# Discovering How Agricultural Development Shapes Climate Change Futures


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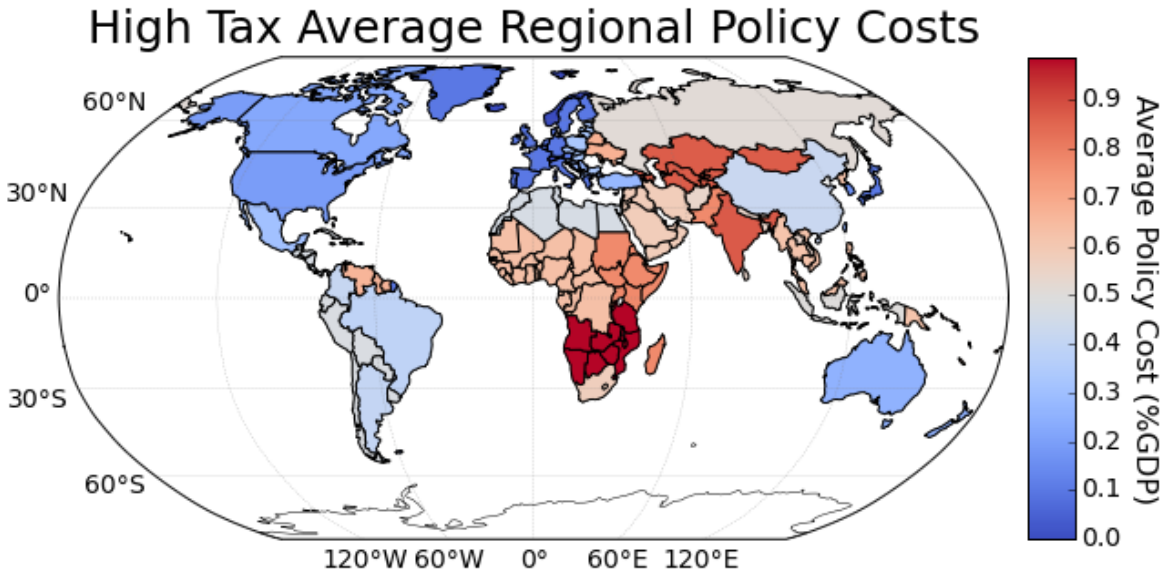



## Jonathan Lamontagne

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Tufts University

# Scenario matrix framework: New climate change scenario paradigm

Community generated successor to IPCC SRES scenarios.

G Model
JGEC-1388; No. of Pages 12

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The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century

Brian C. O'Neill [a,*], Elmar Kriegler [b], Kristie L. Ebi [c], Eric Kemp-Benedict [d], Keywan Riahi [e,f], Dale S. Rothman [g], Bas J. van Ruijven [a], Detlef P. van Vuuren [h,i], Joern Birkmann [j], Kasper Kok [k], Marc Levy [l], William Solecki [m]

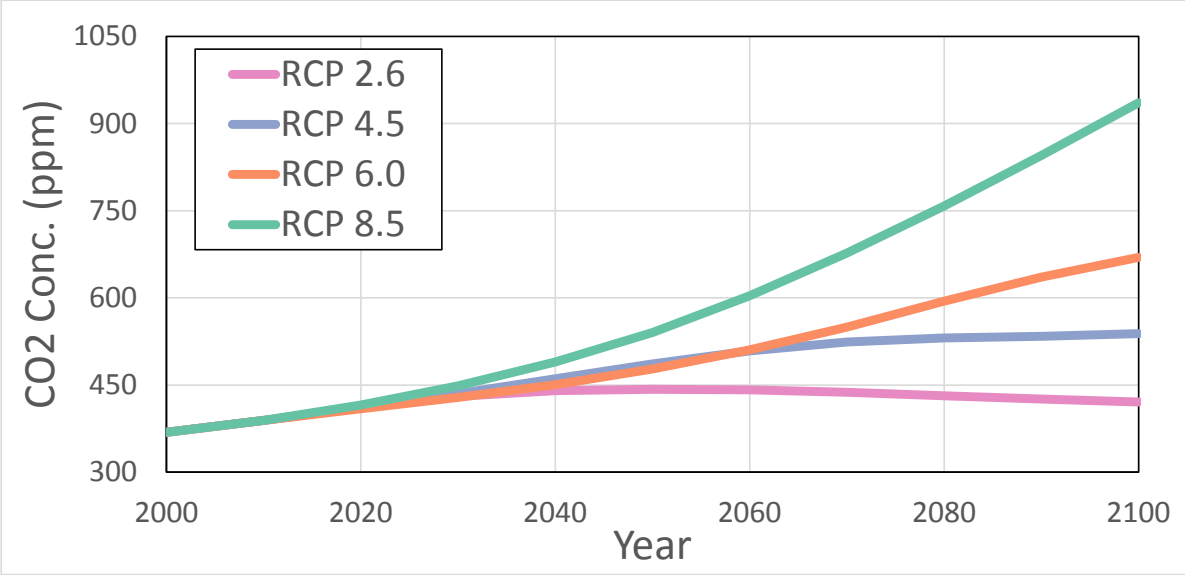
Used in IPCC AR5…likely centerpiece of future IPCC AR6.

Widely used for Impact, Adaptation, & Vulnerability studies.

# Scenario matrix framework:
# Deep narrative scenarios of climate/economic futures

Representative Concentration Pathways (RCPs)

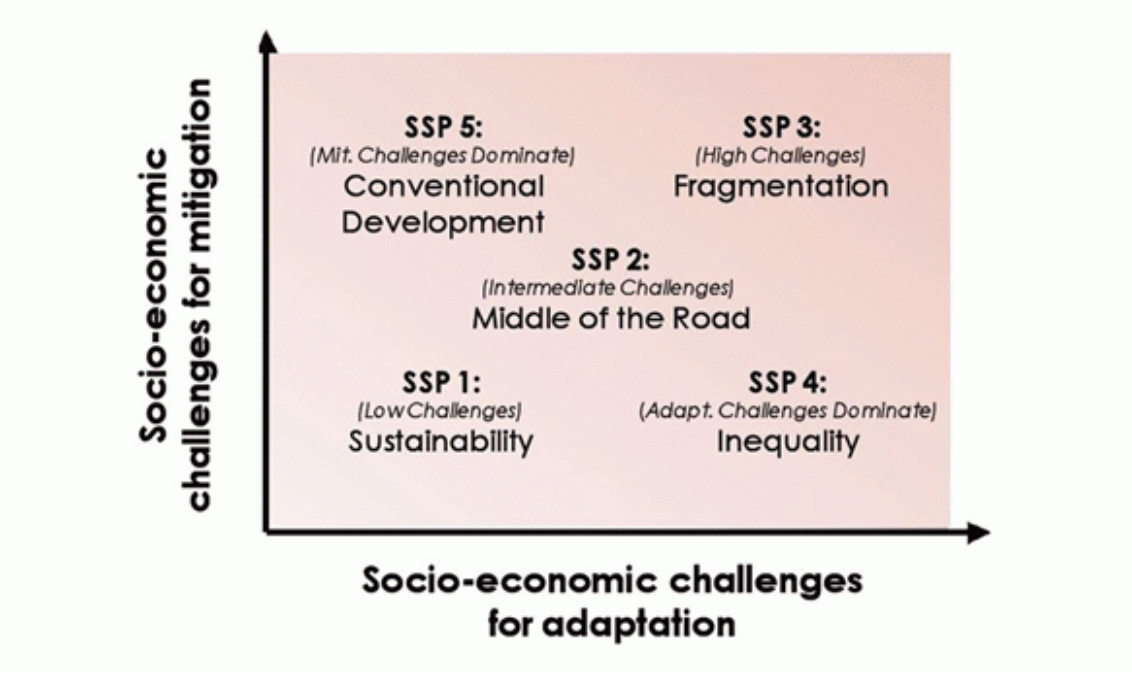
Four emissions trajectories meeting different 2100 forcing levels



# Scenario matrix framework:
# Deep narrative scenarios of climate/economic futures

Representative Concentration Pathways (RCPs)

Shared Socio-Economic Pathways (SSPs)



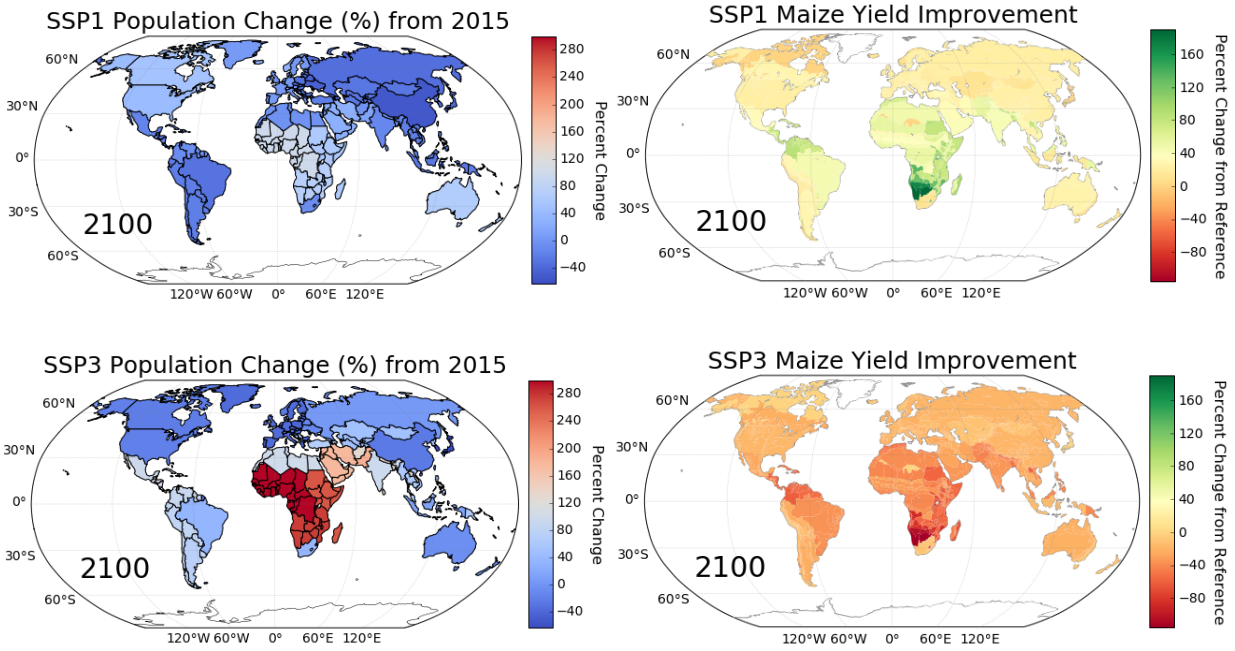

Five narrative scenarios for evolution of the human system, arranged on two 'challenge' axes.

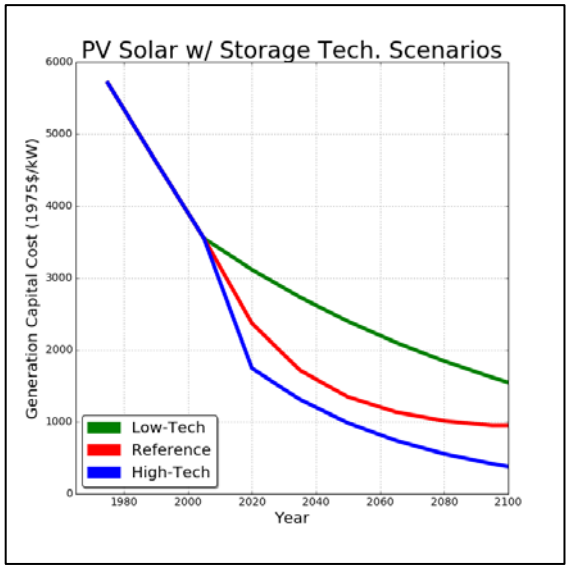
O'Neill et al. 2012

# Scenario matrix framework:
# Deep narrative scenarios of climate/economic futures

Representative Concentration Pathways (RCPs)

Shared Socio-Economic Pathways (SSPs)

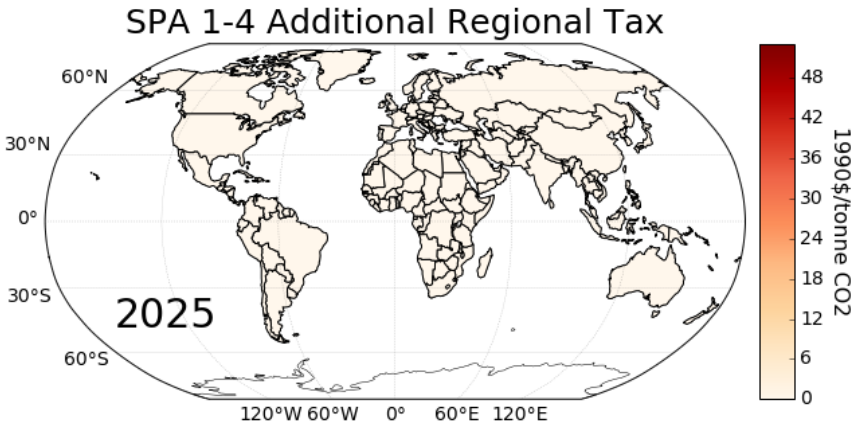


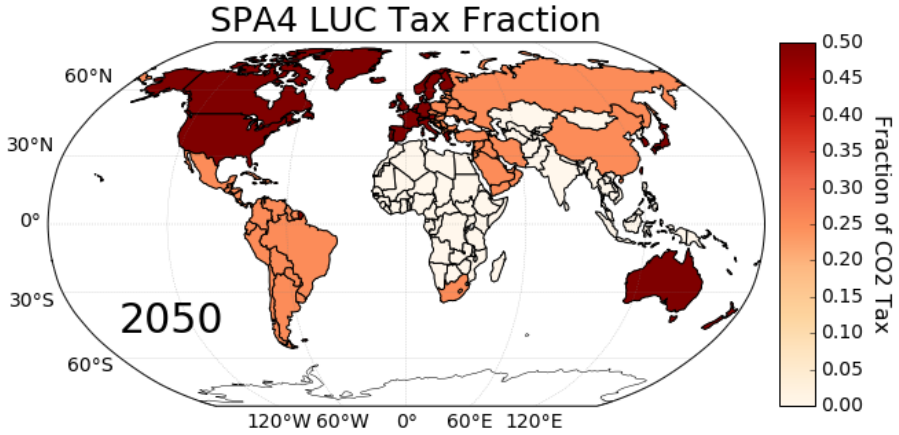



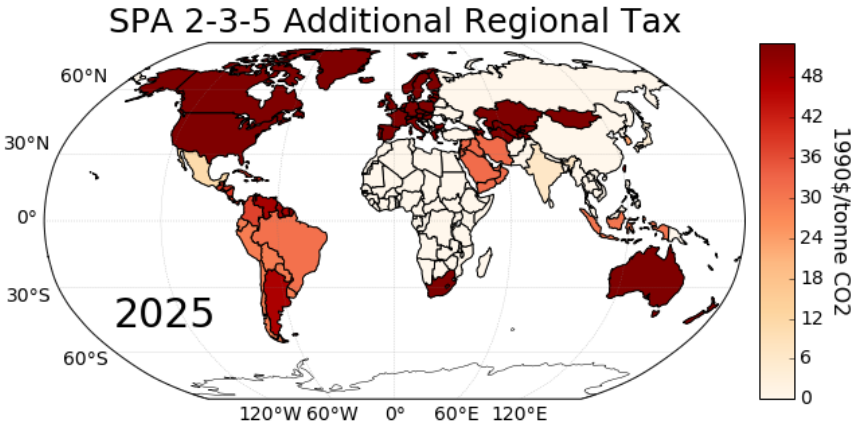

Population | Agriculture | Energy

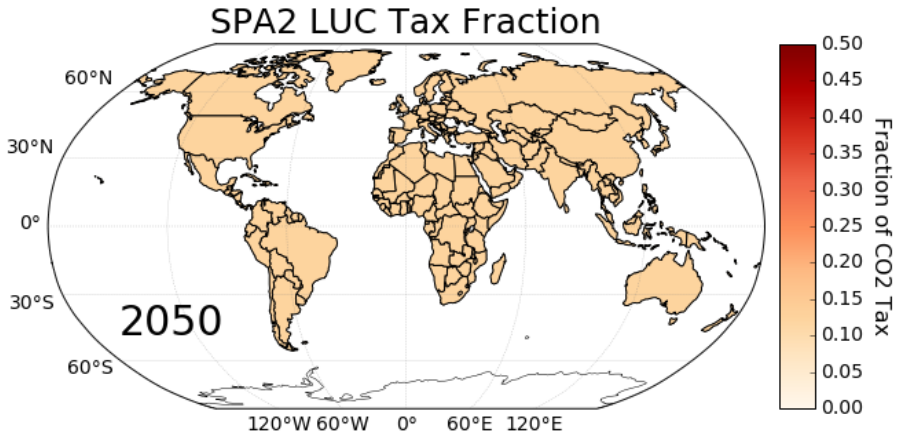
# Scenario matrix framework:
# Deep narrative scenarios of climate/economic futures

Shared Policy Assumptions (SPAs)




Regional Tax Fragmentation

LUC Taxes

Concerns:

Scenario matrix scenarios provide limited glimpse into deeply uncertain future.

SSP 'challenges' nebulous:

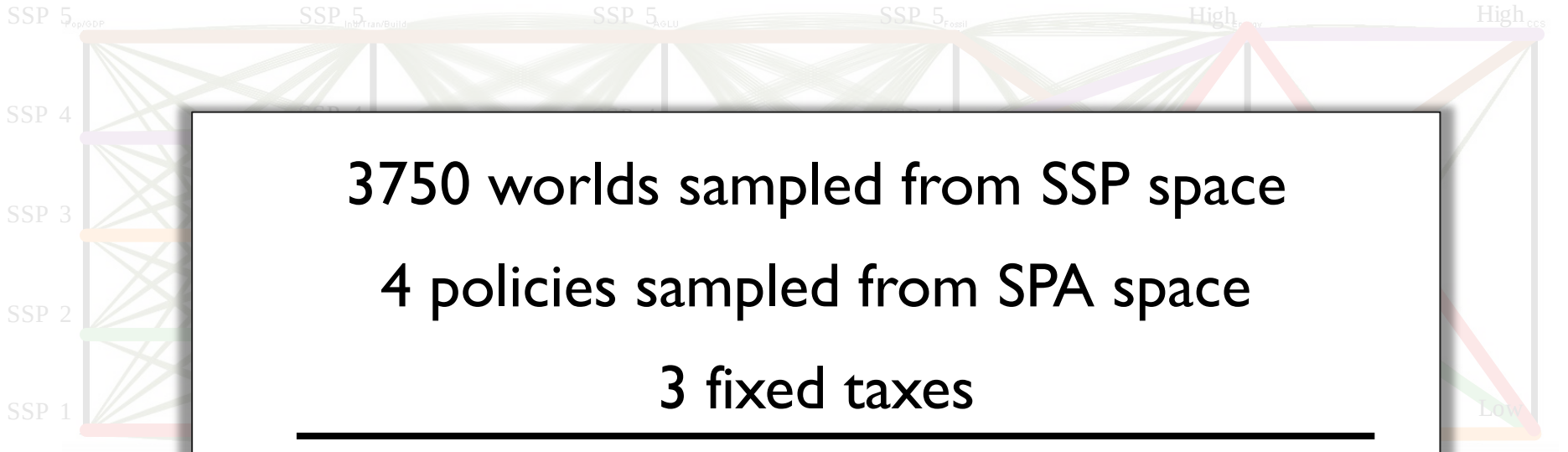
Challenging for whom, when?

By what metrics?

RCP target finding implies greater control, certainty, and coordination:

May underestimate magnitude of challenges

# Experimental Design: SSP sampling




3750 worlds sampled from SSP space

4 policies sampled from SPA space

3 fixed taxes

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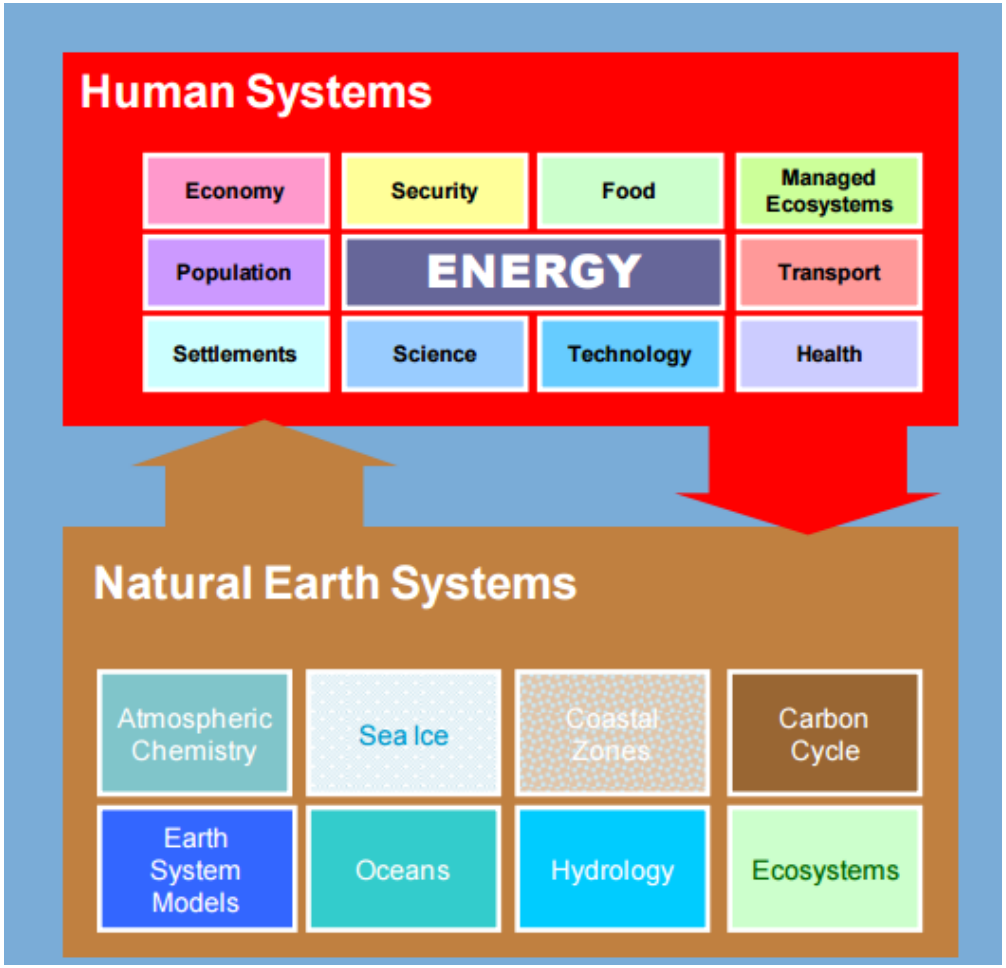
33,750 global change scenarios

Full factorial sampling of SSP space.

Similar strategy SPA space.

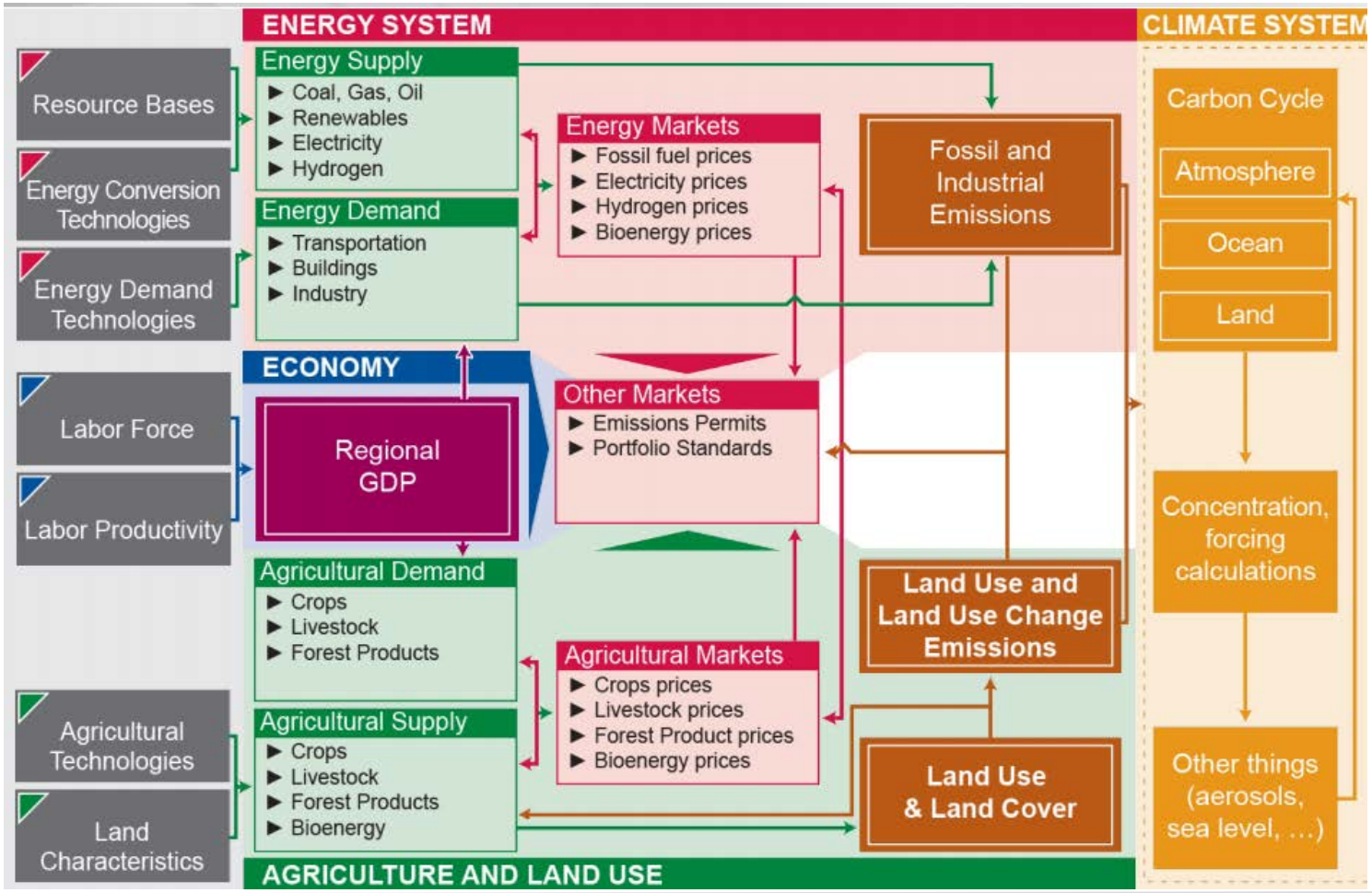
# Global Change Assessment Model (GCAM)

Models interaction between natural and human systems.



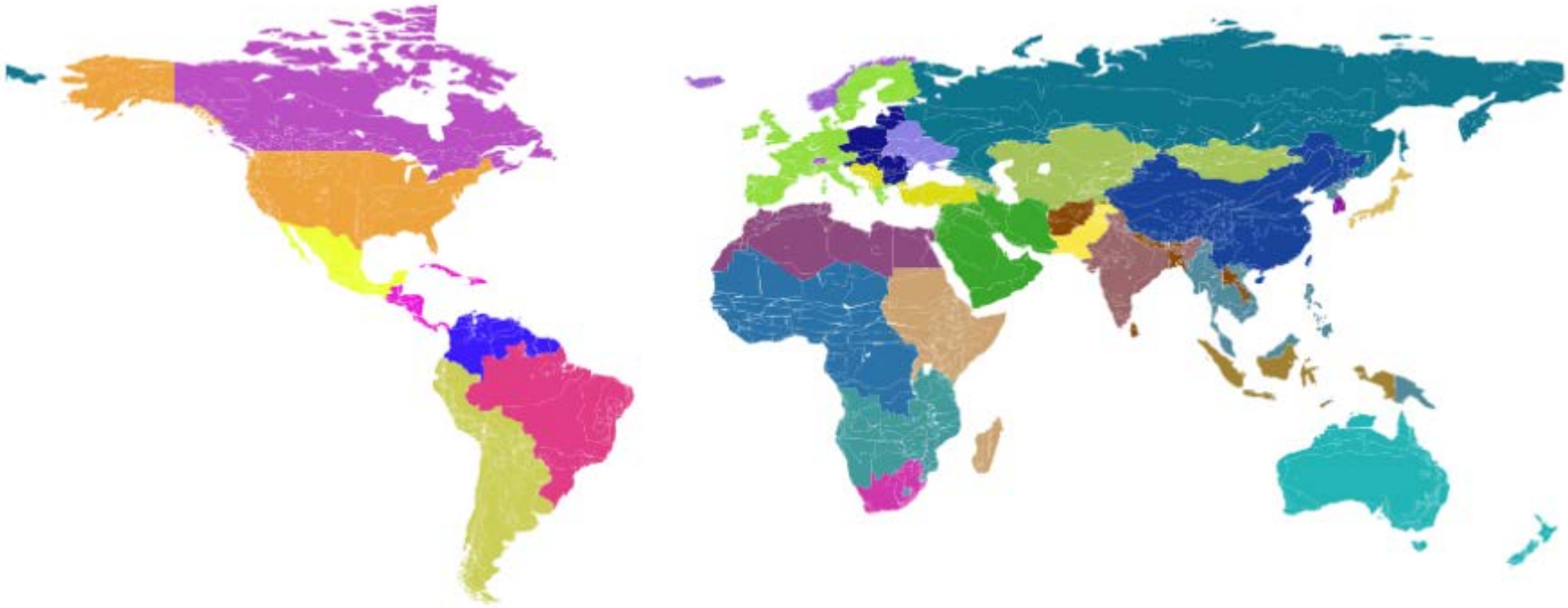
# Global Change Assessment Model (GCAM)

Complex modular representation of supply and demand sectors, linked by markets (energy, ag, ect.) at both regional and international levels.



# Global Change Assessment Model (GCAM)

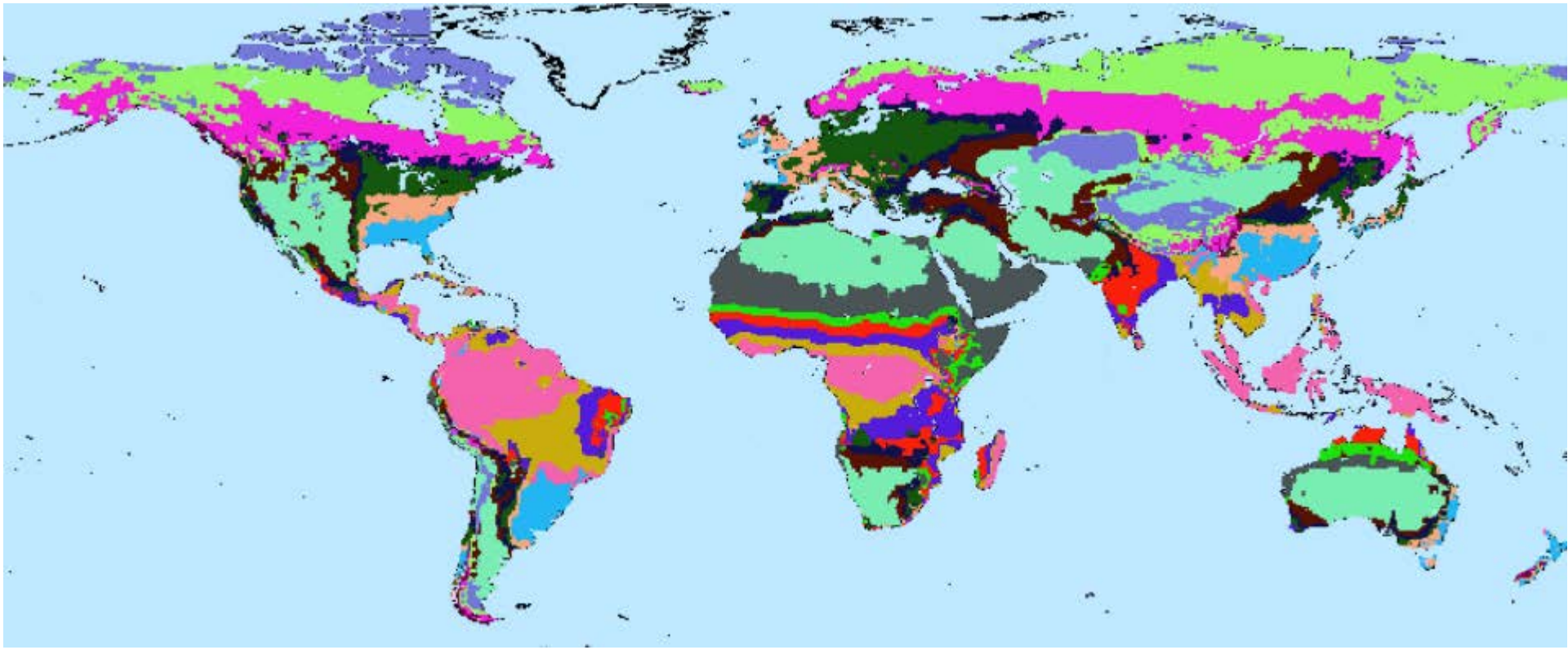
32 Energy-Economic Regions



10 primary energy sources

# Global Change Assessment Model (GCAM)

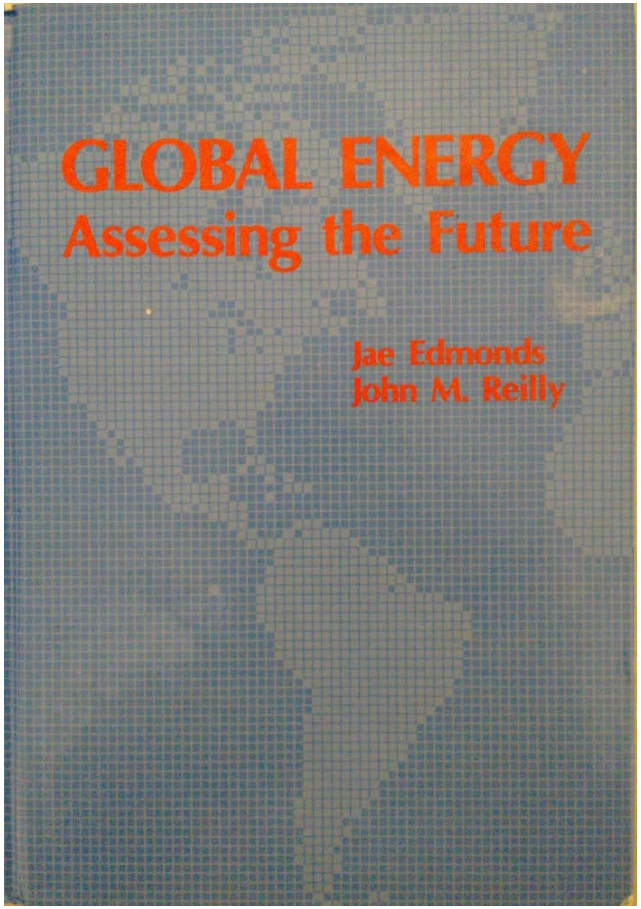
283 Agro-Ecological Zones



12 crops, 6 animal products, forest, and bio-energy crops

# Applications of the GCAM

1. Roots in 1980's DOE's Energy/ Emissions trajectories



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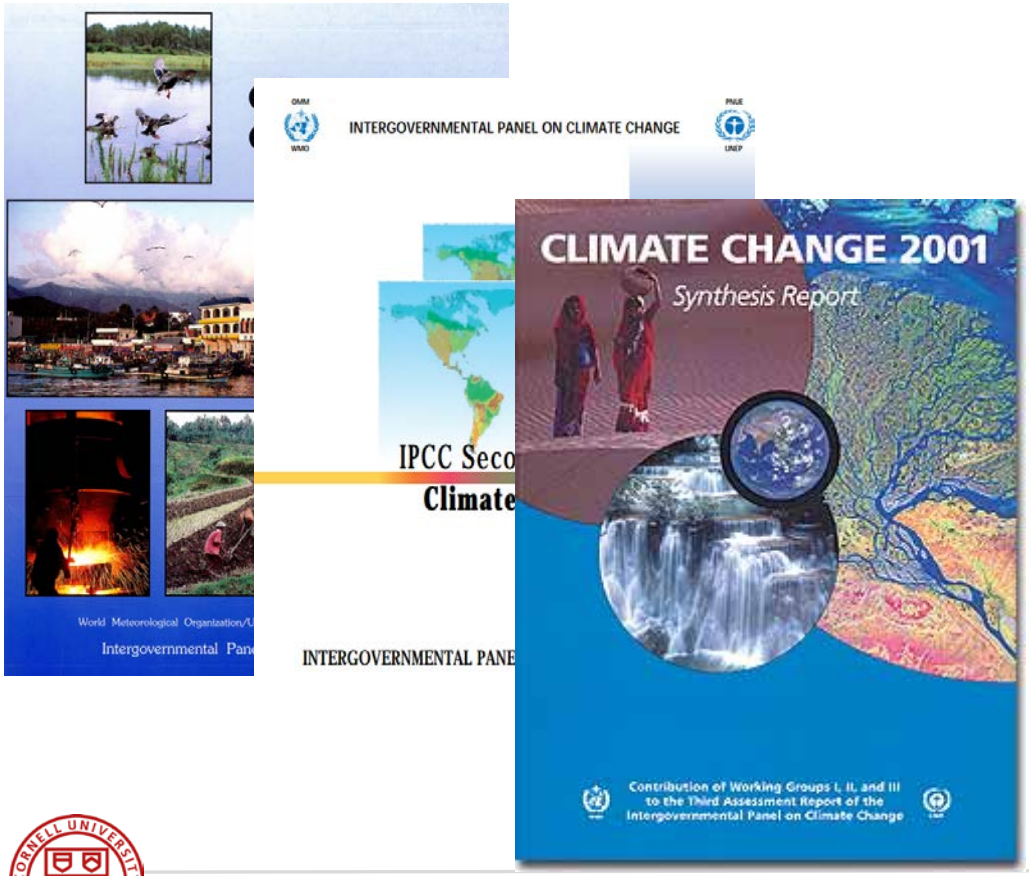


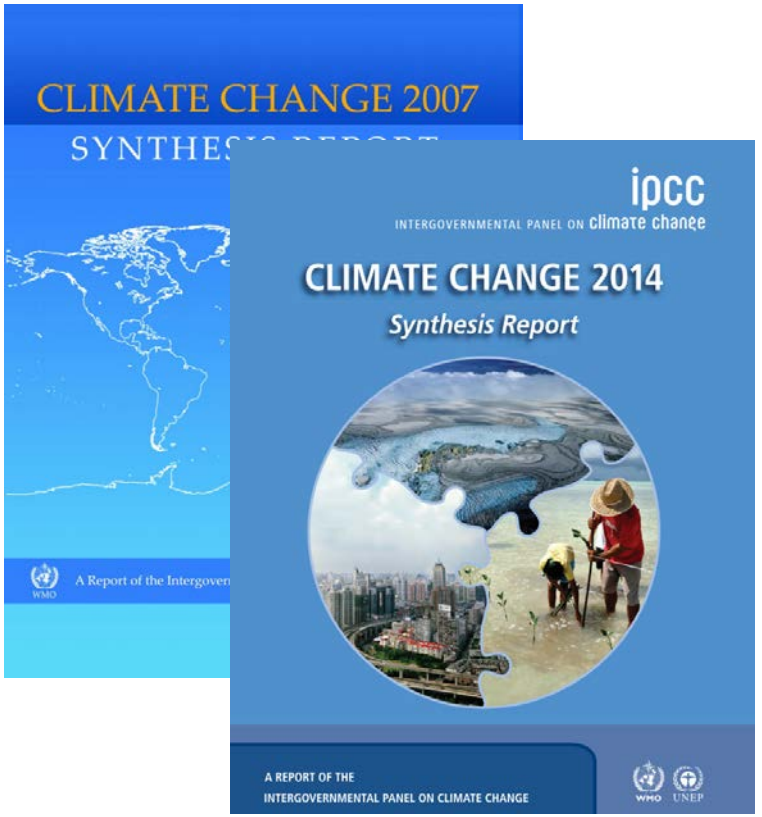

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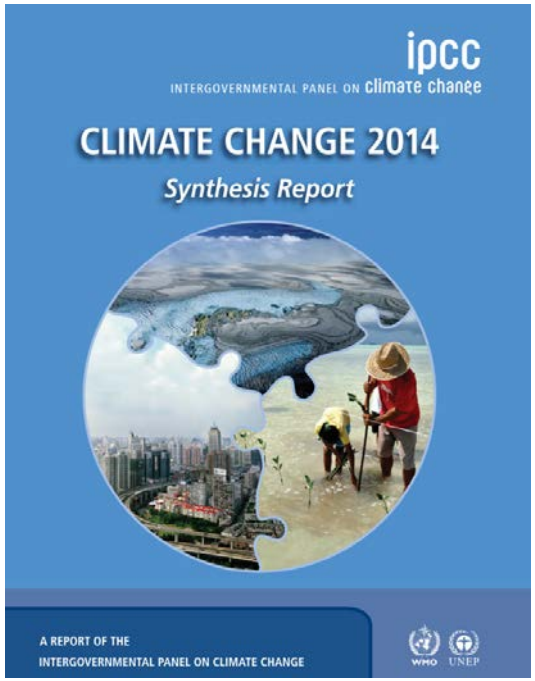
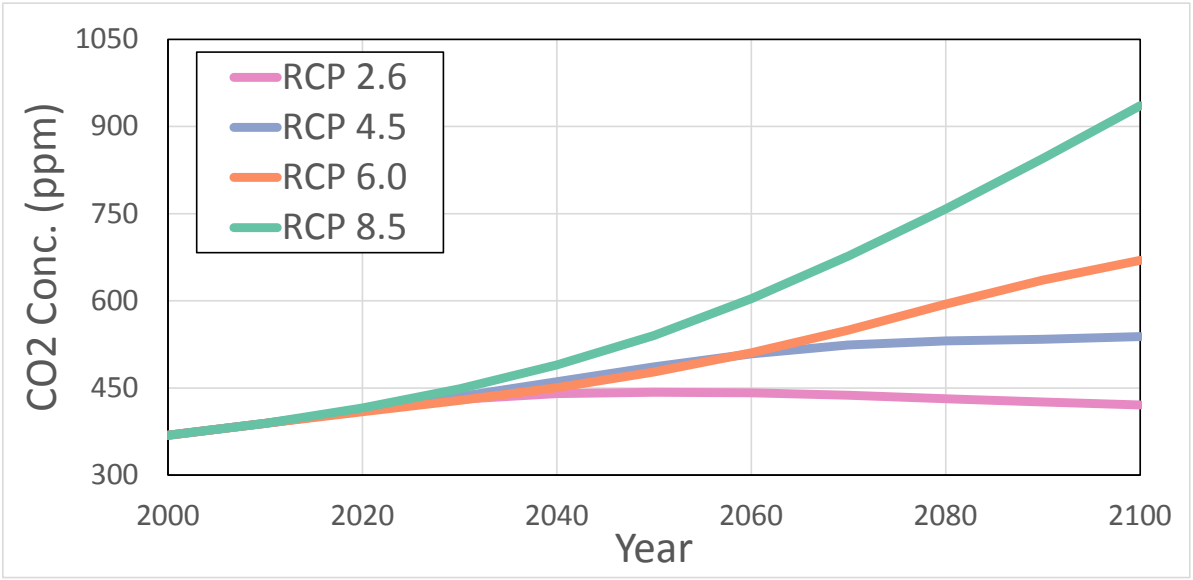
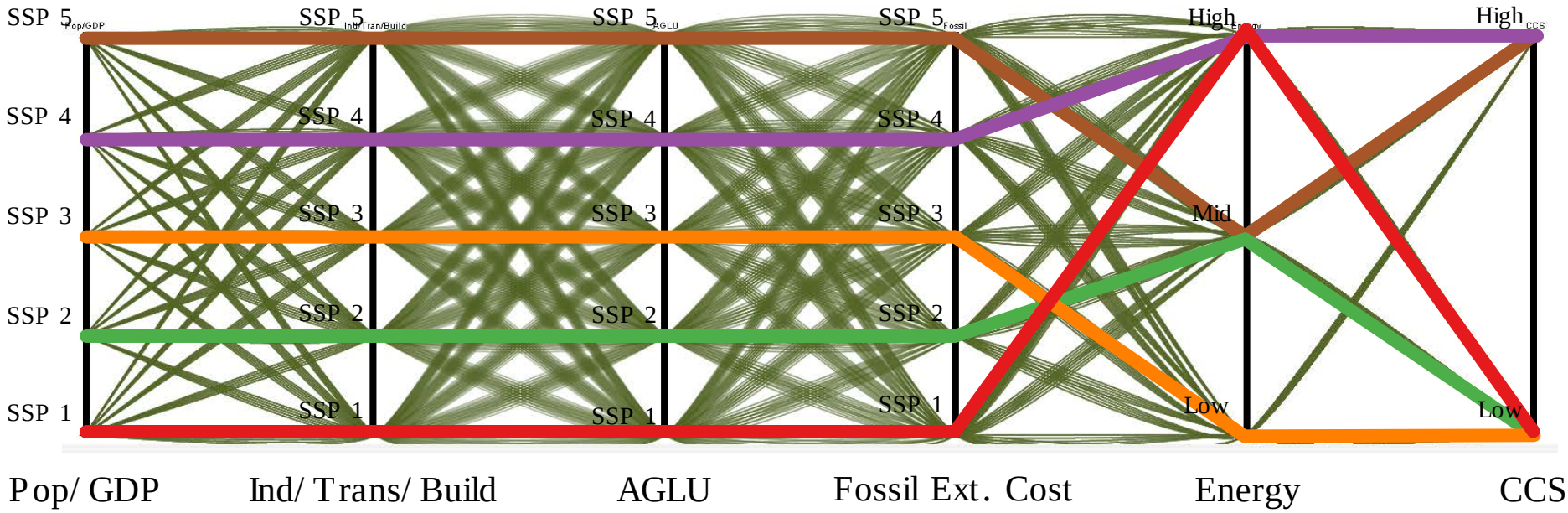


# Applications of the GCAM

1. Roots in 1980's DOE Edmonds-Reilly Model
2. GCAM used in virtually every major climate-energy-economic assessment over the last 20 years, including **every** IPCC assessment.
3. GCAM 1 of 4 models used to create the RCPs for the IPCC's AR5.
4. One of chief models used by US Government

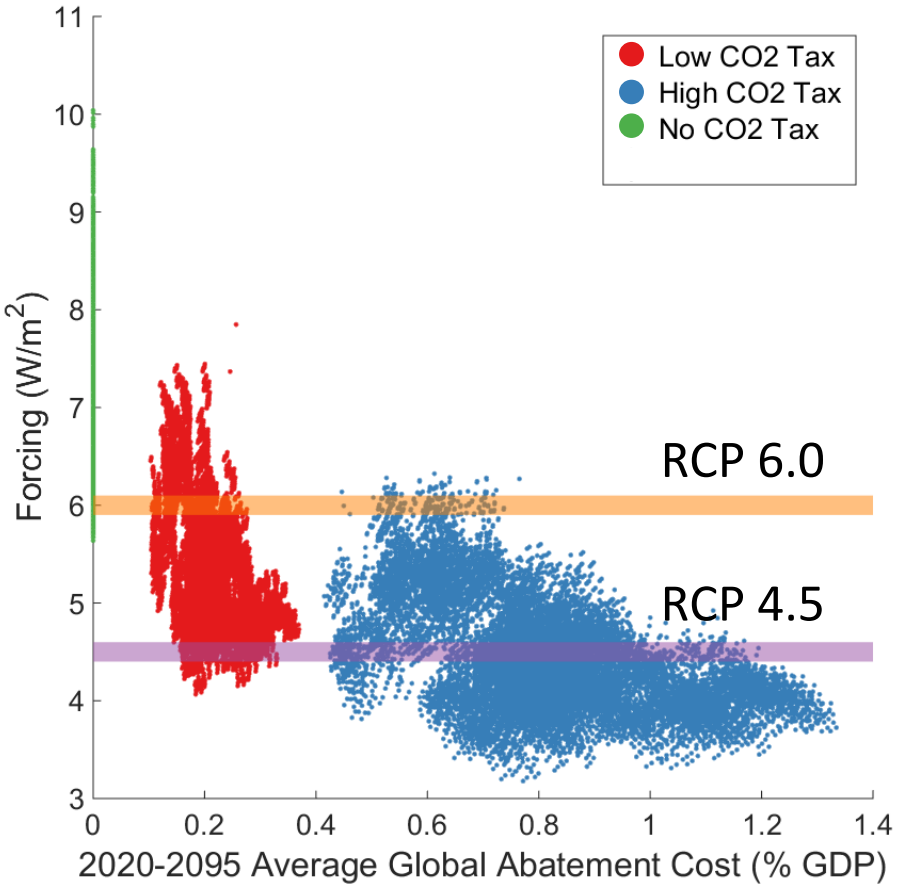
# Experimental Design: SSP sampling



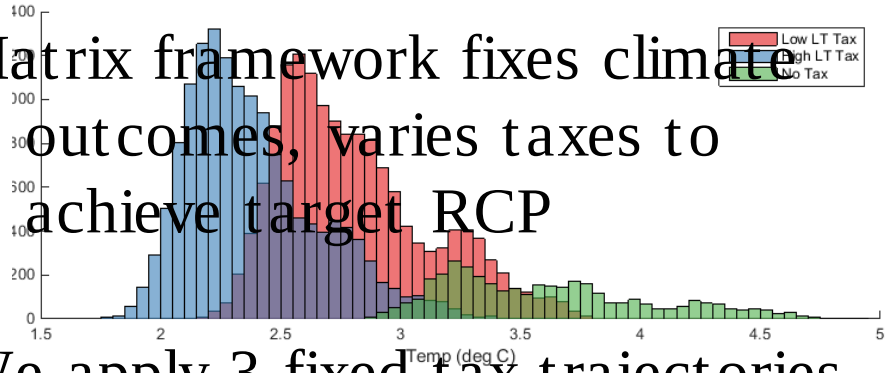

33,750 global change scenarios sampled from the SSP/ SPA space, evaluated using **GCAM**.

Self-consistent, multi-sector, multi-scale, time-evolving scenarios of hundreds of **climate**, **economic**, **demographic**, **land use variables**.

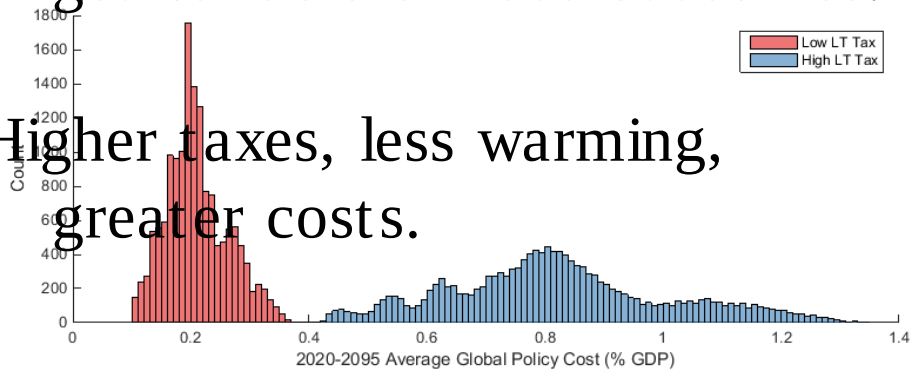
# Radiative Forcing vs. Global Cost




Matrix framework fixes climate outcomes, varies taxes to achieve target RCP




We apply 3 fixed tax trajectories, get variable climate outcomes.

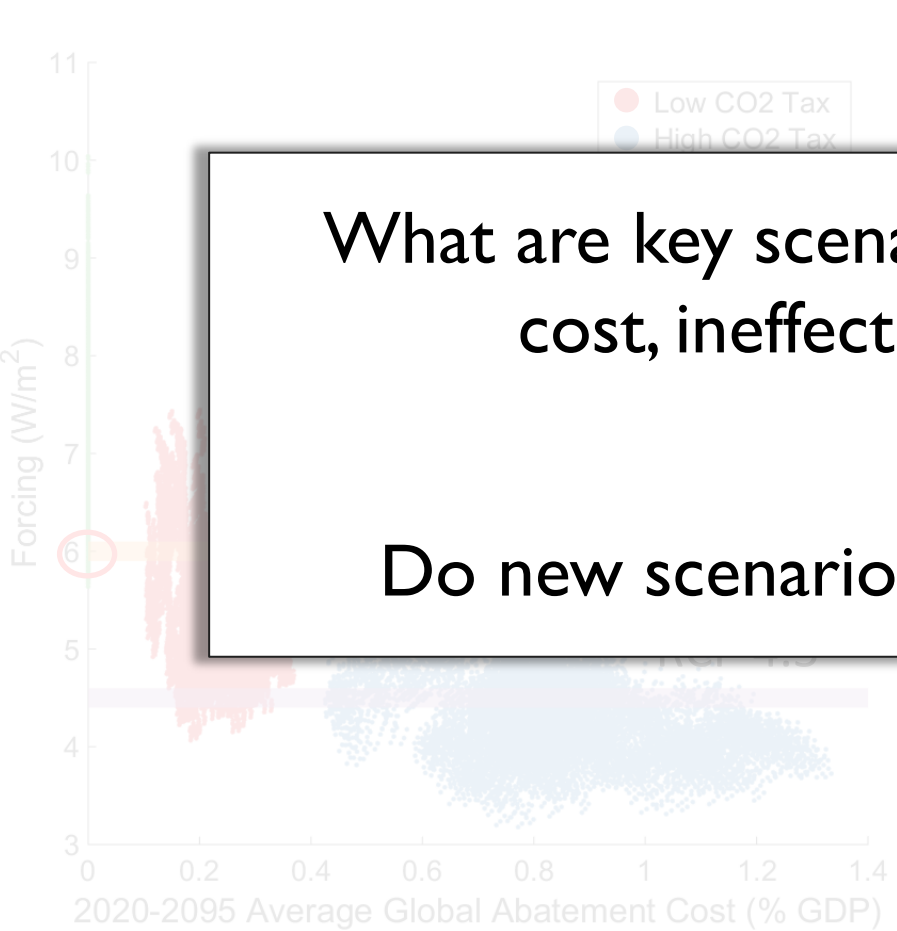


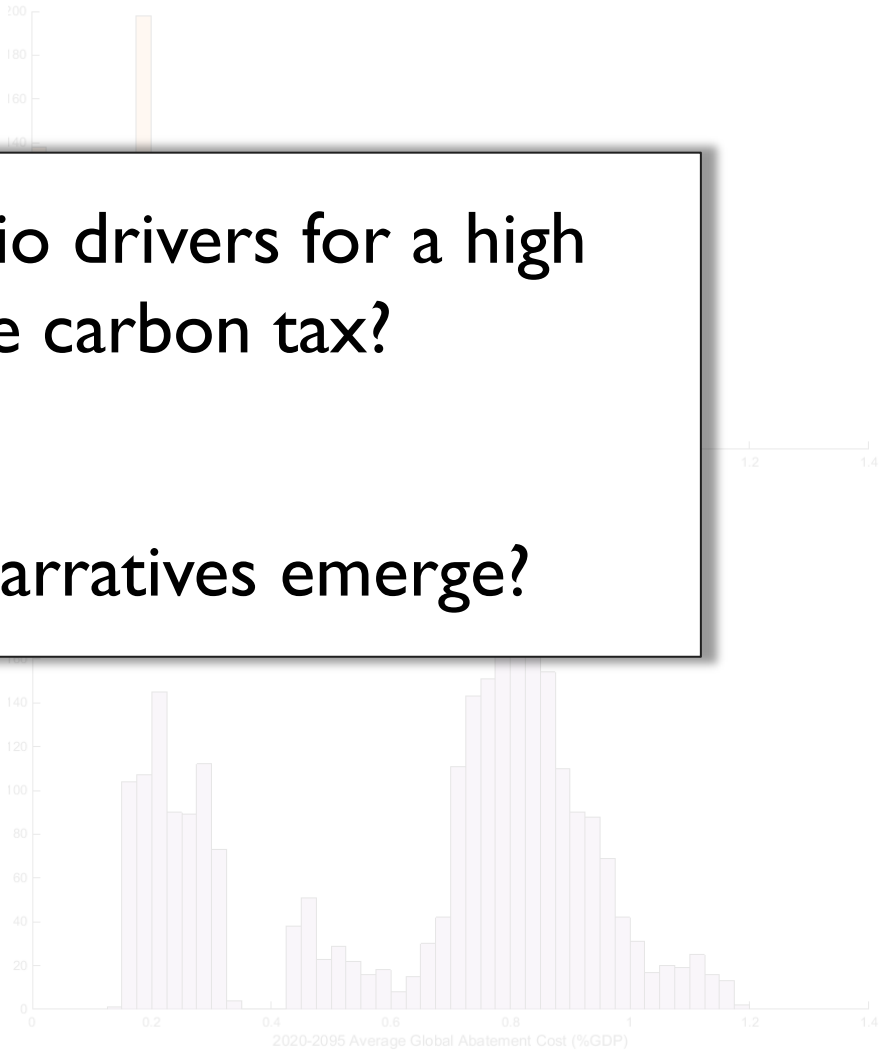

Higher taxes, less warming, greater costs.

Greater taxes, greater variability in outcomes.

Only high tax rate sufficient to reach 2C by 2100.

# Radiative Forcing vs. Global Cost



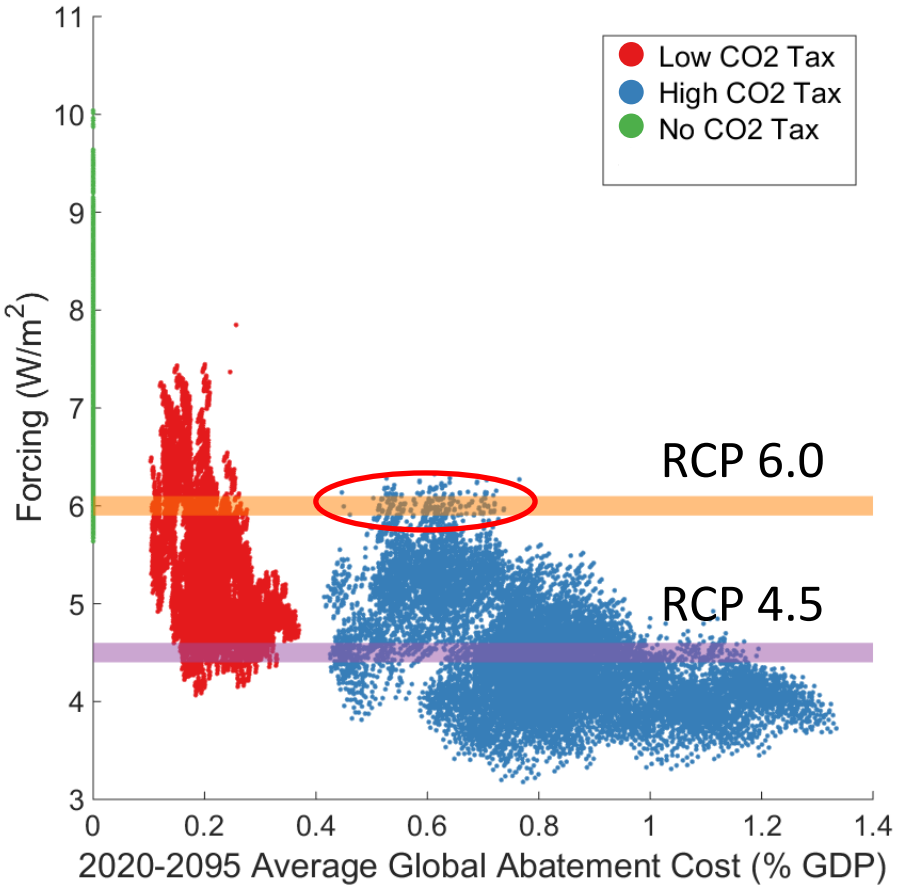




What are key scenario drivers for a high cost, ineffective carbon tax?

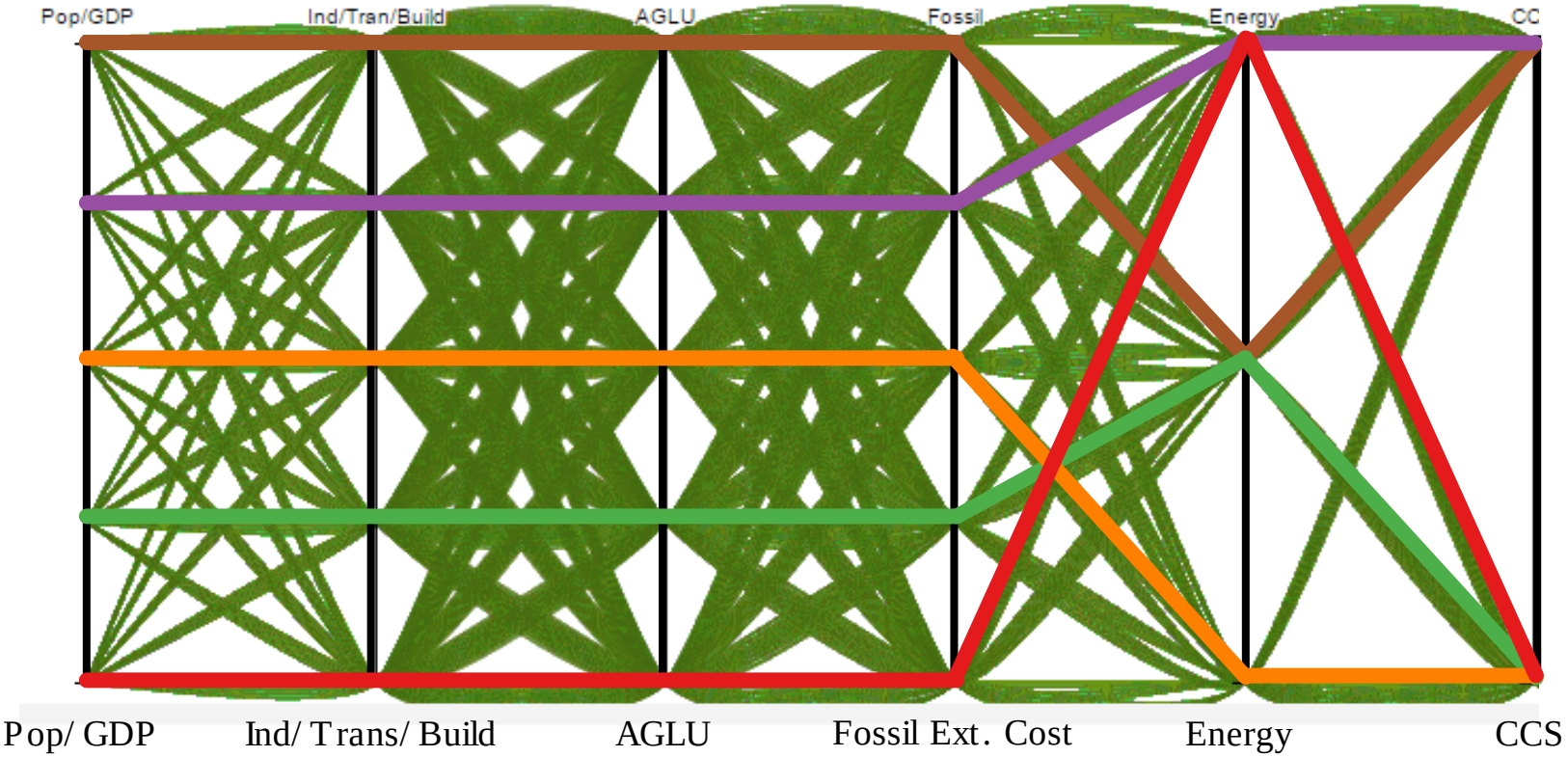
Do new scenario narratives emerge?

RCP6.0 reached both at no cost and high cost

# High cost RCP 6.0:
# Worlds where high tax regime is relatively ineffective



# Ineffective Tax Worlds:
# High tax worlds with high radiative forcing



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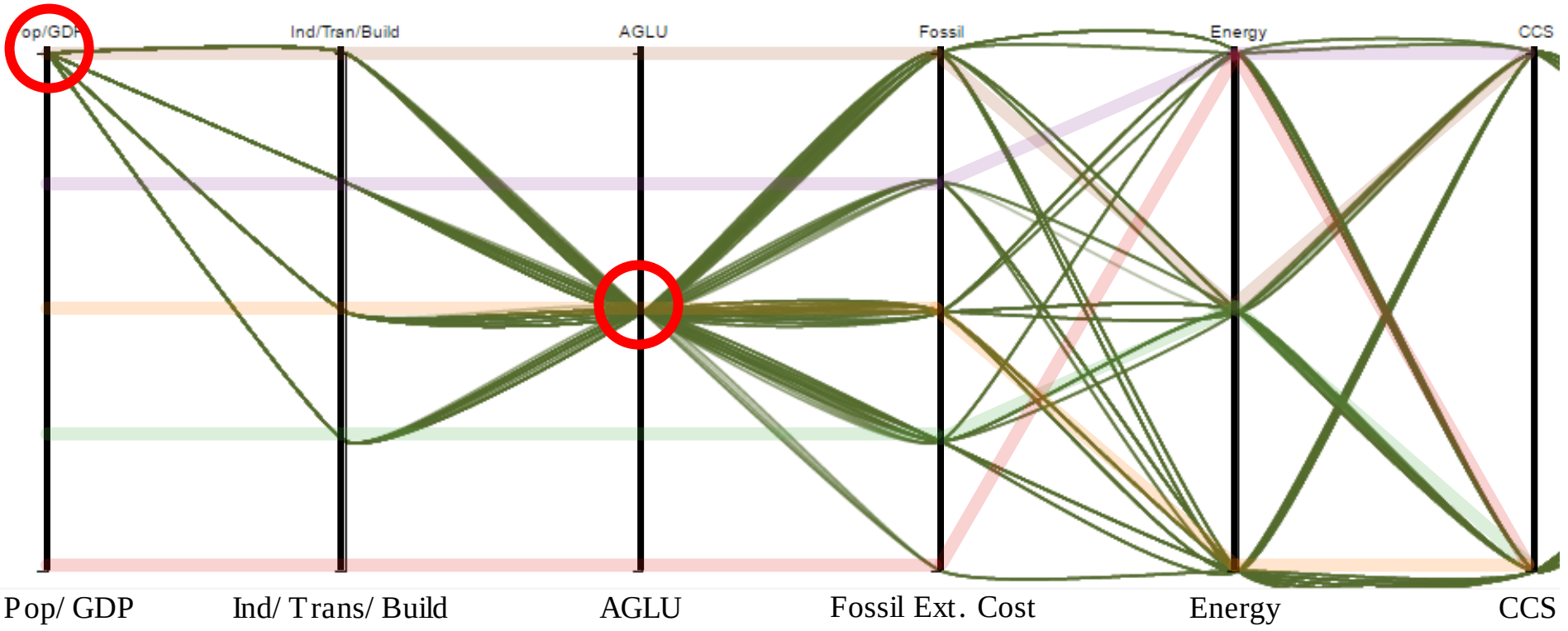
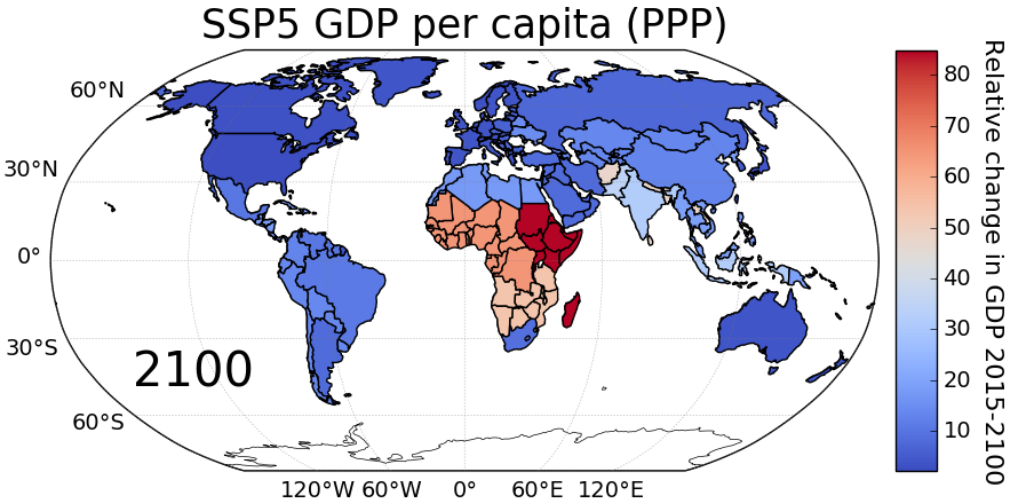



These worlds share SSP5 demographics and SSP3 agriculture and land use assumptions.

# Ineffective Tax Worlds:
# High tax worlds with high radiative forcing

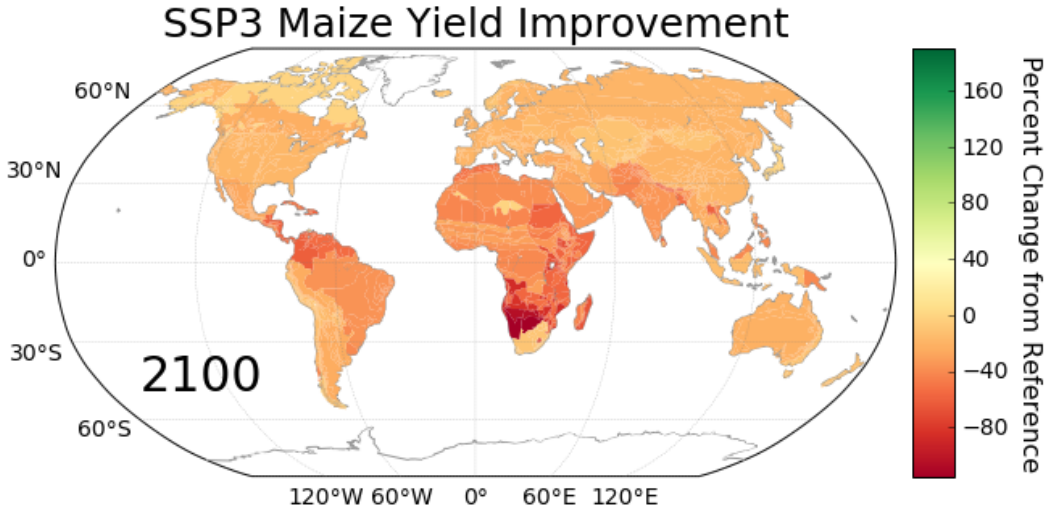



SSP5 sees massive **GDP growth**, particularly in Africa.

Increase in per capita **food demand**, changing diets.

Increased consumption paired with **low agricultural yields** (SSP3) leads to large LUC.

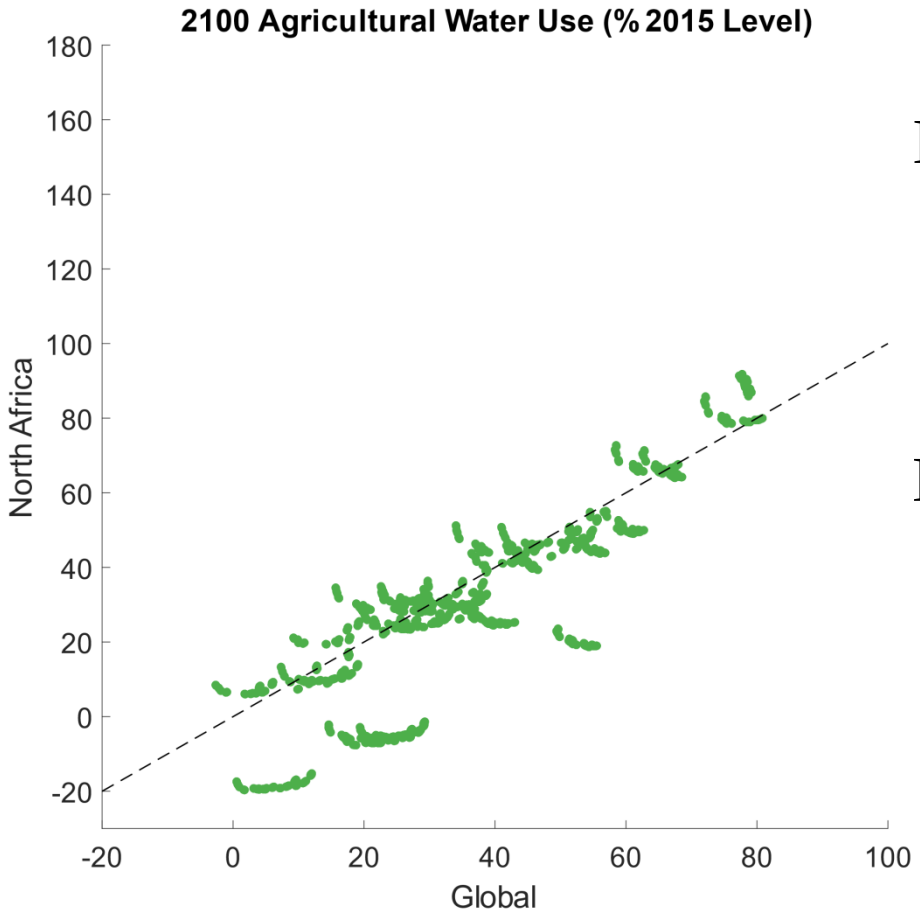
Large **LUC emissions** render tax ineffective.



We've explored how SSP assumptions impact efficacy of abatement regime.

How do SSP elements and abatement regimes impact agricultural water use?

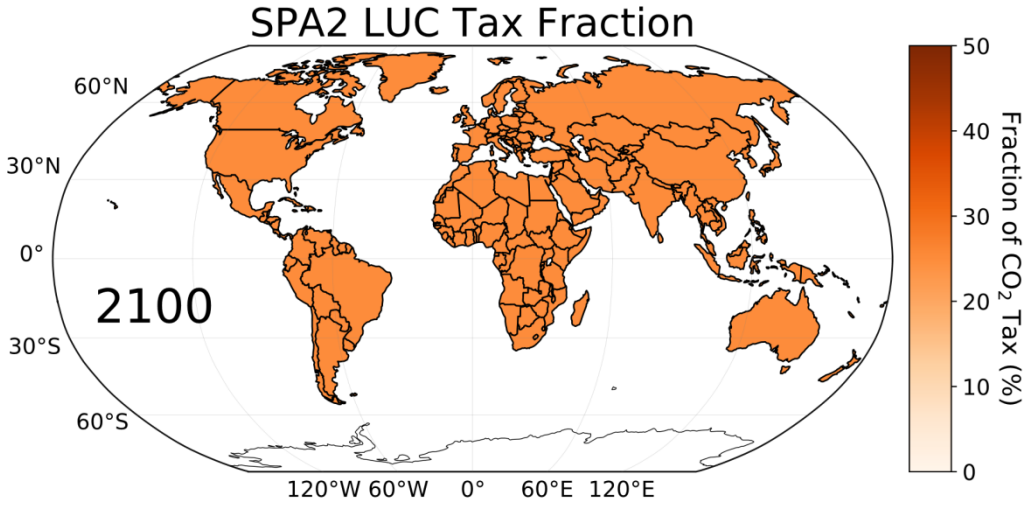
# Without abatement regime, North Africa adheres to global trends



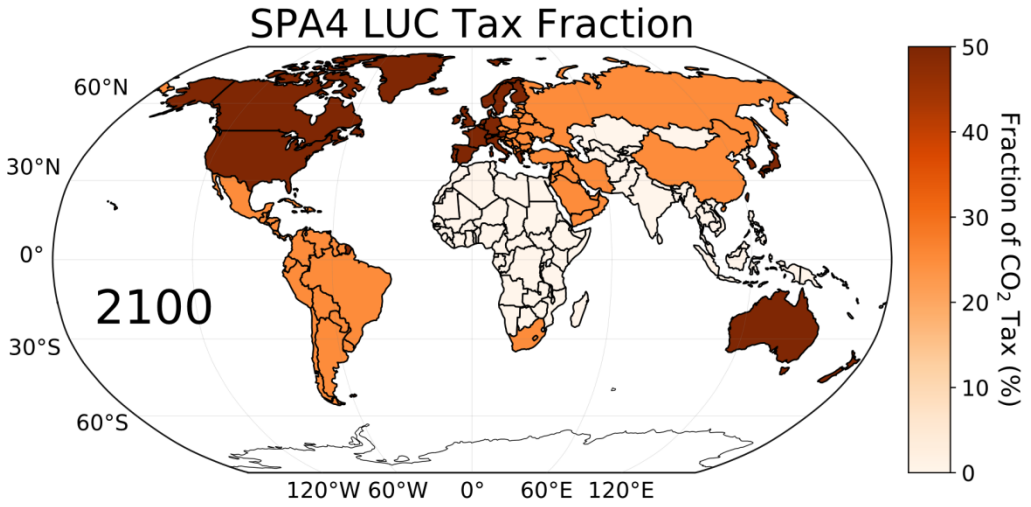

In most cases, water use grows over the 21st century, globally and in North Africa.

How do abatement regimes impact this?

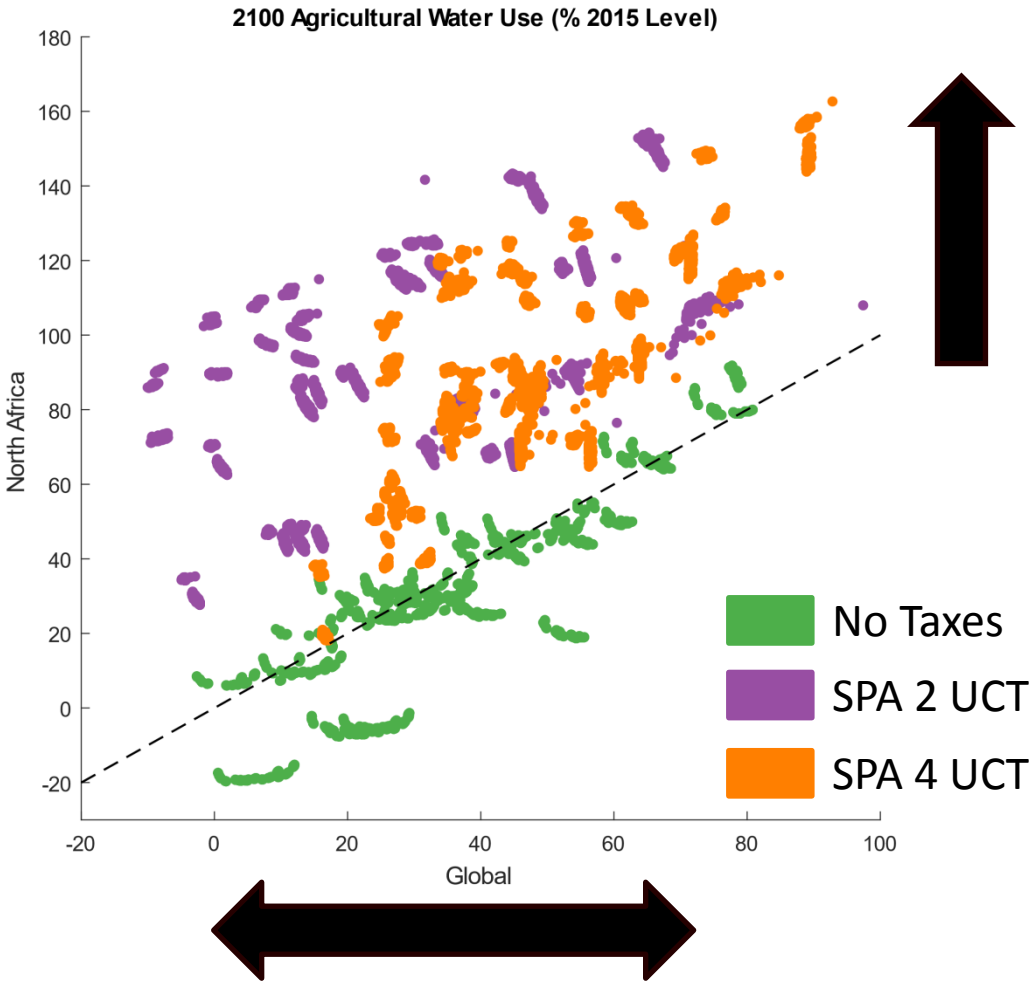
# Impact of Alternative LUC Tax Assumptions on water use: North Africa vs. Global




Uniform vs Fragmented Shared Policy Assumptions

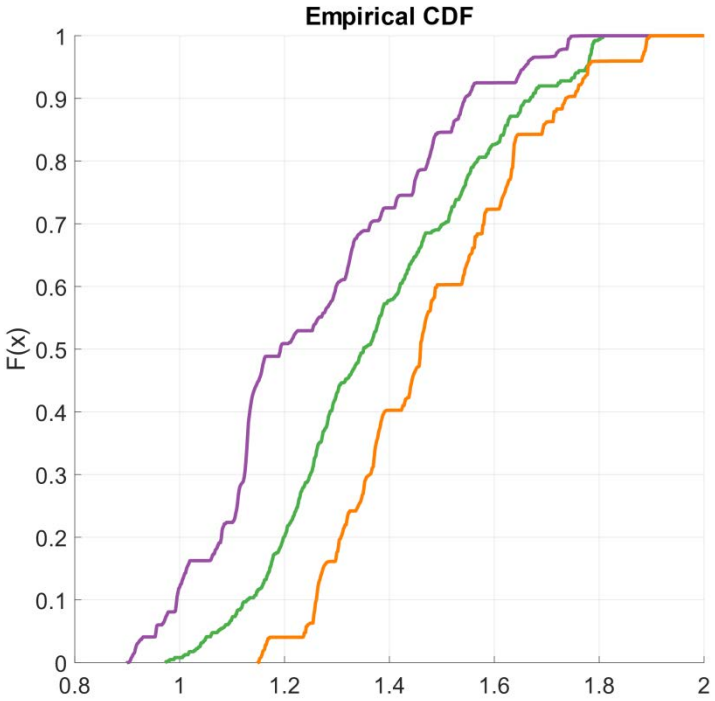


# Impact of Abatement regime on water use: North Africa vs. Global



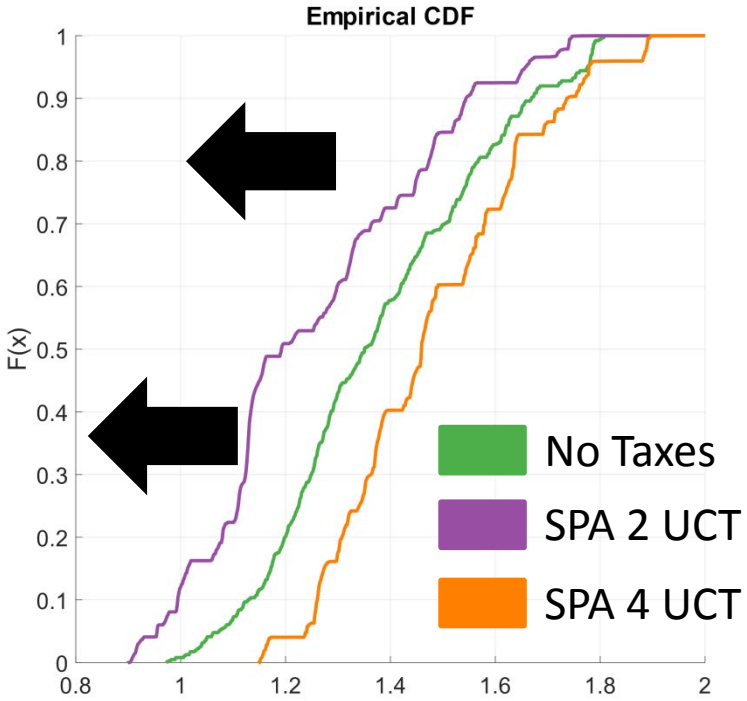

Global Trend Depends on LUC Tax

Increased Water Consumption in North Africa




2100 Agriculture Water use Globally.

# Afforestation vs. Water Outsourcing: Impact of LUC Tax

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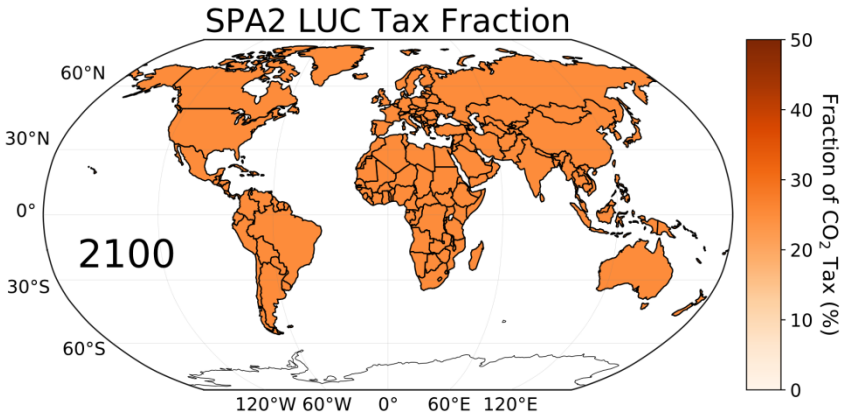
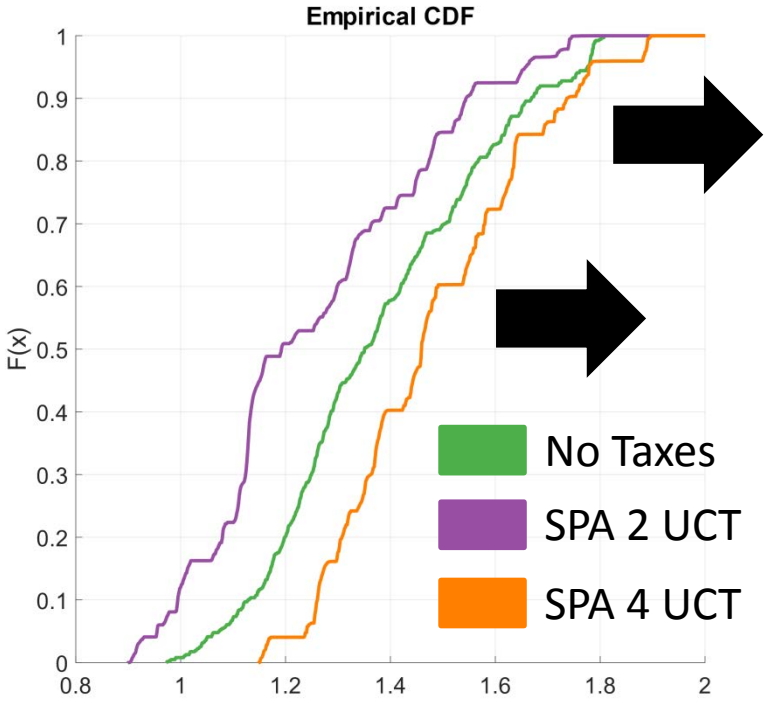



Universal LUC tax raises cost of new agriculture.

Suppresses growth of global ag. water use.

# Afforestation vs. Water Outsourcing: Impact of LUC Tax

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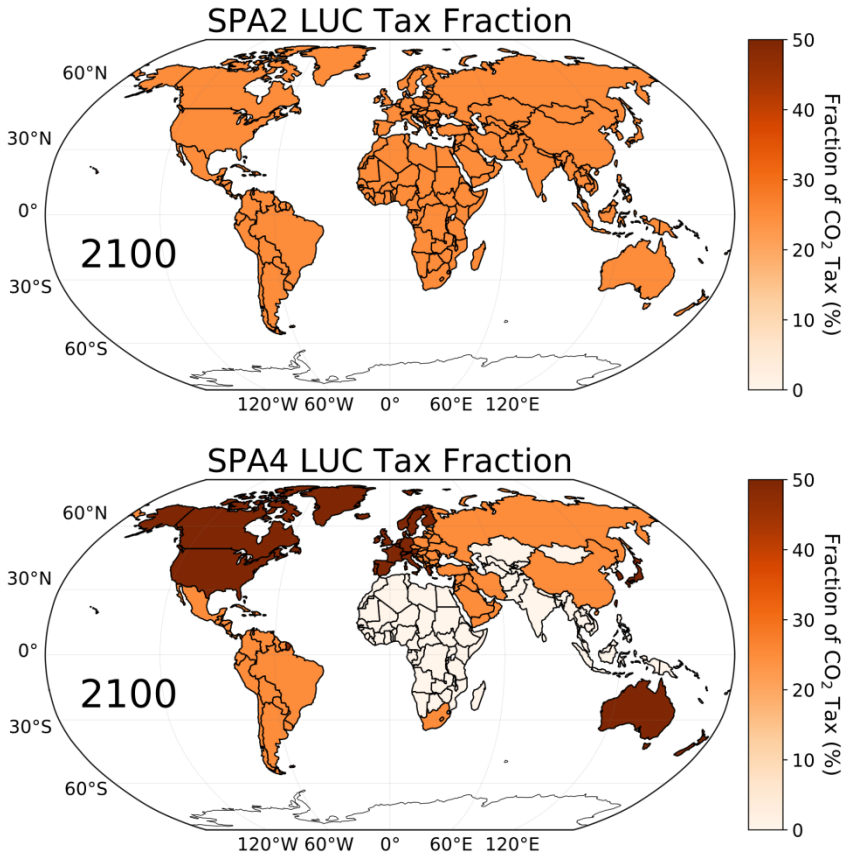
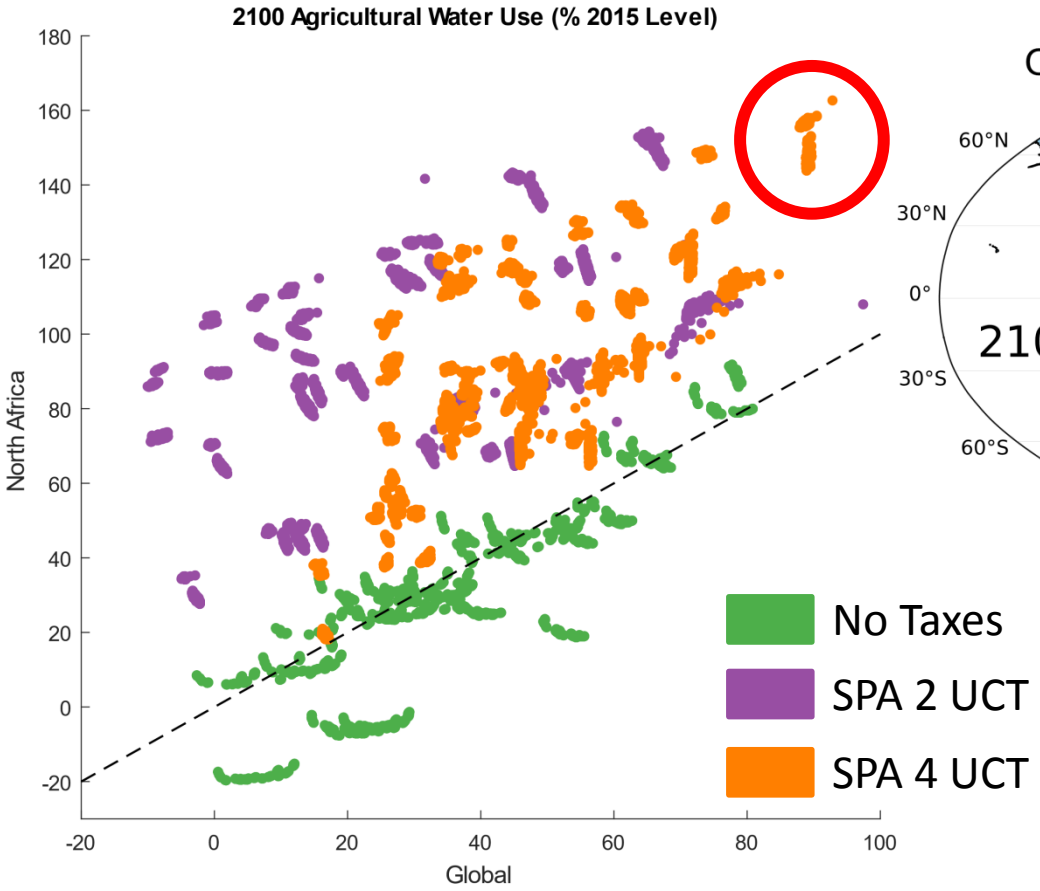
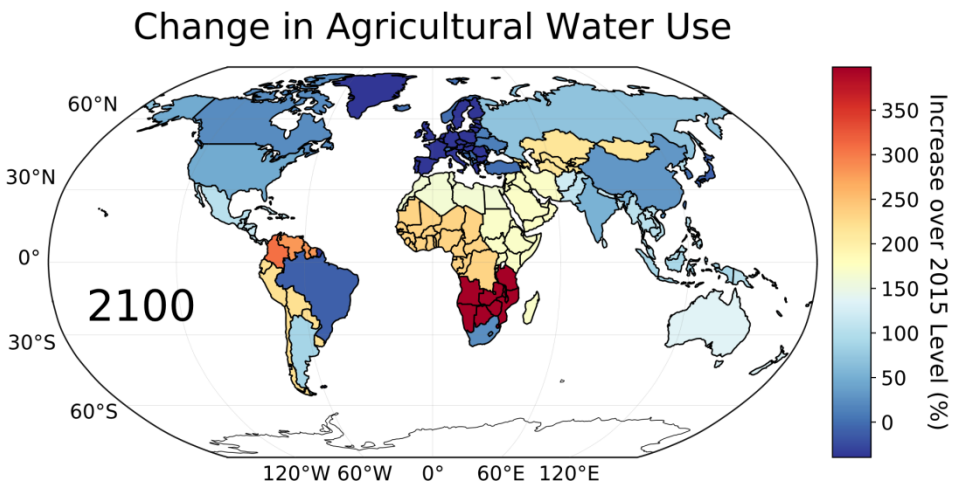



Increased LUC tax raises cost of new ag. in OECD.

Concentrates new ag. in developing world, uses water.

# LUC Emissions Tax Regime water use impacts: North Africa vs. Global



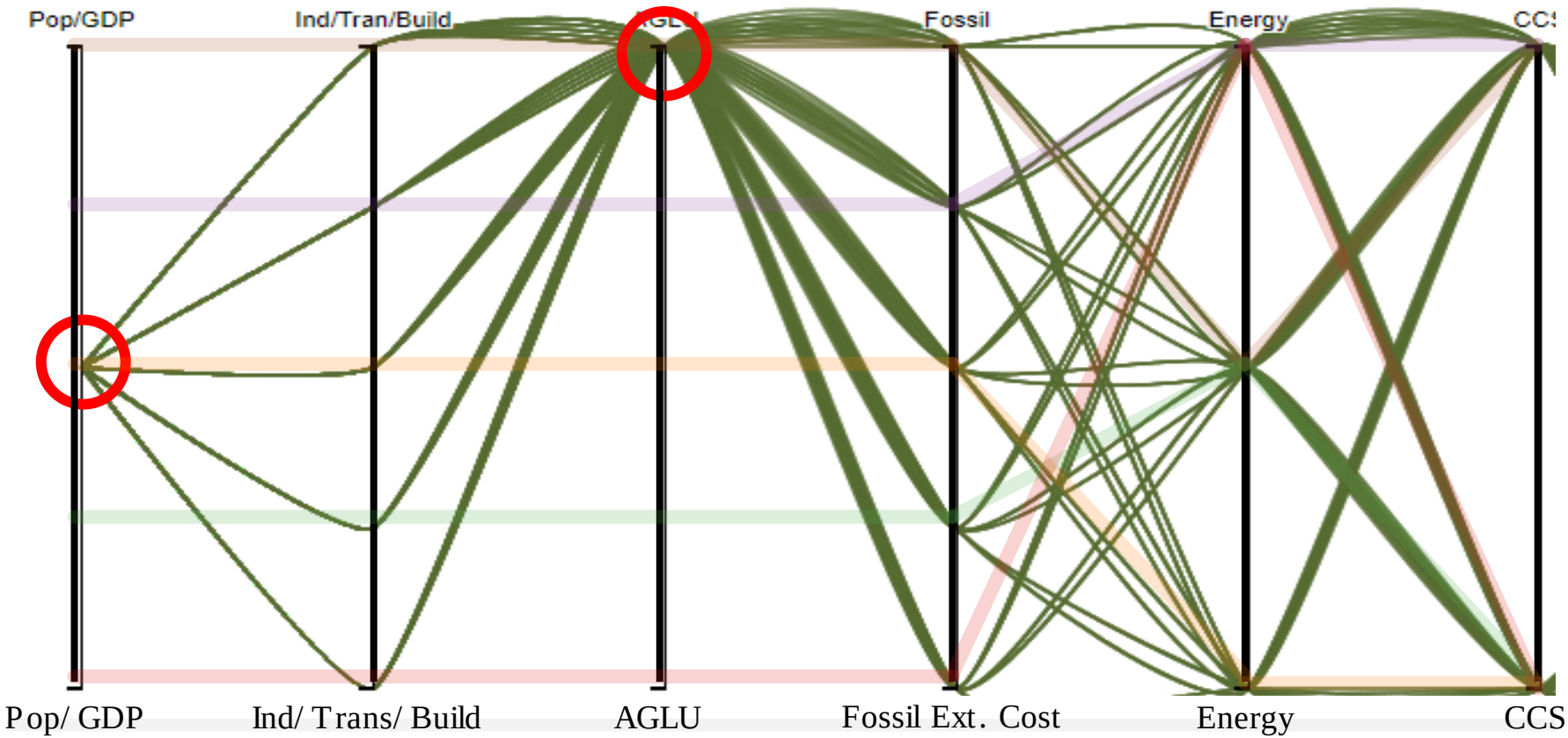




Majority of growth in water use focused in developing world.

High Global & North Africa water consumption:

**Water Intense Worlds**

# Water Intense Worlds:
# High Global & North Africa Water Use




These scenarios share:

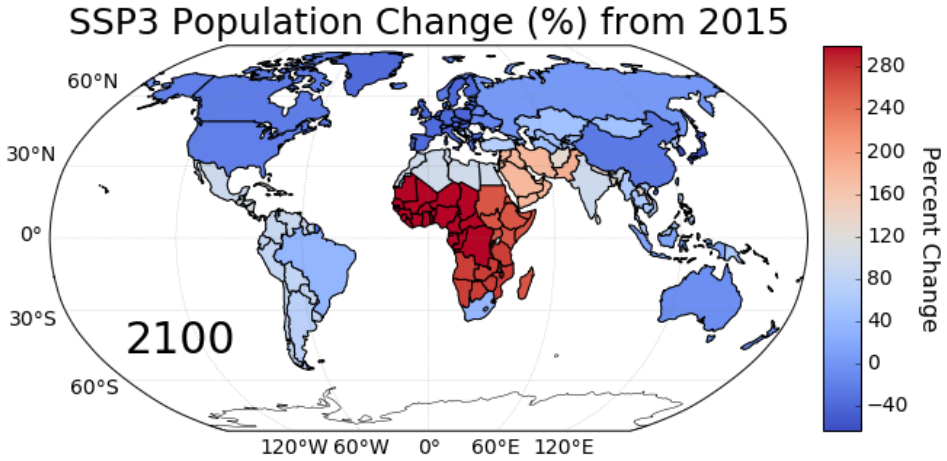
SSP3 Pop/ GDP

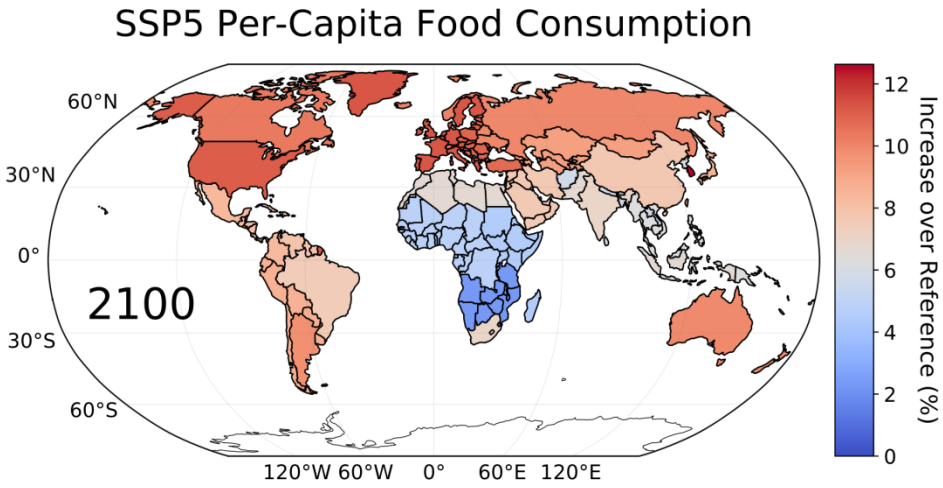
SSP 5 AGLU

SPA 4 LUC Taxes

# Water Intense Worlds
# High Global & North Africa Water Use

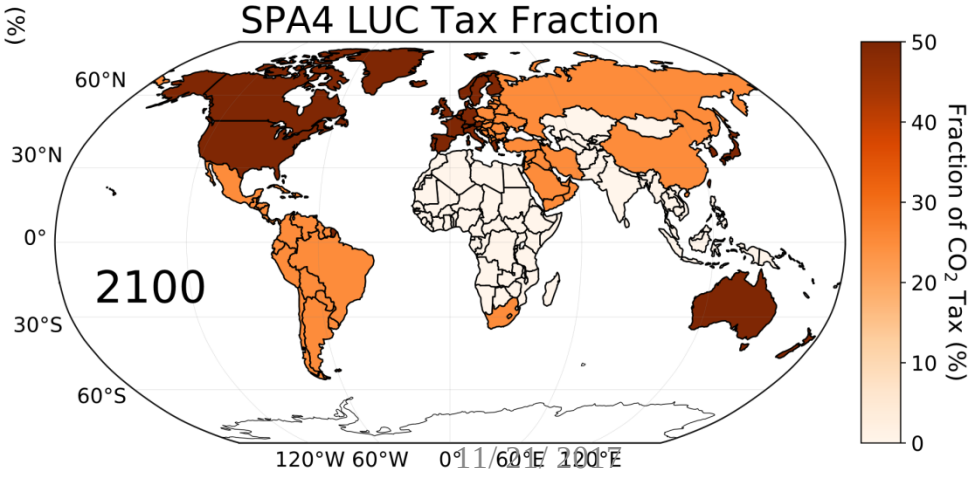
These worlds see huge population growth, particularly in Africa (North Africa 120% increase).



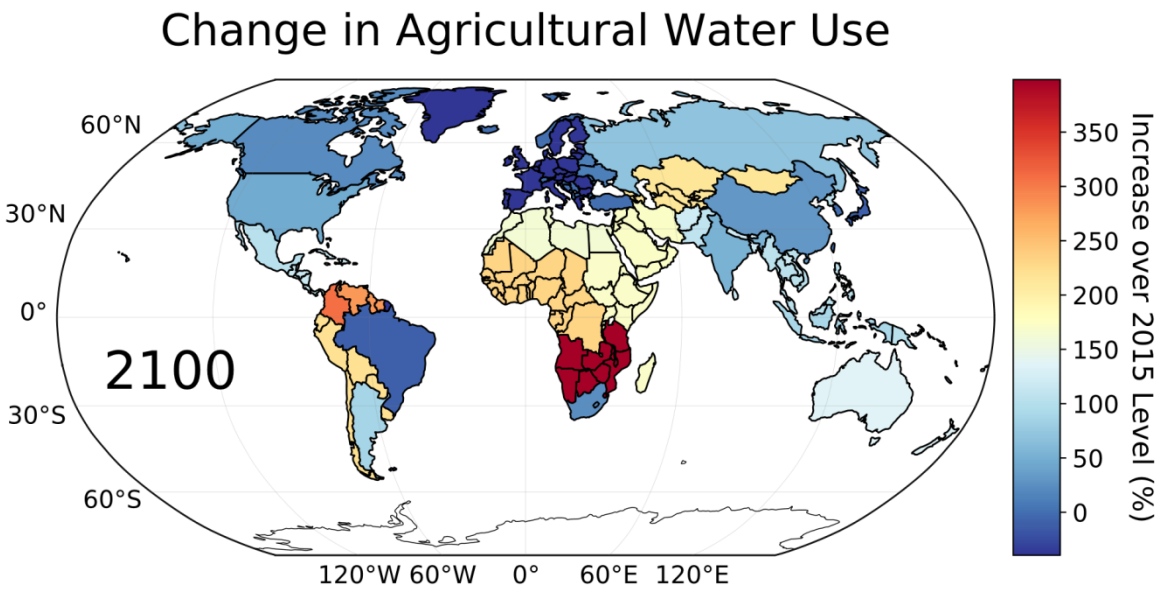




This is accompanied by increased per-capita food and meat demand due to changing preferences.

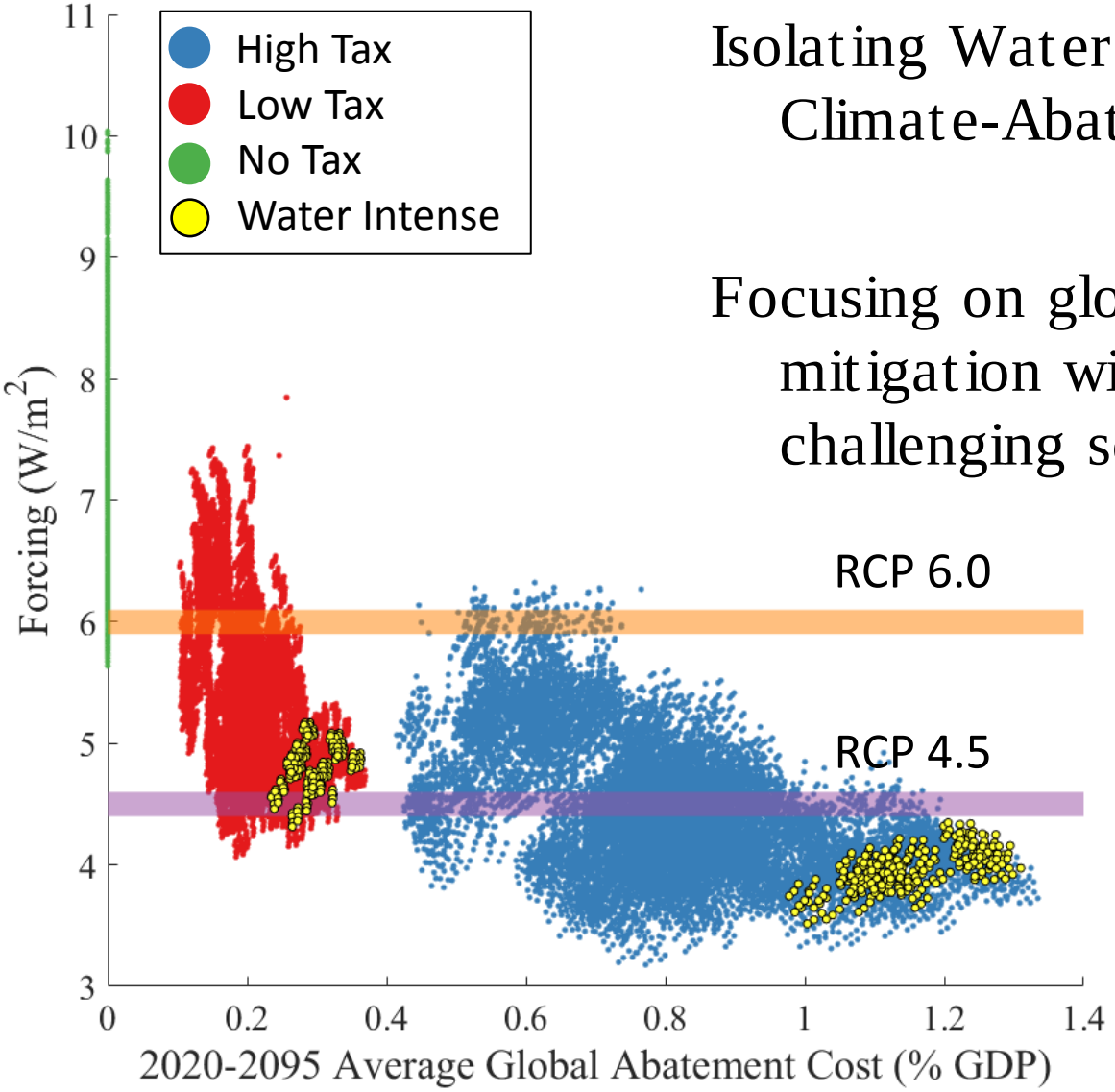
Fragmented LUC tax concentrates new ag. & water use in developing world, where it is not taxed.



Where do water intense worlds reside in the forcing/abatement cost space?



# Mapping Water Intense Worlds in Forcing-Cost Space




Isolating Water Intense worlds in Climate-Abat. Cost space difficult.

Focusing on global costs and mitigation will miss regionally challenging scenarios.

# Conclusions

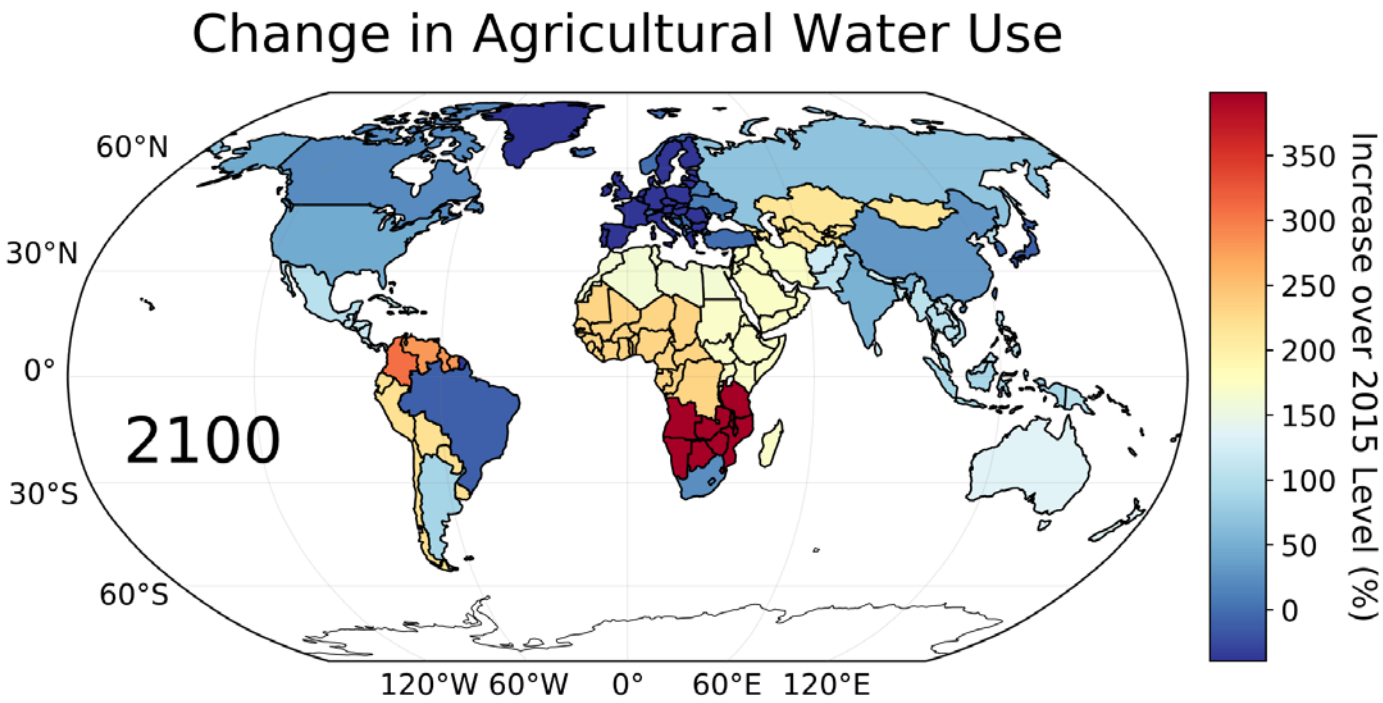
(1) Utilizing a broad ensemble of scenarios and detailed regional metrics, enables the tailoring of assessments to better discover consequential scenarios of interest.

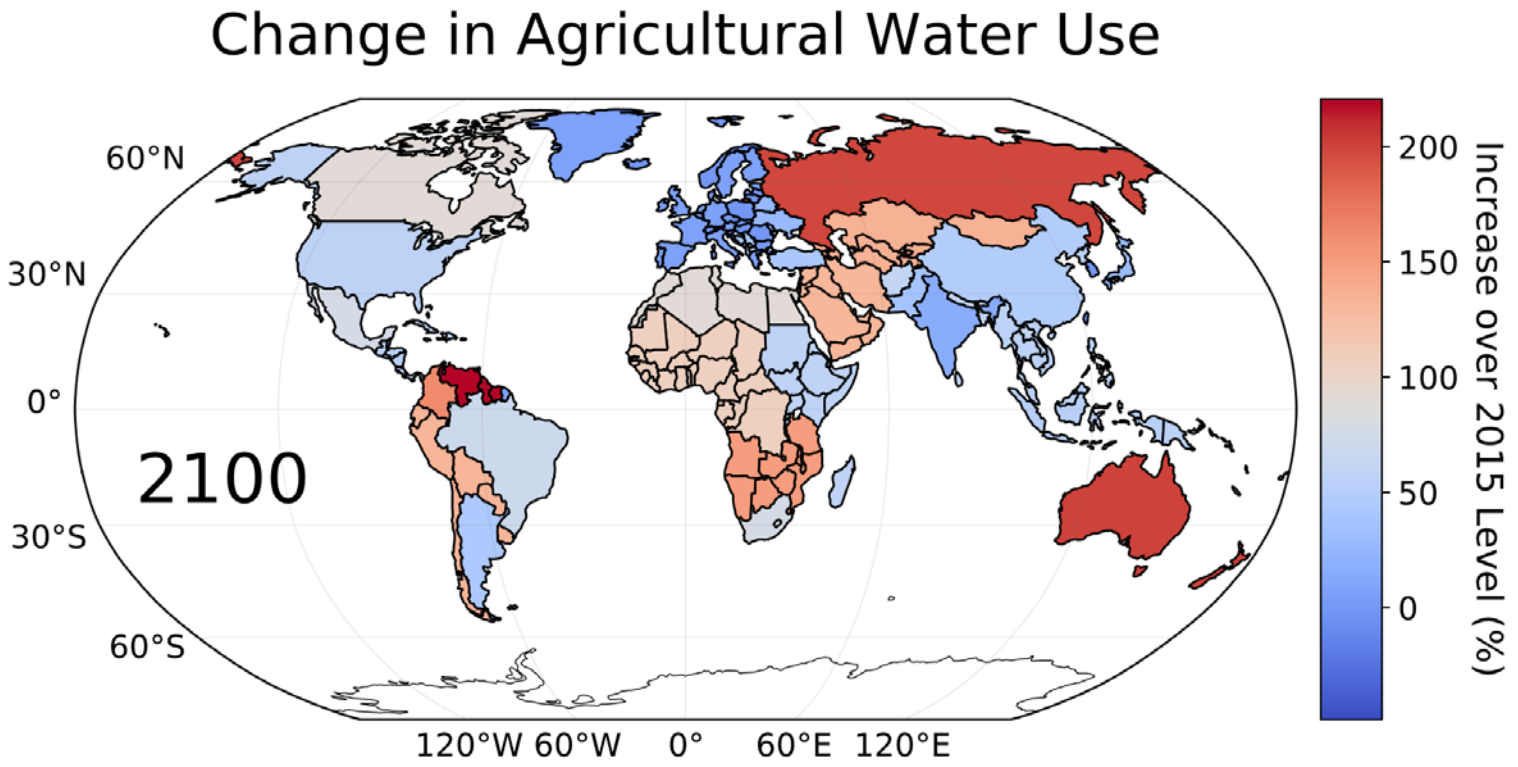
(2) Agricultural development (specifically LUC change) in Africa exerts significant controls over future global-scale mitigation & adaptation challenges

(3) Reducing MENA region poverty, aiding multi-sector technological innovations/ efficiencies and advancing agriculture are all low regret actions across climate futures.

(4) Policy goals for climate futures must consider a diverse ensemble of multi-sector, multi-scale scenarios.

# Questions?

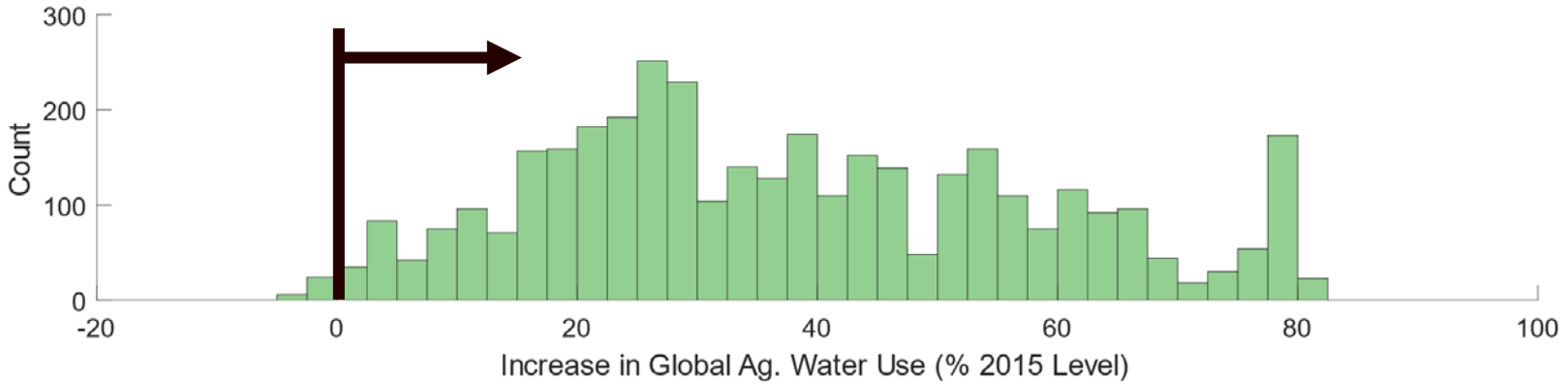

Change in Agricultural Water Use
60°N
30°N
0°
30°S
60°S
2100
120°W 60°W 0° 60°E 120°E
350
300
250
200
150
100
50
0
Increase over 2015 Level (%)




Significant heterogeneity in regional water use, most new water use in generally focused in developing countries.

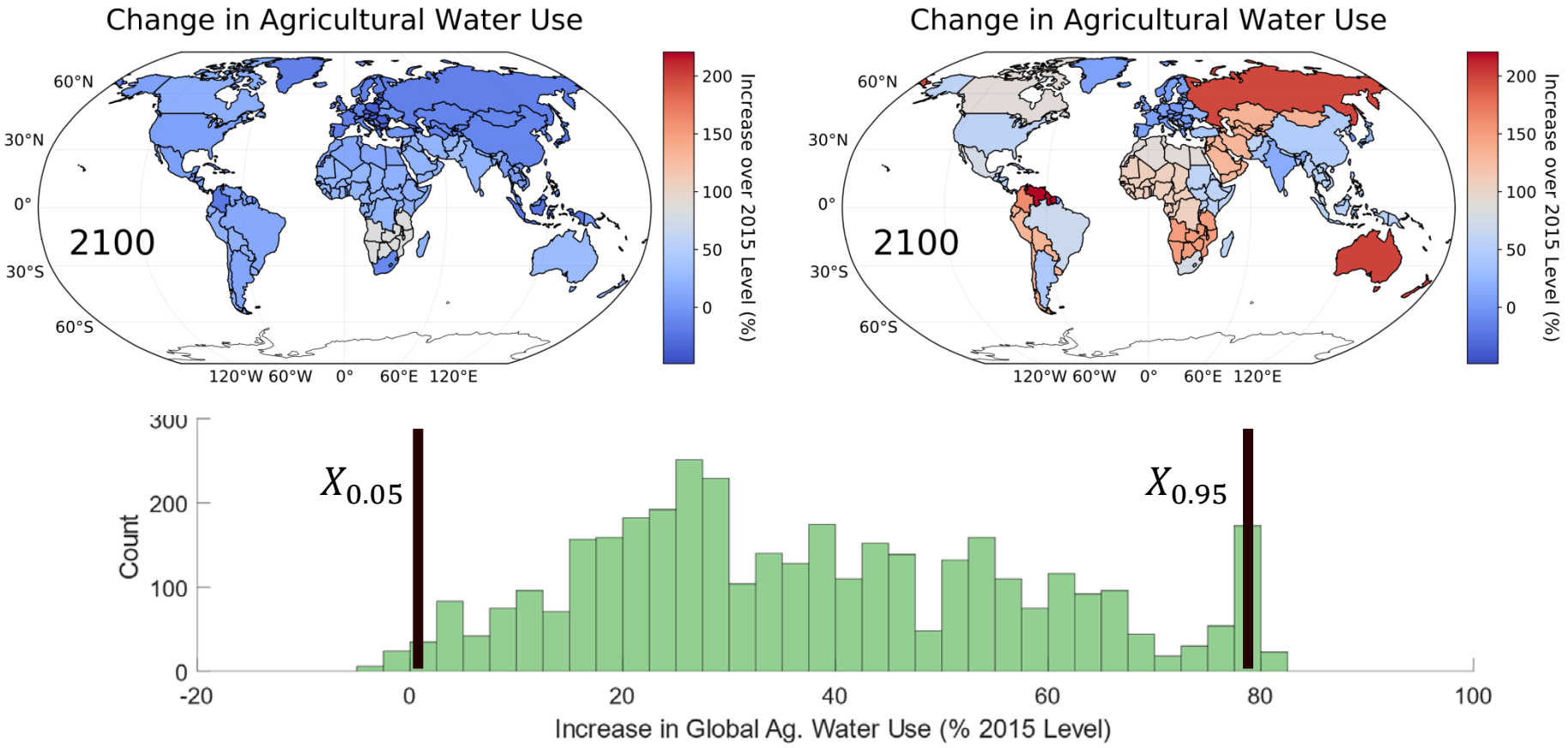
How does North Africa compare to global trends?

# Agricultural water use with no abatement regime




Without abatement regime, most scenarios show increasing water use for agriculture.

# How does regional water use change with increased global water use?

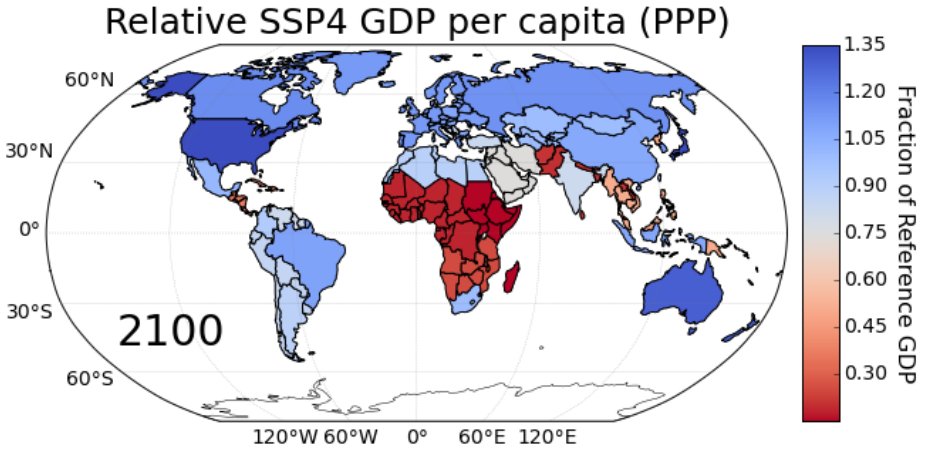


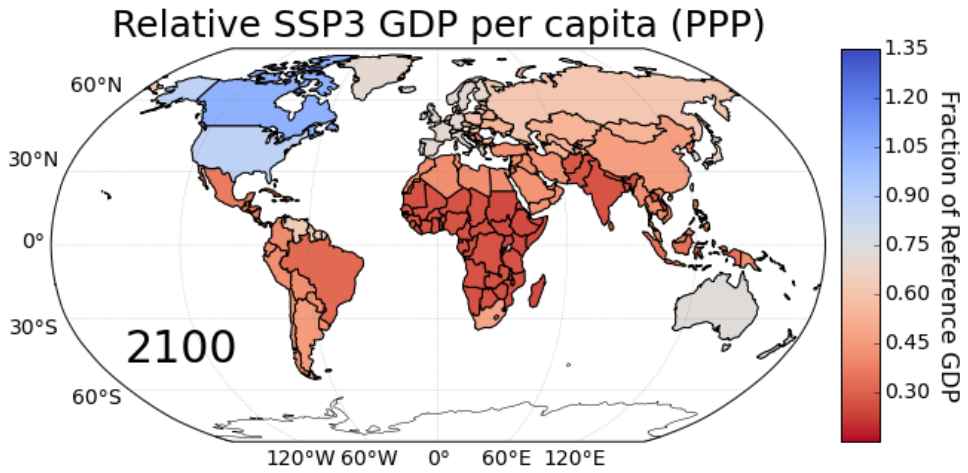

Increased global water use concentrated in Africa, Middle East, and former-USSR.

How does North Africa compare to global water use trends?


Low $CO_2$ Price
High $CO_2$ Price
No $CO_2$ Price
Narrative 1:
Low Short-Term Price Frag.
Low LUC Emissions Price Frag.
Narrative 2:
Low Short-Term Price Frag.
High LUC Emissions Price Frag.
Narrative 3:
High Short-Term Price Frag.
Low LUC Emissions Price Frag.
Narrative 4:
High Short-Term Price Frag.
High LUC Emissions Price Frag.
1
2
3
4
5
6
7
8
9

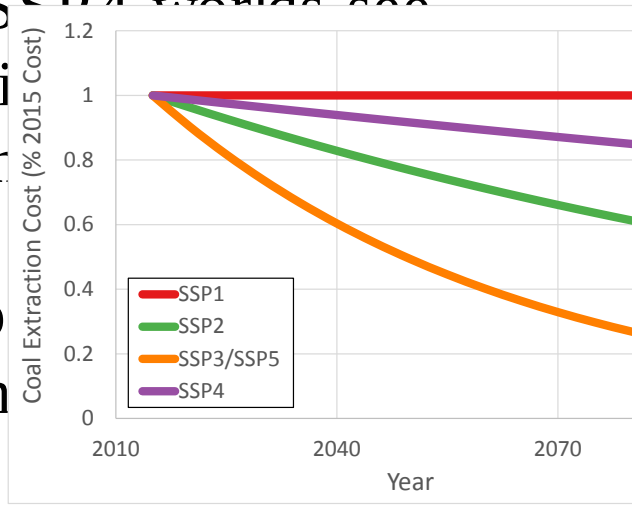
# No tax RCP 6.0 worlds:
# Relatively little warming with no tax applied




SSP3 and SSP4 worlds see growing i… growth ir…

Sustained p… developin… consume… emissions.




When paired with expensive fossil fuels, relatively little warming with No Tax.