

Coupling for IAM: LAND

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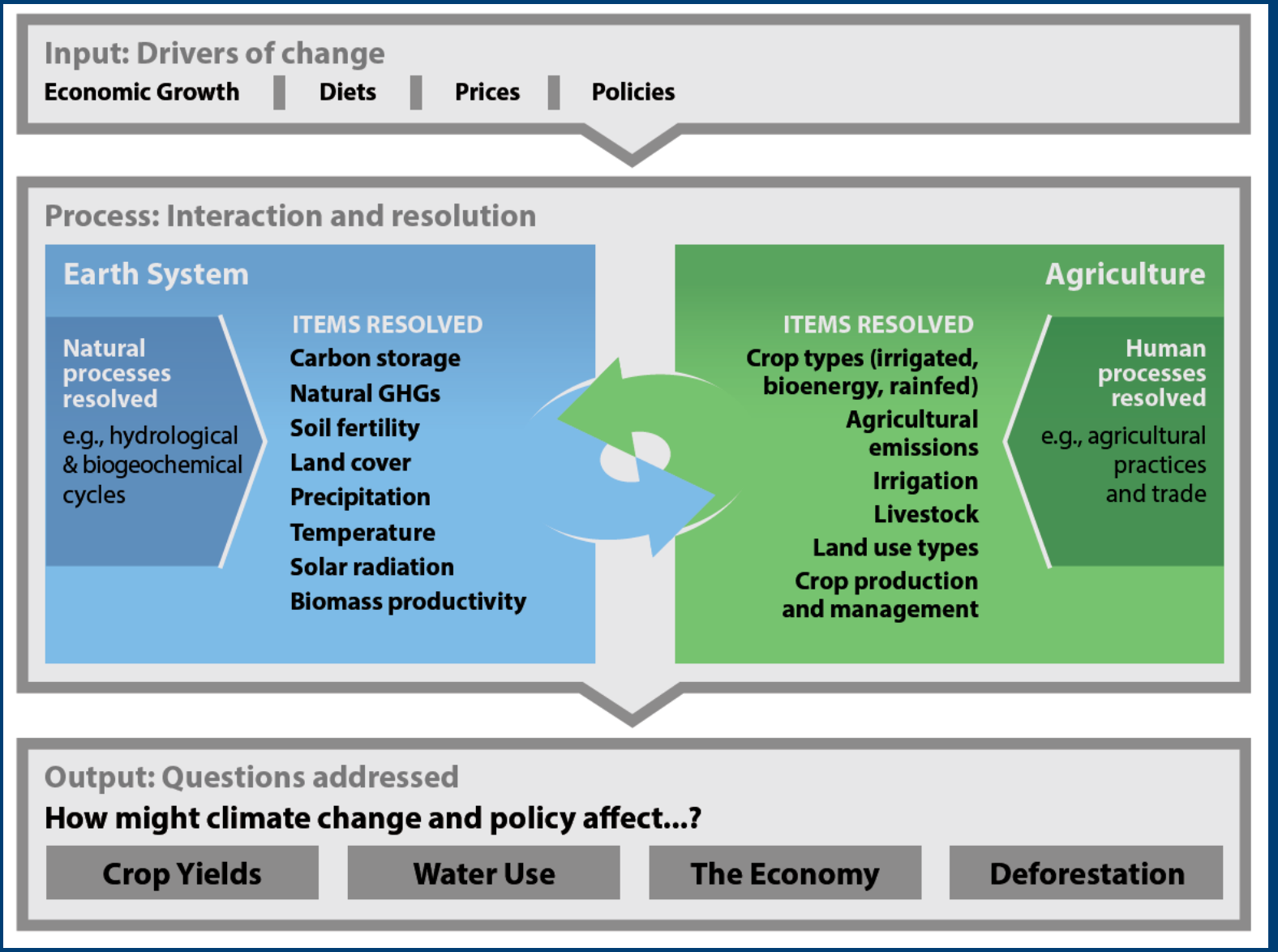
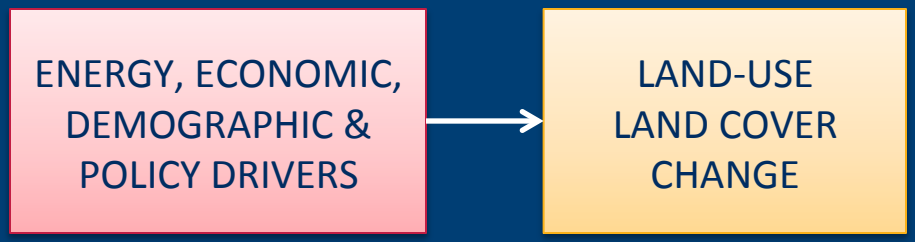
LAND IN INTEGRATED ASSESSMENT MODELS



“RCP LULCC FRAMEWORK”



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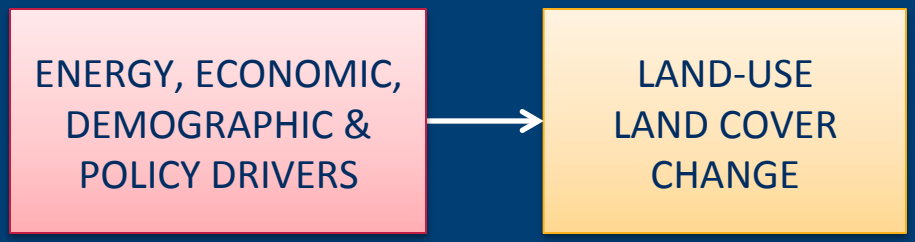

- Resolution of agro-forestry sector in global economic model
  - Representation of various crop types
  - Managed and natural forests
  - Pastureland and natural grassland
  - Livestock
- Interaction with other sectors of the economy
- Representation of trade between various regions of the world
- Demand for agriculture
  - Crops for food & bioenergy
  - Forest products for construction and bioenergy

AGGREGATION OF ELECTRICITY IN IGSM

Regions	Industries
United States	Crops
Canada	Livestock
Japan	Forestry
Australia-New Zealand	Food
European Union	Coal
Eastern Europe	Crude Oil
Russia plus	Refined Oil
Mexico	Gas
China	Electricity
India	Energy Intensive Industry
East Asia	Other Industry
Rest of Asia	Services
Africa	Commercial Transportation
Middle East	Household Transportation
Brazil	
Latin America	

- Coal
- Gas
- Refined oil
- Hydro
- Nuclear
- Wind
- Solar
- Biomass
- Natural gas combined cycle
- Integrated gasification combined cycle

DISAGGREGATING CROPS IN IGSM

Regions	Industries
United States	Crops
Canada	Livestock
Japan	Forestry
Australia-New Zealand	Food
European Union	Coal
Eastern Europe	Crude Oil
Russia plus	Refined Oil
Mexico	Gas
China	Electricity
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- Paddy Rice
- Wheat
- Other grains
- Vegetables, fruits, & nuts
- Oil Seeds
- Sugar Cane, Beet
- Fiber Crops
- Grass Biomass
- Woody Biomass
- Other Crops

“MIT LULCC FRAMEWORK”

"MIT LULCC FRAMEWORK"

- Requires climate information
  - Climate driven by GHG & aerosols emissions (incl. LULCC w/o climate impacts)
- Requires coupling to a terrestrial ecosystem model / crop model
  - With representation of carbon-Nitrogen dynamics (GHG emissions)
  - Consistent physical and economic representation of crops
- Uncertainty analysis
  - Single crop model vs. crop emulator
  - Single climate model vs. multi-model ensemble vs. climate emulator

=> Different LULCC projection depending on climate / crop model simulation

“ENHANCED LULCC FRAMEWORK”

"ENHANCED LULCC FRAMEWORK"

- Requires coupling to a water resources management model
  - Competition for water between energy, agriculture and domestic uses
  - Water availability responds to climate change (i.e. runoff)
  - Water demand responds to climate change (i.e. irrigation needs)
- Requires disaggregation of rainfed and irrigated croplands in the economic model
- Requires estimating the cost and scope to expand irrigable land given available water resources

AGGREGATION IN THE STANDARD IGSM MODEL

Regions	Industries	Production factors
United States	Crops	Capital
Canada	Livestock	Labor
Japan	Forestry	Coal resources
Australia-New Zealand	Food	Oil resources
European Union	Coal	Gas resources
Eastern Europe	Crude Oil	Crop land
Russia plus	Refined Oil	Harvested Forest land
Mexico	Gas	Natural forest land
China	Electricity	Managed pasture
India	Energy Intensive Industry	Natural grass land
East Asia	Other Industry	
Rest of Asia	Services	
Africa	Commercial Transportation	
Middle East	Household Transportation	
Brazil		
Latin America		

EXTENDING LAND TYPES IN THE IGSM

Regions	Industries	Production factors
United States	Crops	Capital
Canada	Livestock	Labor
Japan	Forestry	Coal resources
Australia-New Zealand	Food	Oil resources
European Union	Coal	Gas resources
Eastern Europe	Crude Oil	**Rainfed Crop land**
Russia plus	Refined Oil	**Irrigated Crop land**
Mexico	Gas	Harvested Forest land
China	Electricity	Natural forest land
India	Energy Intensive Industry	Managed pasture
East Asia	Other Industry	Natural grass land
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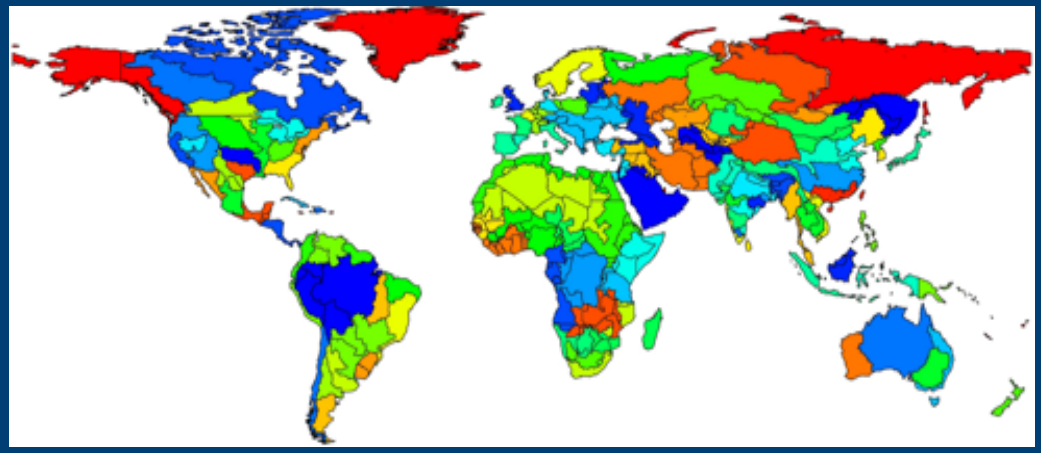
PRELIM. RESULTS: IRRIGATION CONSTRAINTS IN IGSM



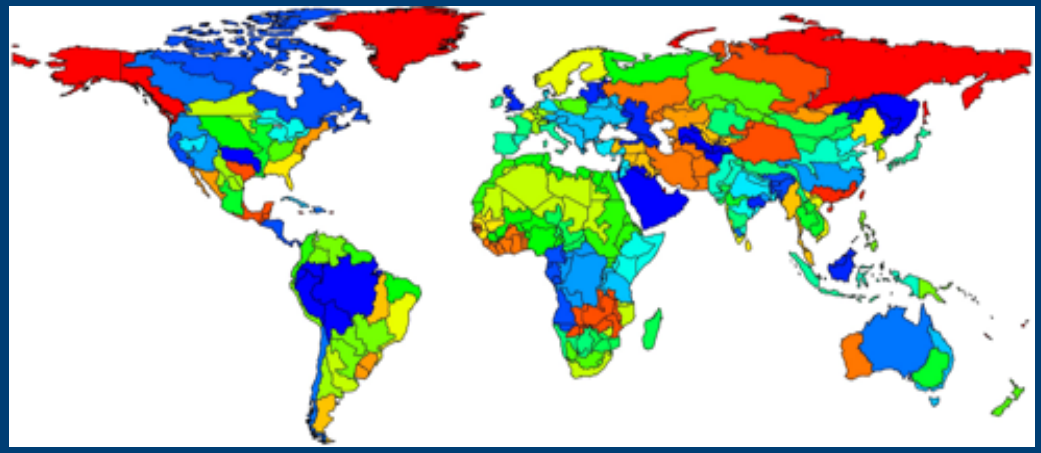
282 Water Basins Interact with 17 IGSM Regions

In each basin:

- 10 storage upgrade options, each with a specific cost and amount of additional water available
- translates into additional hectares of irrigated land based on crop/climate characteristics
- Irrigation by lining canals and efficiency improvements (4 options @ different costs)

Source: Winchester et al. (2016) The Impact of Water Scarcity on Food, Bioenergy and Deforestation, GTAP Fall Meeting paper, also MIT JP report (forthcoming).

PRELIM. RESULTS: IRRIGATION CONSTRAINTS IN IGSM



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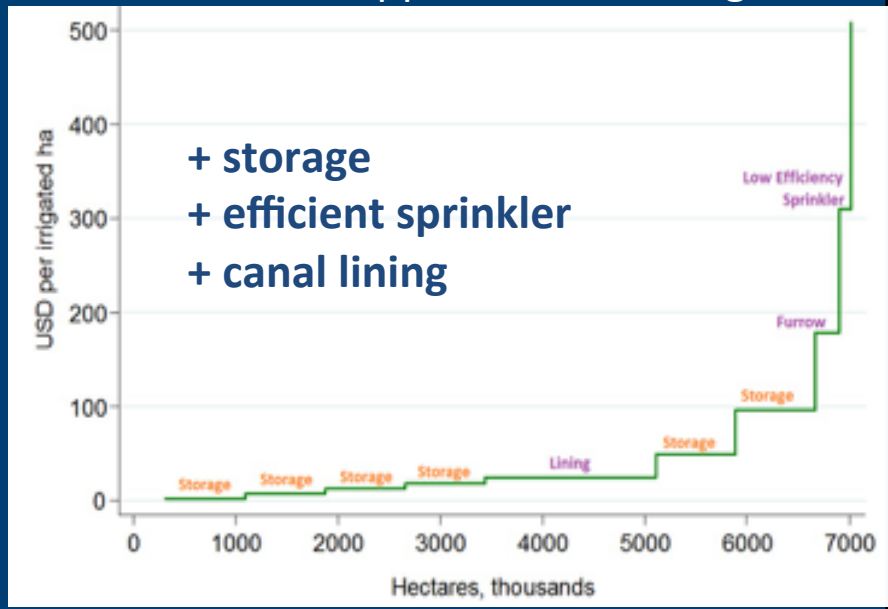
Supply curve for additional irrigable land in the Mississippi River water region



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PRELIM. RESULTS: IRRIGATION CONSTRAINTS IN IGSM

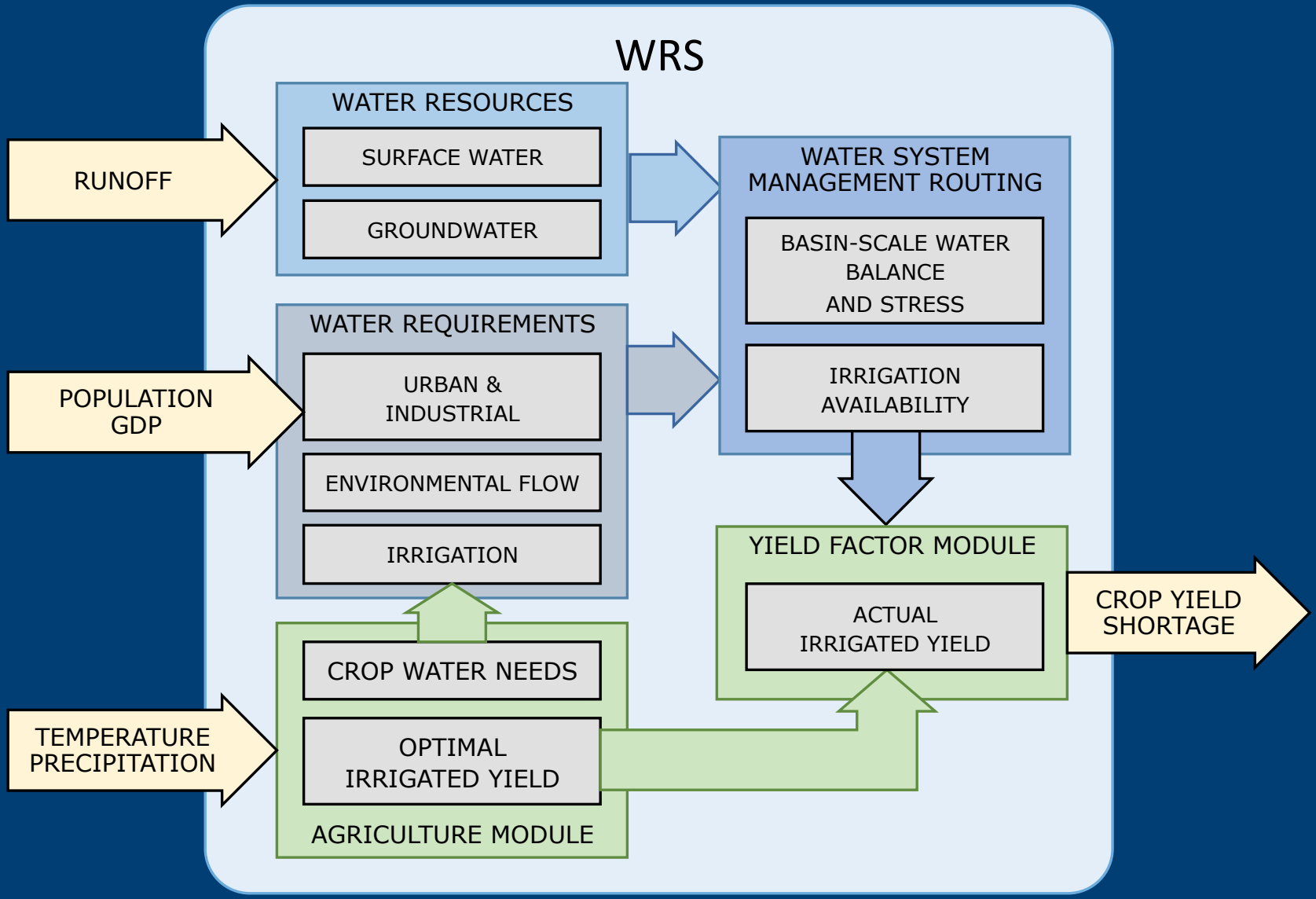
Effect of Water Limits on Land, billion hectares

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

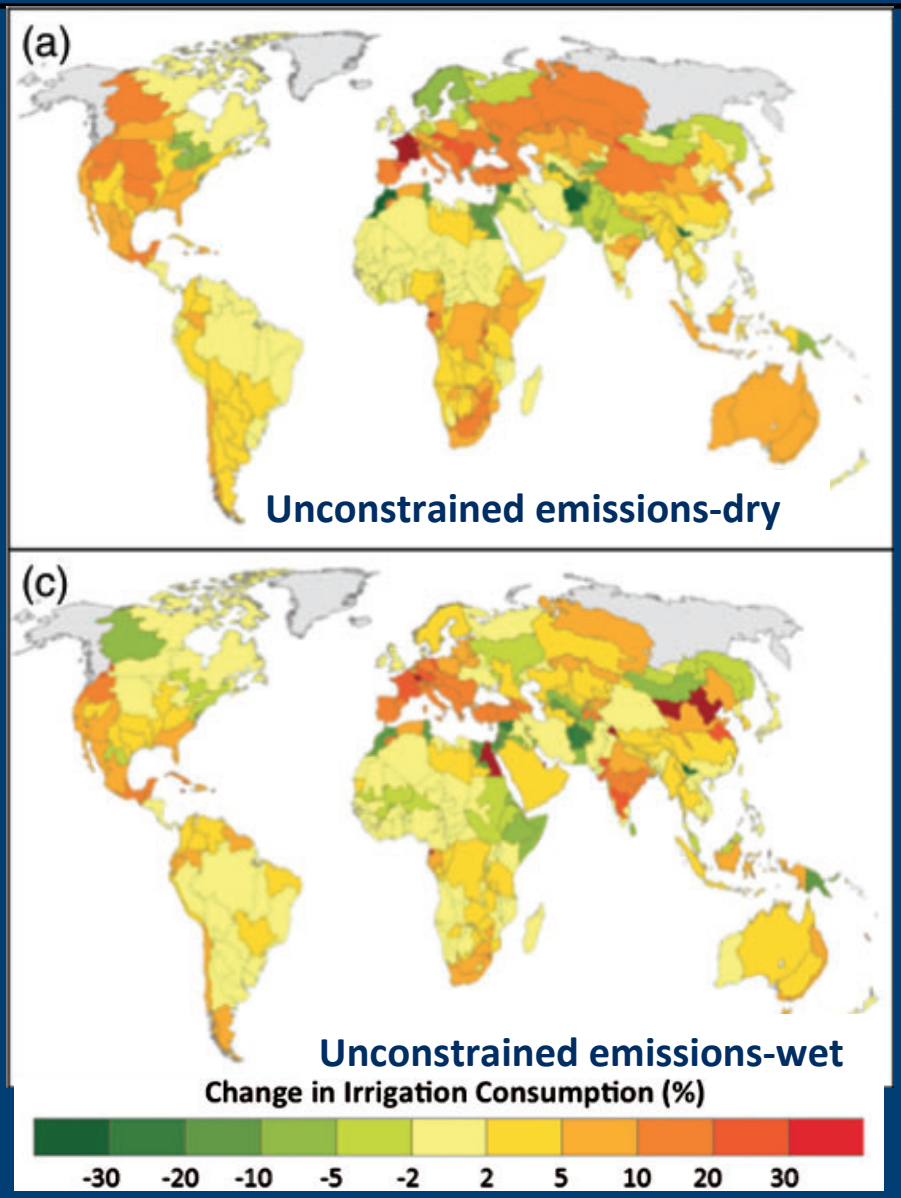
- Greater increase in rainfed land than reduction in irrigated land
- Irrigated land is more productive
- Total expansion by 2050: .20 (prop.); .21 (current); .23 (80%)

Source: Winchester et al. (2016) The Impact of Water Scarcity on Food, Bioenergy and Deforestation, GTAP Fall Meeting paper, also MIT JP report (forthcoming).

WATER RESOURCES SYSTEM (WRS) MODEL



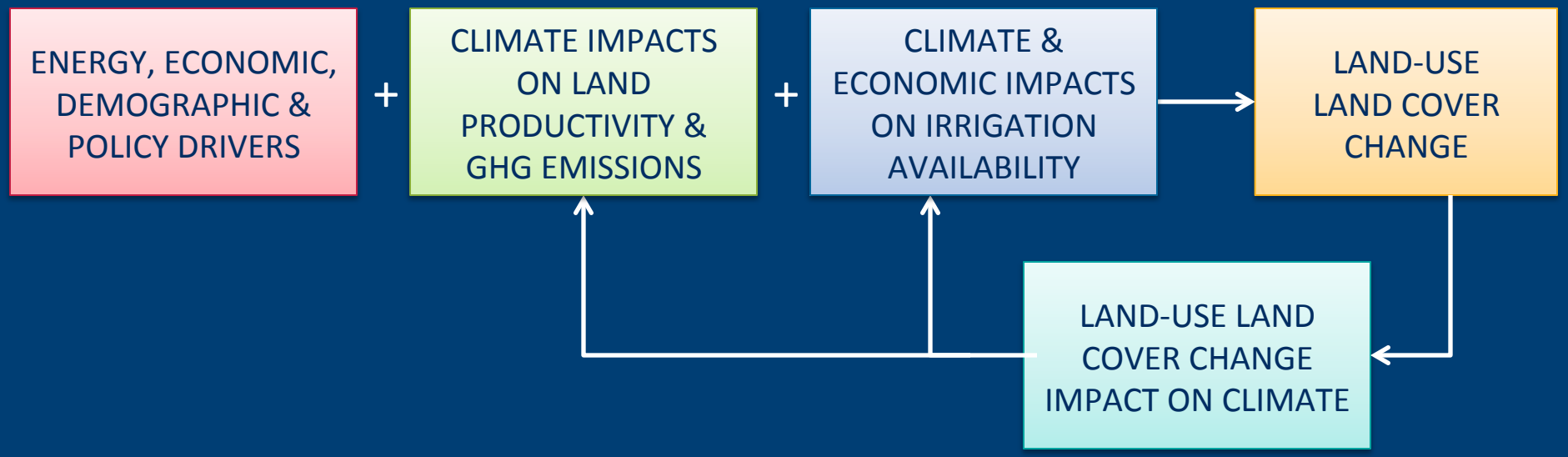
IRRIGATION REQUIREMENT UNDER GLOBAL CHANGE



- Climate change increases irrigation water requirements by 2050 in most regions
- Higher temperatures increase evapotranspiration except in a few areas where precipitation increases more
- Different climate model runs results in different pattern, magnitude and even sign of changes in irrigation consumption

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

"TOWARD A FULLY INTEGRATED LULCC FRAMEWORK"



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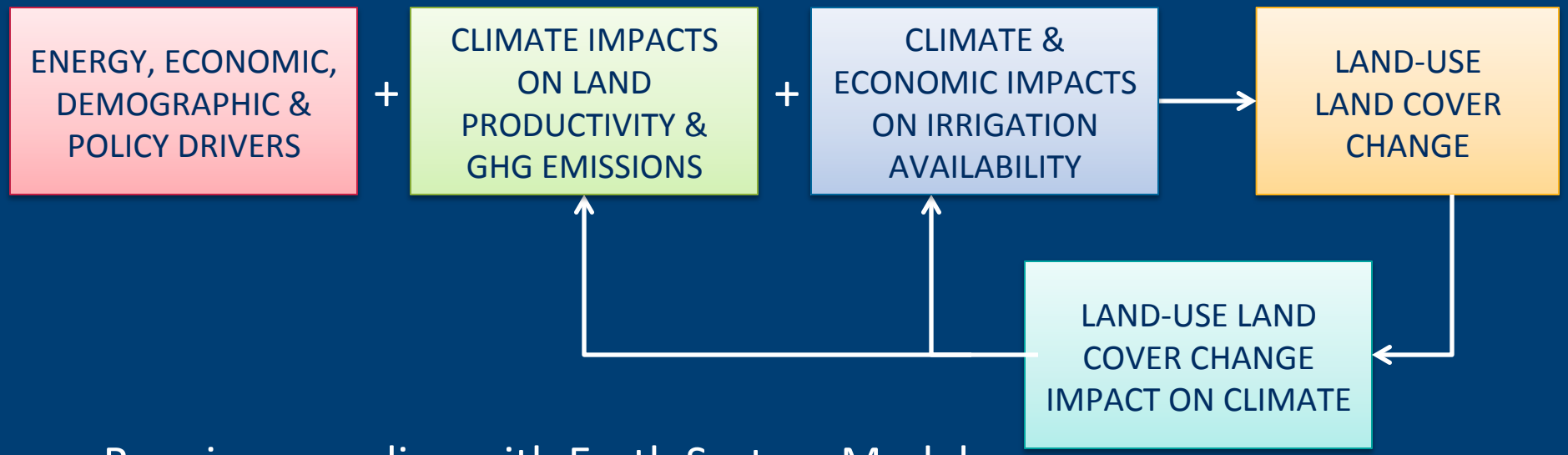
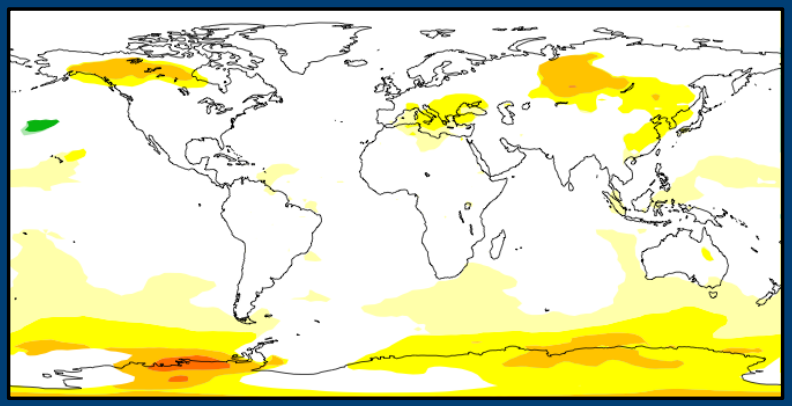


- Requires coupling with Earth System Model
- Focuses on feedback, but major challenge for uncertainty analysis
  - Single ESM
  - Computationally expensive
- Significant impact of LULCC on climate locally & regionally

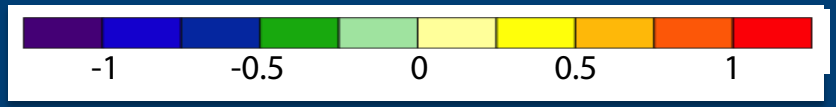
=> could be a paradigm shift in LULCC modeling

LAND-USE CHANGE IMPACT ON CLIMATE

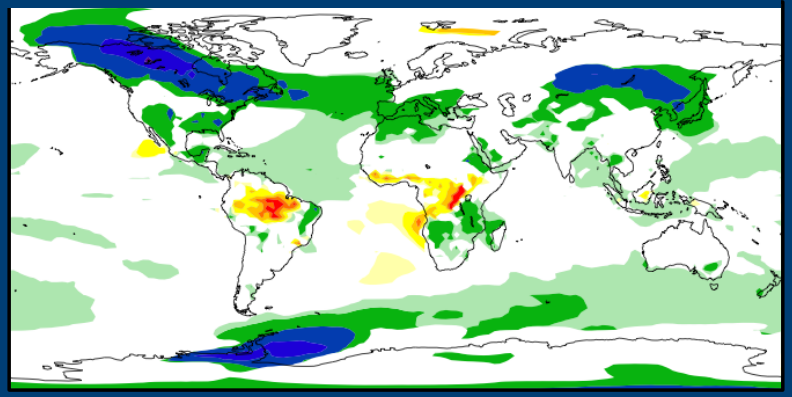
BIOGEOCHEMICAL IMPACTS (TEM)
GHG LAND-USE CHANGE EMISSIONS



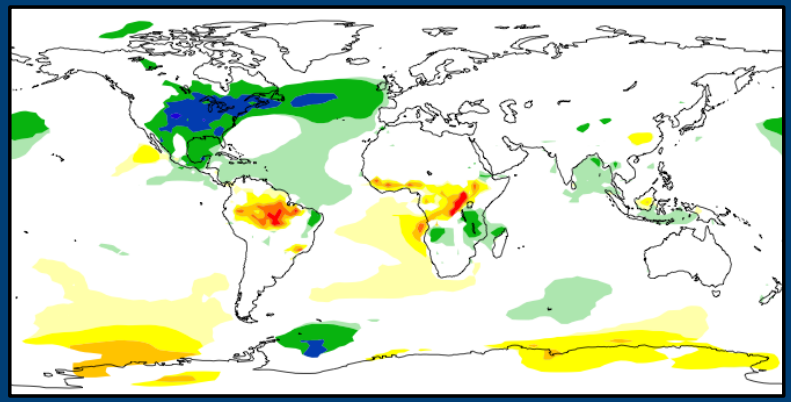
MARGINAL EFFECT OF
LARGE-SCALE BIOFUEL
DEPLOYMENT BY 2050



BIOGEOPHYSICAL IMPACTS (CLM)
CHANGE IN ALBEDO & HYDROLOGY



TOTAL IMPACTS (MESM)



Source: Hallgren et al. (2013) Climate impacts of a large-scale biofuels expansion. GRL, 40(8), 1624-1630.

ALWAYS THE SAME ISSUES

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1) Spatial resolution / uncertainty analysis

- Low resolution
  - More robust downscaling from economic region to grid level
  - Better for uncertainty analysis
- High resolution
  - More relevant to end users
  - Better representation of processes (i.e. extreme events)

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2) Temporal resolution / coupling strategies

- Hourly-to-daily for extreme events
- 5-year time step for the economic model
- Is the mean land productivity and/or water scarcity the most relevant metrics to inform the economic model (instead of more detailed statistics)

MANY ISSUES NOT ADDRESSED IN THIS TALK

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- Natural disturbances (wildfires, storms, pest…)
- Natural plant migration
- Protected areas
- Expansion of available land through permafrost thaw
- Atmospheric chemistry (ozone damage, nitrogen deposition…)
- Past land legacy effects impact present and future GHG fluxes and land productivity (past land transitions/irrigation practices)

THANK YOU

ANY QUESTIONS?