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Water Use Impacts from Corn-based Bio-ethanol Production in Minnesota

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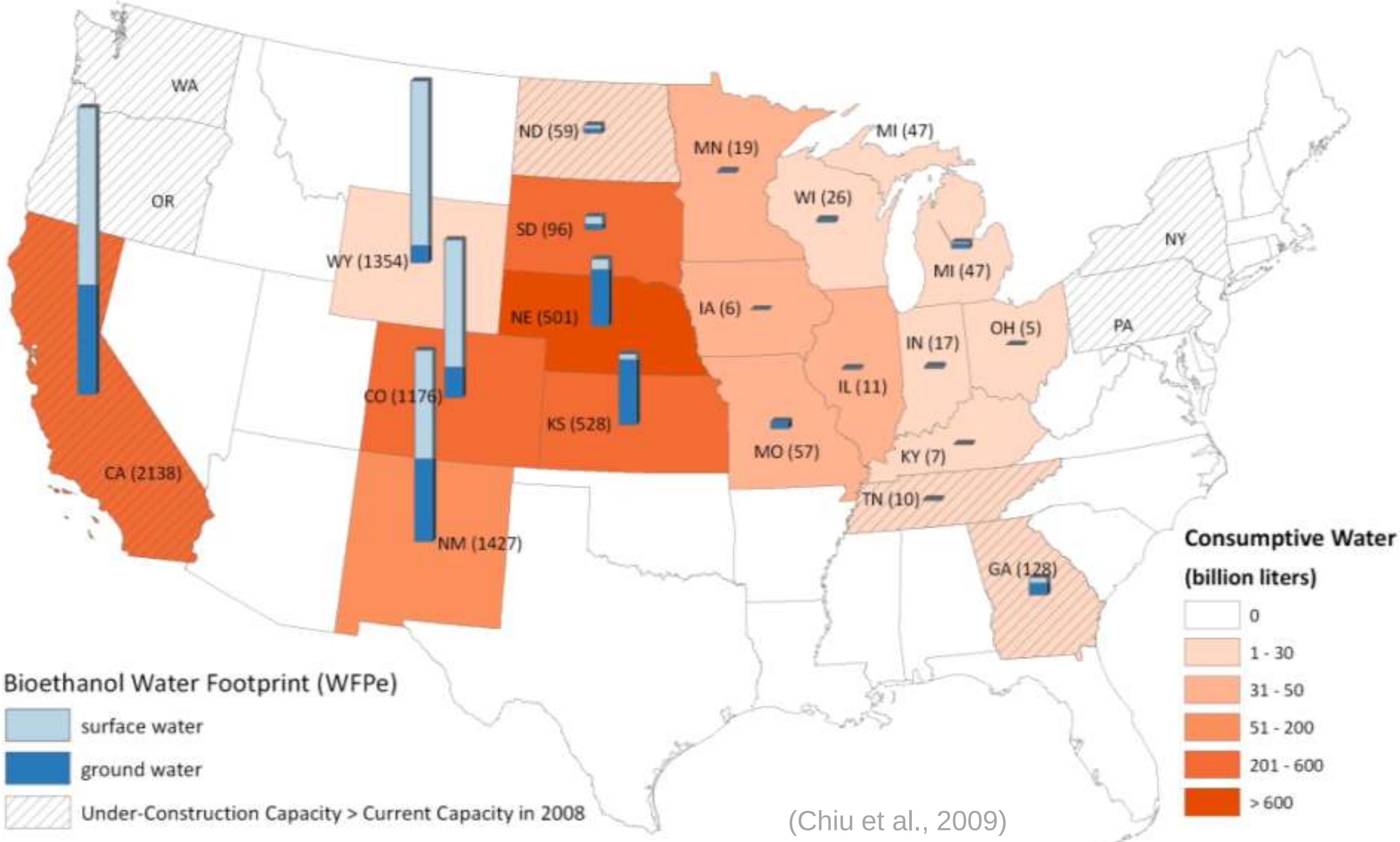
Background



(Chiu et al., 2009)

Overall objectives

- Quantify and analyze environmental impacts of water consumption
- Understand effects of site-selection on water use and ecological impacts
- Determine implications for water management and conservation

Methods

- Spatial scale
  - 81 watersheds in Minnesota
  - 21 corn-based ethanol production facilities
- System boundaries
  - Field to pump
  - Irrigation water and consumptive process water use
- Irrigation water
  - Assuming ethanol plants acquire corn from closest field
- Process water
  - Plant–by–plant estimation based on self-conducted survey and official reports

Methods (cont.)

- Using method of Pfister et al. (2009)
- Preliminary analysis indicates only ecological impacts
- Impact assessment of ecosystem quality impacts

$$\Delta EQ = CF_{EQ} \times WU_{consumptive} = \underbrace{NPP_{wat-lim}}_{\text{potentially disappeared fraction of species (PDF)}} \times \frac{WU_{consumptive}}{P}$$

ΔEQ ($m^2 \cdot yr$): indicator of ecologically degraded area (ecosystem damage)

CF_{EQ} ($m^2 \cdot yr/m^3$): ecosystem quality damage factor

$NPP_{wat\text{-}lim}$: water-limited share of net primary production

P (m/yr): annual precipitation depth

$WU_{consumptive}$ (m^3): consumptive water use

Method (cont.)

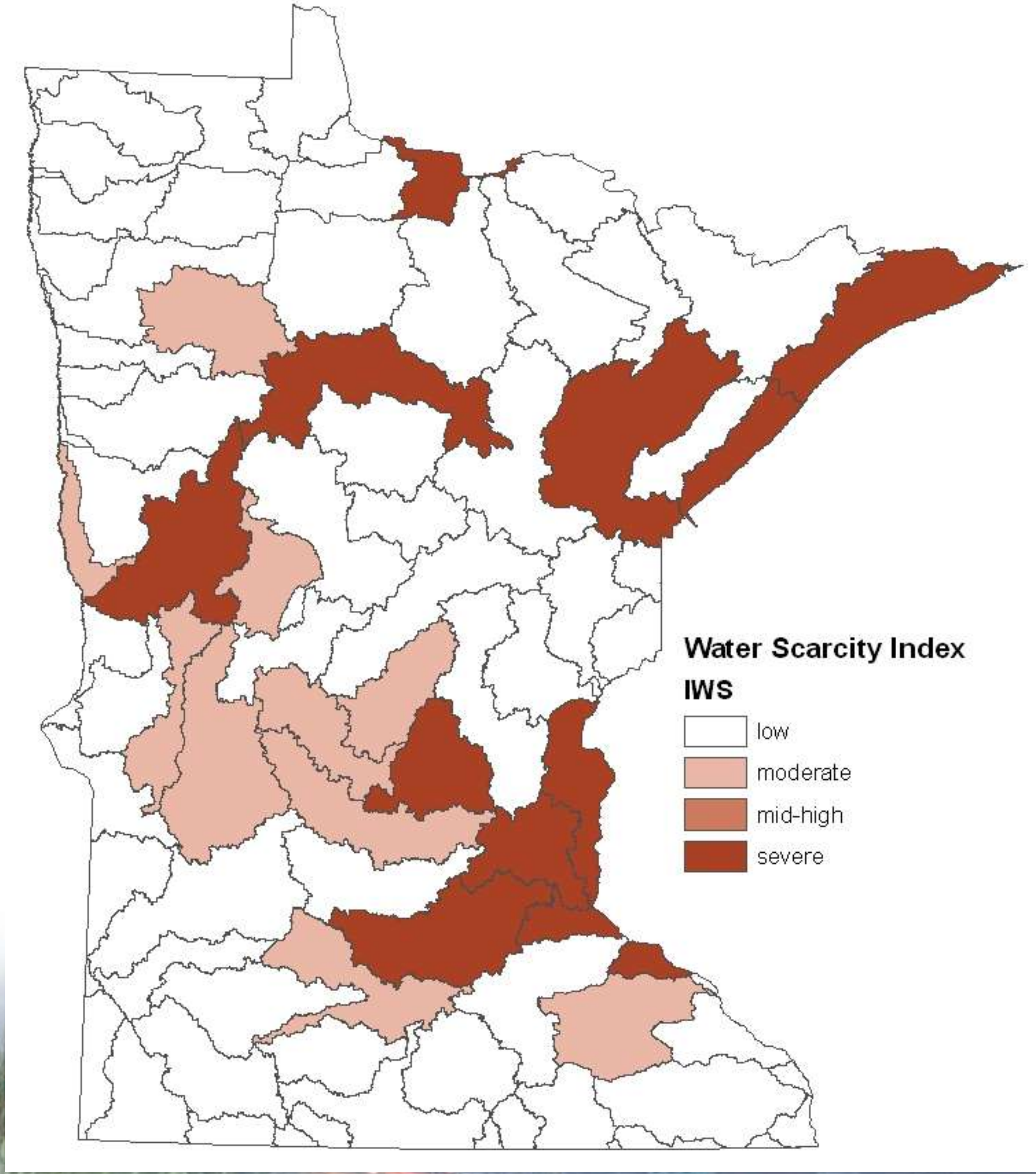
- Water scarcity index

$$IWS_i = \frac{WU_{total\ i}}{A_i(P_i - ET_i)}$$

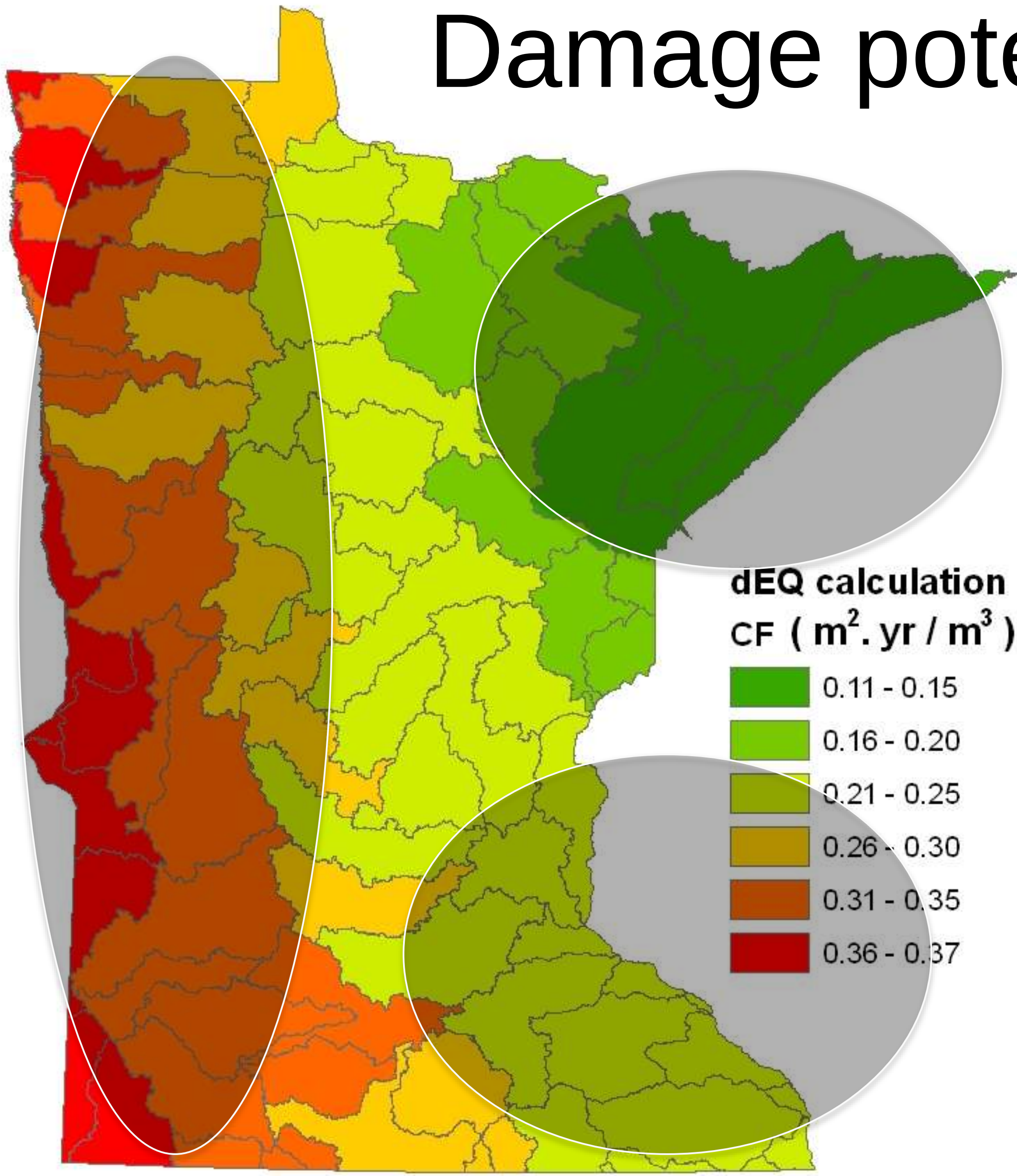
  - IWS of watershed *i*
  - $WU_{total\ i}$ (m^3): total anthropogenic water consumption in watershed *i*
  - A_i (m^2): area size of watershed *i*
  - P_i (m): annual precipitation in watershed *i*
  - ET_i (m): evapotranspiration in watershed *i*

Results – Water scarcity index

IWS	Scarcity
< 0.1	Low
0.1 - 0.2	Moderate
0.2 - 0.4	Mid-high
> 0.4	Severe



Damage potential

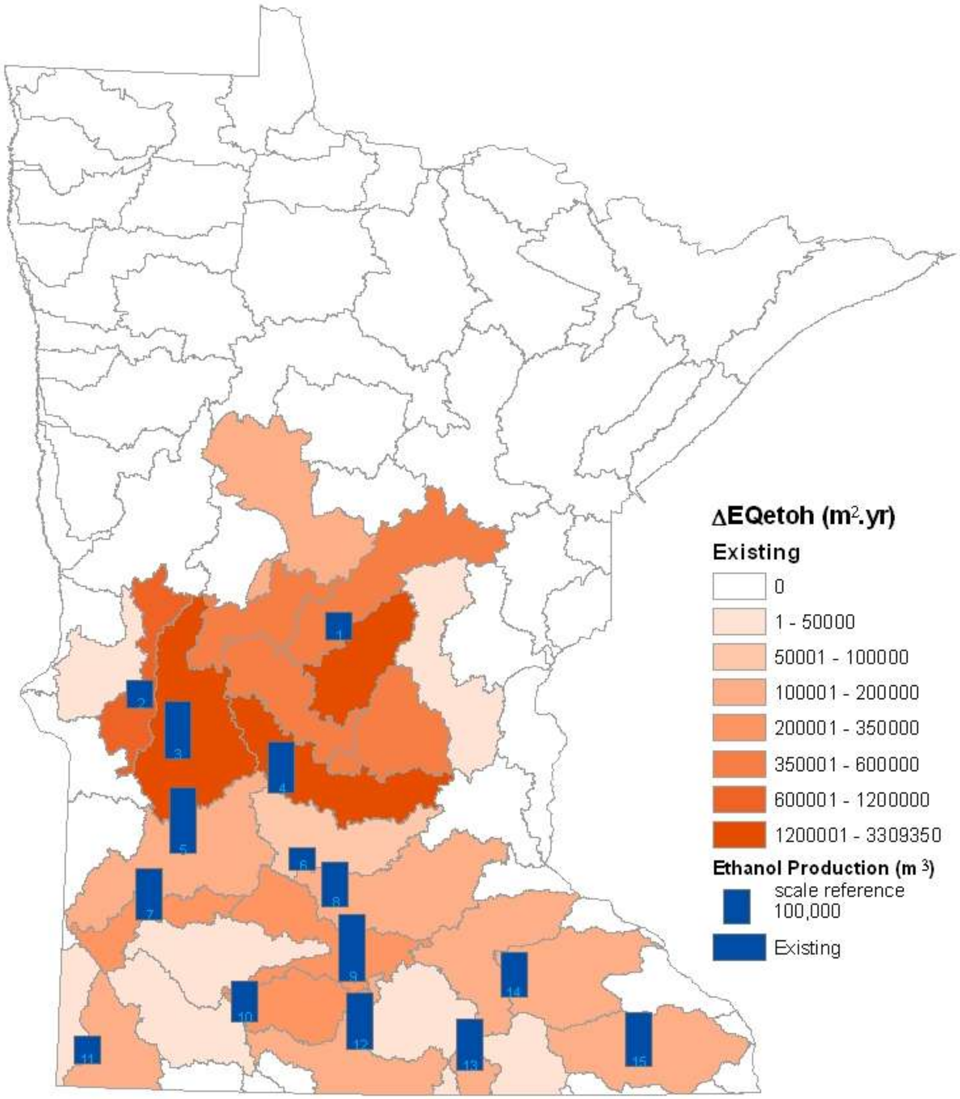


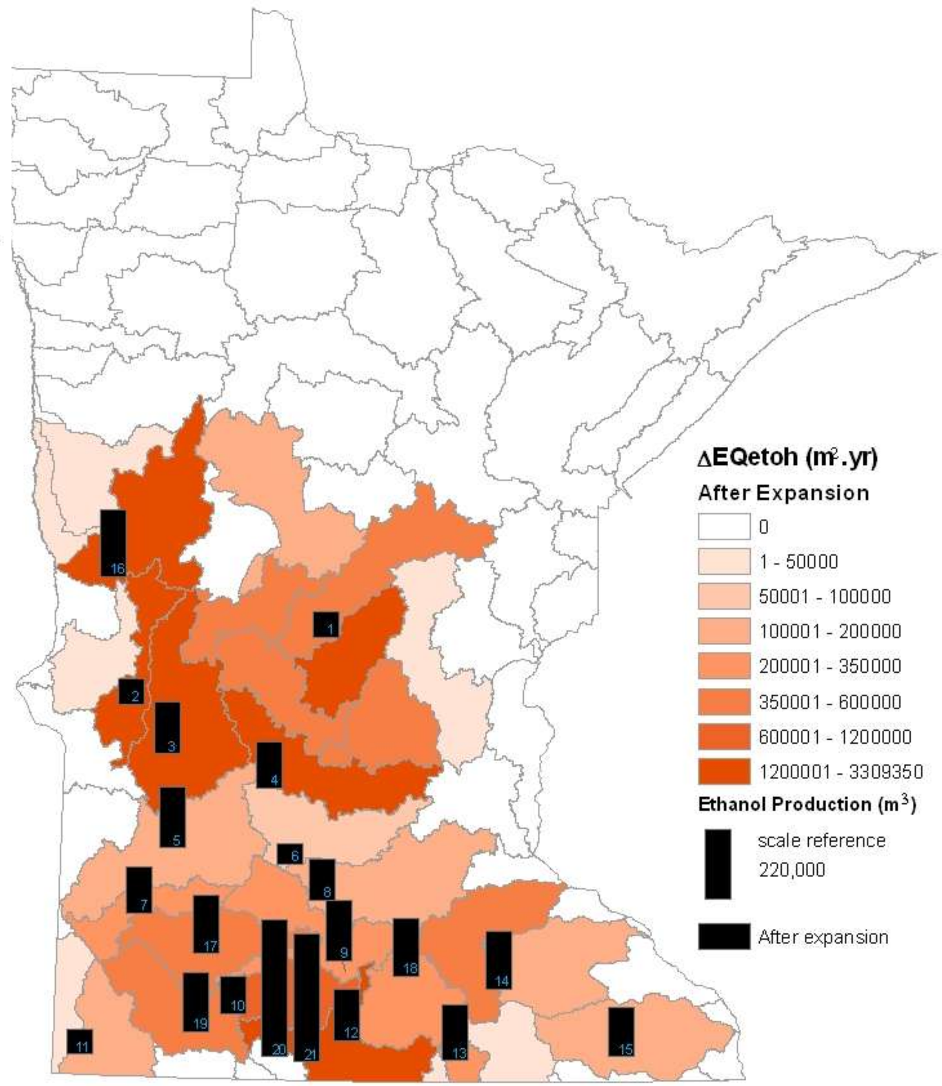
$$\frac{\text{high } NPP_{wat-lim}}{\text{low } P}$$

$$\frac{\text{low } NPP_{wat-lim}}{\text{high } P}$$

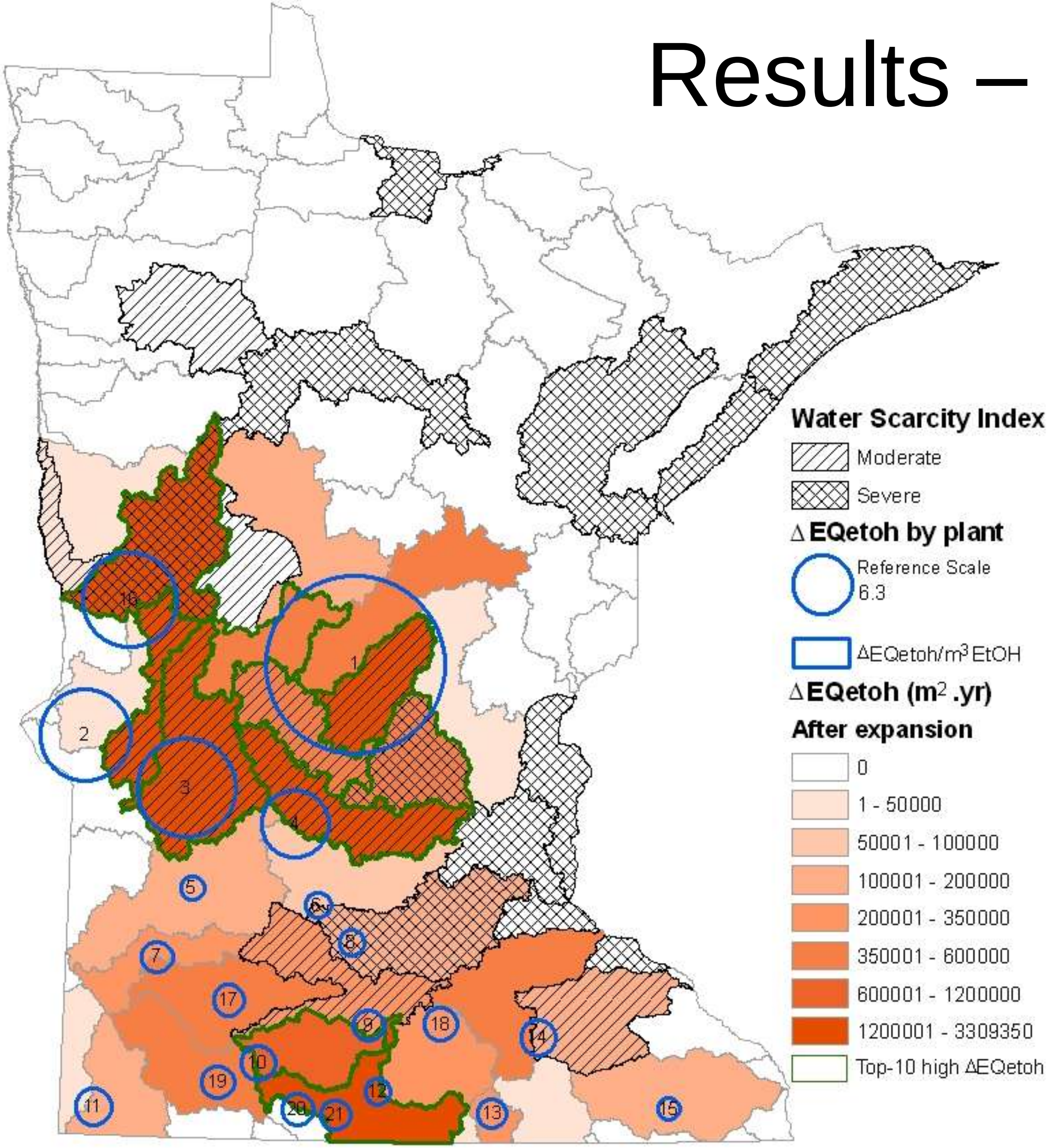
$$\frac{\text{moderate } NPP_{wat-lim}}{\text{low } P}$$

Results – ΔEQ vs. EtOH Production





Results – Facility basis

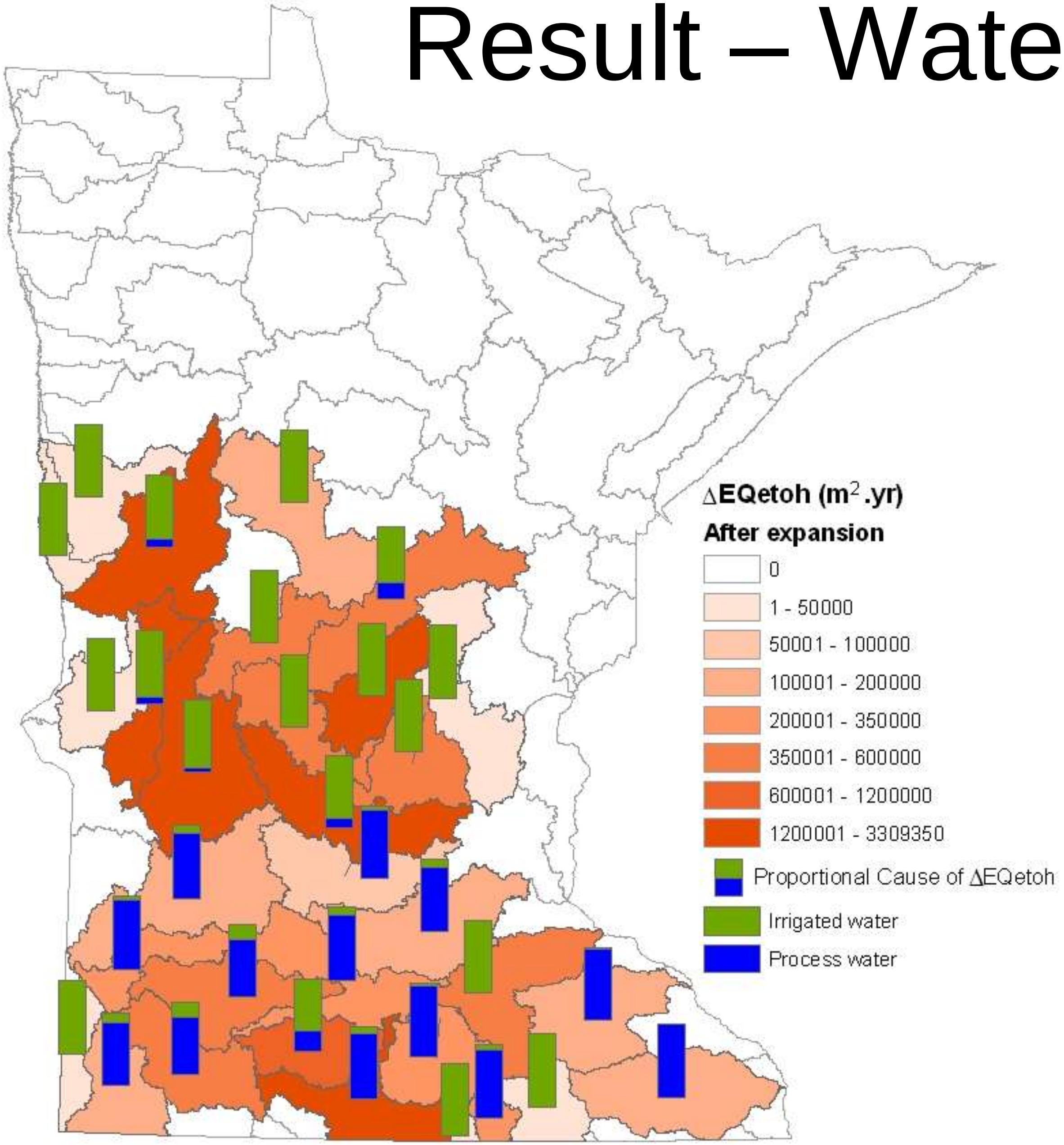


- Facility basis:

  Ecological damage to produce 1 m^3 of bio-ethanol:

  0.9~59.0 PDF $m^2 \cdot yr/m^3$

Result – Water use types



- Normalized ecological damage to 100%
- Damages of 19 out of 37 affected watersheds dominated by irrigation
- 79% of total ΔEQ_{etoh} of MN due to irrigation

Water management implications

- Quantifying water consumption alone not sufficient
  - Water footprint (m^3 water consumed/ m^3 bio-ethanol) does not provide environmental implications
- Commonly-known water scarcity index is not sufficient
  - Top-10 watersheds with highest ΔEQ_{etoh} account for 81% of total ΔEQ_{etoh} after expansion, but only two watersheds classified have severe water scarcity

Water management implications

Irrigation water and process water

- ΔEQ_{etoh} of 35% of watersheds affected by bio-ethanol production are dominated by process water consumption
- Location of highly-affected watersheds not necessarily related to location of bio-ethanol facilities
- Water regimes of adjacent corn-supply regions of an ethanol facility play critical role in determining the impacts of a given facility on water resources

Conclusions

- LCIA method provides better understanding of ecological consequences of (excessive) freshwater consumption
- LCIA –on top of water footprint– better informs decision makers on planning water conservation and selecting effective strategies for bio-fuel production
- Industrial facility site selection should take nearby watershed characteristics into account
- Water input and output data collection at bio-refineries is in urgent demand

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QUESTIONS?

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