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The hydroeconomic resilience of cities in the US virtual water trade network

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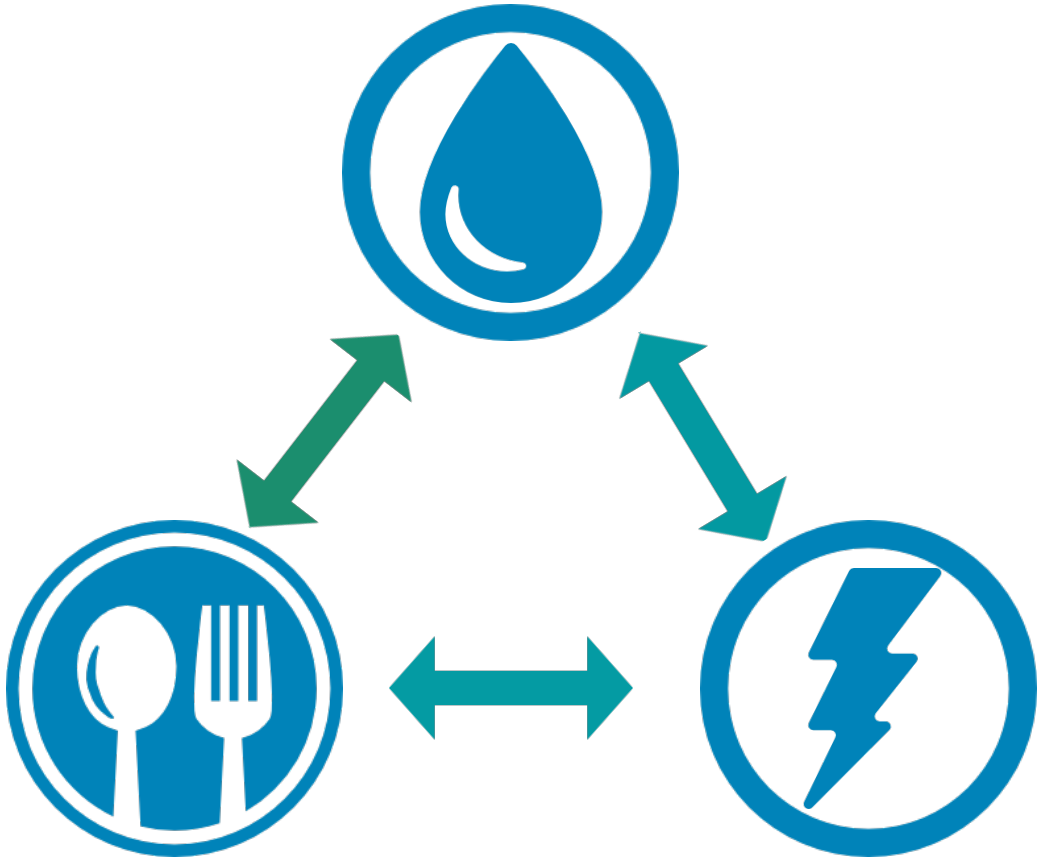
Understanding FEW interdependencies critical to national security



Sources: www.freepik.com; www.flaticon.com/authors/smashicons; www.flaticon.com/authors/vaadin

Cities are central to FEW: They drive FEW production/use through consumption and agglomeration

- Consume 2/3 of world's energy
- Account for 70% of global CO_2 emissions

Source: **www.pexels.com/search/city%20lights/**

We calculate resilience for a geographic region by adapting the definition of ecological resilience to virtual water trade networks

We define resilience from a structural and systemic perspective, where a resilient region is one that outsources water from multiple trading partners with ***diverse*** hydroeconomic characteristics[1]

[1]Rushforth and Ruddell, WRR 2016

We measure the hydroeconomic distance between regions by means of 5 indicators

Five hydroeconomic distance indicators ($A_{i,j}^{r}$) are defined for each i region and its trading partners j:

1. Physical Distance Indicator
2. Drought Correlation Indicator
3. Hydroeconomic Specialization Indicator
4. Shared Virtual Water Community Indicator
5. Urban Classification Indicator

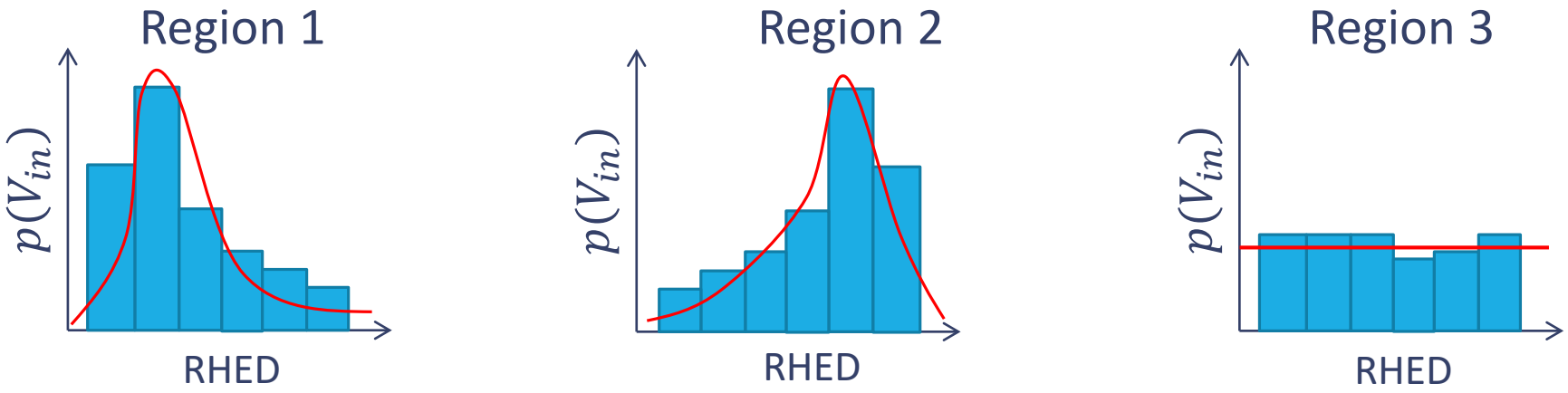
Indicators are normalized by the maximum observed distance in the network as

$$A_{i,j}^{r} = \frac{A_{j}^{r} - A_{i}^{r}}{\max(A_{j}^{r} - A_{i}^{r})}$$

The average of the normalized indicators represents the Relative Hydroeconomic Distance (RHED) between a region and trading partner

The resilience metric (cont'd)

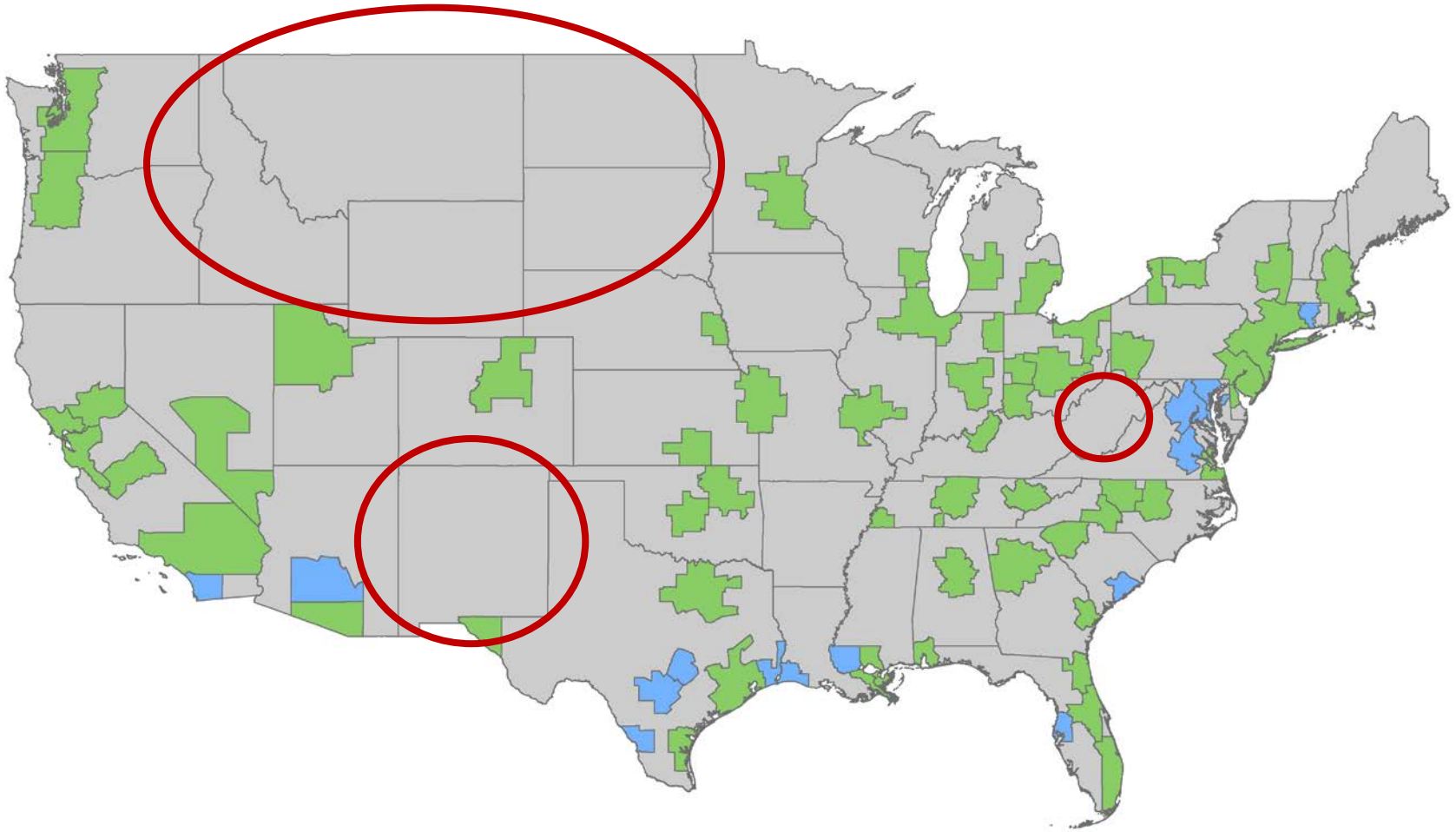
RHED indicators from trading partners of a region were binned into i bins and the relative abundance of virtual water inflows, V_{in}, was calculated



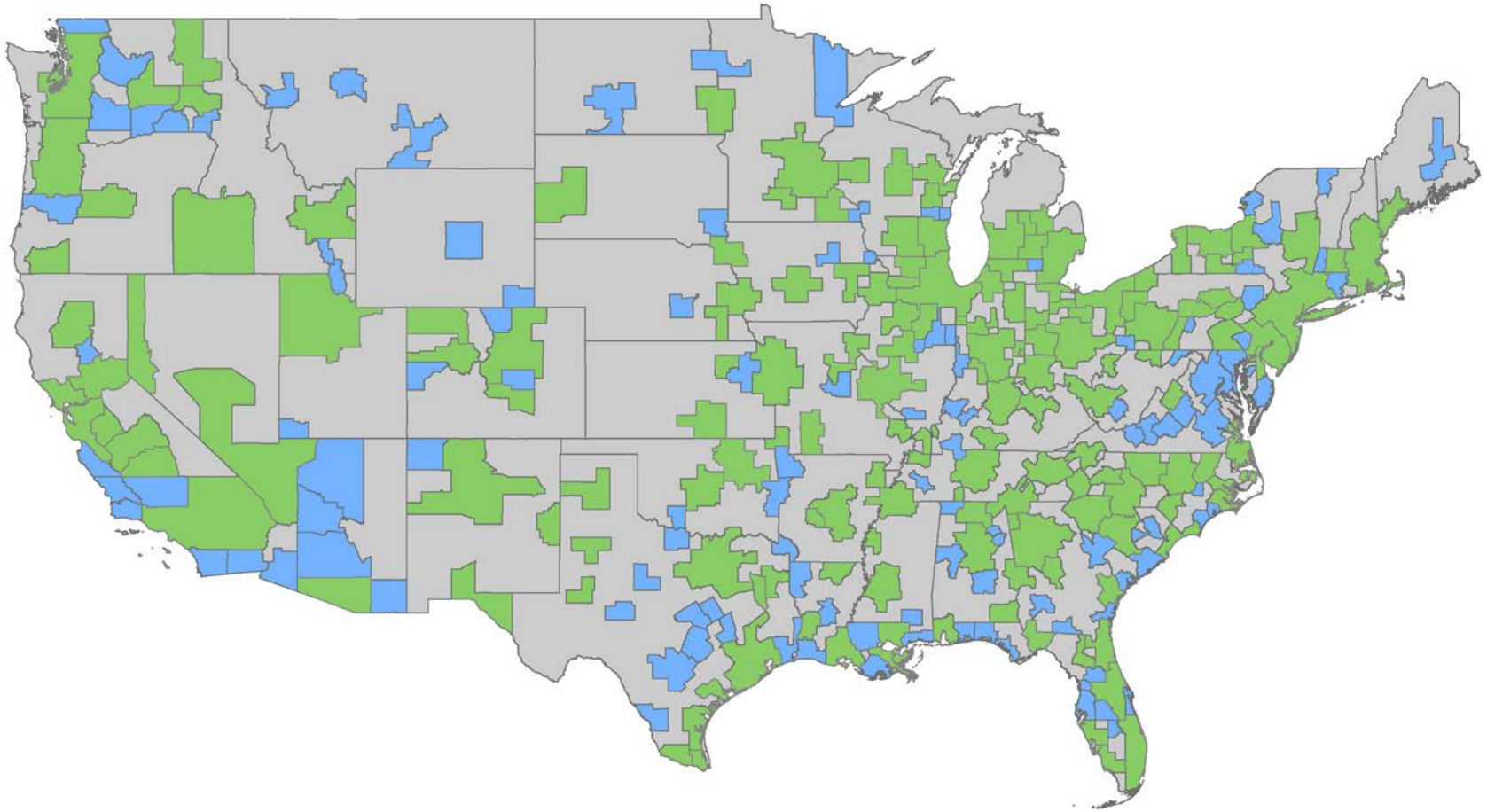
A normalized Shannon Diversity Index (SI^{RHED}) was calculated from the distribution of virtual water inflows to the region as

$$SI^{RHED} = \frac{-\sum_i p(V_{in,i}) \cdot \log p(V_{in,i})}{logN}$$

FAF dataset does not include all cities



We include all US cities (CSAs and MSAs)



We use socioeconomic and agricultural data to downscale FAF

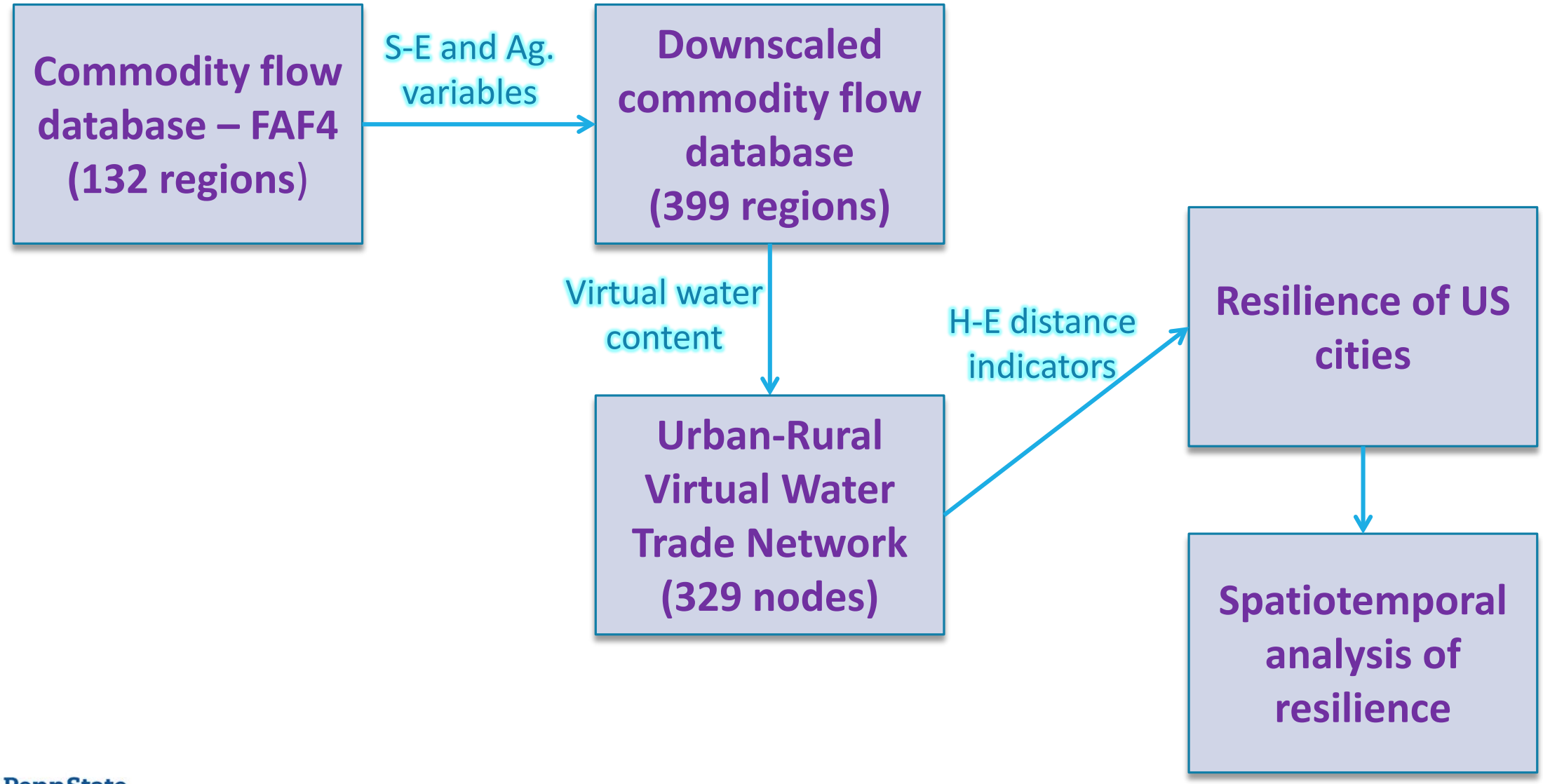
Socioeconomic and agricultural data (e.g., labor, population, crop land, etc.) is used to spatially downscale commodity flows

Downscale is done in a two-phase approach:

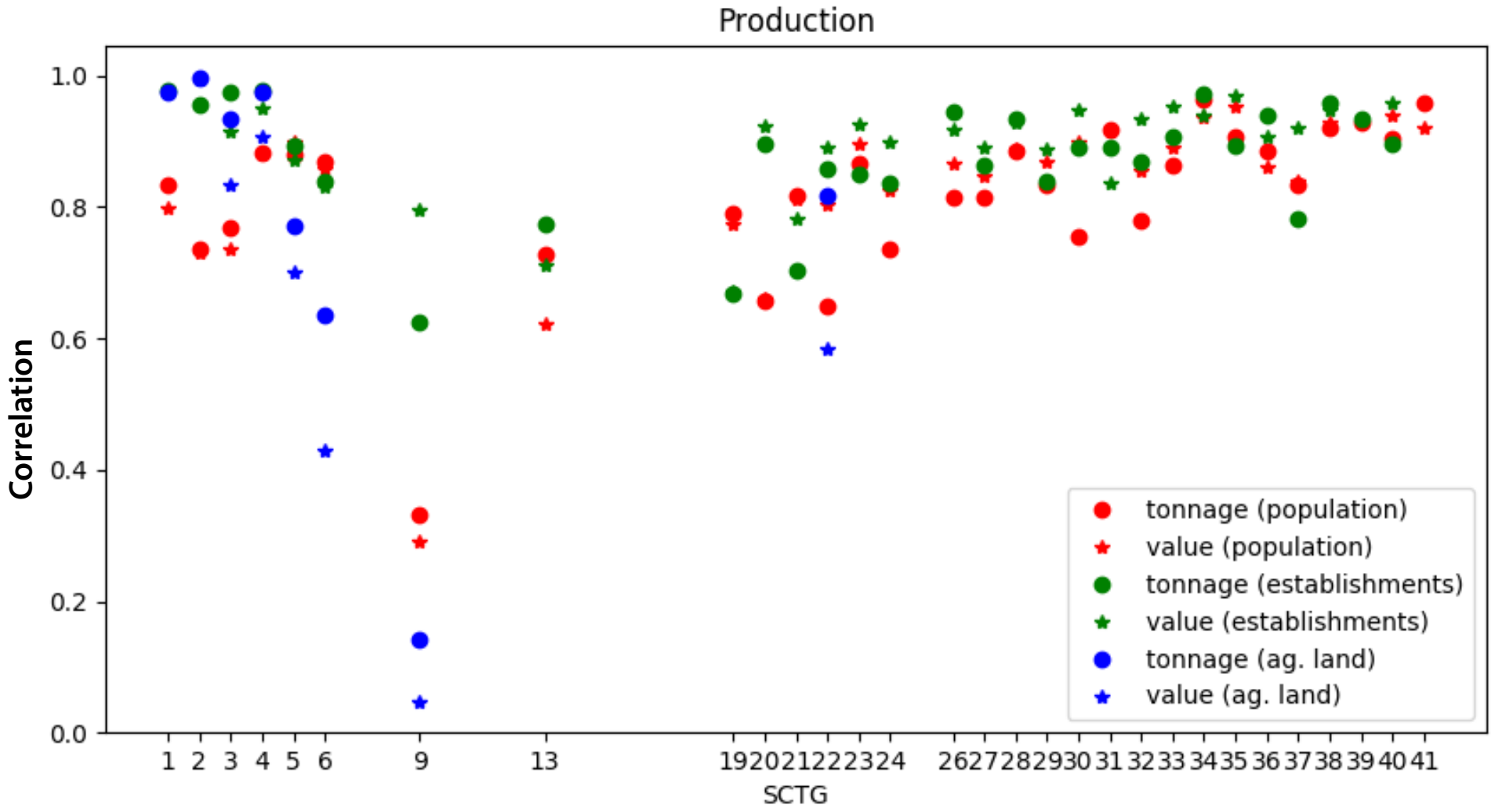
1. State level production is downscaled to CSA/MSA level
2. CSA/MSA exports to other states are downscaled to CSA/MSA level to get consumption

Downscaling solution is tested at the commodity level (SCTG classification)

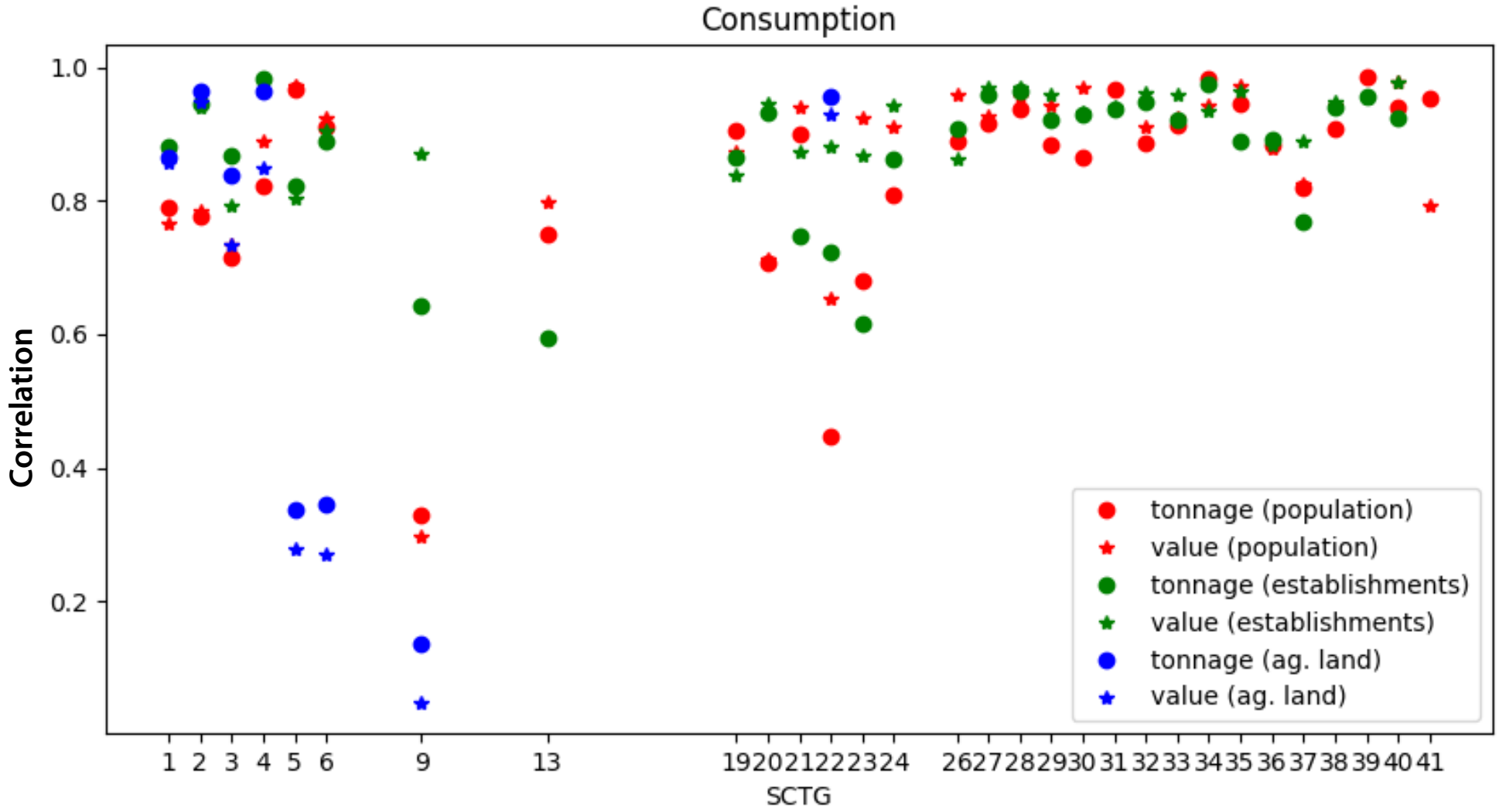
Our overall approach is as follows…



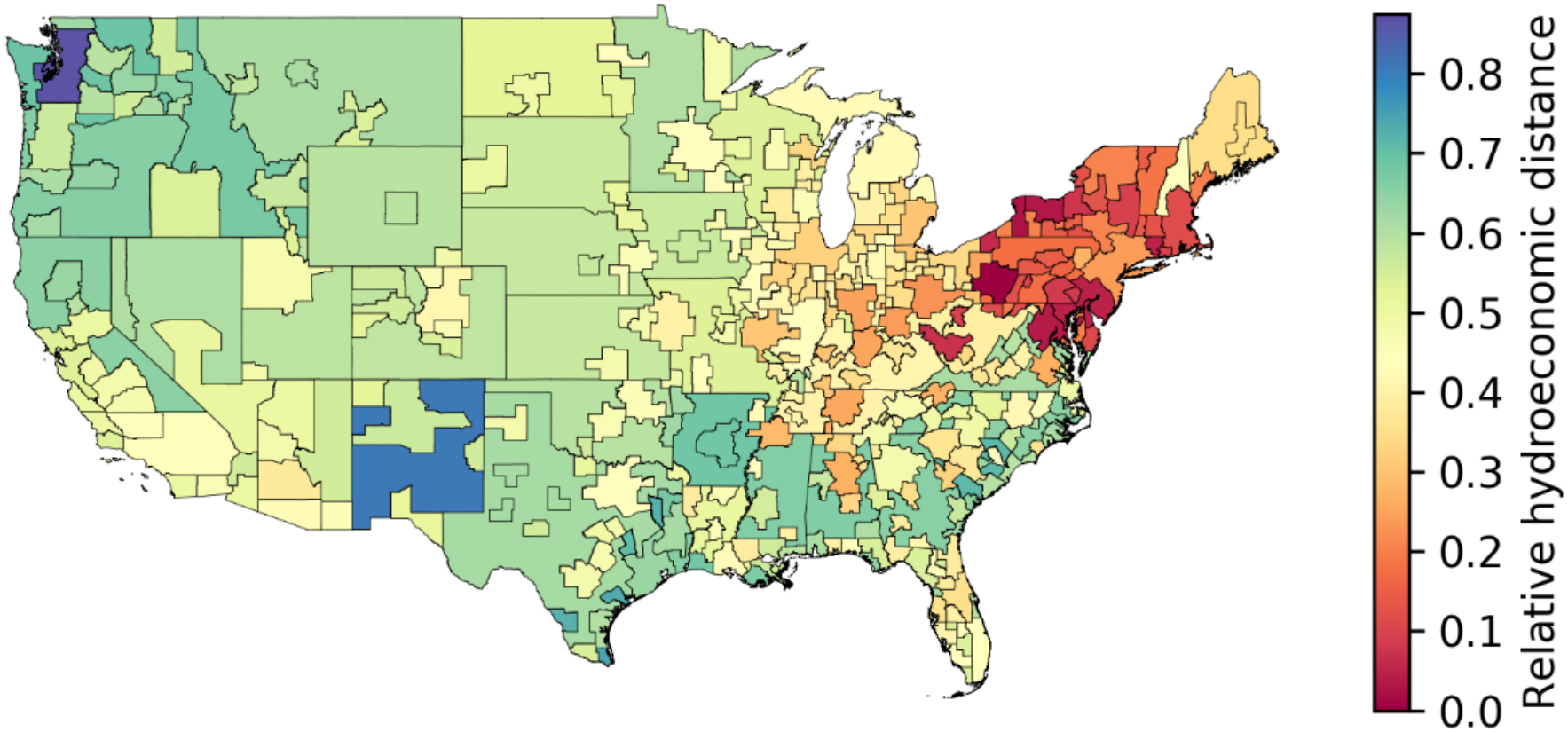
Verification of downscaling approach (production-side)



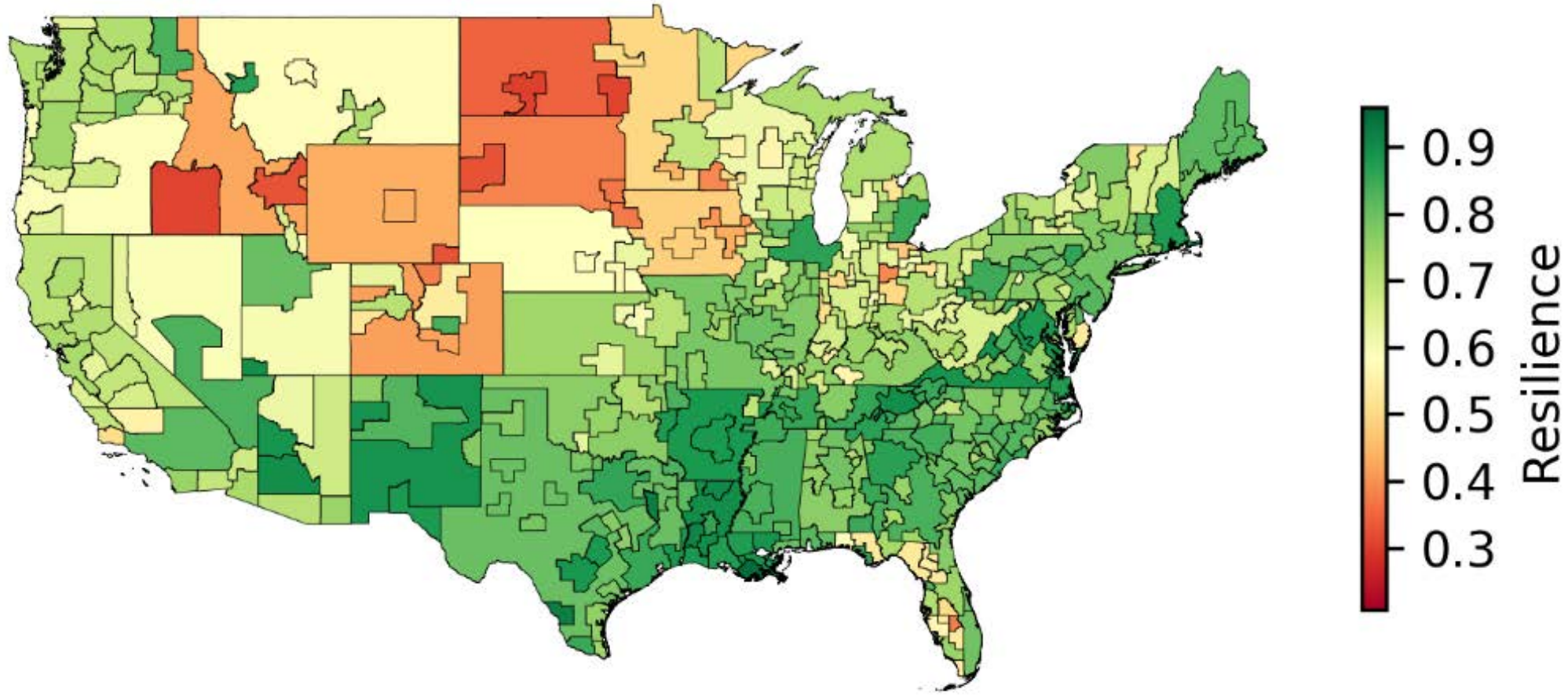
Verification of downscaling approach (consumption-side)



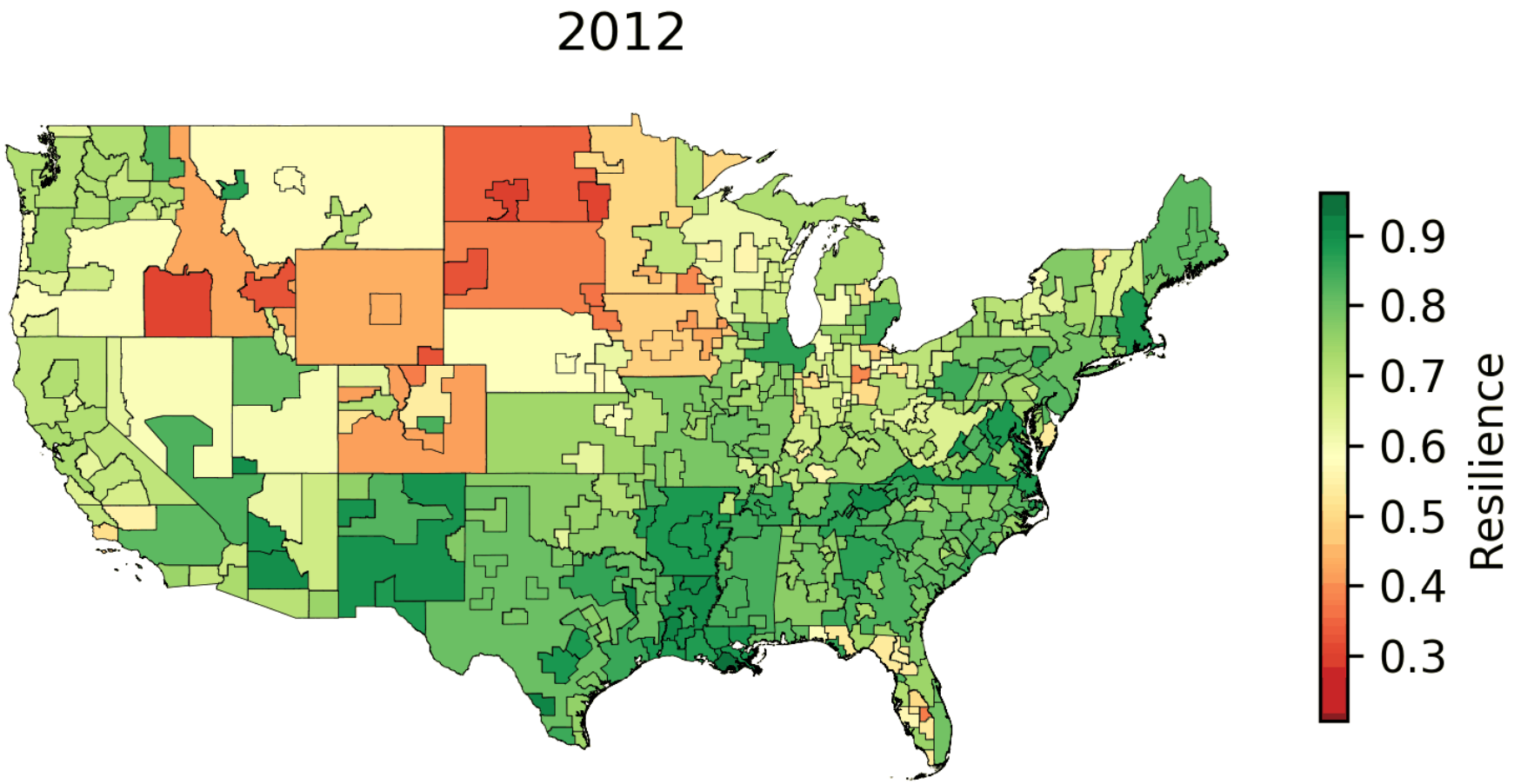
The Relative Hydroeconomic Distance (RHED)



Resilience results for year 2012



Total resilience with *temporal* virtual water trade networks



Our concluding remarks are…

- We successfully developed and verified the ***urban-rural virtual water trade networks***

- Resilience metric varies in space and time with changes in hydroeconomic indicators (e.g., drought index) and network structure (e.g., node weighted degree)

- For the selected years, we observe geographical regions of consistent low resilience

Thank you!

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