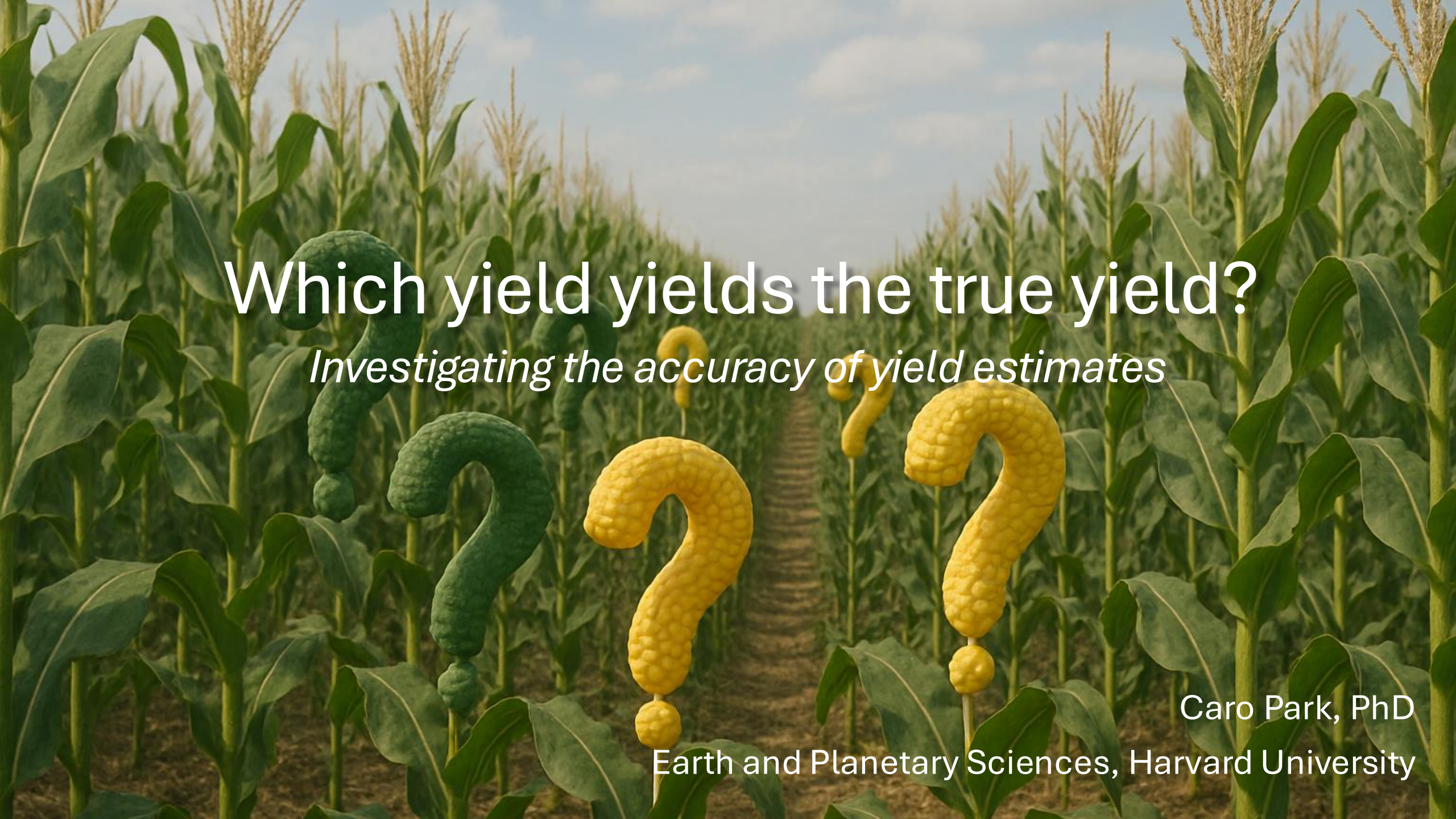


Which yield yields the true yield?

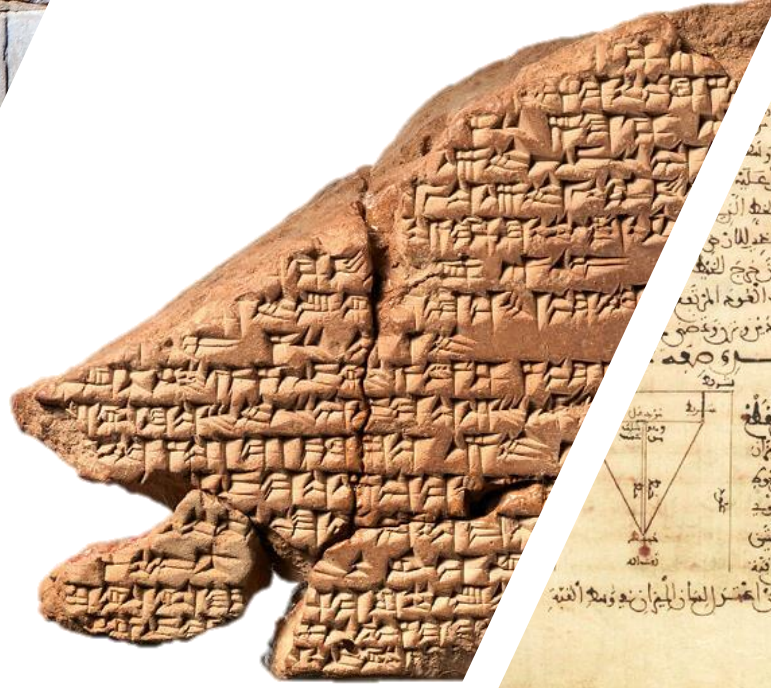
Investigating the accuracy of yield estimates

Caro Park, PhD

Earth and Planetary Sciences, Harvard University

In 2023, an estimated 28.9 percent of the global population – **2.33 billion people** – were moderately or severely food insecure.

FAO, IFAD, UNICEF, WFP and WHO (2024)



How weather determines yields is one of the oldest scientific questions...

How weather determines yields is one of the oldest scientific questions…

… and the answer varies depending on which data you use.

Census yields
(Food and Agriculture Organization)

How weather determines yields is one of the oldest scientific questions…

… and the answer varies depending on which data you use.

Census yields
(Food and Agriculture Organization)

vs.

Remote-sensed yields
(Contiguous Solar Induced Fluorescence)

How weather determines yields is one of the oldest scientific questions…

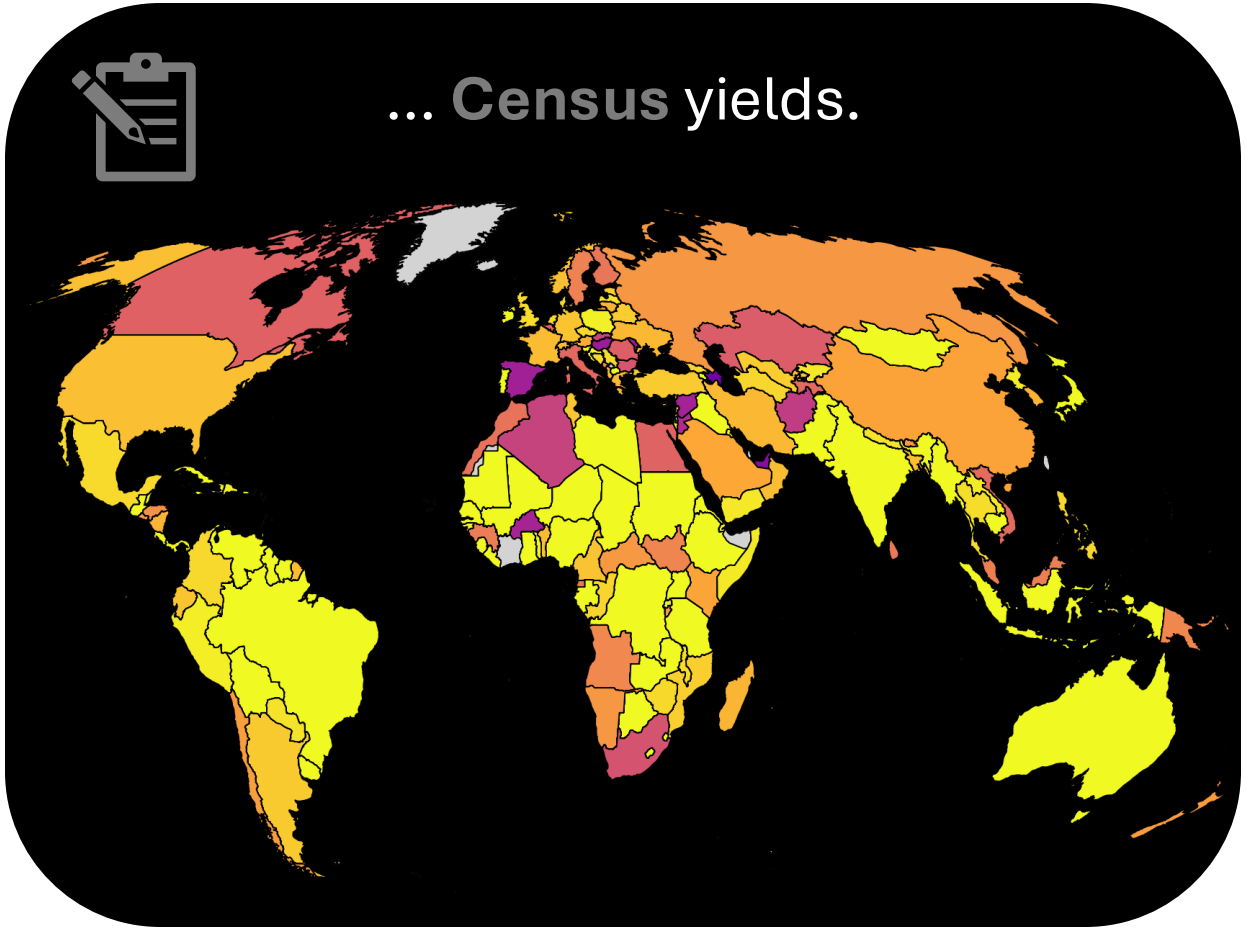
… and the answer varies depending on which data you use.

Year-to-year yield variability explained by weather, when using…

… **Census** yields.

$$log(C_{ij})' = c + \alpha_1 T'_{ij} + \alpha_2 T'^2_{ij} + \beta_1 SM'_{ij} + \beta_2 SM'^2_{ij} + \epsilon_{ij}$$

Year-to-year yield variability explained by weather, when using...

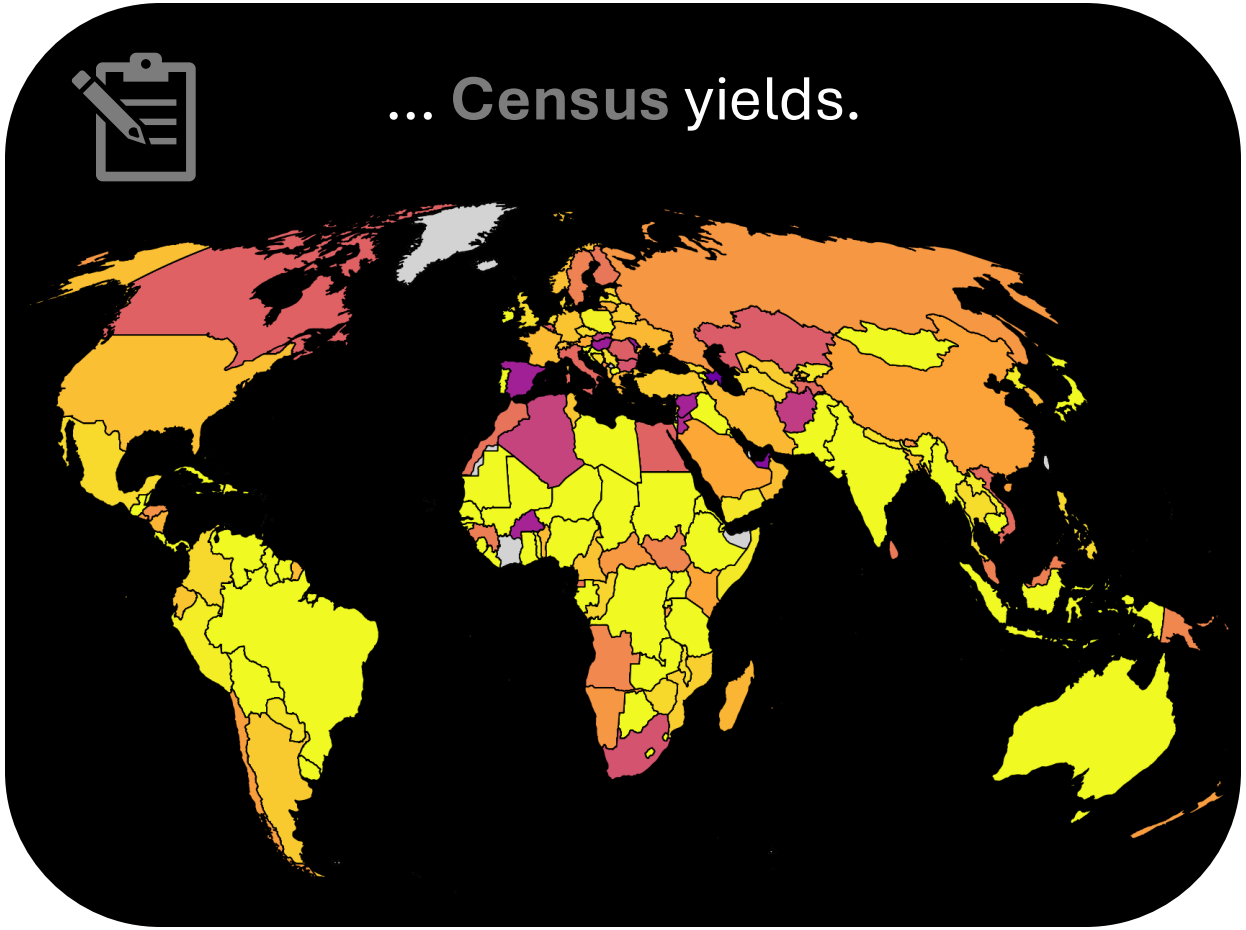


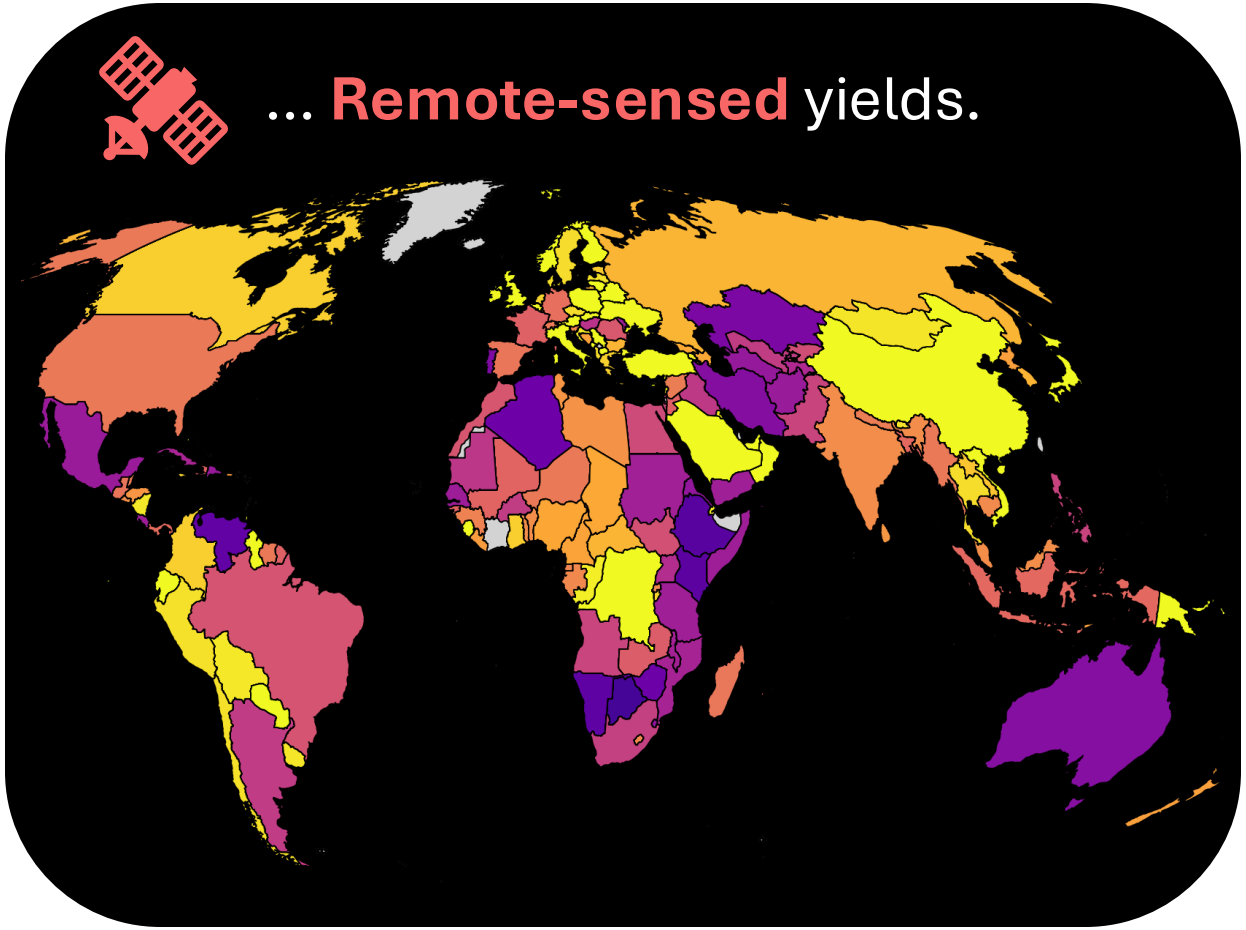
$$log(C_{ij})' = c + \alpha_1 T'_{ij} + \alpha_2 T'^2_{ij} + \beta_1 SM'_{ij} + \beta_2 SM'^2_{ij} + \epsilon_{ij}$$

Not explained by weather

Perfectly explained by weather

Year-to-year yield variability explained by weather, when using...





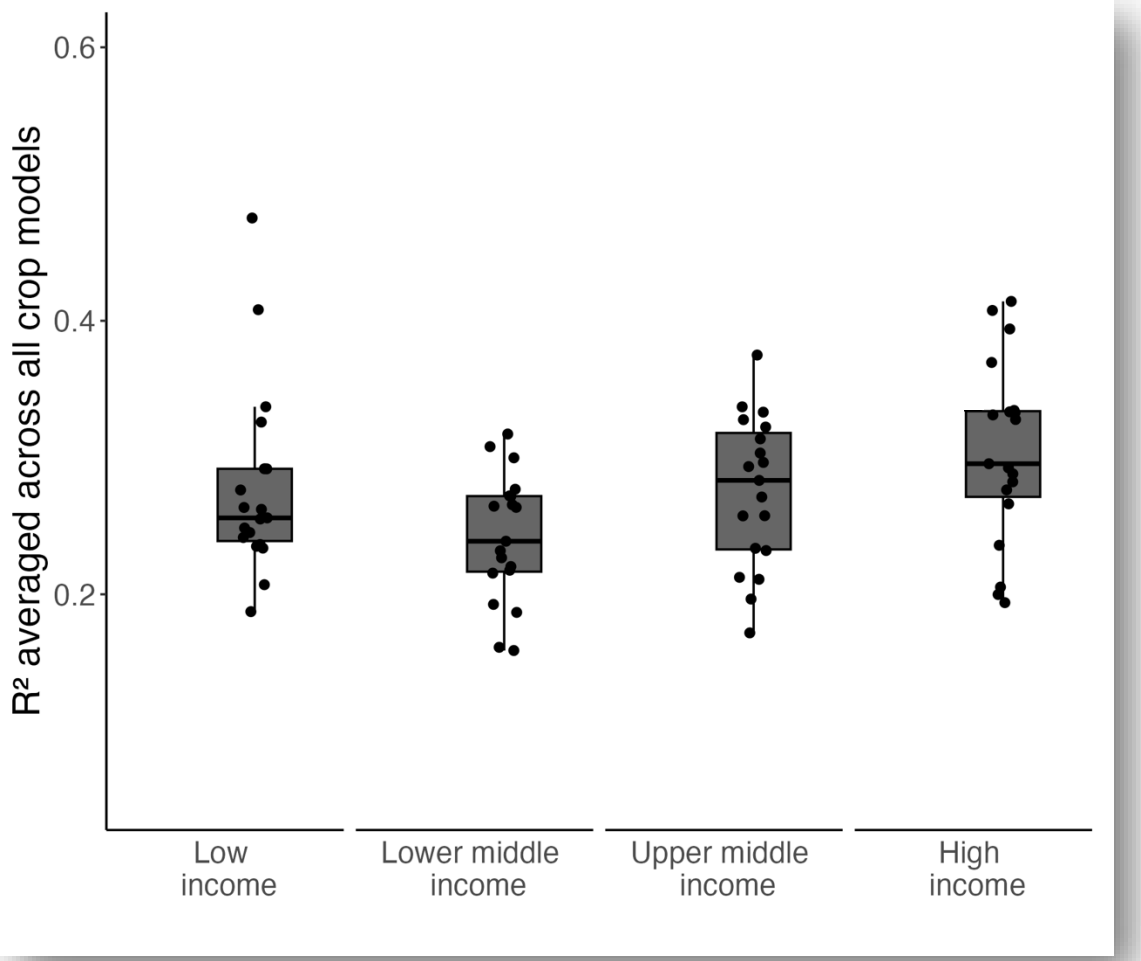
Adj. R2

0.00 0.25 0.50 0.75 1.00

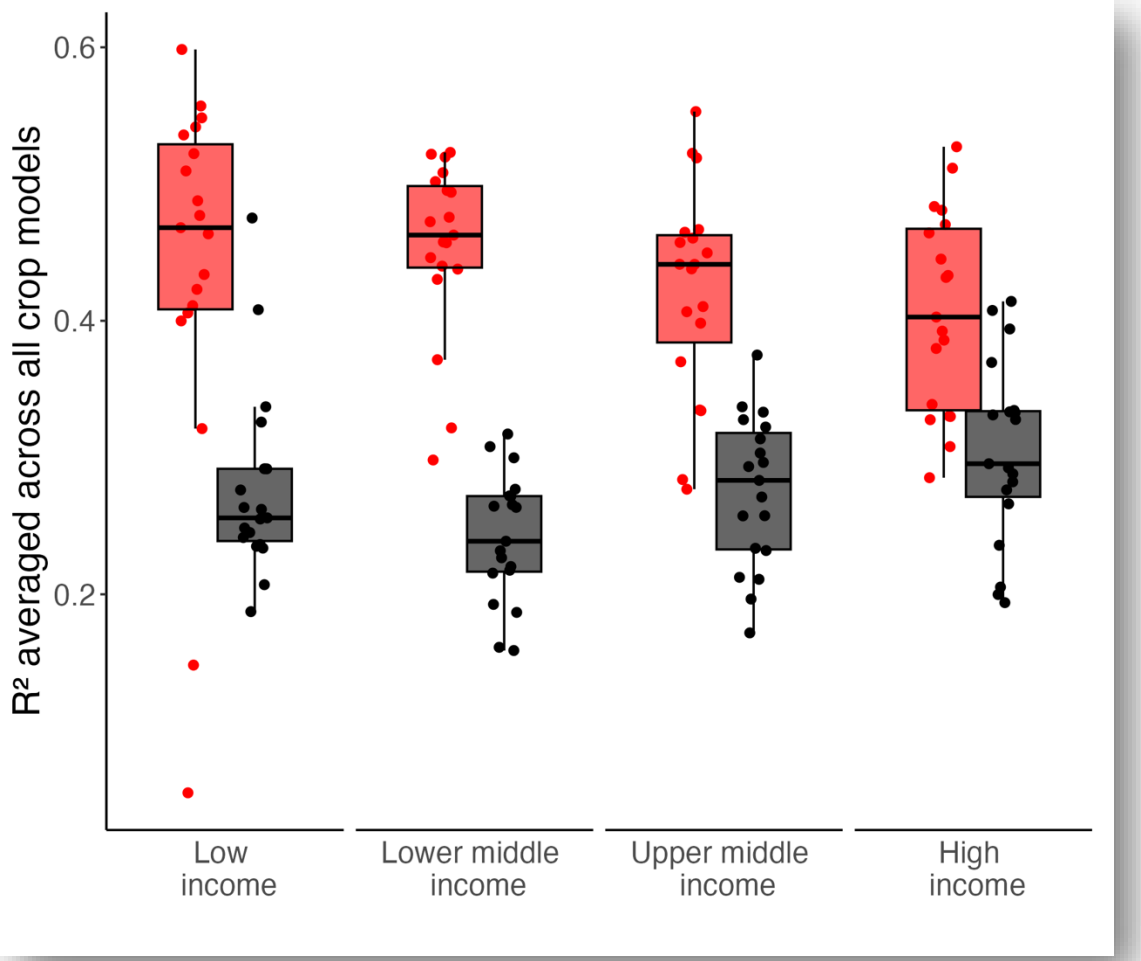
Not explained by weather

Perfectly explained by weather

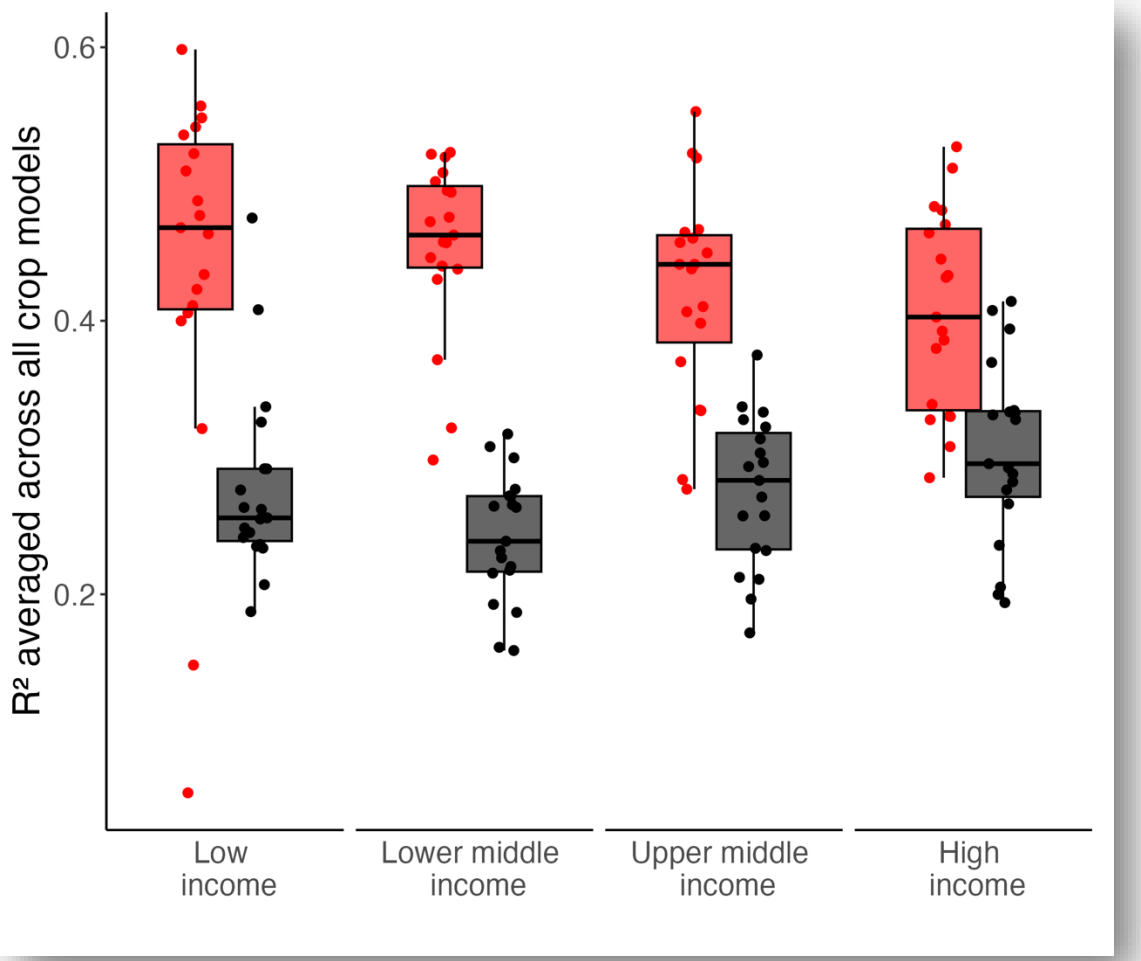
Census yield variability attributable to weather remains constant across class.

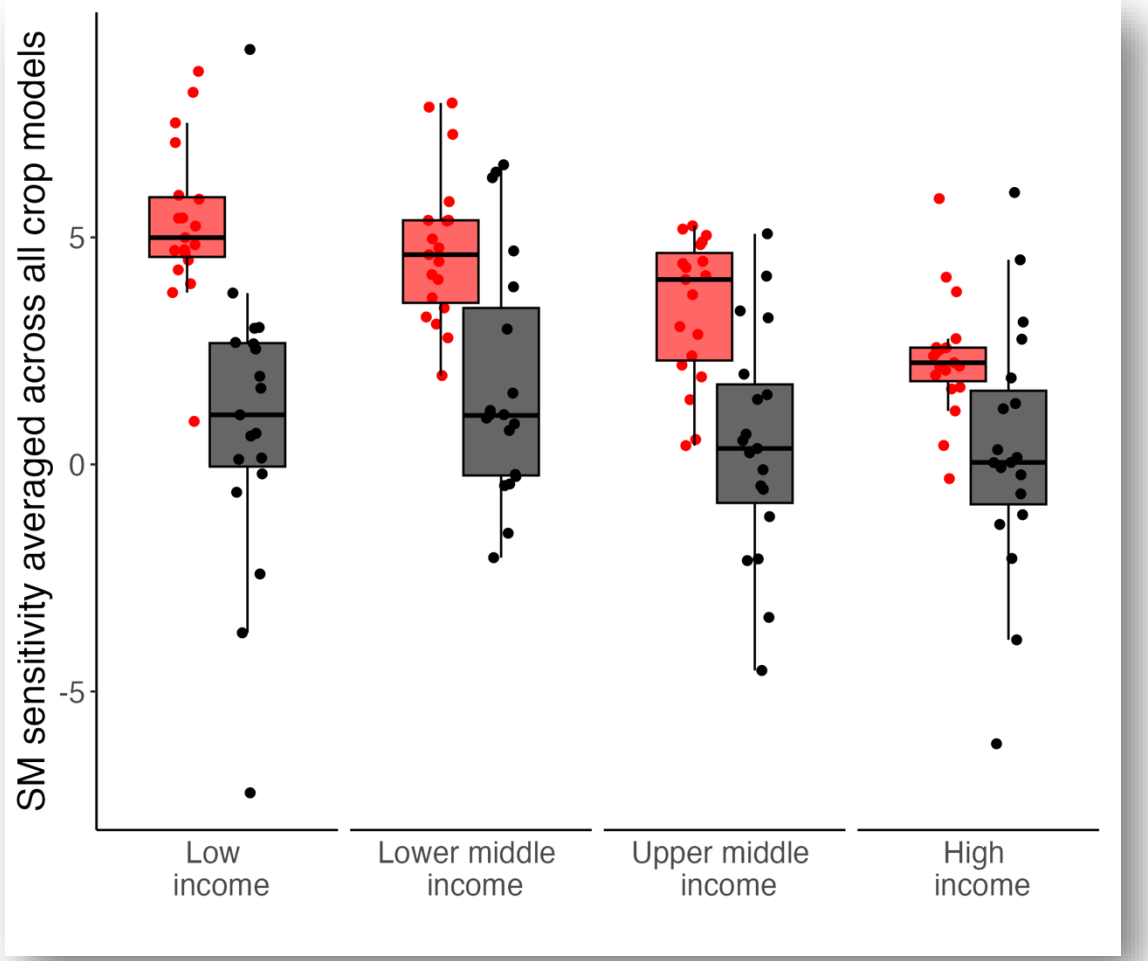


Remote-sensed (but not **census**) yield variability attributable to weather follows an income gradient.



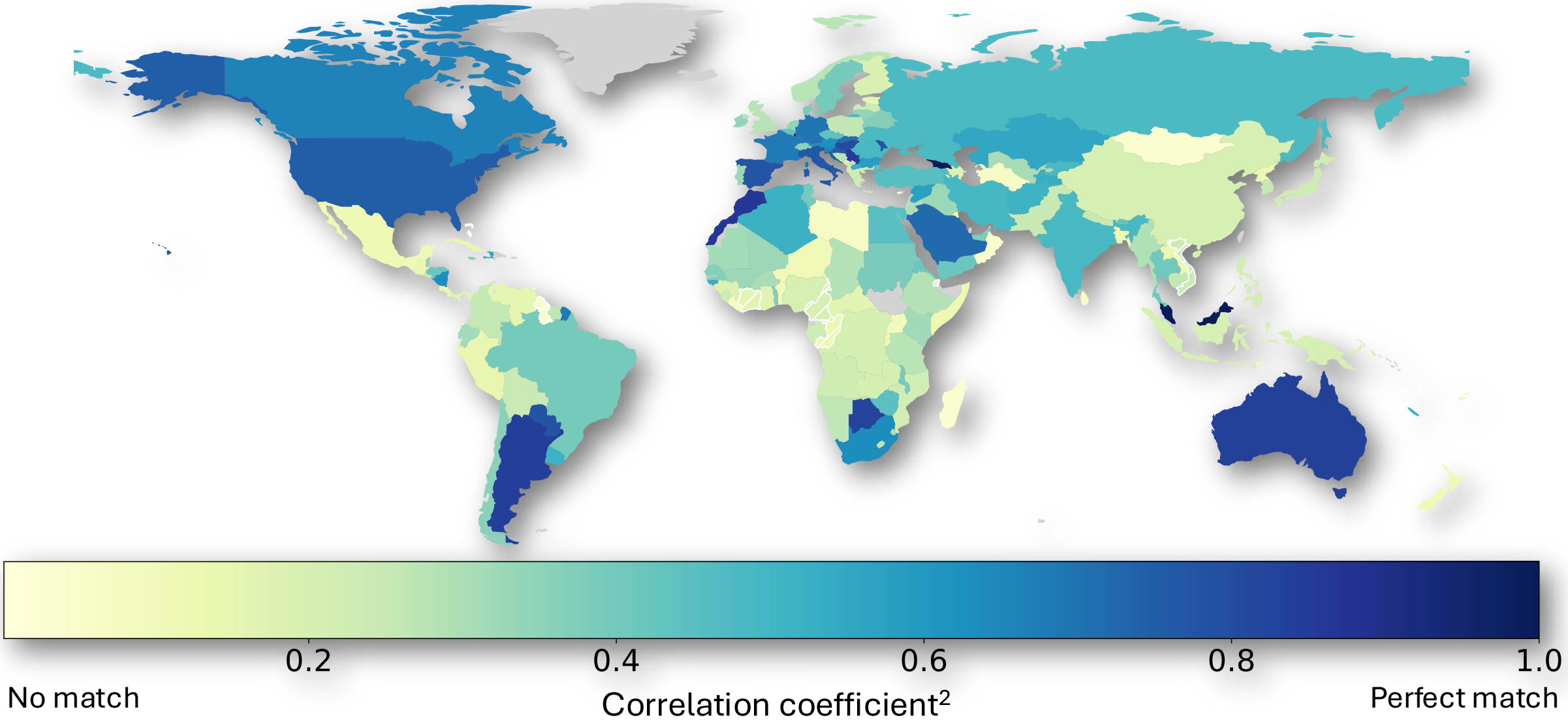
Depending on which yield you use, you will get **two very different stories** about how climate change will impact future food security.





What explains the discrepancy between the **census** yields and the **remote sensed** yields?

In wealthier countries, census and remote-sensed yields match better.



Global All-crop Bayesian Mixed Model (beta distribution)

	Correlation coefficient[2]	
Predictors	*Estimates*	*CI (95%)*
Intercept (Class: High income)	0.18***	0.16 – 0.21
Class: Low income	0.76***	0.61 – 0.93
Class: Lower middle income	0.77***	0.65 – 0.92
Class: Upper middle income	0.81***	0.68 – 0.96
Time offset: lag	0.66***	0.58 – 0.75
Time offset: lead	0.68***	0.60 – 0.77
FAO flagged percentage	0.91***	0.85 – 0.96
Total harvested area	1.09***	1.04 – 1.15
Average harvested area	1.06***	1.00 – 1.13
Cropland fraction	1.11***	1.03 – 1.18
Average CSIF	0.92***	0.86 – 0.98

Random Effects

σ^2	1.00
$\tau_{00\ country}$	0.06
$\tau_{00\ crop}$	0.03
ICC	0.08
N_{crop}	19
$N_{country}$	160
Observations	1568
Marginal R^2 / Conditional R^2	0.092 / 0.153

*$p<0.05$ **$p<0.01$ ***$p<0.001$

Higher income, fewer data flags, and larger cropland area are all associated with a higher correlation between **census** yields and the **remote sensed** yields.

Global All-crop Bayesian Mixed Model (beta distribution)

	Correlation coefficient[2]	
Predictors	*Estimates*	*CI (95%)*
Intercept (Class: High income)	0.18***	0.16 – 0.21
Class: Low income	0.76***	0.61 – 0.93
Class: Lower middle income	0.77***	0.65 – 0.92
Class: Upper middle income	0.81***	0.68 – 0.96
Time offset: lag	0.66***	0.58 – 0.75
Time offset: lead	0.68***	0.60 – 0.77
FAO flagged percentage	0.91***	0.85 – 0.96
Total harvested area	1.09***	1.04 – 1.15
Average harvested area	1.06***	1.00 – 1.13
Cropland fraction	1.11***	1.03 – 1.18
Average CSIF	0.92***	0.86 – 0.98

Random Effects

σ^2	1.00
$\tau_{00\ country}$	0.06
$\tau_{00\ crop}$	0.03
ICC	0.08
N_{crop}	19
$N_{country}$	160
Observations	1568
Marginal R^2 / Conditional R^2	0.092 / 0.153

*$p<0.05$ **$p<0.01$ ***$p<0.001$

So… which yield yields the true yield?

So… which yield yields the true yield?

Peter Huybers

Michael Foley

Weston Anderson
Kyle Davis
Steffen Ehrmann
Rafaela Flach
Andy Hultgren
Carsten Meyer
Caro Park
Jonathan Proctor
Deepak Ray
Liangzhi You