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Balancing global water supplies and demands: initial experiments in an integrated assessment model

Sonny Kim, Mohamad Hejazi, Lu Liu, Kate Calvin, Page Kyle, Pralit Patel, Marshall Wise, Leon Clarke, and Jae Edmonds

JGCRI Technical Workshop and GCAM Community Modeling Meeting 2014

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Roadmap

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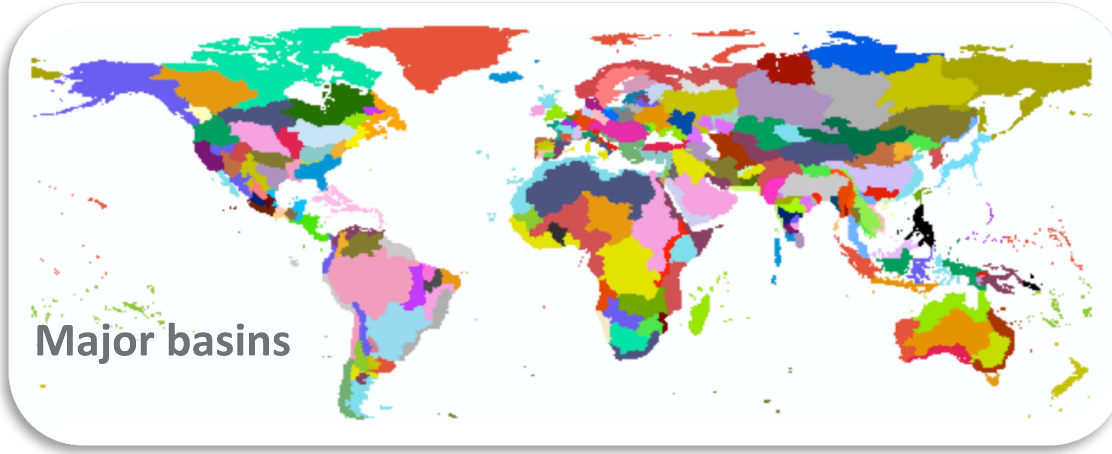
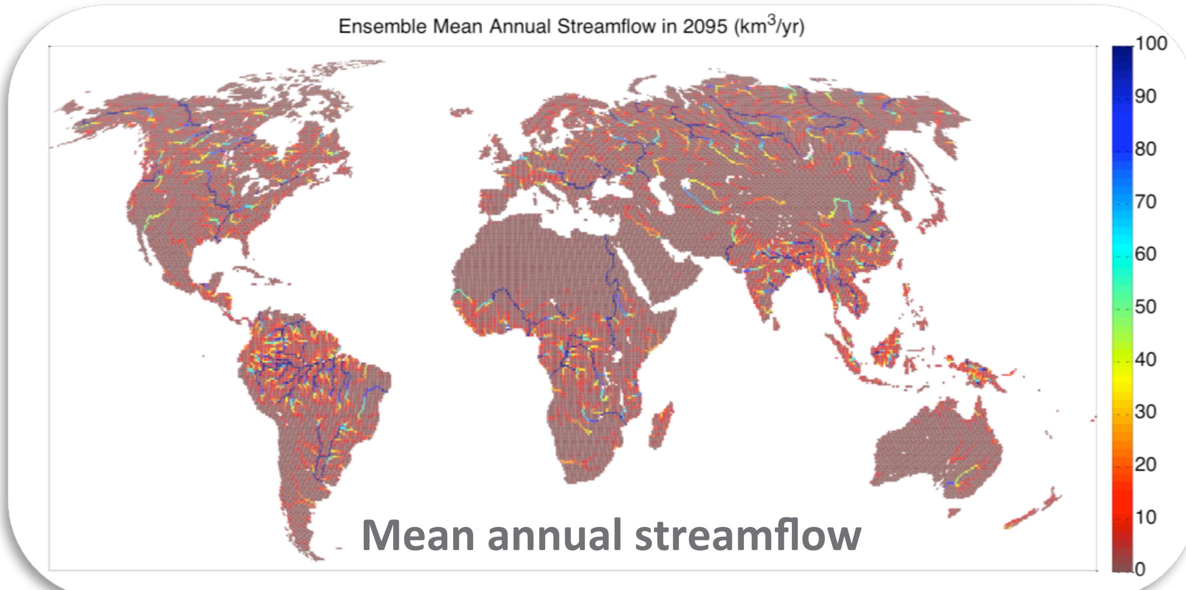
1. Methodology - representing water in GCAM
   - Water supplies and demands
   - Mapping water supplies and demands
   - Balancing supplies and demands
2. Impact of water pricing and closing water markets
3. Sensitivity studies
   - renewable runoff water supply
   - non-renewable ground water
   - alternative water pricing
4. Climate mitigation and water pricing interactions

GCAM Global Water Supplies: Renewable Water



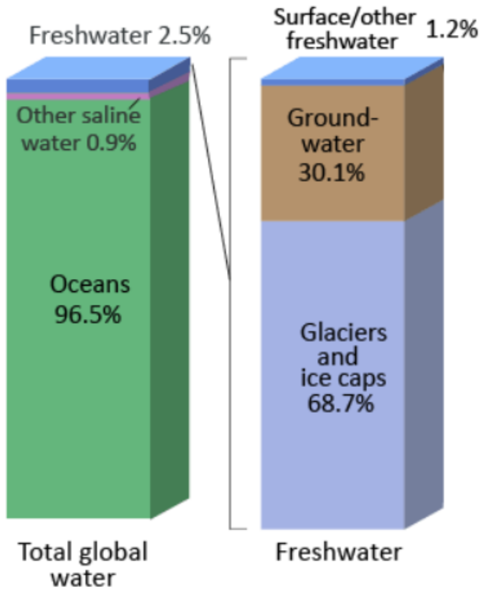


- GCAM has a macroscale global hydrologic model
- Modified River Transport Model scheme
- Simulates runoff and streamflow (1901-2100)
- Requires climate information from GCMs as inputs
- 233 basins globally
- 18 basins in the US consistent with the USGS WRRs
- Monthly temporal scale
- 0.5x0.5 degree spatial resolution

Toward understanding the implications of **climate change impacts** on **water** availability and on **energy and land** decisions in GCAM

GCAM Global Water Supplies:
Non-renewable Water Resources

- Non-renewable (fossil) groundwater
  - Depletable resources
  - No constraint on maximum volume due to lack of information and the large amounts that are available
  - Cost of groundwater pumping increases with depth following the work of Zhu et al., (2007)
- Desalinated water
  - Assumed a constant per unit cost

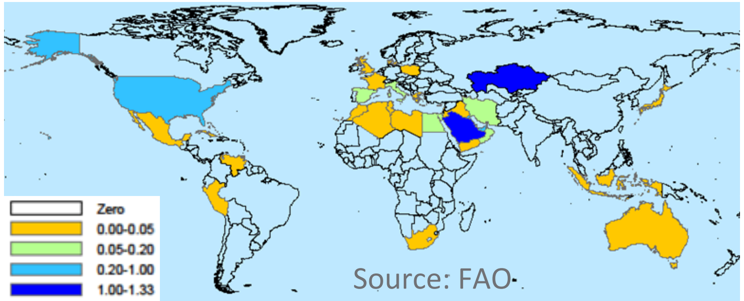


Gleick (1993)

	Global		US	
Desalination water source	Share (%)	Cost ($/ m3)	Share (%)	Cost ($/m3)
Sea	56%	1	7%	1
Brackish	24%	0.6	51%	0.6
River	9%	0.6	26%	0.6
Waste water	6%	0.6	9%	0.6
Pure	5%	0.6	7%	0.6
Brine	0%	-	0%	-
SUM	100%	0.824	100%	0.628

Wangnick/GWI (2005)
Zhou & Tol (2005)

Desalinated water produced (10^9 m3/yr) (2005)



Water Flow Schematic

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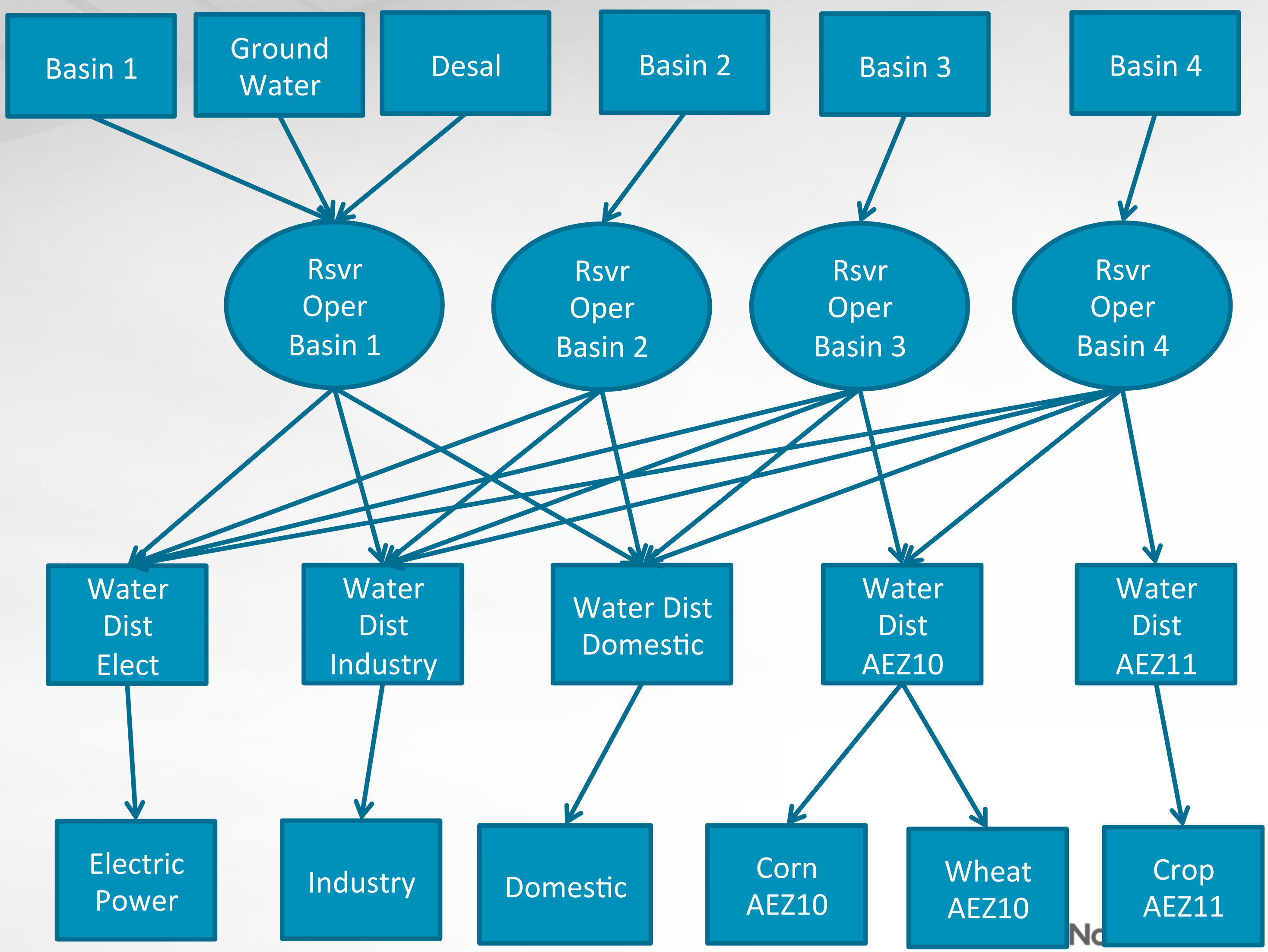
Basin Runoff, Ground Water & Desalination

Total Basin Supply

Water Distribution & Mapping

Consumer



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Closure of the Water System in GCAM

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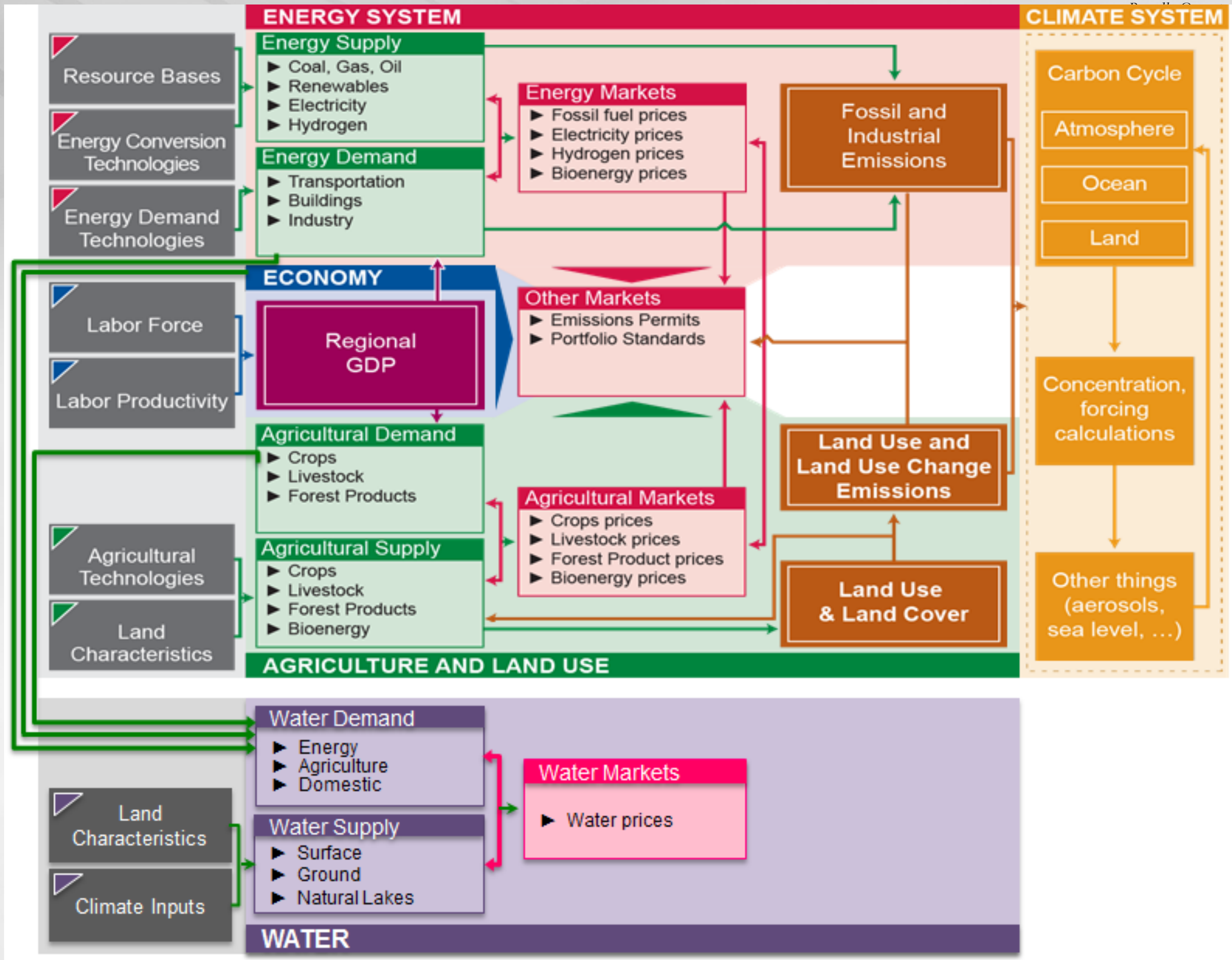

2. IMPACT OF WATER PRICING AND CLOSING WATER MARKETS

Impact of Water Pricing and Water Markets

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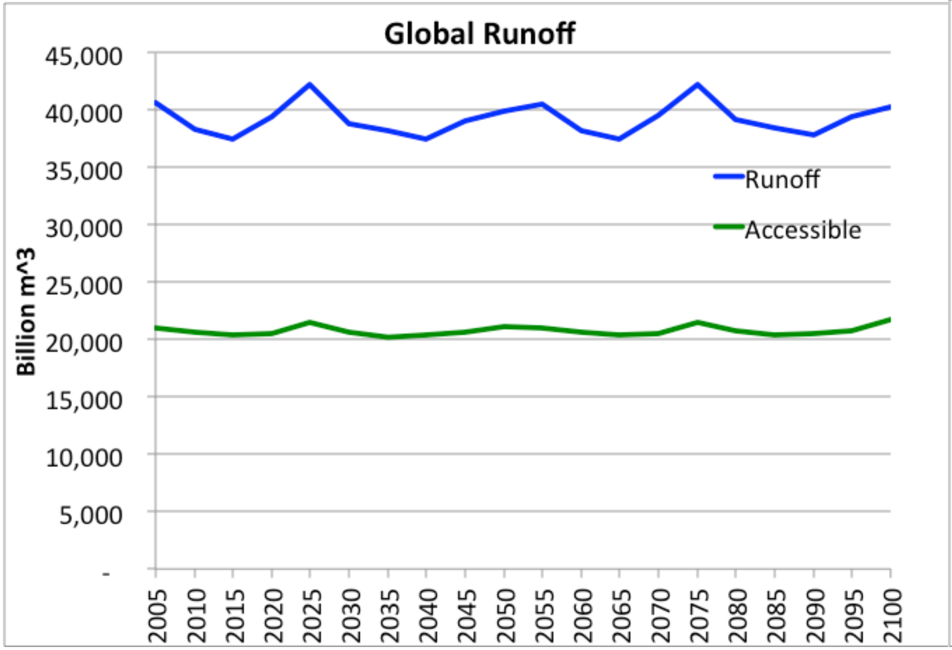
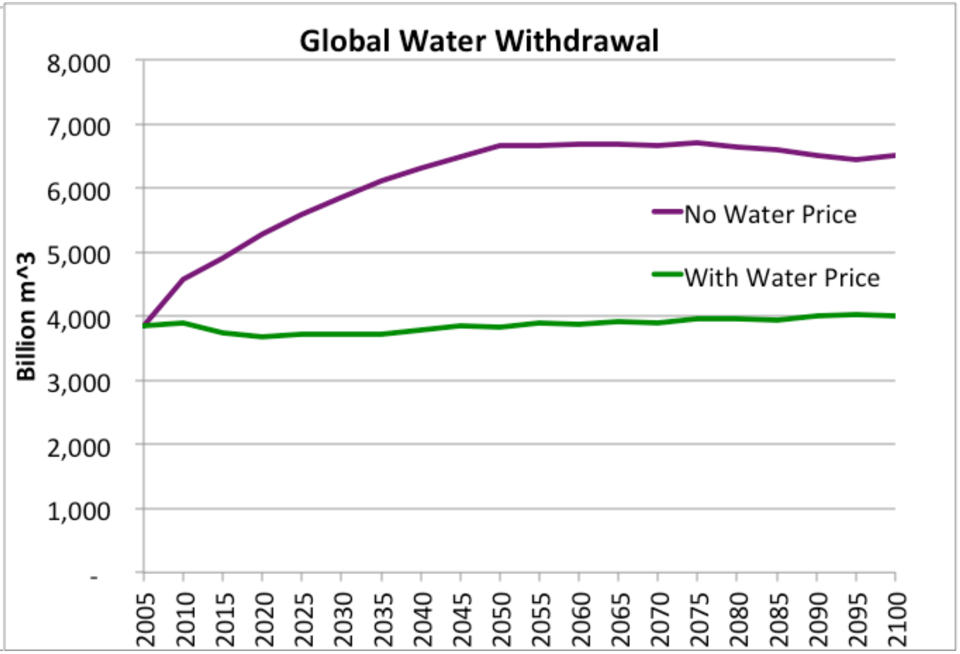
- Comparison of scenario with and without water pricing
  1. No Water Constraint (No Water Price)
  2. “Accessible” Water Constraint with Water Price (53% avg. of total runoff)
     - “Accessible” Water accounts for renewable inflow, reservoir capacity and storage, and environmental requirements





Which regions are affected by water pricing?

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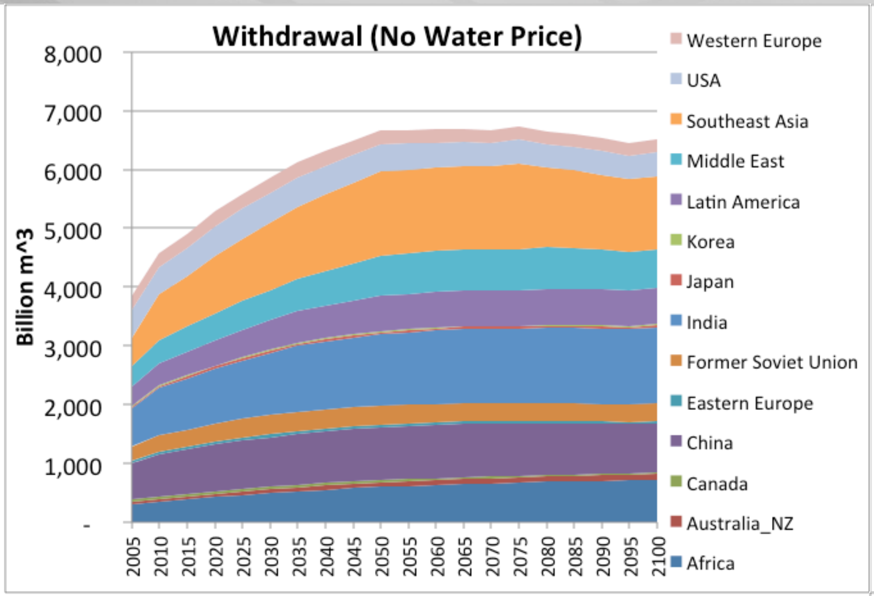
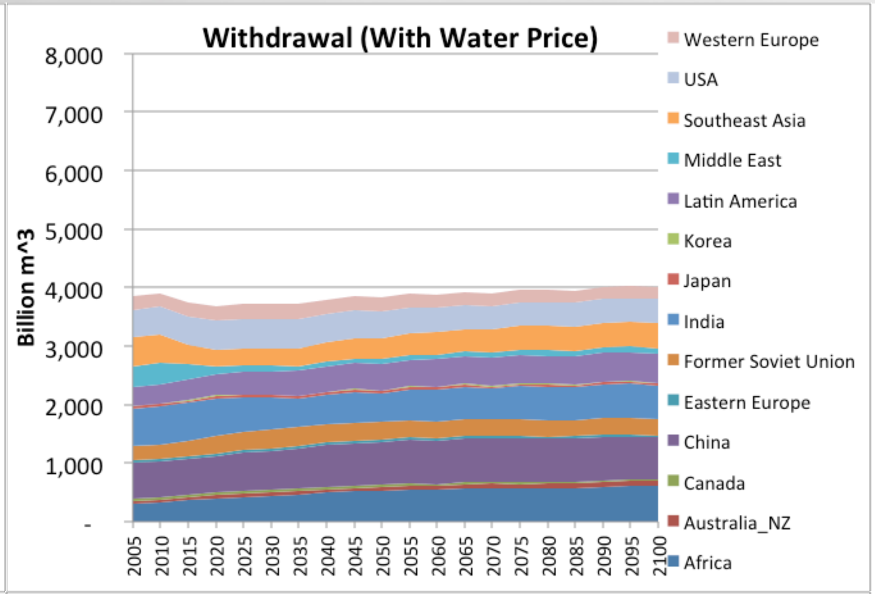
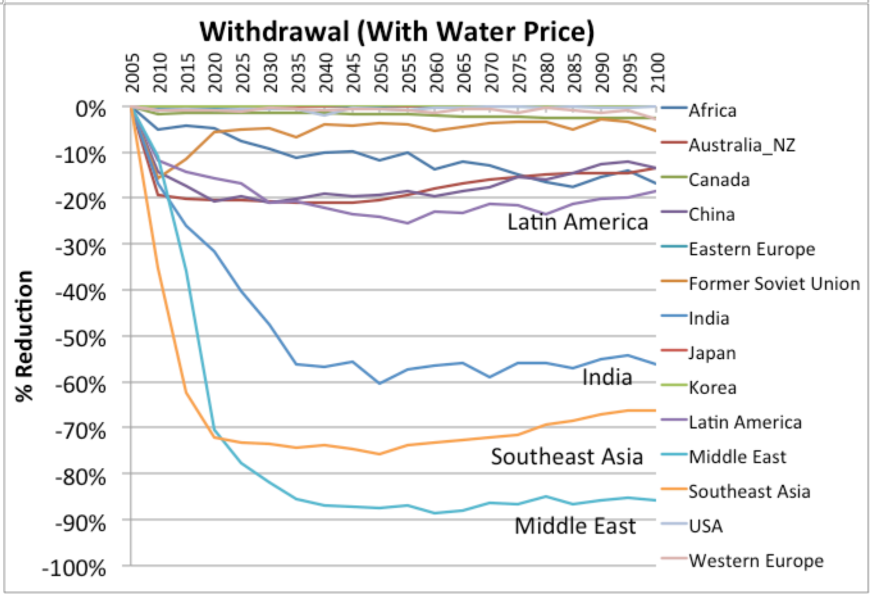
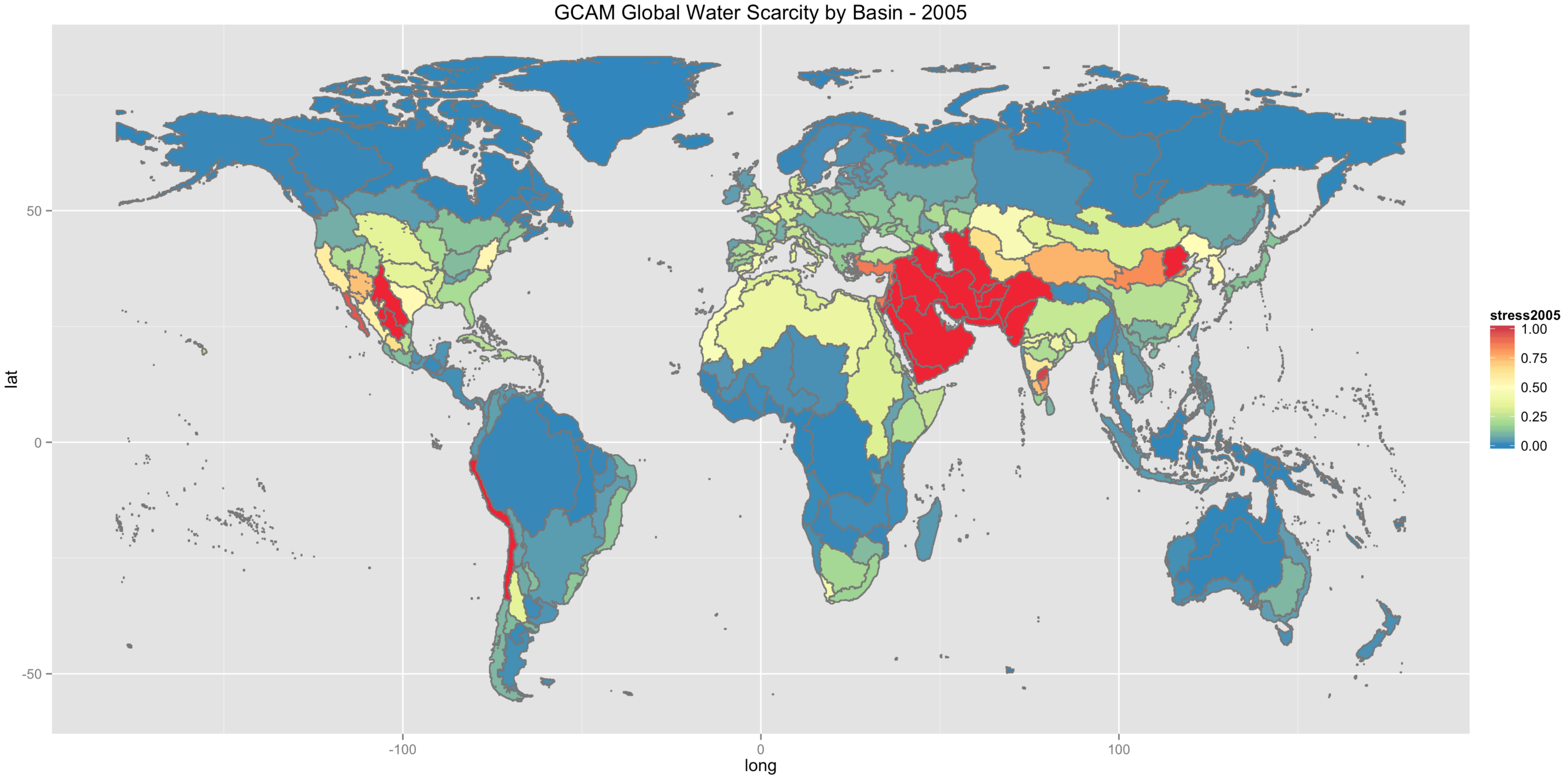


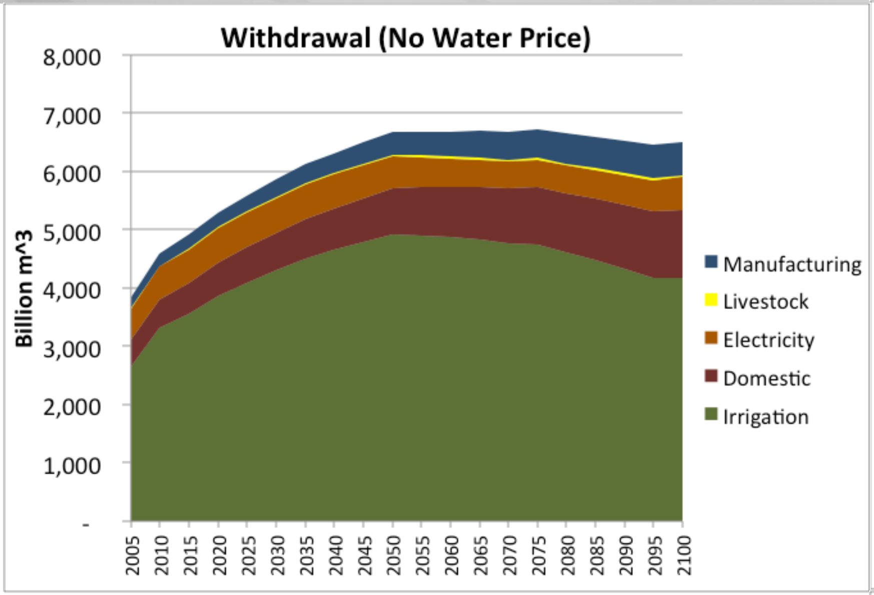


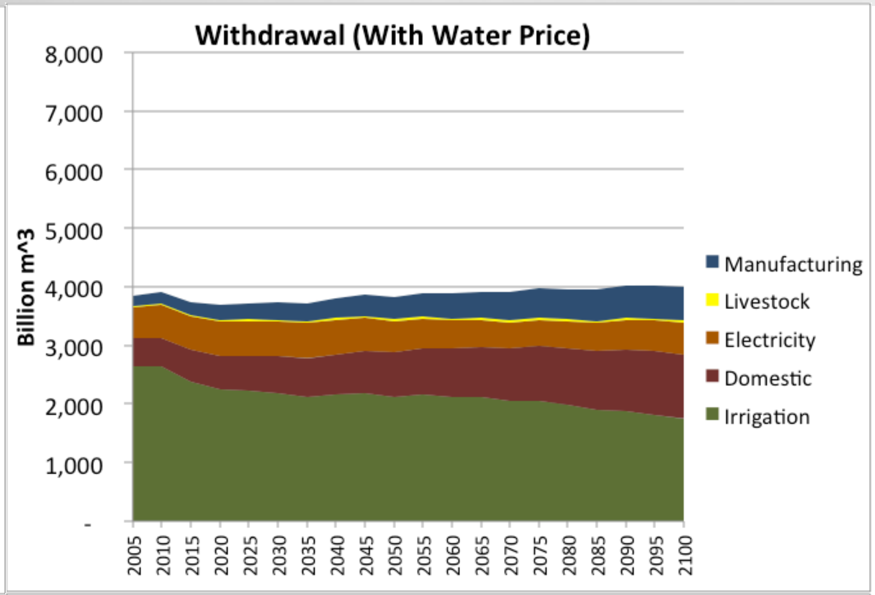


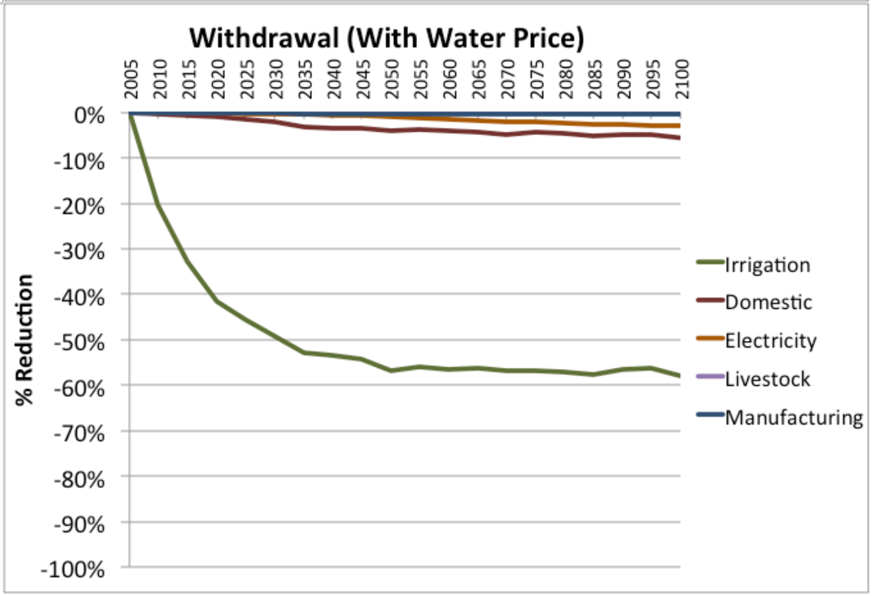
Global Water Scarcity 2005



Which sectors are affected by water pricing?







How does water scarcity affect global agriculture production?

1. Total global agriculture production
2. Regional shifts in agriculture production
3. Changes to the price of agricultural goods
4. Share of irrigated and non-irrigated agriculture

Changes to Global Agriculture Production With & Without Water Pricing

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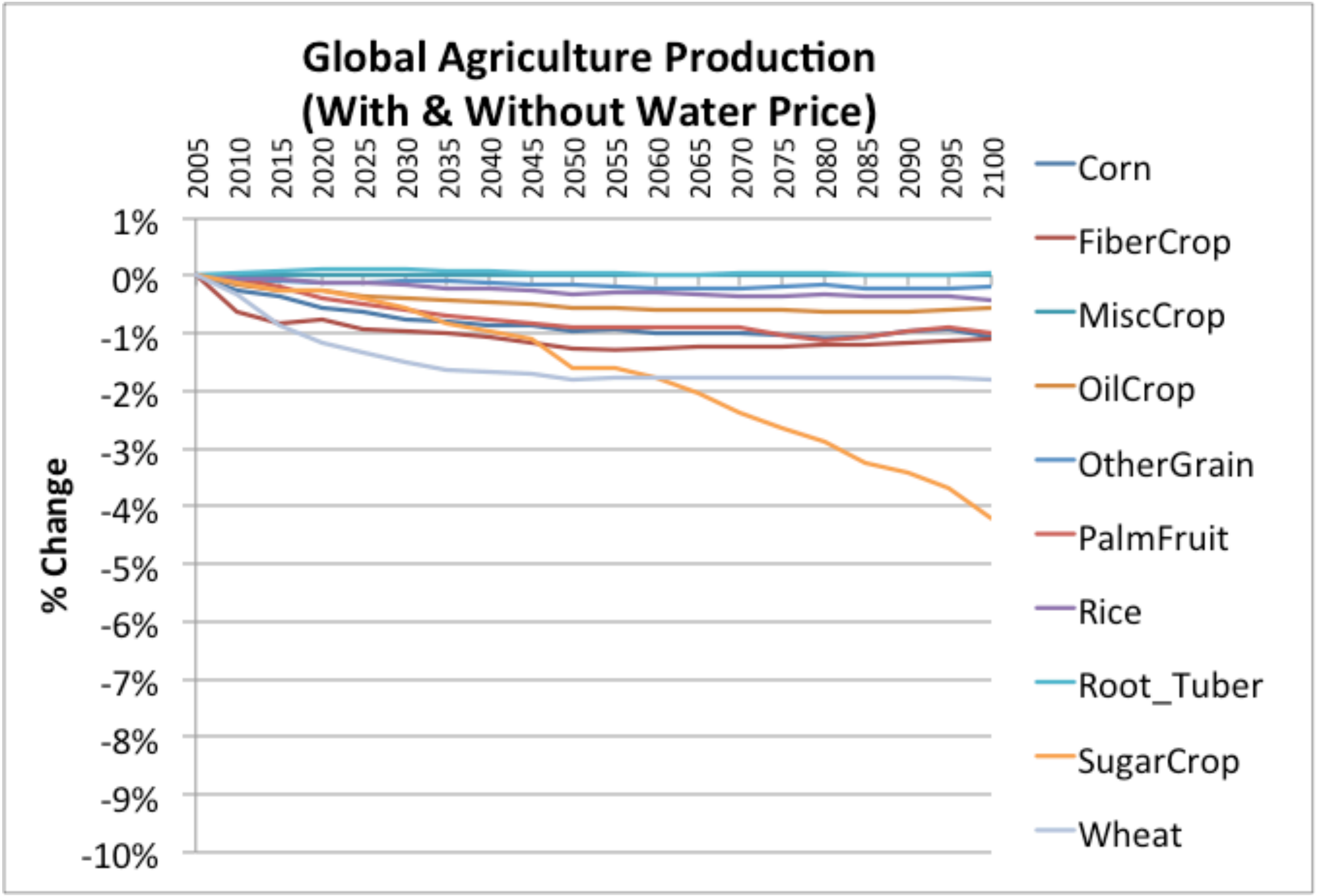

Changes to Regional Agriculture Production With & Without Water Pricing

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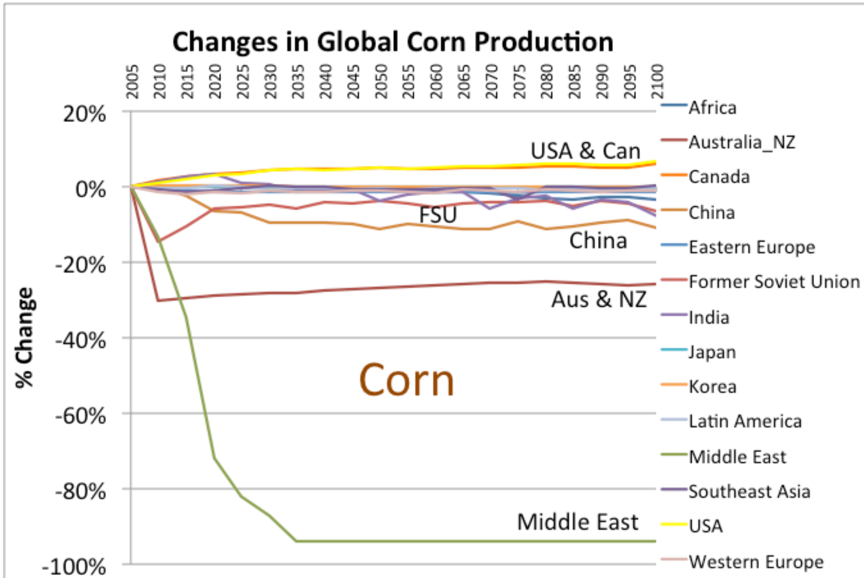
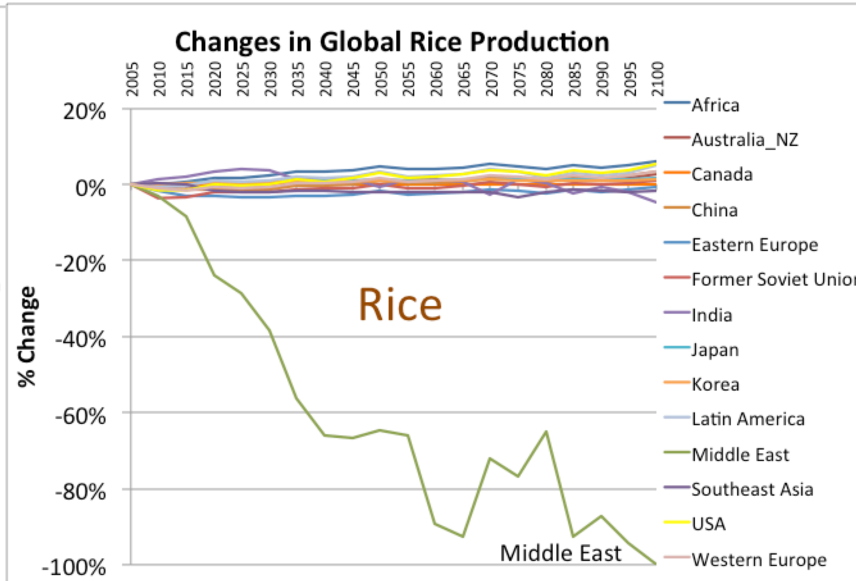
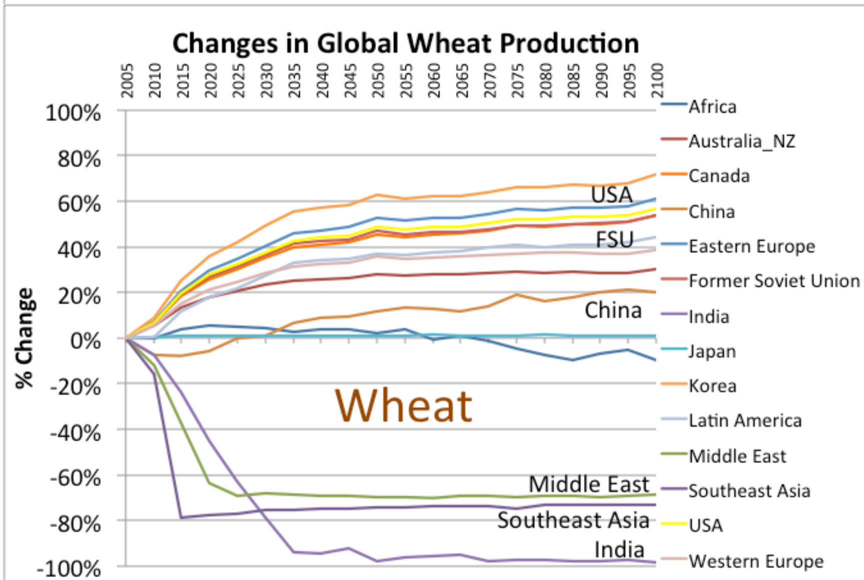
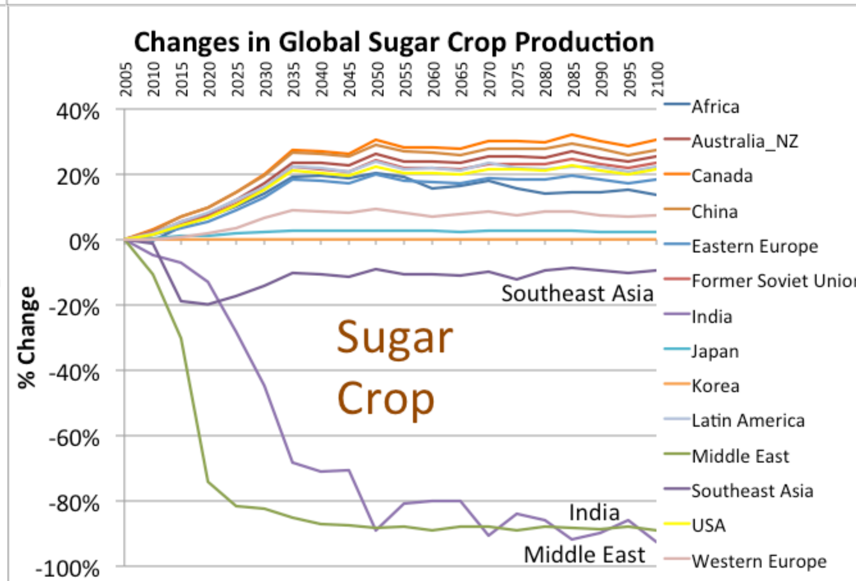
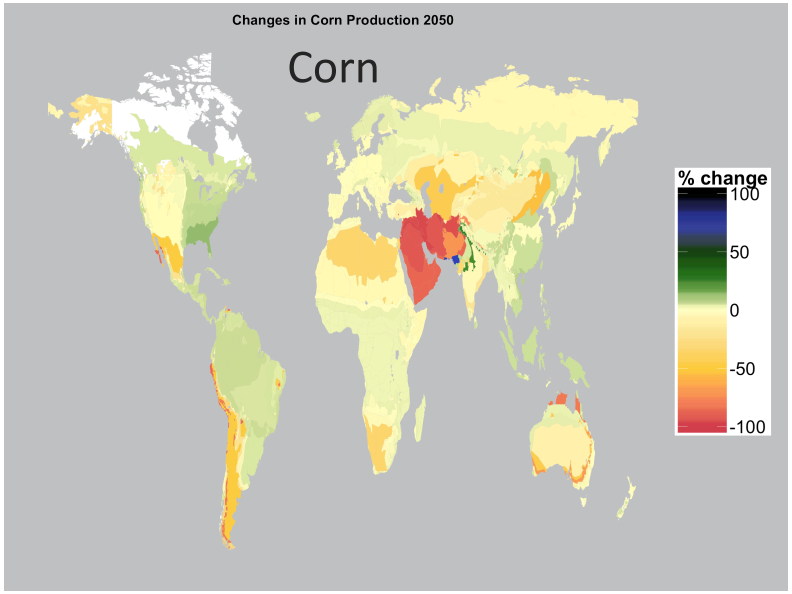


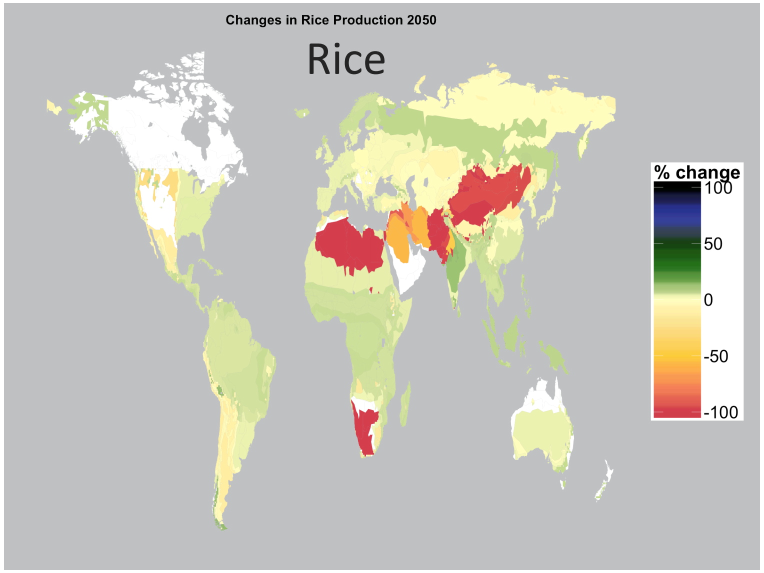


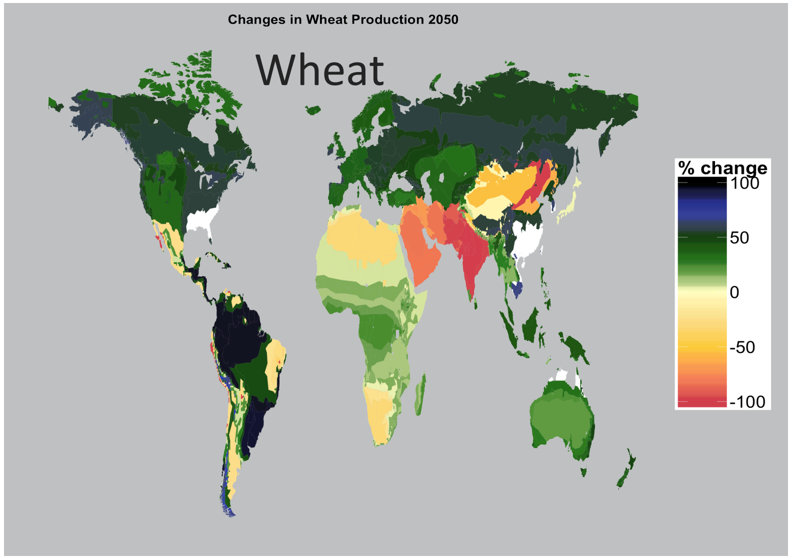


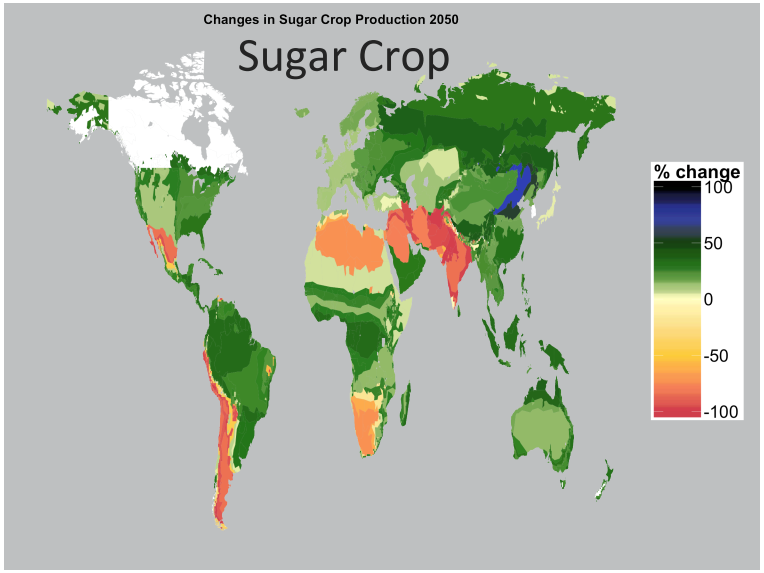


Regional Changes in Corn, Rice, Wheat, & Sugar Crop Production in 2050 with Water Pricing (by AEZs)









Changes to Global Agriculture Commodity Prices with Water Pricing

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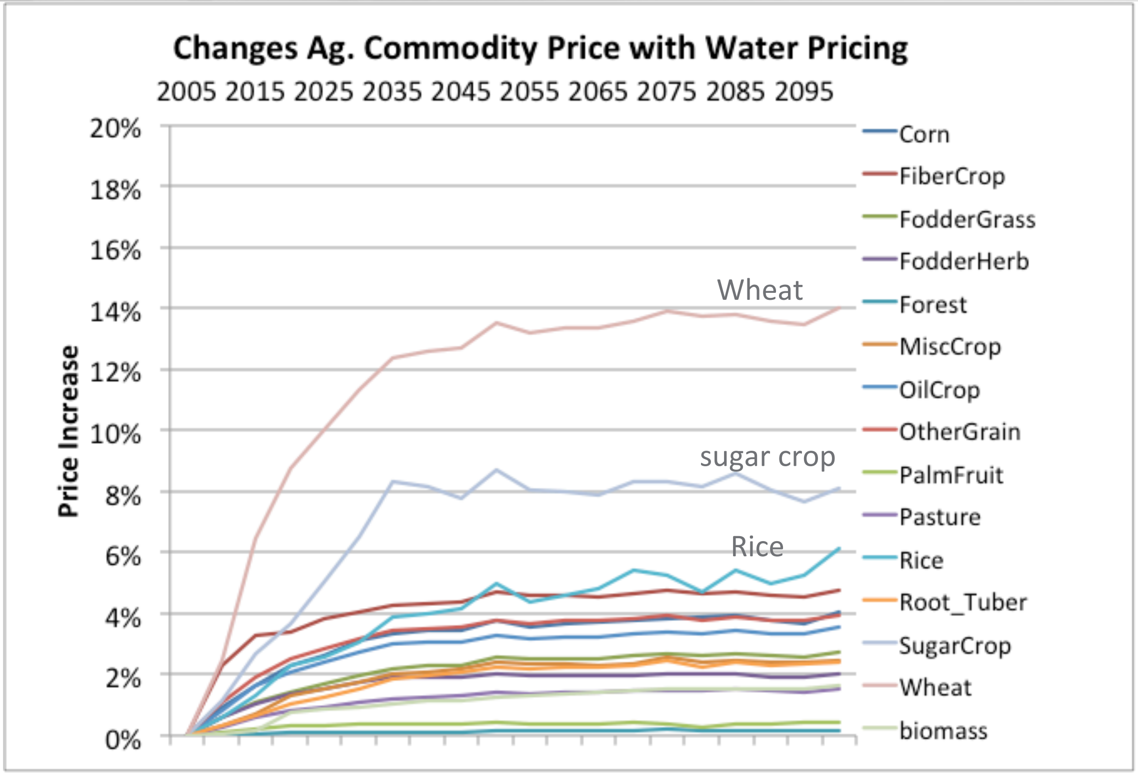

- Agriculture commodity prices do not change significantly due to global trade.
- Constraining global trade of agricultural goods is likely to result in higher prices (not explored).

Changes in Irrigated and Rain-fed Agriculture Production with Water Pricing

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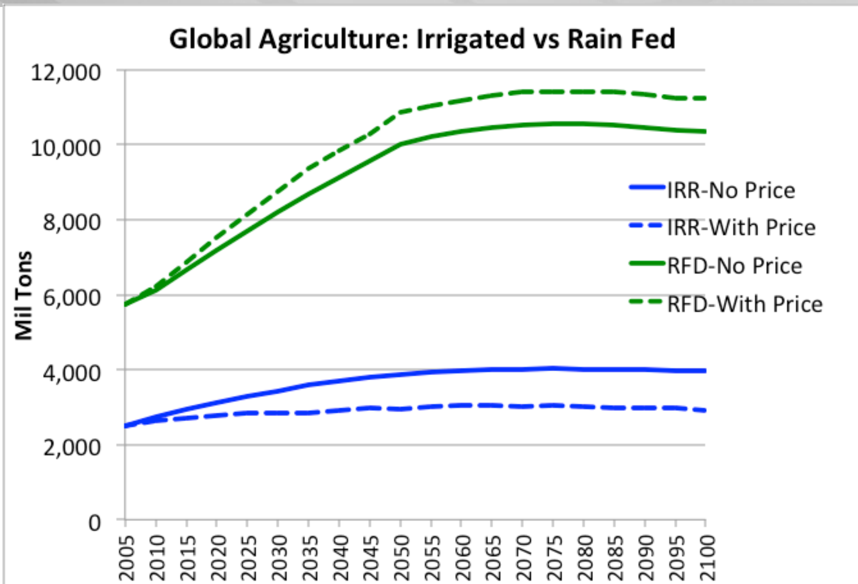

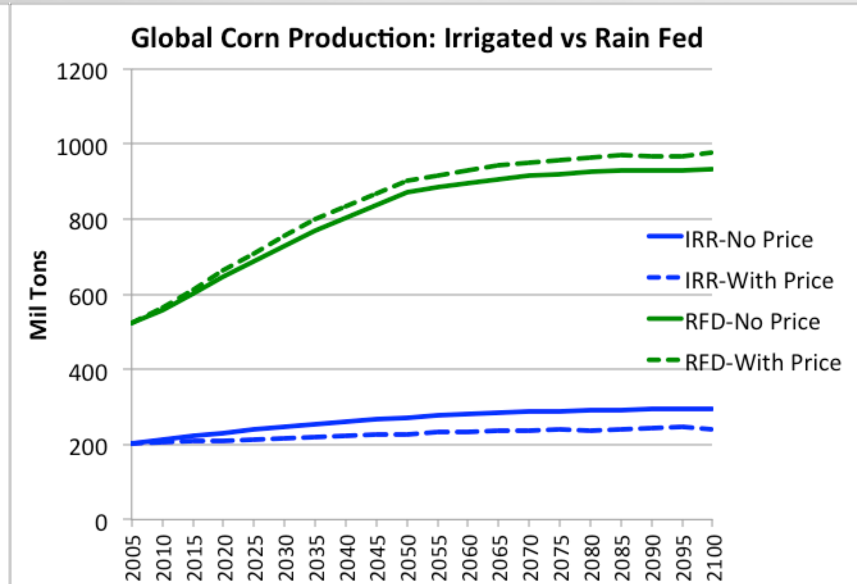

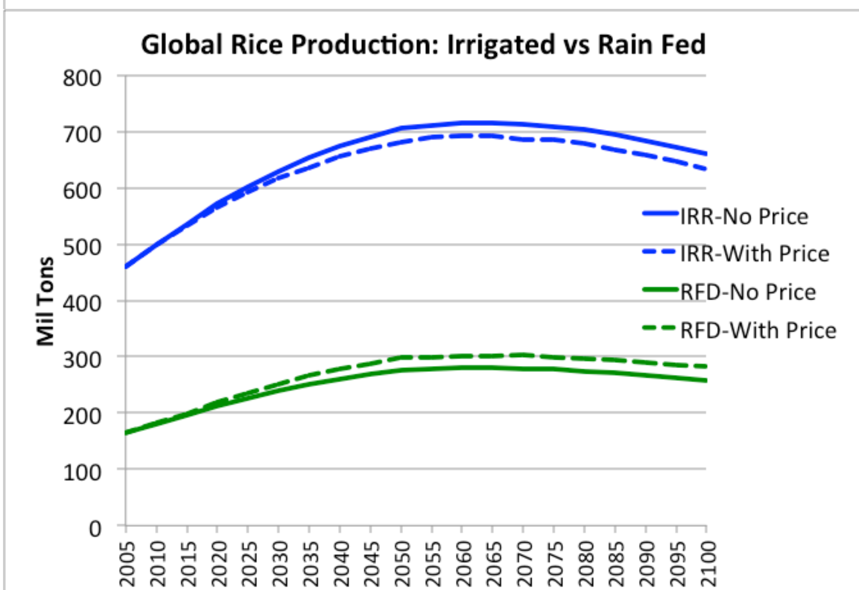

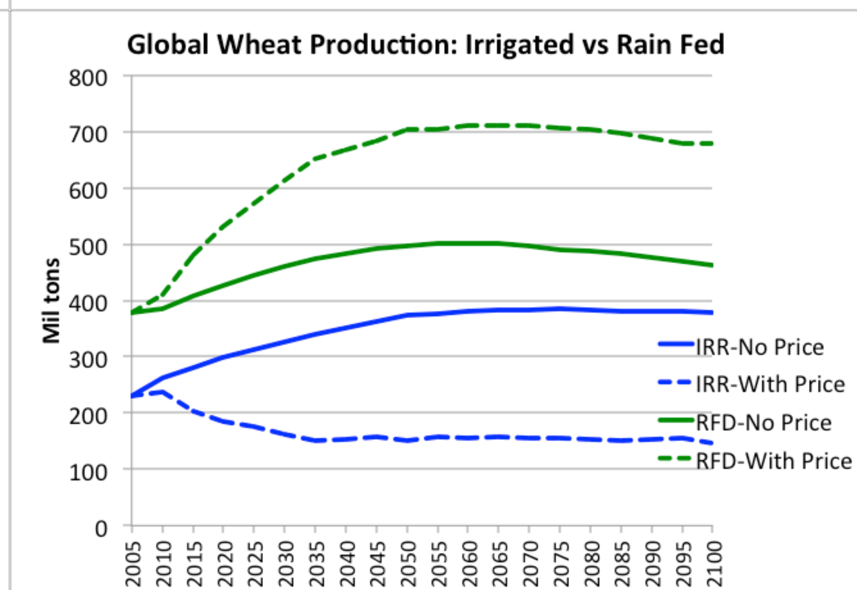

Water Scarcity with and without Water Pricing 2050 and 2100 by Basin

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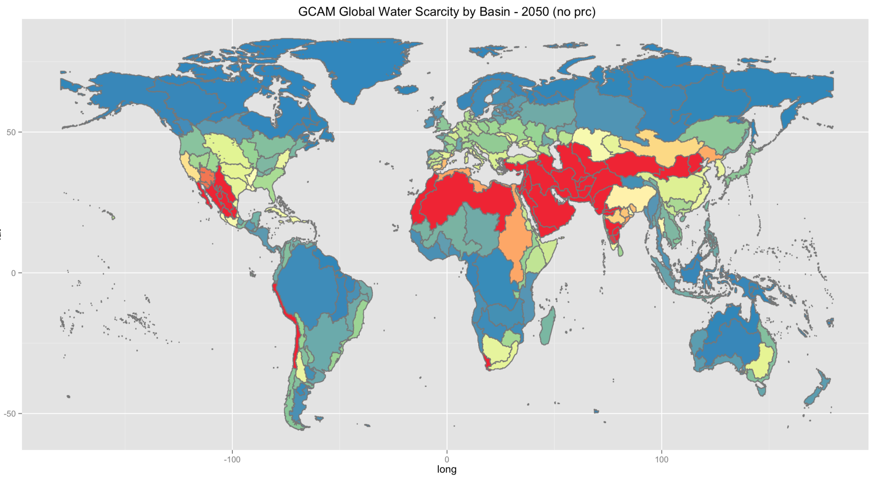
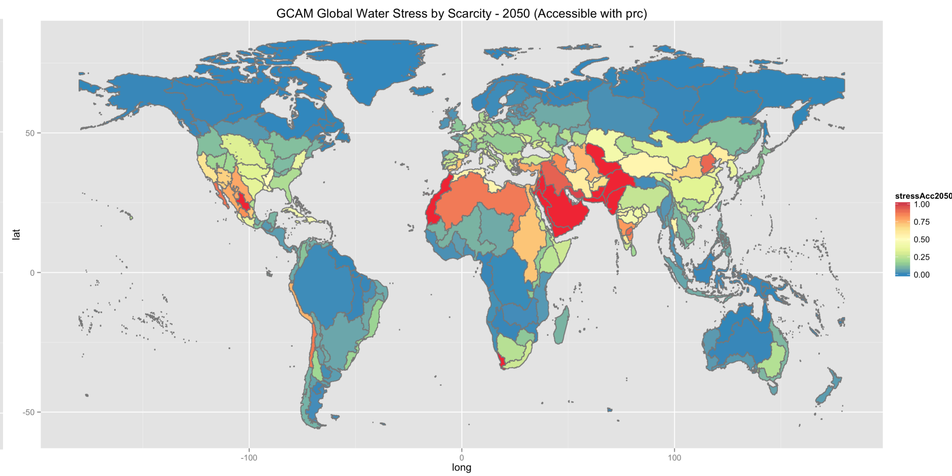
No Water Price

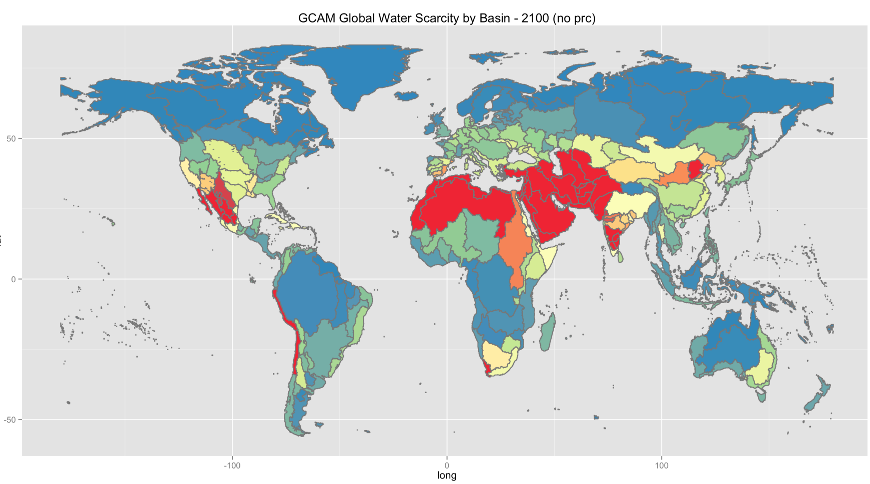
With Water Price

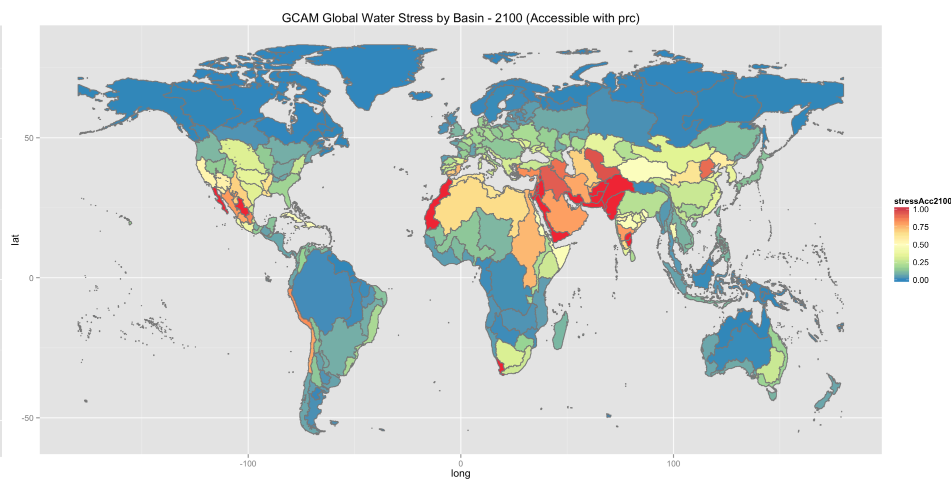
2050





2100

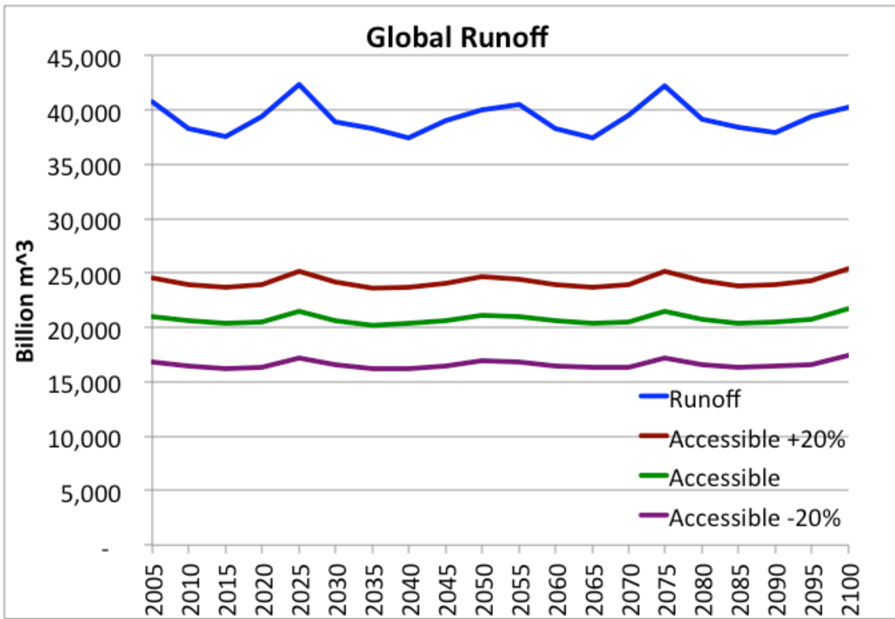


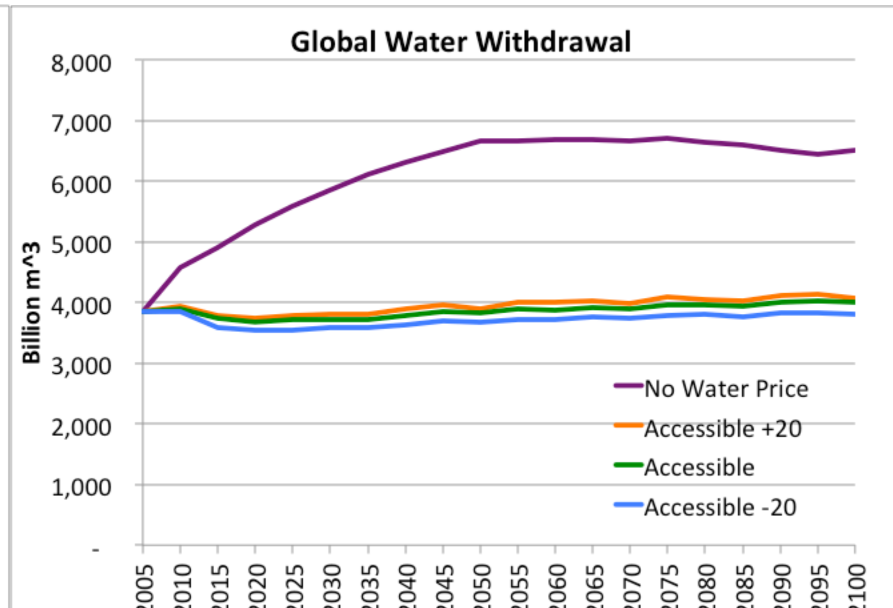


3. SENSITIVITY STUDIES

Renewable Runoff Sensitivity Cases

- "Accessible" Water (53% avg. of total runoff)
- "Accessible" Water + 20%
  - 20% greater accessible for each basin (62% avg. of total runoff)
- "Accessible" Water – 20%
  - 20% less accessible for each basin (42% avg. of total runoff)





- Why is global water withdrawal insensitive to alternative assumptions of "Accessible" water?

  Water stressed regions are already at near max or exceed renewable runoff.

Changes to Regional Agriculture Production with 20% Greater Accessible Water

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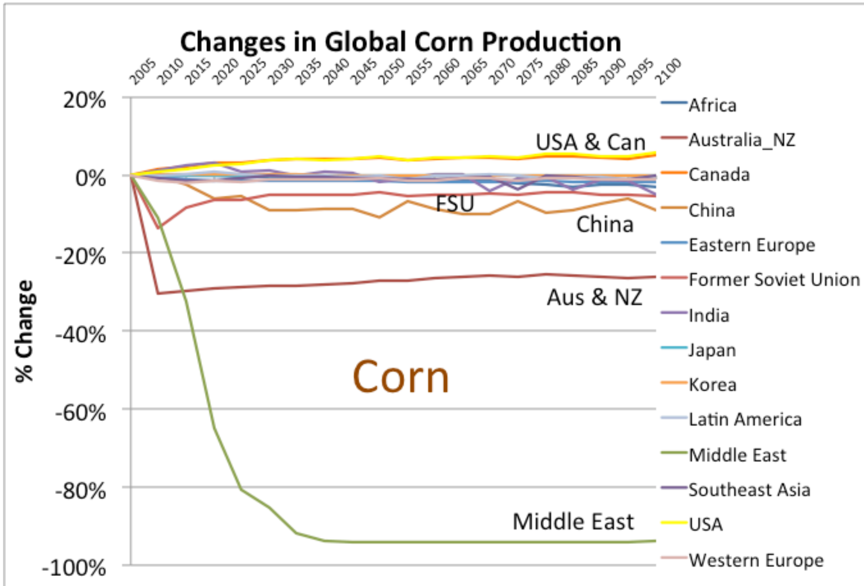
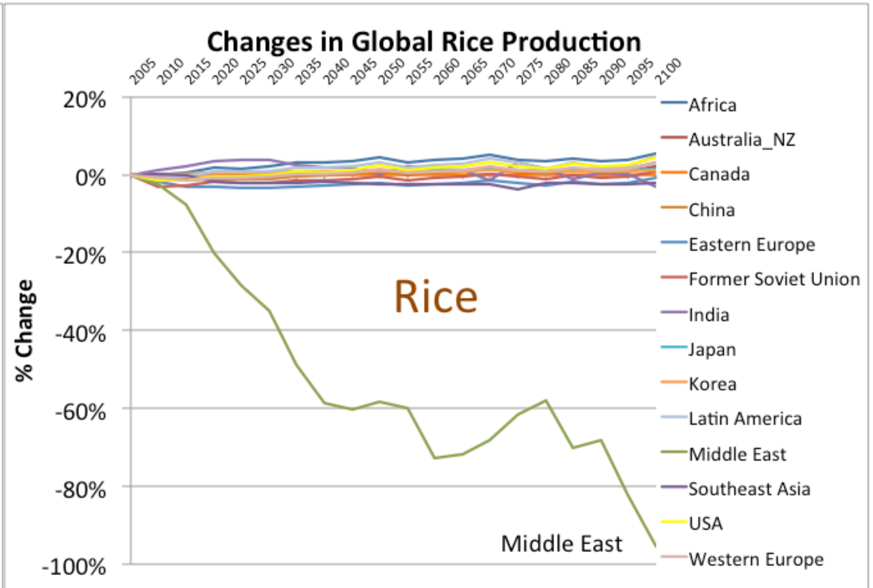
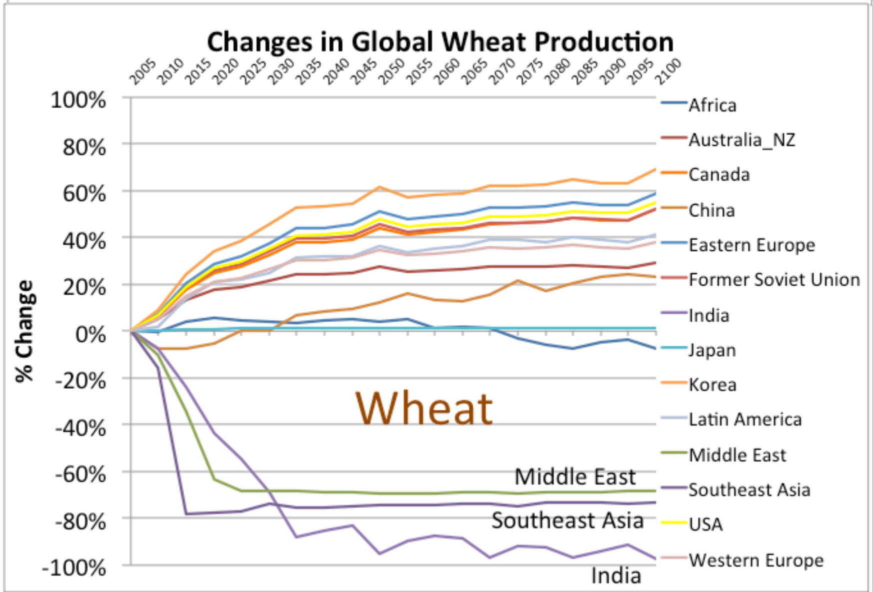
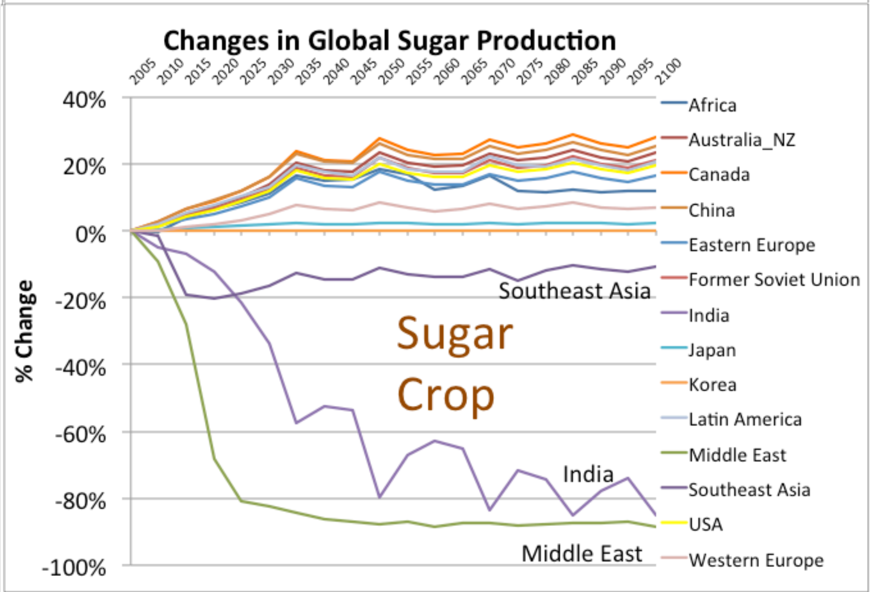


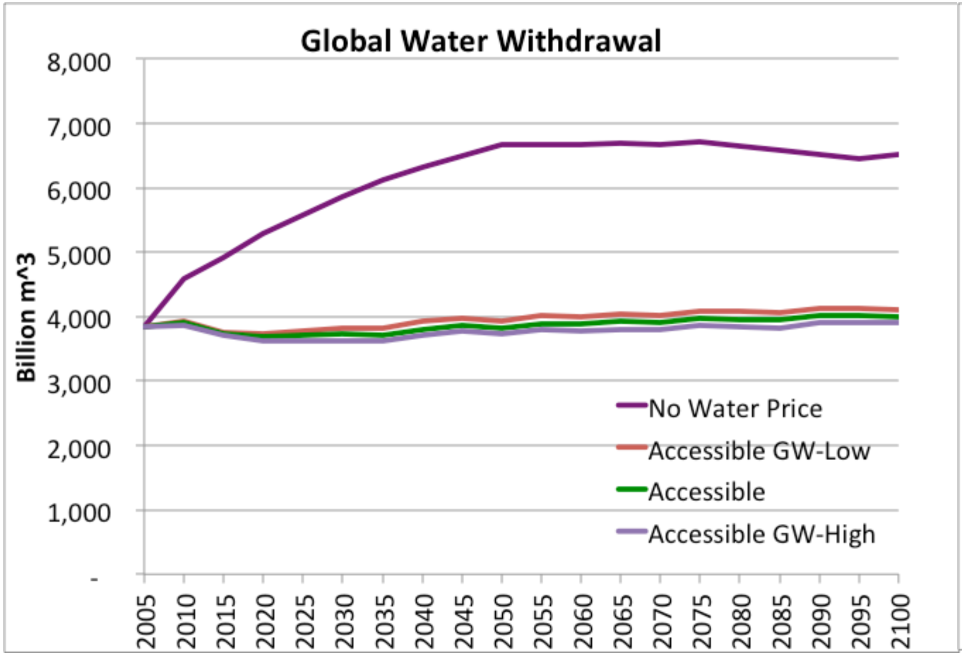


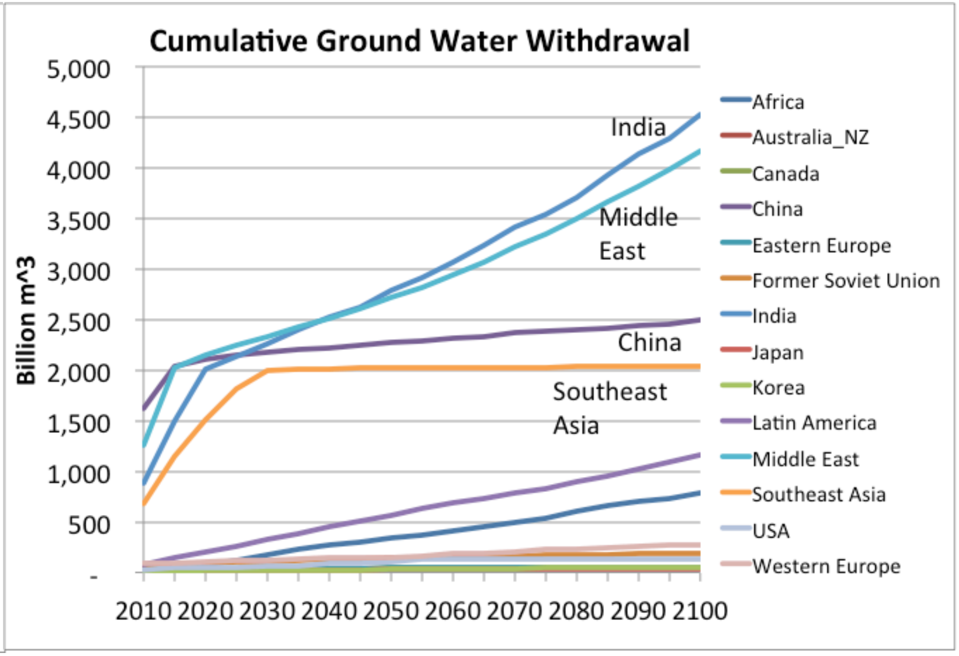




Ground Water Sensitivity Cases

- "Accessible" Water and Low Ground Water Cost
- "Accessible" Water and High Ground Water Cost





- Ground water is not a significant share of global withdrawal.
  - It's a depletable resource with rising cost of production.
- Non-renewable ground water has important local and regional impact.
  - More research needed on ground water cost and availability.

Relative Cost of Water

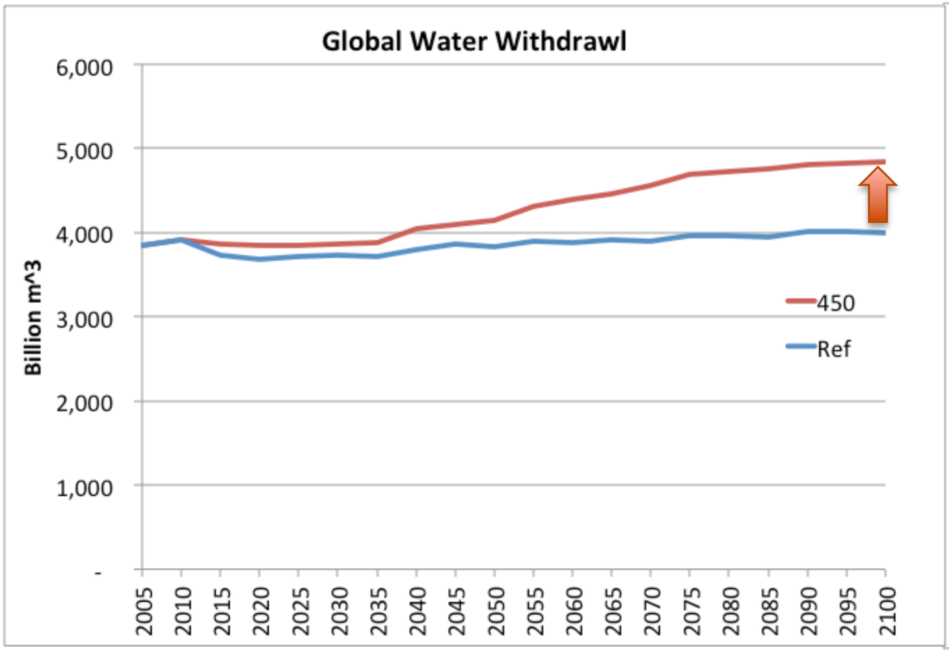
- Why did water pricing affect agriculture more?
- Why did water pricing not affect energy generation?

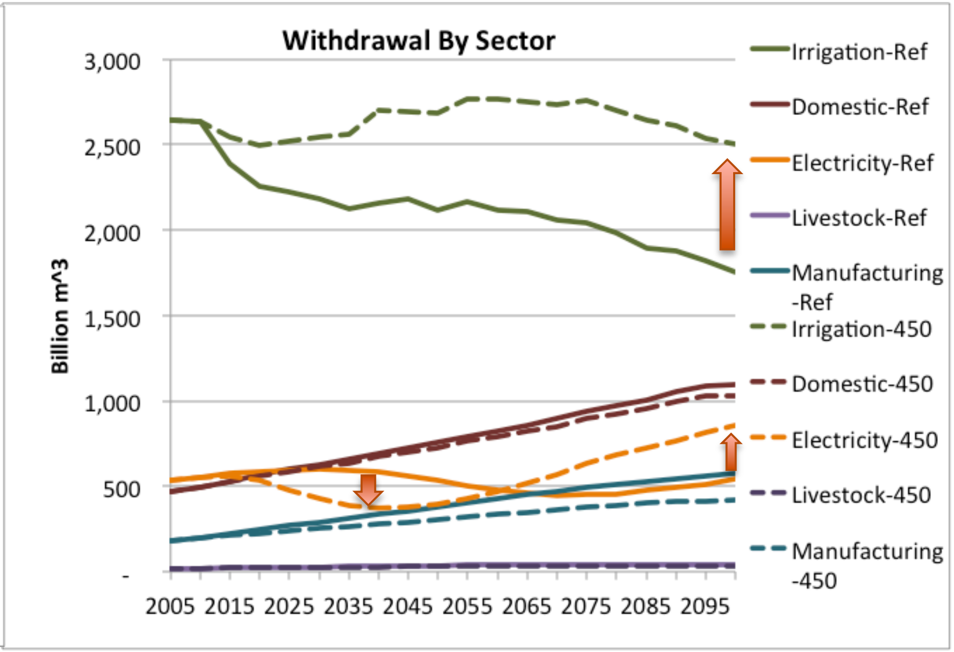
Agriculture	Water Coefficient (m^3/kg)	Water Price ($/m^3)	Water Cost ($/kg)	Crop Price ($/kg)	Water Cost Share
corn	0.42	0.10	0.042	0.10	43%
rice	0.80	0.10	0.080	0.66	12%
wheat	0.58	0.10	0.058	0.13	45%
Electricity	**Water Coefficient (m^3/GJ)**	**Water Price ($/m^3)**	**Water Cost ($/GJ)**	**Elect Price ($/GJ)**	**Water Cost Share**
coal conv	2.24	0.10	0.22	15.26	1%
gas cc	0.20	0.10	0.02	13.71	0.1%
nuclear	1.65	0.10	0.17	15.89	1%

4. CLIMATE MITIGATION AND WATER PRICING INTERACTIONS

Climate Mitigation Scenarios

- Ref Scenario with Water Pricing
- 450 ppm Scenario with Water Pricing (same runoff constraint)





- Global water withdrawal increases under climate mitigation policy.
- Irrigation and electricity withdrawals are responsible.

Climate Mitigation Scenarios
Which crops are responsible for increased irrigation demand?

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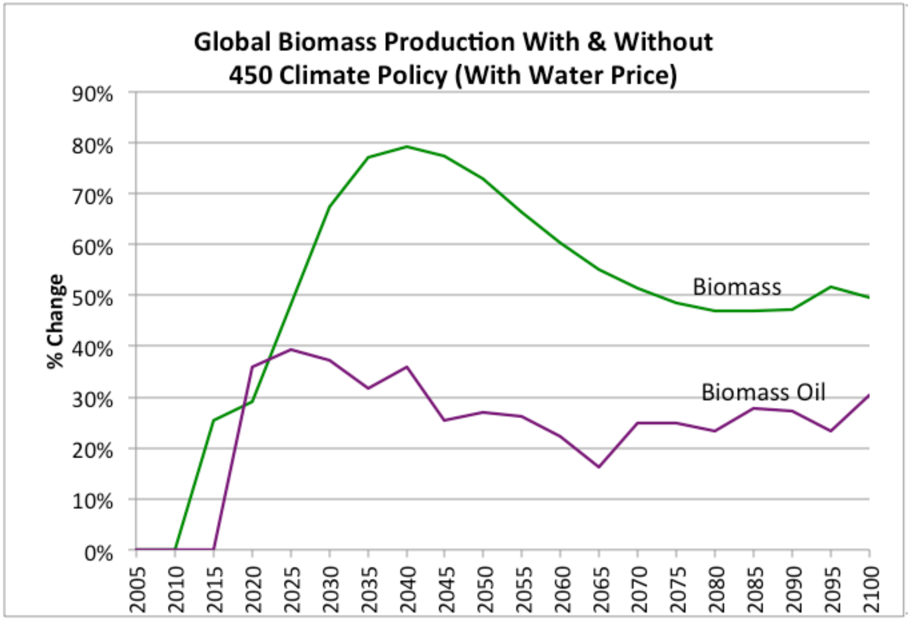
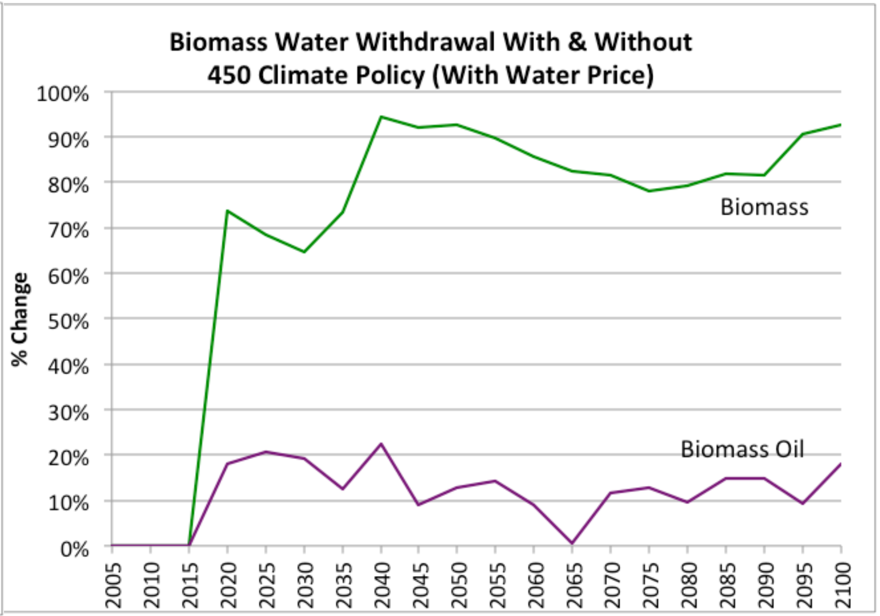




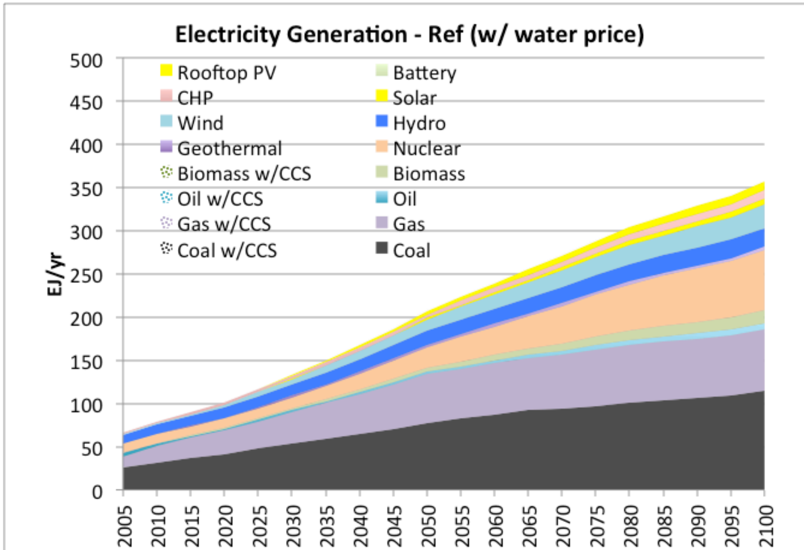
- Increased use of biomass for energy contributes to greater irrigated water use.
- Additionally, higher agricultural prices from increased biomass use and valuing carbon on land raise irrigated water use for other crops.
- Greater investigation of land-water-energy-carbon interactions required.

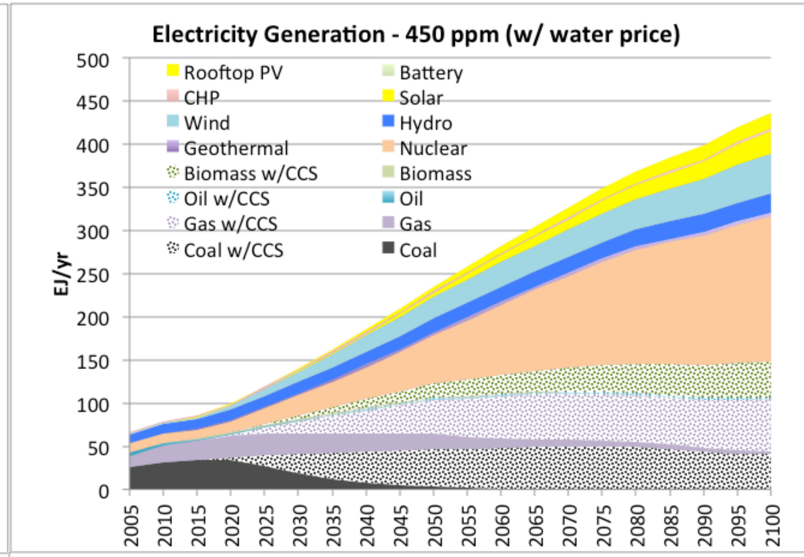
Climate Mitigation Scenarios
Which technologies are responsible for increased electricity water withdrawal?

Ref

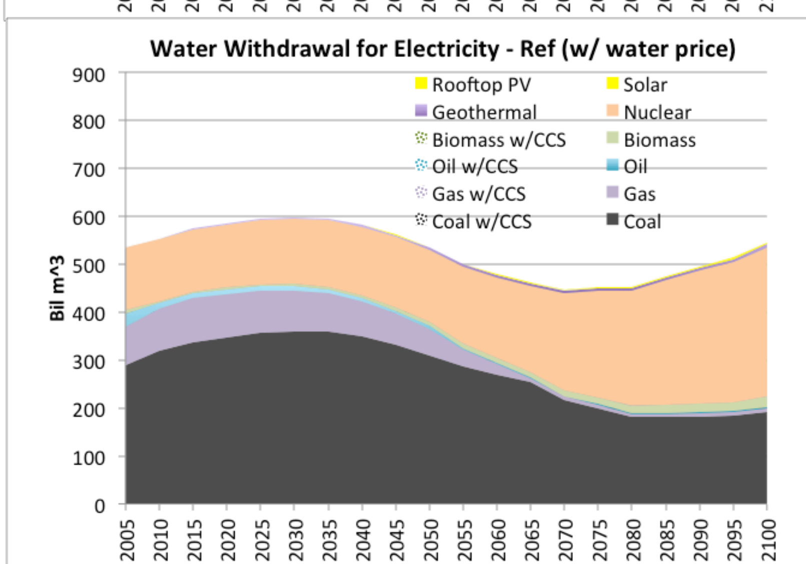
450

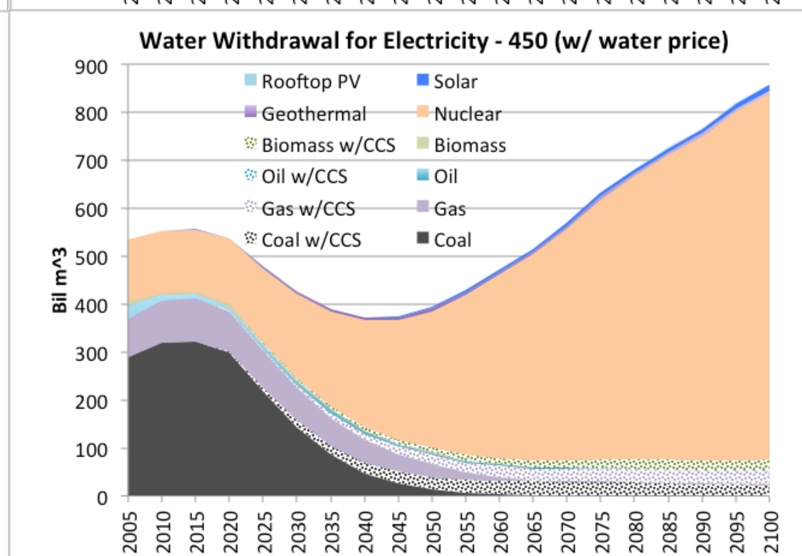
Elect. Gen.





Withdrawal





Questions

Thank you :

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