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# Extreme Events, Agriculture, and Integrated Assessment

KATE CALVIN

Snowmass 2015

August 23, 2015

PNNL-SA-111683

# Outline

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- Why model extreme events & agriculture in an IAM?
- How do you model extreme events & agriculture in an IAM?
- What are the challenges, gaps, and areas for further research?

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# Why model extreme events & agriculture in an IAM?

# Integrated Assessment Model (IAM)

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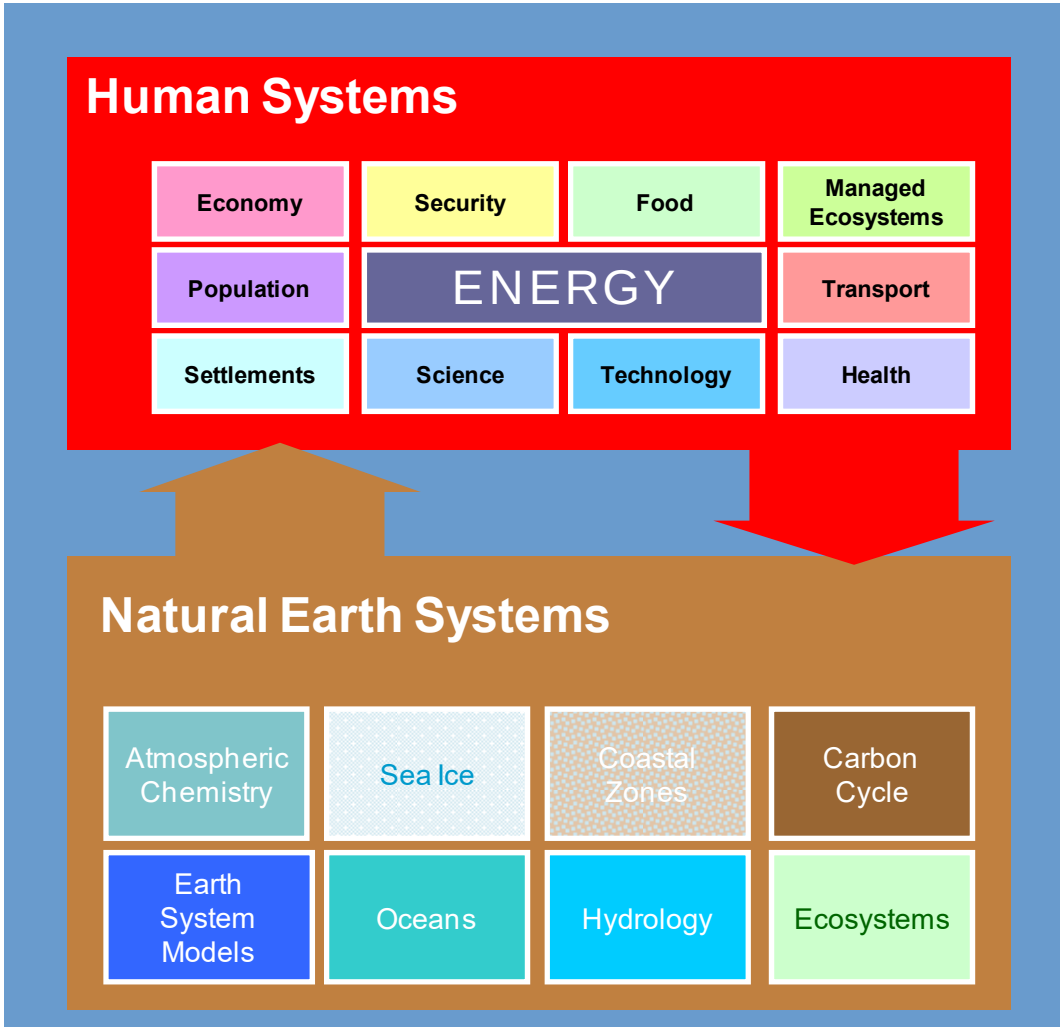
## IAMs integrate human and natural Earth system climate science.

- IAMs provide insights that would be otherwise unavailable from disciplinary research.
- IAMs capture interactions between complex and highly nonlinear systems.
- IAMs provide natural science researchers with information about human systems such as GHG emissions, land use and land cover.

## IAMs allow for global drivers to be represented in regional and national scale outcomes!

- IAMs support national, international, regional, and private-sector decisions.




Janetos et al. (2009)

# The inclusion of an impact in an IAM is important if…

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- You expect feedbacks from one sector to another
- You expect feedbacks between regions
- You expect the effect to be important for emissions, climate, or mitigation

# The inclusion of an impact in an IAM is important if…

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- You expect feedbacks from one sector to another
  - Agricultural production has implications for energy (via bioenergy), water (and thus other human systems), livestock, the economy
- You expect feedbacks between regions
  - Agriculture is widely traded, so a shortage could put pressures on production, prices, or consumption in other regions.
- You expect the effect to be important for emissions, climate, or mitigation
  - To the extent the effect feeds back onto energy, you could see changes in energy-related emissions (e.g., increase in $CH_4/CO_2$ from natural gas power). There may also be changes in AFOLU emissions either due to effects on carbon storage or due to adaptation responses.

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# How do you model extreme events & agriculture in an IAM?

# Modeling approach…



- For most IAMs, productivity is an input on some level.
  - For some models, adaptation (e.g., changes in fertilizer or water) measures are included either through functions (e.g., GTAP, IGSM) or different technological options (e.g., GCAM). In those cases, yield in a given region is endogenous, but the productivity of land is often still an input.
  - Including extreme events in these models requires modifying the productivity input to reflect the extreme event.

- There are some exceptions (e.g., IMAGE, iESM).
  - In these cases, productivity is dynamic as the IAM is linked to a process-based model.
  - Including extreme events in these models requires ensuring that the embedded crop model (or other representation) can respond appropriately to extreme events.

# Modeling an Extreme Event in GCAM

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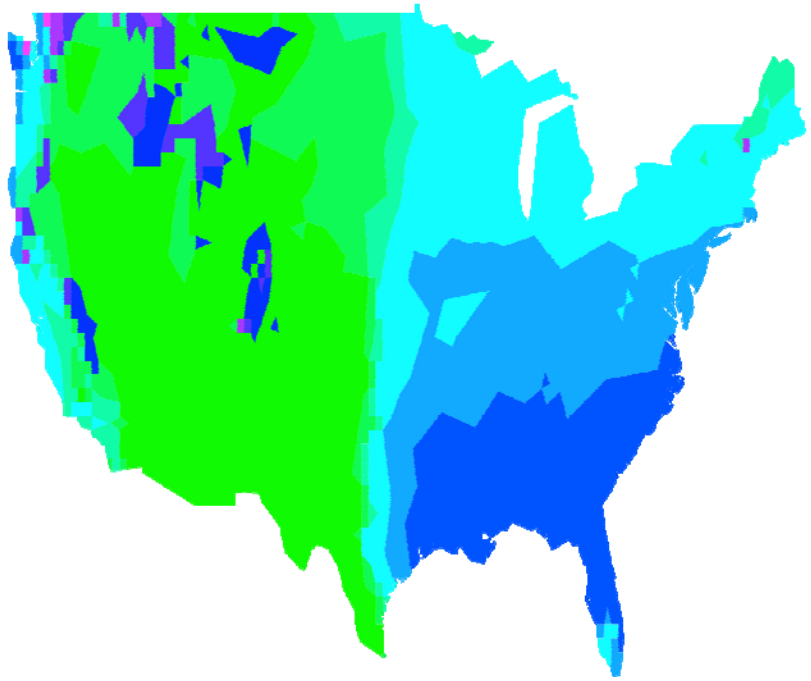
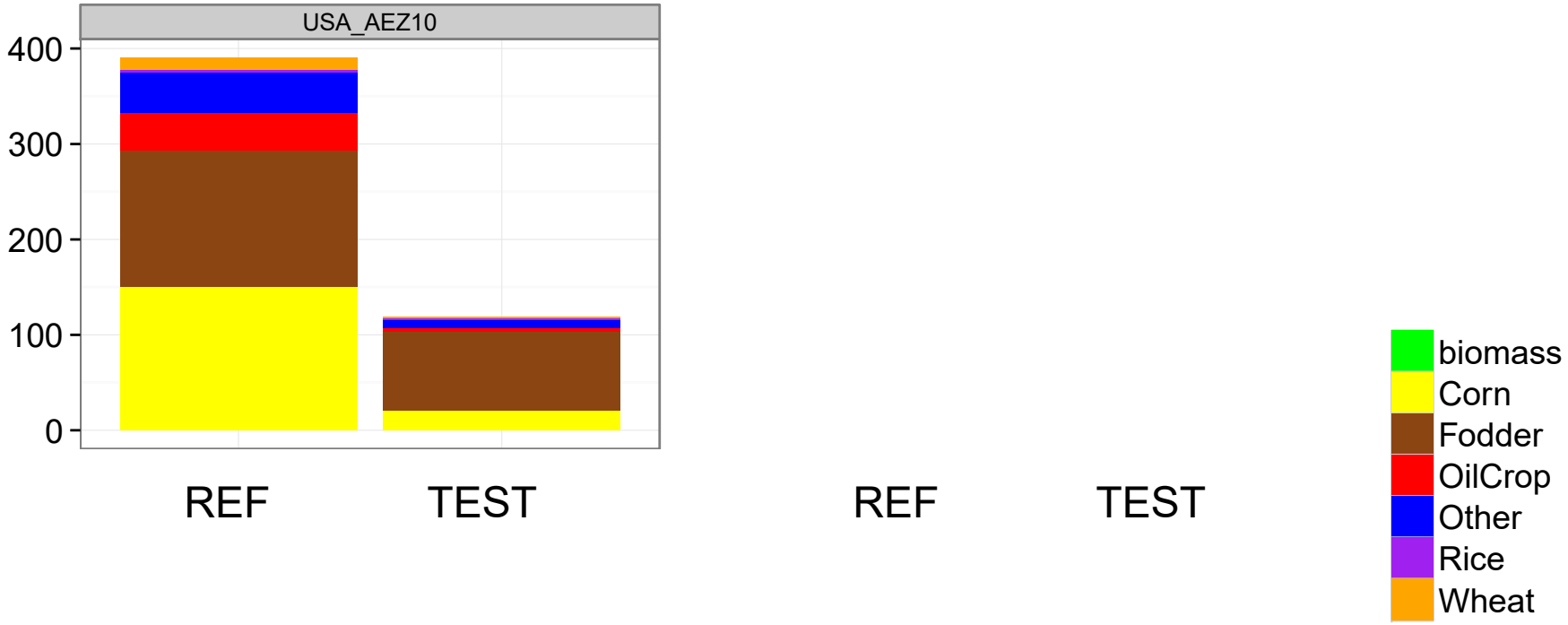
- The scenario:
  - Something happens (e.g., severe drought, abundance of pests, the apocalypse) that leads to a 50% decline in yield for all crops in AEZ10 of the United States in 2020.
- The question:
  - What are the implications of such an event on agricultural production, agricultural consumption, land use, energy, and emissions both in the United States and globally?
  - Do those responses make sense?



AEZ10 = Turquoise Region

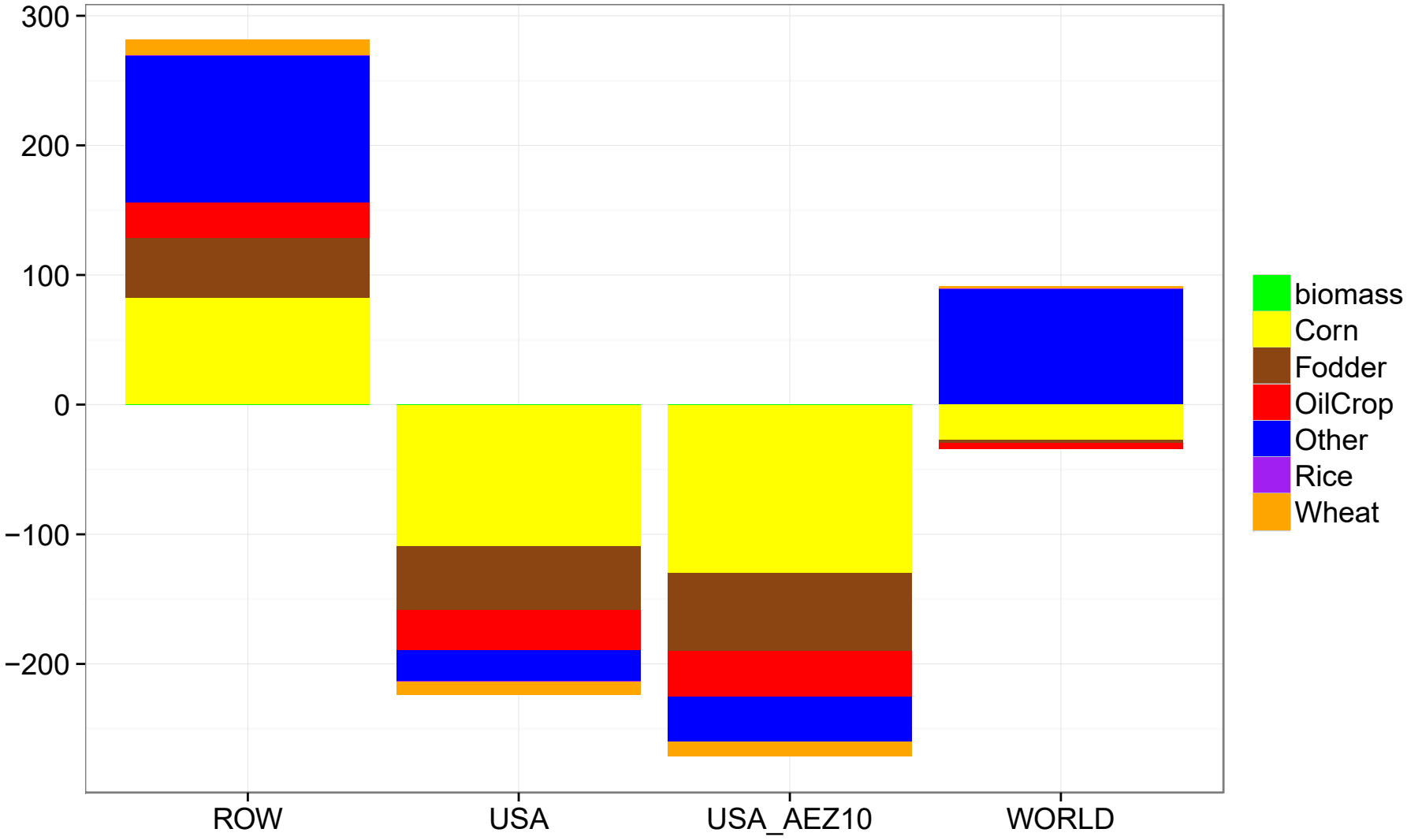
# Agricultural Production






The ROW (and to a lesser extent the rest of the USA) compensate for declines in production. As a result, global production is almost unchanged. This is probably unrealistic.

# Difference in Agricultural Production



# Food Consumption

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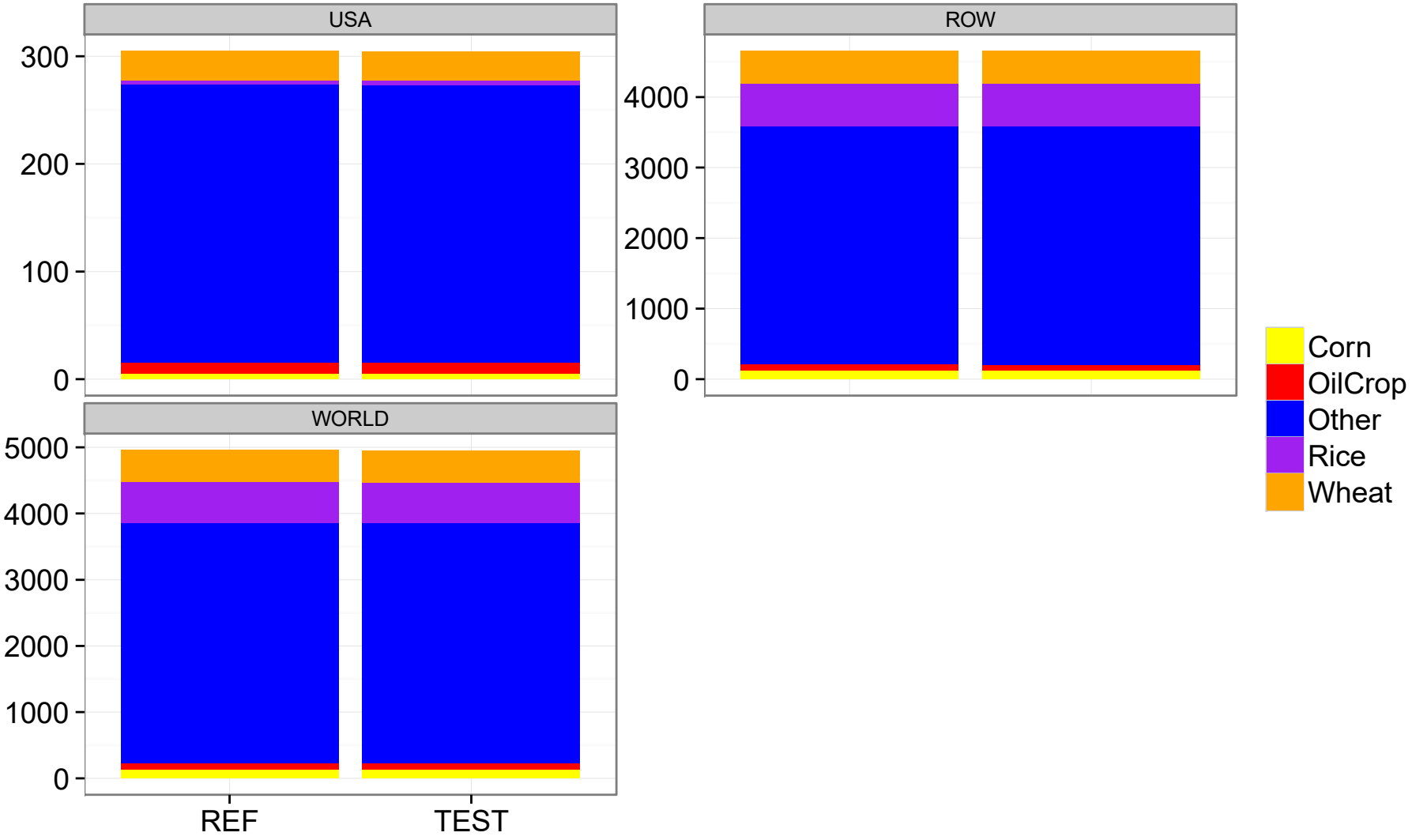
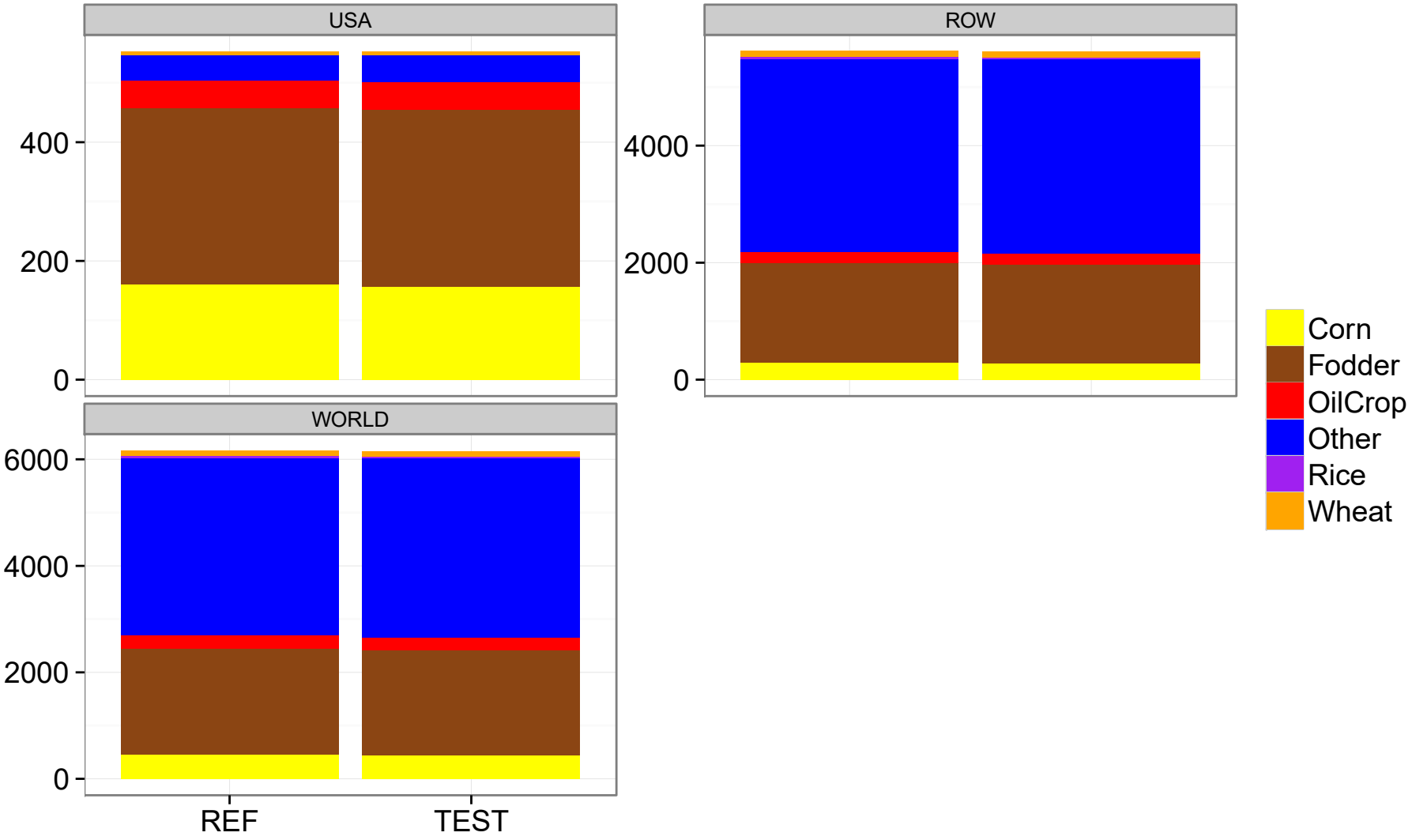



Food consumption is fairly unresponsive to the event, mostly because the event has little effect on production & prices, but partly because GCAM doesn't allow much change in food consumption.

# Feed Consumption





# Difference in Feed

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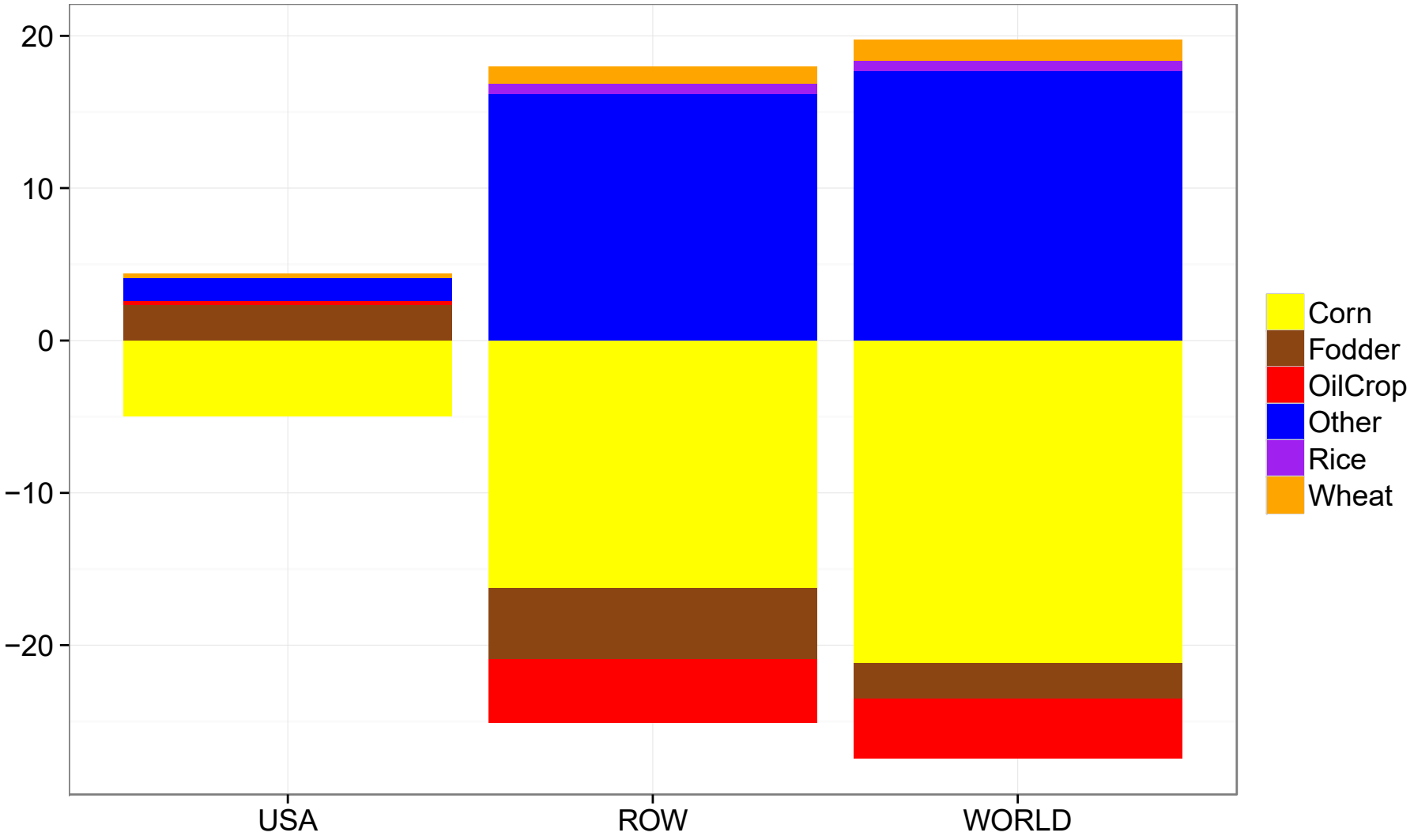
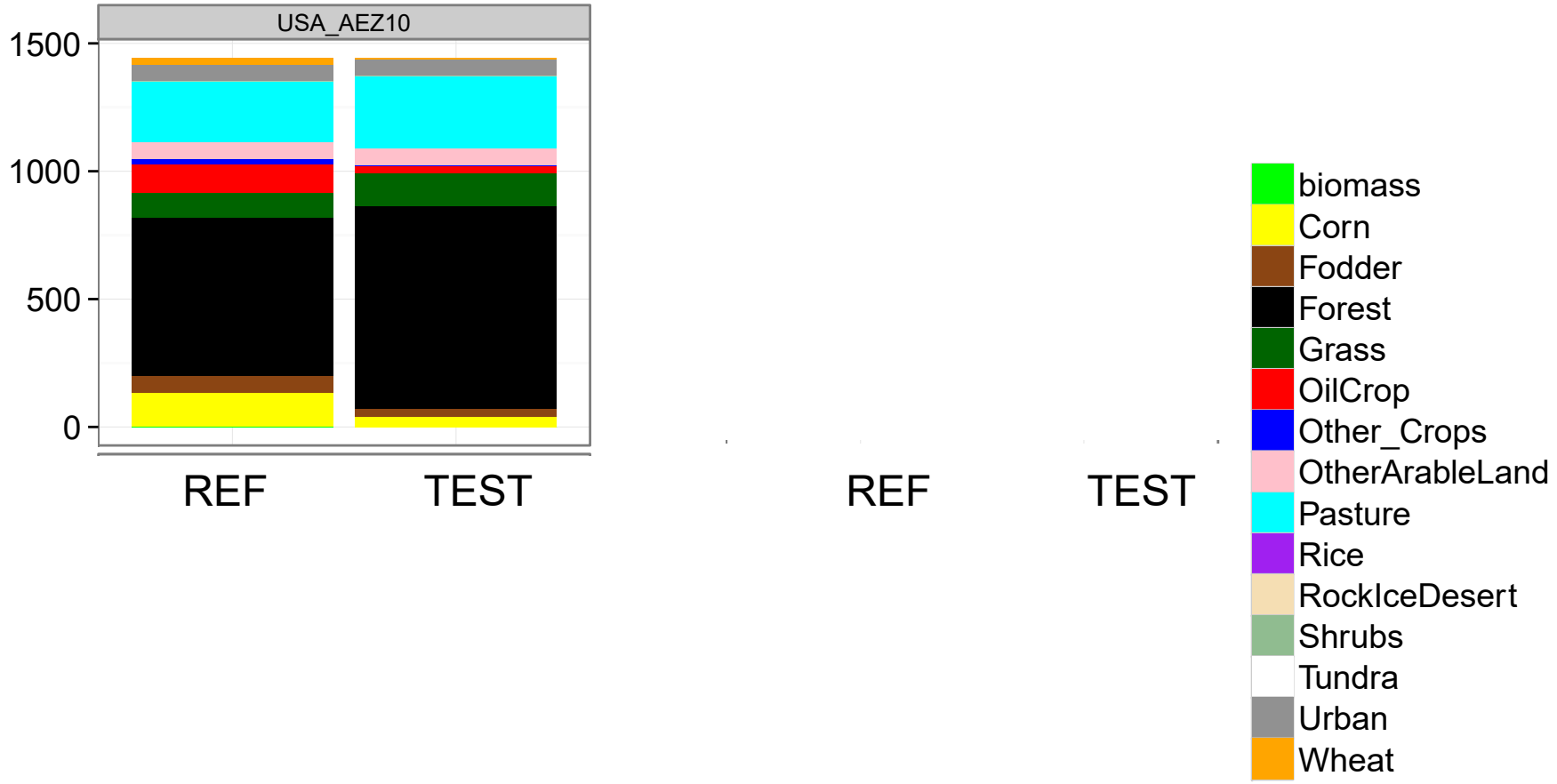



Similarly, we get very small changes in feed, shifting away from the commodity that was most impacted (Corn). But, these changes are very small due to only small changes in price.

# Land Cover




USA_AEZ10
1500
1000
500
0
REF
TEST
REF
TEST
biomass
Corn
Fodder
Forest
Grass
OilCrop
Other_Crops
OtherArableLand
Pasture
Rice
RockIceDesert
Shrubs
Tundra
Urban
Wheat

# Difference in Land Cover

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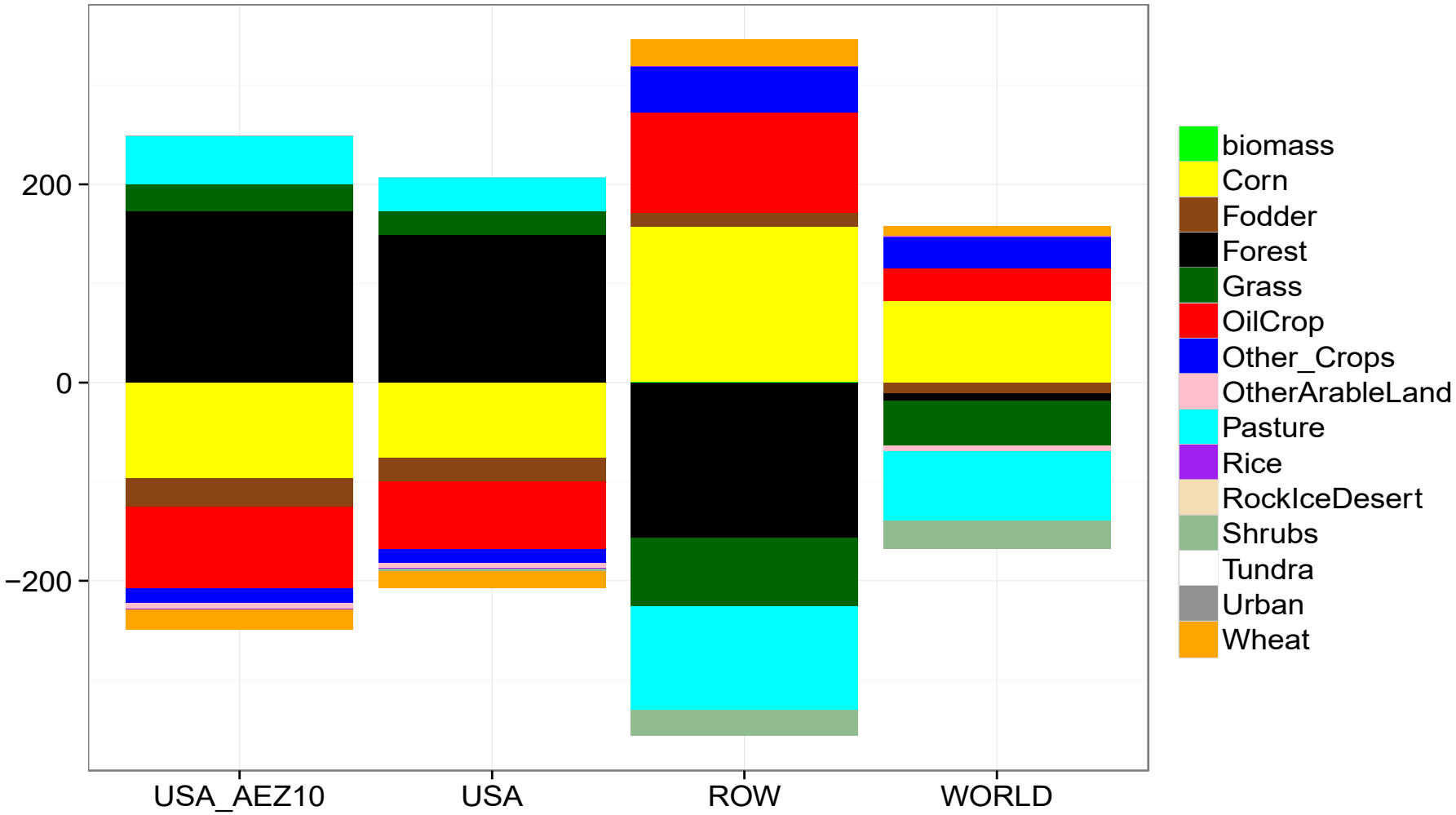


All regions shift land allocation in response to the extreme event, implying that they know about it in advance. I could have prevented this behavior by fixing land to its REF values as done in Diffenbaugh et al (2012), but it would have required multiple model runs in GCAM.

# Energy, Emissions, Climate



- Energy:
  - With extreme event, corn ethanol production in the USA declines by 25%. However, it is pretty small to begin with, so it has a negligible effect on other energy carriers. Similarly, there is a decline in bioelectricity, but it is small (0.1%).
- Emissions:
  - LUC $CO_2$ emissions more triple in the USA (from ~55 MtC to ~190 MtC), but changes outside the USA mean that the global effect is only an increase of ~10%, which is fairly small compared to energy-related $CO_2$.
- Climate:
  - Very, very small change in radiative forcing and temperature (probably not significant)

# What are the challenges, gaps, and areas for future research?

# Challenges, Gaps, and Areas for Future Research



- Spatial resolution:
  - Challenge: IAMs typically model at country to regional scales, while impacts are local.
- Temporal resolution
  - Challenge: IAMs typically model at annual, multi-annual, or decadal time scales, while extreme events can be sub-annual.
- Degree of foresight
  - Challenge: Even recursive-dynamic IAMs may have some degree of intra-temporal optimization, where decision-makers may not have the right information to optimize over.
- Adaptation:
  - Challenge: IAMs may not include all adaptation options and they may not capture frictions associated with adapting.


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THANK YOU!