Measuring Water Use Implications of Biofuel at Different Scale and Decision Framework

World Biofuels Markets

The Water Debate

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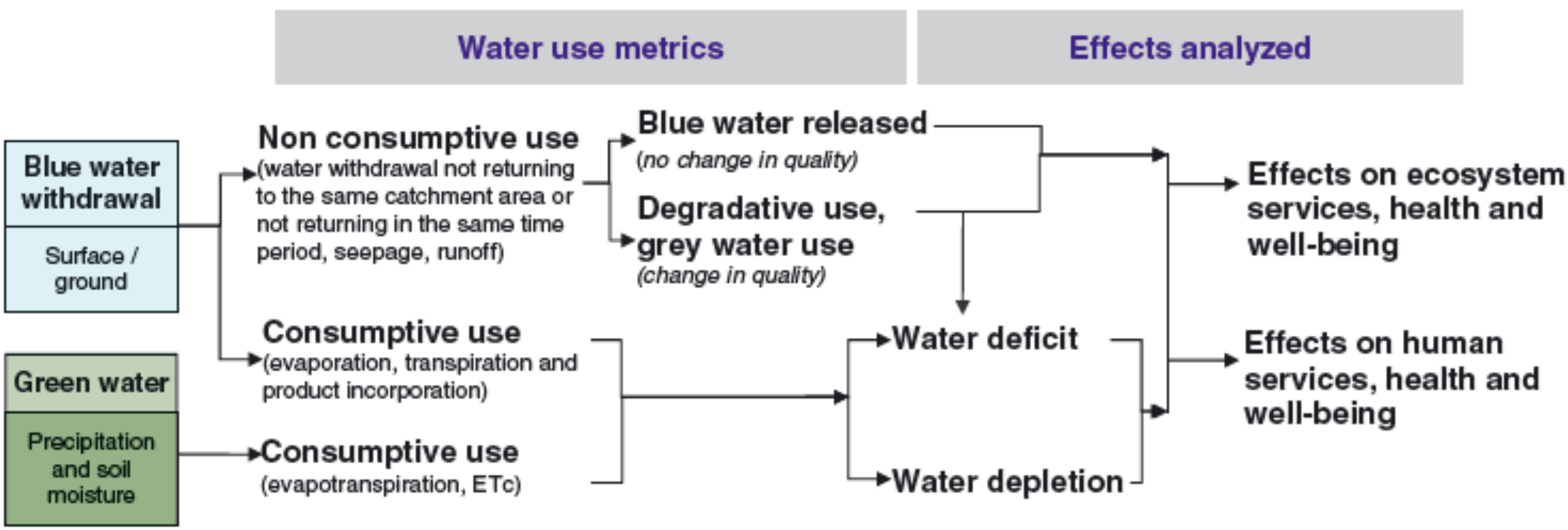
Different types of water use and resulting effects measured by various indicators



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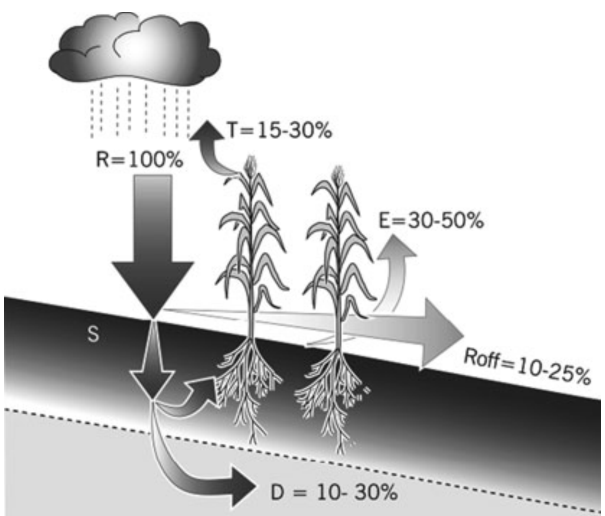
Crop Water Balance / Water Intensity Indicator

- Measure water balances of crop system:
  - Evapotranspiration (ET) water use intensity (L H_2O/MJ fuel)
  - Consumptive (irrigation) water use intensity (L H_2O/MJ fuel)
  - runoff (outflow) and groundwater recharge



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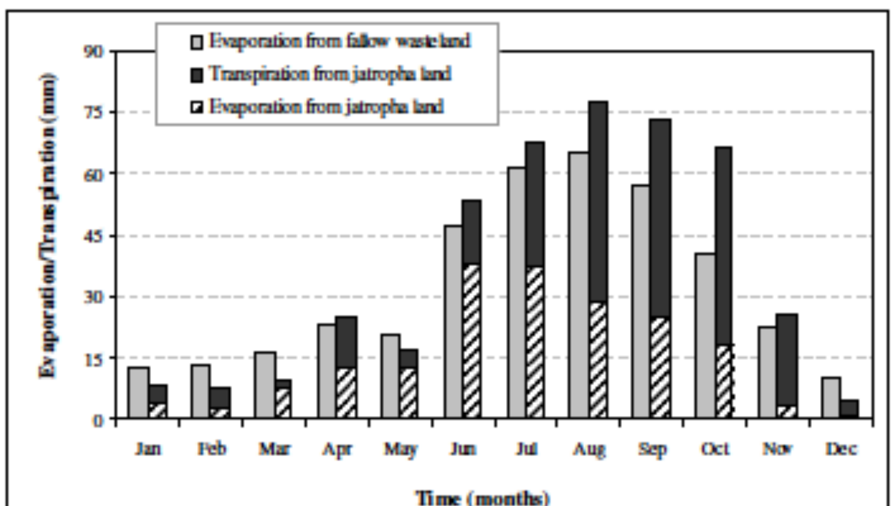
- Factors to consider include:
  - Impact on crop yields and water productivities from crop genomes, optimal fertilizer application, scientific water application, water salt content, etc.
  - Comparison of water intensities of first-generation versus cellulosic / advanced biofuels
  - Impact of climatic changes – increased temperature and CO2 concentrations – on crop yields and water productivities

Dedicated Energy Crops

- Some biofuel plantations have the potential to rehabilitate degraded land and wastelands by:
  - shifting *non-beneficial* E loss in fallow land to *productive* ET_a for plant growth,
  - storing more moisture in soil (& sequestering more soil carbon),
  - protecting land from soil erosion and nutrient losses

  (reducing the frequency and likelihood of extreme runoff/flooding).
- These indicators provide a much more accurate depiction of the *changes* in water use & the actual water use impacts at the local level.
- Measure against previous land-use, against a counterfactual, and/or among policy scenarios



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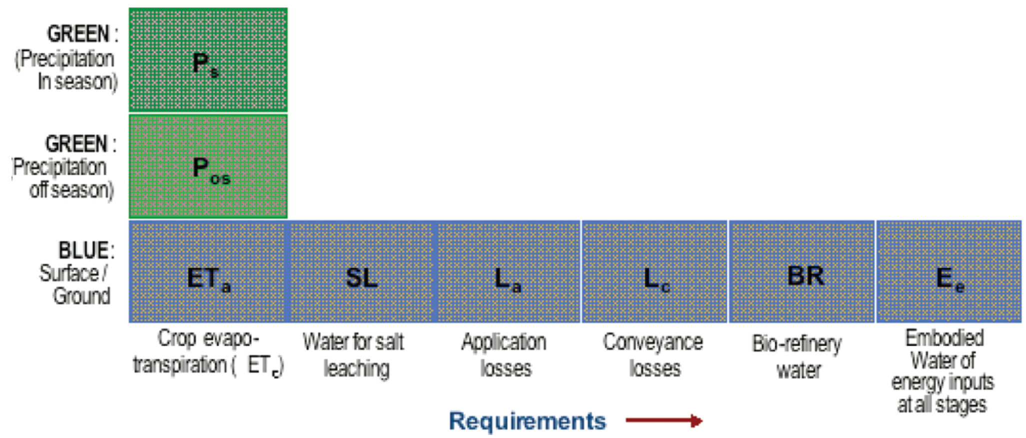
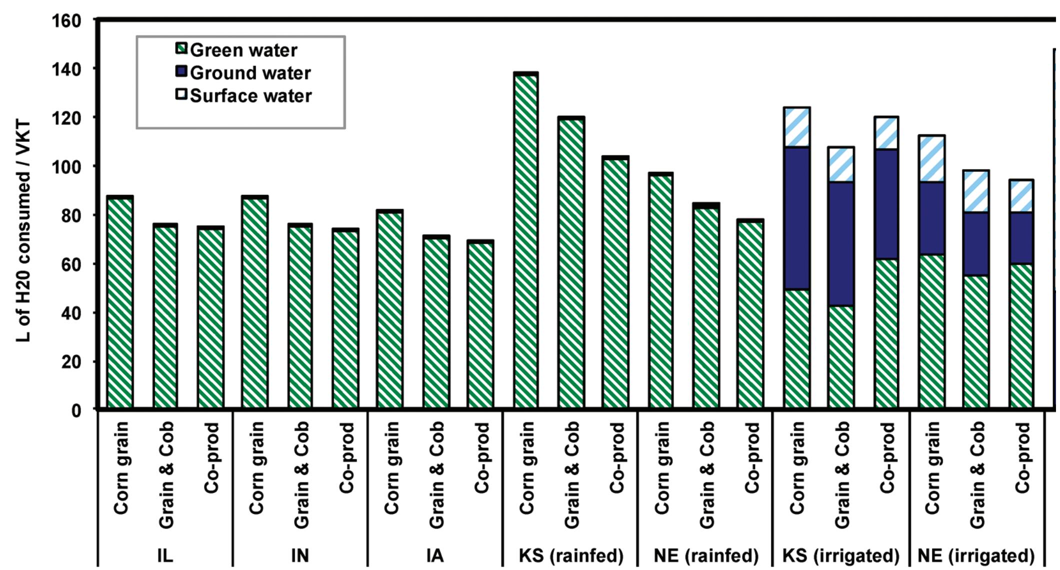
ITS

Lifecycle Analysis of Water intensity

1. Blue versus green water requirement?
2. Water withdrawal versus water consumption – how much water is used vs. returned to the source.
3. Variability of water intensities across regions due to factors such as weather, soil, management practices, and other variables.
4. Sensitivity to co-product allocation.

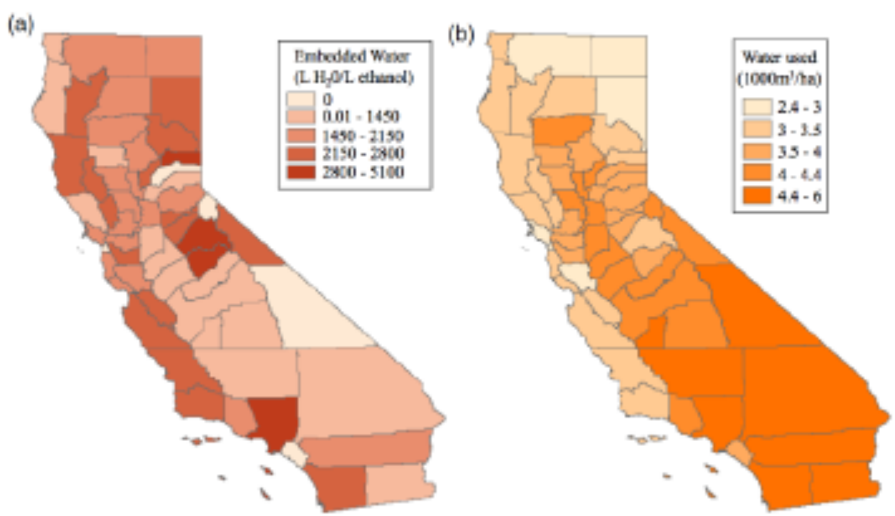




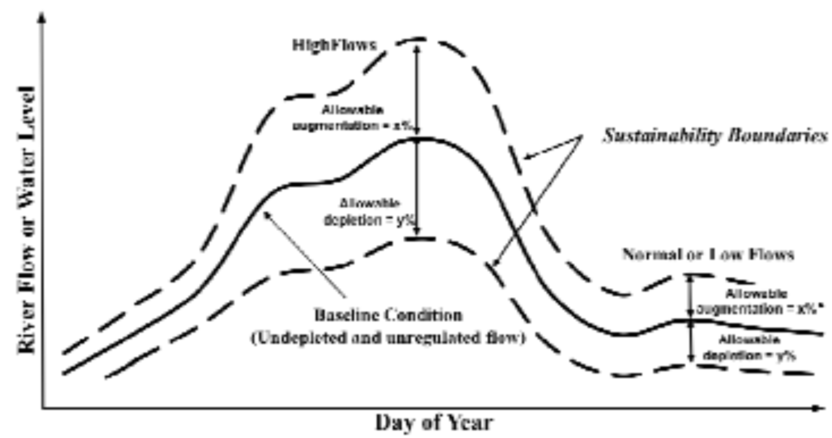
Mishra and Yeh. 2011

Hydrological Basin

- What are the effects on competing demands for water use?

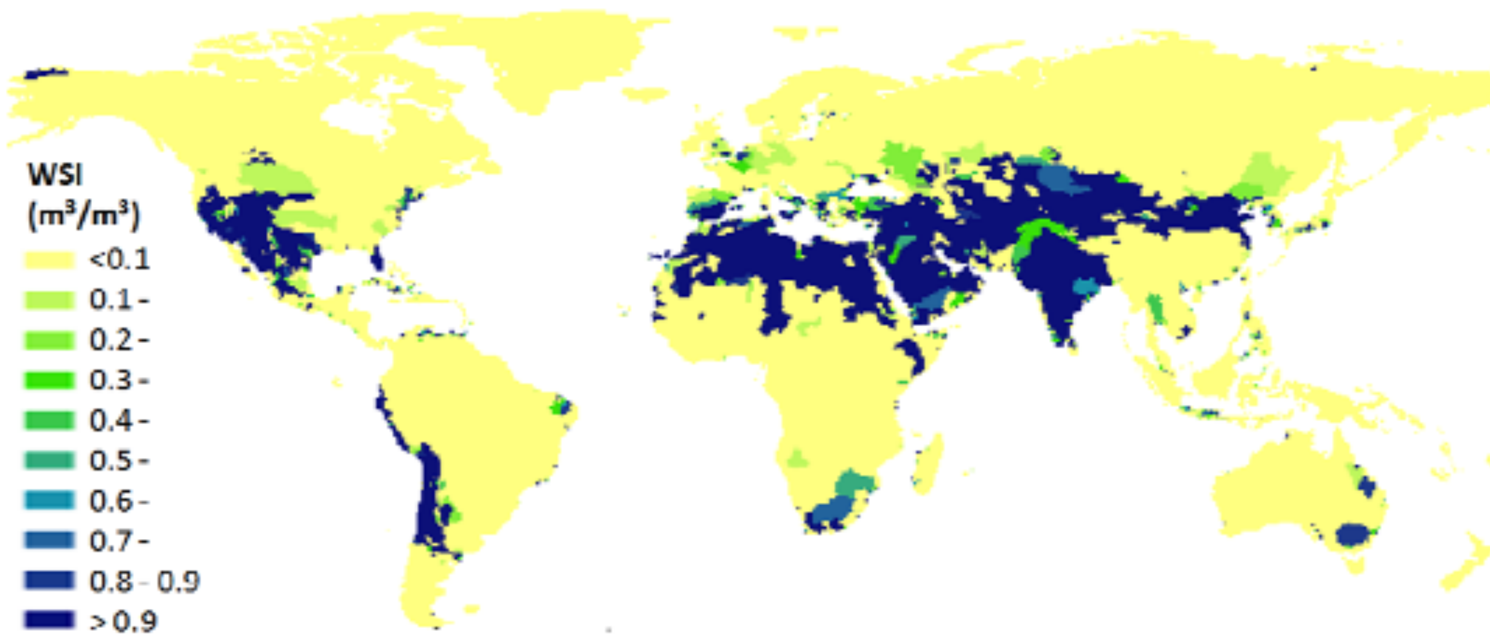


- What are the effects on hydrological water balances, eco-services, and human health, and the environment?



UNEP. 2011. The Bioenergy and Water Nexus. Paris: United Nations Environment Programme.

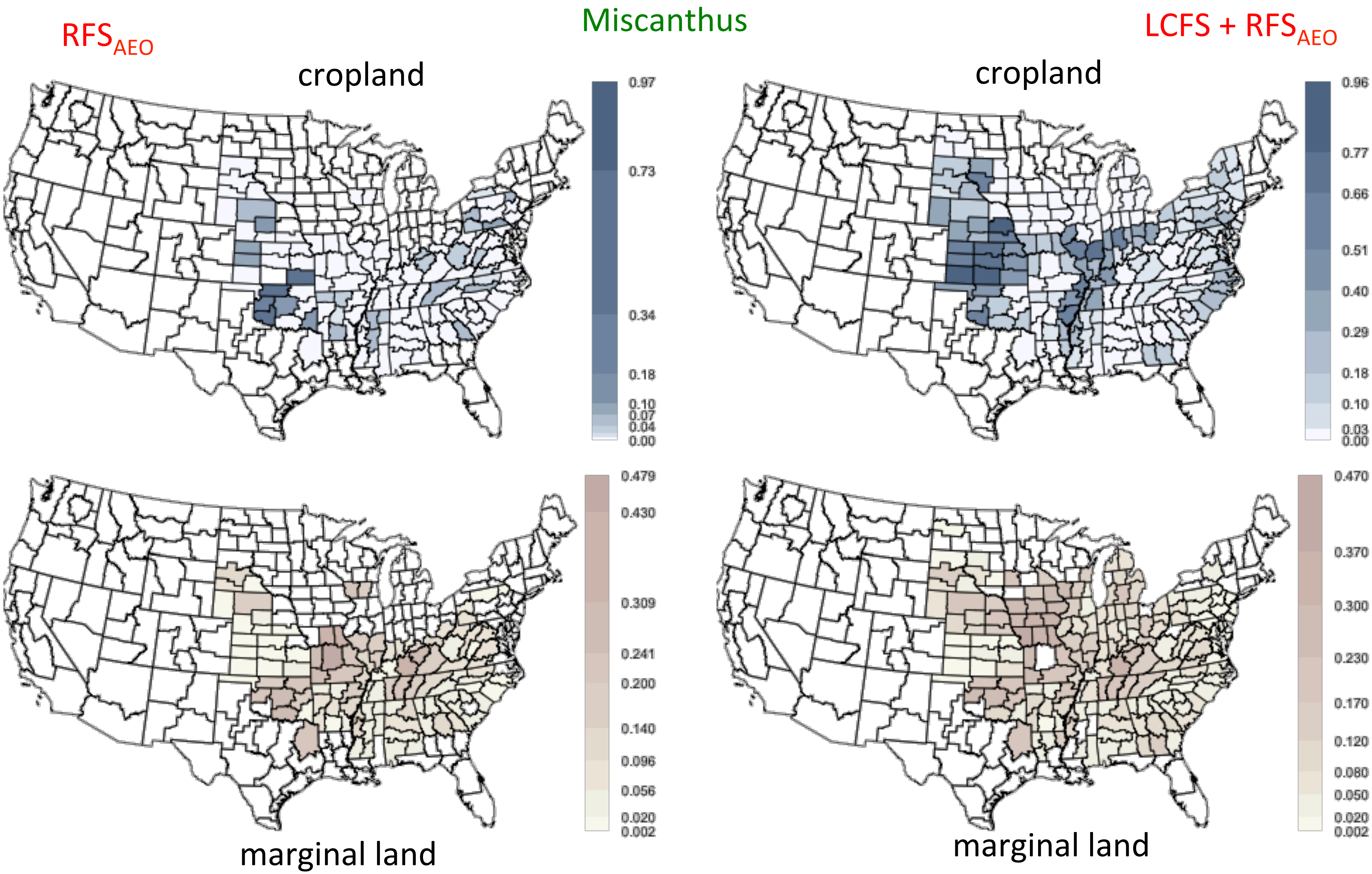
- What are the land use change patterns and resulting changes in water use at global scale?
- What's the impact on water accessibility and water availability, human health and environment?
- What's the effect on global water scarcity index (WSI)?



Water Use Impacts of Biofuel Policy

- What are the land use impacts of biofuel policies?
  - **Counterfactual (REF):** no government policies incentivizing biofuels
  - **RFS_{AEO}**: U.S. first- and second-generation biofuels volumetric mandates as projected by the U.S. Department of Energy (2nd gen not fully implemented).
  - **LCFS**: Hypothetical low-carbon fuel policy that incentivizes cellulosic biofuel and dis-incentivizes food-based biofuels.
- Water use impacts are a function of changes at the extensive (land use change) and intensive (e.g. irrigation) margin.
  - Dedicated biofuel feedstock cropping in currently uncropped land.
  - Dedicated biofuel feedstock cropping displacing currently cropped land.

2035 LUC (million acres) for dedicated biofuel feedstocks



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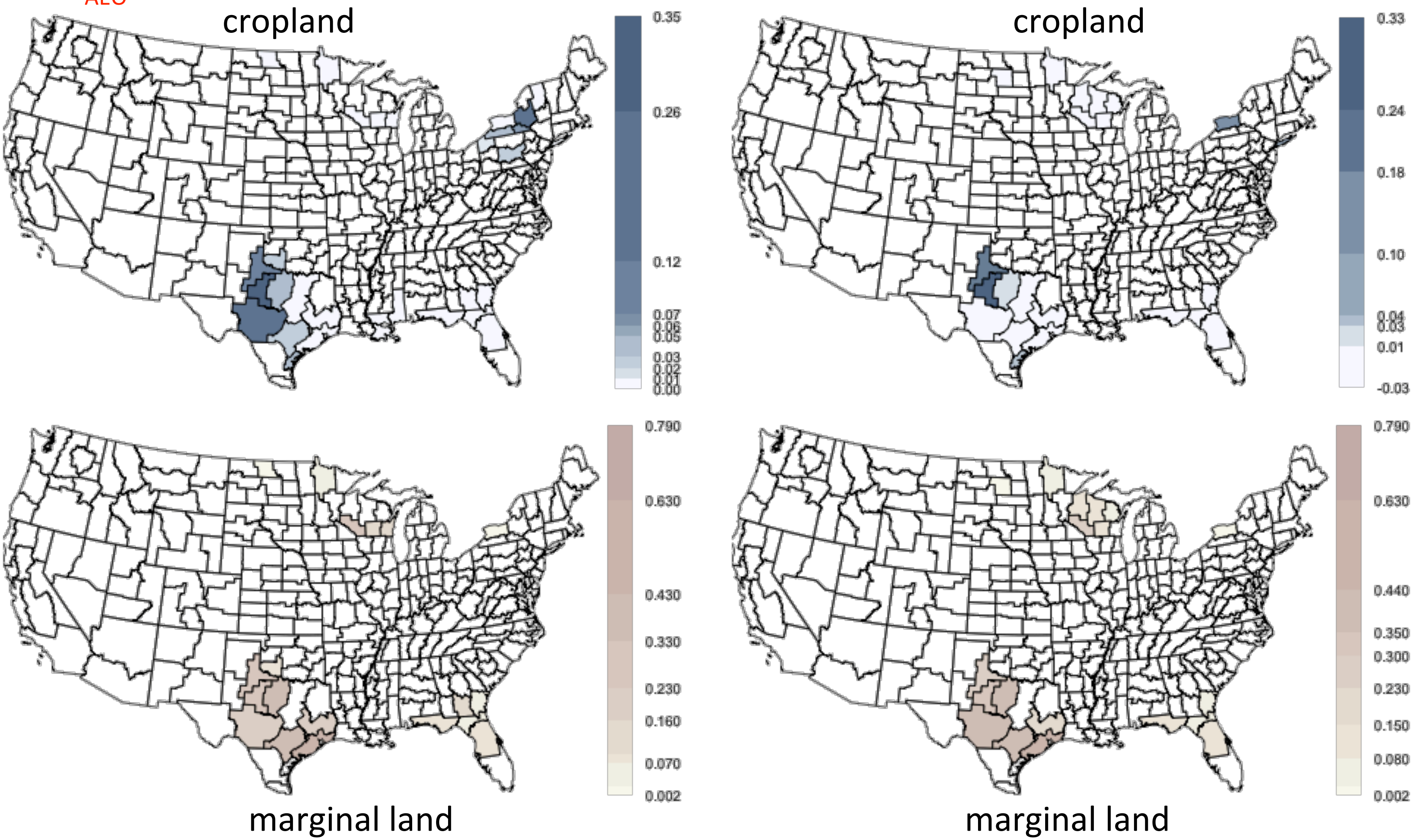
Huang, Haixiao, Madhu Khanna, Hayri √ñnal, and Xiaoguang Chen. 2012. "Stacking low carbon policies on the renewable fuels standard: Economic and greenhouse gas implications." *Energy Policy*. doi: 10.1016/j.enpol.2012.06.002.

2035 LUC (million acres) for dedicated biofuel feedstocks

Switchgrass

RFS_{AEO} | $LCFS + RFS_{AEO}$



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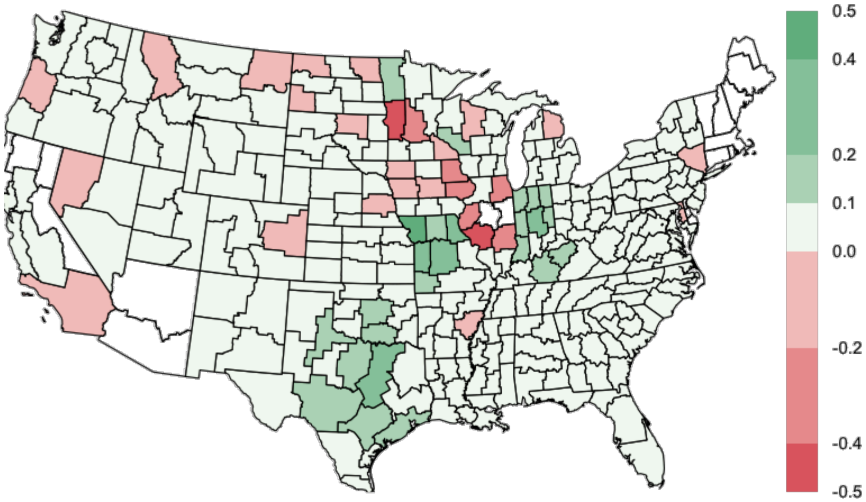
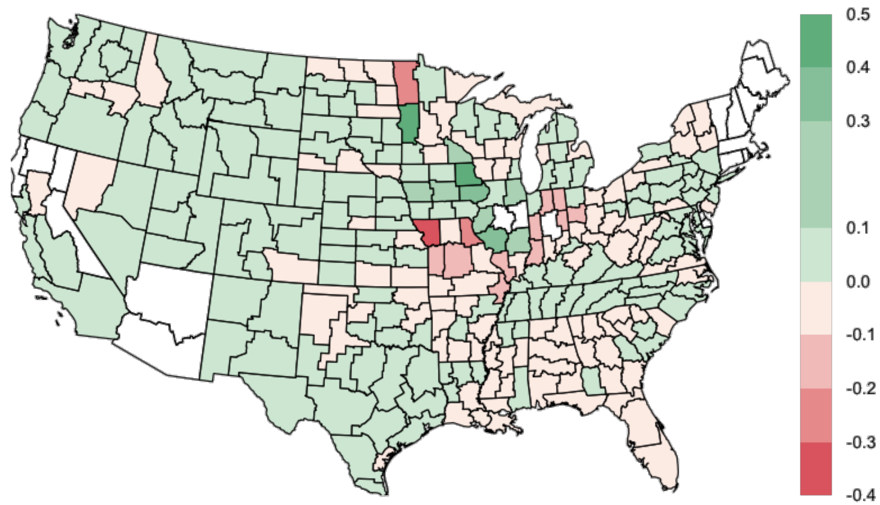
Marginal Land Use Changes of all crop types

RFS-AEO *minus* REF



RFS-AEO+LCFS *minus* RFS-AEO



Marginal land use change (million hectares) in 2035 in two alternative scenarios

Huang, Haixiao, Madhu Khanna, Hayri √ñnal, and Xiaoguang Chen. 2012. "Stacking low carbon policies on the renewable fuels standard: Economic and greenhouse gas implications." *Energy Policy*. doi: 10.1016/j.enpol.2012.06.002.

Water footprint measurement (e.g. blue/green water use intensity) should be considered within the context of land use change, a reference system, and impacts on water resource flow and availability.

- Comparing the aggregated volumetric water-use intensities of different energy pathways is too simplistic.
  - Crops reported to have a have higher "water use intensity" based on LCA studies do not necessarily have more detrimental environmental/water use impacts than those with lower water use intensity
- The impacts of water use vary greatly depending on the affected resource base, the previous state of that resource, and the location and timing of the use in question.
- So, e.g. relatively low water footprints in water scarce areas can be of more environmental relevance than large water footprints in regions where water is abundant.

The Importance of Comparison with a Reference Case

- The sign of water use can be +/-
  - In some cases, conversion of degraded land to irrigated/non-irrigated cropland can reduce non-beneficial consumptive water loss, increase beneficial consumptive water use (increase *water productivity*), & increase ground water recharge.
    - but can reduce fresh water availability if irrigated.
  - Replacing grassland with forest could reduce runoff.
    - Increasing ET means that more of the precipitation is consumed, and this might significantly reduce streamflow.

The Importance of Considering Land Use

- Replacing high water intensity crops with low water intensity, low yield crops on degraded lands at a large scale will still affect regional water use and/or availability.
  - Transformation of intensive framing (irrigated system) to large-scale pasture (rainfed) may reduce blue water consumption, but
  - In some cases may increase ET and reduce water recharge, seasonal water flow, and downstream water availability for other uses.

The Importance of Considering Sources of Water

- Rainfed agricultural systems also have impacts on environmental quality and water availability:
  - A rainfed ag system will consume water that would otherwise have replenished groundwater levels or contributed to river flows required for maintaining healthy aquatic ecosystems.
  - Variation in precipitation (e.g. drought) affects irrigation water demands.
  - Accounting for green water may also help to better assess the effects on water in agricultural production in sub-humid and semi-arid regions, and develop strategies for tapping the *productivity* of the green water, not just the blue water.

Opportunities to Promote Synergies, Manage Water Use and Impacts

- Increase water productivity by :
  - shifting *non-beneficial* E loss in fallow land to *productive* ET_a for plant growth,
  - storing more moisture in soil (& sequestering more soil carbon),
  - protecting land from soil erosion and nutrient losses.

  (reducing the frequency and likelihood of extreme runoff/ flooding)
- Using treated agricultural effluent for bioenergy crop irrigation.
- Controlled drainage and water table management.
- Virtual water imports.

Other Impact Assessment

- Localized effects – refinery withdrawal is not a major LCI fraction, but may have an important local impact.
- Localized effect of non-consumptive use – ecosystem disruption, heat pollution, etc.
- Timing of use (seasonality, crop growth cycles, variability)
- Impact on key habitats such as wetlands, floodplains, aquifer-recharge zones
- Toxicity, increased/reduced eutrophication risk from N/P loading
- Health effects
- Changes in groundwater recharge (salinity?)
- Consideration of "indirect water use change"

Conclusion

- **A proper consideration of water use intensity and water use impacts should be evaluated properly within the context of sources of water, land use change, a reference system, and impacts on water resource flow and availability, at proper scales.**
- It is necessary to build a decision support framework to guide the evaluation of biofuel water use and associated impacts.

Acknowledgement

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- Göran Berndes, Suhas P. Wani, André Elia Neto, Sangwon Suh, Louise Karlberg, Jens Heinke, and Kaushal K. Garg.
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