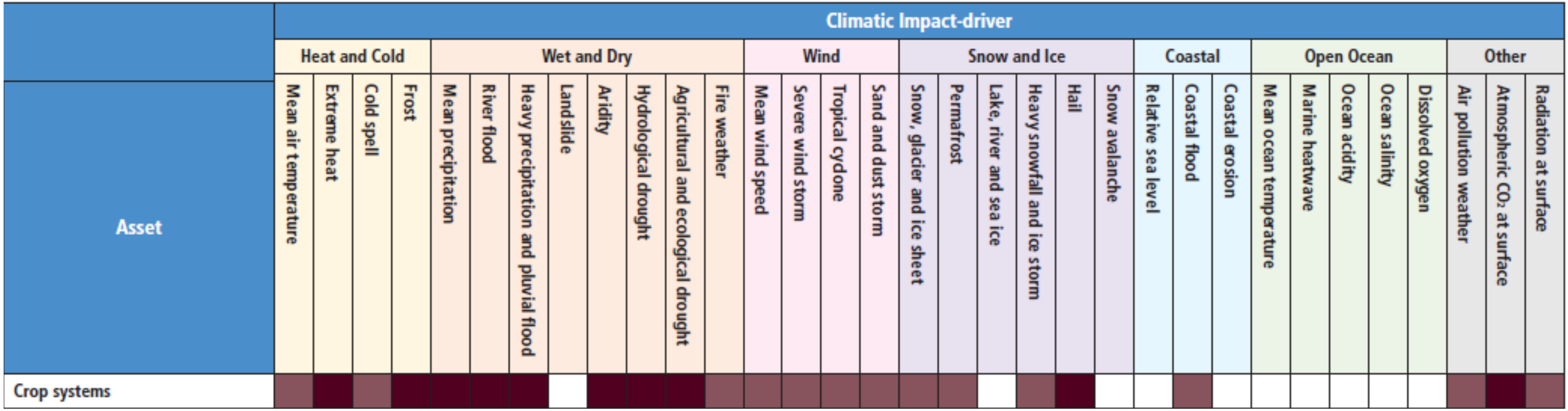
c1) **Maize yield**[4]

Changes (%) in yield



[4] Projected regional impacts reflect biophysical responses to changing temperature, precipitation, solar radiation, humidity, wind, and CO_2 enhancement of growth and water retention in currently cultivated areas. Models assume that irrigated areas are not water-limited. Models do not represent pests, diseases, future agro-technological changes and some extreme climate responses.

Agricultural Sector is Responsive to Many CIDs



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Crop systems	Low/moderate	High	Low/moderate	High	High	High	High	None/low confidence	High	High	High	Low/moderate	Low/moderate	Low/moderate	Low/moderate	Low/moderate	Low/moderate	Low/moderate	None/low confidence	Low/moderate	High	None/low confidence	None/low confidence	Low/moderate	None/low confidence	None/low confidence	None/low confidence	None/low confidence	None/low confidence	None/low confidence	Low/moderate	High	Low/moderate

None/low confidence	Low/moderate	High

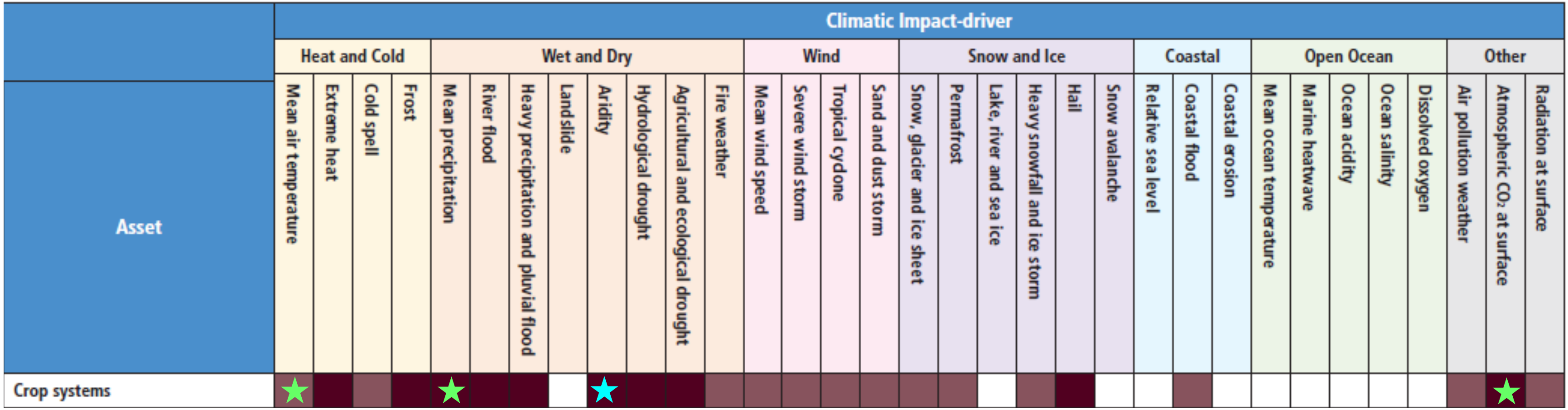
Impacts and risk relevance

IPCC AR6 WGI Table 12.2

The information we need

vs. the information we can provide

Are we appropriately handling Ag CIDs?



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□ None/low confidence ▨ Low/moderate ■ High

Impacts and risk relevance

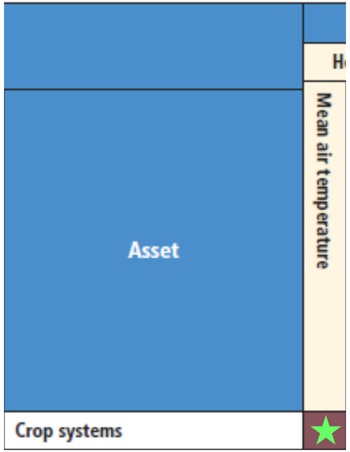
IPCC AR6 WGI Table 12.2

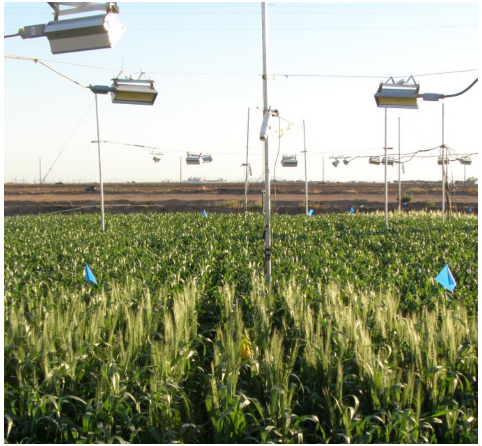
Mean air temperature: Growing Degree Days

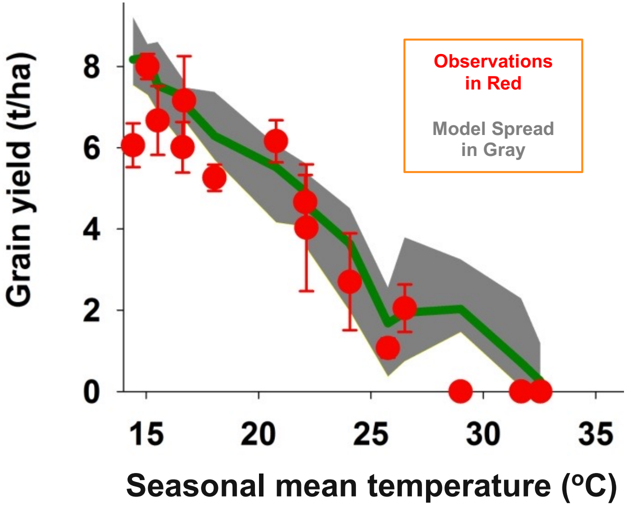
Mean Precipitation: Monsoon onset date

Aridity: Reduction in groundwater

Are we appropriately handling Ag CIDs?







Asseng et al., 2015 – 40 wheat models
Nature Climate Change

Mean air temperature

Ds?

Hea

Asset

Mean air temperature

Crop systems ★

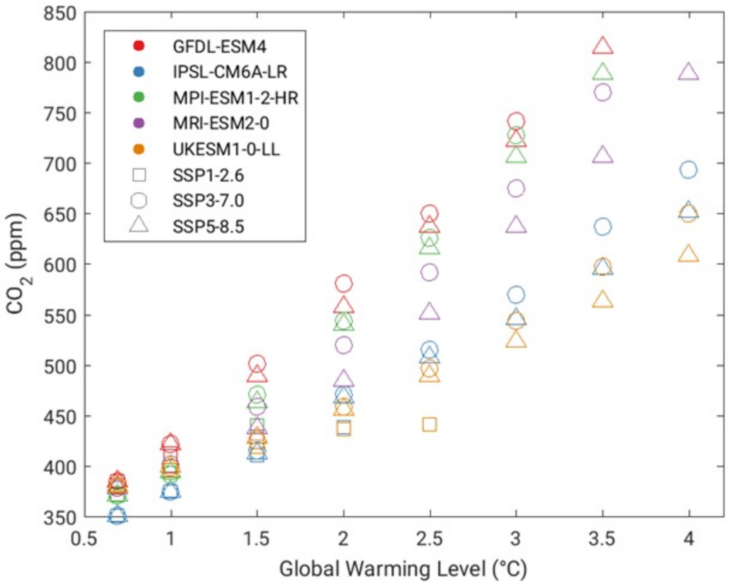
Other

Air pollution weather

Atmospheric CO₂ at surface

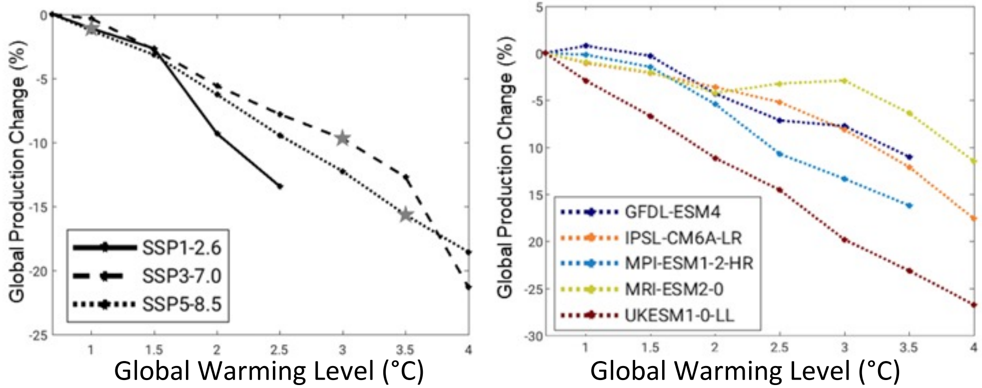
Radiation at surface

★



Mean air temperature
CO2 at surface

Maize



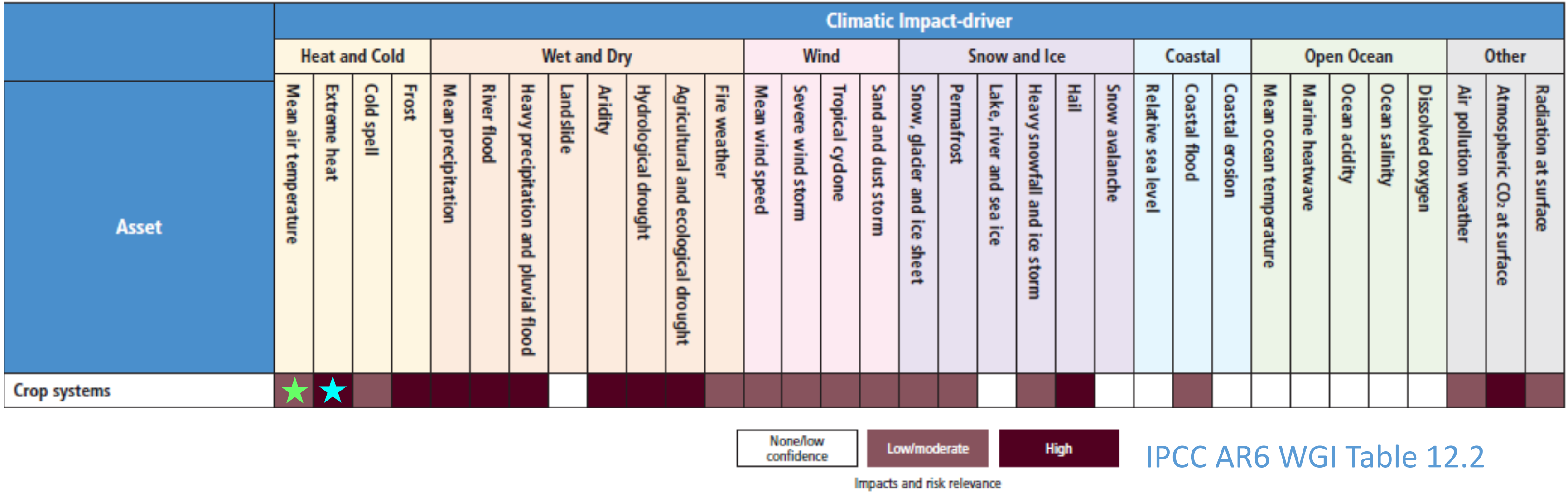
Ensemble of All GCMs

All SSP-RCPs

2.2

Ruane et al., 2023
(in review)

Are we appropriately handling Ag CIDs?



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Crop systems	★	★	▨	■	■	■	■	□	■	■	■	▨	▨	▨	▨	▨	▨	▨	□	▨	■	□	□	▨	□	□	□	□	□	□	▨	■	▨

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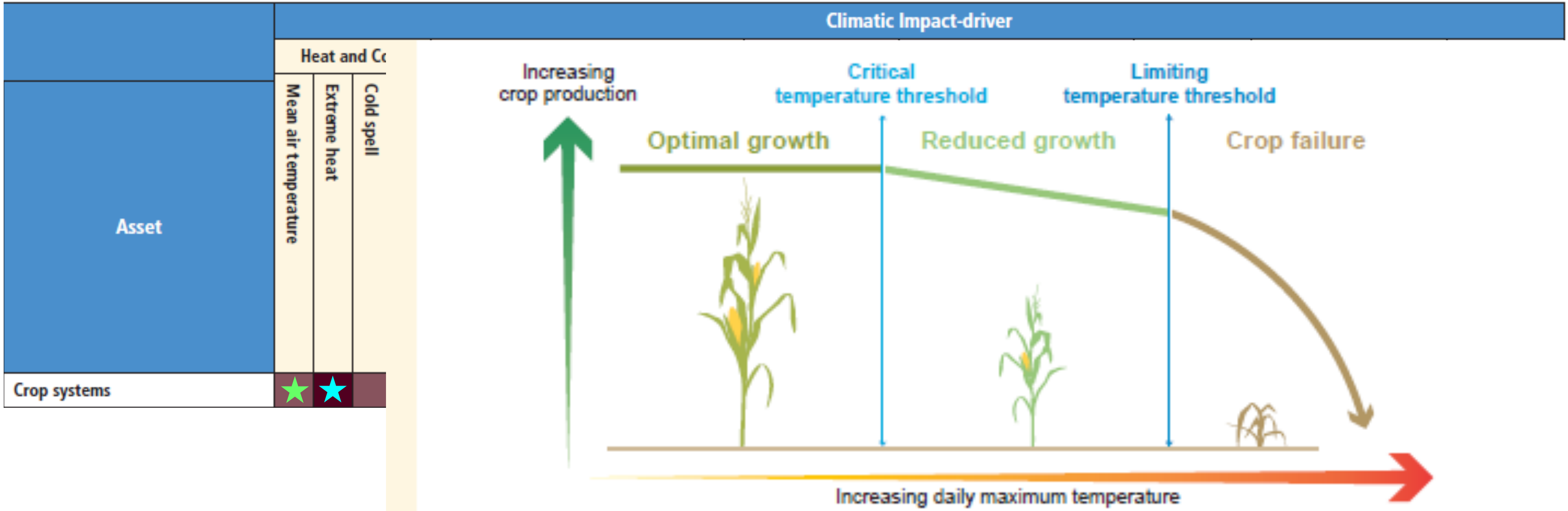
Impacts and risk relevance

IPCC AR6 WGI Table 12.2

Are we appropriately handling Ag CIDs?



Asset	Climatic Impact-driver		
	Heat and C		
	Mean air temperature	Extreme heat	Cold spell
Crop systems	★	★	

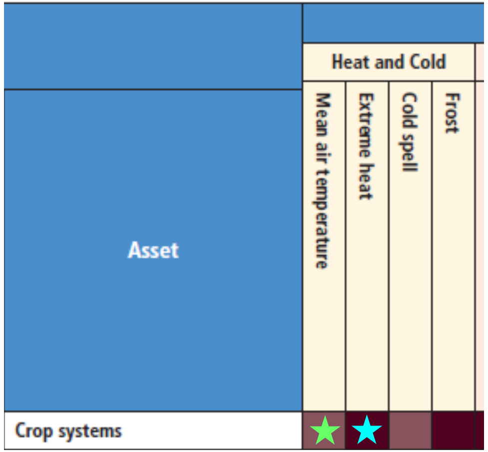
FAQ 12.2, Figure 1 | Crop response to maximum temperature thresholds. Crop growth rate responds to daily maximum temperature increases, leading to reduced growth and crop failure as temperatures exceed critical and limiting temperature thresholds, respectively. Note that changes in other environmental factors (such as carbon dioxide and water) may increase the tolerance of plants to increasing temperatures.

Extreme heat:
#days where Tx>35C
#days where Tx>40C
‘killing degree days’

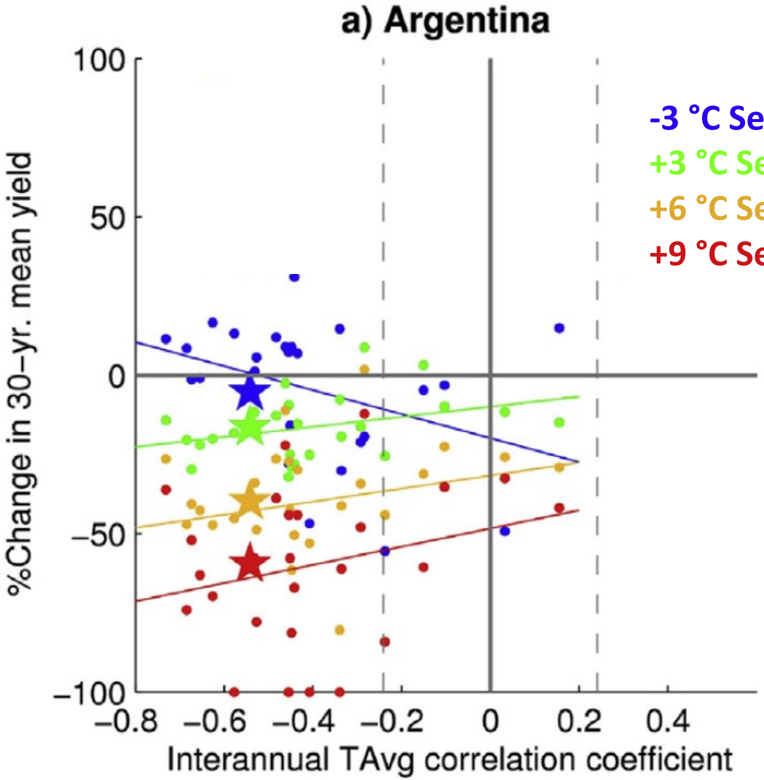
Temperatures above a plant’s tolerance thresholds temperatures can slow growth, damage tissues, cause leaf senescence, and sterilize pollen.

Are we appropriately handling Ag CIDs?

Seasonal response ≠ Climate Response



	Heat and Cold			
Asset	Mean air temperature	Extreme heat	Cold spell	Frost
Crop systems	★	★		



-3 °C Sensitivity Test

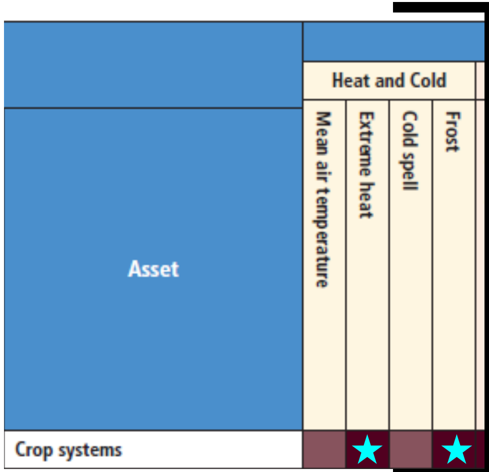
+3 °C Sensitivity Test

+6 °C Sensitivity Test

+9 °C Sensitivity Test

Ruane et al., 2016 (EMS)
Multi-wheat-model ensemble responses to interannual climate variability

Are we appropriately handling Ag CIDs?



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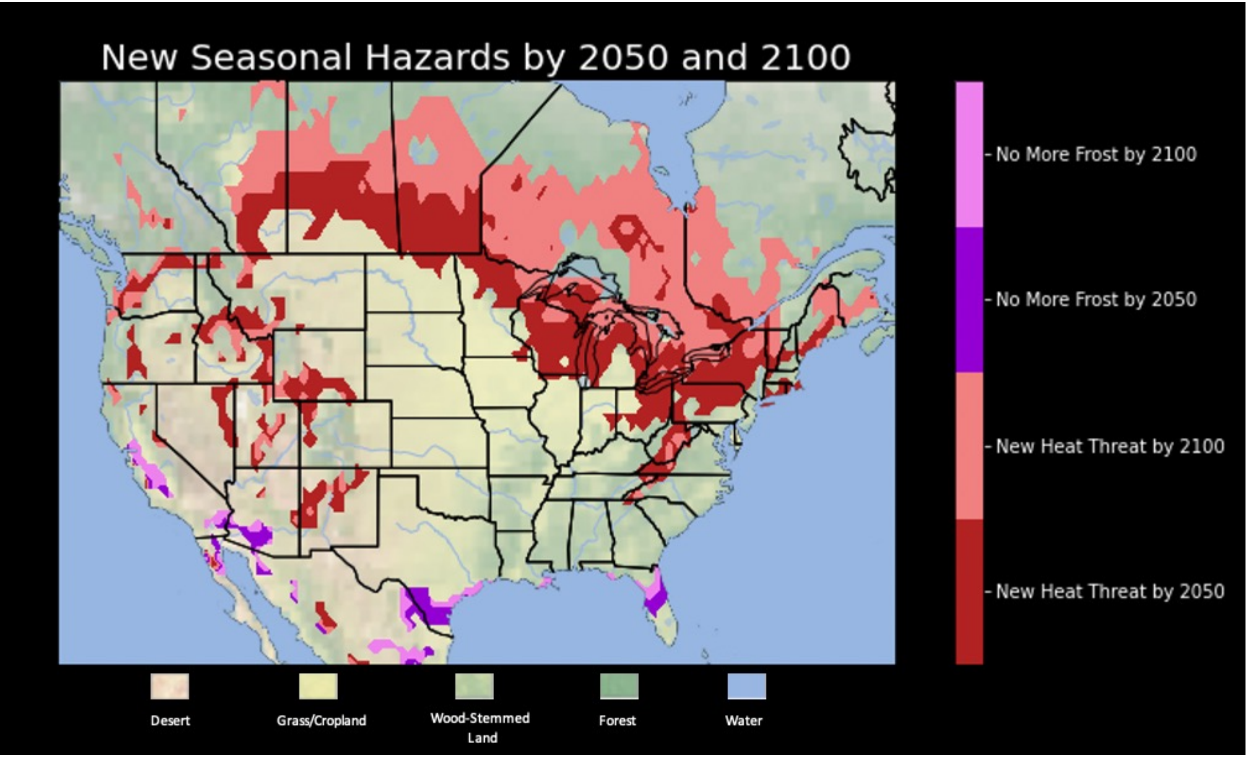
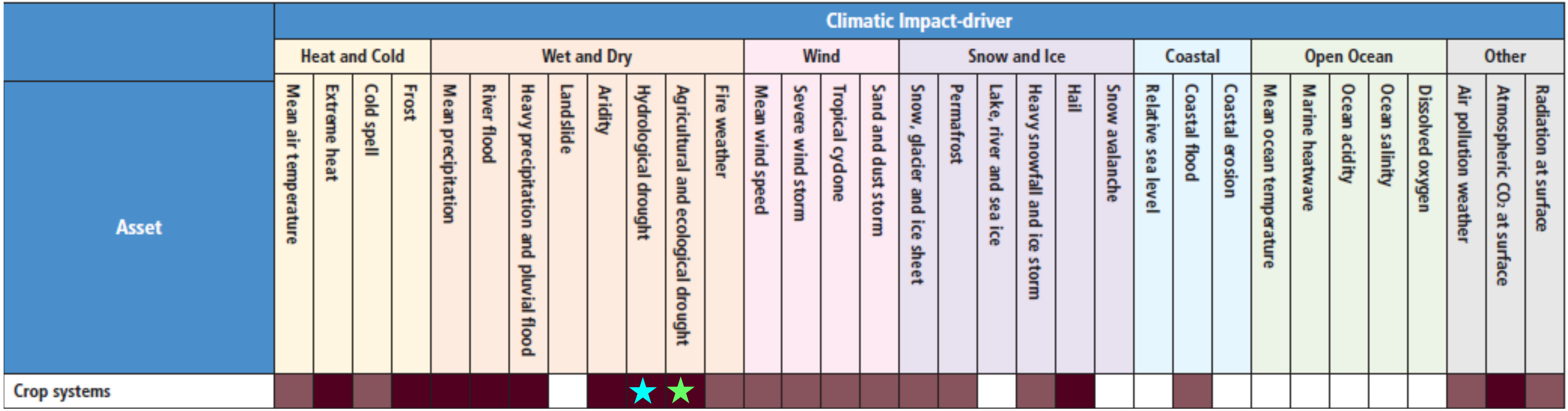
Crop systems	▨	★	▨	★



Extreme Heat
Frost

Heat = Days where T_{max}>35 ℃ Frost = Days where Tmin<0 ℃
SSP5-8.5 from 5 ISIMIP bias-adjusted ESM Projections – Lucke et al., in prep.

Are we appropriately handling Ag CIDs?



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Crop systems	▨	■	▨	■	■	■	■	☐	■	■ ★	■ ★	▨	▨	▨	▨	▨	▨	▨	☐	▨	■	☐	☐	▨	☐	☐	☐	☐	☐	☐	▨	■	▨

☐ None/low confidence ▨ Low/moderate ■ High

Impacts and risk relevance

IPCC AR6 WGI Table 12.2

Hydrological Drought – availability of surface and groundwater resources (extractable).

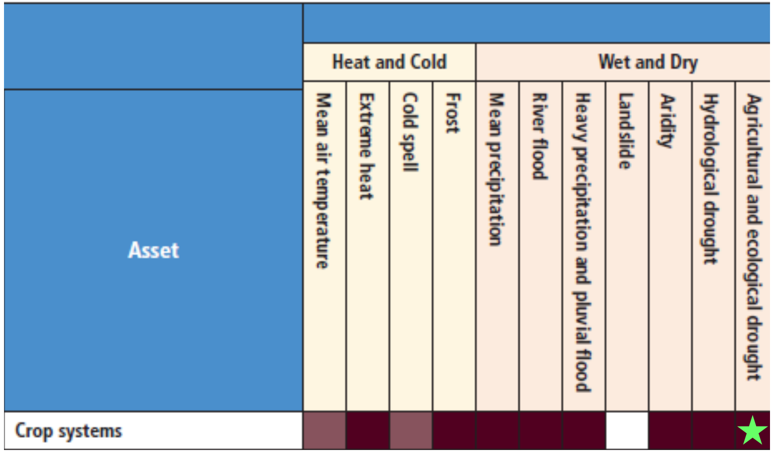
- requires water systems and management models

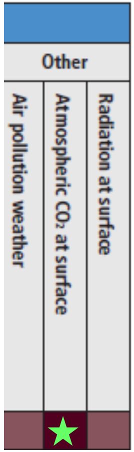
Agricultural and Ecological Drought – Soil moisture availability for plants.
Standardized Precipitation Evapotranspiration Index (SPEI)

Both have water balance focus (supply and demand)

Are we appropriately handling Ag CIDs?

Interactions between CIDs may be important





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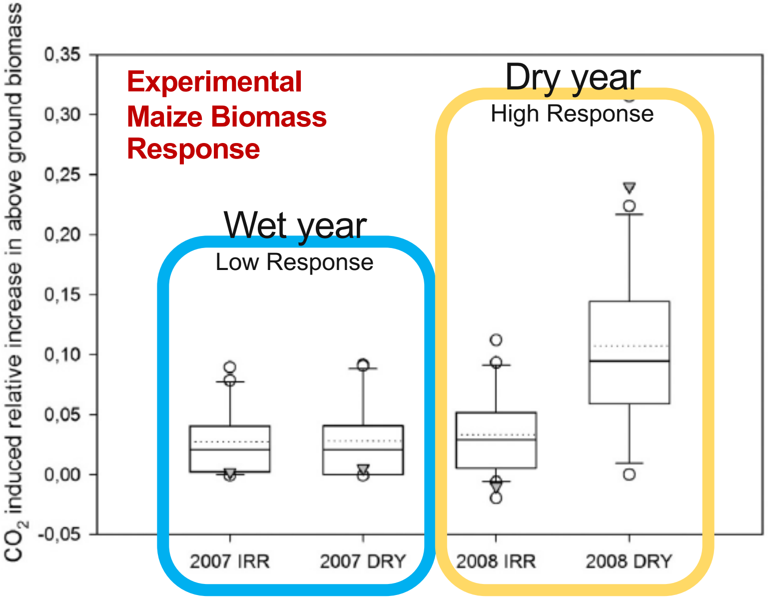


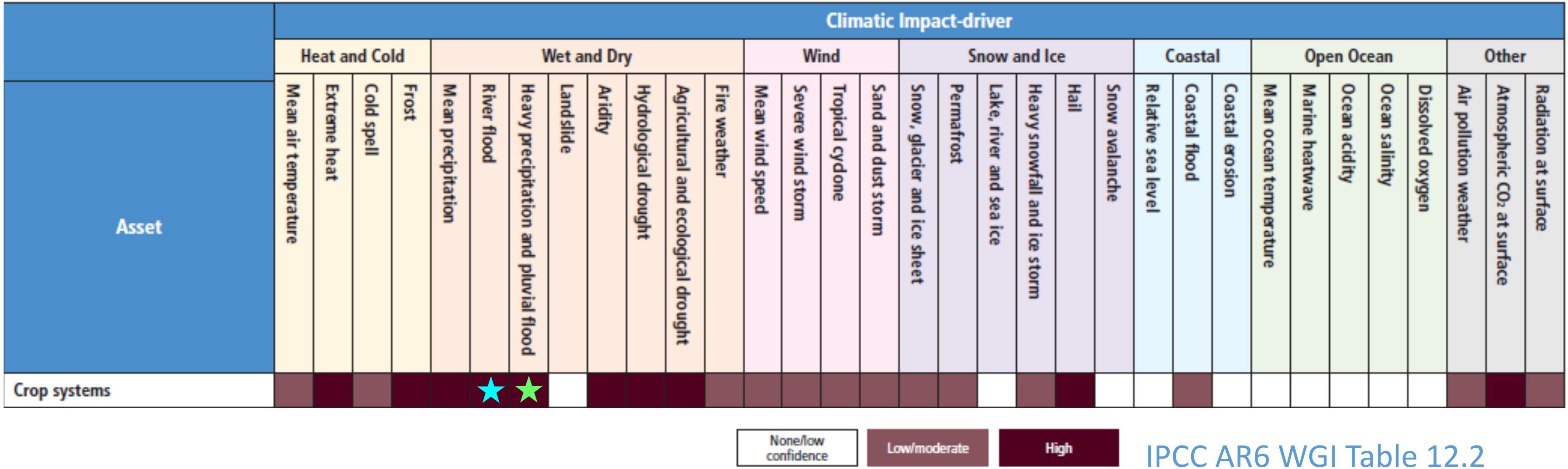
Fig. 6. Simulated relative increase of maize Above Ground Biomass at 550 ppm *versus* the ambient air [CO_2] in 2007 and 2008 for irrigated and dry plots: ((FACE-AMBIENT)/AMBIENT).

Drought
CO2 at surface

CO_2 benefits are strongest during drought years
Durand et al., 2018

See also: Elliott et al. (2014) noted that CO_2 / water efficiency effects often not included in hydrology models

Are we appropriately handling Ag CIDs?



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□ None/low confidence ▨ Low/moderate ■ High

Impacts and risk relevance

IPCC AR6 WGI Table 12.2

River Flood – water levels rising from precipitation and/or meltwater in a basin creating high river levels

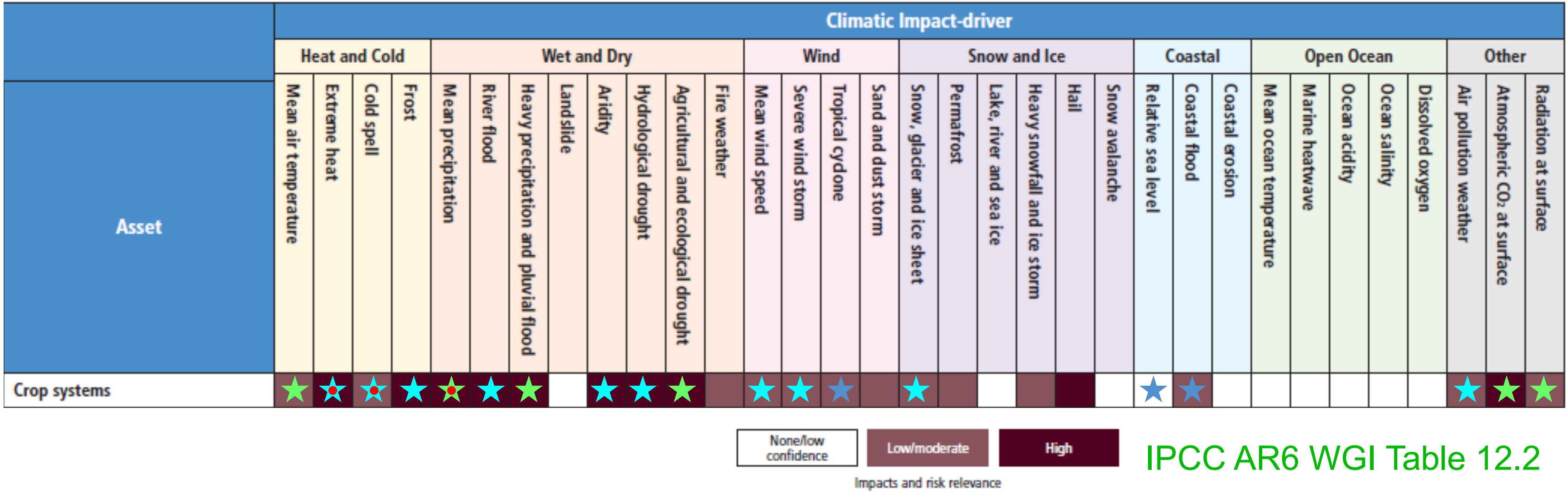
- e.g., areas where inundation > 10cm at typical 1-in-10yr peak flow
- *requires hydrological models*

Pluvial Flood – water levels rise because rainfall rates exceed runoff/drainage rates of an area

- different damage profile (nitrogen leaching, soil runoff) and adaptation options
- e.g., #hours where rainfall > 8mm (*USGS calls this 'very heavy rainfall'*)

Are we appropriately handling Ag CIDs?

Summary of typical agricultural models



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Crop systems	★	★	★	★	★	★	★		★	★	★		★	★	★		★						★	★							★	★	★

None/low confidence | Low/moderate | High

Impacts and risk relevance

IPCC AR6 WGI Table 12.2

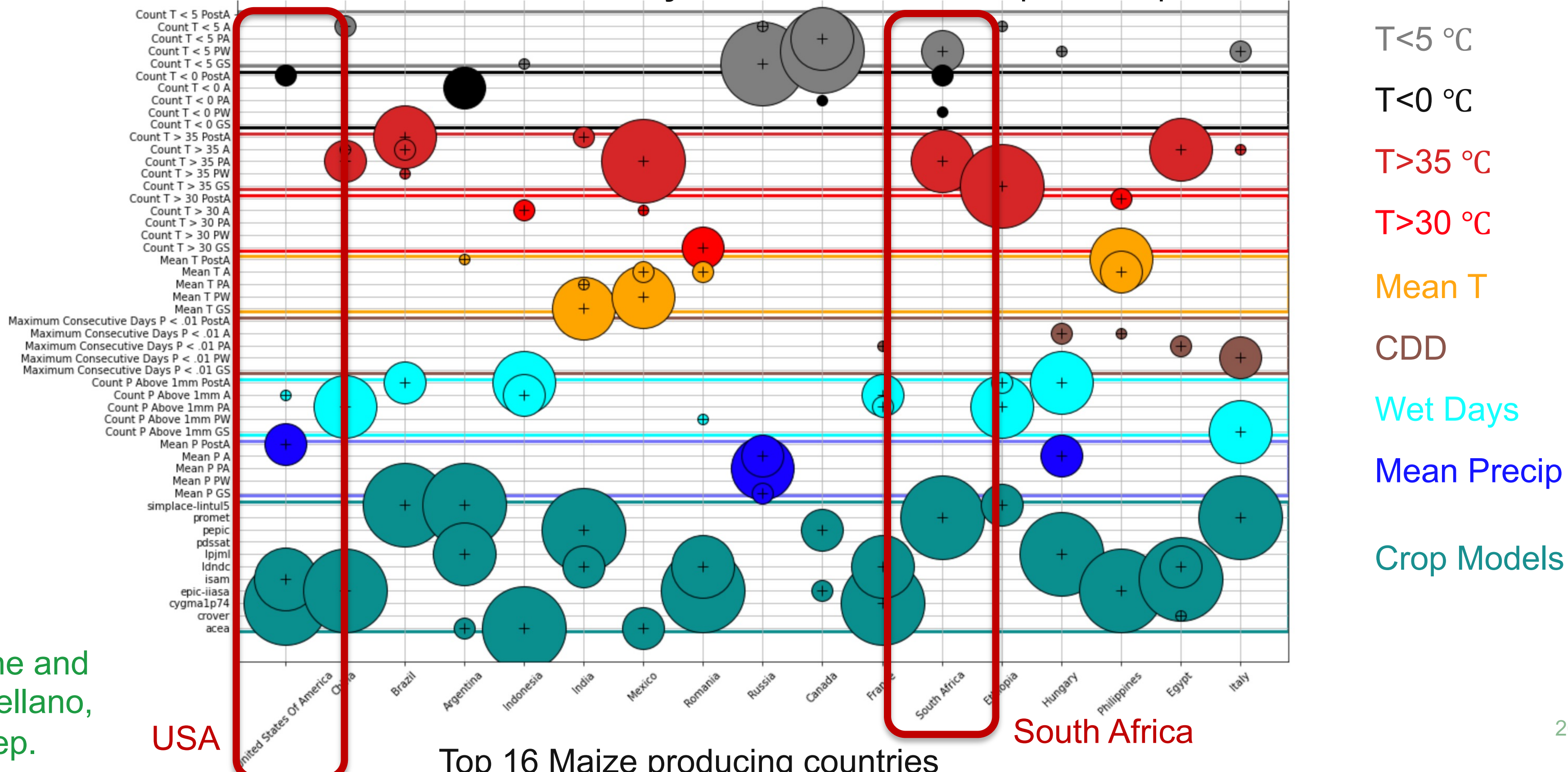
★	Agricultural models currently include CID response
★	(Some) models include partial CID response
★	Response could be added in soft coupling
☐	Responses generally missing

Note: bias-adjustment may determine which CIDs can be examined

- More effort needed: Water logging, labor health, pests and diseases, sequential extremes

Machine Learning helps us identify what are most important missing elements

5 feature model fit to FAO yields – size of circle represents prominence of features



USA

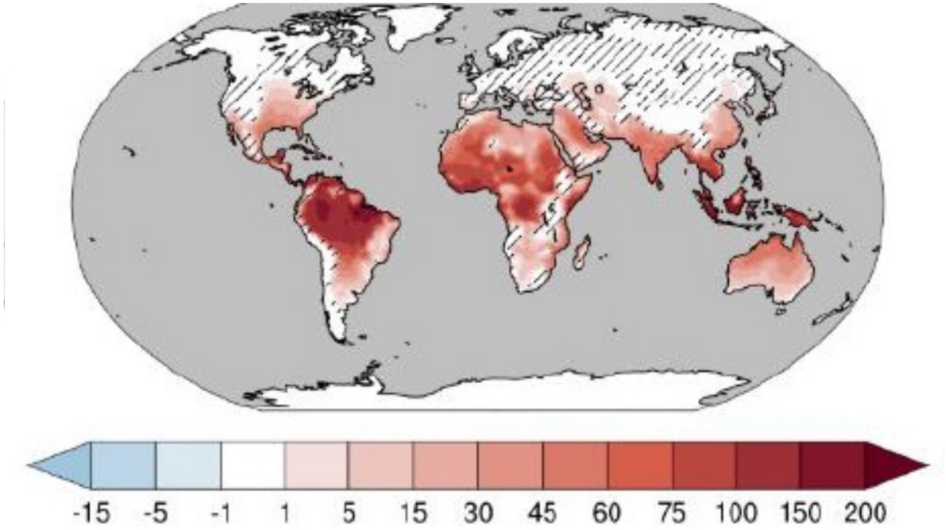
South Africa

Top 16 Maize producing countries

Ruane and Castellano, in prep.

Anticipating the future of food requires understanding of food systems (not just crops)

Outdoor heat tolerance thresholds more frequently exceeded



Change in the Number of days per year where the NOAA Heat Index indicates “dangerous” conditions

Mid-century under a high emissions pathway

- Future agriculture could be disrupted by impacts on farm laborers

- Many indices and metrics, but be careful with over-generalizations:
  - different types of workers
  - diurnal cycle of weather and labor

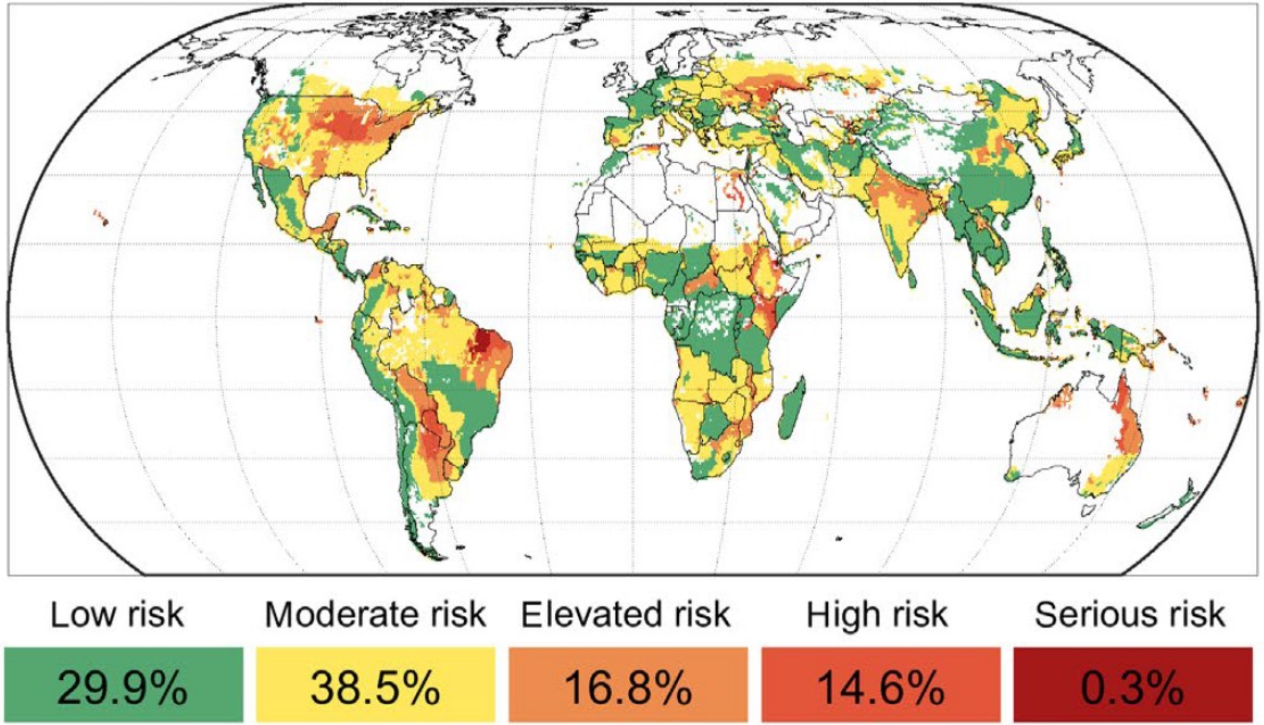
Figure 12.4

Adaptations targeted toward specific CIDs

Case study on adaptation potential:
What cultivars can we transfer, what genotypes need to be created?

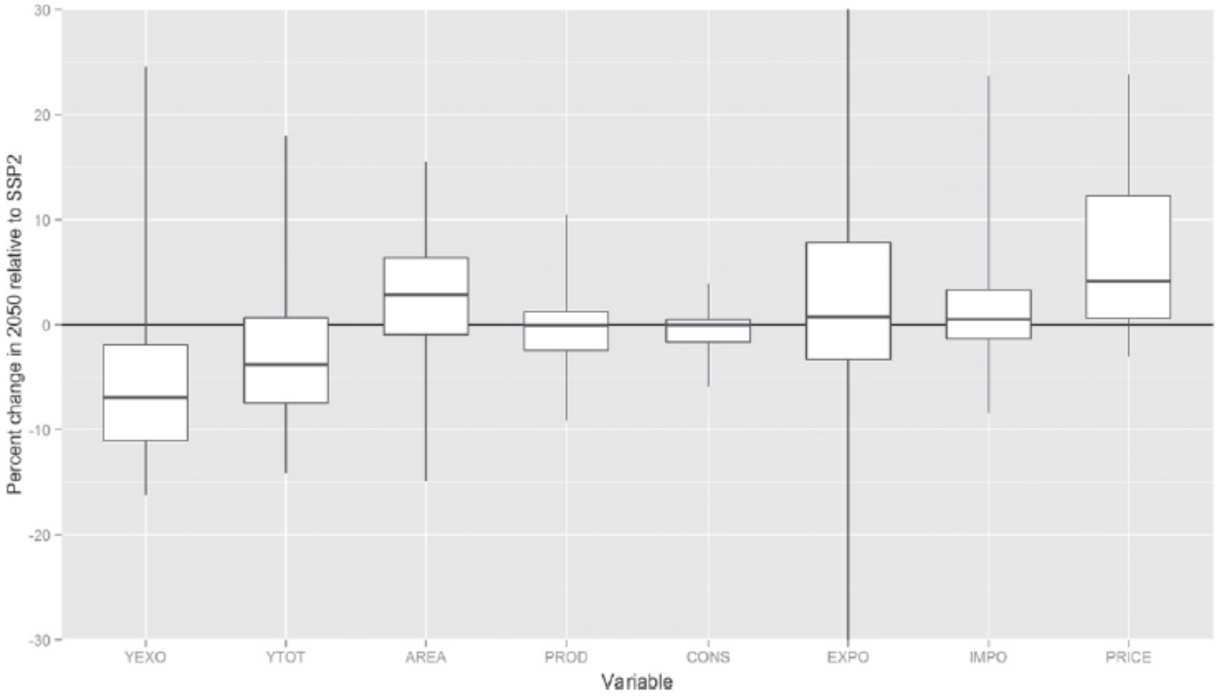
Plant suitability often determined by growing degree day (GDD) requirements in agricultural season

Is there an existing variety with GDD attributes that match with future growing season temperatures?



Florian Zabel et al., 2021 -
High emissions;
end of century

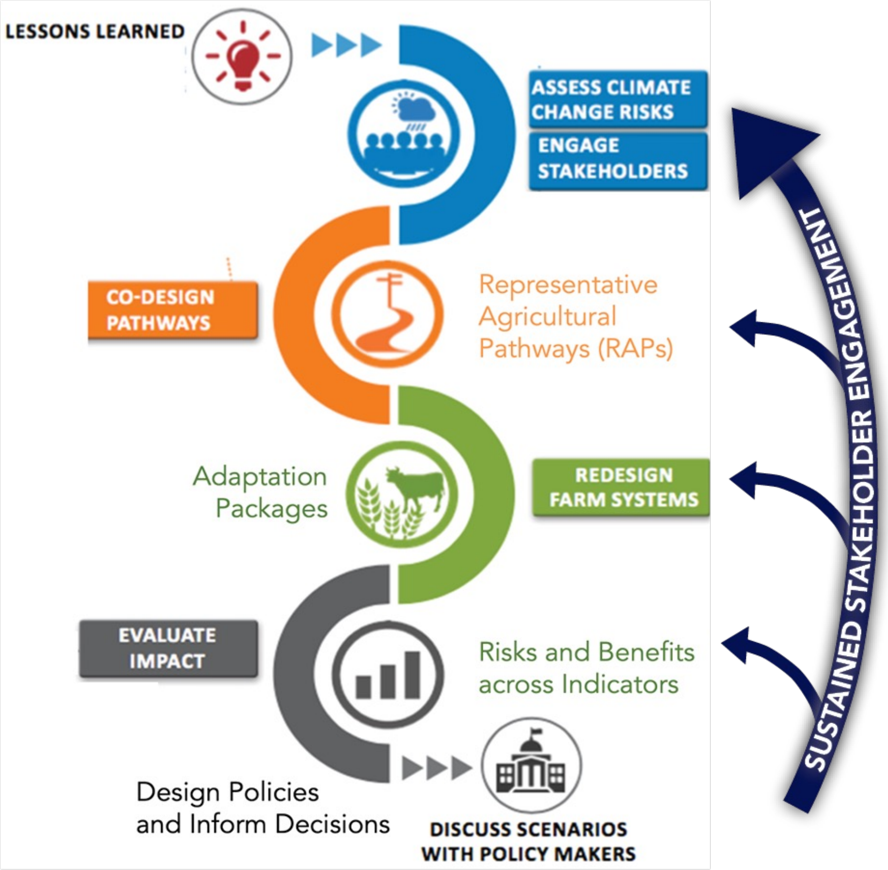
Food system and market resilience



Note: The plots show pooled results for five commodities in thirteen regions from three GCMs and five economic models (n = 975). All pooled data are combined into the sample for each boxplot, and cannot be distinguished individually.
Variables: YEXO = exogenous yield shocks, YTOT = realized yields after management adaptation, AREA = agricultural area in production, PROD = total production, CONS = total consumption, EXPO = exports, IMPO = imports, PRICE = price.

Future depends on climate impacts, and
land use shifts,
food/dietary demand,
trade policy,
food waste,
and agrotechnology.

Envisioning and Co-Assessing Future Agricultural Systems



LESSONS LEARNED

ASSESS CLIMATE CHANGE RISKS

ENGAGE STAKEHOLDERS

CO-DESIGN PATHWAYS

Representative Agricultural Pathways (RAPs)

Adaptation Packages

REDESIGN FARM SYSTEMS

EVALUATE IMPACT

Risks and Benefits across Indicators

Design Policies and Inform Decisions

DISCUSS SCENARIOS WITH POLICY MAKERS

SUSTAINED STAKEHOLDER ENGAGEMENT

India

Zimbabwe

Senegal

Priorities for Agricultural Risk Assessment

- **Agriculture responds to many climatic impact-drivers, and we only track a subset**
- **Agricultural modeling approaches allow us to capture specific responses and adaptation approaches – more data and model development needed**
- **Adaptations target specific climatic impact-drivers, and we need more work to identify appropriate CID indices and thresholds**
- **Co-development process is vital to contextual risk management and planning for climate adaptation and mitigation**