Network Analysis for Watershed Management

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Introduction

Lake Champlain is surrounded by three agricultural regions (Vermont, New York and Quebec) and is negatively affected by **agricultural runoff** ⟹ Nutrients (**phosphorus and nitrogen**) are transported from the land, into rivers and ultimately to the lake.

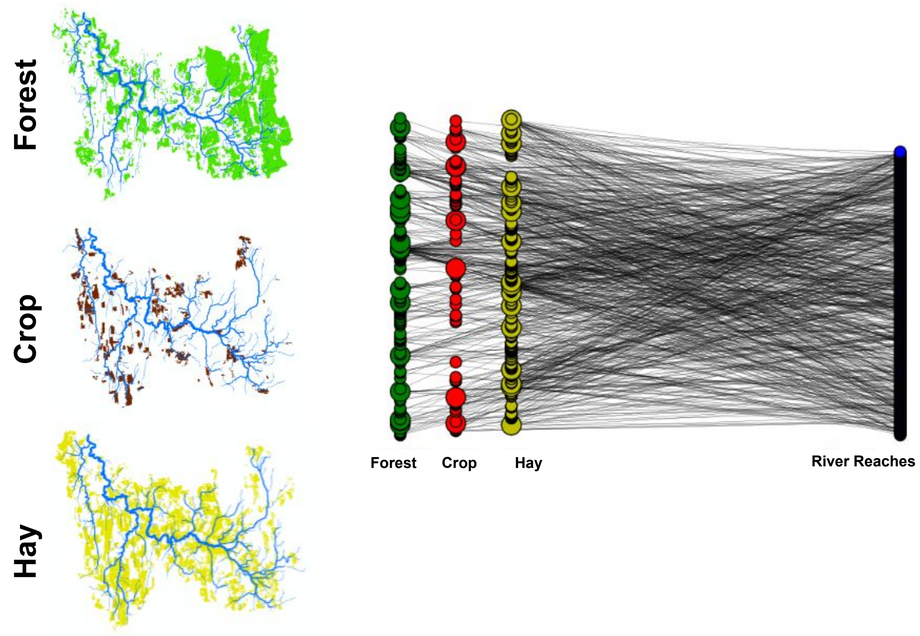
Excessive nutrient loading in water is bad and can cause **algal blooms** ⟹ disrupting recreation, causing fish die-offs, decreasing biodiversity, & releasing toxins that can cause illness.

This is a global challenge. Surveys show excessive nutrients in lakes globally: 45% in the Americas, 54% in Asia, 53% in Europe, and 28% in Africa. **Collecting water quality data** is ⟹ **expensive** and time and labor **intensive.**

Network analysis techniques may help to:

- **identify hotspots** to target for **data collection**
- **prioritize conservation** by layering additional goals and considerations

Bipartite Network: LaPlatte River Watershed



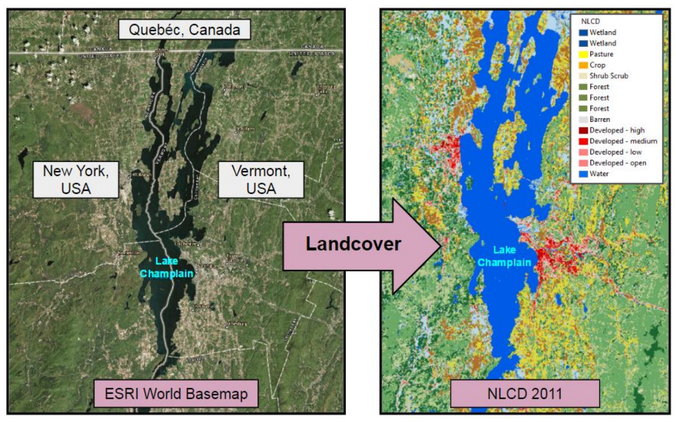
- Each NLCD land cover patch is represented as a node.
- Land nodes connect to river nodes if the land patch spatially intersects that river reach.
- Node size is based on a threshold of 40 hectares: large patches correspond to larger nodes.

Set Up: Landcover and Nutrients

Land use and land cover are determinants of nutrient export and subsequent loading in rivers and lakes. The Lake Champlain Basin Program[1] uses this equation:

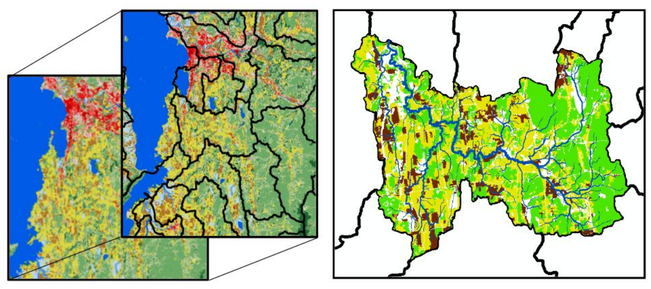
TLD = ECK * A

TLD = total annual load for a cell (kg)
ECK = export coefficient for land use K
A = area of cell (constant of 0.09 ha)



Certain land types export more nutrients than others[2]. For this study, three NLCD land cover types were used. **Cropland** and **Hay/Pastureland** are two of the land types that have the highest nutrient export coefficients. **Forests** export much less and can even serve to lessen runoff when present along rivers as riparian buffer zones.

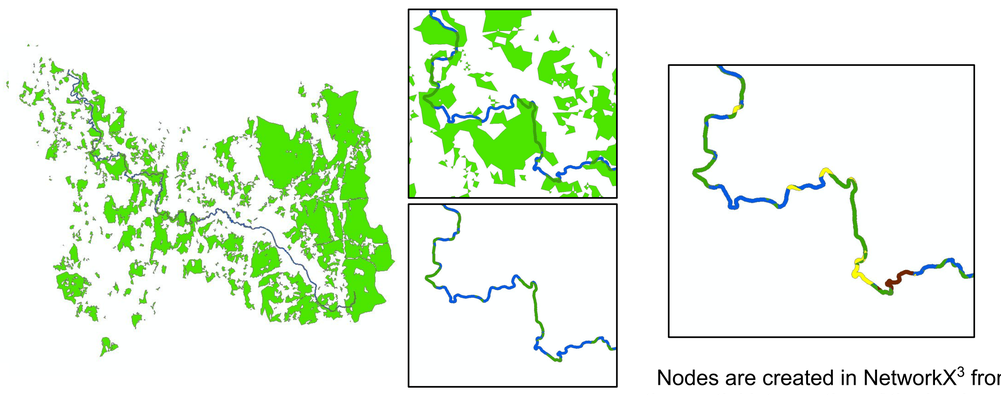
Study Site: LaPlatte Watershed



The LaPlatte Watershed is comprised of 727 river reaches, distinct segments identified by unique "reach codes".

This river network is 281,943m and drains a total area of 145 km2.

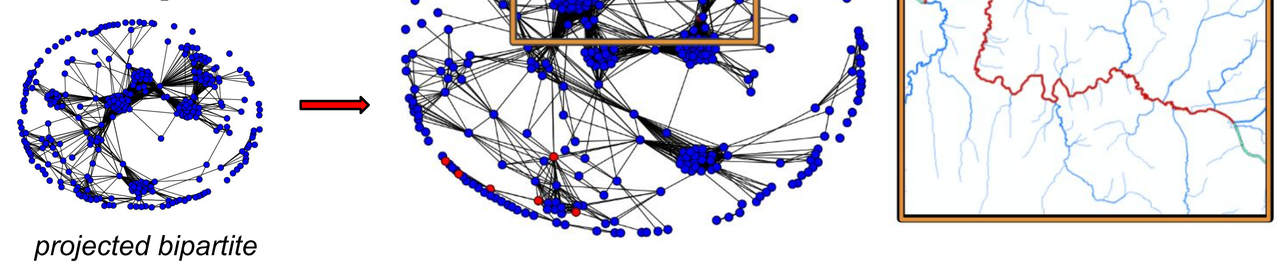
Network: Creating Nodes & Edges



Nodes are created in NetworkX[3] from the spatial intersection of the land cover patches and the river.

Network Analysis: Prioritizing Conservation

River Reach Hotspots

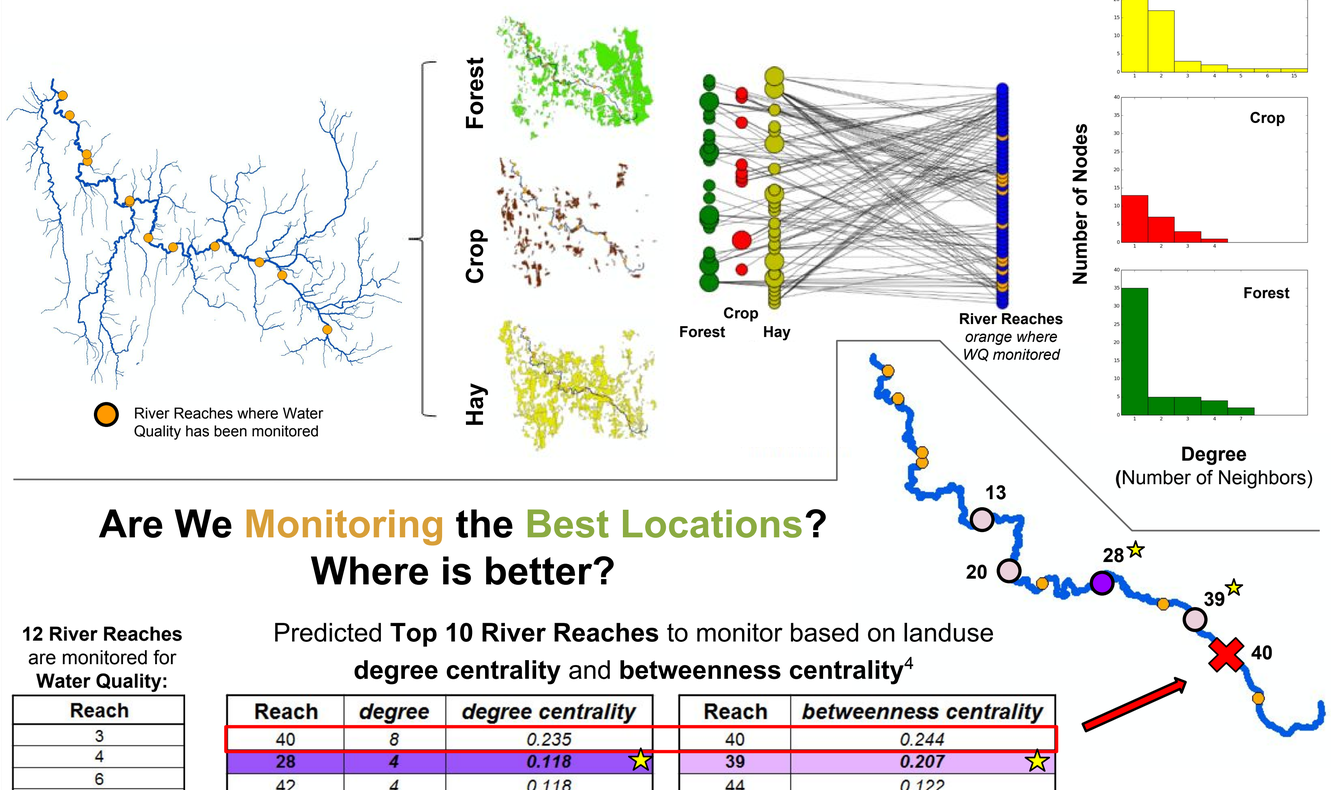


projected bipartite network of river nodes

detecting the major river reaches in the network

Major Reaches: LaPlatte River

A subset of the full watershed, this network represents land patches that intersect reaches in the LaPlatte River. **Orange points** = 12 water quality monitoring points



Are We Monitoring the Best Locations? Where is better?

12 River Reaches are monitored for **Water Quality:**

Reach
3
4
6
8
13
20
21
28 ★
35
39 ★
48

Predicted **Top 10 River Reaches** to monitor based on landuse **degree centrality** and **betweenness centrality**[4]

Reach	*degree*	*degree centrality*
40	*8*	*0.235*
28 ★	***4***	***0.118***
42	*4*	*0.118*
12	*4*	*0.118*
43	*3*	*0.088*
20	***3***	***0.088***
44	*3*	*0.088*
13	***3***	***0.088***
11	*3*	*0.088*
37	*3*	*0.088*

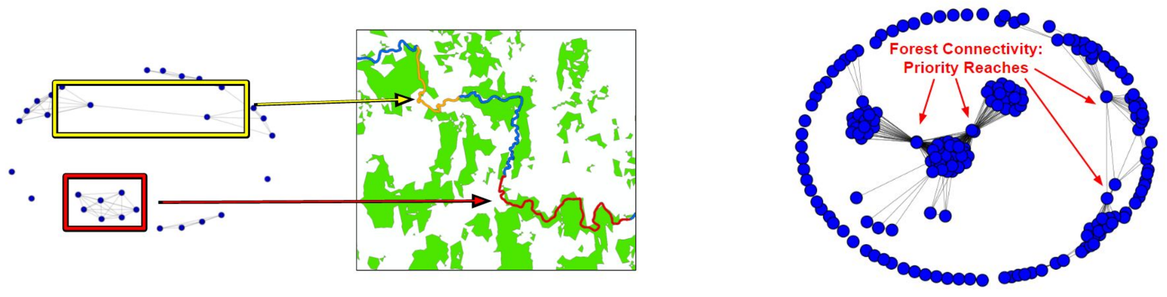
Reach	*betweenness centrality*
40	*0.244*
39 ★	***0.207***
44	*0.122*
28 ★	***0.069***
46	*0.067*
42	*0.024*
37	*0.022*
12	*0.016*
11	*0.016*
43	*0.013*

★ *The Top 2* ***highest Nutrient Loading Averages*** *were observed at these reaches*

*Reaches are highlighted if they are both **1.** monitored for water quality and **2.** predicted to be a top node to monitor in the network*

Future Work: *Forest Connectivity*

Select river reaches for high nutrient loading potential, then add Forest Connectivity objectives: Which reach is best to focus mitigation efforts (E.g. riparian forests) to reduce nutrient loading and to connect forest ecosystems.



Conclusions

- **Network metrics are useful** to explore a wide range of challenges in natural resource management and environment
- Landscape management goals **may be easier to layer and assess quickly in NetworkX** than with more specialized network tools
- **Layering of conservation priority areas is important** given:
  - Spatial extent of **natural resource challenges**
  - **Money and time it takes to sample** for water quality, and other natural resource indicators - **priority areas help to target places for more in depth monitoring**

References: **1.** Austin Troy, Deane Wang, David Capen, 2007 Updating the Lake Champlain Basin Land Use Data to Improve Prediction of Phosphorus Loading, Lake Champlain Basin Program Technical Report 55 **2.** EPA TMDL: Phosphorus Tmdls Vermont Segments Lake Champlain, 2015 **3.** Hagberg, A., Schult, D.A. and Swart, P.J. "Exploring network structure, dynamics, and function using NetworkX", in Proceedings of the 7th Python in Science Conference (SciPy2008), Gäel Varoquaux, Travis Vaught, and Jarrod Millman (Eds), (Pasadena, CA USA), pp. 11–15, Aug 2008 **4.** MEJ Newman, 2010 Networks: An Introduction, Oxford University Press