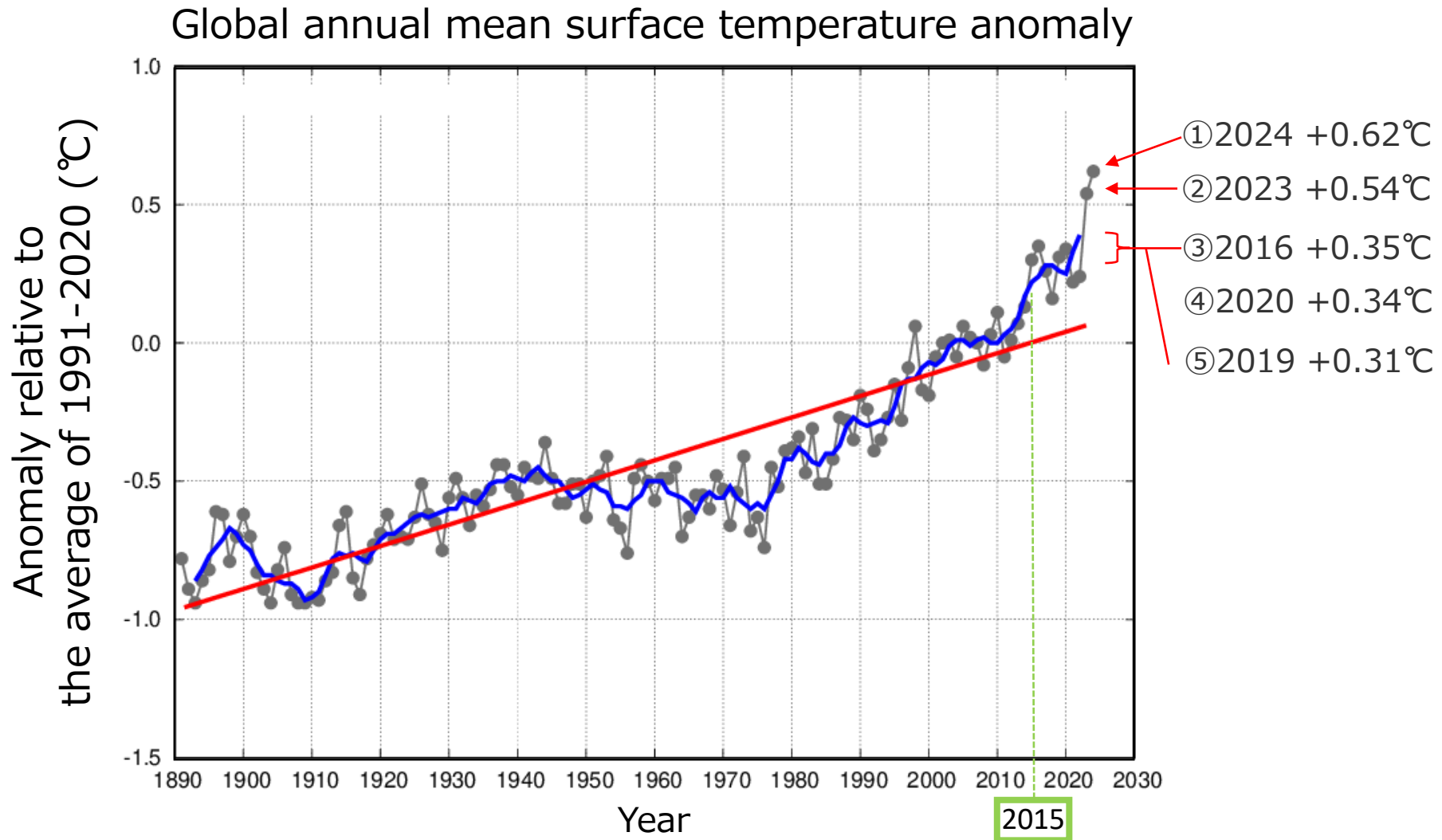


Global pre-harvesting crop yield forecasting for climate-resilient agri-food systems

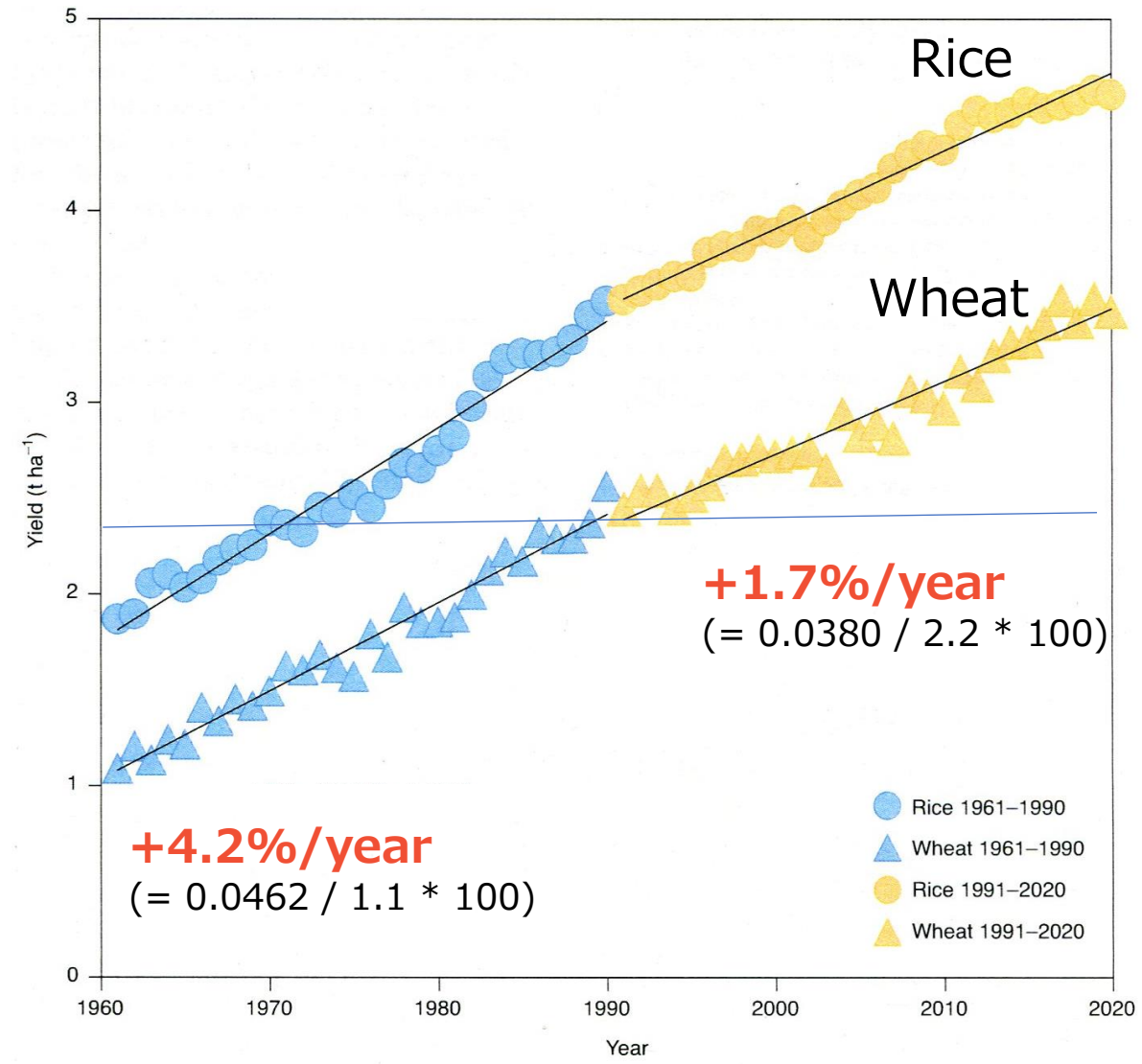
Toshichika IIZUMI

National Agriculture and Food Research Organization

Climate change is underway



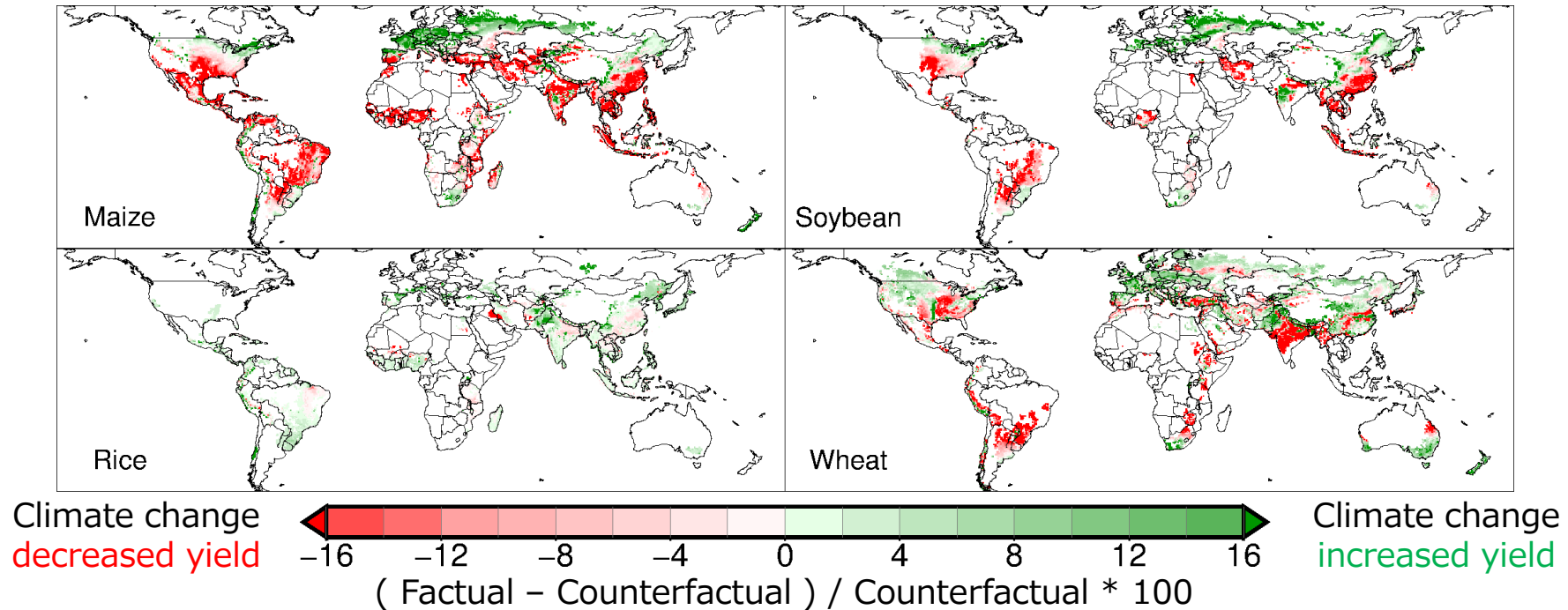
Climate change has slowed yield growth



“SPM.B.1.3 ... Although overall agricultural productivity has increased, climate change has slowed this growth over the past 50 years globally (medium confidence), ...”

IPCC WG2 AR6 SPM

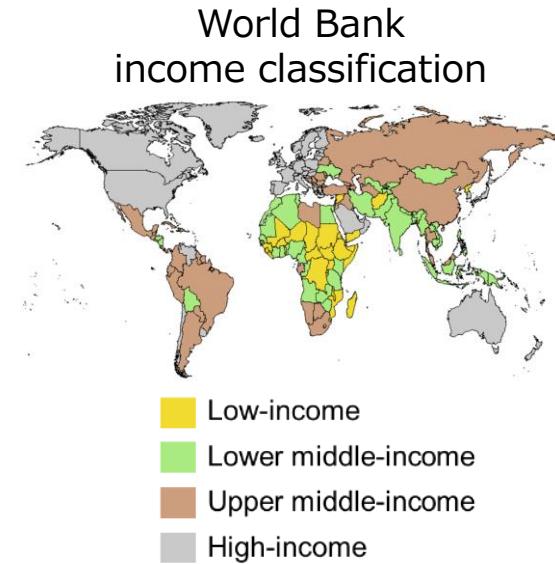
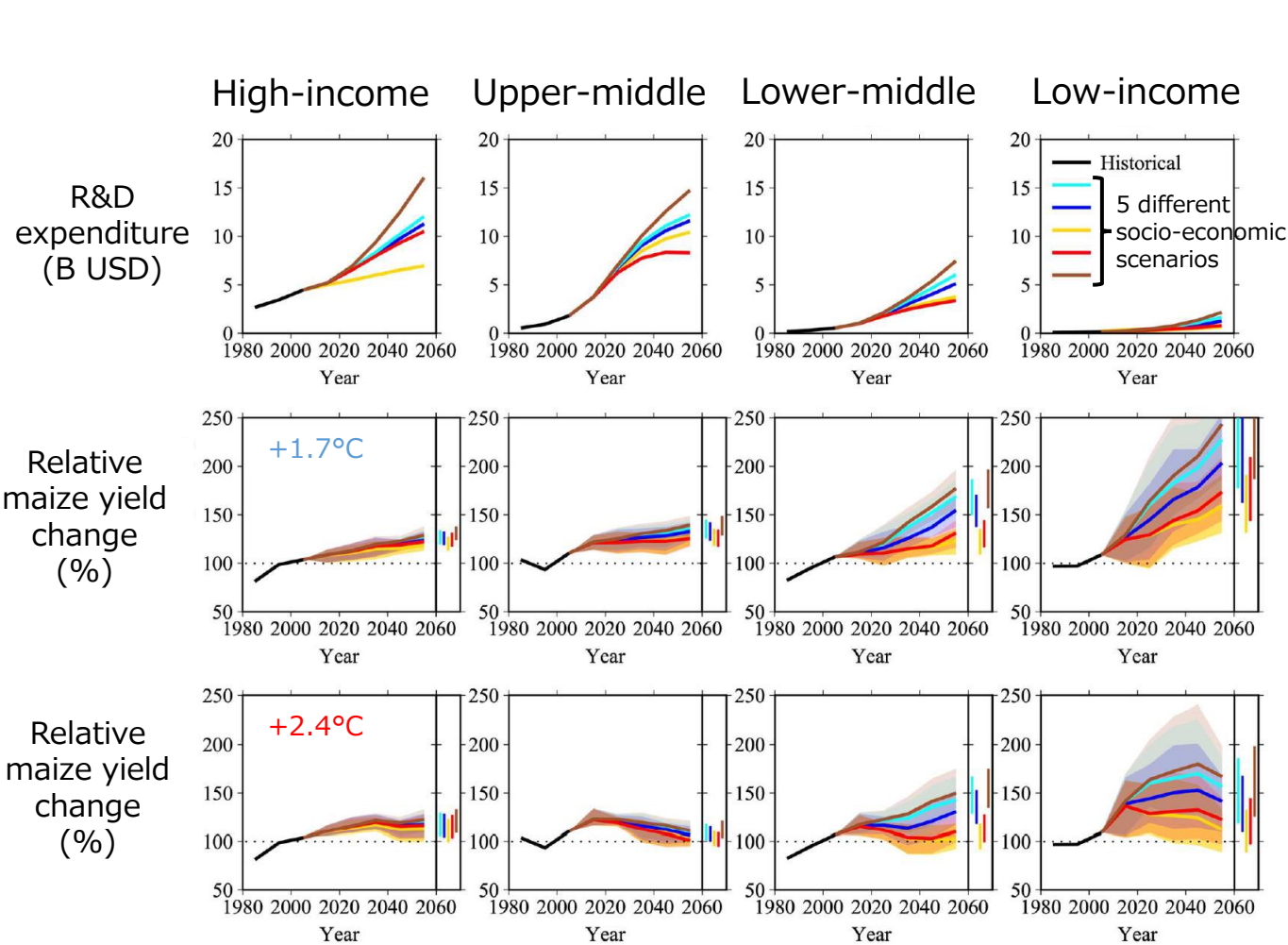
Global production loss associated with climate change for the 1981-2010 accounts for 42.4\$B per year



Global mean surface temperature increase for 2006–2015: **0.87 °C** relative to 1850–1900 (IPCC SR1.5 SPM)

Crop	Average yield impact (%)	Production loss (USD Billion)
Maize	-4.1	22.3
Soybean	-4.5	6.5
Rice	-1.8	No significant yield impact
Wheat	-1.8	13.6

Yield growth per unit investment in R&D would be lower under high warming than lower warming scenario

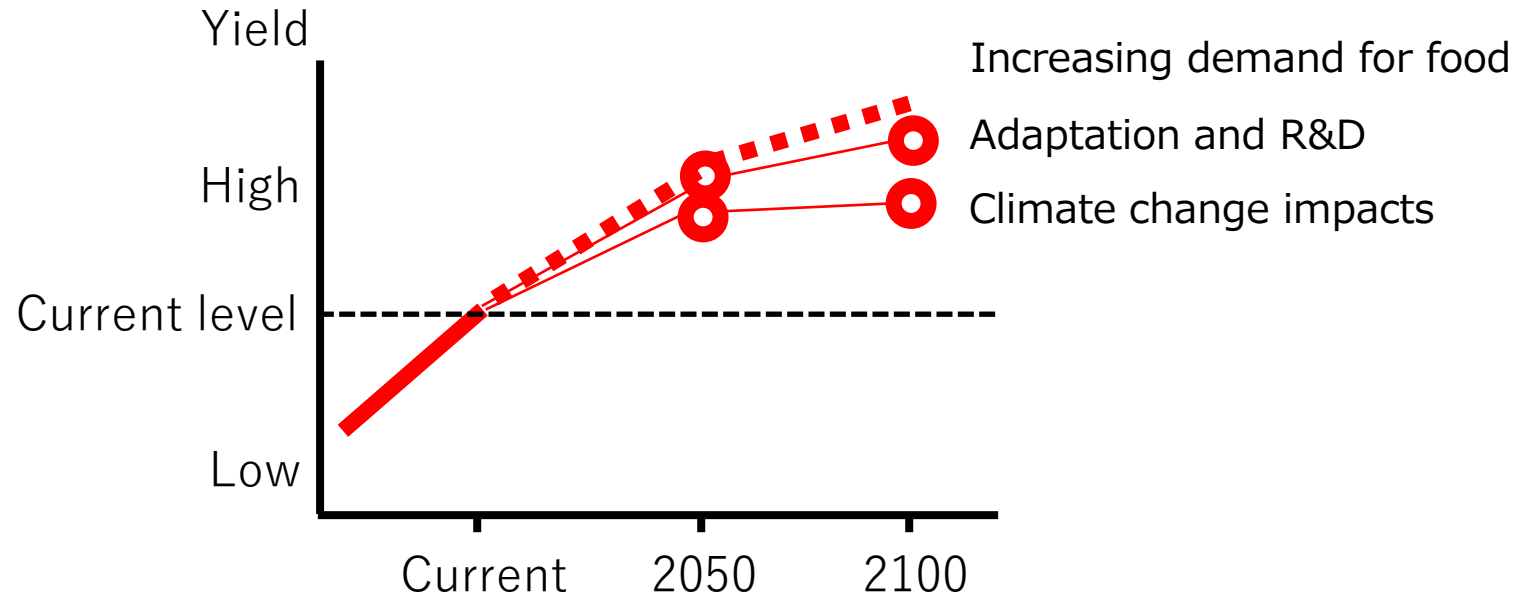


Change in corn yield per \$1 billion of agricultural R&D investment

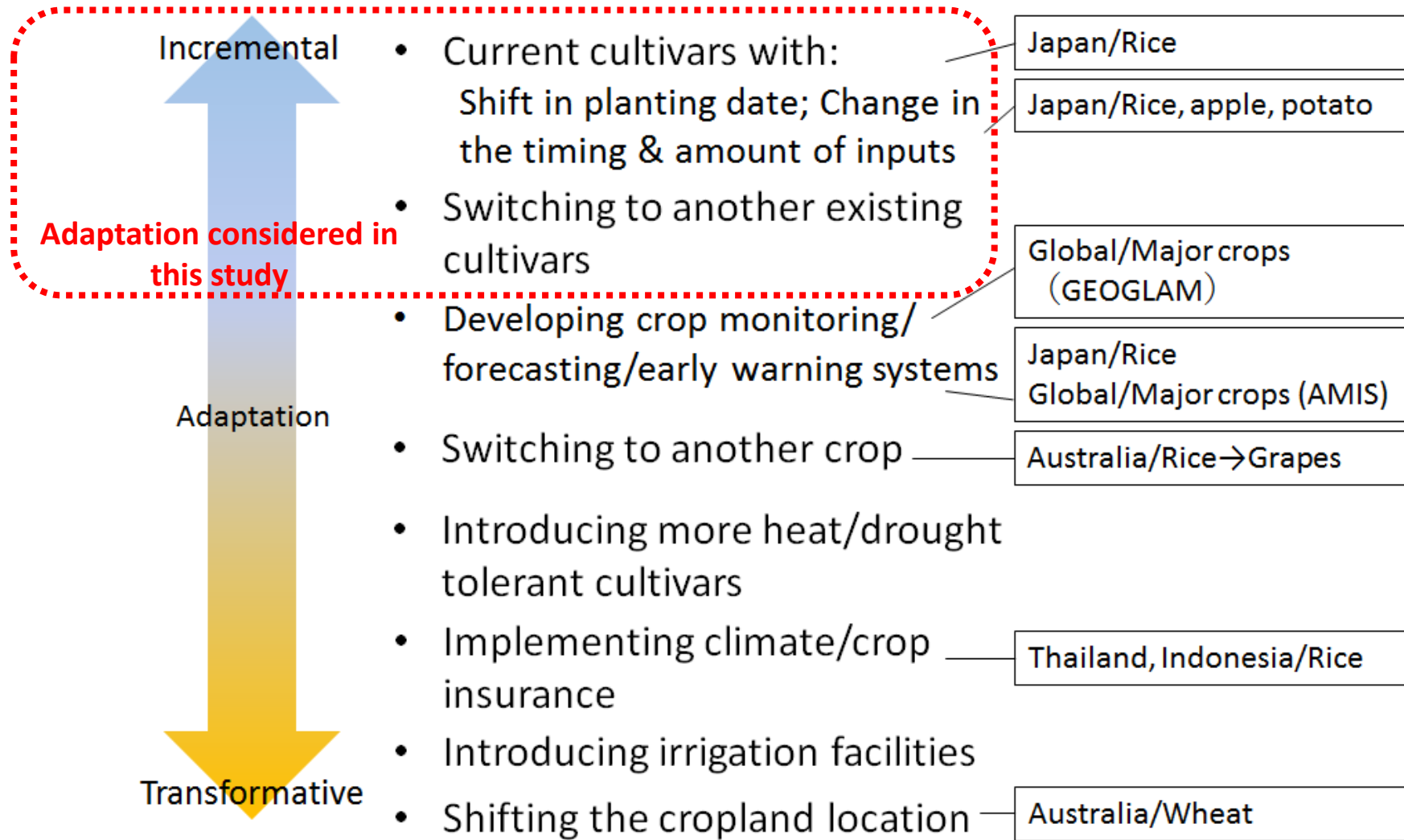
Income group	+1.7°C	+2.4°C
Low-income	27.2%	15.6%
Lower-middle	6.6%	1.7%
Upper-middle	1.0%	0.6%
High-income	0.1%	-0.2%

Current average yield=100%
 Temperature changes are for 2041–2060 relative to 1850–1900

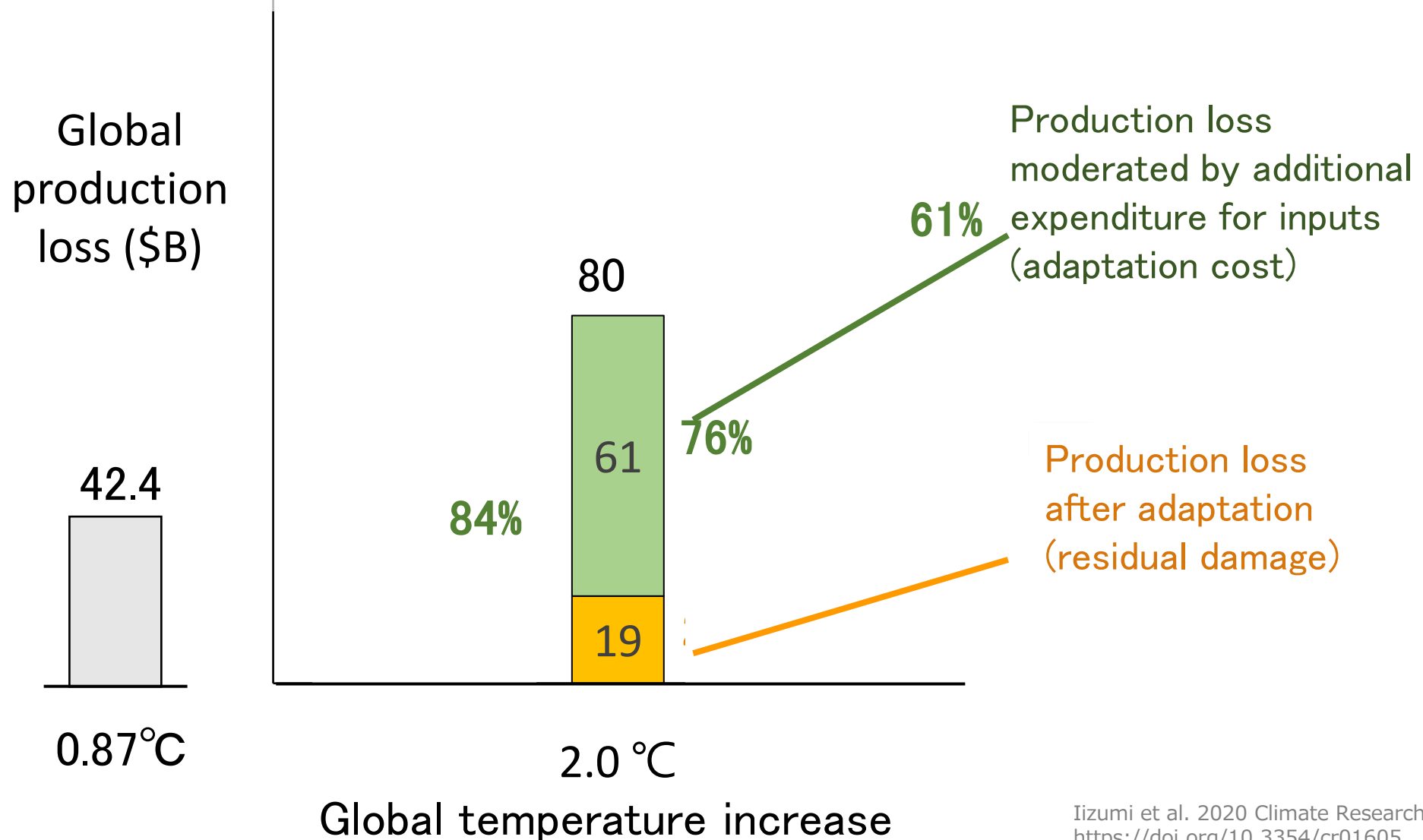
Yield growth under climate change and effects of adaptation and R&D



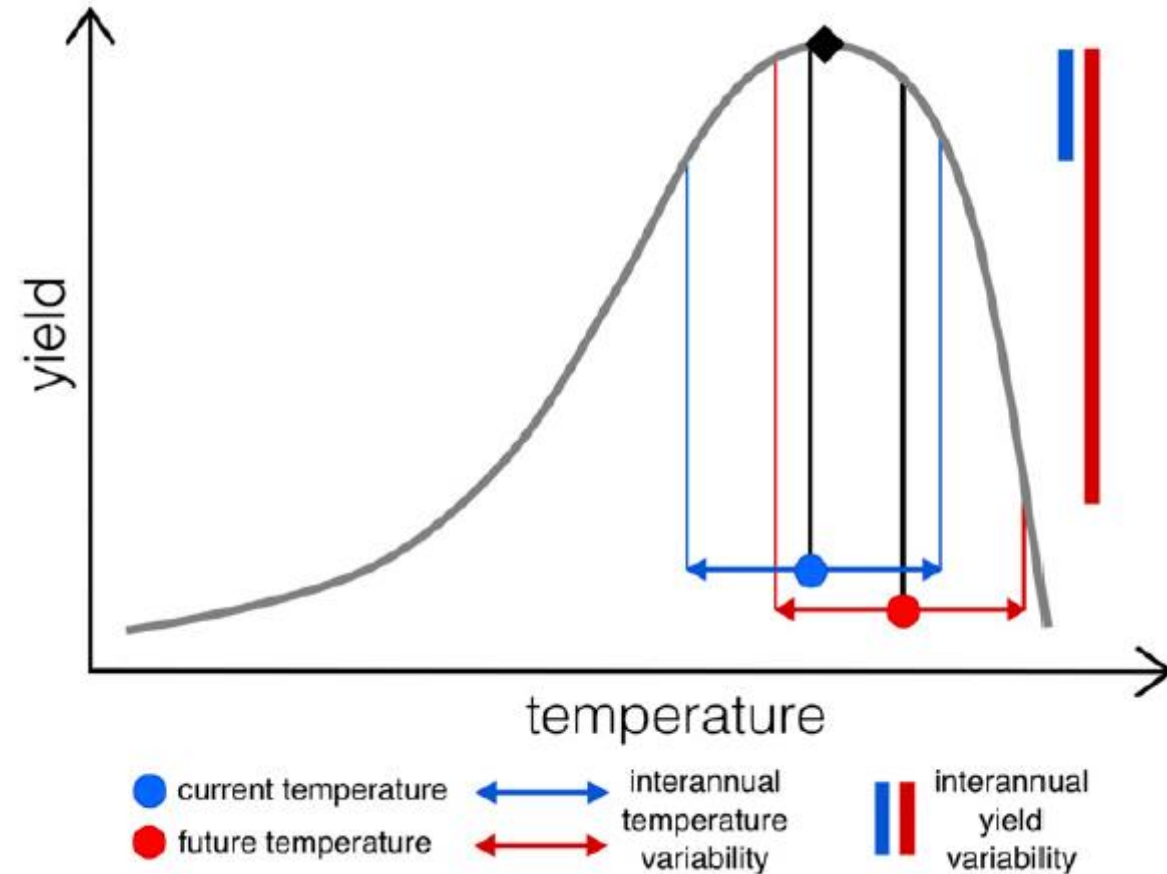
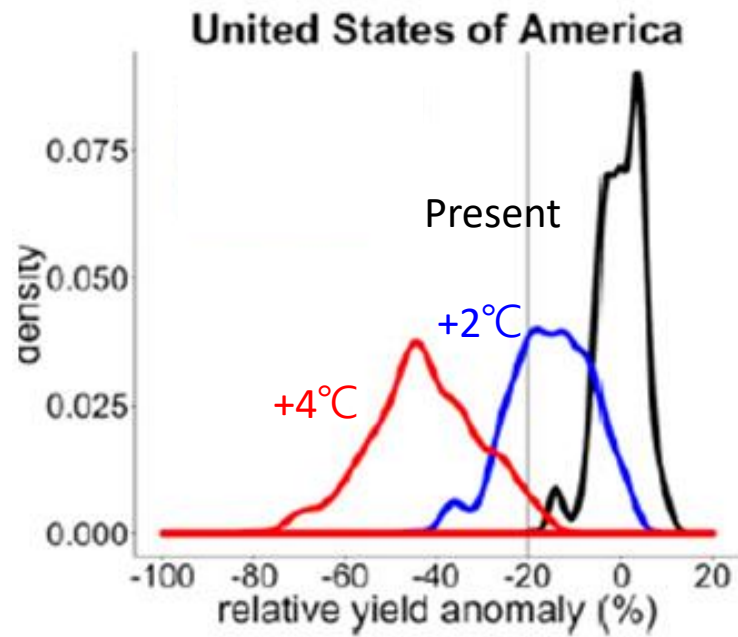
Adaptation and R&D have being proceeded



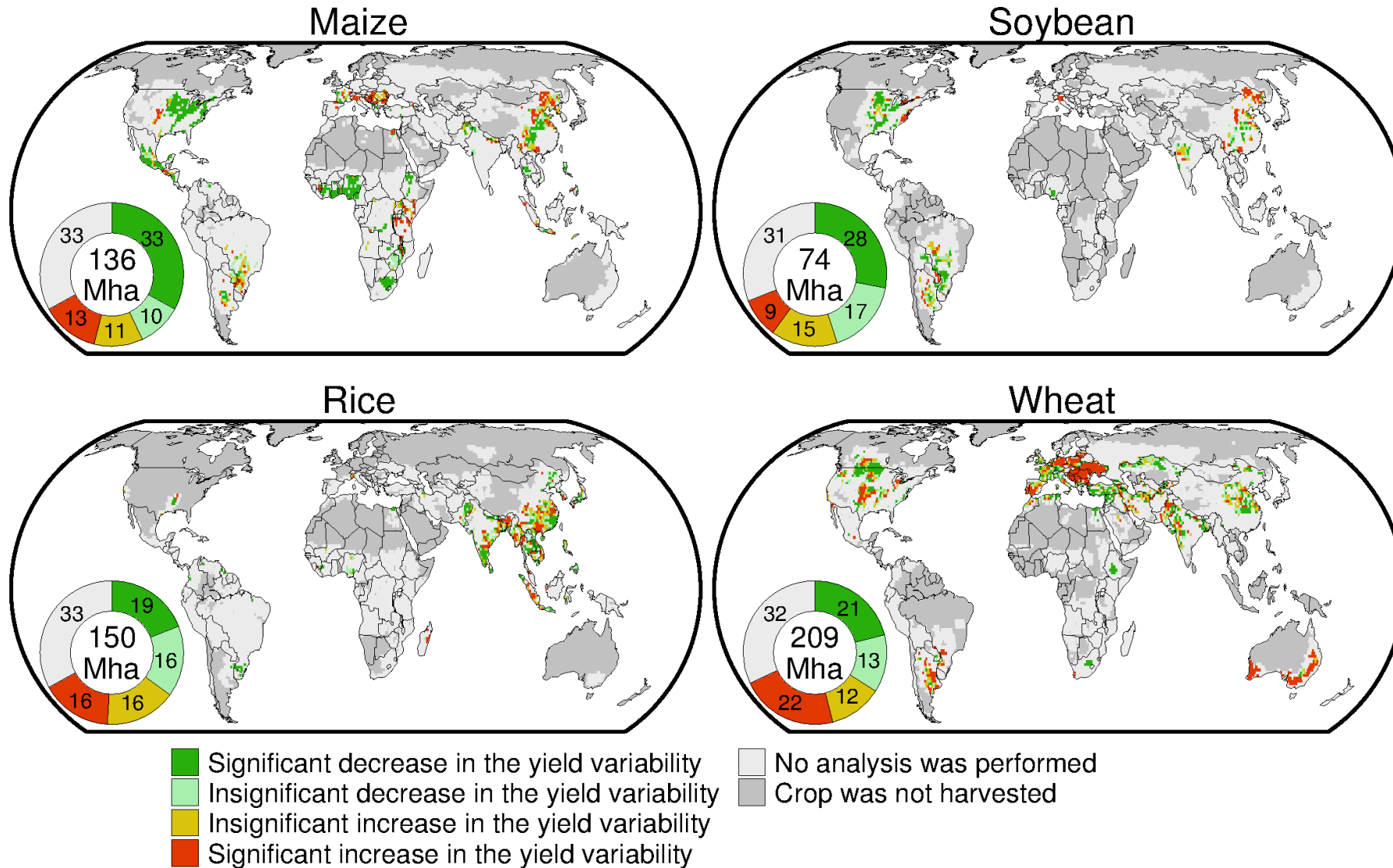
With a 2 °C warming, global production loss is \$80 B per year. Of this amount, \$61 B can be avoided by adaptation, with residual damage of \$19 B that cannot be avoided



Warming would also worsen yield stability



Yields became unstable in 16.6% of the global harvested area between 1981 and 2010



Update

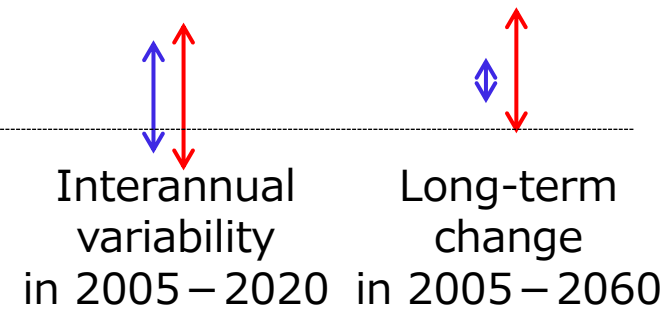
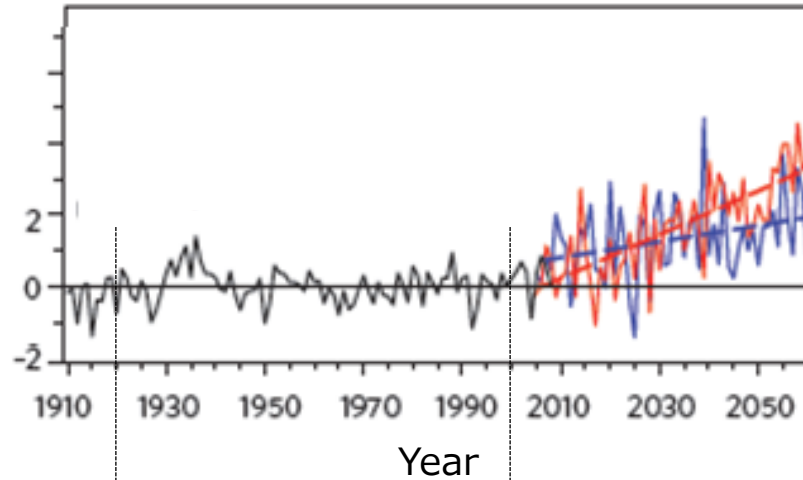
- Between 2000-2019, yields became unstable in 20% of the global harvested area.
- Climate change contributed to half of this change in yield stability.
- Adaptation and R&D to maintain and increase yield stability may be lagged behind the negative impacts of climate change.

Iizumi et al. 2025 PNAS Nexus
<https://doi.org/10.1093/pnas/nexus/pgaf099>

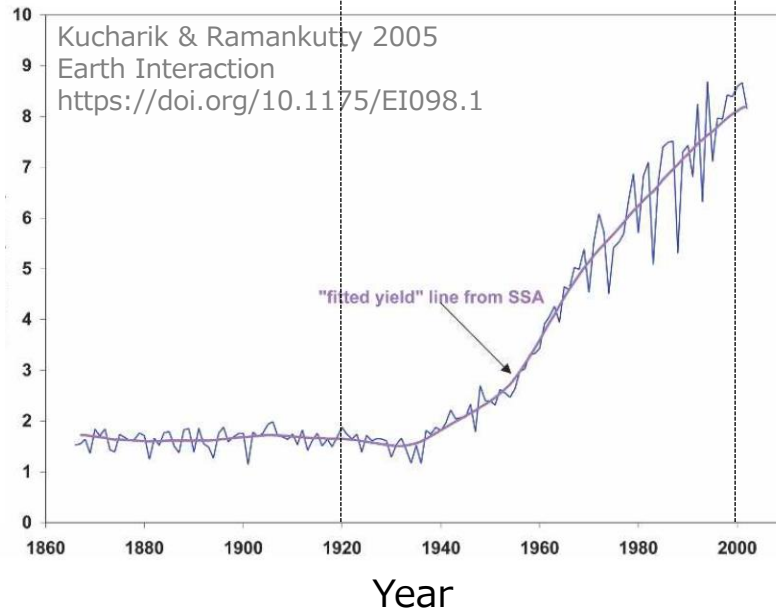
Year-to-year variations in the growing season climate are testbed for adaptation measures

Deser et al. 2012 Nature Climate Change <https://doi.org/10.1038/nclimate1562>

U.S. average summer temperature anomaly (°C)

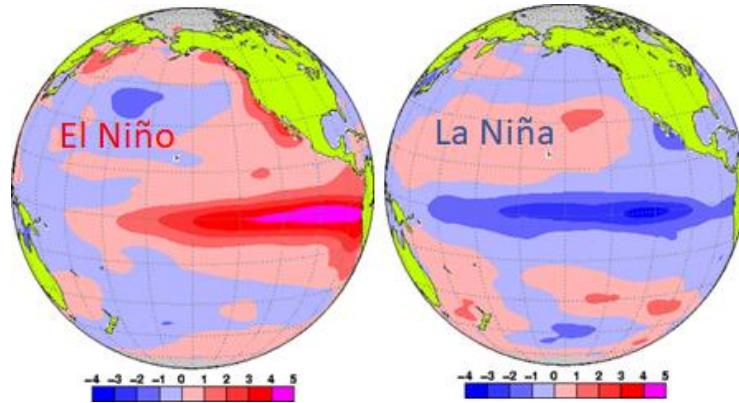


U.S. average corn yield (t/ha)



- The amplitude of interannual temperature variation is generally larger than long-term change in mean temperature.
- Responding effectively to seasonal climate-induced production shocks will increase the capacity of stakeholders in agri-food systems to adapt to climate change.

Source: Japan Meteorological Agency



<https://openknowledge.fao.org/server/api/core/bitstreams/1794e261-d1b7-42fd-8939-1fb765b77571/content>

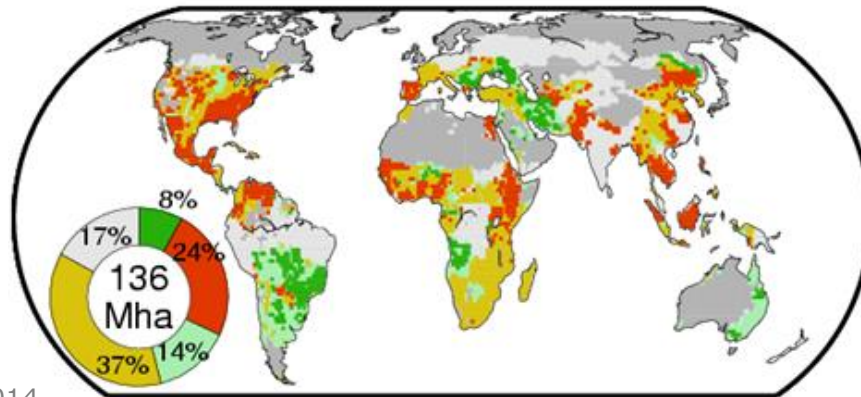
Food and Agriculture Organization of the United Nations

2015–2016 El Niño

Early action and response for agriculture, food security and nutrition



Maize yield (El Niño minus neutral)



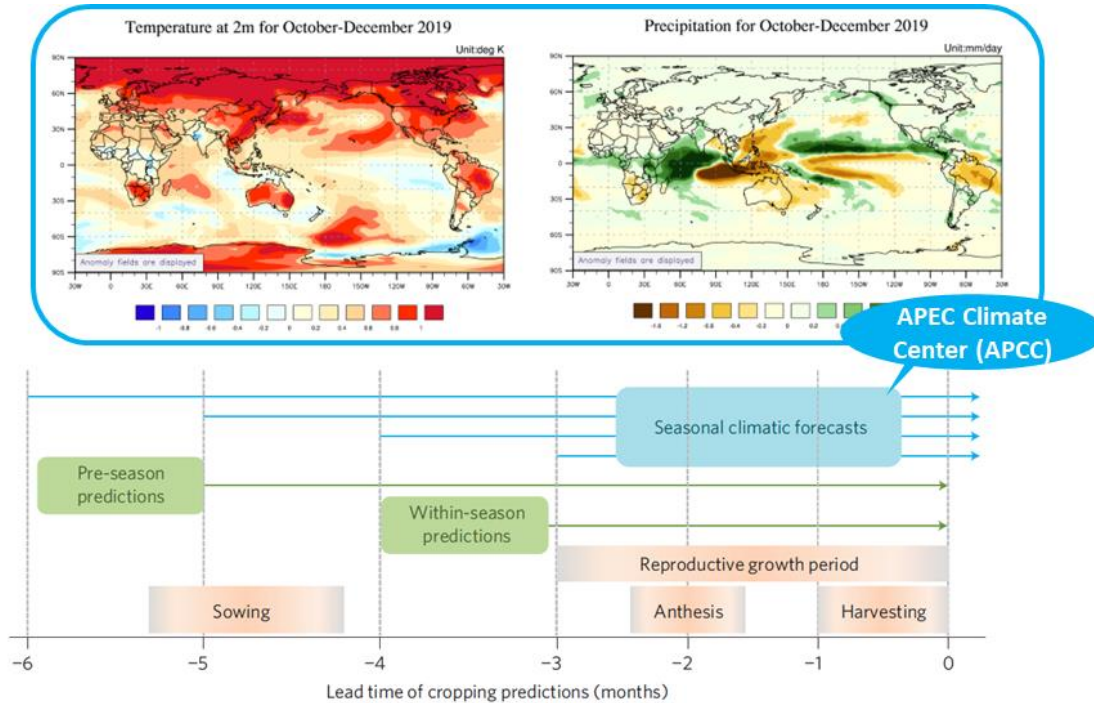
- Significant positive impacts
- Insignificant positive impacts
- Significant negative impacts
- Insignificant negative impacts
- No yield data are available
- Non-cropland

Iizumi et al. 2014
Nature Communications
<https://doi.org/10.1038/ncomms4712>

Monthly Oversea Food Demand & Supply Report

In June 2014, JMA predicted the occurrence of El Niño. In July, NARO provided yield forecasts (1 to 6 months prior to harvest) to MAFF

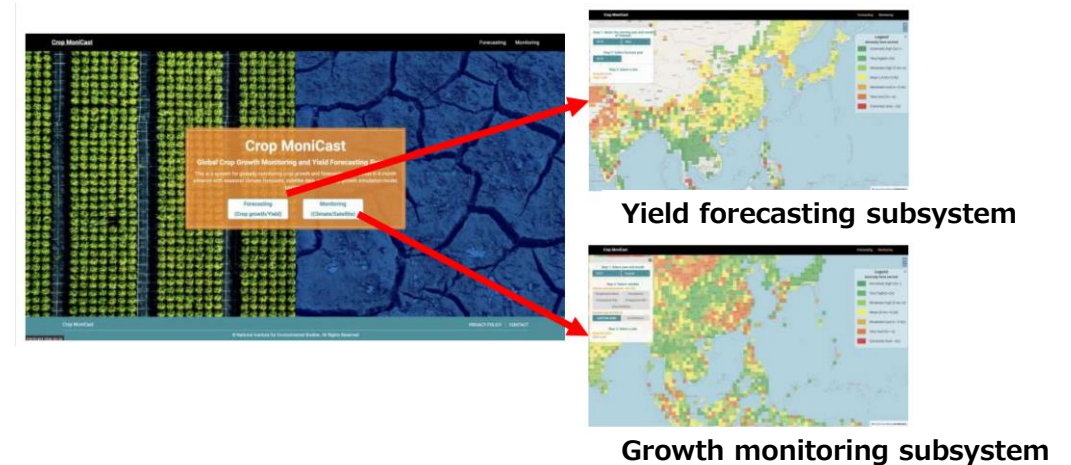
APCC-NARO Joint Crop Forecasting yield predictions 3 to 6 months before harvest



APCC began providing global crop yield forecast information through its official website to government and public institutions in APEC member economies starting in October 2024.

<https://apcc21.org/?lang=en>
 > Climate Information Services
 > Applied Forecast

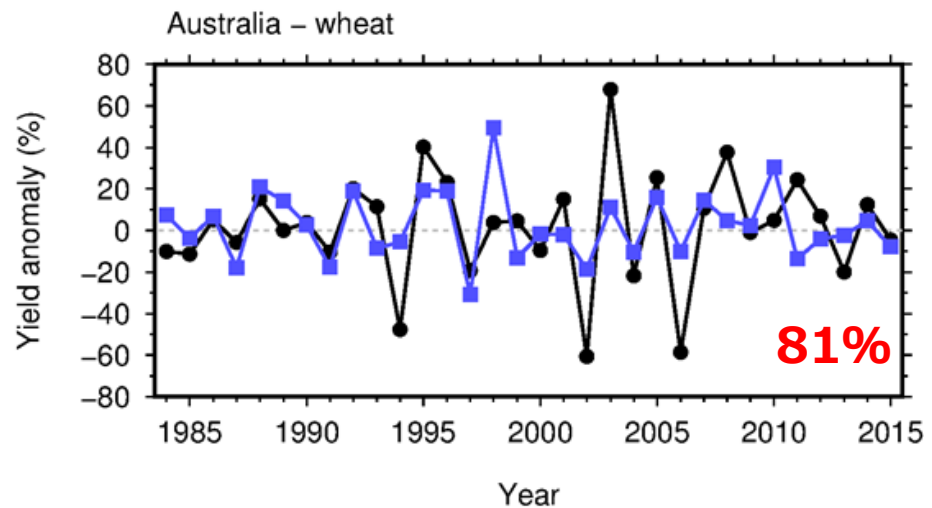
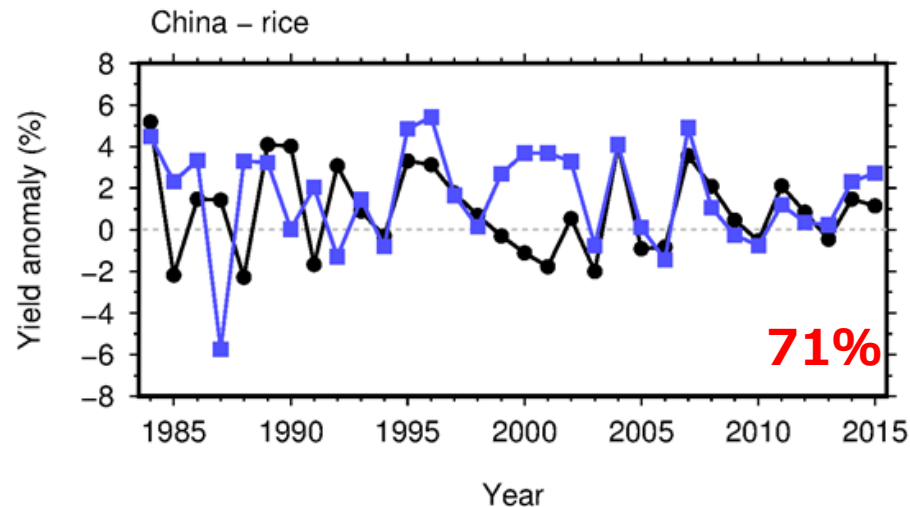
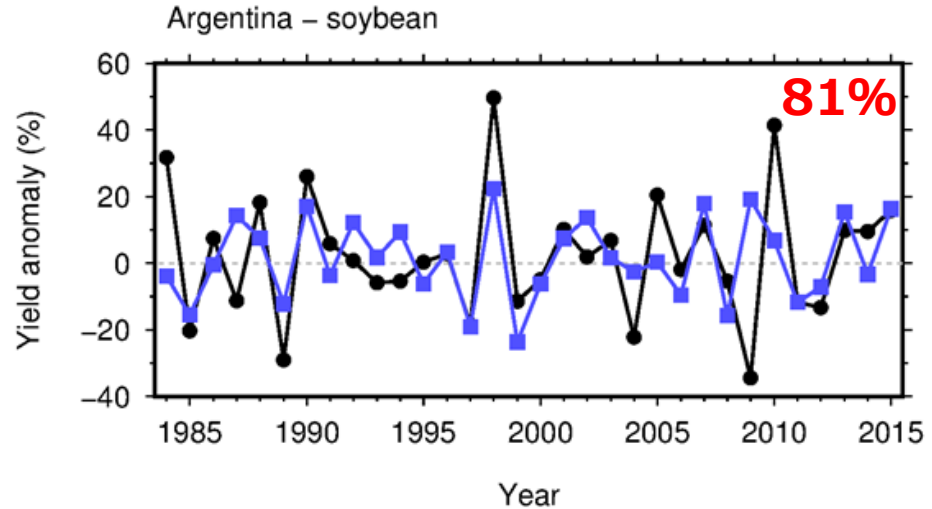
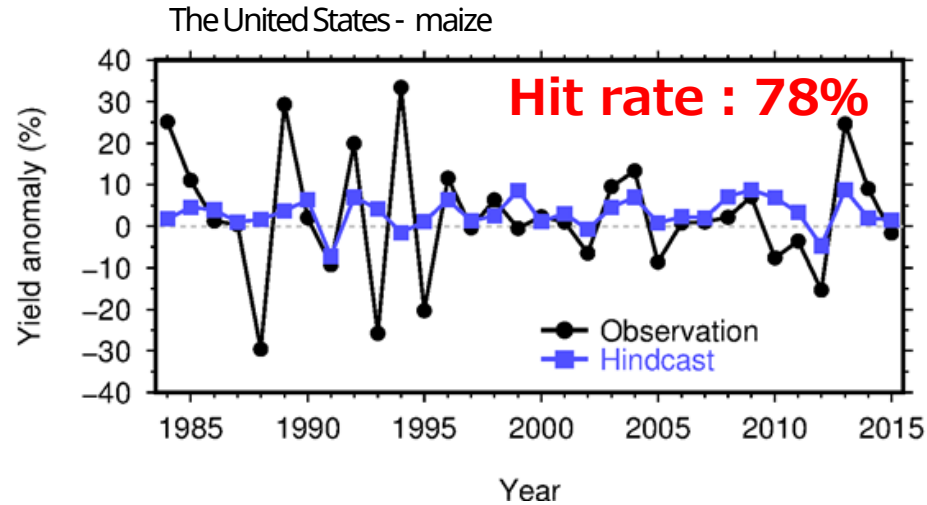
CropMoniCast Global crop monitoring and forecasting system @ Center for Climate Change Adaptation, NIES



NARO granted permission to use its program to generate reanalysis-forecast hybrid meteorological data for CropMoniCast

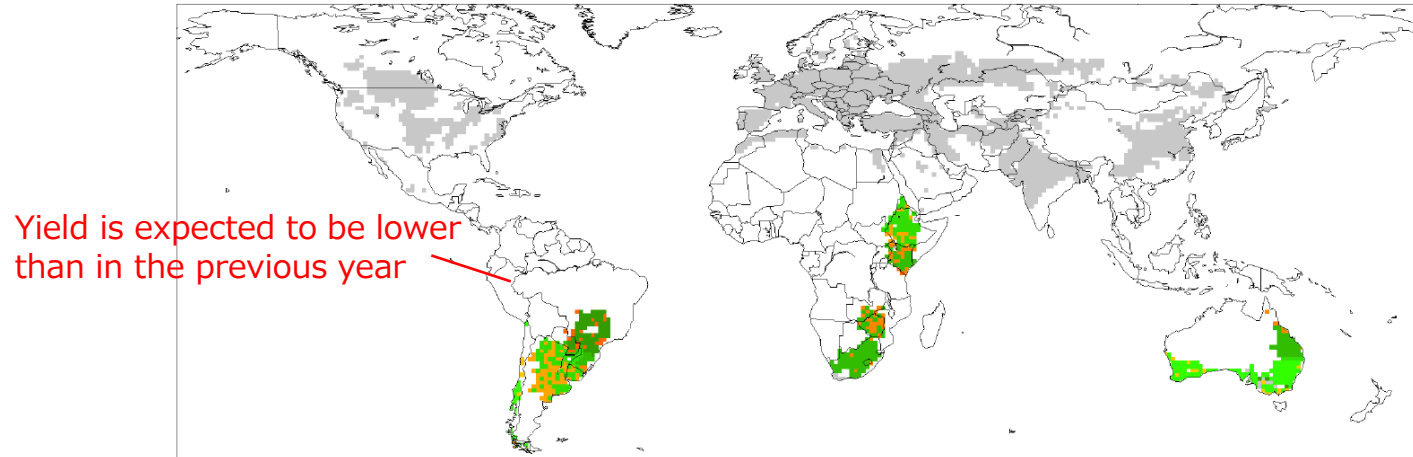
MEXT (in Japanese)
https://www.mext.go.jp/content/20230315-mxt_uchukai01-1406357_00004_5.pdf

Yield variability predicted at 3-month before the harvesting

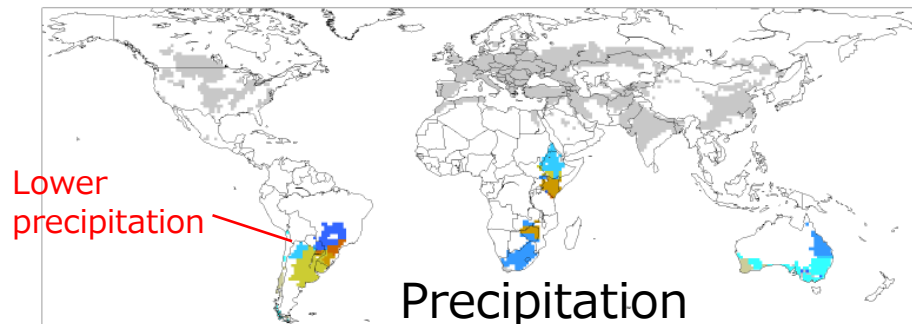


Example: wheat prediction issued July 1, 2022

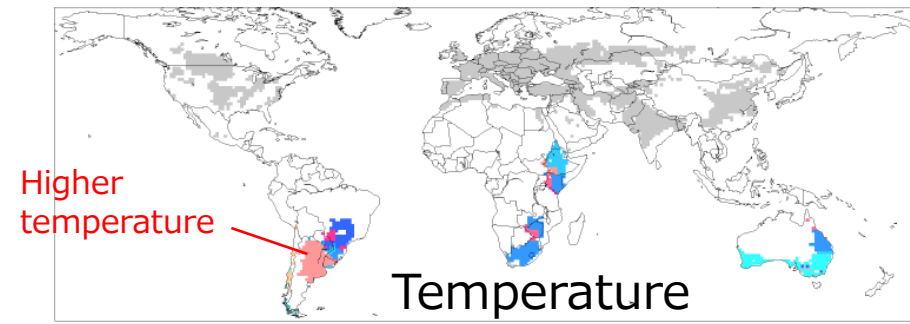
Wheat yield for coming harvest from Sep 2022 to Dec 2022 predicted using APCC MME (SCM) forecasts from Jul 2022 to Dec 2022



Lower-than-previous-year: 3-month lead (dark orange), 4-month lead (orange), 5-month lead (light orange), 6-month lead (yellow)
 Higher-than-previous-year: 3-month lead (dark green), 4-month lead (green), 5-month lead (light green), 6-month lead (yellow-green)
 Other legends: No crop forecast is available (grey), Wheat is rarely produced (white)



Drier-than-previous-year: 3-month lead (dark blue), 4-month lead (blue), 5-month lead (light blue), 6-month lead (very light blue)
 Wetter-than-previous-year: 3-month lead (dark blue), 4-month lead (blue), 5-month lead (light blue), 6-month lead (very light blue)
 Other legends: No crop forecast is available (grey), Wheat is rarely produced (white)

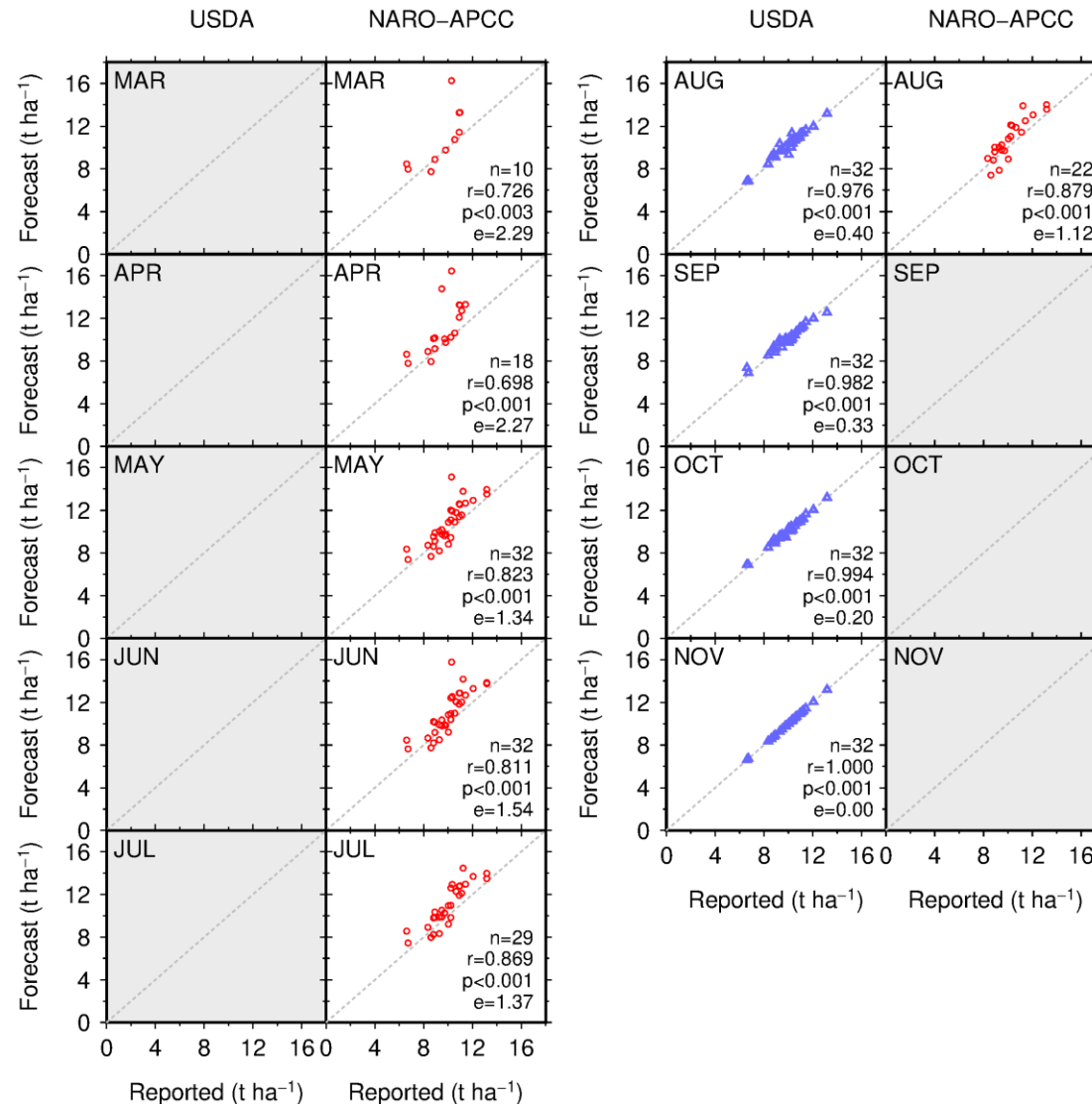


Cooler-than-previous-year: 3-month lead (dark blue), 4-month lead (blue), 5-month lead (light blue), 6-month lead (very light blue)
 Warmer-than-previous-year: 3-month lead (dark red), 4-month lead (red), 5-month lead (light red), 6-month lead (orange)
 Other legends: No crop forecast is available (grey), Wheat is rarely produced (white)

Evaluation of APCC-NARO forecasts for the 2019 season

Yield forecast for the 2019–season maize for the US

Iizumi et al. 2021 Weather and Forecasting
<https://doi.org/10.1175/WAF-D-20-0149.1>



- The 2019 season average yields for 32 maize-producing states in the US.
- Two forecasts: USDA and NARO-APCC.
- NARO-APCC forecast starts March and ends August.
- NARO-APCC forecast enables users to have a plausible estimate before a precise forecast becomes available.

scientific data

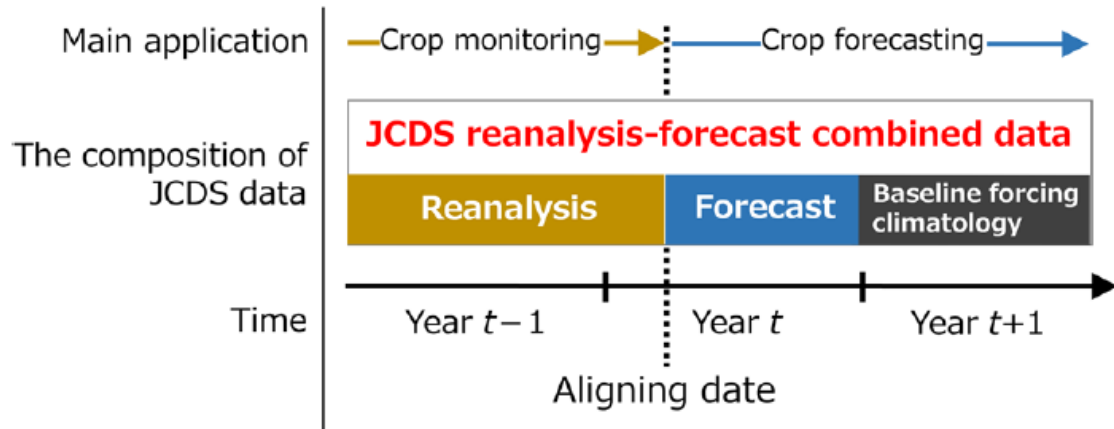
OPEN

DATA DESCRIPTOR

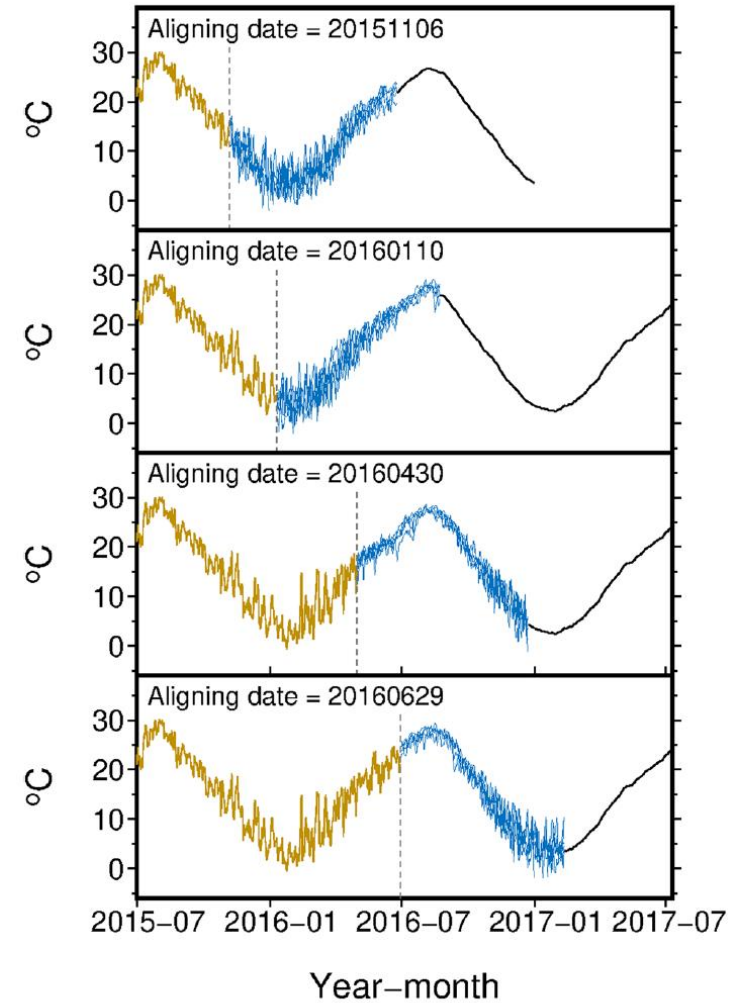
A hybrid reanalysis-forecast meteorological forcing data for advancing climate adaptation in agriculture

Toshichika Iizumi¹, Takahiro Takimoto¹, Yoshimitsu Masaki¹, Atsushi Maruyama¹, Nobuyuki Kayaba², Yuhei Takaya³ & Yuji Masutomi⁴

<https://doi.org/10.1038/s41597-024-03702-5>



Tochigi, Japan (lon=139.67, lat=36.25)



— Reanalysis
— Forecast (5-member)
— Baseline forcing climatology

Thailand's drought weakens agricultural outlook

Thailand | Agriculture

Economic News

Text size + -

9 May 2016

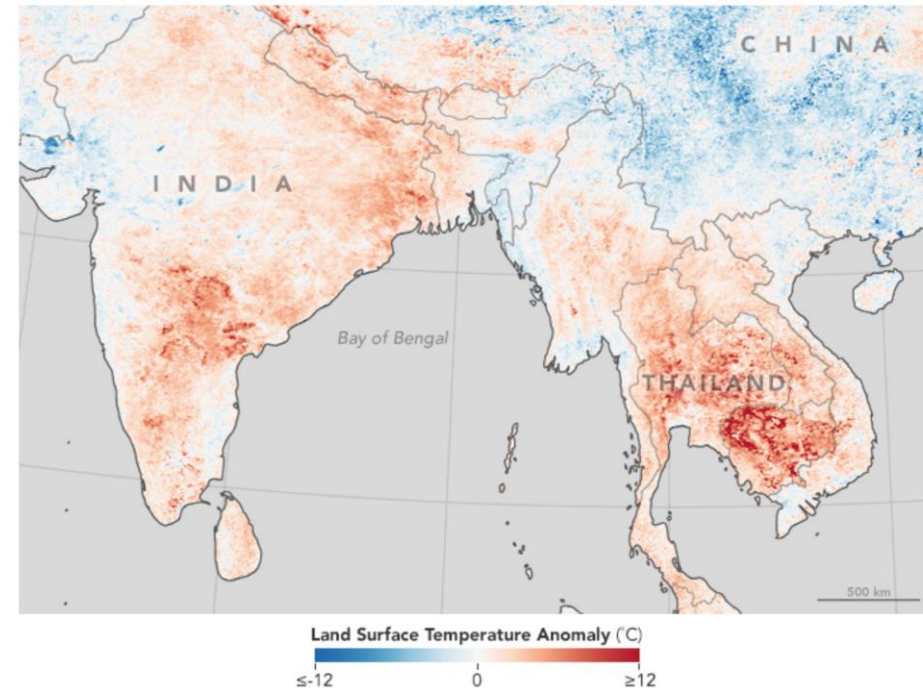


Drought conditions caused by the El Niño weather pattern have seen output ease in Thailand's agricultural sector, with water shortages predicted to slow economic growth in 2016.

In early April the government declared 74 of the country's 77 provinces as either drought-stricken or drought-affected areas.

<https://oxfordbusinessgroup.com/news/thailand%E2%80%99s-drought-weakens-agricultural-outlook>

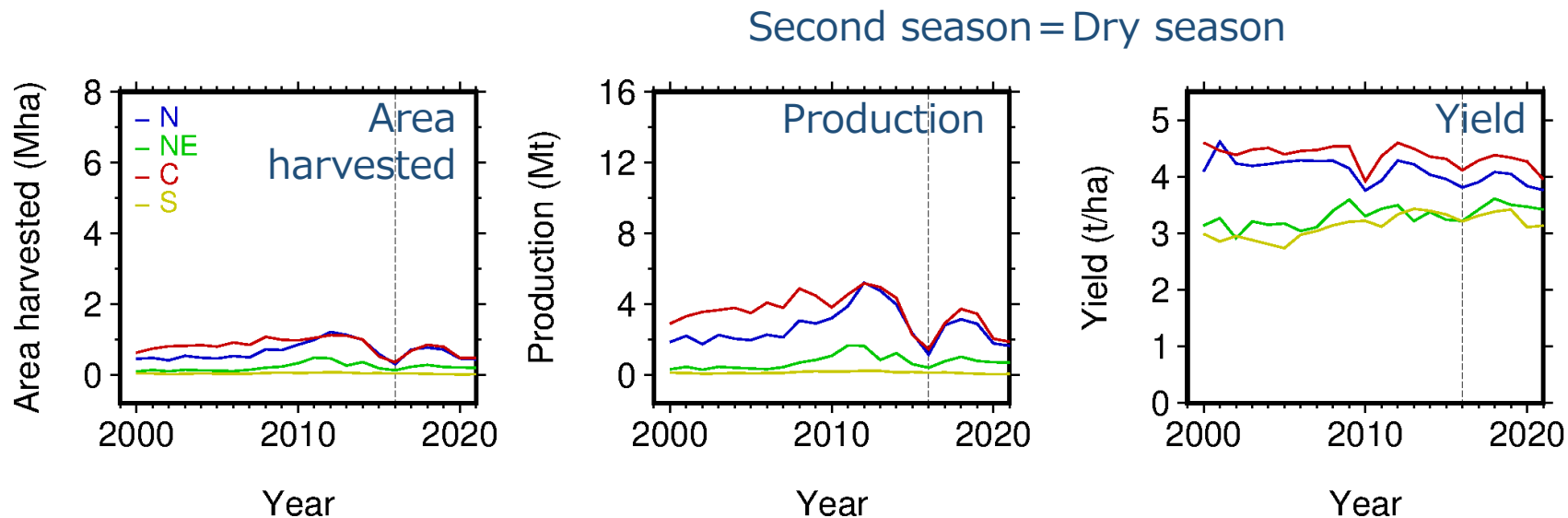
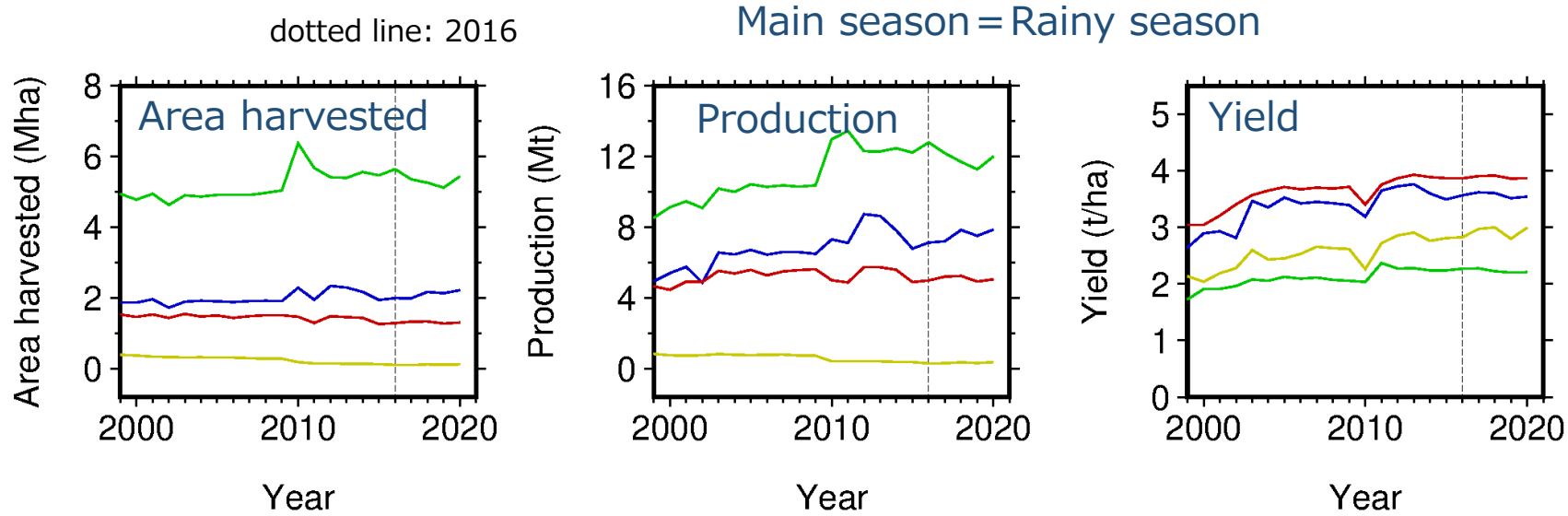
Heat Wave Hits Thailand, India



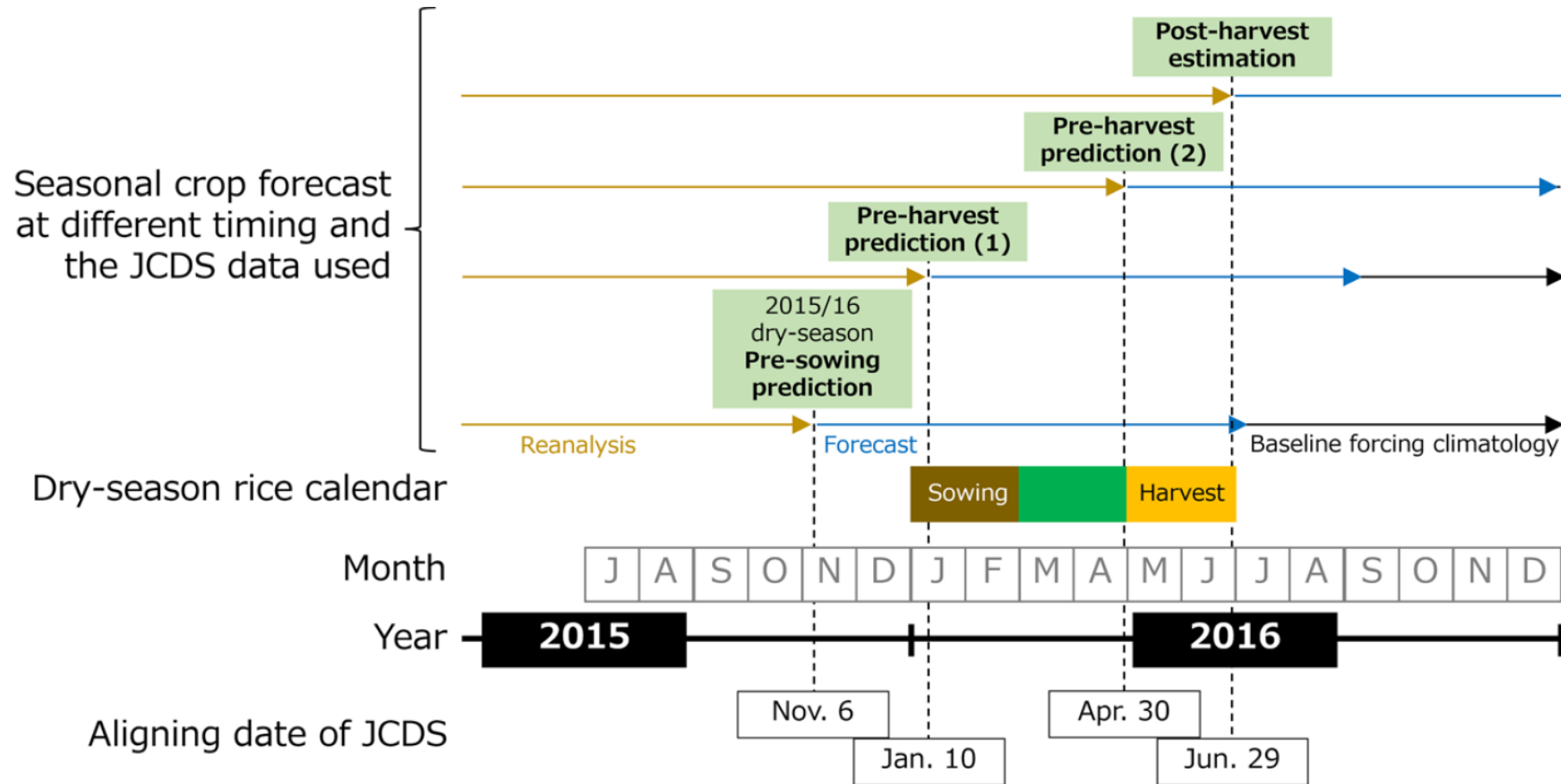
April 2016

<https://earthobservatory.nasa.gov/images/87981/heat-wave-hits-thailand-india>

Rice statistics for 2015/16 season

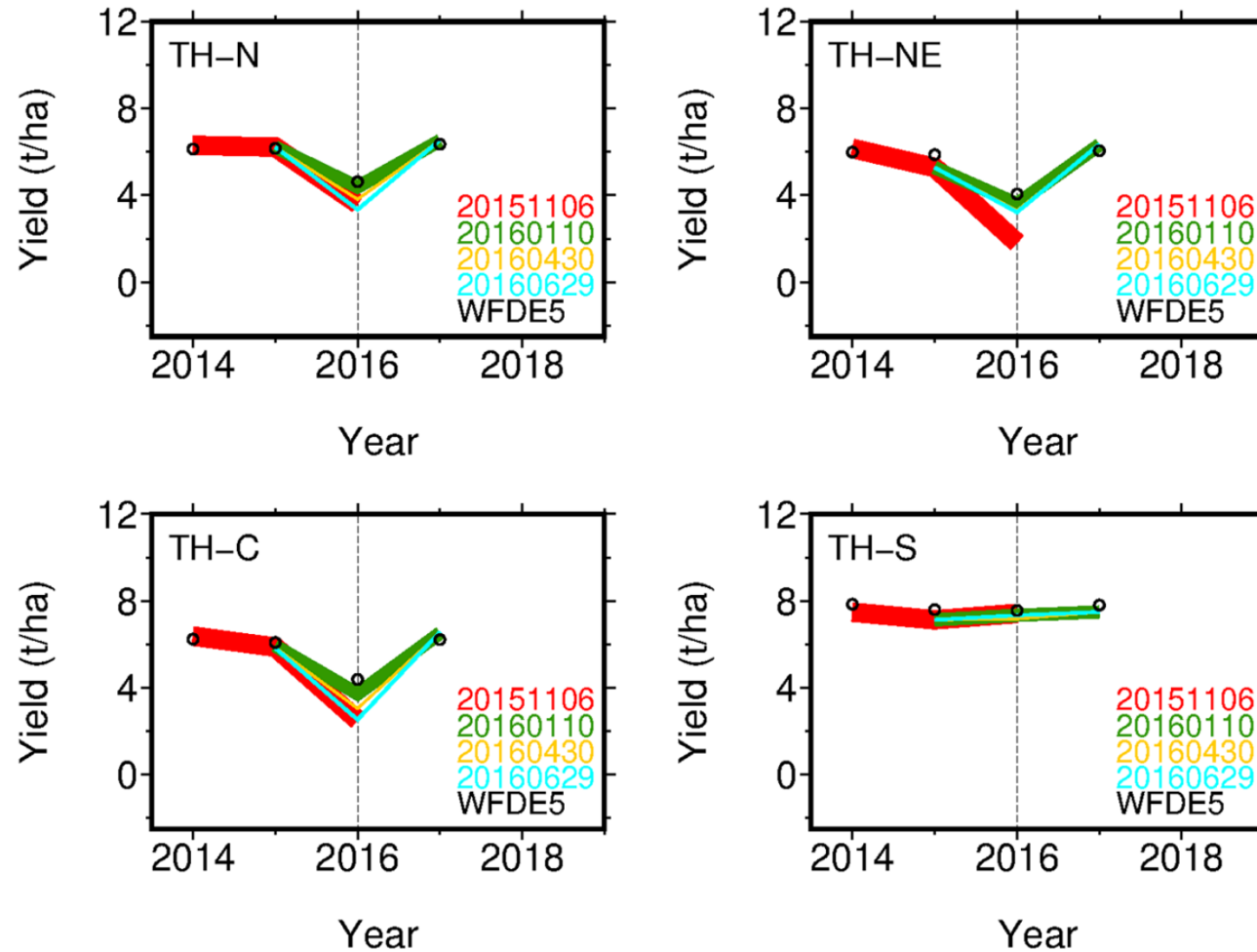


Pre-sowing and pre-harvesting yield predictions



The 2015/16 dry season rice in Thailand

Pre-sowing and pre-harvesting prediction of heat impact in the 2015/16 season



“The dry season rice for 2015/16 would see a significant drop in yield in northern (N), central (C) and northeastern parts (NE), with no impact in southern part (S) of Thailand” could be predicted in the prediction on October 7, 2015, which is equivalent to three months before sowing.

- The impacts of climate change on yield growth and stability have already become detectable.
- It is likely difficult to offset the negative impacts of climate change with simple adaptation measures alone, and major changes will need to be considered if warming continues.
- Although R&D plays a key role, the outcomes of agricultural R&D could be reduced at higher levels of warming.
- Increasing preparedness for climate-induced production shocks in the ongoing season is a key step toward adaptation.
- In support of this effort, the use of crop forecasts in agri-food systems has been promoted.