Nature's Value in Reducing Flood Risk

Environmental Justice Dialogue on Flood Risk, Vulnerability, Resilience Capacity Analysis of the Upper Mississippi River Basin (UMRB)

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Saint Paul Minnesota

Institute on the Environment University of Minnesota Driven to Discover℠

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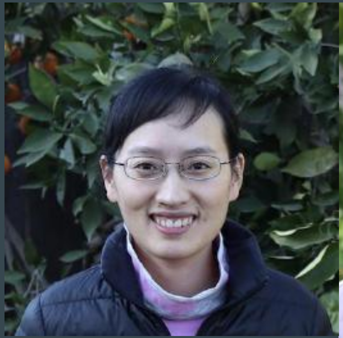

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Nature's value in reducing flood risk impacts in the Upper Mississippi River Basin

Background

Current and projected floods area and will adversely impact lives, livelihoods, community resilience, ecosystems, and the services they provide.

GOALS:

1. Assess and develop an index to identify flood risk hotspot locations.
2. Quantify the benefits of nature-based adaptation solutions within hotspots.
3. Collaborate with at-risk community members to co-develop a climate action plan.

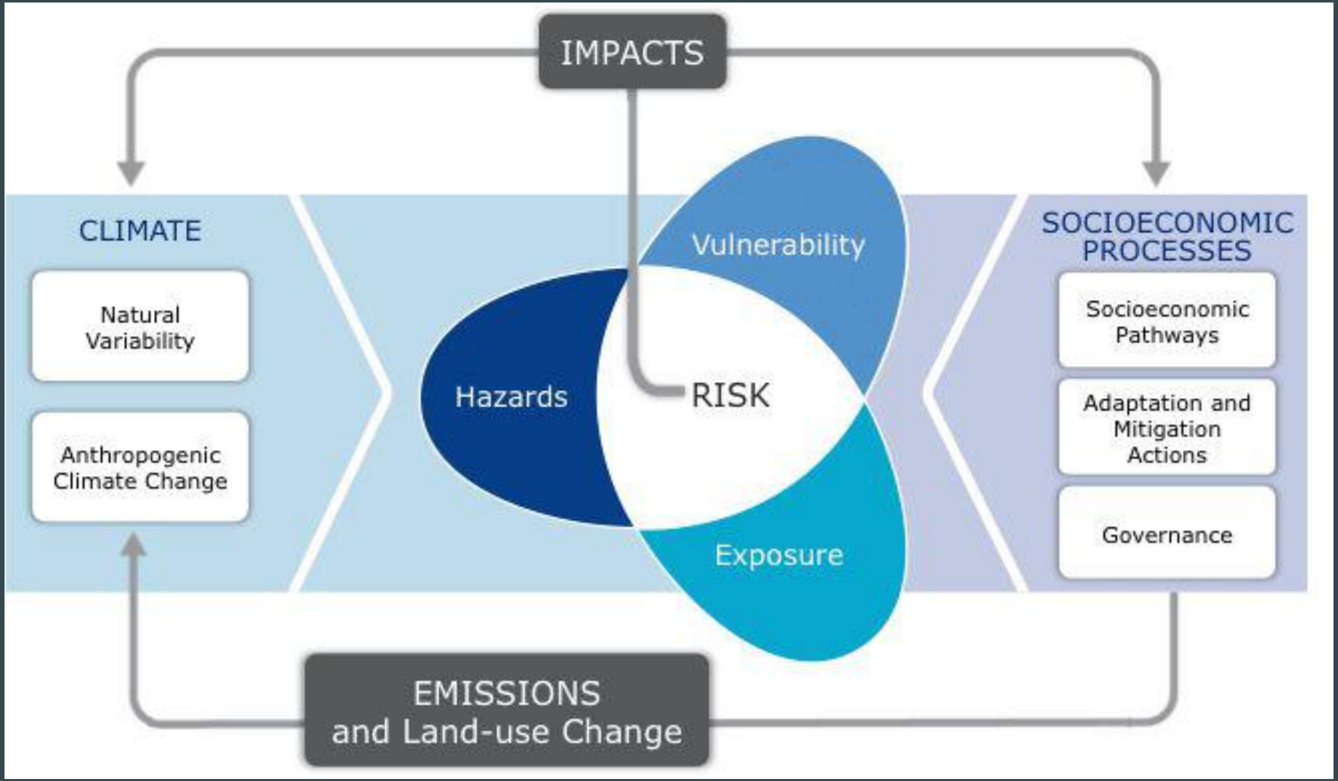
PI: Nfamara K Dampha (UMN)

Timeline: 2 years

Nature-based solutions may reduce flood risk in the Upper Mississippi River Basin, especially for at-risk communities.

Partners: Rainbow Research, Institute on the Environment, St. Anthony Falls Lab, Natural Capital Insights, USGS, UMN-Duluth

IPCC- Risk Analysis Approach Framework



INFORM RISK:

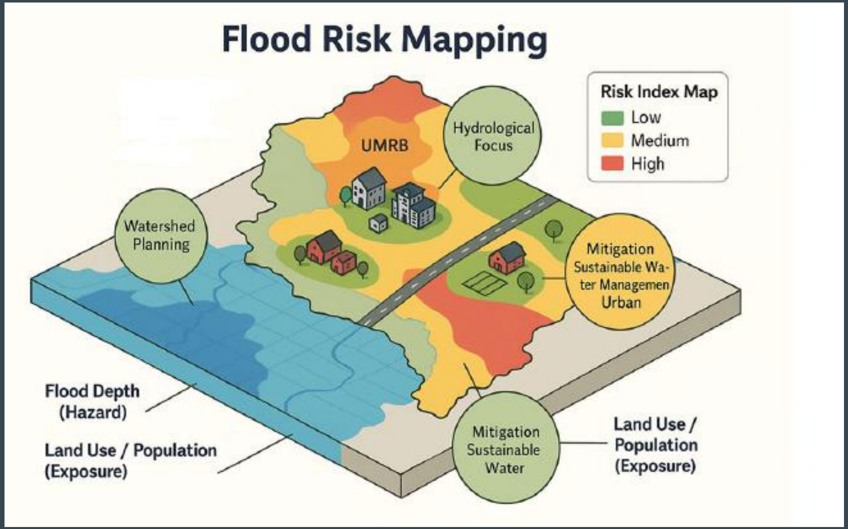
$$Risk = Hazard\&Exposure^{1/3} \times Vulnerability^{1/3} \times Lack\ of\ coping\ capacity^{1/3}$$

It is a multiplicative equation. The risk equals zero if one of the three dimensions above is zero.

What is Flood Risk Mapping?

- **Flood Hazard** : probability and intensity of flooding (e.g., 0.1 - 3+ meters)
- **Exposure** : people, buildings, infrastructure, land use
- **Vulnerability** : Sensitivity of those exposed
- **Flood Risk** : Hazard (What could happen) * Exposure (Who) * Vulnerability (What is affected)

- Used to prioritize planning, mitigation, adaptation, and emergency response zones



Credit: ChatGPT

Purpose for Decision Making

- Flood risk maps are used to identify hotspots/flood prone areas
- Support flood early warning systems and evacuation planning
- Guide equitable infrastructure investments
- Critical for climate adaptation and risk reduction

MAY 3, 2023: Floodwater from the Mississippi River surrounds homes and covers streets in Rapids City, Illinois. (Video by Scott Olson/Getty Images)

Downtown Davenport, Iowa

Floodwater from the Mississippi River inundates the riverfront section of downtown on May 02, 2023 in Davenport, Iowa. (Photo by Scott Olson/Getty Images)

Flood Hazard Modeling

Two Spatial Scopes:

1. Upper Mississippi River Basin (UMRB)

Purpose: Riverine flood hazard modeling and 'Hot Spot' identification

2. Smaller Case Studies (***2-3, urban and rural*** **)**

Purpose: More detailed pluvial flood risk assessment (including urban flash flooding) and Community engagement (St. Paul)

Riverine Flood Hazard Modeling for UMRB Scale

1. Flood Hazard Exposure

Method: Height Above Nearest Drainage (HAND)

Output: Flood hazard maps for various return period based on past or future streamflow (likelihood)

2. Flood Risk Impacts (Historical Damage)

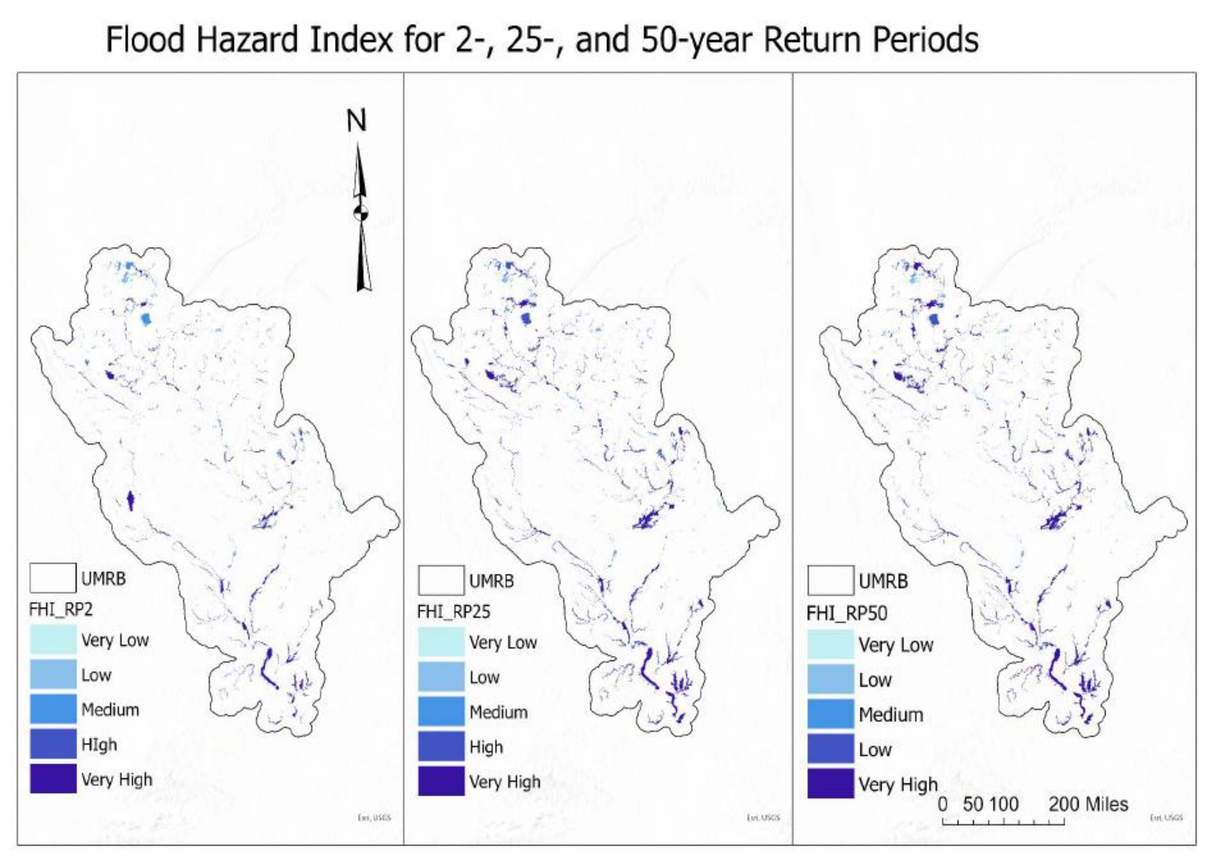
Method: FEMA National Risk Index

Output: Expected Annual Loss for buildings, agriculture land, and populations

Riverine Flood Hazard Mapping with HAND

- Uses river depth and elevation data to estimate flood depth and extent
- River flooding only (unable to assess urban flash flooding)
- Computationally efficient
  - Less accurate than full hydraulic models
  - Suitable for large spatial scope of UMRB
- NOAA using same approach to produce flood inundation maps across the US
- Future climate and streamflow: from a NOAA-UMN project projecting streamflow across UMRB (2015-2100)

Flood Hazard:

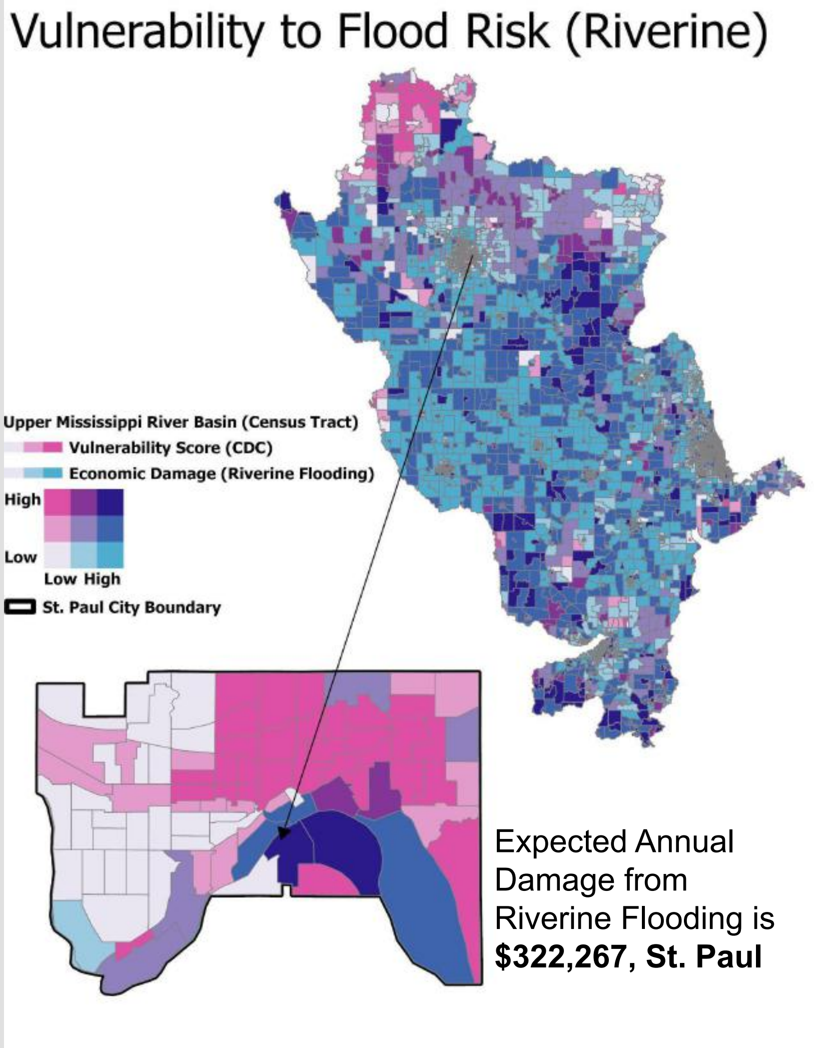


Vulnerability:

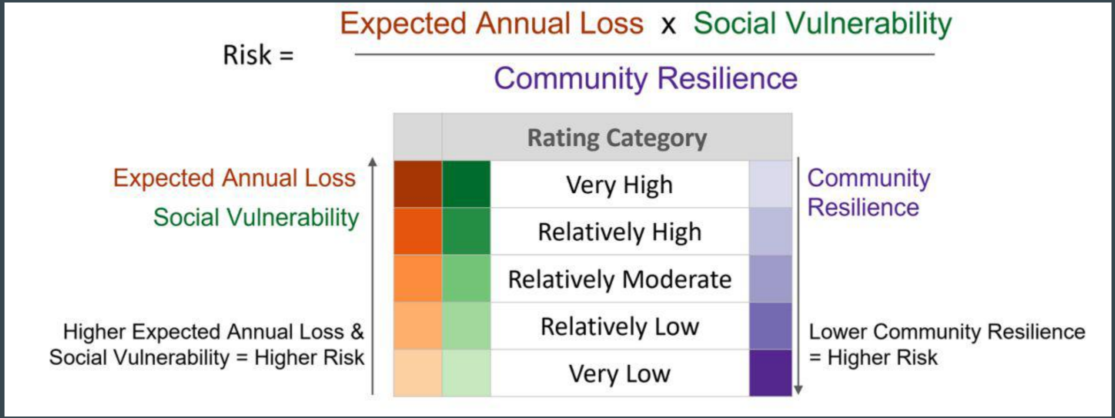
Vulnerability tells us who is at risk and why?
Figure shows a bivariate correlation: :

CDC Social Vulnerability Index (SoVI, 29 Variables)
FEMA National Risk Index (on Expected Annual Loss)

Expected Annual Loss from Riverine Flooding across the entire UMRB is **$ 339.47 million**



FEMA Climate Risk Indexing Approach



AF= probability of a hazard occurrence per year

*A county's **Hazard Loss Ratio (HLR)** could be the simple average of loss ratios (losses divided by exposure) from past hazard occurrences*

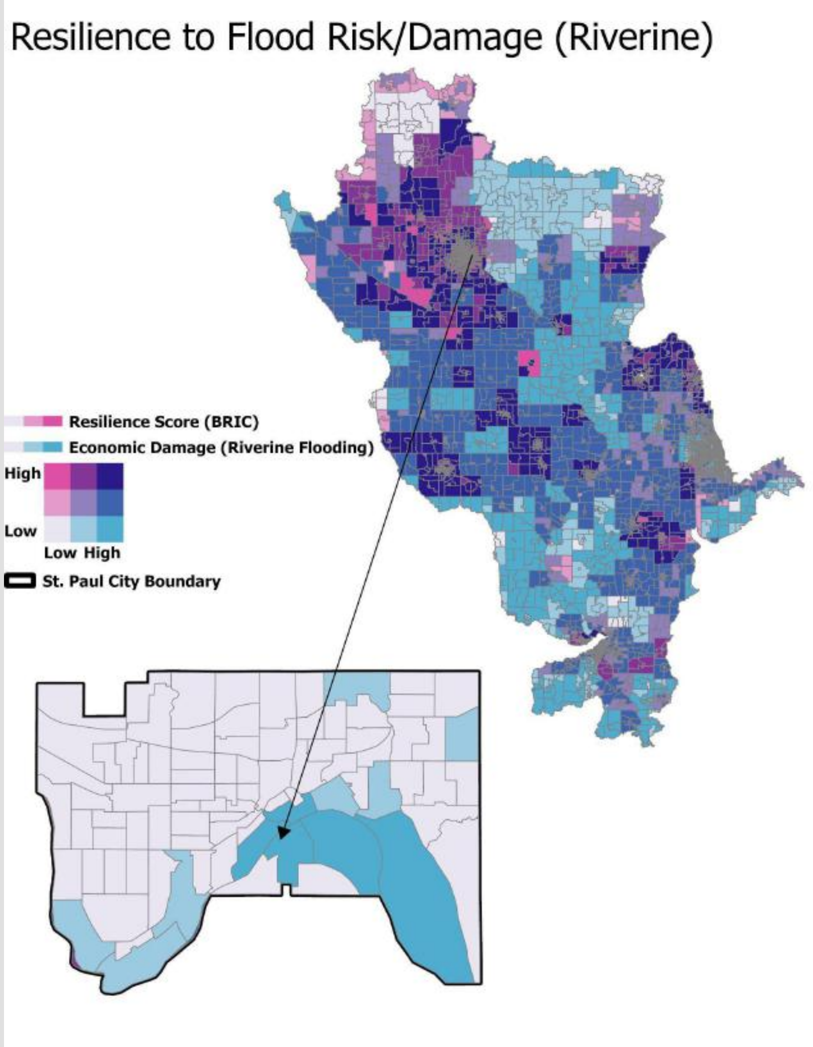
Zuzak et al., 2022

Resilience Capacity

Resilience tell us how well they can cope or bounce back.

Figure shows a bivariate correlation:

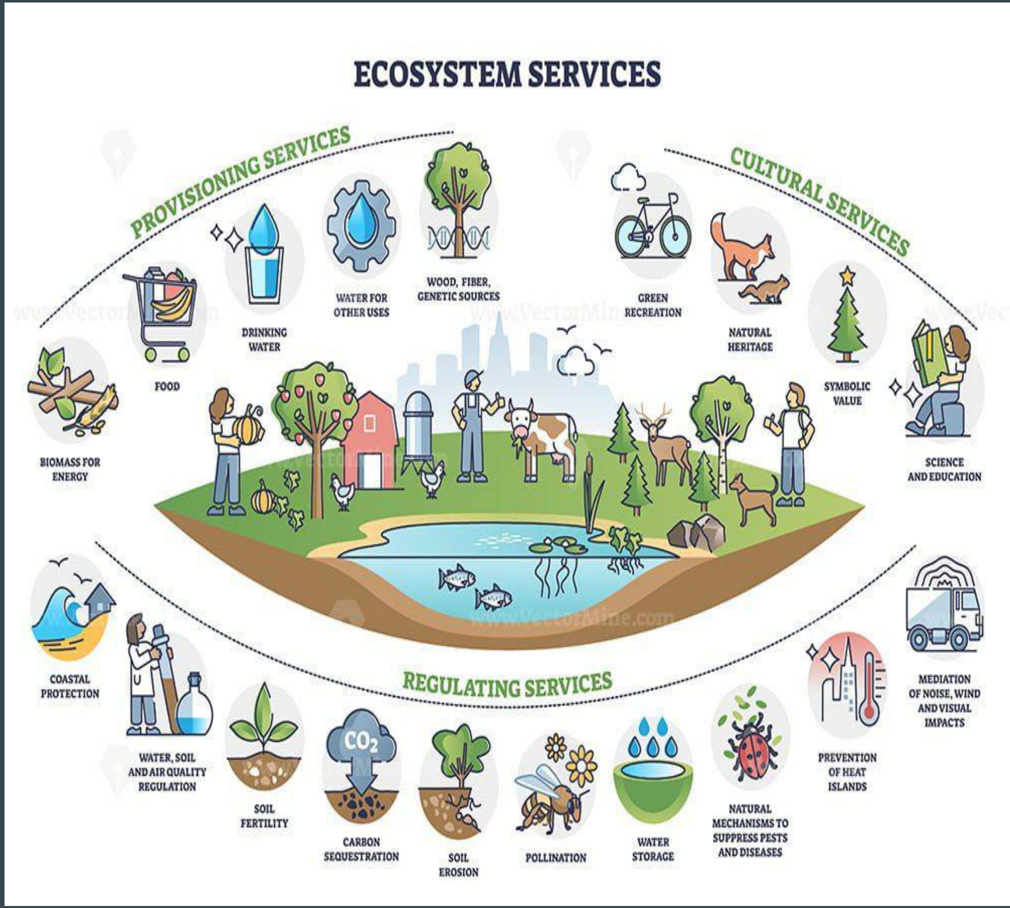
Baseline Resilience Indicators for Communities (49 variable):
FEMA National Risk Index (on Expected Annual Loss)



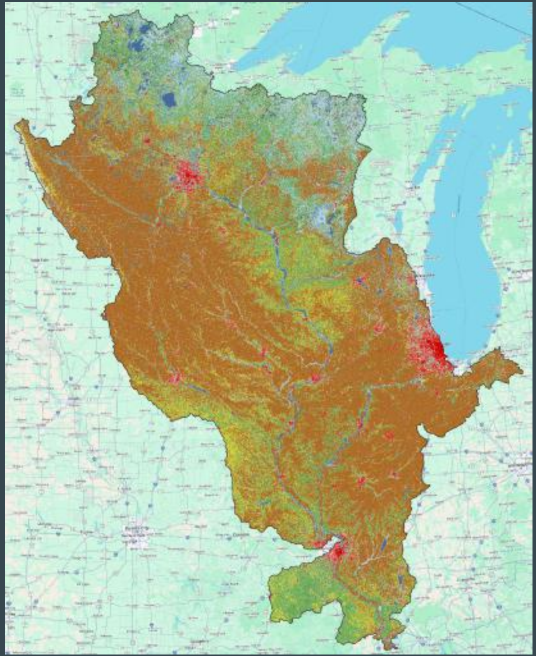
Ecosystem Services Assessment

- Nature's contribution to people

- Six Ecosystem Services:



Carbon Sequestration

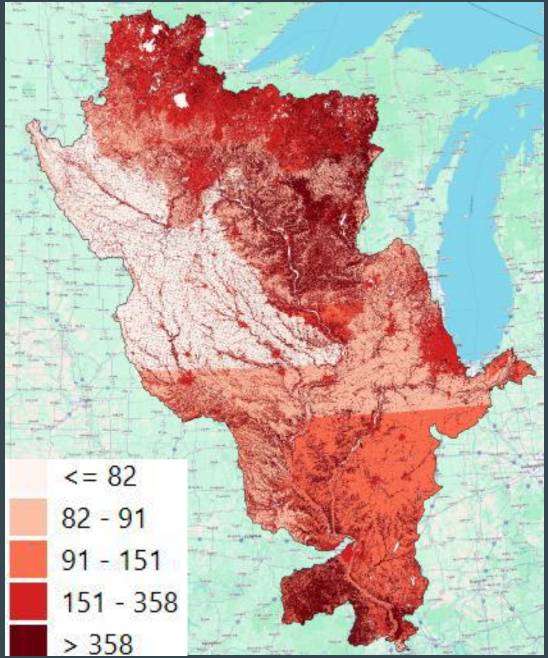


Land Use

Ecoregions

Carbon Sequestration by land type table

Carbon
(tons/ha)



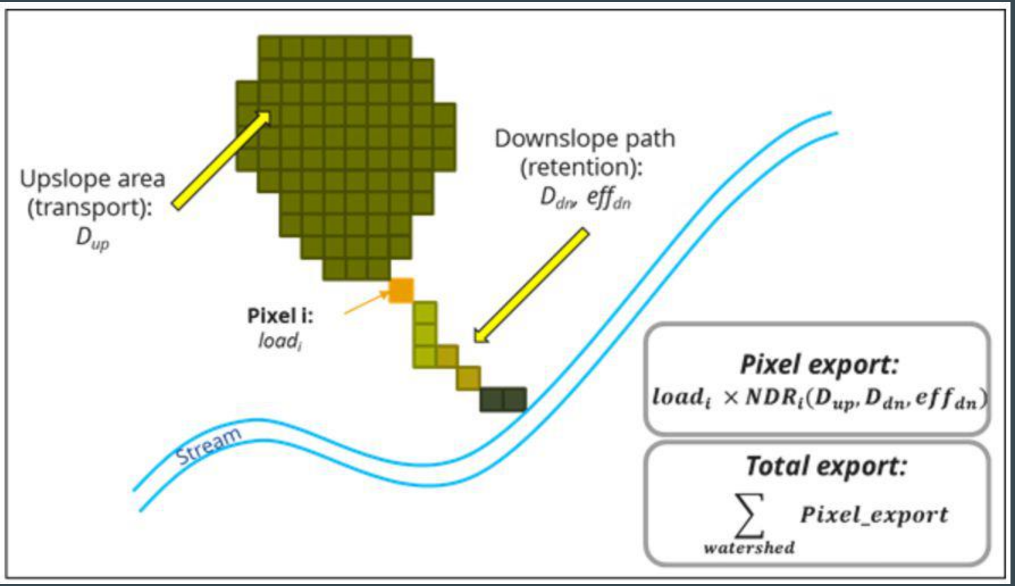
Nutrient Delivery Ratio

Nitrogen
(kg/year)

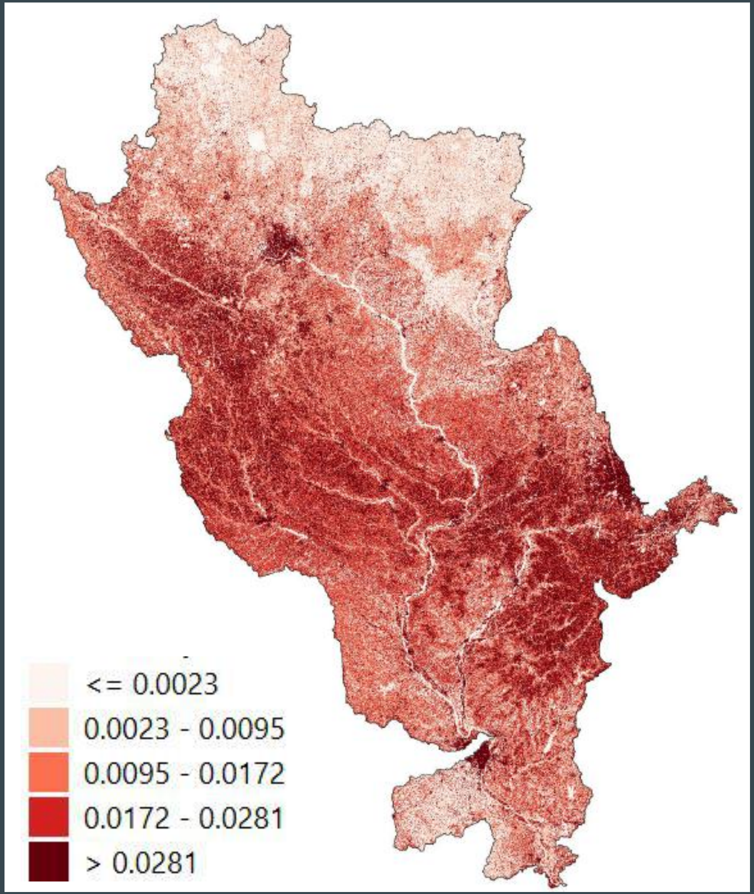
Map nutrient sources from watersheds and their transport to the stream

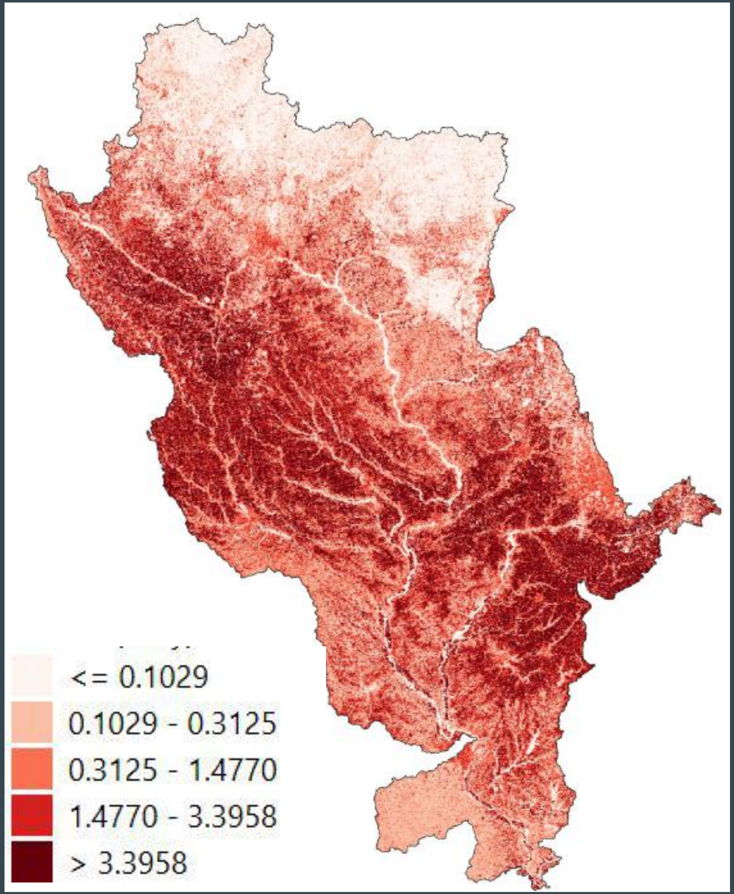
We track Nitrogen and Phosphorus

This has consequences for people, directly affecting their health or well-being (Keeler et al., 2012), and for aquatic ecosystems that have a limited capacity to adapt to these nutrient loads.



Nutrient Delivery Ratio (Results)



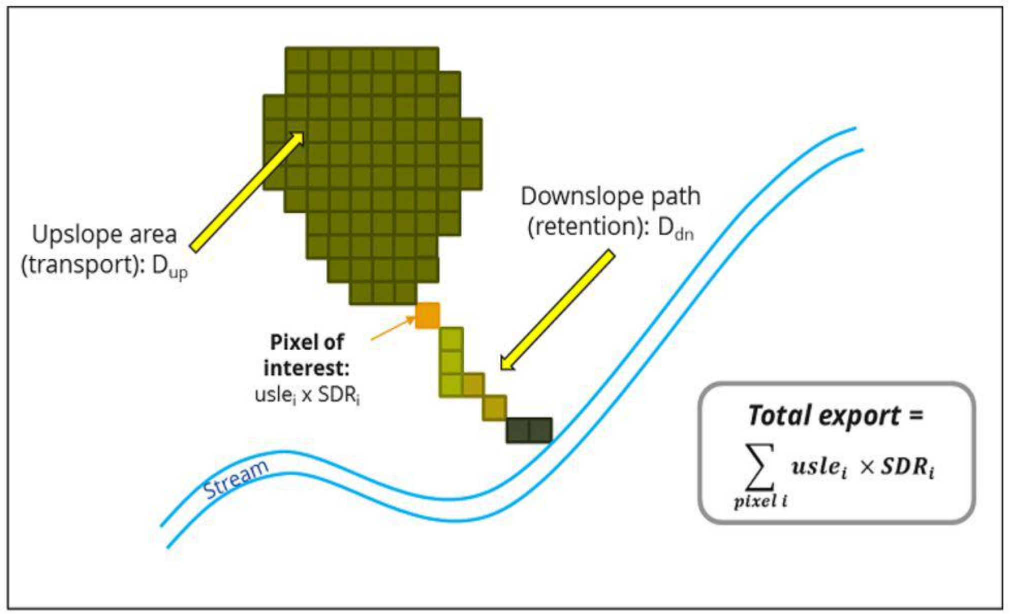


Sediment Delivery Ratio

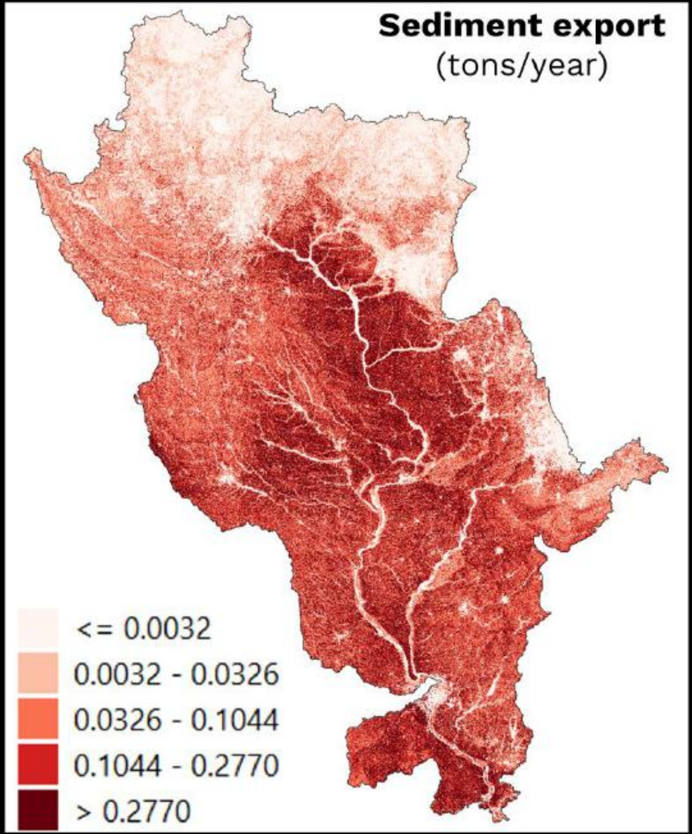
Quantify and map overland sediment generation and delivery to the stream

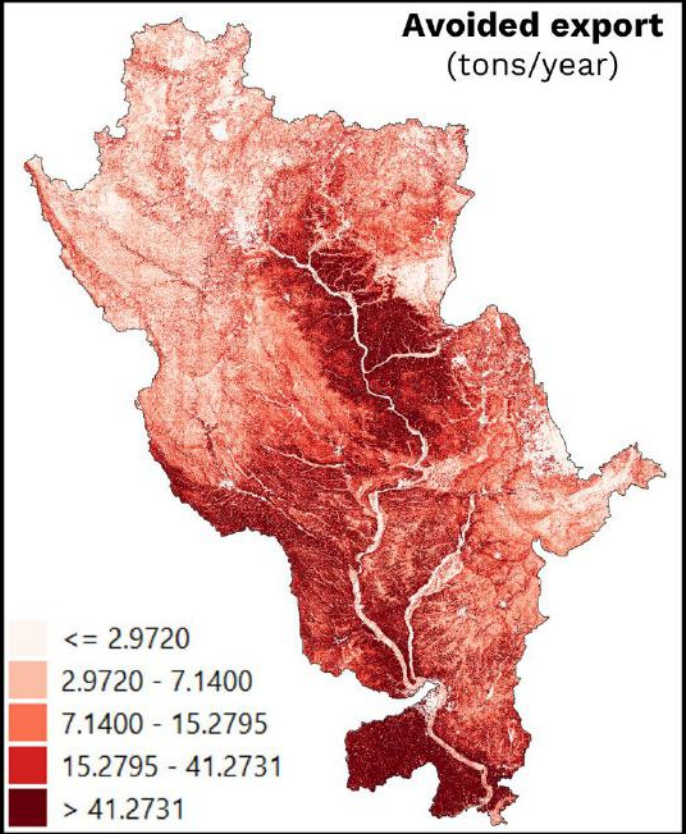
The sediment retention service provided by vegetation is of great interest to water managers and land managers

Changes in sediment load can have impacts on downstream irrigation, water treatment, recreation, and reservoir performance, while soil loss from the land can reduce agricultural productivity.



Sediment Delivery Ratio (Results)



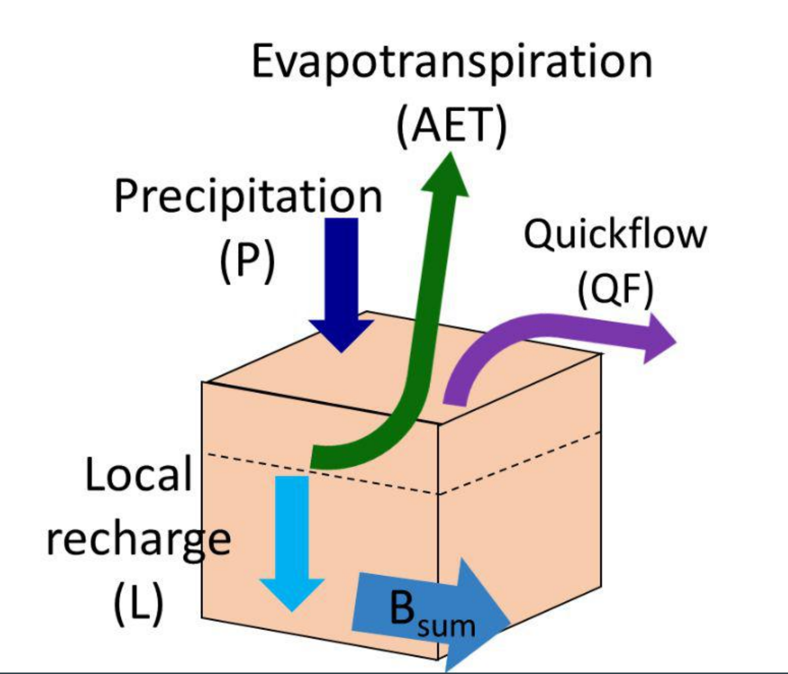


Seasonal Water Yield

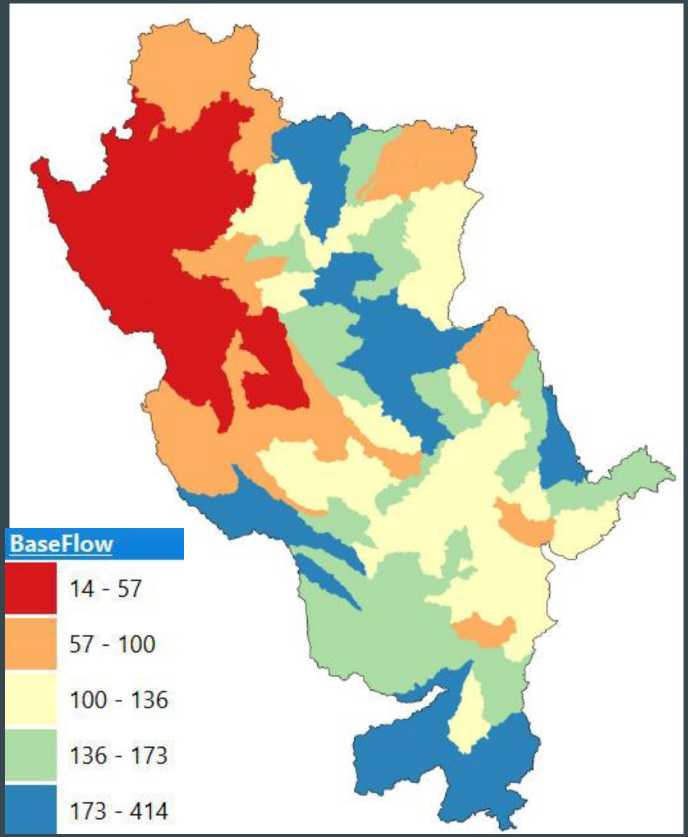
Quantify and map how a catchment contributes to availability of water in the stream.

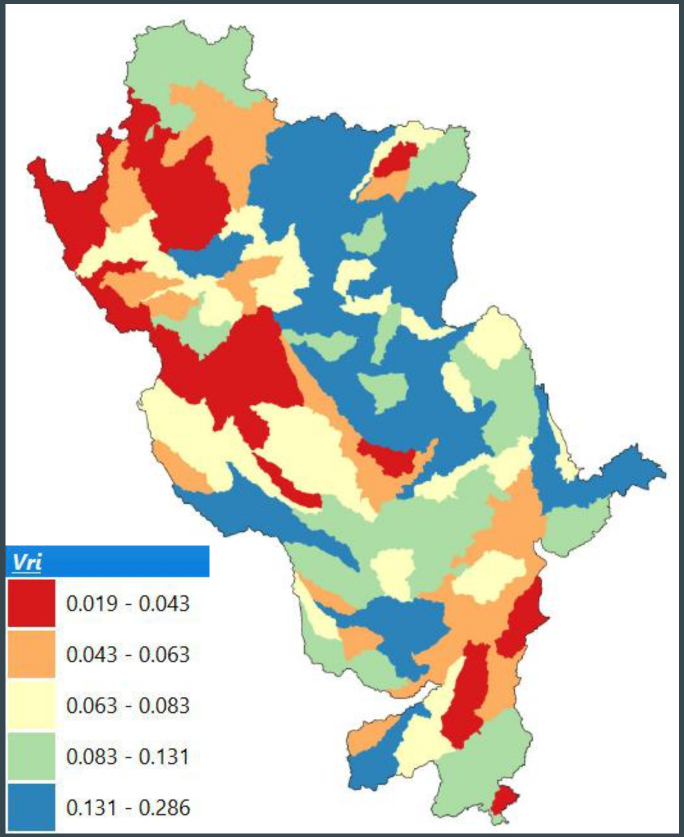
The contribution of a given parcel to streamflow depends on a number of environmental factors including climate, soil, vegetation, slope, and position along the flow path.

Estimating the effect of landscape management on the water supply service, for uses like irrigation, domestic consumption and hydropower production.



Seasonal Water Yield (Results)





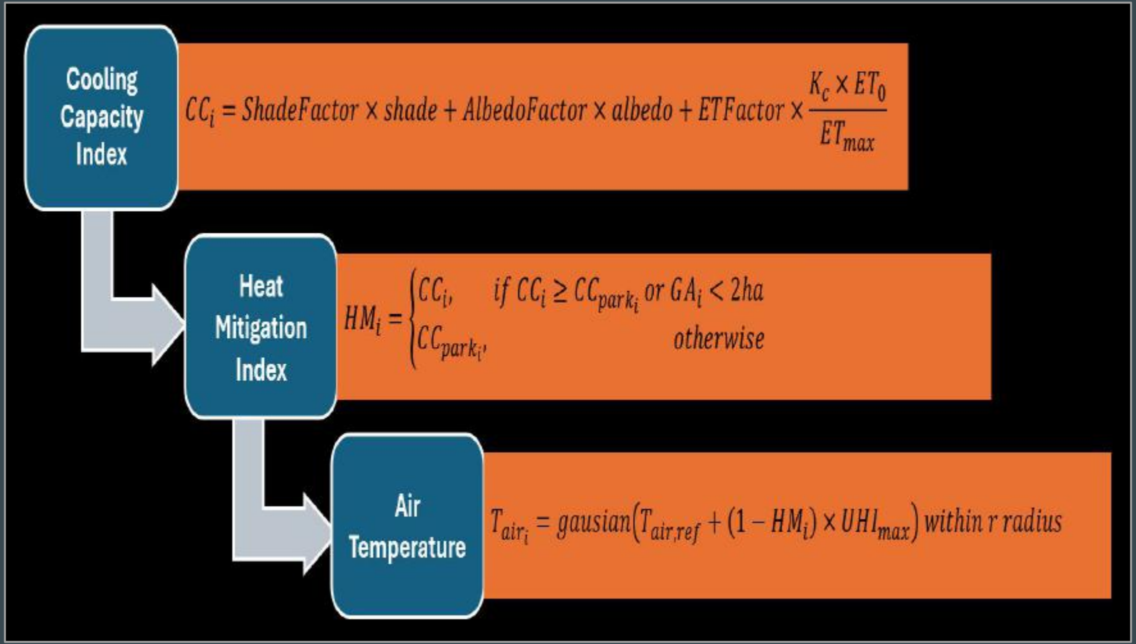
Urban Cooling Model

Temperature
(℃)

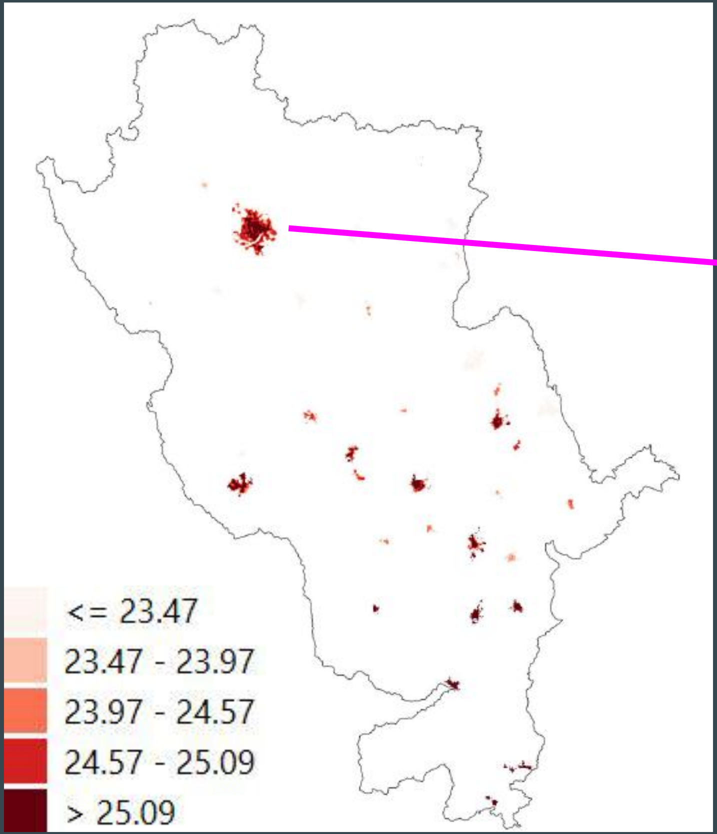
Estimates the cooling effect of vegetation based on commonly available data on climate, land use/land cover (LULC), and (optionally) A/C use.

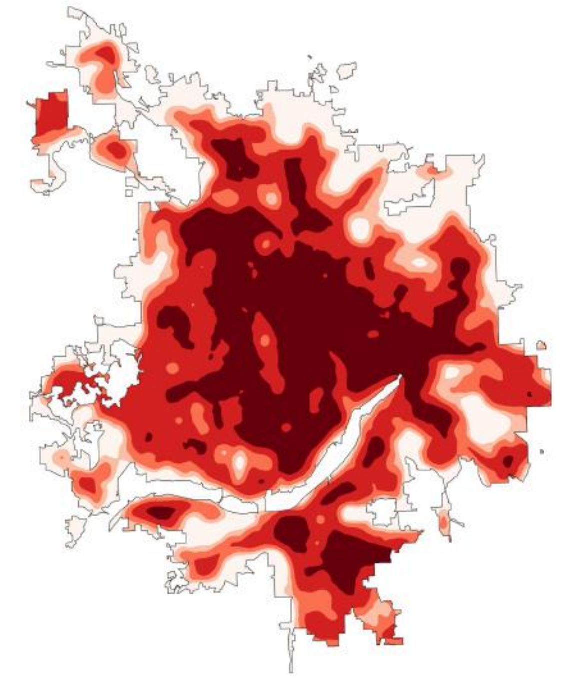
The contribution of a given parcel to streamflow depends on a number of environmental factors including climate, soil, vegetation, slope, and position along the flow path.

This has consequences for the health and wellbeing of citizens through reduced mortality and morbidity, increased comfort and productivity, and the reduced need for air conditioning (A/C).



Urban Cooling Model (result)



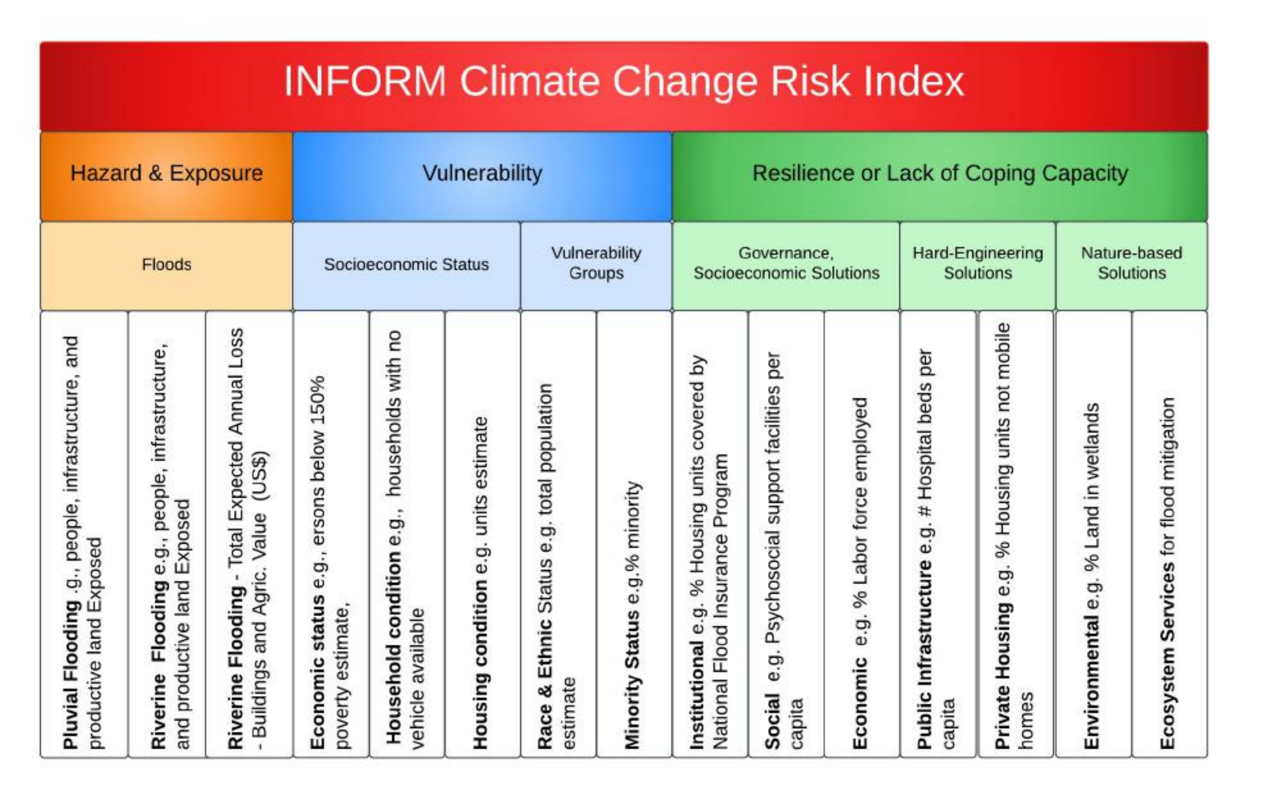


Minneapolis-Saint Paul, MN
Reference temp: 19.5 ℃

Future Collaboration Opportunities/Finishing!

Source: NPCA. Reimagining the Mississippi river

Step 1. Complete the INFORM Flood Risk Index



Step 2. Ecosystem Services Scenario Modeling

1. Now that we have Baseline ES values, we need to develop land-use and land management scenarios to account for changes in values and impacts on various ecosystems, communities, and populations

2. We would like to work with various actors such as land managers, state agencies, to develop feasible scenarios – that could be implemented

3. This allows us to also estimate various **ecosystem service co-benefits** of each management scenario to inform strategic decision making

4. Doing these additional analysis require additional financing, to closely work with partners such as UMRBA/ Americas Watershed Initiative, state agencies to conduct these analysis in 2-3years.

Source: NPCA. Reimagining the Mississippi river

Step 3. INFORM Climate Change Index (Multi-Risk Hotspot Mapping)

INFORM CLIMATE CHANGE RISK INDEX

DIMENSIONS

Hazard and exposure		Vulnerability		Lack of coping capacity	

CATEGORIES

Natural	Human	Socio-economic	Vulnerable groups	Institutional	Infrastructure

COMPONENTS

Natural	Human	Socio-economic	Vulnerable groups	Institutional	Infrastructure
Earthquake, Tsunami, River Flood, Coastal Flood, Cyclone, Drought, Epidemics	Current conflict intensity, Projected conflict risk	Development and deprivation (50%), Inequality (25%), Aid dependency (25%)	Uprooted people Other vulnerable groups	DRR Governance	Communication Physical infrastructure Access to health system

Models & Methodologies

Some of the models & methodologies used by our team:

- **InVEST** Models: Integrated Valuation of Ecosystem Services and Tradeoffs
  - Carbon Storage & Sequestration Model
  - Urban Cooling Model
  - Urban Flood Risk Mitigation Model
  - Urban Nature Access Model
- **HAND** Technique: Height Above Nearest Drainage
- **CADDIES** Framework: Cellular Automata Dual-DraInagE Simulation
- **INFORM** : Index For Risk Management

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Team Researchers Participating in Today’s Discussion:

Nfamara Dampha, PhD, UMN

Philip Adalikwu, PhD, UMN

Heman Das Lohano, PhD, UMN

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Thank you for joining us today!

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