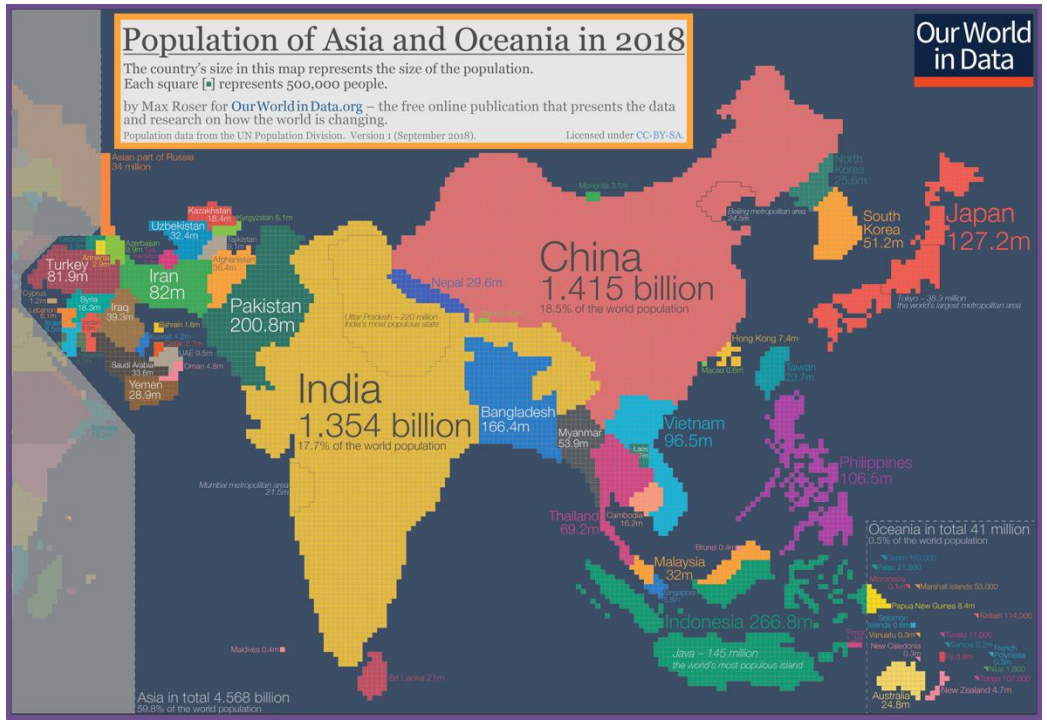
Air quality improvements can strengthen China's food security

Xiang Liu

2025/5/1

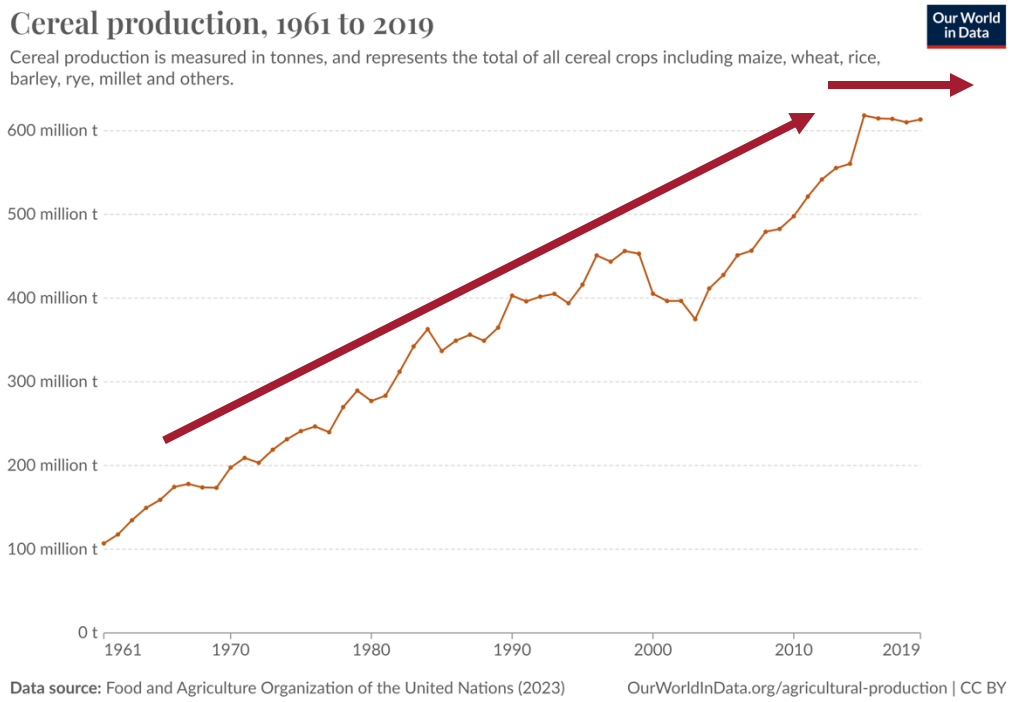
China's population and crop production

Demand: large population



- China's population exceeds 1.4 billion
- Grand challenge to feed its population

Supply: cereal production

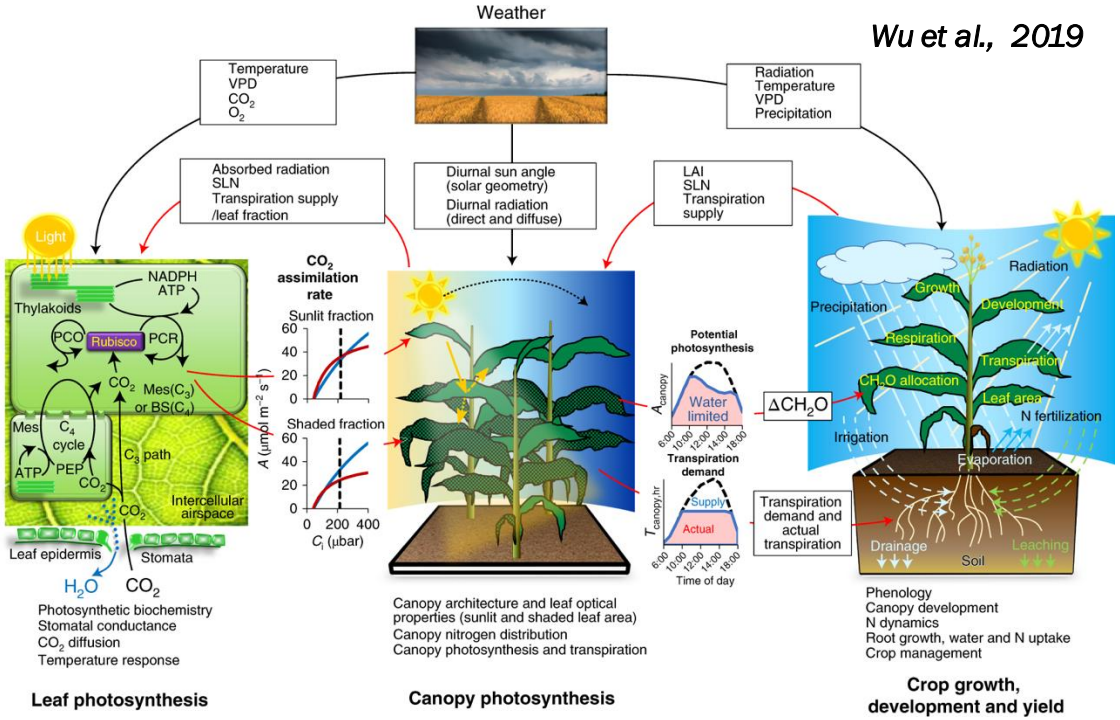


- Cereal production surged until 2015 and then stabilized

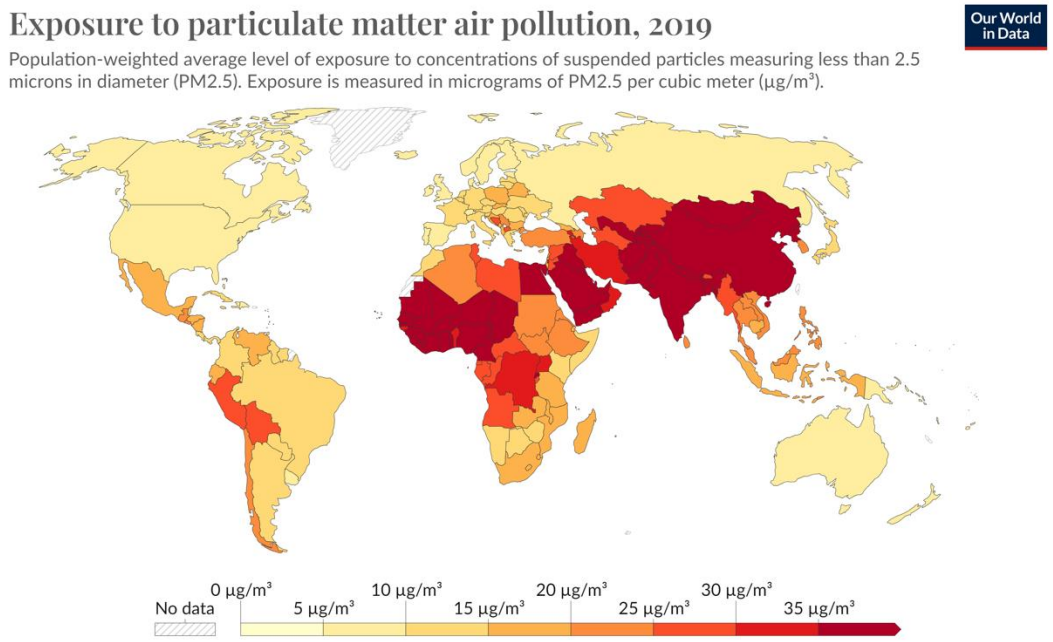
What drives crop yield?

Environmental drivers

Wu et al., 2019



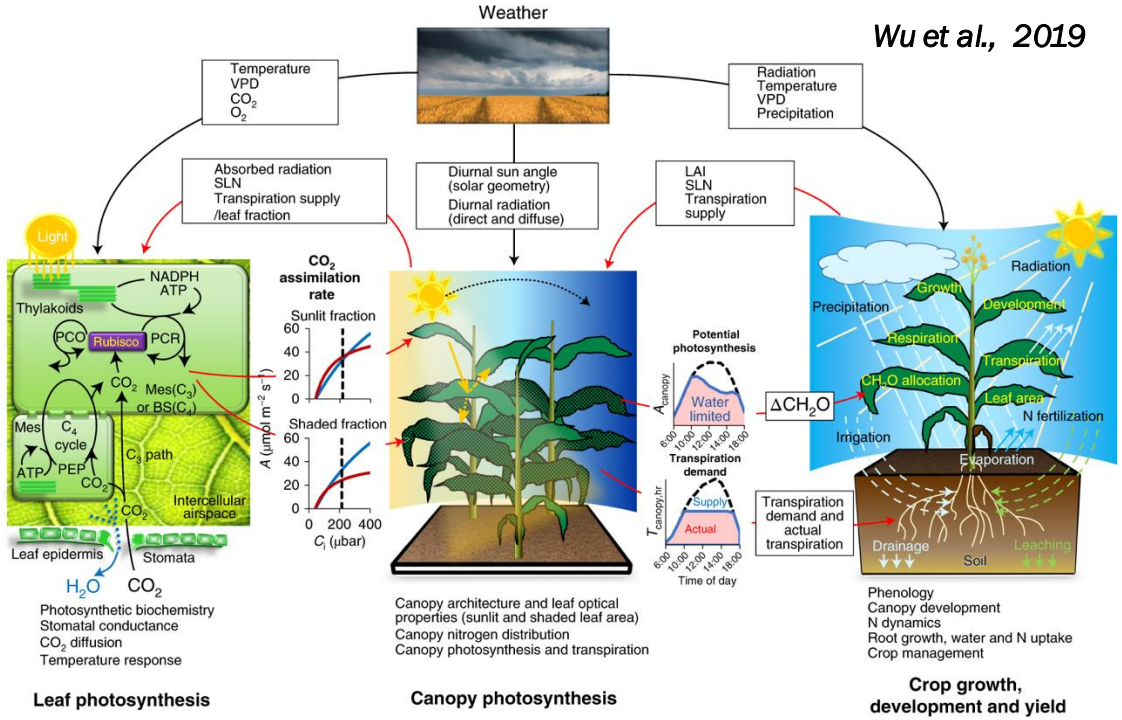
High air pollution levels



What drives crop yield?

Environmental drivers

Wu et al., 2019



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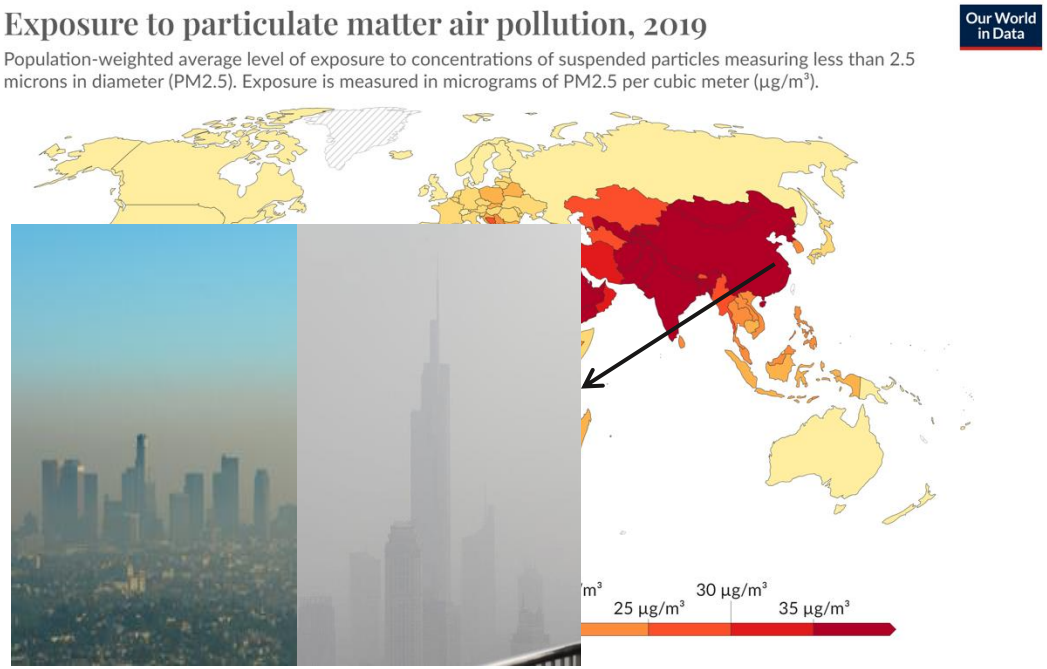

Severe particulate pollution

Nanjing, 2016

What drives crop yield?

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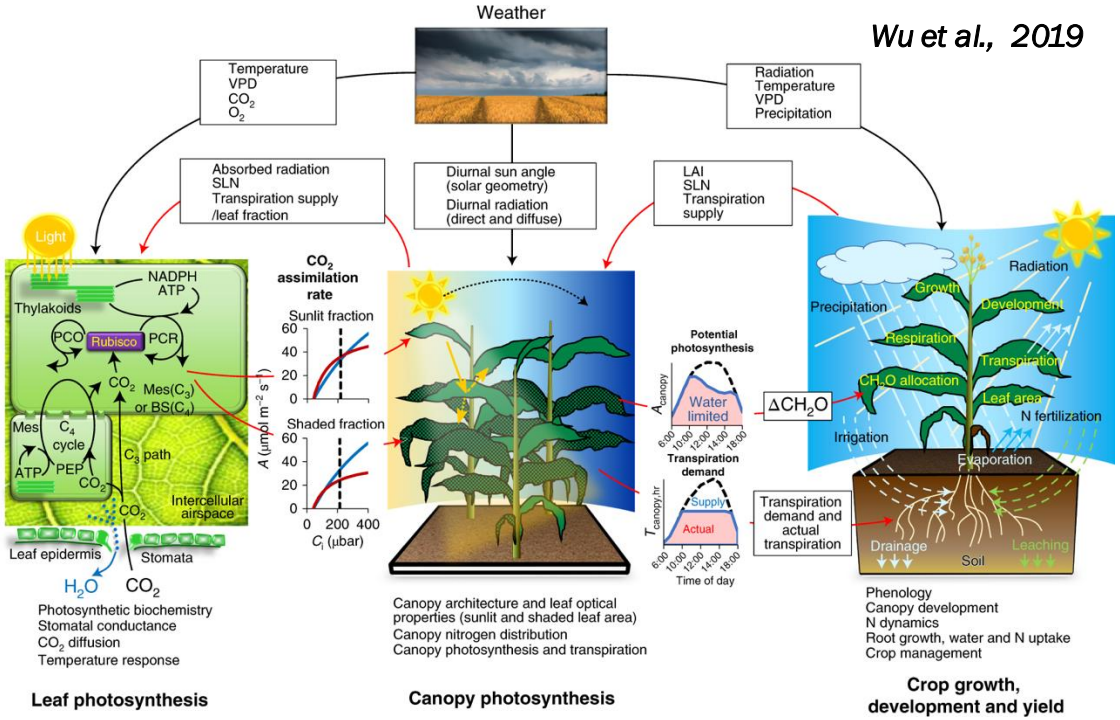

Wu et al., 2019

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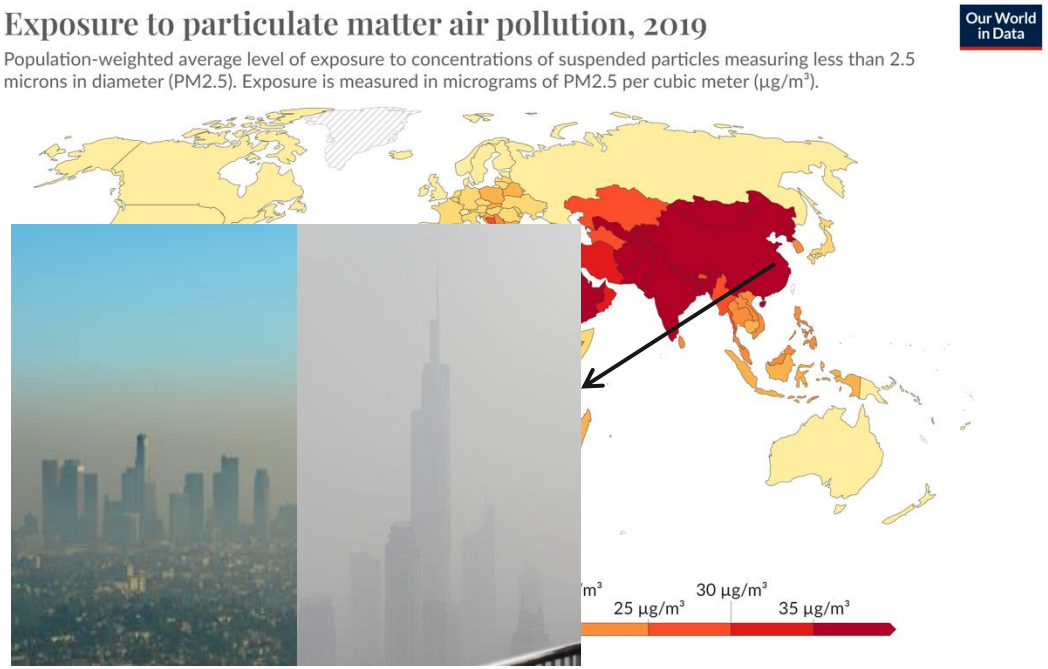


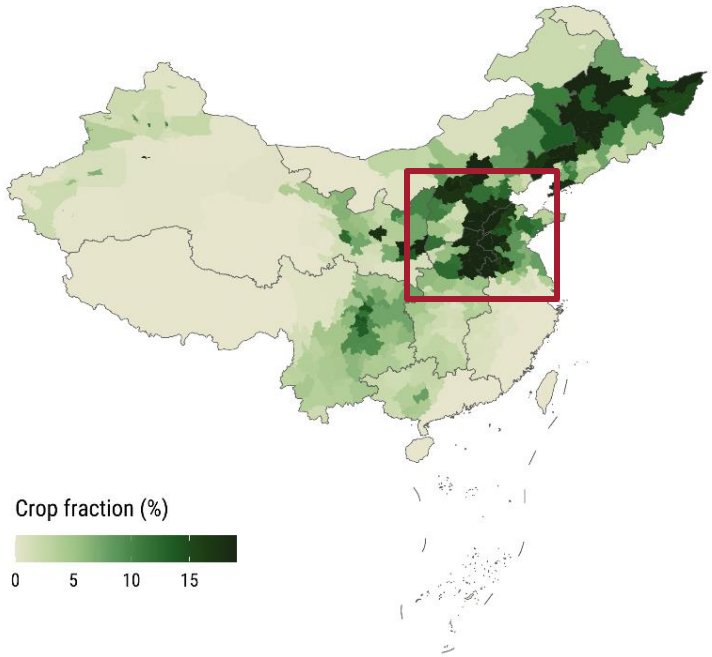
Severe particulate pollution

Nanjing, 2016

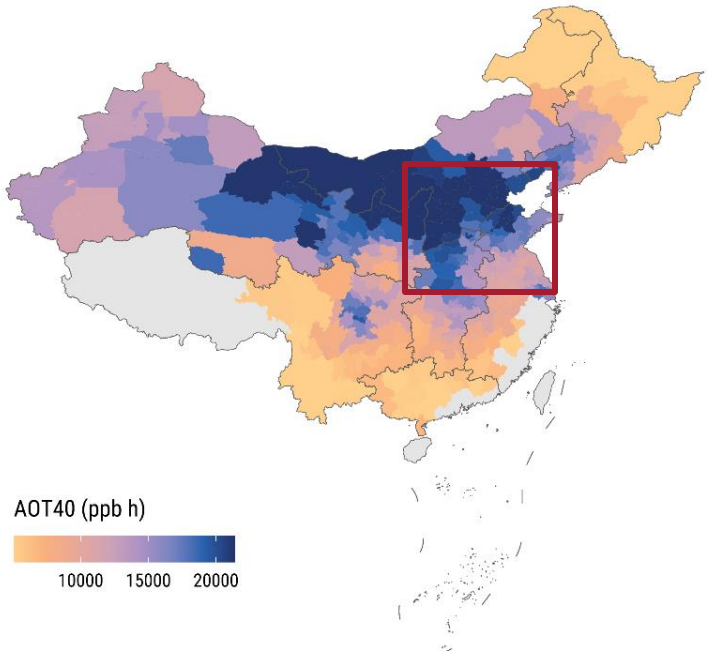
How does this high level of air pollution affect crop production in China?

Crop exposure to air pollution

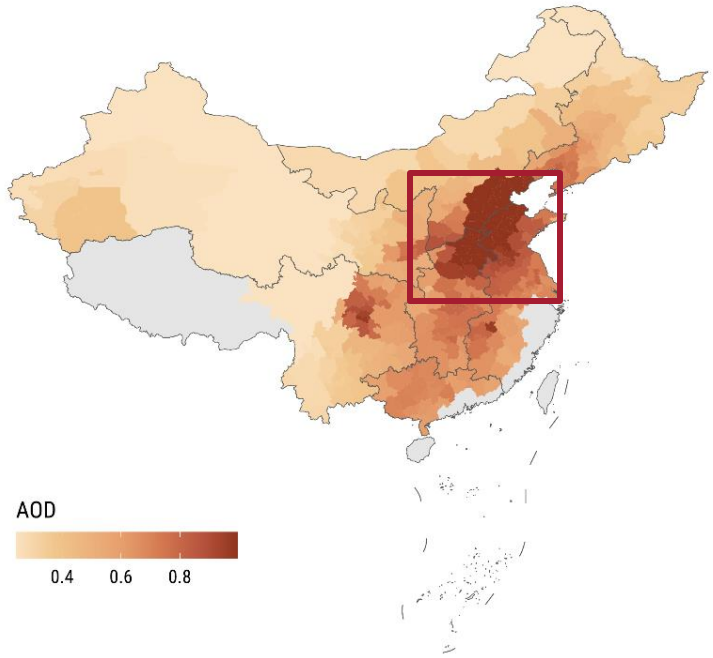
Maize planted area



Ozone exposure



Aerosol exposure



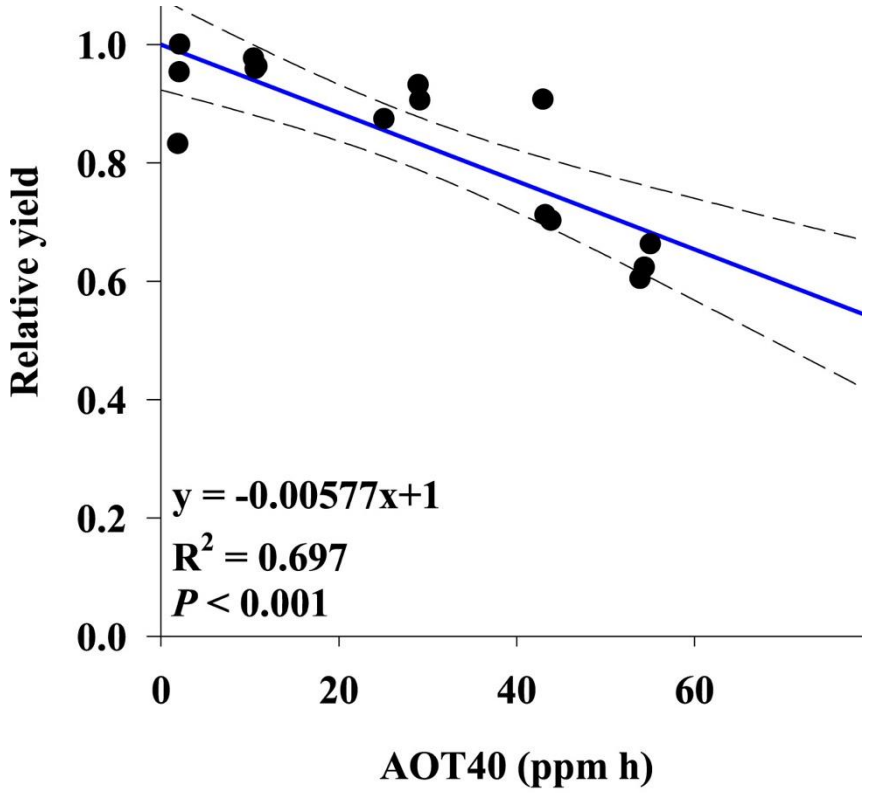
Liu et al., 2024. Nat. Food.

- Co-occurrence of maize and pollution levels, especially in the North China Plain
- Further understanding of the relationship between air pollution and crop growth is needed

Air pollution affects crop growth

Ozone reduces yield

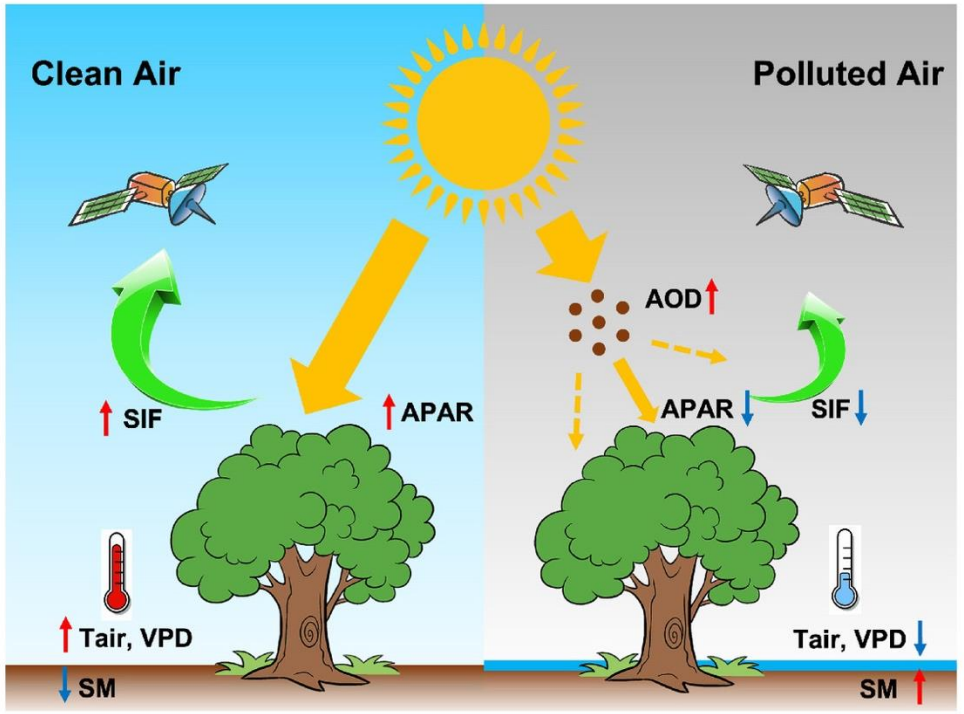
Peng et al., 2019



- Ozone injures plant cells, affects photosynthesis and reduces crop productivity

Aerosol impacts are complex

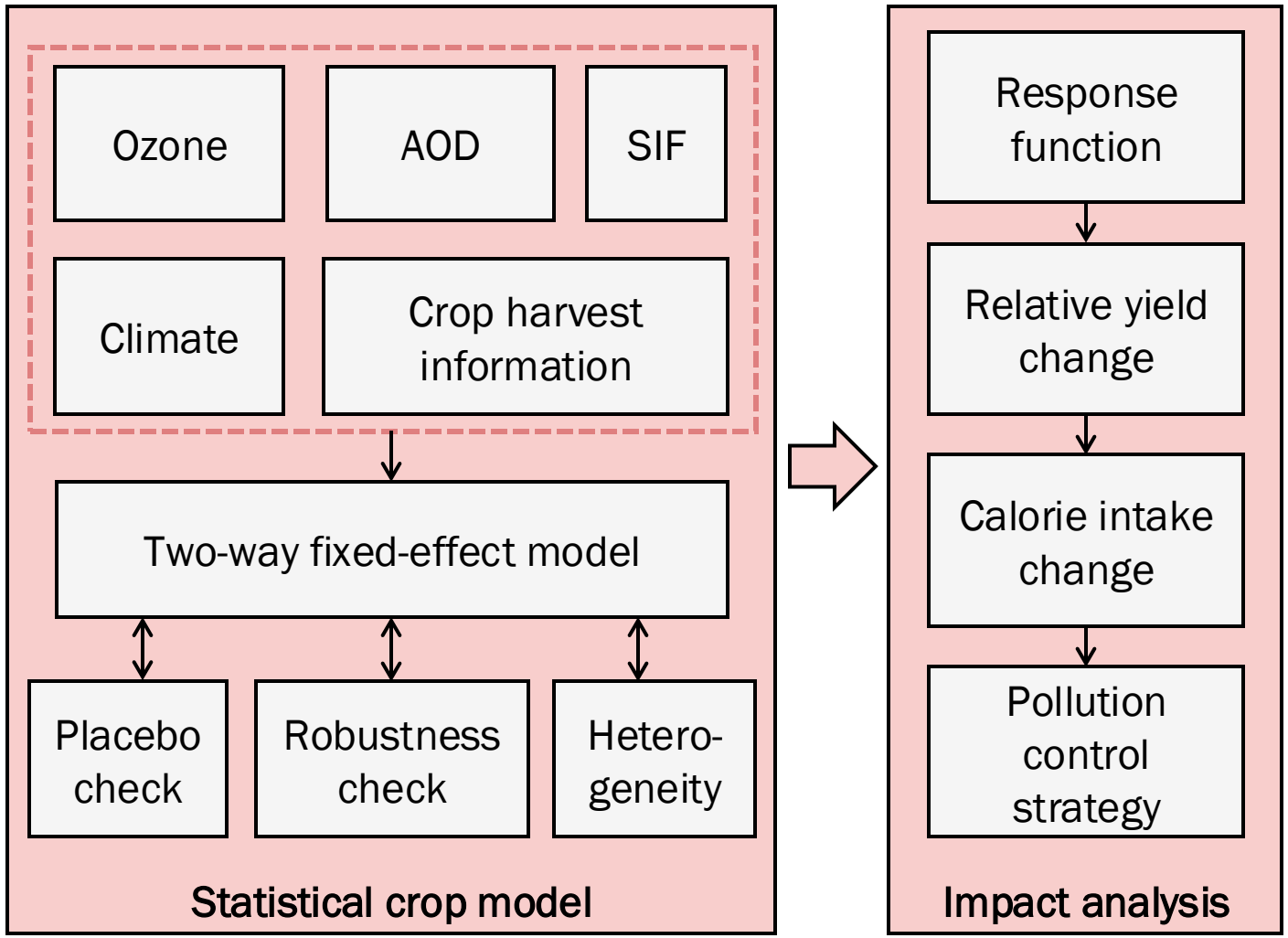
He et al., 2023



- Aerosols reduce direct radiation but increase diffuse radiation
- Diffuse radiation can benefit photosynthesis

Method

- Goal: To quantify the impacts of air pollution on crop production in China.



- Crop: maize, rice, and wheat
- Time: 2005 to 2019
- Statistical model:

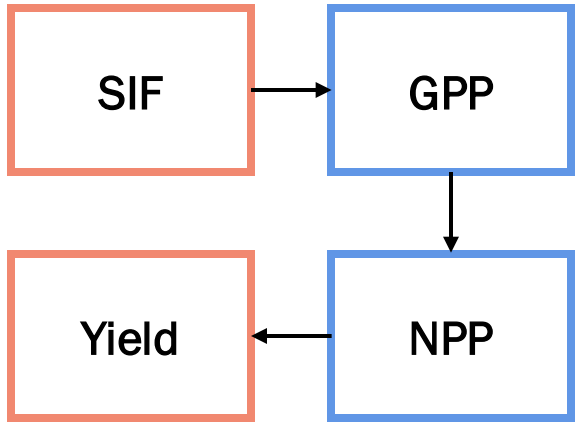
$$log(SIF) = f(Ozone) + f(Aerosol) + f(Temperature) + f(Precipitation) + f(Cloud) + year + gridcell + \varepsilon$$

Liu et al., 2024. Nat. Food.

SIF indicates crop growth

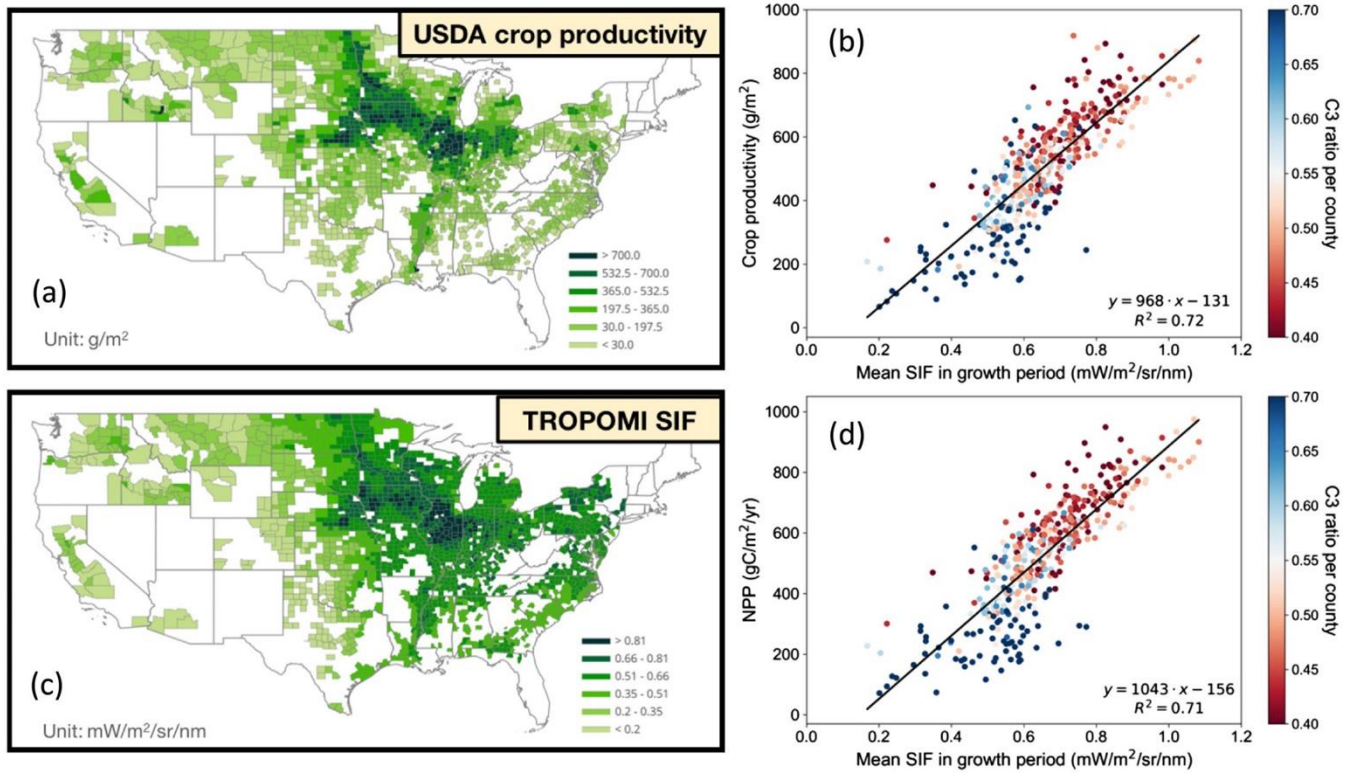
Solar-induced chlorophyll fluorescence (SIF) is emitted by chlorophyll molecules with a wavelength of 650-800 nm when exposed to sunlight by plants

Theoretical relationship between SIF and yield



Guan et al., 2015

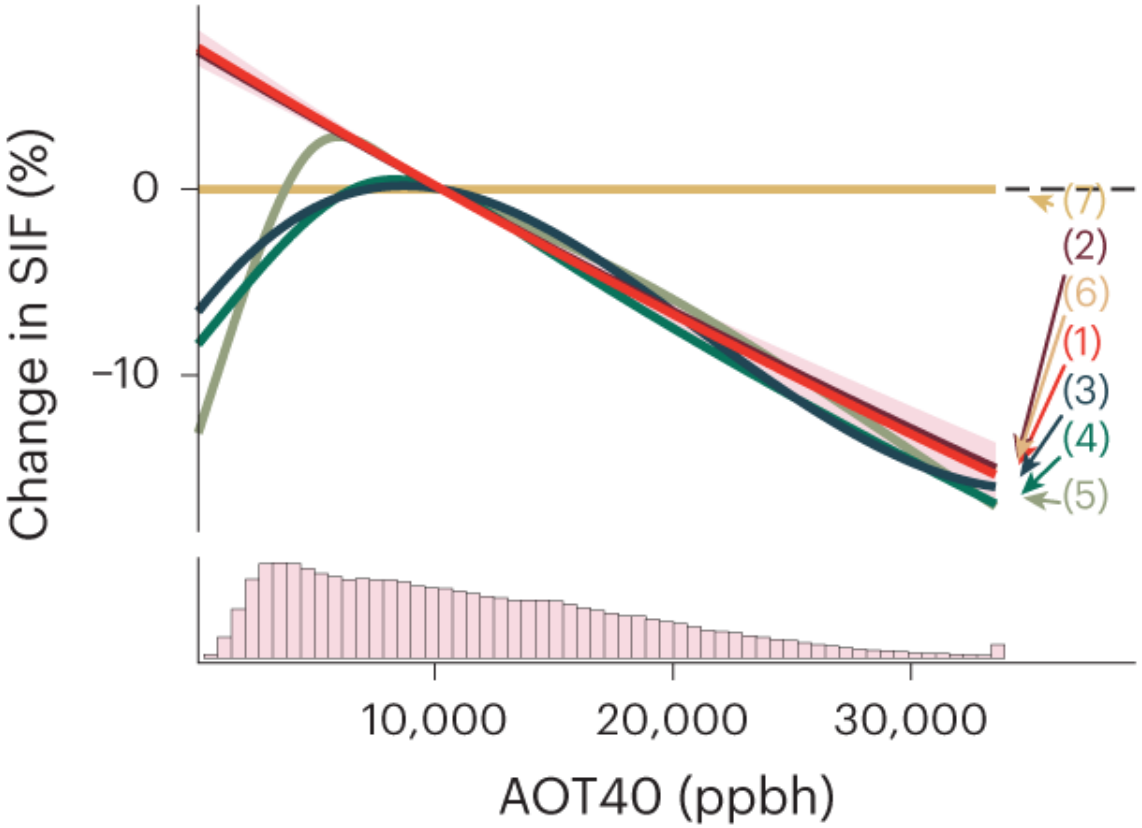
Observational relationship between SIF and yield



He et al., 2020

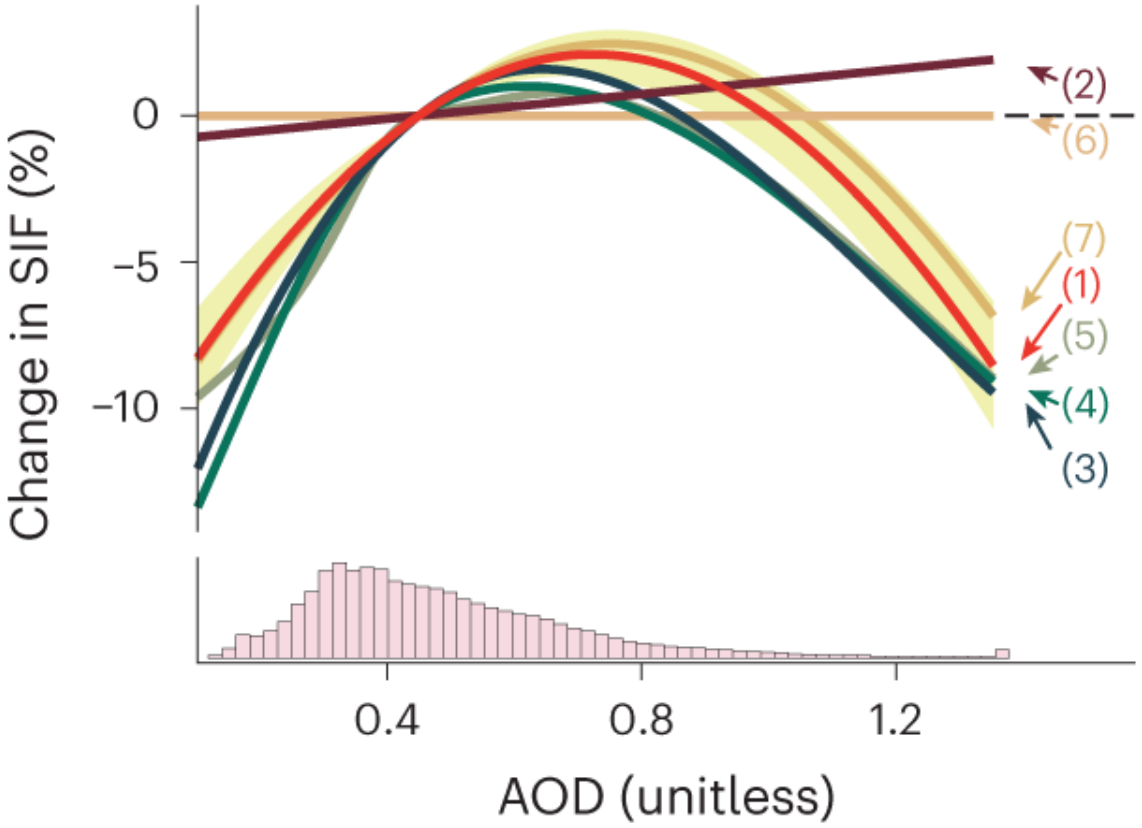
Response functions of ozone and aerosol — Maize

Ozone negatively affects SIF



AOT40: Accumulated Ozone Exposure Over a Threshold of 40 ppb

Nonlinear response of SIF to aerosol

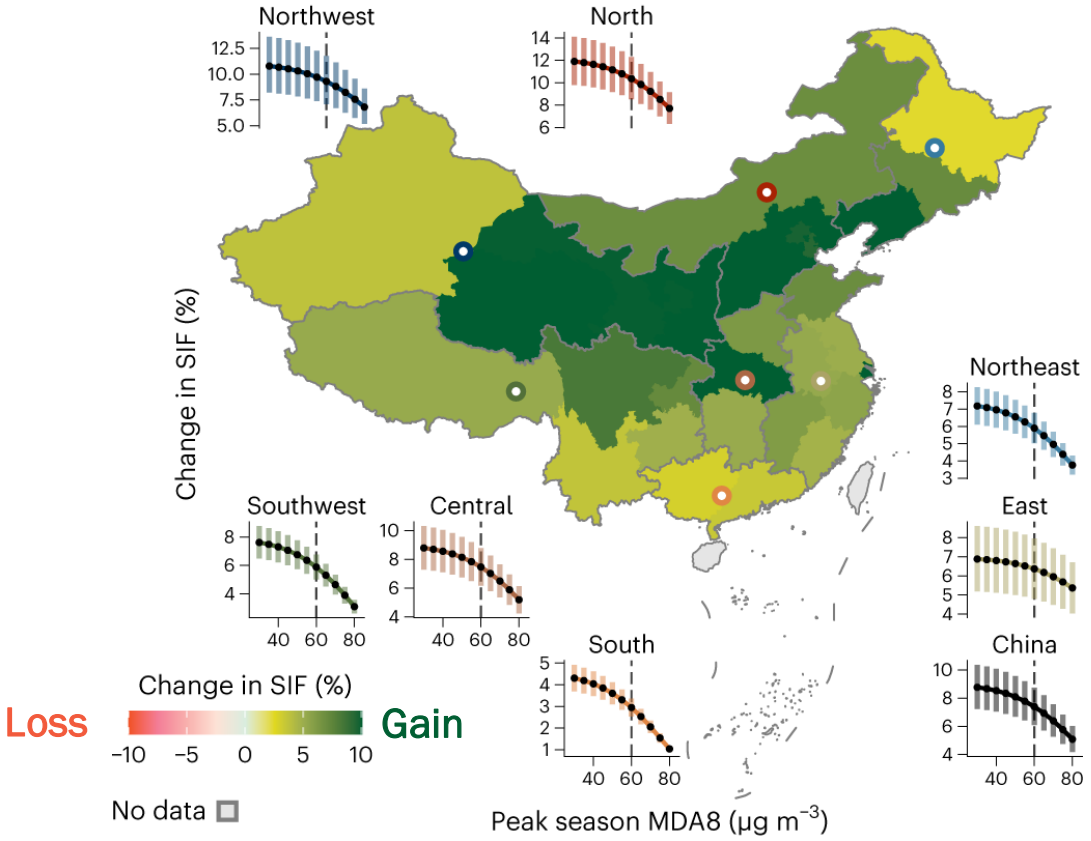


AOD: Aerosol Optical Depth

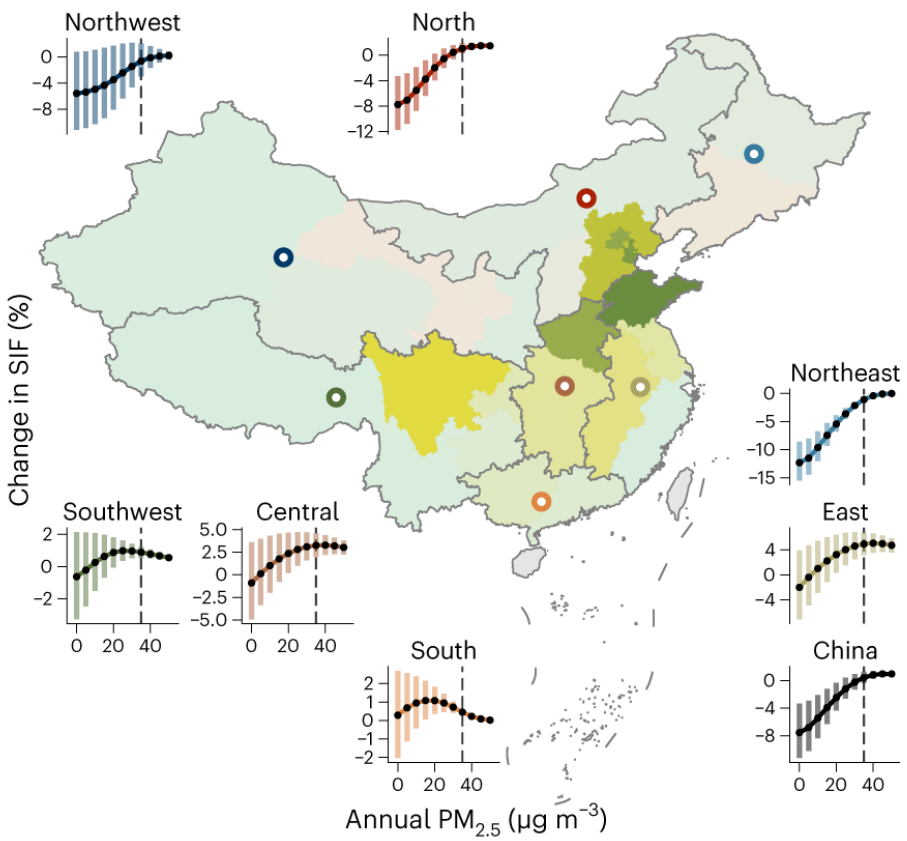
Liu et al., 2024. Nat. Food.

Impacts of air quality improvements on SIF — Maize

Ozone: MDA8 to 60 μg m^{-3}



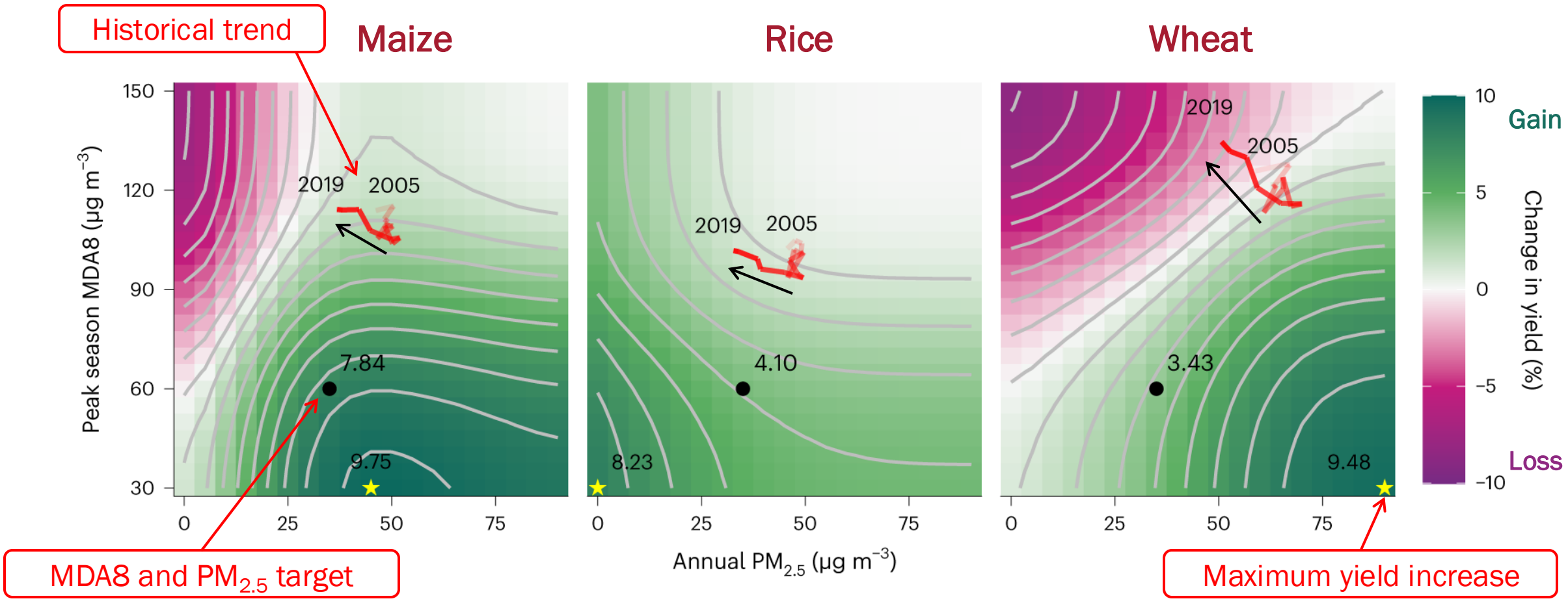
Aerosol: $PM_{2.5}$ to 35 μg m^{-3}



- Reducing ozone can lead to country-wide yield increases
- Reducing $PM_{2.5}$ has varied impacts on yields with large regional differences

Liu et al., 2024. Nat. Food.

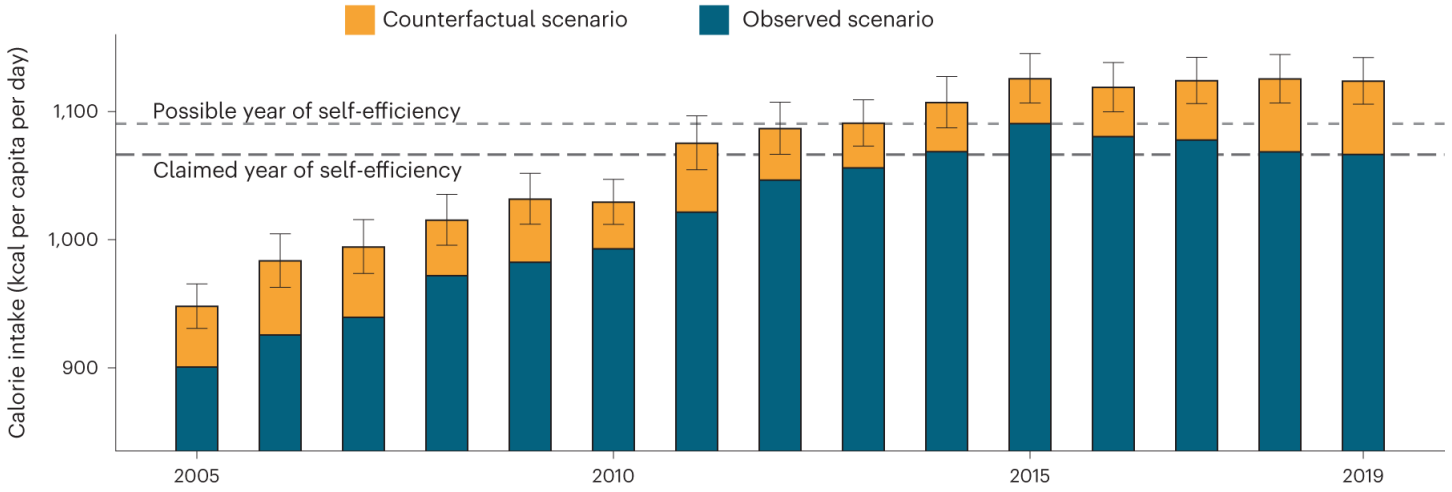
Effects of ozone and $PM_{2.5}$ reductions on crop yields

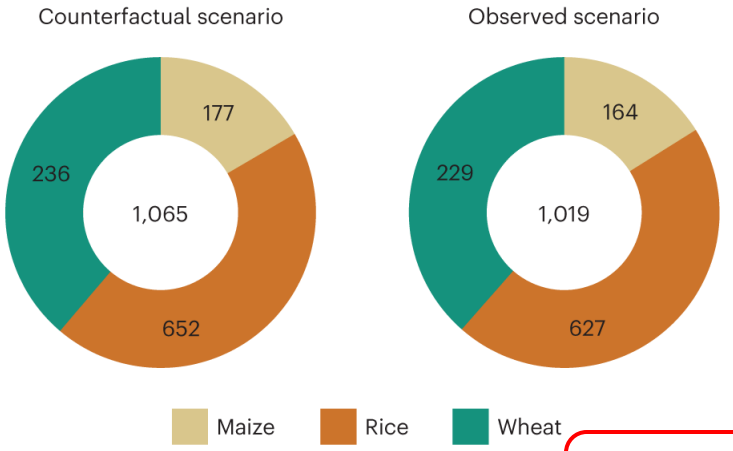


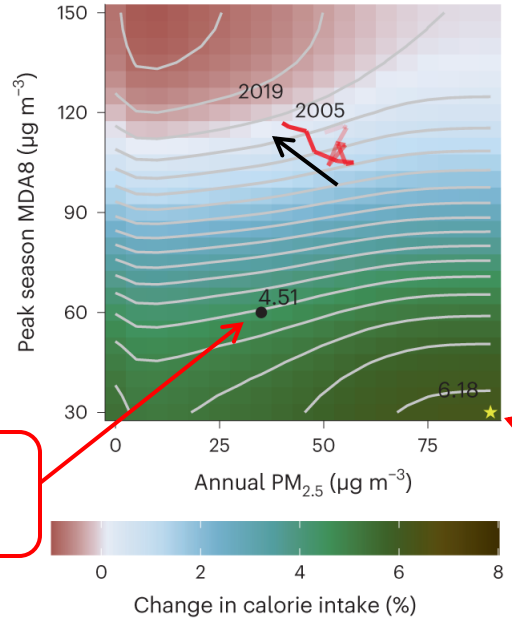
- Meeting two air quality standards can increase 7.8%, 4.1%, and 3.4% yields for three crops
- Recent trends in air pollution may threaten maize and wheat yields

Liu et al., 2024. Nat. Food.

Impacts of air quality improvements on food security







MDA8 and $PM_{2.5}$ target

Maximum calorie increase

- Calorie intake calculation:

$$Cal = \sum_{i=1}^{3} \chi A_i Y_i \eta_i (1 - \omega_i) E_i$$

- Meeting two air quality standards can significantly increase edible food production by 4.5%
- Priority should be given to ozone pollution mitigation

Liu et al., 2024. Nat. Food.

Conclusion and perspectives

1. Air quality improvements can significantly enhance crop production, **but a smarter path will better benefit its food security**

2. Some other factors are not considered, such as **CO_2 and fertilizer**

3. Future studies are encouraged to investigate **other economically vital crops**, conduct **field experiments**, and use **process-based models** to understand the physiological mechanisms

Thanks for your attention!