Chaos in Climate Change Impacts Estimates

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Motivation

- Climate change impacts mostly depend on local climate change
- There is wide uncertainty in future climate at local level
- The literature has largely ignored this uncertainty
- Implications for policy makers are important

Sources of Uncertainty

- Future climate projections have three main sources of uncertainty
  1. Emissions scenario (RCP 8.5, RCP 2.6, etc...) — RCP Scenario Spread
  2. Model uncertainty (NCAR, CMCC, Hadley, ...) — Model Spread
  3. Chaotic dynamics of weather, for the same model — Internal Variability

- The literature on climate change impacts is
  1. mostly concerned with the Scenario Spread,
  2. modestly concerned with Model Spread,
  3. not concerned with Internal Variability.

Understanding Internal Variability

- Deterministic Chaos
  - The climate system has *chaotic* dynamics: very small changes to initial conditions lead to vastly different outcomes
  - Each model run is fully deterministic, but we do not know exactly the initial conditions
  - Extremely small changes to initial conditions lead to large different outcomes

- As initial conditions are essentially random, one single scenario is a random realization from the pdf of all scenarios for a model-emission scenarios combination
  - Climate Models typically provide only one random future realization of climate
  - The impacts literature relies on random scenarios of unknown probability

Climate Data

- CESM Large Ensemble Community Project developed at NCAR
  - 40 ensemble members for RCP 8.5 and 15 ensemble members for RCP 4.5
  - No data for RCP 6.0 and for RCP 2.6

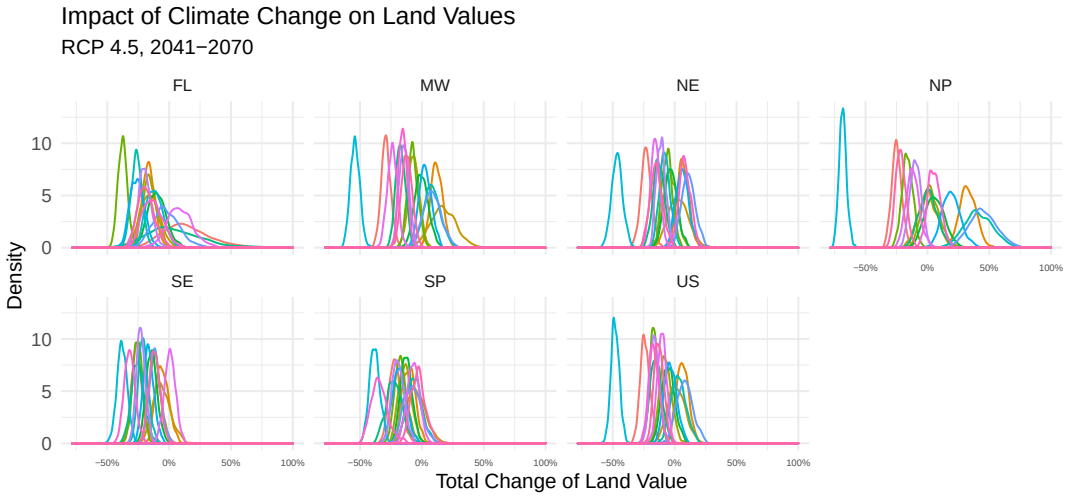
- We are interested in climate change
  - Change of average 2011-2040, 2041-2070, 2071-2100 seasonal temperature and precipitation wrt average 1976-2005
  - We are eliminating a great deal of short-term and seasonal noise

Effect of Climate on Agricultural Land Values

The econometric climate impact model:

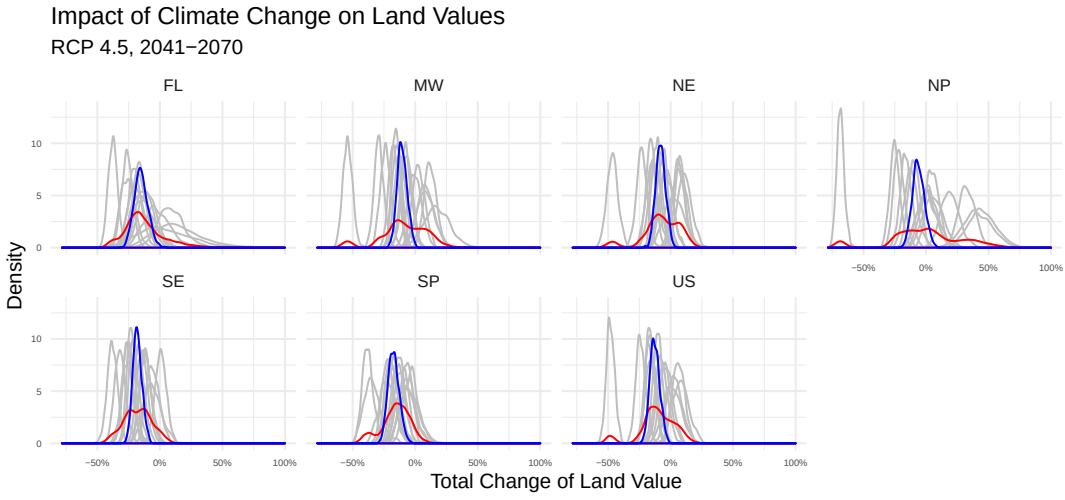
- Ricardian model of Eastern US agricultural land values (Massetti and Mendelsohn, 2011)
- Agricultural land values as a measure of discounted rents from agriculture
- Changes in agricultural land values measure discounted welfare effect of climate change, with adaptation

Macroregions



Bootstrap distribution for each ensemble scenario, 1,000 repetitions. (NARR − tp − at4s)

Macroregions - Entire Distribution (red) vs Ensemble Mean (blue)



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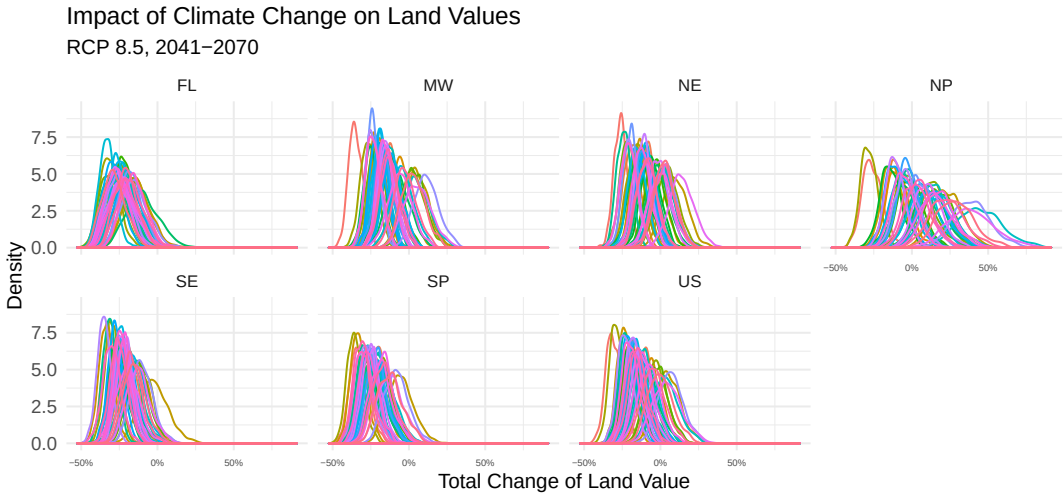

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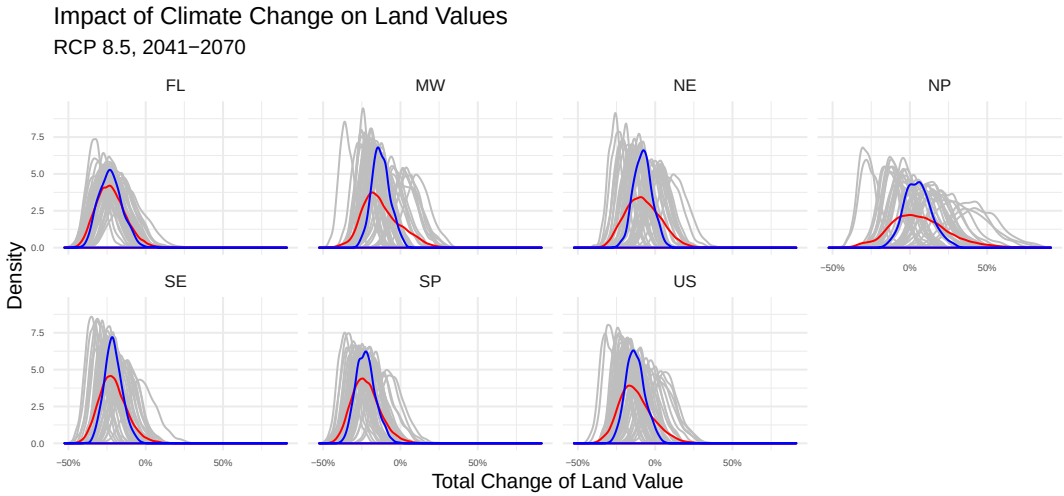

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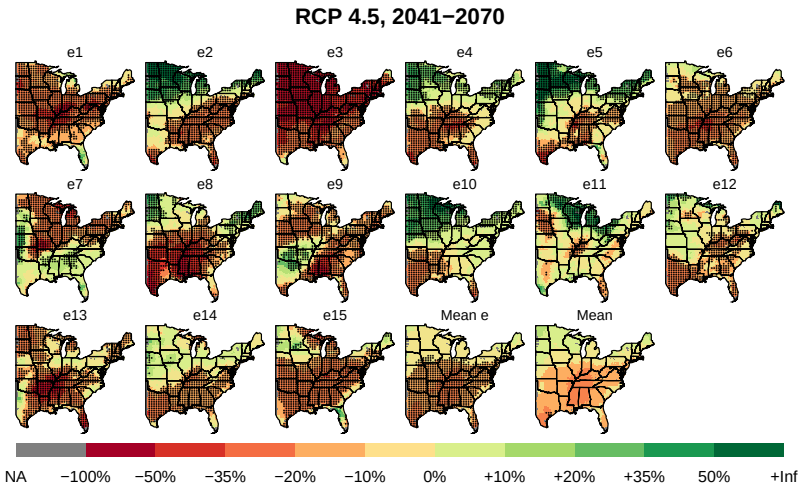
RCP 4.5, 2041−2070
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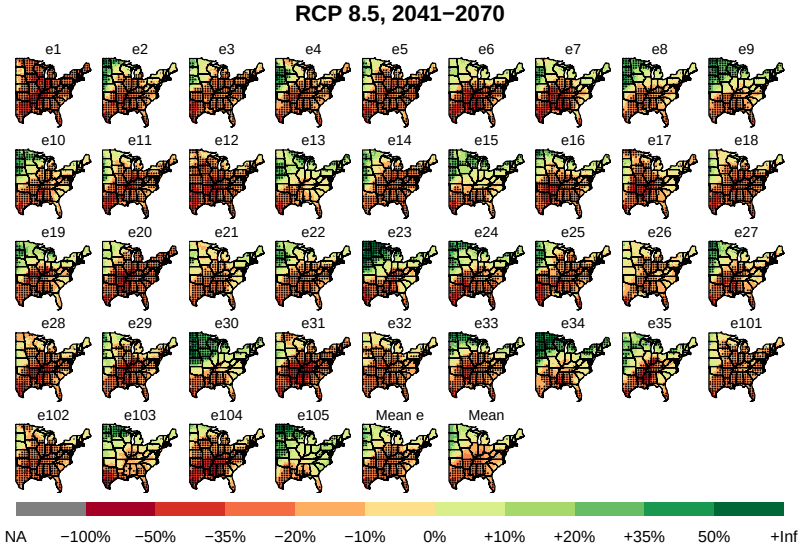
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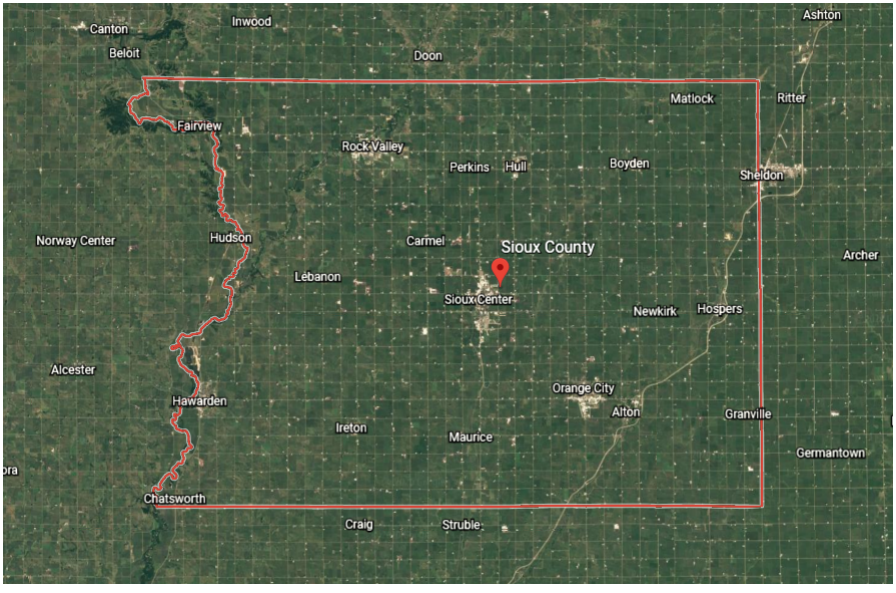
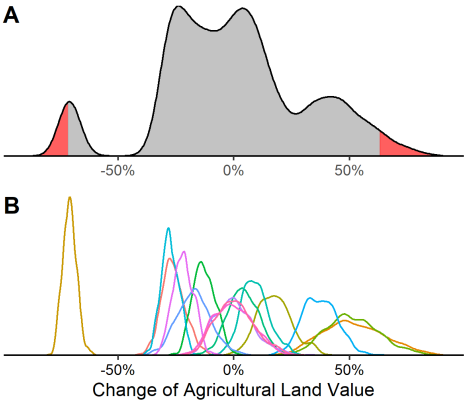
Sioux County, Iowa



Sioux County, Iowa



Percentage change of agricultural land values under RCP 4.5 in 2041-2070.
Panel A: bootstrap distribution over all ensemble members with 95% conf. int.
Panel B: bootstrap distribution for each ensemble member.
Source: Massetti and Di Lorenzo (2020).

Figure 1: RCP 4.5, 2041-2070

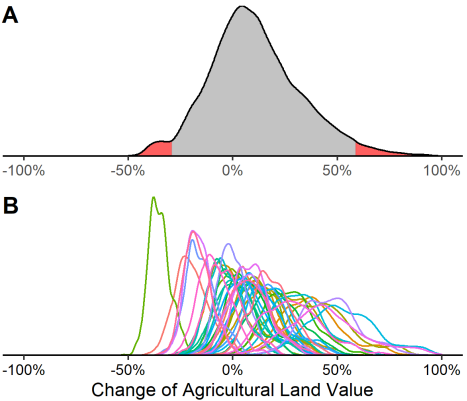


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Figure 2: RCP 8.5, 2041-2070

Conclusions

- Implications for the literature
  - Estimates of climate change impacts ignore large source of uncertainty
  - The impacts literature should start using ensemble scenarios
  - Climatologists should invest more resources in developing large ensembles

- Policy implications
  - The range of possible outcomes is larger than previously thought
  - In some areas, anticipatory adaptation carries large risks