Deficiencies of models, data, methods, and applications

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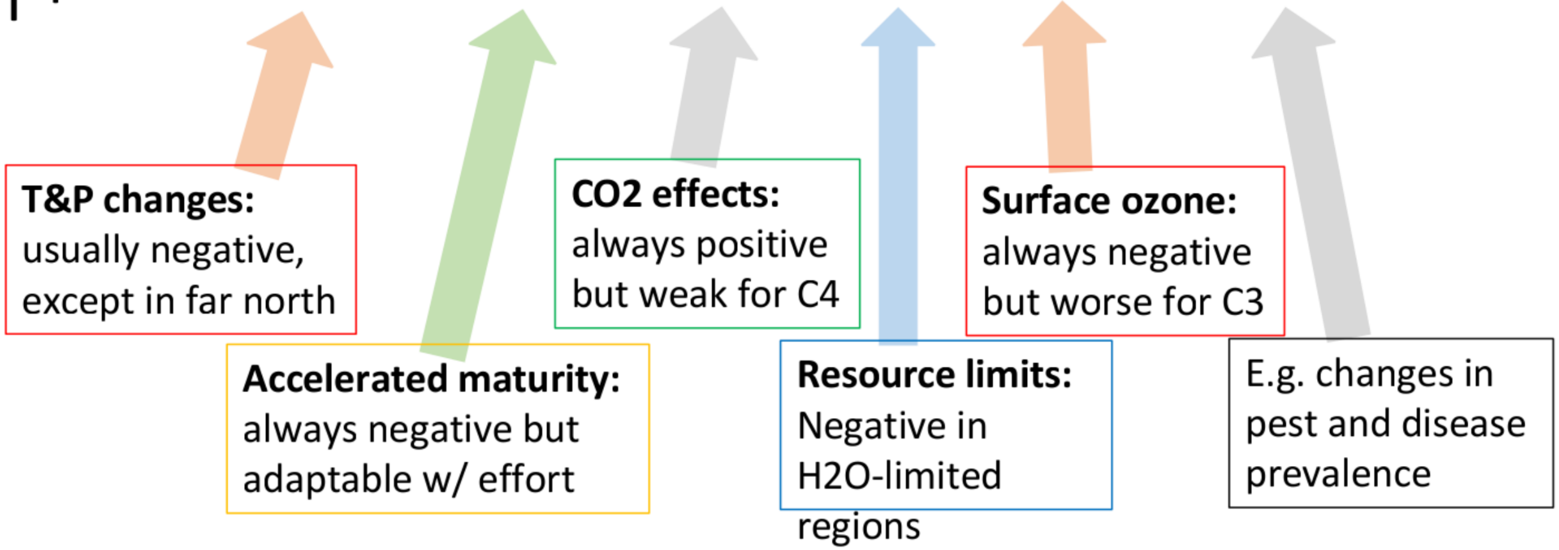
How do emissions impact food production?

Total Impact = Climate + GDD + CO2 + H2O + O3 + other



- Effects of emissions on crops are **highly complex**
  - Many of these terms have **strong interactions**!
  - **Requires integrated approaches** to modeling to inform integrated approaches to adaptation (esp. breeding)

Deficiencies of models, data, methods, and applications

- Known model issues
  - + Heat; drought; phenology
  - - Flood damage; uncertain CO_2 response; diffuse radiation; high T sterilization; planting dates; cold temperatures
- Unknown model issues (could become major issues in future climate)
  - Complex CO_2 responses (e.g. nutrients)
  - Ozone damage
  - Increased pest/disease?
  - Soil microbiome; etc.

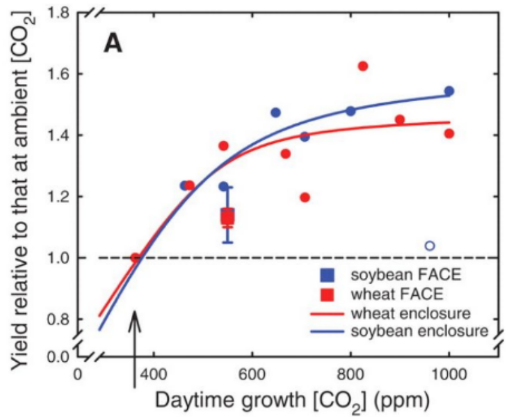
+ CO_2

CO2 and yield

[CO2] effects:
always positive
but weak for C4

- Many and diverse effects of ↑ CO2
  - ↑ photosynthesis rate in C3 plants
  - ↓ water use in all plants
- Soy sees largest yield benefit by far
- C4 only gets effective benefit from water use in drought years
- Limitations of CO2 effects
  - Effect rapidly flat after ~550ppm
  - Effects limited by nutrient availability
  - Food quality (protein, zinc and iron) declines with CO2 in C3 crops

Source	Rice	Wheat	Soybeans	C_4 crops
Yield				
Kimball (1983)	19	28	21	-
Cure and Acock (1986)	11	19	22	27
Cure and Acock (1986)	35	21	32	4
FACE studies	9	13	19	6



Can breeding realize higher potential yield gains from CO2?

Deficiencies of models, data, methods, and applications

- Data issues (esp. for large scale studies)
  - Management data (fertilizers, irrigation, planting, cultivar, etc.)
  - Soil data and dynamics
  - Reference data quality
  - Generating/using proxies from remote sensing more effectively
  - Historical climate in data-poor regions
  - Climate change at the extremes
- Methodological issues
  - Model uncertainty
  - Accelerated phenology and adaptation
  - Calibration methods (esp. in data poor environments)
  - Inter-season dynamics
  - Calories to nutrients
  - Extreme events and variability
  - Orphan crops
  - Representations of irrigation
  - Linking approaches across scales
- Applications
  - Seasonal forecasting
  - Interactions between climate, extremes, tech trends, management, LUC, demand…
  - Data integration and Reanalysis
  - Deep model comparison
  - Coupled cross-domain decision support

+ GDD

Accelerated maturity: always negative but adaptable w/ effort

Accelerated maturity and adaptation

- As temps ↑, phenologies based on accumulated thermal units (GDD) experience **accelerated maturity**
  - Especially strong for cereal crops, weak for soybean
- Recent rate of genetic gain ~1/4 that required to keep up w/ expected warming
- Adaptation natural in breeding, but not perfect
  - ≥10 year "adaptation delay" expected w/o intervention (considered here as the **Business-As-Usual** case)

Can breeding keep up as climate change accelerates?