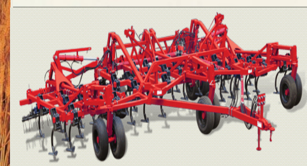
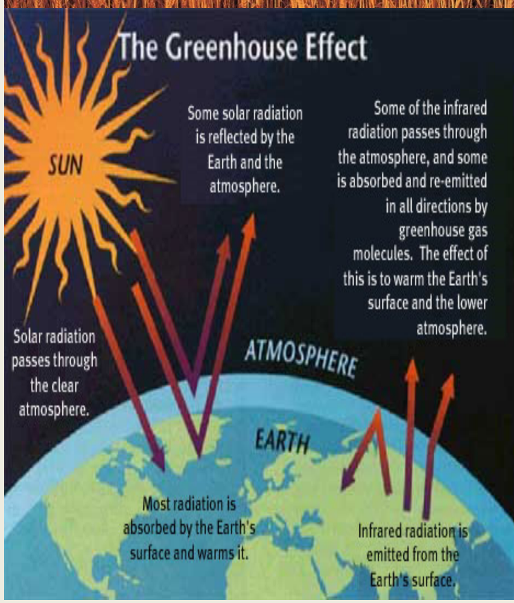
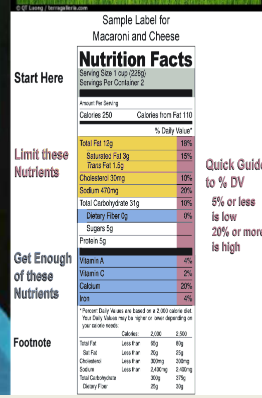
MIT Joint Program, Forum XXXIX
Corporate Strategies and Climate Change,
Cambridge MA, June 15-17, 2016







Agricultural Challenges for the Coming Decades

John Reilly
MIT Joint program on the Science and Policy of Global Change

Agriculture Challenges: Reducing Number of Hungry People

Why are people hungry? From United Nations Experts:

“The world produces enough food for everyone to be properly nourished and lead a healthy and productive life.”

“Hunger exists because of poverty, natural disasters, earthquakes, floods and droughts.”

“Hunger exists because of conflict and war, which destroy the chance to earn a decent living. It exists because poor people don’t have access to land to grow viable crops or keep livestock, or to steady work that would give them an income to buy food.”

“Nearly half the world’s population, 2.8 billion people, survive on less than $2 a day.”

Agriculture Challenges: Reducing Number of Hungry

Where are hungry people and who are they? From United Nations Experts:

The largest number of hungry are in the Asia/Pacific region (578 million) the greatest proportion of hungry are in Sub Saharan Africa (239 million, 30% of the population); worldwide total 926 million.

"Most hungry people are the rural poor living in developing countries – villages in Asia, Africa, Latin America and the Caribbean." Oddly hunger is occurring largely in people involved in producing food or near land resources where food could be produced.

"Women make up a little over half of the world's population, but they account for over 60 percent of the world's hungry."

Obesity now affects more people than malnutrition and some individuals suffer from both stunting and obesity.

1st Set of Conclusions

Increasing food production is not the obvious solution to the challenge of reducing hunger and nutrition—improving income opportunities for those who are hungry is more important.

Requires: Access to land, energy, communication and infrastructure links to markets for production and inputs for rural production (of food and other goods)—for those involved in agriculture higher commodity prices improve their income.

Calories not the answer: Cheap sugars and fats are largely behind the obesity epidemic.

Needed Focus: Nutrition and access to quality food, especially women and children to avoid pre-natal and early childhood stunting.

How?

“Food is good business. When nations solve the problem it fuels their economy.”
Josette Sheeran, Executive Director World Food Programme

Now discredited economic policies focused on industrialization (modern manufacturing) at the expense of agriculture, protecting domestic industry leading to high input prices for agriculture, and often controlling food prices with the idea that it would make food affordable.

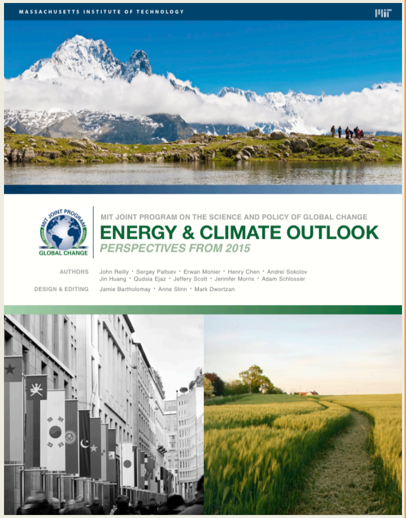
The Result: Undermined agricultural development and domestic food production, and created a manufacturing sector that could not compete in international markets, creating an ongoing demand for tariff protection.

Agriculture Challenges: Growing Demand

		/yr
•	2050 global population, 9-10 b., from 7.3 b. in 2015	
	• 13 years (1974-87) to go from 4 to 5b.	1.7%
	• 12 years (1987-99) to go from 5 to 6b.	1.5%
	• 11 or 12 years (1999-2011 or 2012) from 6 to 7b.	1.3%
	• 12.66 years per b. added if 7 to 10b. (2012-2050).	0.9%

- We expect the world to be wealthier.
  - World GDP up nearly 4x; per capita, 2x
  - Per cap. in developing: China 6x, India 5x, others 2 ½ to 3 x
- Global Food Demand more than doubles
  - Crops ~2.2
  - Livestock 2.5-3.4

See our 2015…



Source: Chen, et al. 2016, Long-term economic modeling for climate change assessment, *Economic Modelling,* **52(B)**: 867–883 & JP 2015 Climate and Energy Outlook

Are Land Resources Adequate?

FAO Global Land Availability (ha x 10^6)

	Total land surface	Suitable land*	Of which		Of which in use as (1999/2001)		Gross balance	Not usable**	Net balance
			Prime land	Good land	Rainfed land	Irrigated land			
World	13 295	4 495	1 315	3 180	1 063	197	3 236	1 824	1 412
Developing countries	7 487	2 893	816	2 077	565	138	2 190	1 227	963
Sub-Saharan Africa	2 281	1 073	287	787	180	3	890	438	451
[illegible]	2 022	1 095	307	788	137	15	943	580	363
Near East / North Africa	1 159	95	9	86	38	12	45	9	37
South Asia	411	195	78	117	85	55	55	43	11
East Asia	1 544	410	126	283	122	53	234	140	94
Other developing countries	70	25	9	15	2	0	23	16	7
[illegible]	5 486	1 592	496	1 095	497	58	1 037	590	447
Rest of the world***	322	11	3	8	2	0	8	7	1

Source: GAEZ-v3.0 in Fischer *et al.* (2011).

* Crops considered: cereals, roots and tubers, sugar crops, pulses and oil-bearing crops. Includes Very Suitable, Suitable and Moderately Suitable land.

** Land under forest, built-up or strictly protected.

*** Countries not included in the regions above and not covered in this study.

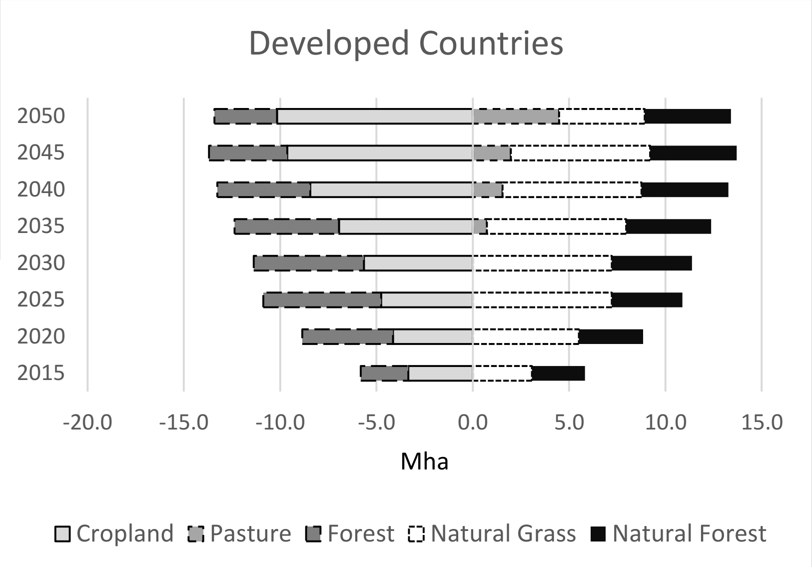
Issue: Sufficient resources but regional differences

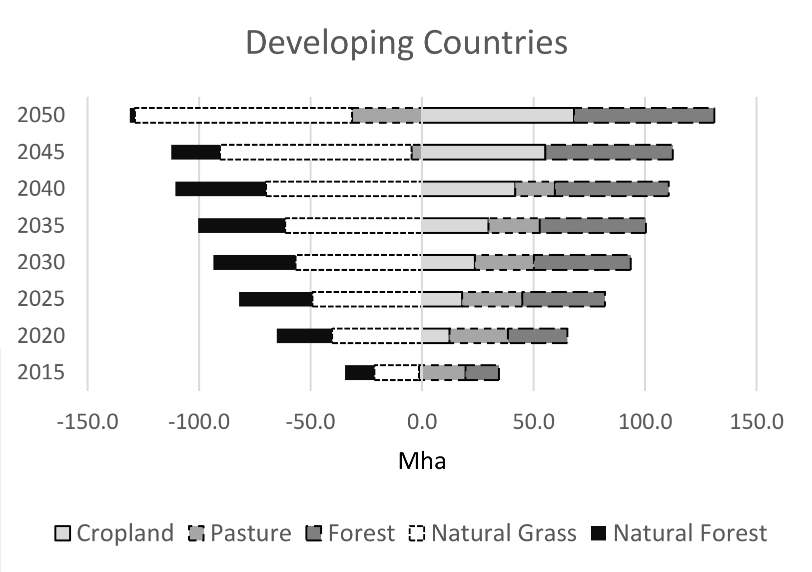
Agriculture Challenges: Future Land Needs

With continued yield increases pressure on land for crop and livestock production does not create strong pressures on land, more reforestation in developed with deforestation in developing countries (Gurgel, et al. 2015, forthcoming)

Table 5. Global land use, Mha.

	Cropland	Pasture	Forest	Natural Grass	Natural Forest
2010	1555	2822	335	2028	3389
2015	1551	2841	347	2011	3378
2020	1564	2848	357	1993	3367
2025	1569	2849	366	1986	3359
2030	1573	2848	372	1979	3356
2035	1578	2846	377	1974	3354
2040	1589	2841	381	1965	3353
2045	1601	2819	388	1949	3371
2050	1613	2795	394	1935	3391

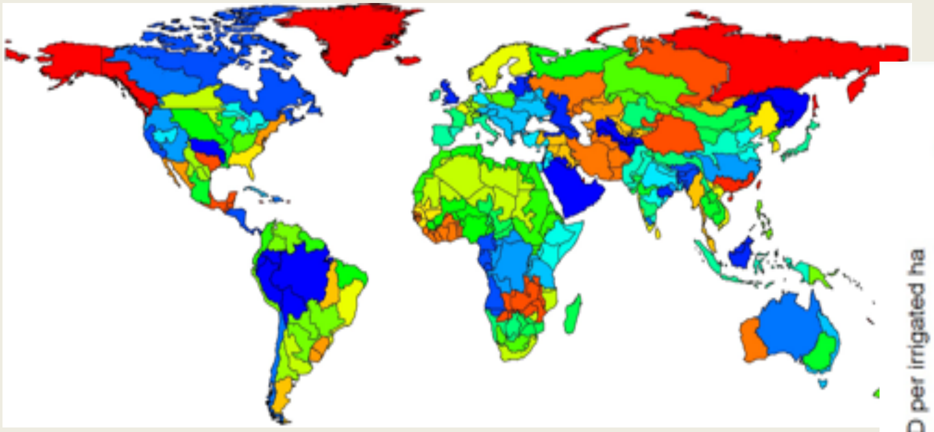




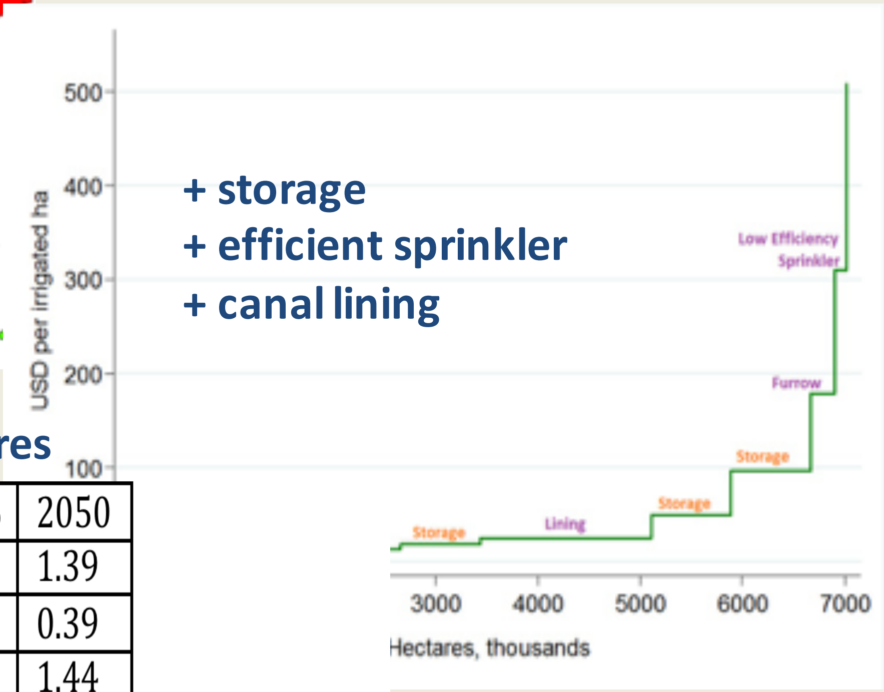
Source: Gurgel, et al., forthcoming, Linking natural resources to the CGE framework **, Book Chapter**

Are Current Water Resources Adequate?

282 Water Basins Interact with 17 EPPA Regions



Basin-Specific Assessment of Irrigation Expansion Potential



Effect of Water Limits on Land, bill. hectares

Scenario	Crop land type	2010	2025	2050
Proportional expansion, rainfed & irrigated	rainfed	1.24	1.24	1.39
	irrigated	0.34	0.35	0.39
Irrigated/rainfed split current water supply	rainfed	1.24	1.26	1.44
	irrigated	0.34	0.32	0.35
Irrigated/rainfed split 80% water supply	rainfed	1.24	1.28	1.46
	irrigated	0.34	0.32	0.33

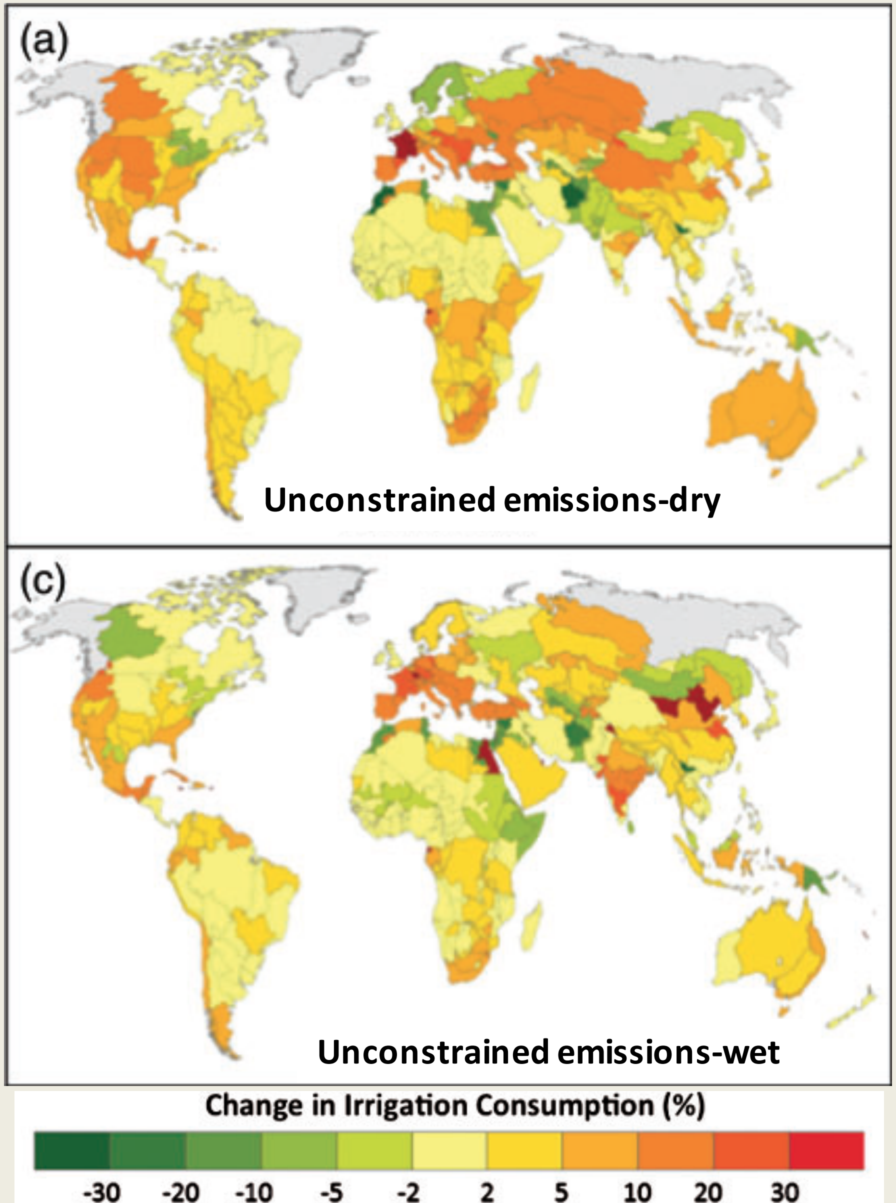
Greater increase in rainfed than reduction in irrigated—irrigated more productive
(Total expansion: .20 (prop.); .21 (current); .23 (80%)

Issue: Water constraints under current conditions not a global concern, regional hotspots.

Source: Winchester, et al., forthcoming **The Impact of Water Scarcity on Food, Bioenergy and Deforestation, JP Report**

Agriculture Challenges: How will irrigation requirement change with climate?

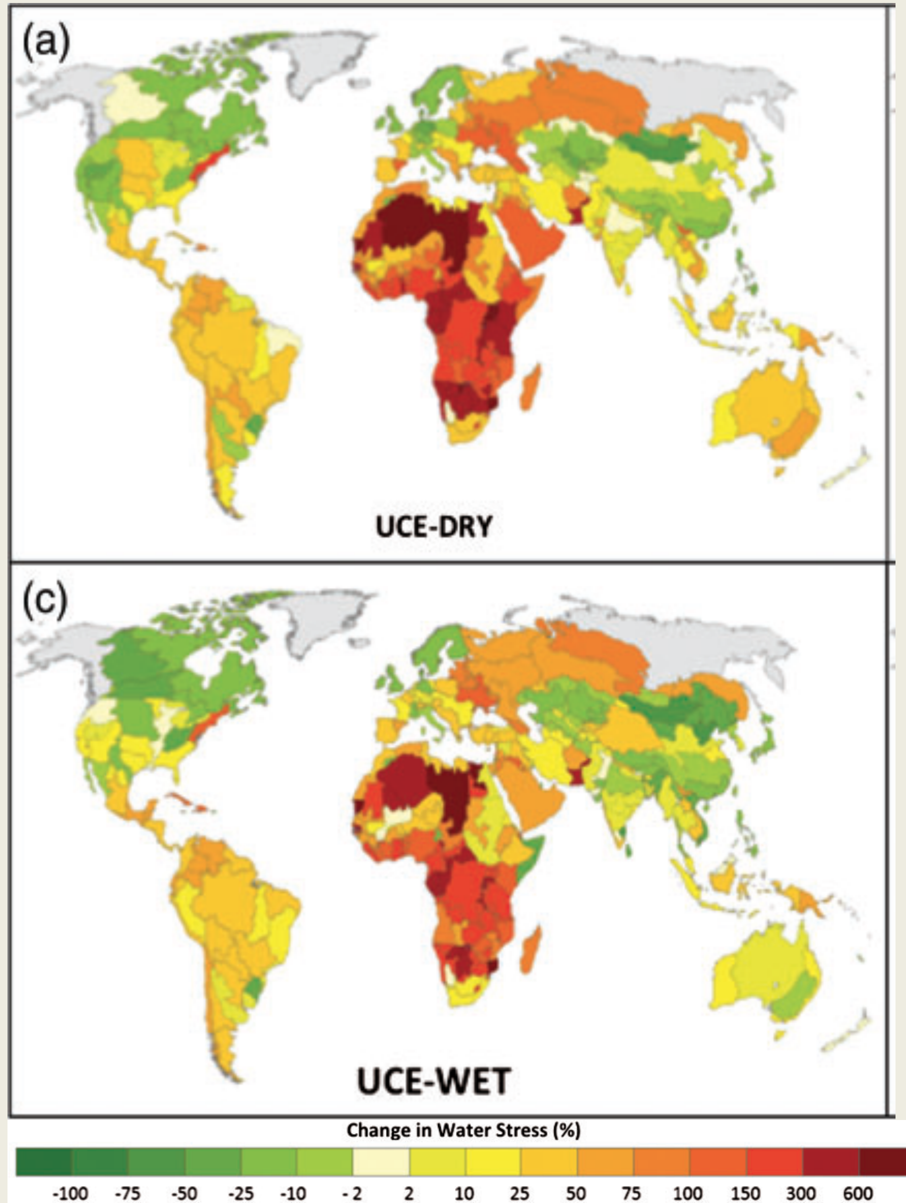
Climate increases irrigation water requirements (2050's compared with 2010's) in most regions…higher temperatures increase evapotranspiration except in a few areas where precipitation increases more



Source: Schlosser, et al. 2014. The future of global water stress: An integrated assessment *Earth's Future* **2(8):** 341-361

Agriculture Challenges: Irrigation and increased demand from other sectors?

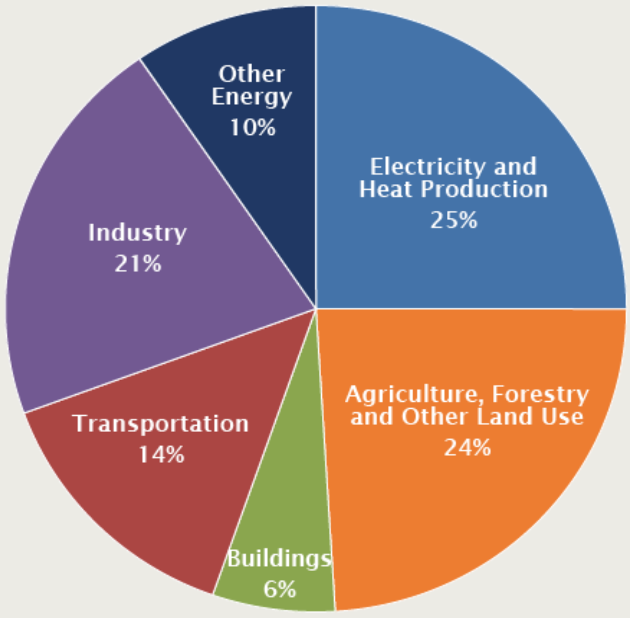
Big increases in water stress (2050's compared with 2010's), irrigation requirements combined with growth in population and economic activity

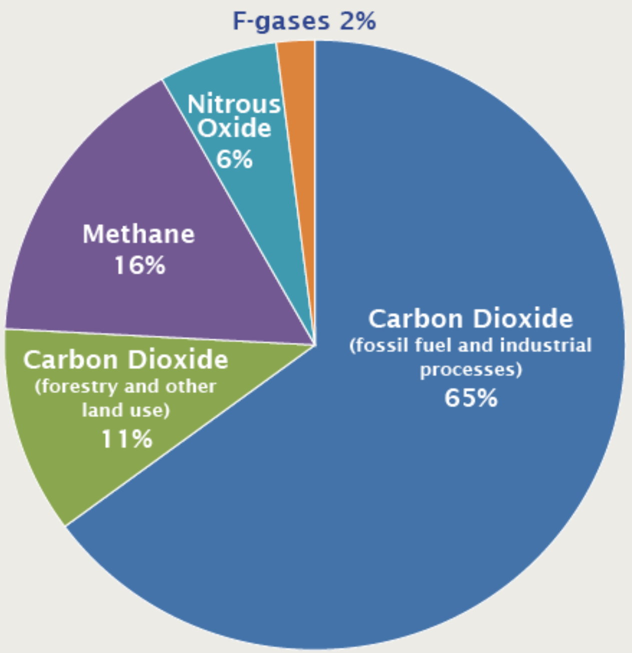


Source: Schlosser, et al. 2014. The future of global water stress: An integrated assessment *Earth's Future* **2(8):** 341-361

Agriculture Challenges: GHG Footprint

- Agriculture (including forestry) & land use globally estimated to account for 24% of GHG emissions (but land sequestration offsets an estimated 1/5)
  - ~85% of nitrous oxide-largely from fertilizers
  - ~50% of methane—rice, ruminants, manure mgmt.

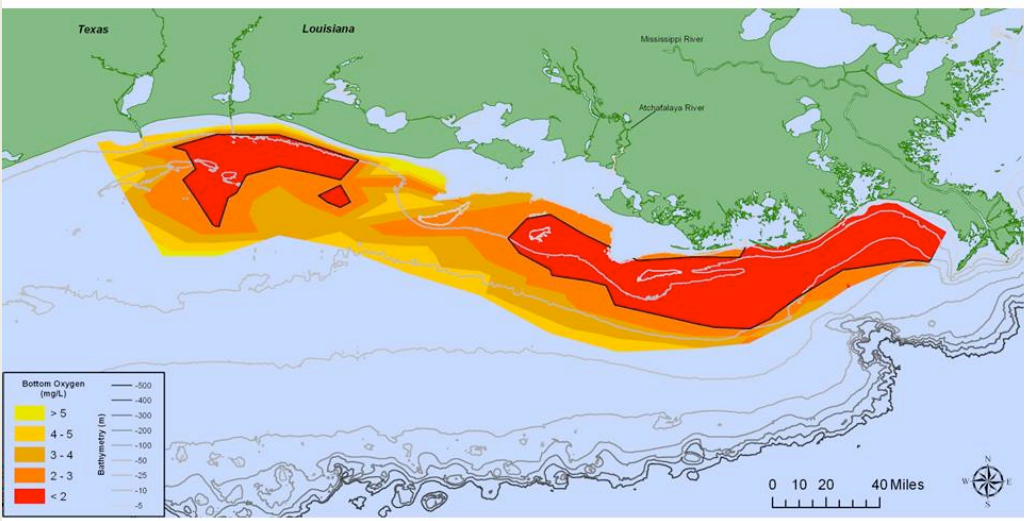




Agriculture Challenges: Broader Environmental Footprint

- Other environmental issues
  - •Soil erosion effects on streams, lakes, and coastal waters (e.g. hypoxic zone in the Gulf of Mexico, Chesapeake Bay)
  - •Nitrates and ground water

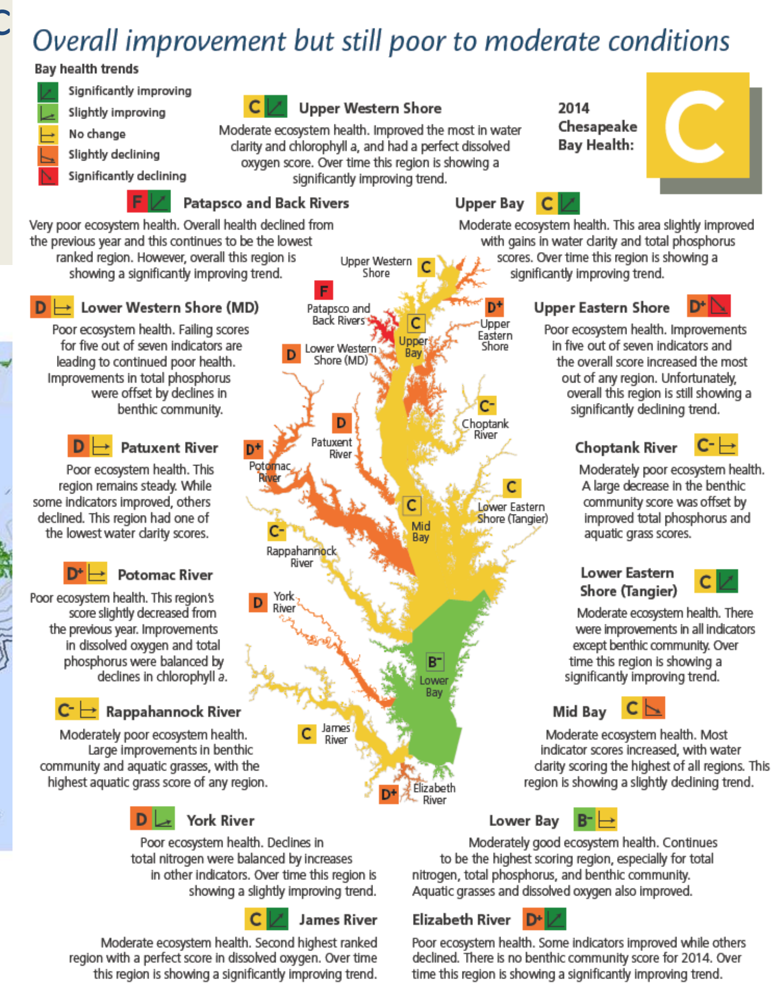
Bottom-water Dissolved Oxygen – 2014



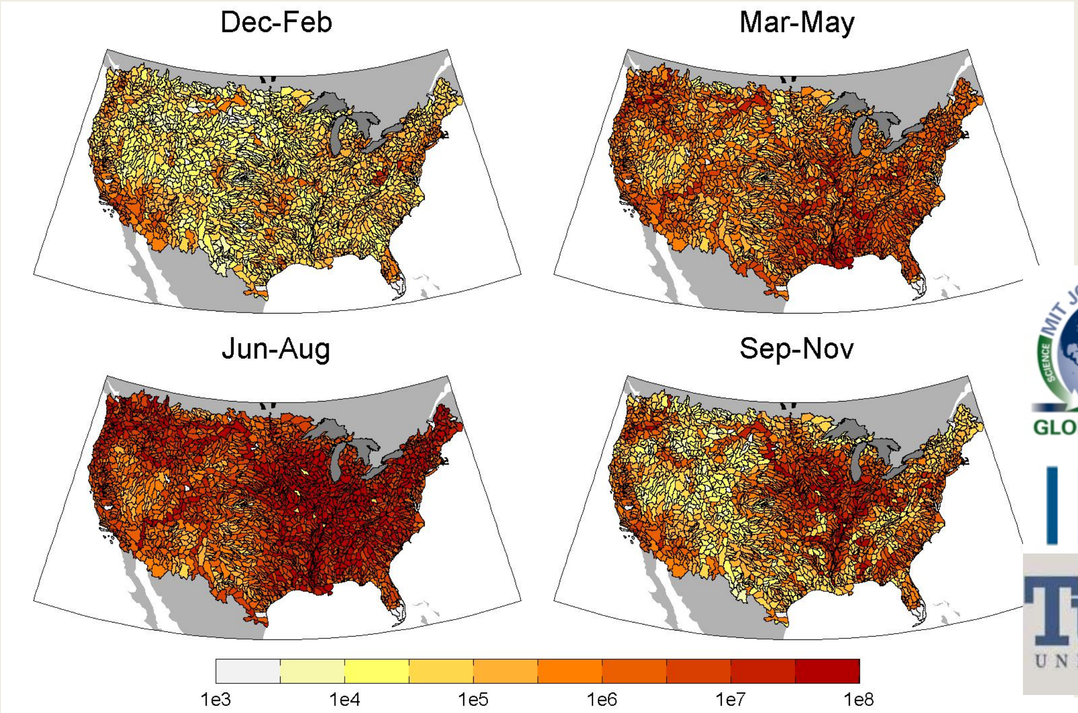
Distribution of bottom-water dissolved oxygen July 27-August 1 (west of the Mississippi River delta), 2014. Black line indicates dissolved oxygen level of 2 mg/L.

Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU

Funding sources: NOAA Center for Sponsored Coastal Ocean Research and U.S. EPA Gulf of Mexico Program



Research can tell us the actual sources and how climate change may affect runoff.



Average Seasonal Nitrogen Loading (kg)

A new modeling tool collaboratively developed

MIT JOINT PROGRAM SCIENCE POLICY GLOBAL CHANGE

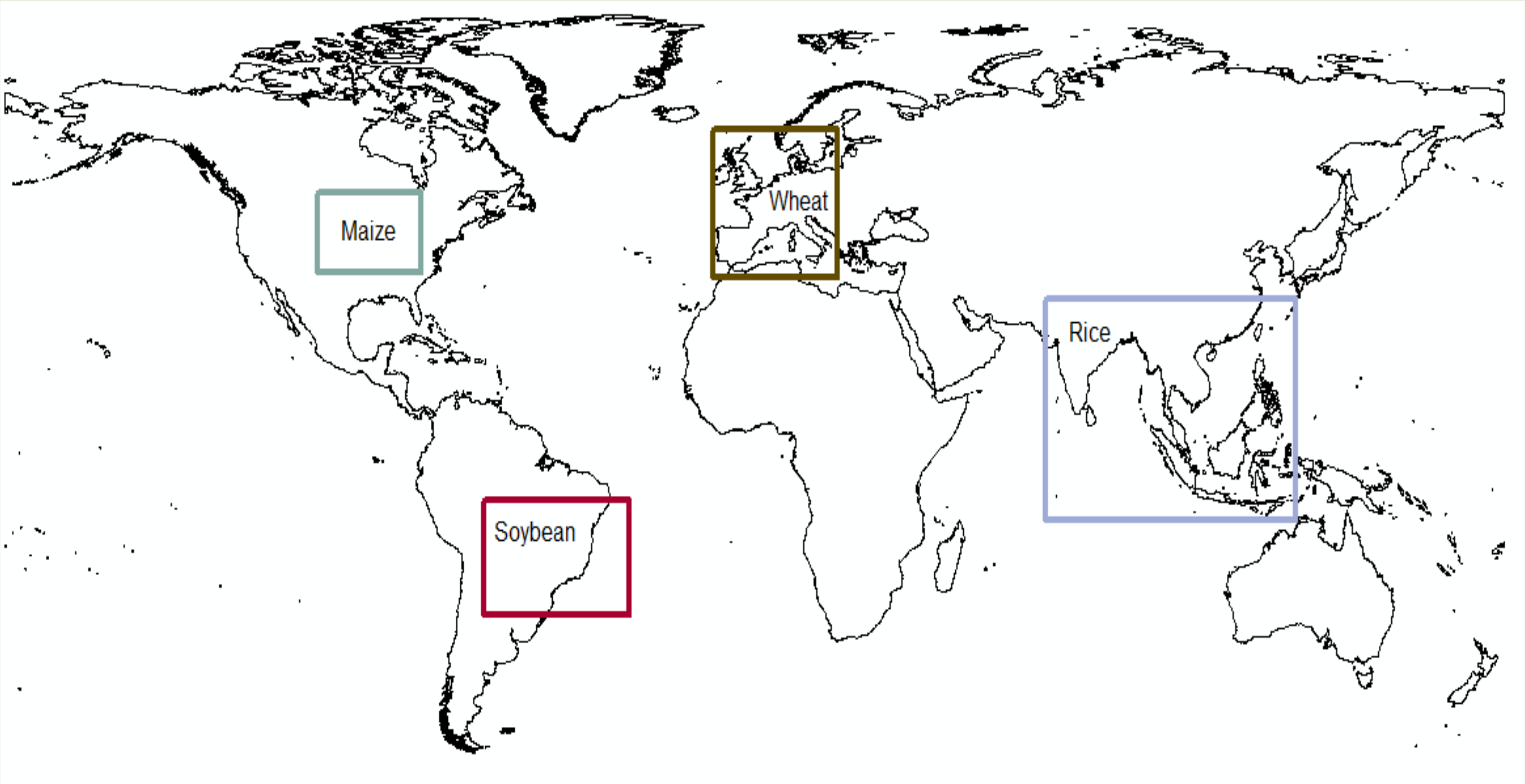
IEc

Tufts UNIVERSITY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Water Quality Model for Assessing Climate Change Impacts…: Boehlert et al., 2015, *JAMES*, ***7*(3)** 1326-1338

Agriculture Challenges: Climate change and yields in the World's Breadbaskets



Yield simulations with 5 (emulated) globally gridded crop models for COP 21 climate (2015 JP Climate and Energy Outlook) for 2 GCM climate patterns, no yield enhancing technical change.

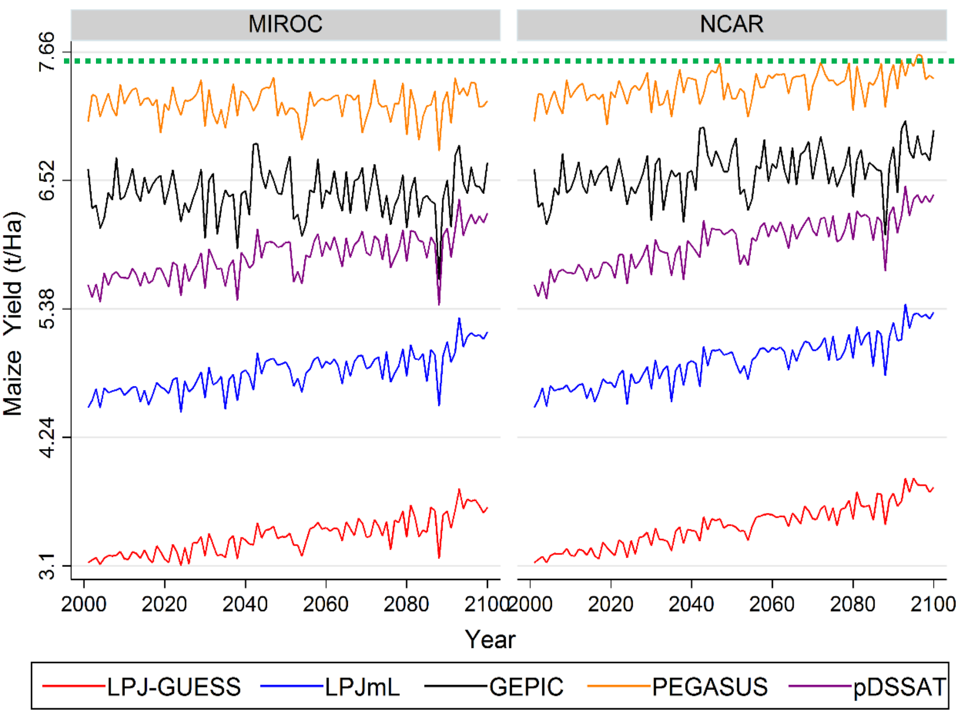
Source: Based on methods in: Blanc, 2016. Statistical Emulators of Maize, Rice, Soybean and Wheat Yields from Global Gridded Crop Models, Joint Program Report No. 296.

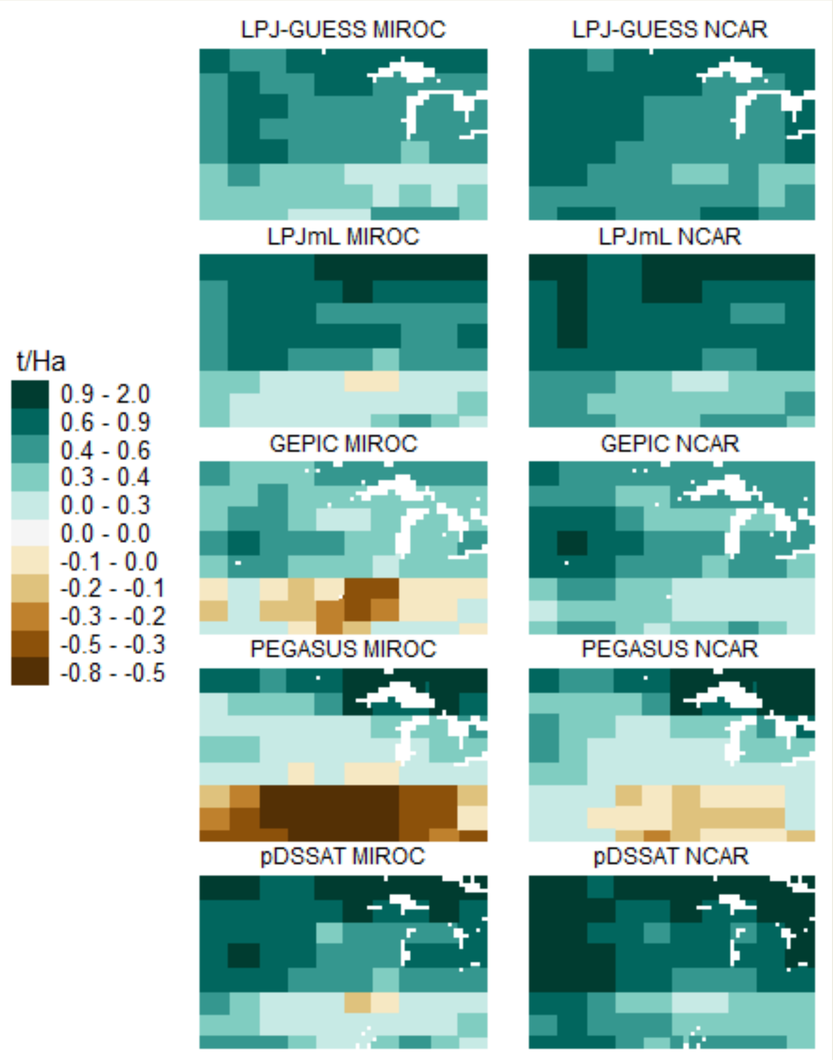
Agriculture Challenges: Maize yields, US

Regional patterns:
2091-2100 compared to period 2001-2010)

Average yields (in t/Ha) for the period 2001-2100

Actual 2014/15 U.S. Average: ~10.7 tons/hectare



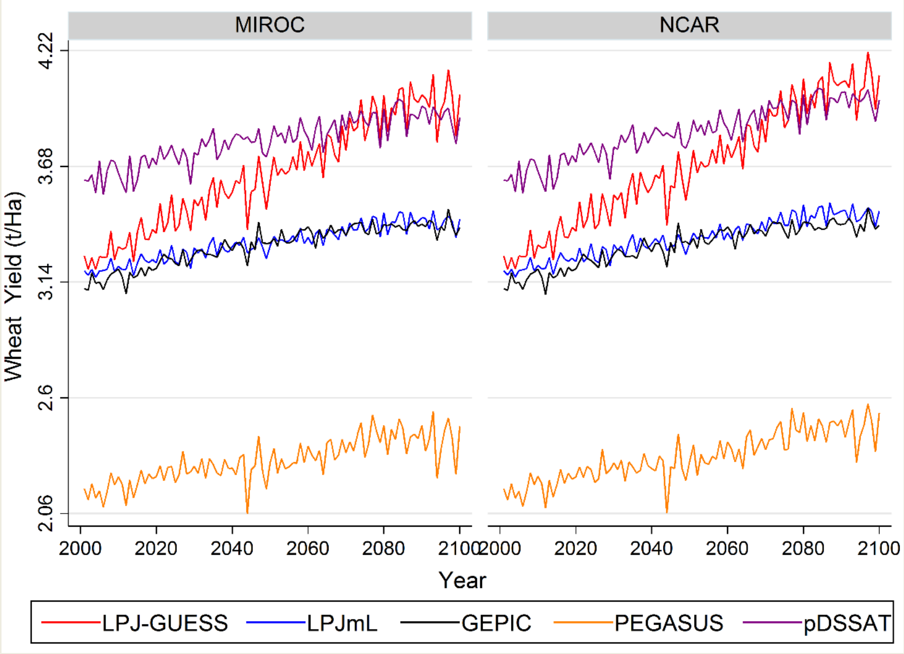


Source: Based on methods in: Blanc, 2016. Statistical Emulators of Maize, Rice, Soybean and Wheat Yields from Global Gridded Crop Models, Joint Program Report No. 296.

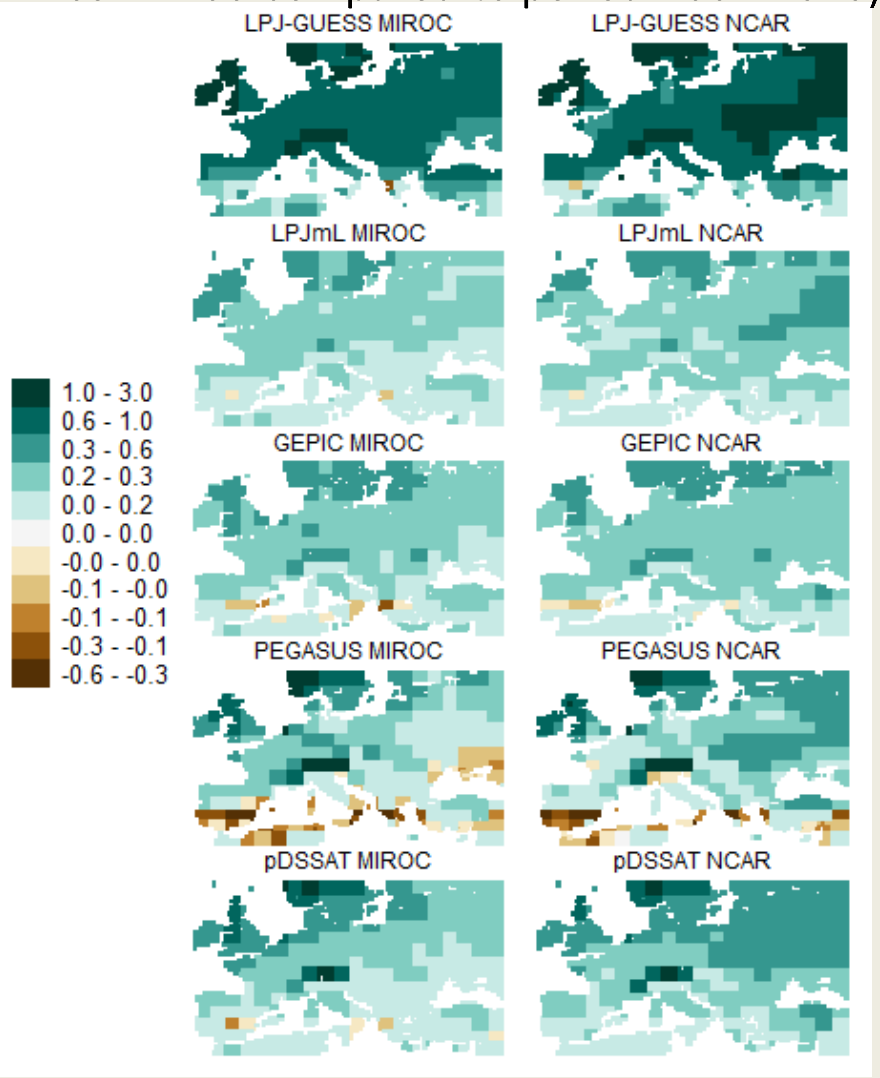
Agriculture Challenges: Wheat yields, Europe

Average yields (in t/Ha) for the period 2001-2100

Actual 2014/15 Europe Average: ~5.9 tons/hectare



Regional patterns:
2091-2100 compared to period 2001-2010)

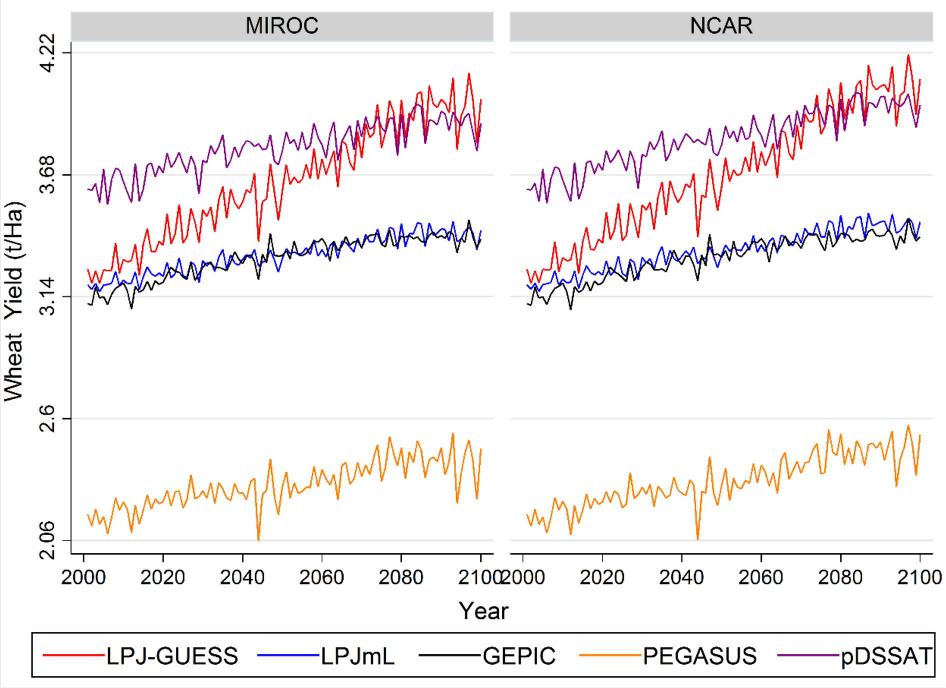


Source: Based on methods in: Blanc, 2016. Statistical Emulators of Maize, Rice, Soybean and Wheat Yields from Global Gridded Crop Models, Joint Program Report No. 296.

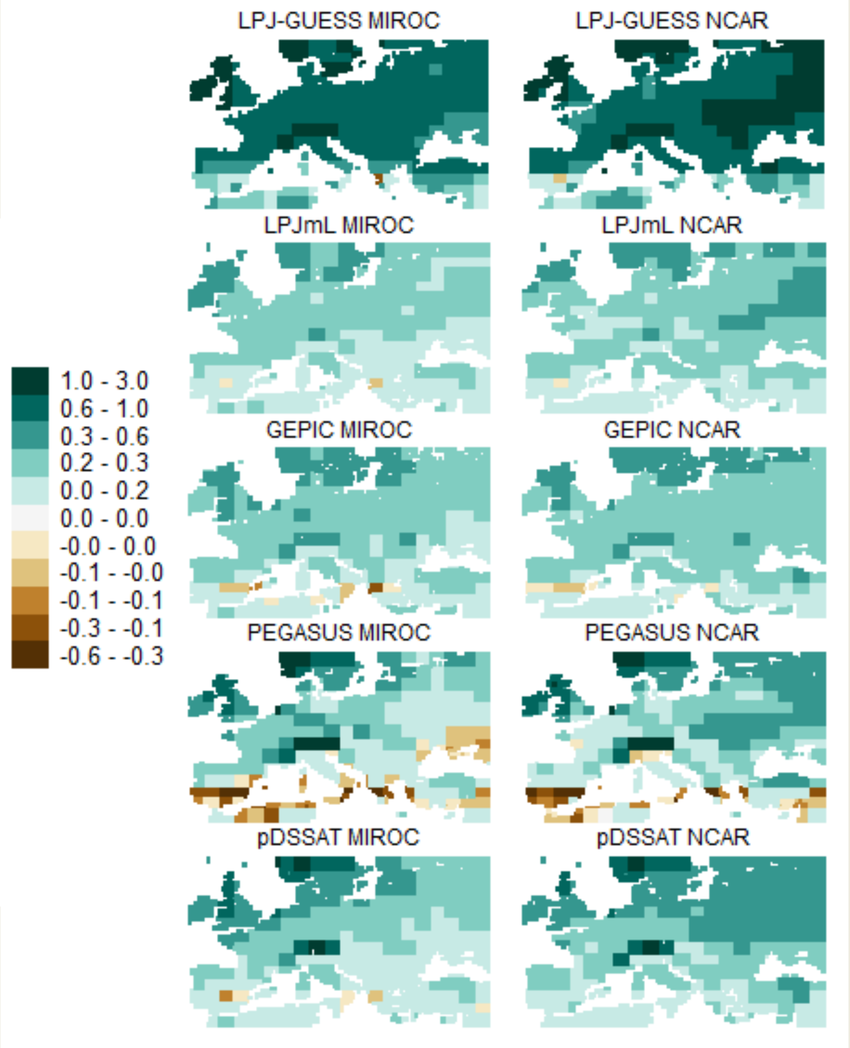
Agriculture Challenges: Upland Rice yields, SE Asia

Average yields (in t/Ha) for the period 2001-2100

Actual 2014/15: E. Asia, 7.0; S. Asia,3.7; S.E. Asia, 4.0



Regional patterns:
2091-2100 compared to period 2001-2010)

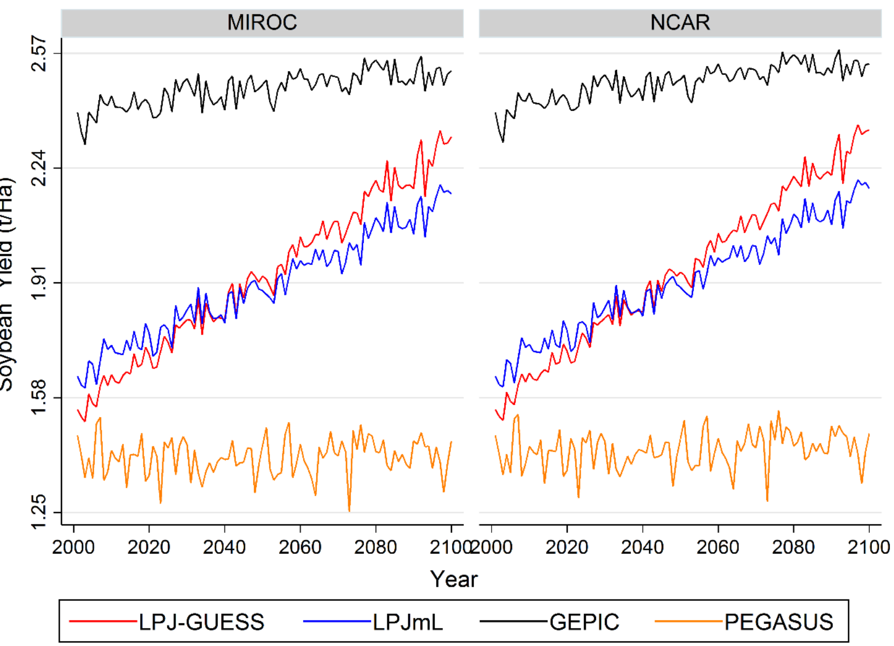


Source: Based on methods in: Blanc, 2016. Statistical Emulators of Maize, Rice, Soybean and Wheat Yields from Global Gridded Crop Models, Joint Program Report No. 296.

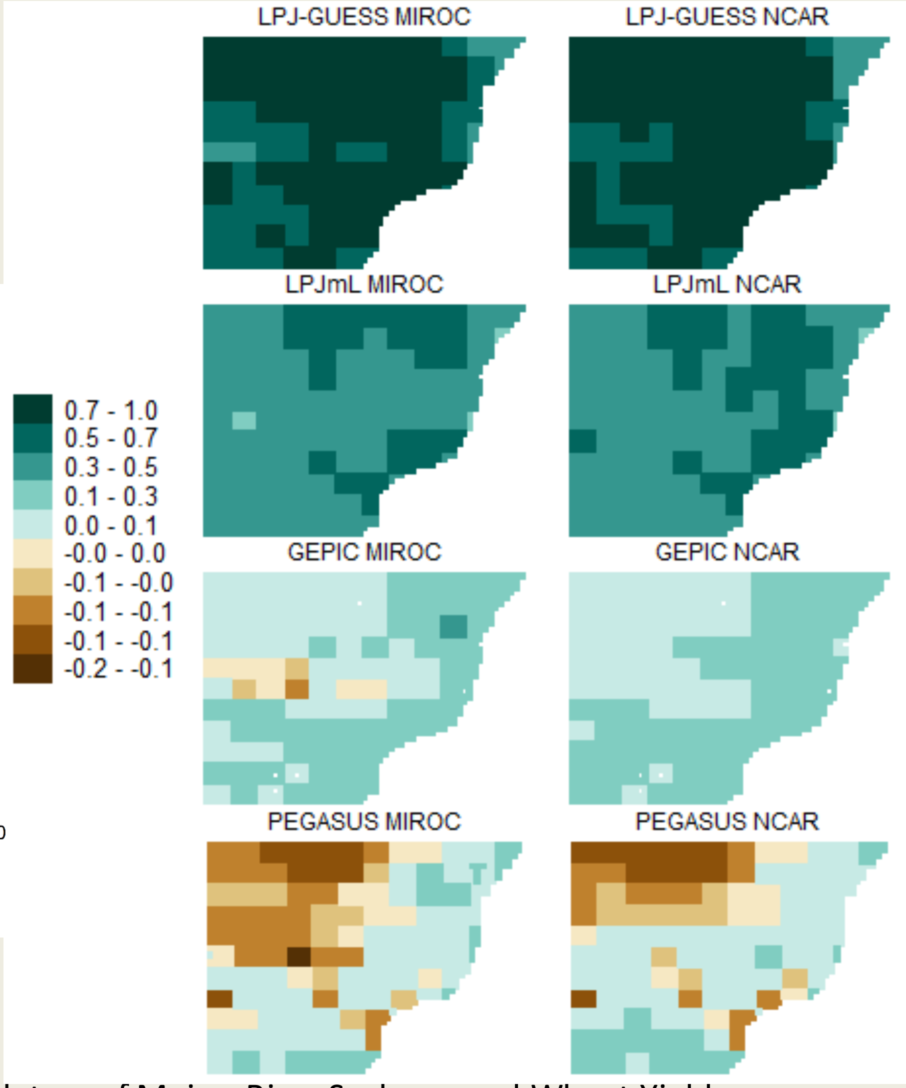
Agriculture Challenges: Soybean yields, Brazil

Average yields (in t/Ha) for the period 2001-2100

Actual 2014/15 Average for Brazil: 2.9 tons/hectare



Regional patterns:
2091-2100 compared to period 2001-2010)



Source: Based on methods in: Blanc, 2016. Statistical Emulators of Maize, Rice, Soybean and Wheat Yields from Global Gridded Crop Models, Joint Program Report No. 296.

Numerous forces affecting agriculture and forestry:

- How to improve incomes, reduce hunger, and provide nutritious food to 10 billion people, many with greater meat in diets?
- Can we limit environmental changes and adapt to unavoidable change?
- How to meet competing demands for natural resources—while global resources adequate, regional stresses may be severe for water, land?
- How to farm with less impact on the environment?
- How to maintain diversity, support local agriculture, and remain resilient in the face of environmental change?
- How to control technology toward positive ends, and what tradeoffs to accept?
- How to better calibrate globally gridded crop models to actual data—does the range of results reflect irreducible uncertainty or can we do better?