NCAR Earth System Laboratory NESL

Using the CLM Crop Model to assess the impacts of changes in Climate, Atmospheric, CO_2, Irrigation, Fertilizer and Geographic Distribution on Historical and Future Crop Yields

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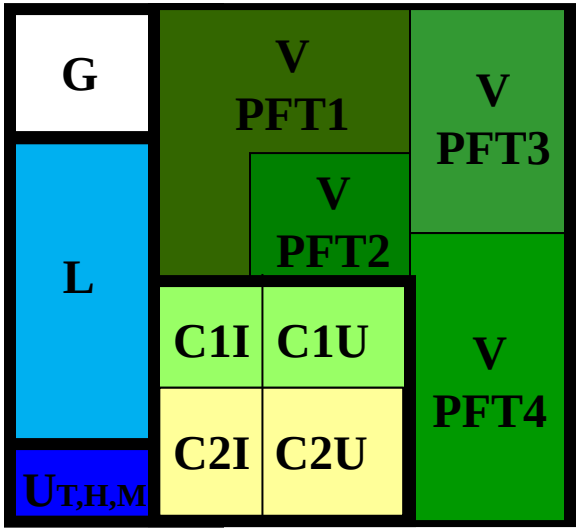
Gridcell

CLM 5 Crop subgrid tiling



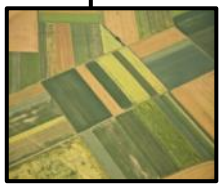
Landunit


Vegetated

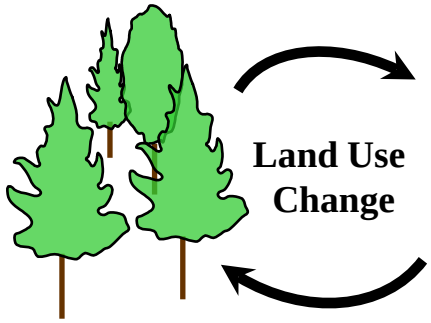

Lake

Urban


Glacier


Crop

Crop Model



Planting


Leaf emergence


Irrig / Fertilize


Grain fill


Harvest


Unirrig


Irrig


Unirrig


Irrig


Crop1


Crop1


Crop2


Crop2 …

CLM Crop – Crop Simulations

We would like to evaluate agriculture in CLM Crop with CESM forcing from the Historical, RCP 4.5 and RCP 8.5 time periods

Problems with CLM4.5 Crop:

- Fixed Crop distribution as crop land unit can not be changed through time like PFTs

- Only simulates Cotton, Corn, Rice, Soy, Sugarcane, Wheat (temperate/tropical)

- Nitrogen fertilizer is fixed by crop type independent of region or time period based on North American application rates

- Has fixed irrigation area based on crop distribution

CLM Crop – Idealized Crop Simulations

Idealized Crop simulations are suite of CESM simulation with transient CESM forcing from the Historical, RCP 4.5 and RCP 8.5 time periods that can be combined with cropping and management scenario

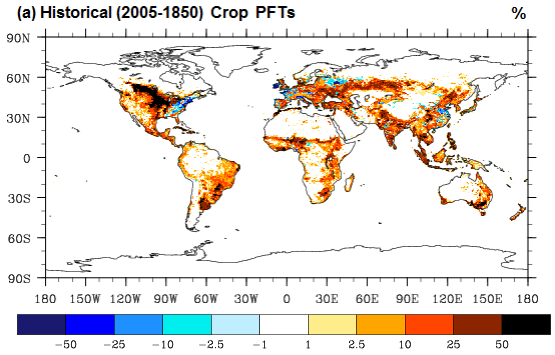
Globally simulate in CLM Crop for every land grid cell:
- Cotton, Corn, Rice, Soy, Sugarcane, Wheat (temperate/tropical)

With Management:
- N Fertilizer and Irrigated
- N Fertilizer and Rainfed
- No N Fertilizer and Irrigated
- No N Fertilizer and Rainfed

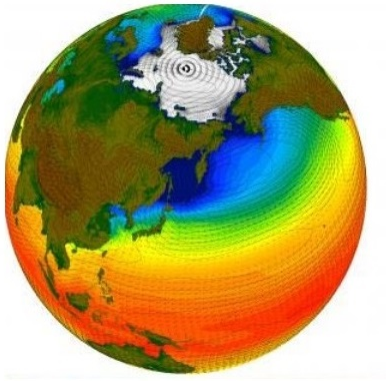
With Atmospheric Forcing as:
- Transient Climate and CO_2
- Transient Climate and Constant CO_2
- Constant Climate and Constant CO_2

CLM Crop – Scenario Simulations

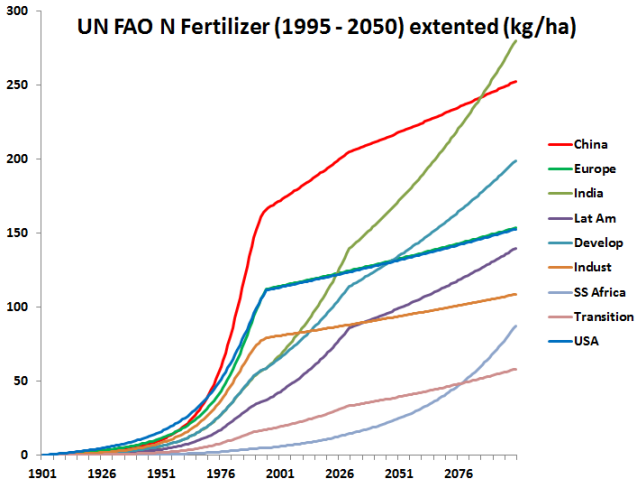
Crop Area time series CMIP5 / other scenario



CESM Climate / CO_2 Scenario – Hist/RCP4.5/RCP8.5



Crop Type / Irrigation time series
Portmann et al. (2010)



Global CLM Crop Simulation

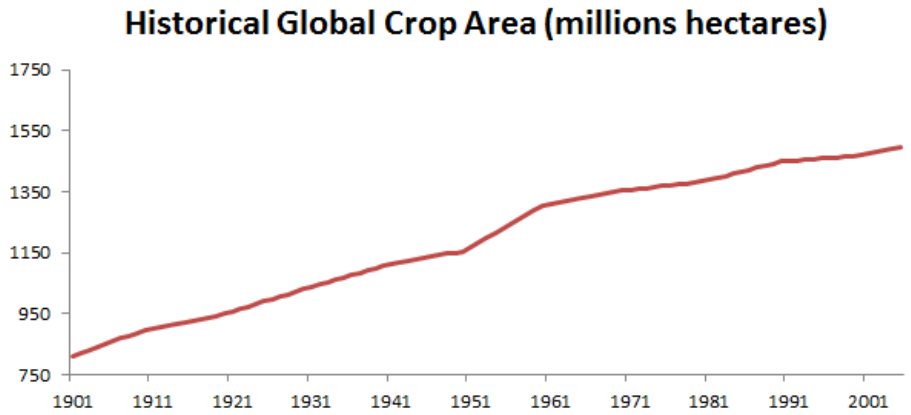
- Scenario
- Crop
- Year
- Area
- Yield
- Fertilizer
- Irrigation
- Temp.
- Precip.
- Solar
- CO_2

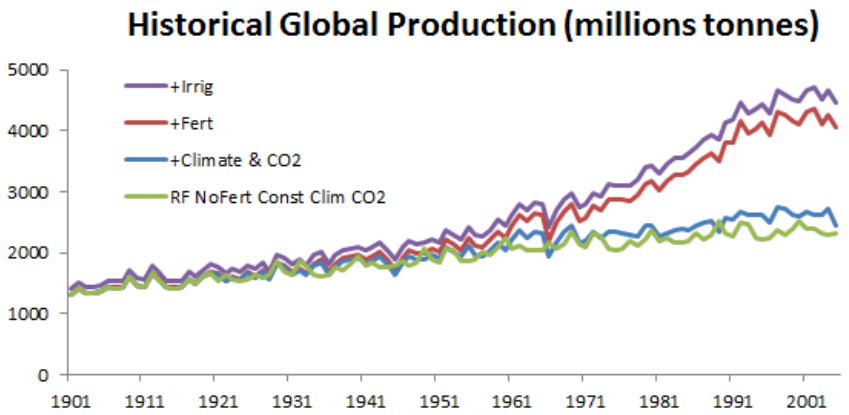
Global Idealized CLM Crop Simulation Database

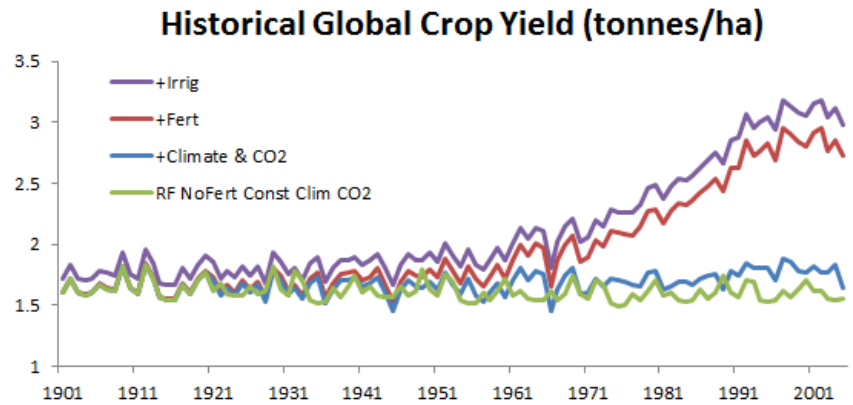
For Historical, RCP4.5 and RCP8.5 time series and for each crop

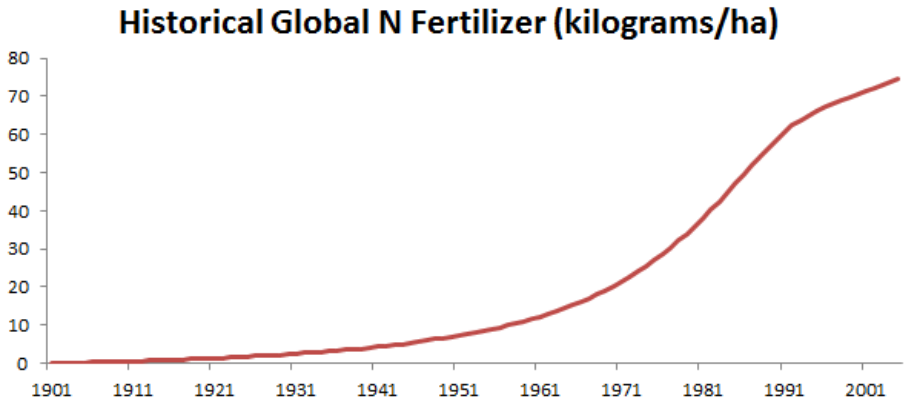
Rainfed / Irrigated	N Fertilizer	CO2 Concentration	Climate
Irrigated	UNFAO Fertilizer	Transient	Transient
Rainfed	UNFAO Fertilizer	Transient	Transient
Irrigated	No/Const Fertilizer	Transient	Transient
Rainfed	No/Const Fertilizer	Transient	Transient
Irrigated	UNFAO Fertilizer	Constant	Transient
Rainfed	UNFAO Fertilizer	Constant	Transient
Irrigated	No/Const Fertilizer	Constant	Transient
Rainfed	No/Const Fertilizer	Constant	Transient
Irrigated	UNFAO Fertilizer	Constant	Constant
Rainfed	UNFAO Fertilizer	Constant	Constant
Irrigated	No/Const Fertilizer	Constant	Constant
Rainfed	No/Const Fertilizer	Constant	Constant

Global Historical CMIP5 (All Crops) Area, Yields, N Fert



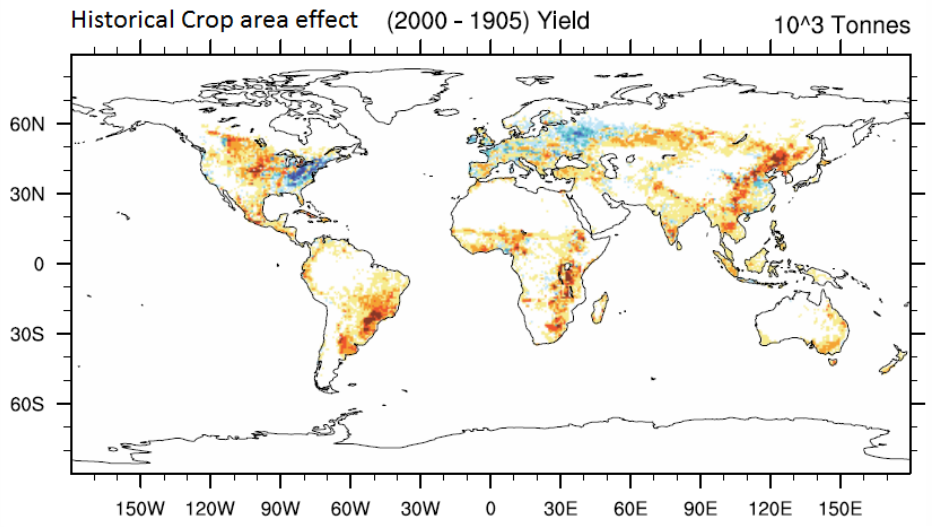


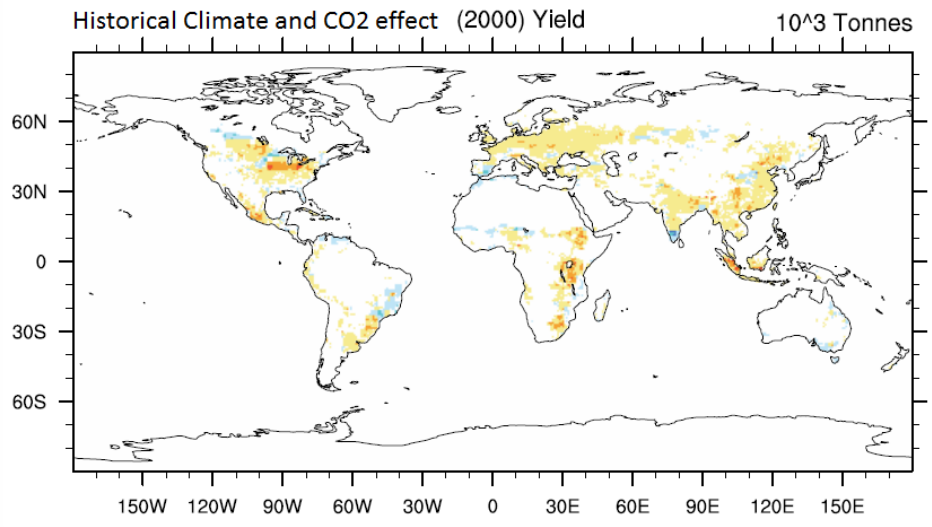


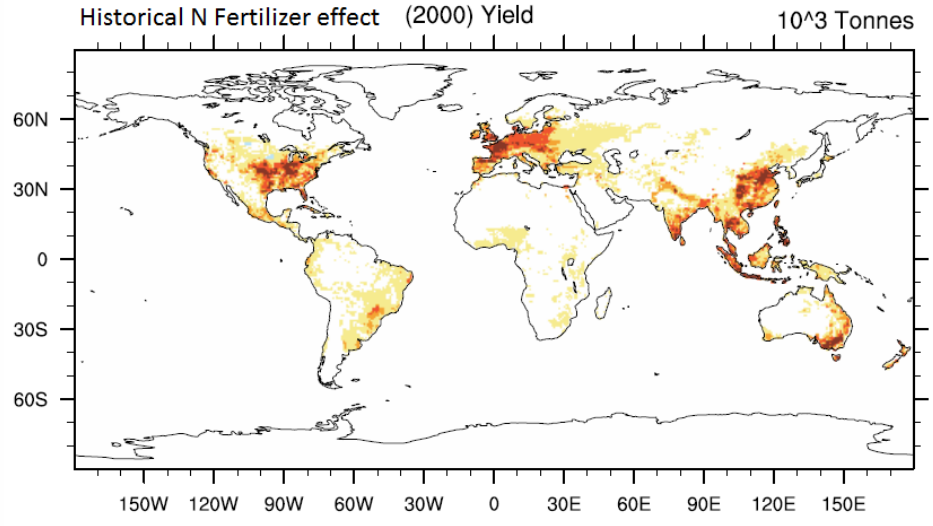


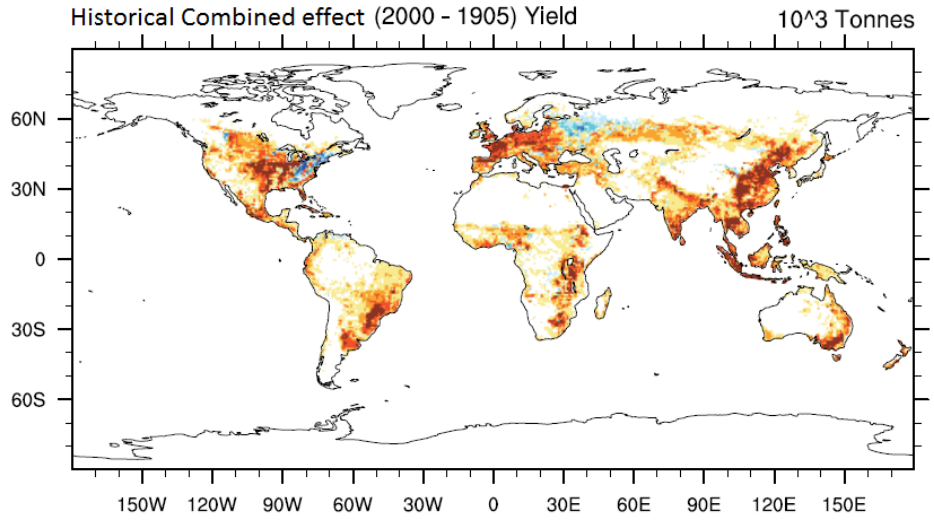
Area Effect	Climate / CO2	N Fert Effect	Irrig Effect	Total Effect
+77.2%	+5.8%	+65.6%	+9.5%	+226.8%

Global Historical CMIP5 (All Crop) Crop Production

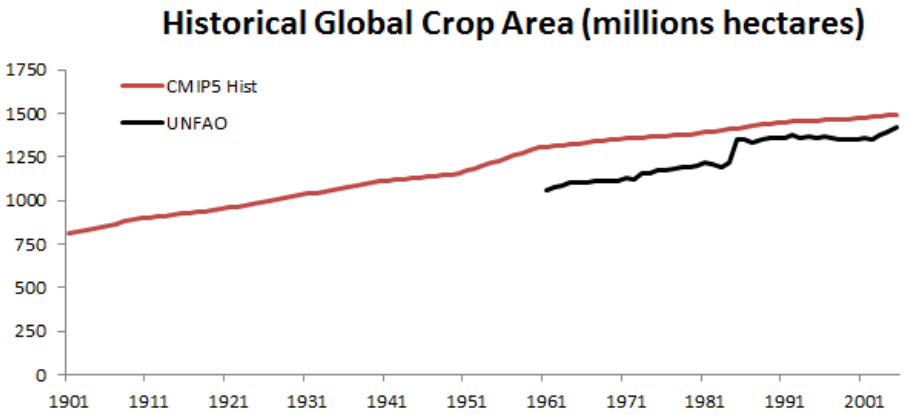


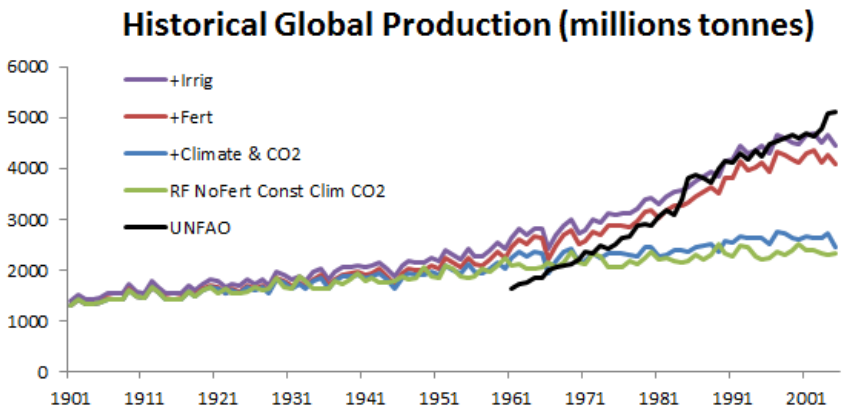


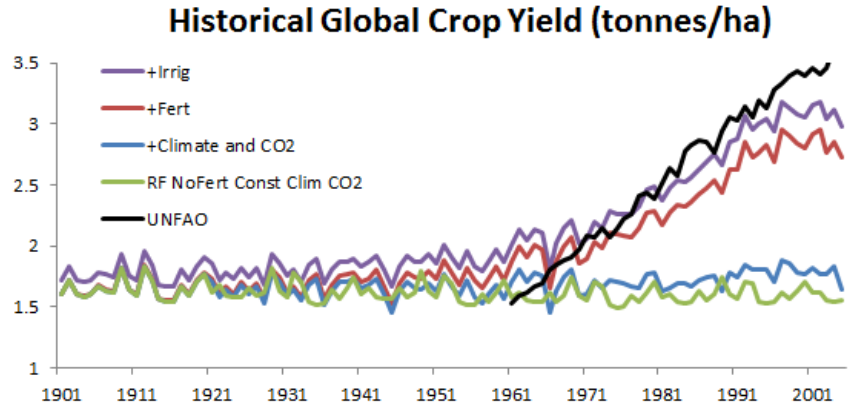


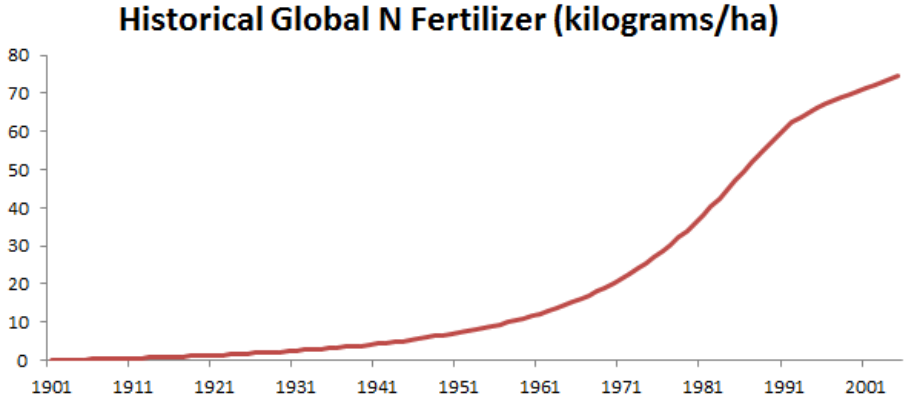


Global Historical CMIP5 – UNFAO Area, Yields, N Fert





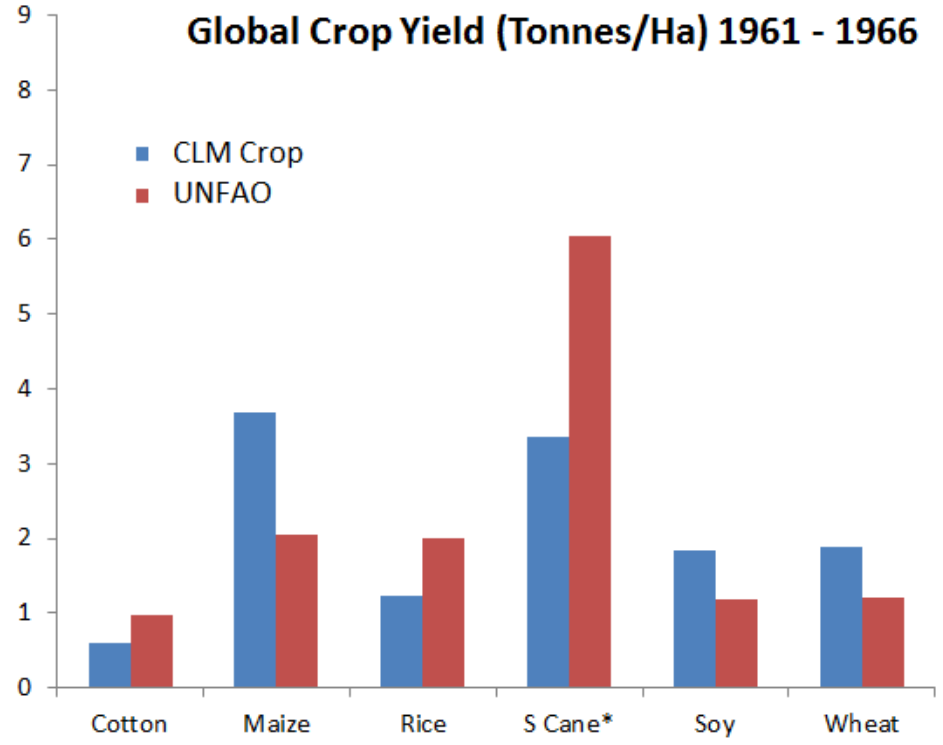


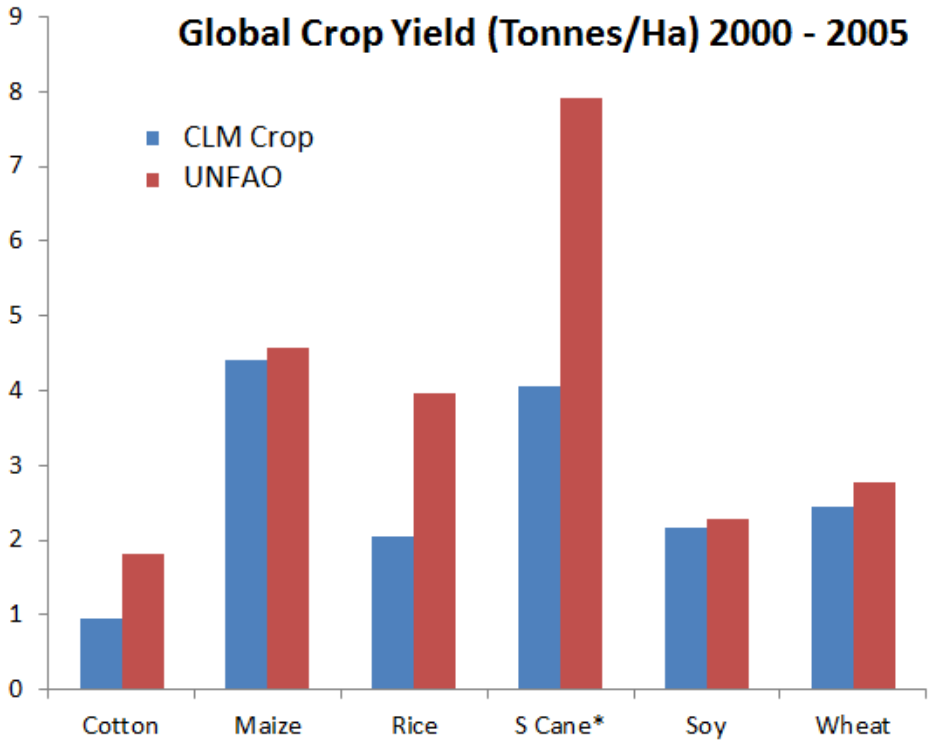


Area Effect	Climate / CO2	N Fert Effect	Irrig Effect	Total Effect
+77.2%	+5.8%	+65.6%	+9.5%	+226.8%

*UNFAO only using Yields for CLM Crop Types over All Crop Areas

Global Historical CMIP5 UNFAO Yields by Crop

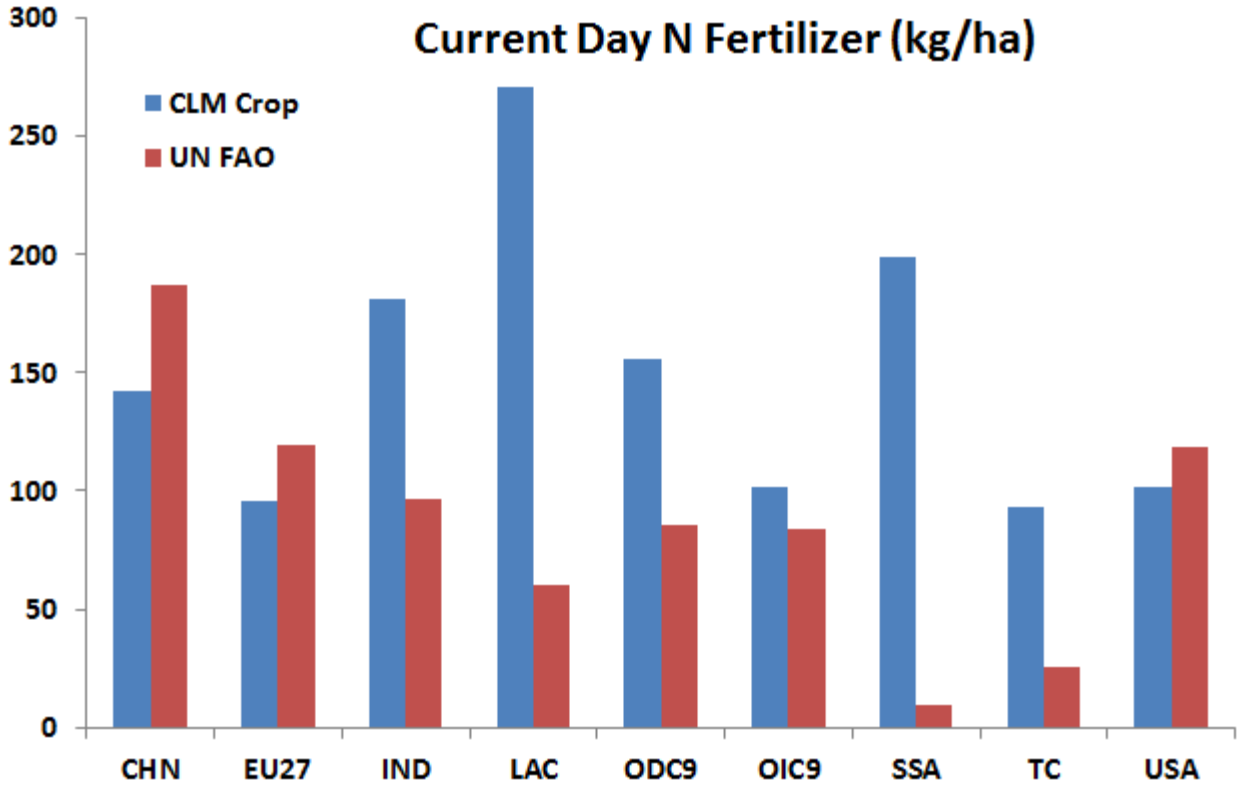




*UNFAO Sugar Cane scaled by 0.12 for sugar from cane

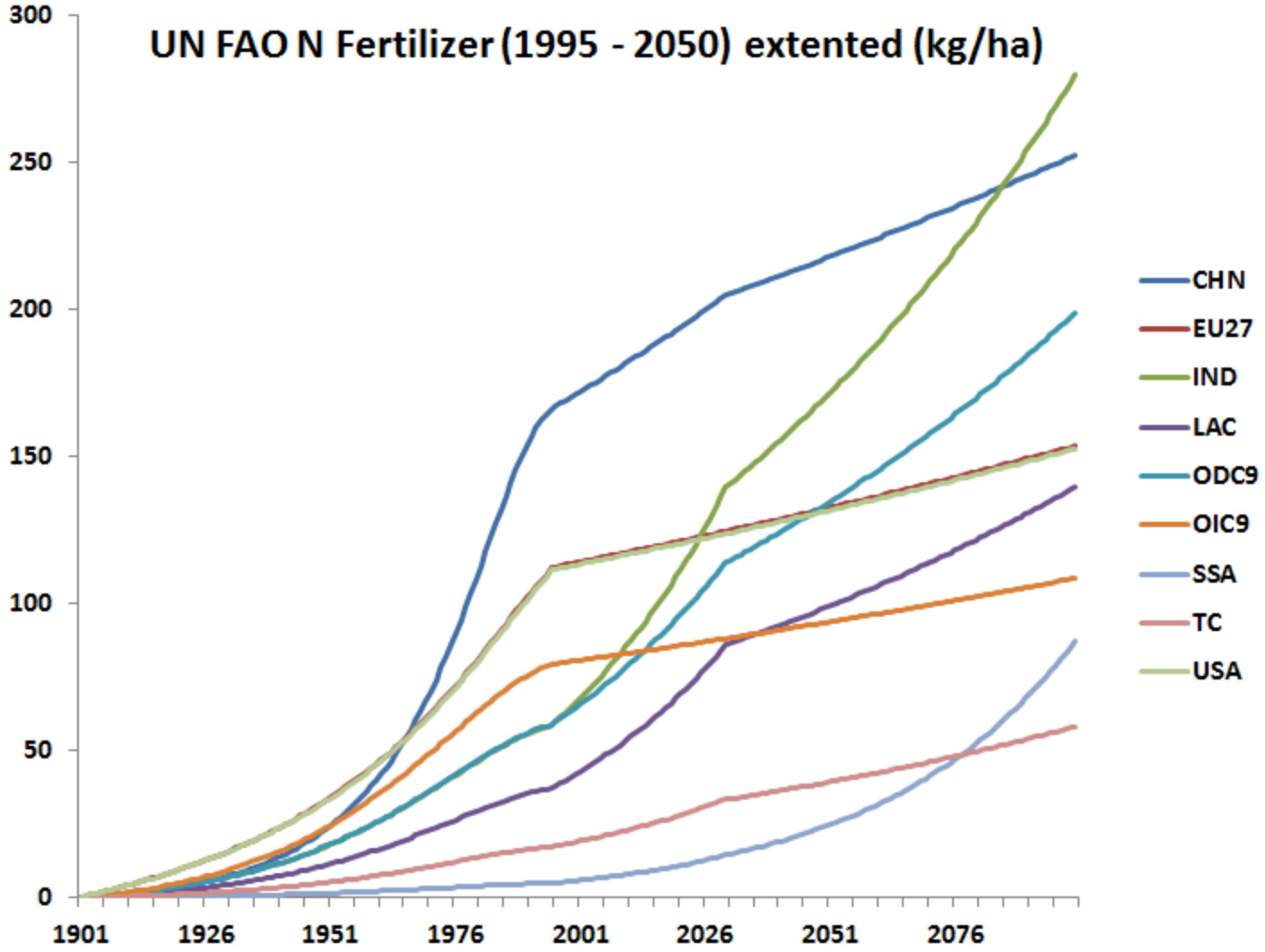
CLM Crop – UNFAO Regional N Fertilizer Application

Regional Current Day CLM Crop N Fertilizer compare to UN FAO estimates



CLM Crop – N Fertilizer Application

Current Day and Projected UN FAO N Fertilizer Application Rates (1995 – 2050)



Historical CLM Crop and UN/FAO - Yield Summary

1. CLM Crop represents the world with six crops with climate varieties as well as rainfed and irrigated management.

2. Historical Crop Area increased from 1901 – 2005 by 685 million hectares (83%) and Industrial Fertilizer increased from 0 to 77 kg/ha

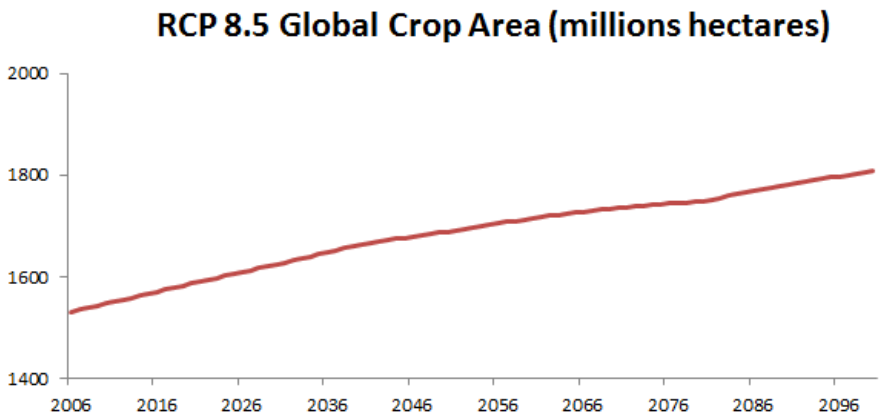
3. Crop Area increases resulted in an increase in Production of 77% with Fertilizer another 66% and irrigation 9.5%. CO_2 only added another 6%

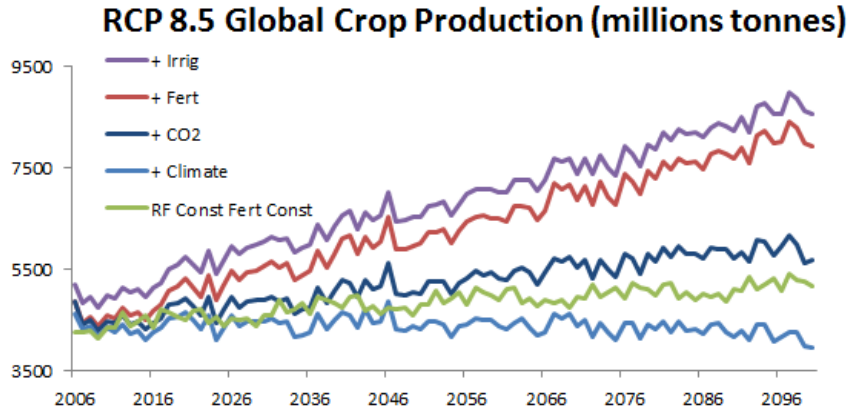
4. Compared to UNFAO, CLM Crop has a similar Production and Yield amounts for the crops simulated for current day

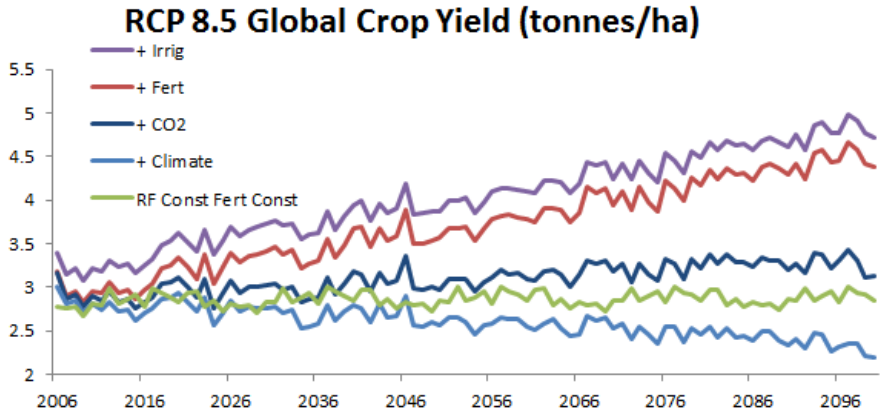
5. UNFAO increases in Production and Yield occur slightly more quickly than CLM Crop (1961 – 2005) possibly due to differences in crop varieties and management such as planting density and irrigation.

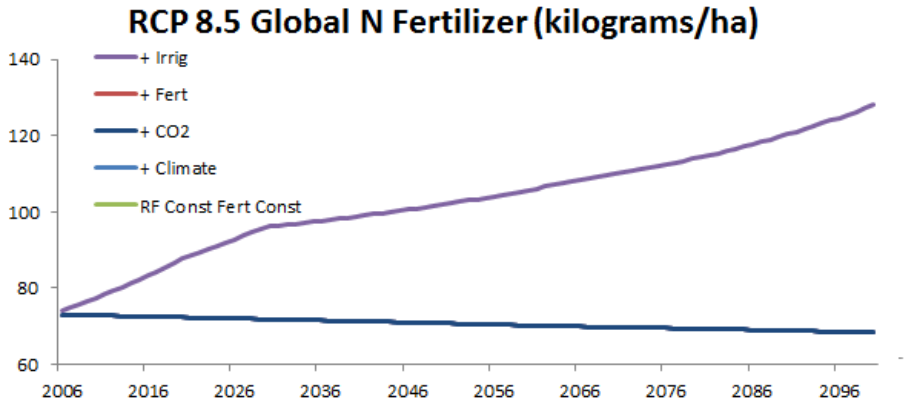
6. Default N Fertilizer for CLM Crop are not applicable for much of the world and need to be changed to transient regional values

Global CMIP5 RCP 8.5 (All Crops) Area, Yield, N



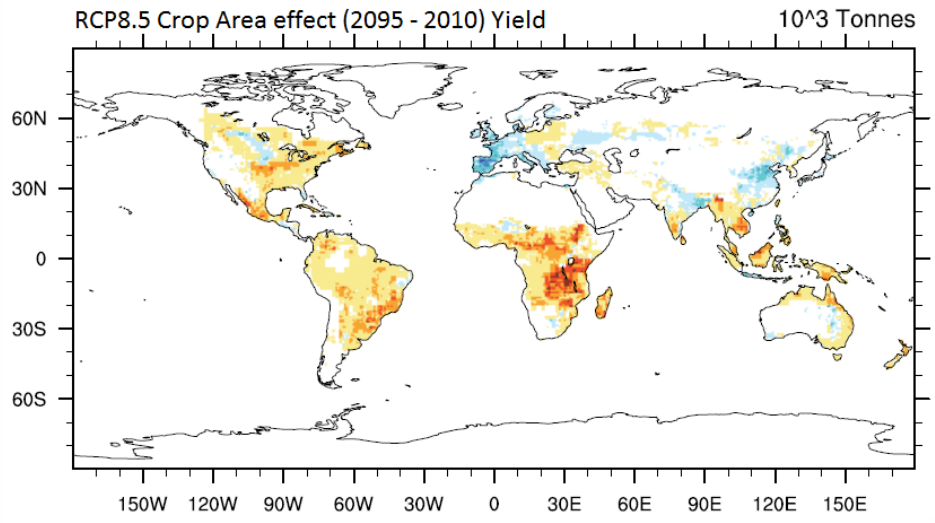


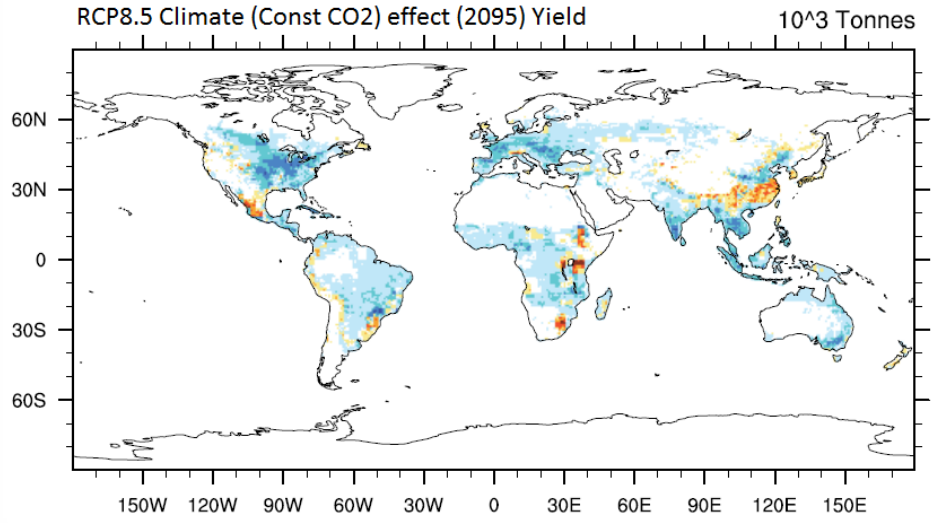


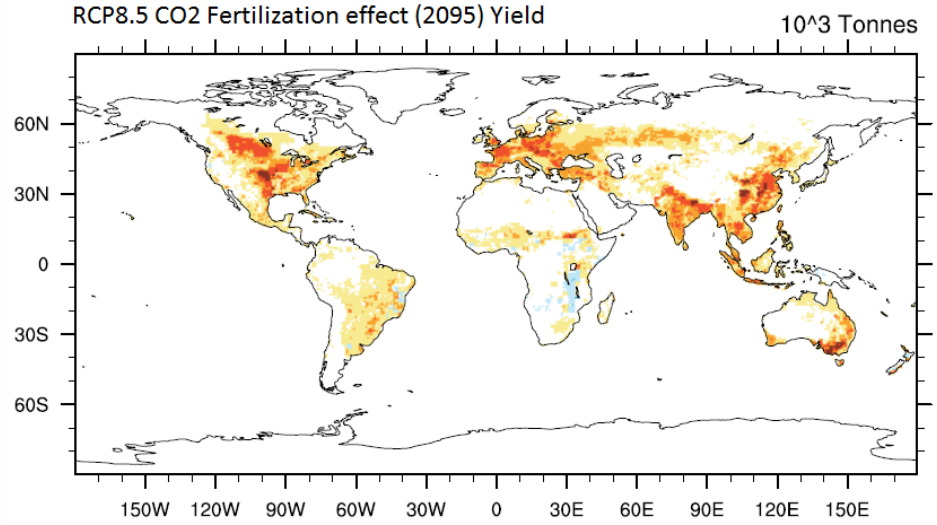


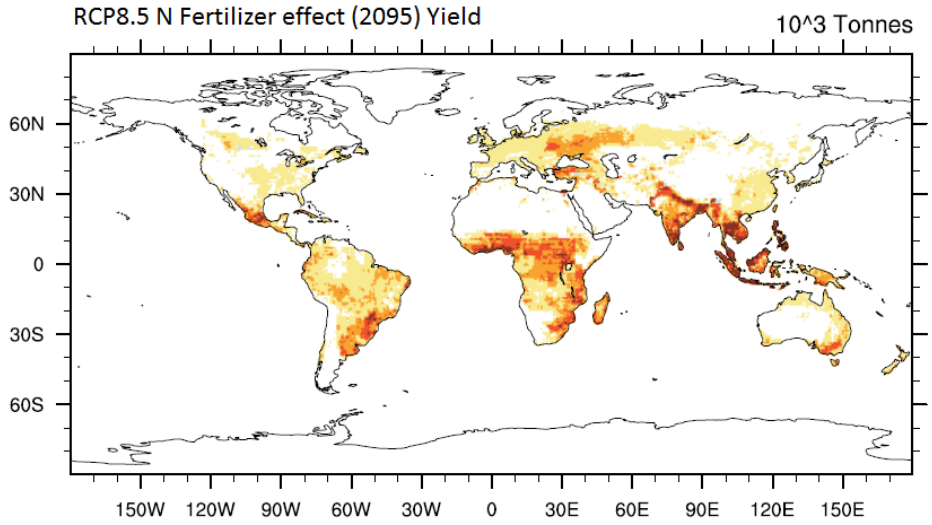
Area Effect	Clim Effect	CO2 Effect	N Fert Effect	Irrig Effect	Total Effect
+21.2%	-23.4%	+43.3%	+39.6%	+8.0%	+64.6%

Global CMIP5 RCP 8.5 Analysis (All Crop) Production

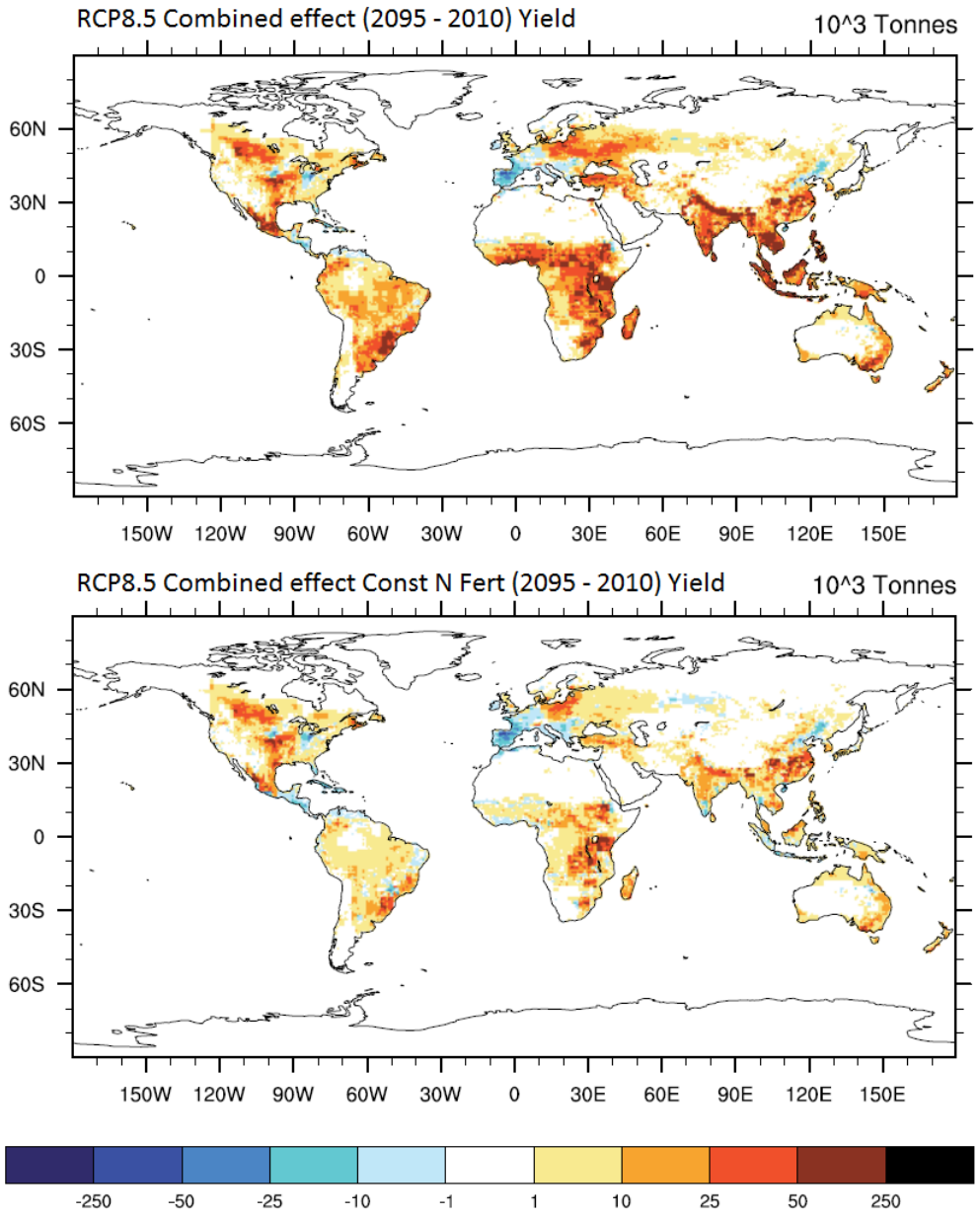








Global CMIP5 RCP 8.5 Analysis (All Crop) Production



Future CLM Crop – Yield Summary

1. RCP 8.5 has an increases in: cropping area of 280 million hectares (18%); average land temperature of +4^{o}C; CO_2 to 930 ppm (150%); and Fertilizer to 117 kg/ha (60%)

2. RCP 8.5 CLM Crop results in changes in Global Production of:

Area Effect	Clim Effect	CO2 Effect	N Fert Effect	Irrig Effect	Total Effect
+21.2%	-23.4%	+43.3%	+39.6%	+8.0%	64.6%

3. Future climate impacts may be under estimated as CLM Crop does not properly account for damage from Heat Waves, Droughts, Ozone, Insects, Diseases, and Floods.

4. Currently CLM Crop responds to temperature, vapor pressure, soil moisture and light to limit photosynthesis which then impacts grain production, but this is only one element impacting yield.

CLM Crop Simulations – Conclusions

1. CLM Crop allows us to investigate changes in Agricultural Production as climate and CO_2 change in combination with cropping area and management

2. Historical increases in cropping area result in a +77% gain with fertilizer and irrigation adding an additional +75% gain. CO_2 results in only another +6% gain.

3. RCP 8.5 crop expansion results in a +21% gain which is offset by climate losses of -23%. CO_2 results in a +43% gain which combines with a fertilizer and irrigation gain of +48% to leave a net +65% gain in Production for the scenario

4. Historically differences from UNFAO may be due no management to change varieties and planting densities. Future impacts do not properly account for damage from Heat Waves, Droughts, Ozone Insects, Disease, and Floods. All of these are current research

Thanks – Questions?