Role of cities in the Virtual Water Network of U.S. Commodity Flows

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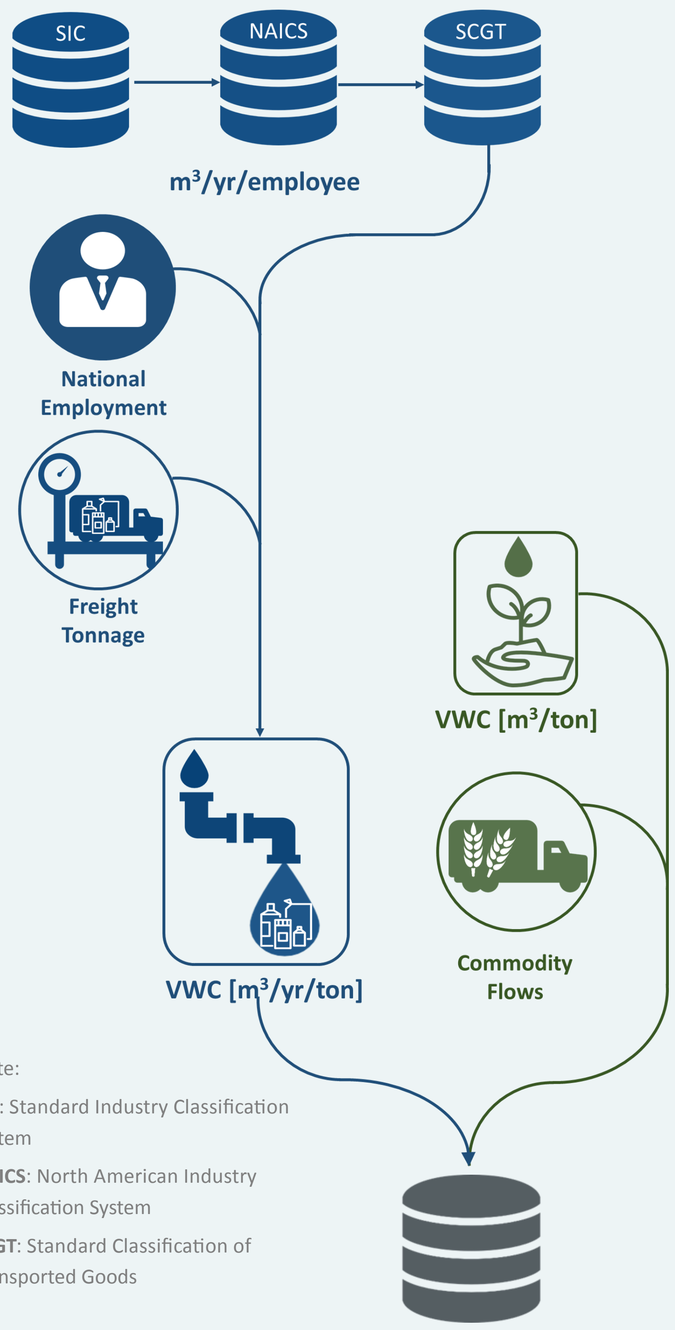
1 Virtual Water content of a commodity represents the water used in its production.

Through the exchange of commodities and their associated virtual water content, cities are hydroeconomically (virtually) interconnected giving rise to network structures.

2 A database of virtual water flows was generated using Freight Analysis Network (FAF3) data of commodity flows and virtual water content of commodities.



Note:

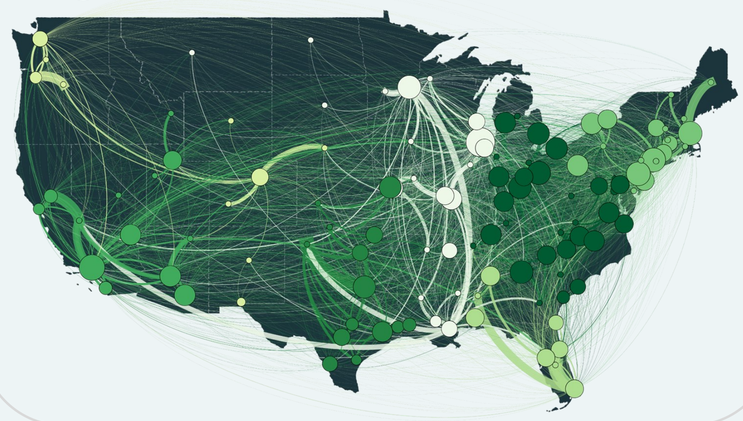
SIC: Standard Industry Classification system

NAICS: North American Industry Classification System

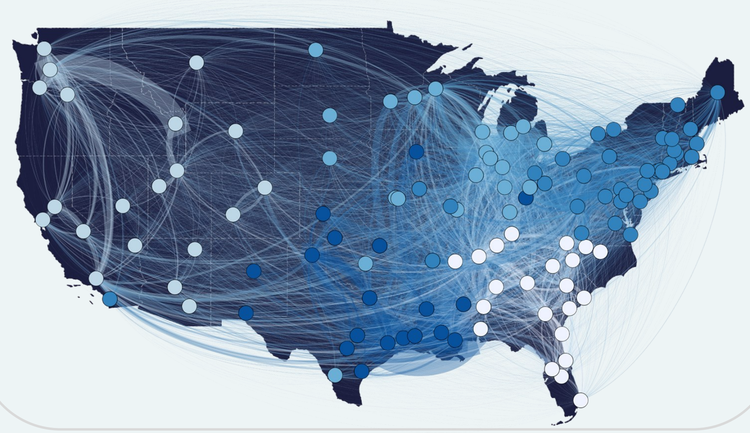
SCGT: Standard Classification of Transported Goods

3 Using the U.S. network of commodity flows and their associated virtual water content, we use network theory to analyze topological properties of virtual water flows for major U.S. cities.

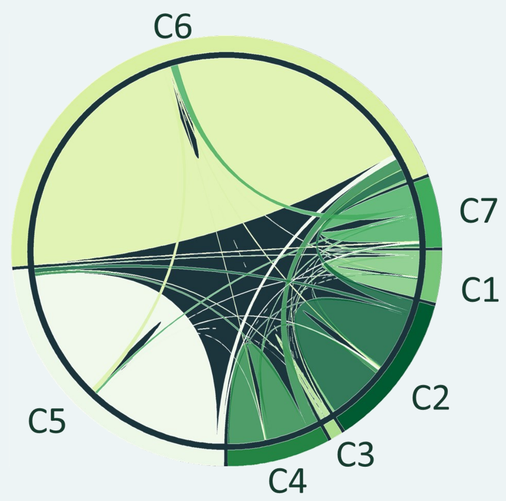
Agricultural & Livestock Network



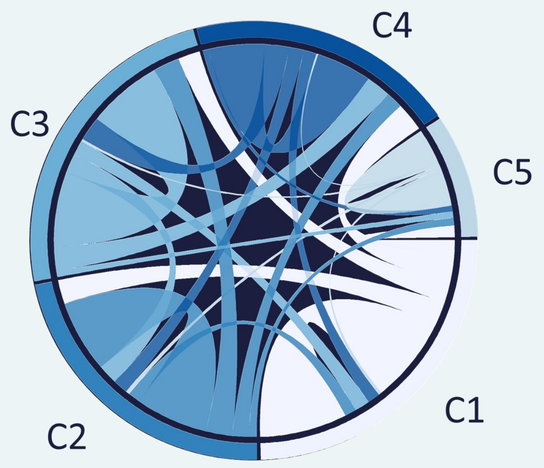
Industrial Network



Network is composed of **65 cities, 33 remainders of state, and 17 full states**. They are represented as **nodes** and **weighted directed links**, symbolizing the **volume** and **direction** of the virtual water flows associated with the transfer of agricultural, livestock and industrial commodities.



Communities of cities (megaregions) with strong interdependencies are detected in the topological analysis of the network.



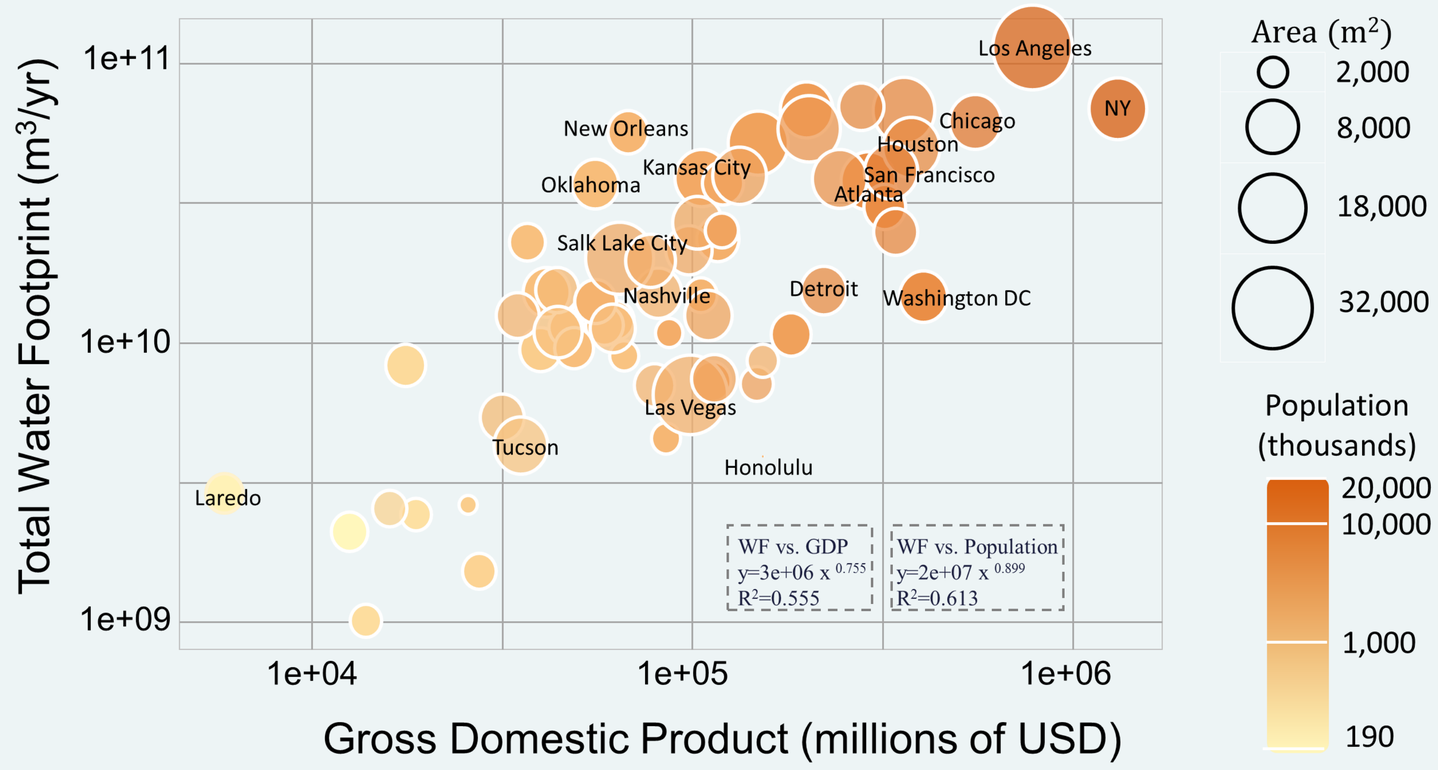
Agricultural Network Topology

- **Cities have greater out-degree** than remainders of states.
- **Nebraska, Iowa, Texas, and Kansas** have the greatest **weighted (in and out) degree.**
- **Cities are strongly connected**. Remainders of states and full states are weakly connected.

Industrial Network Topology

- **Strongly connected**
- **Homogeneous degree distribution**.
- Cities of **Houston, New Orleans, and Chicago** have the greatest **weighted (in and out) degree**.
- Cities of **Chicago and Los Angeles** are detected as "**hubs**" based on centrality measures.

4 Total Water footprint (TWF) scales sublinearly with population and GDP indicating that per capita TWF declines as urban population increases and economic productivity of water increases with GDP



5 Water footprint is dominated by agricultural and livestock commodities, and by indirect water use (virtual water). The topological analysis of the network shows the formation of megaregions and hubs. Future work will involve the analysis of a dynamic network and possible cascading effects due to stressors.

References

[1] W. Paterson, R. Rushforth, B. Ruddell, M. Konar, I. Ahams, J. Gironás, A. Mijic, and A. Mejia, "Water Footprint of Cities: A Review and Suggestions for Future Research," *Sustainability*, vol. 7, no. 7, pp. 8461–8490, Jun. 2015.

[2] Q. Dang, X. Lin, and M. Konar, "Agricultural virtual water flows within the United States," *Water Resour. Res.*, vol. 51, no. 2, pp. 973–986, Feb. 2015.

[3] Icons by flaticon.com and freepik.com

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