Global dataset of historical yields: development, improvement and application

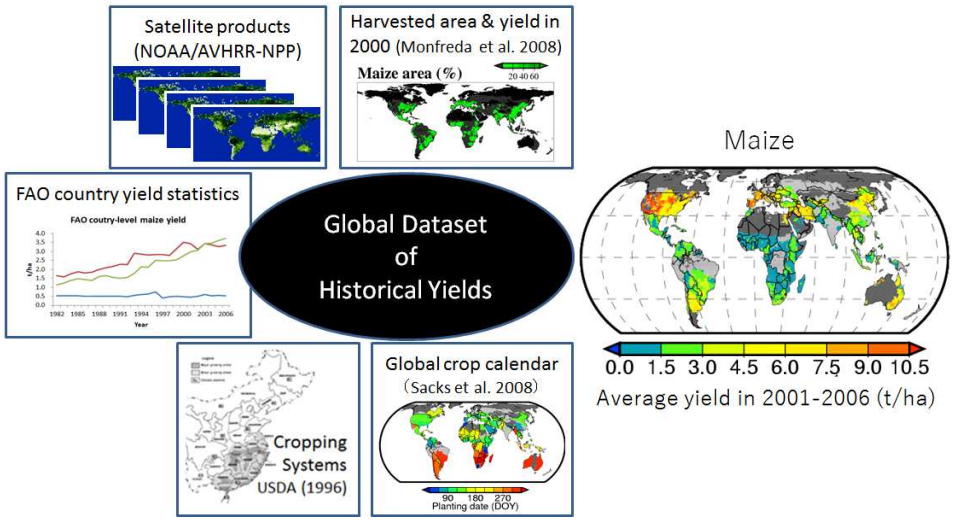
Toshichika Iizumi

National Agriculture and Food Research Organization (NARO), Japan

Purposes of today's talk

- National yield statistics available from FAO database are most reliable source of information on crop yield.
- However, a geographically-detailed yield data are essential to study climate-yield relationships (especially, climate extremes).
- Earlier gridded yield datasets (M3-Crops and MapSPAM) offer no time series data (average yield circa 2000 is available).
- Currently, only two datasets offer the information on global, gridded, historical yields
  1) Ray et al., 2012, Nature Communications, doi:10.1038/ncomms2296 (not publicly open)
  2) Iizumi et al., 2014, Global Ecology and Biogeograhy, doi:10.1111/geb.12120 and updates (publicly available and known as Iizumi dataset)
- This talks aims to provide a brief overview on the development, improvement and application of Iizumi datasets.

Global dataset of historical yields (GDHY)



Iizumi et al., 2014, Global Ecology and Biogeography, doi:10.1111/geb.12120

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Improvements to GDHY datasets

	GDHY1.0	GDHY1.1	GDHY1.2	GDHY1.3
Reference	Iizumi et al. (2014)	Iizumi & Ramankutty (2016)	Iizumi et al. (2018)	In preparation
Period	1982–2006	1981–2011		2000-2016
Resolution	1.125°		0.5° (0.083/1/2)	0.5°
Crops	Maize (major/secondary), soybean, rice (major/secondary), wheat (winter/spring)			
Yield statistics	FAO national yield statistics	Same as the version 1.0, but errors in earlier version were fixed (e.g., Democratic Republic of the Congo)		
Satellite products	2nd generation GIMMS 0.073° bi-monthly NDVI data. The NDVI data were aggregated to 1.125° using harvested area maps and then used to estimate LAI and FPAR at 1.125° resolution. LAI and FPAR were used to derive crop-specific NPP.	3rd generation GIMMS 0.083° bi-monthly LAI and FPAR data. Crop-specific NPP at 0.083° resolution was estimated from LAI and FPAR.		MOD15A2H LAI and FPAR data (1-km 8-day composite data were processed to be 0.083° and daily resolution data)
Radiation	JRA-25 reanalysis			JRA-55 reanalysis
Harv. area	M3-Crops (Monfreda et al., 2008)			
Calendar	SAGE (Sacks et al., 2010)			
Production share by season	USDA (1994)			

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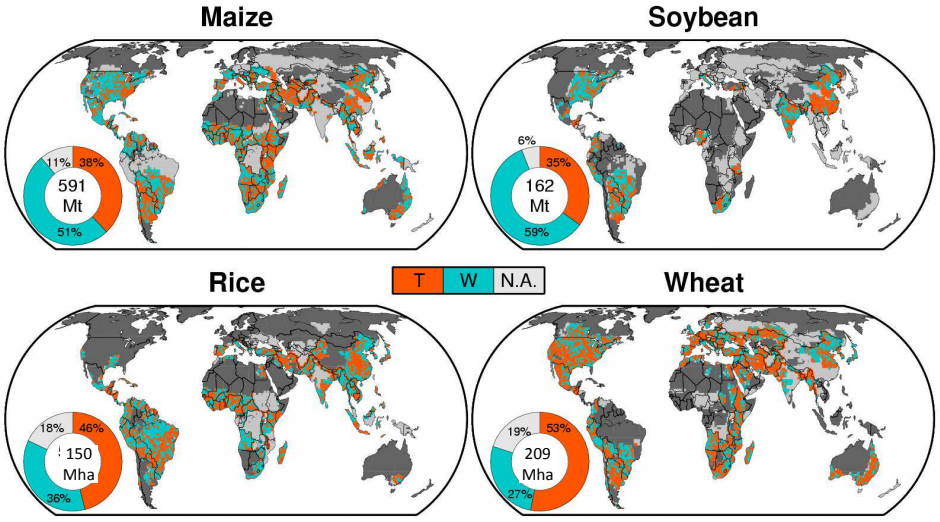
Main climatic driver of yield variability



Temperature-driving / Soil moisture-deriving

Iizumi et al., 2013, Nature Climate Change, doi:10.1038/NCLIMATE1945

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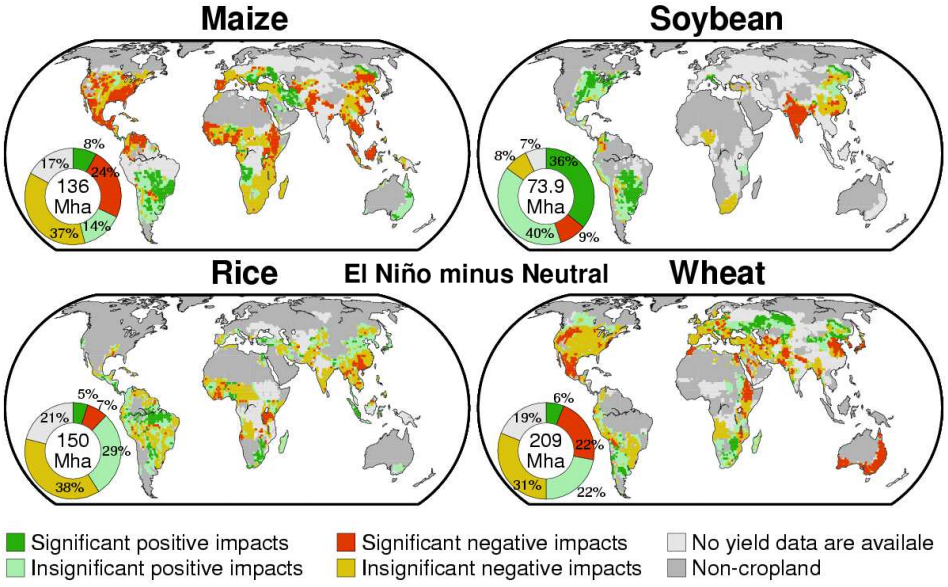
Yield impacts associated with ENSO



Iizumi et al., 2014, Nature Communications, doi:10.1038/ncomms4712

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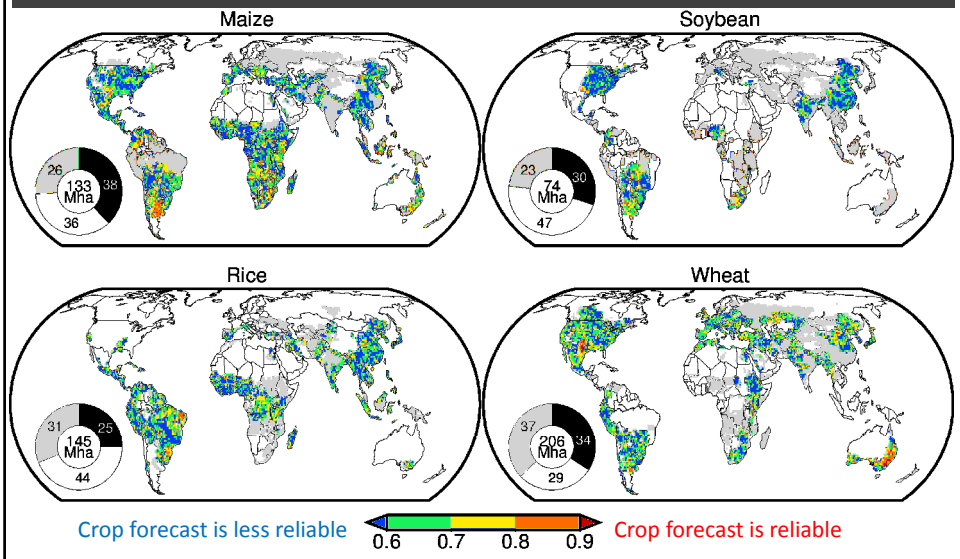
Basis in developing global crop forecasting services



Crop forecast is less reliable 0.6 0.7 0.8 0.9 Crop forecast is reliable

■ Good skill (ROC is significant at 10%)
□ No skill (ROC is not significant)
No data available

ROC score

Iizumi et al., 2018, Climate Services, https://doi.org/10.1016/j.cliser.2018.06.003

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Validation data in global gridded crop model intercomparison

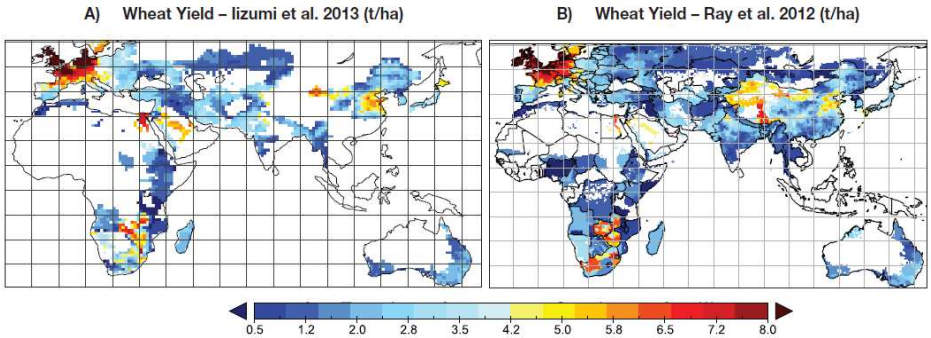

Figure 4. Example of historical evaluation data for year 2000 wheat yields from **(a)** Iizumi et al. (2013) (at 1.125° spatial resolution) and **(b)** Ray et al. (2012) (aggregated from 5 arc minutes to 0.5°).

Elliott et al., 2015, Geoscientific Model Development, doi:10.5194/gmd-8-261-2015

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Uncertainties associated with different yield datasets

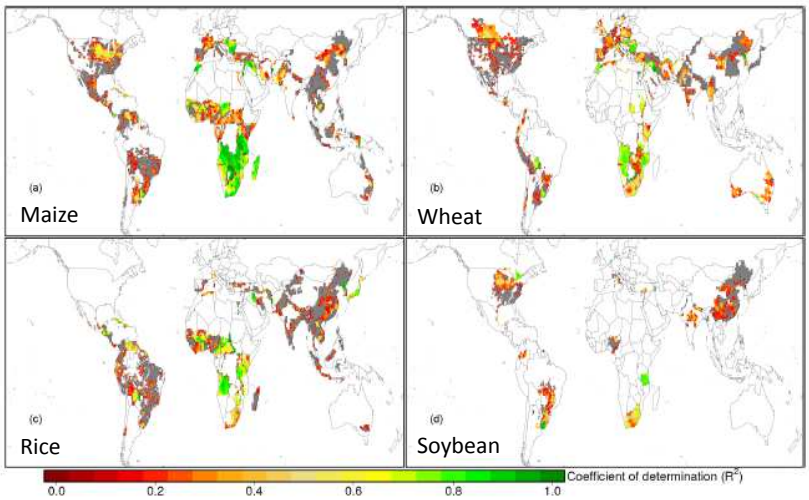

Figure 9. Analysis of time series correlation between the two gridded yield reference data sets after removing trends via a moving average (see methods). Gray areas depict areas where there is no statistically significant correlation between the two data sets ($p > 0.1$), white areas have no yield data for that crop in at least one of the two data sets. Panel **(a)** shows coefficients of determination (R^2) for maize, **(b)** for wheat, **(c)** for rice, **(d)** for soybean.

Müller et al., 2017, Geoscientific Model Development, doi:10.5194/gmd-10-1403-2017

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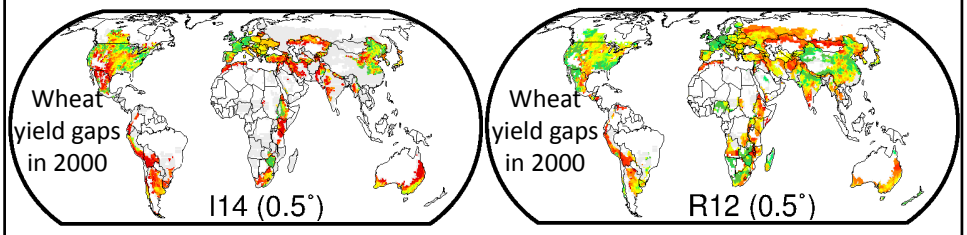
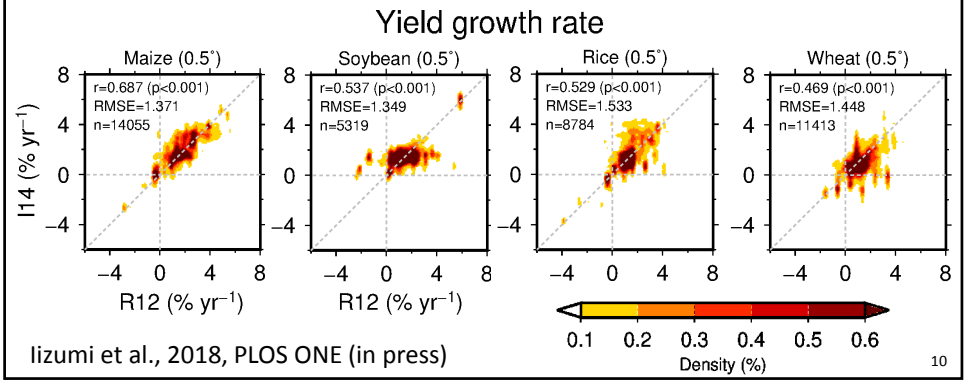
Uncertainties in estimated yield gaps and growth rate





Iizumi et al., 2018, PLOS ONE (in press)

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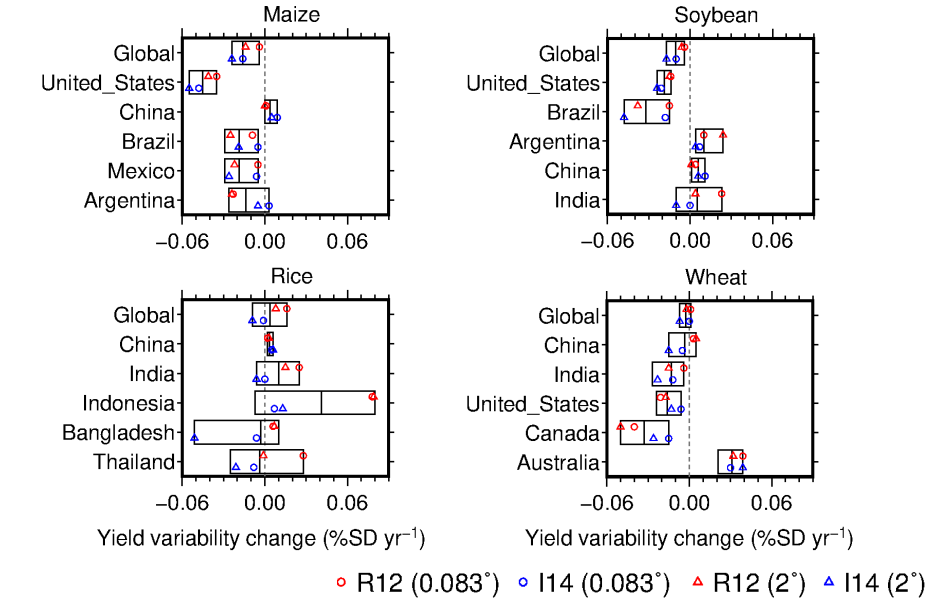
Uncertainties in detected yield variability change



Iizumi et al., 2018, PLOS ONE (in press)

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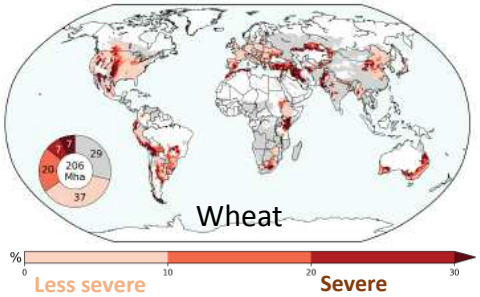
Crop production losses associated with droughts

Kim et al. (in review)

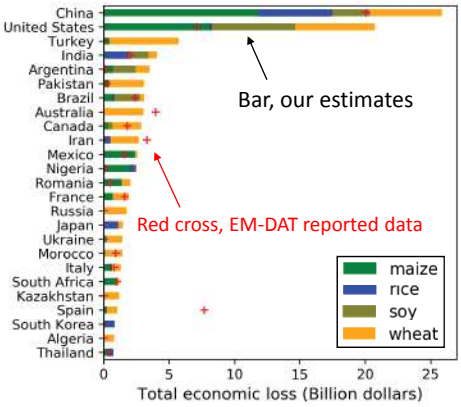
Average yield loss per drought



Yield losses are estimated using yield and SPI data. Gray area indicates no yield data are available or no drought damages are detected

Total loss for the 26 years

(＝Drought events x Yield loss x Area harvested x Producer price)



Total production loss for 4 crops and 26 years at the global level accounts for 108 billion USD (B$), indicating that average loss is 1.04 B$ per drought and per crop

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Advantages and limitations of GDHY datasets

Advantages

- Yields of a crop for different growing seasons are available.
- Winter and spring wheat are explicitly separated.
- The spatial representativeness of grid-cell yields is more consistent across grid cells locate within an administrative unit.
- Relatively frequently updated (not regularly, but every 2 years)

Limitations

- No separation is available between irrigated and rainfed conditions.
- GDHY datasets offer estimates of grid-cell yield, but not reported (or observed) yields.
- GDHY datasets are largely depend on satellite products, and thus grid-cell yield estimates in minor-cropping areas is less reliable than those in major-growing areas.

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Note for users

- A recommended practice is to use subnational (or national) yield statistics in addition to GDHY datasets.
- Analyses for a large spatial domain (continental to global) are suitable for the application of GDHY datasets.
- Keep in mind that stating your conclusions in a qualitative manner rather than in a quantitative manner to be more robust against the uncertainties associated with use of different datasets.

- Good practices are seen:
  - Iizumi & Ramankutty, 2016, Environmental Research Letters, doi:10.1088/1748-9326/11/3/034003
  - Challinor et al., 2016, Nature Climate Change, doi:10.1038/nclimate3061
  - Schauberger et al., 2017, Global Change Biology, https://doi.org/10.1111/gcb.13738

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Questions?

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