Can Watershed Land Use Legacies Inform Nitrogen Management?

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Project Partners:

- UConn CLEAR (Emily Wilson, Chet Arnold)
- Univ of New Hampshire (Wil Wollheim)
- CT DEEP (Chris Bellucci, Mary Becker)
- USGS (Marty Briggs, Janet Barclay, Dave Bjerklie)
- Footprints in the Water, LLC (Paul Stacey)
- UConn Graduate students: Eric Moore, Adam Haynes, Kevin Jackson, Alaina Bisson

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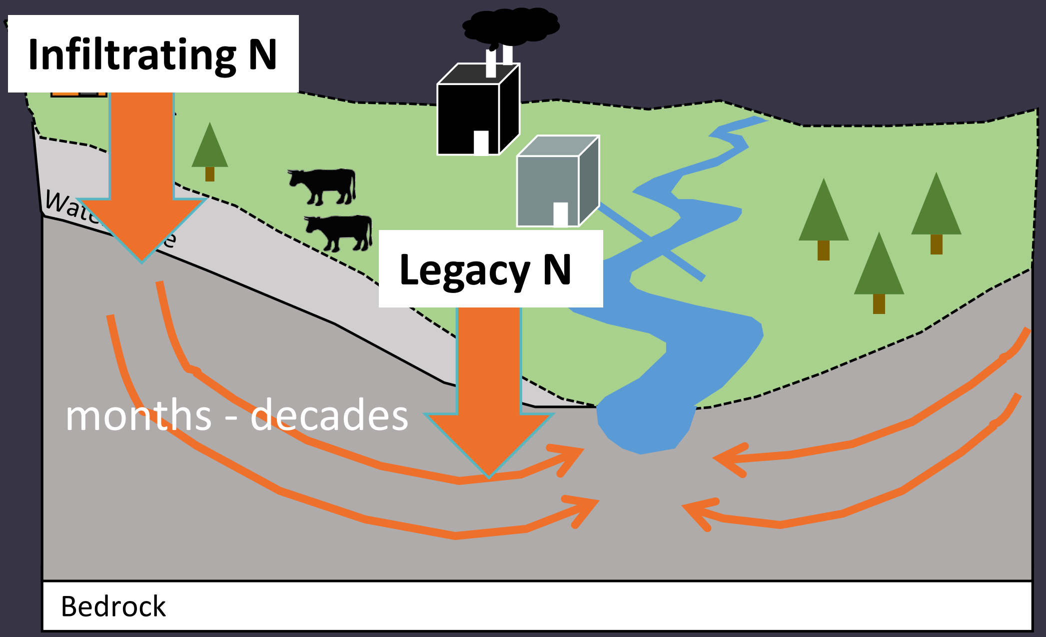
Today's talk

- Some background on legacies
- Evidence for legacies in CT
- Overview of LIS watershed project

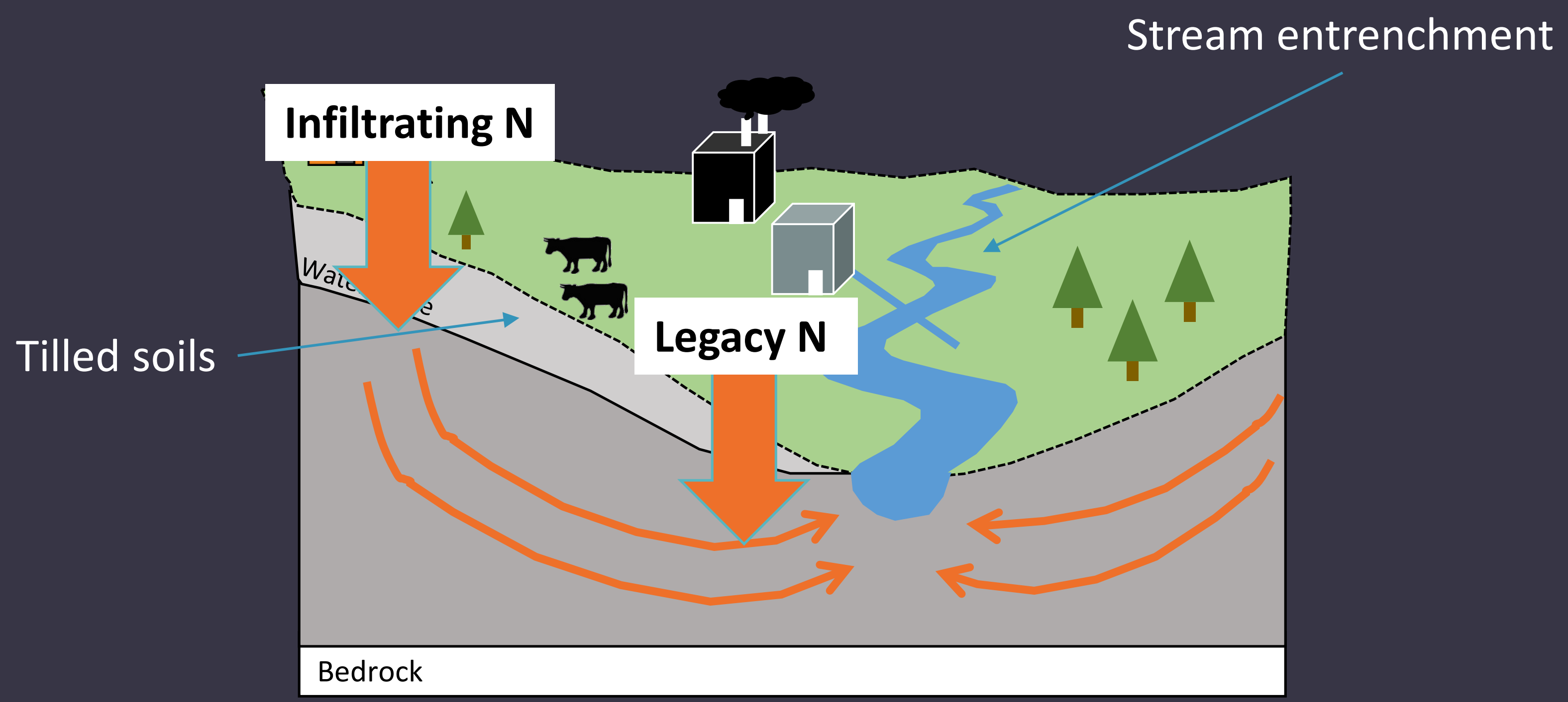
"...most scientists engaged in ecology, conservation, and natural resource management, have come to recognize that site history is embedded in the structure and function of all ecosystems, that environmental history is an integral part of ecological science, and that historical perspectives inform policy development and the management of systems ranging from organisms to the globe…"

- *Foster et al. (2003) The importance of land-use legacies to ecology and conservation. Bioscience, 53(1), 77-88.*

Signal legacies – Nitrogen applied in the past accumulates in soils and groundwater is eventually transported to surface waters

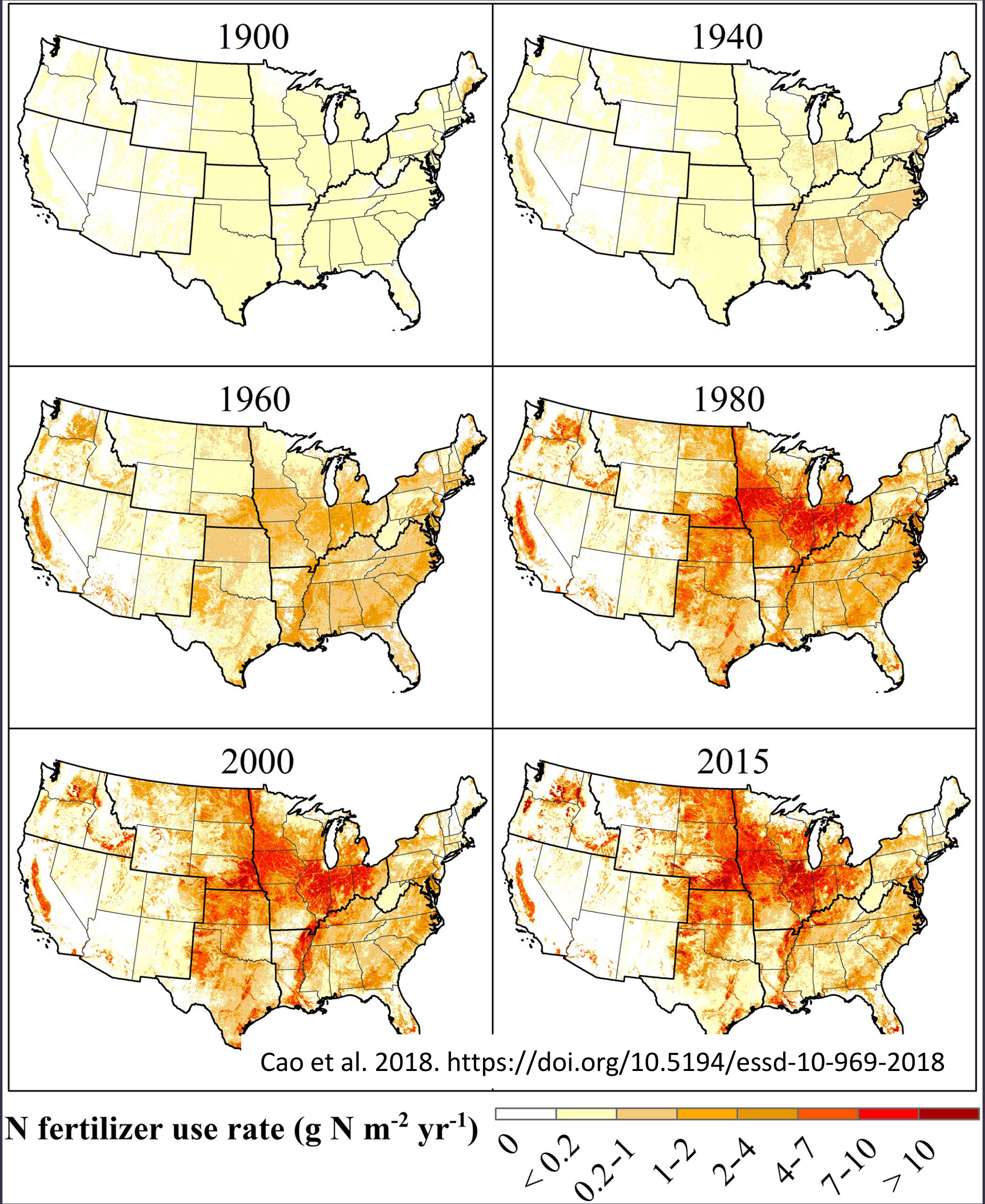


Structural legacies – Alteration of watershed structure can disrupt functions that maintain nitrogen cycling



Most nitrogen legacy research has been on signal legacies in agricultural regions

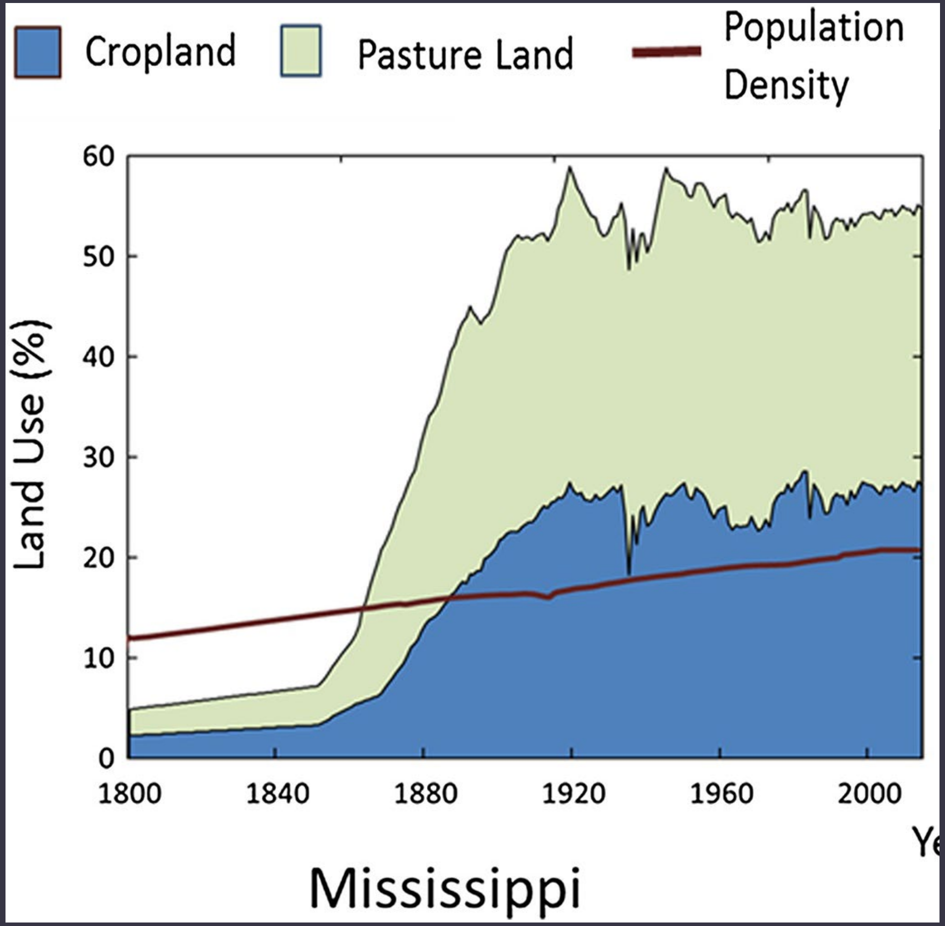
- Mississippi River - 55% of N loads are older than 10 years and even if N inputs were eliminated it would take several decades to achieve the management goal of a 60% load reduction[a,b].
- Chesapeake Bay - 20-40 year groundwater travel times result in lag times of several decades for BMPs to attain the management goal of a 25% load reduction[c].



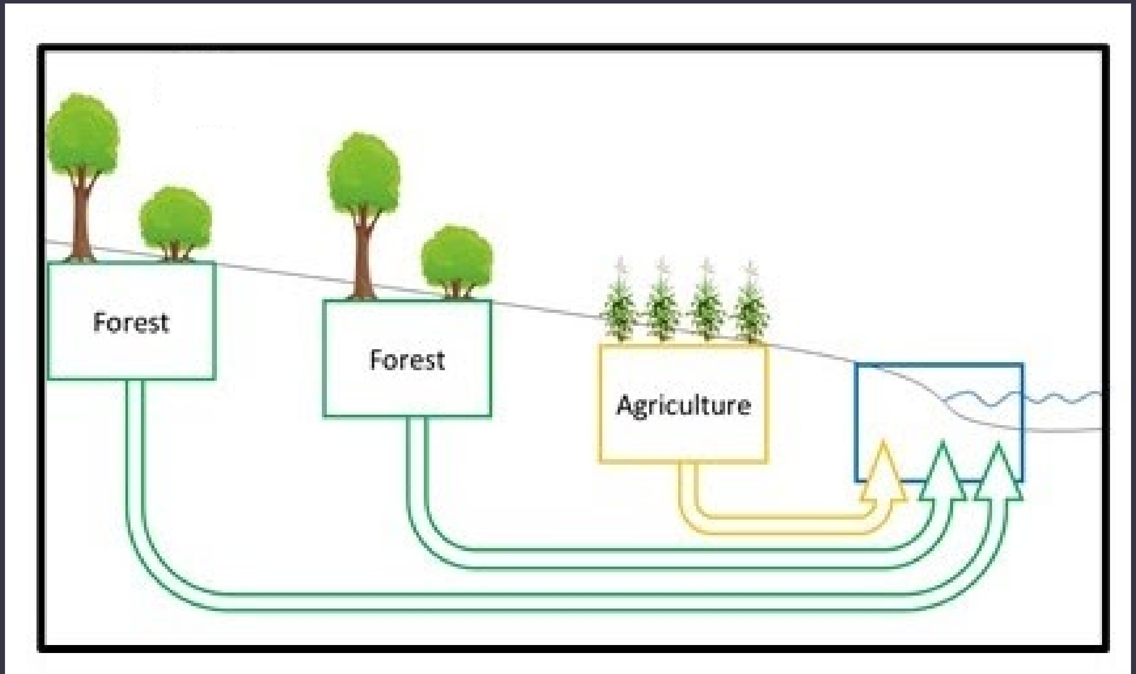
Cao et al. 2018. https://doi.org/10.5194/essd-10-969-2018

a. Van Meter et al. 2017. https://doi.org/10.1088/1748-9326/aa7bf4
b. Van Meter et al. 2018. https://doi.org/10.1126/science.aar4462
c. Sanford and Pope. 2013. https://doi.org/10.1021/es401334k

Land use change & N legacies in agricultural regions

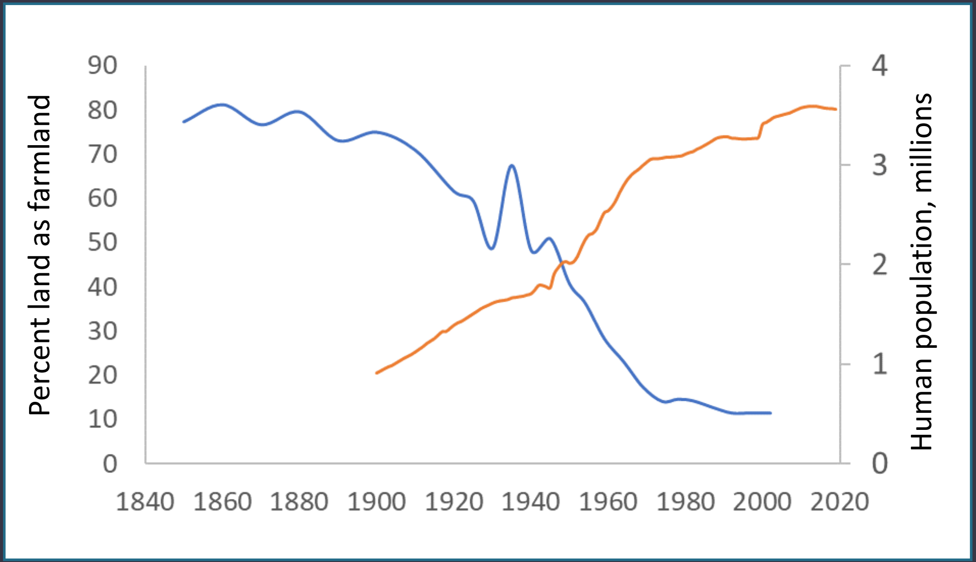


Van Meter et al. 2017. https://doi.org/10.1088/1748-9326/aa7bf4

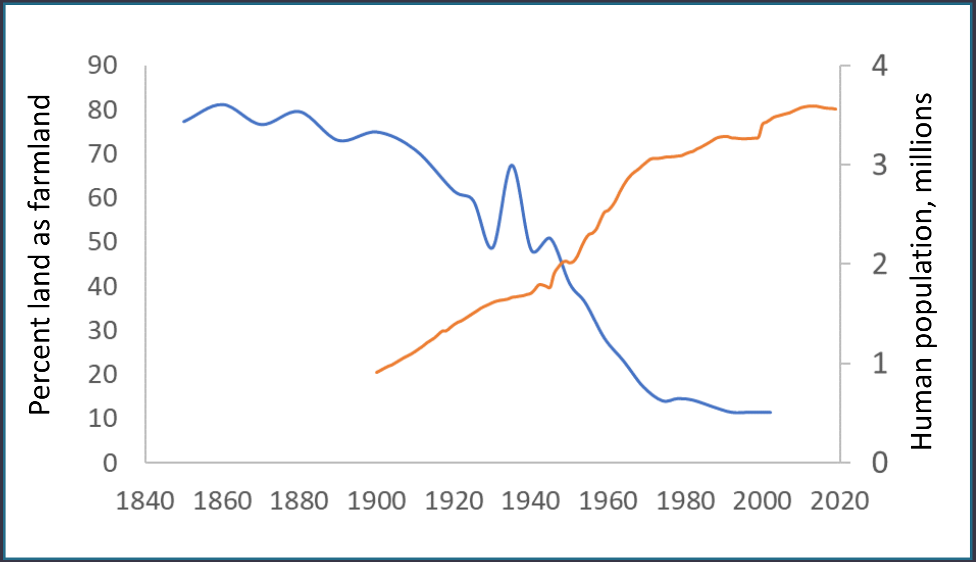


- How have rates of N application changed?
- How long will reduction in N applications or agricultural BMPs take to improve water quality?

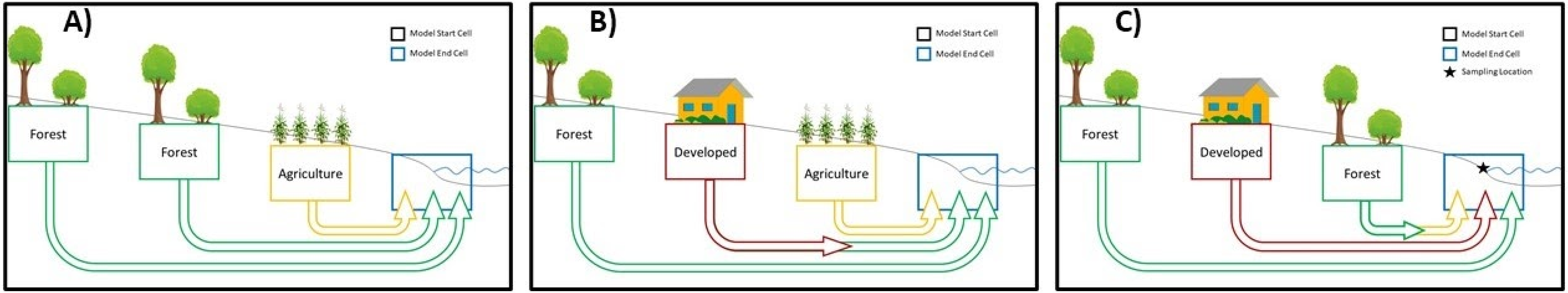
Land use change & water quality legacies in New England



Land use change & water quality legacies in New England



- Groundwater discharge chemistry decoupled in space from its source land use.
- Development plays larger role in N application
- Reforestation -
    - How long does it take for a reforested farm field to "recover"?
    - Do reforested farm fields yield the same water quality benefit as older forests?



1800s 1900s Today

We can clearly see these changes through remote sensing: Connecticut River at border of South Windsor and East Hartford

1934 Aerial Photo

Today

Are land use legacies related to water quality, and can we use those relationships to inform watershed management?

Today's talk

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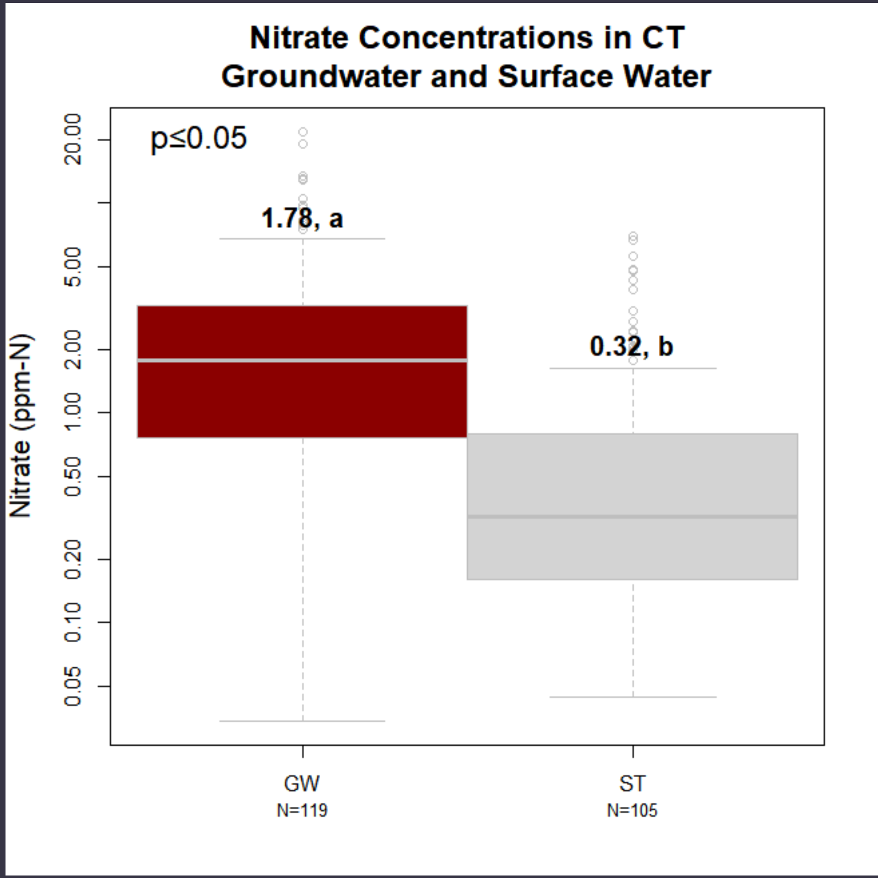
Elevated groundwater nitrogen concentrations

1) Average groundwater N is 4× higher than surface water in CT

2) High rates of N loading from groundwater to streams has been measured in parts of the LIS watershed[a]

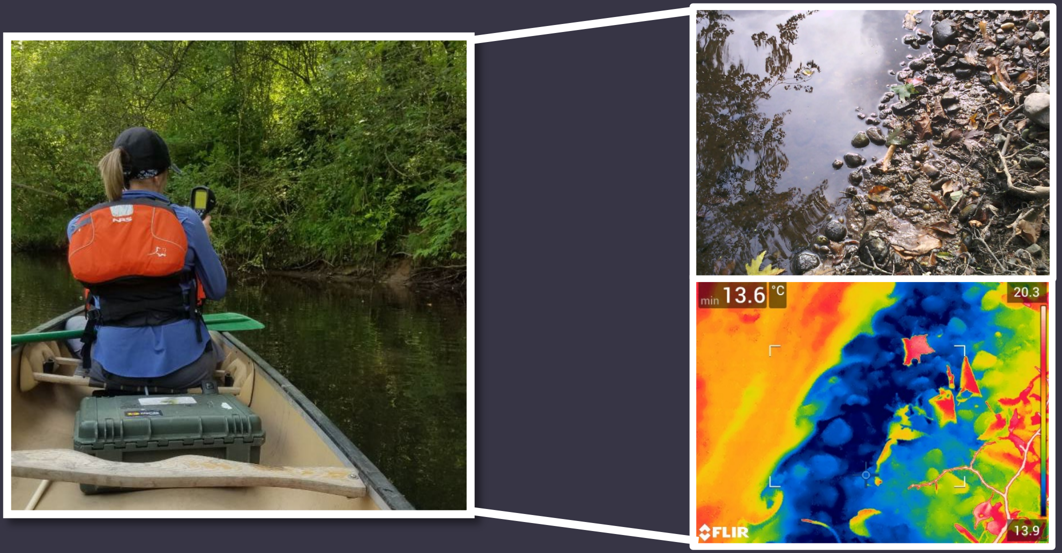
3) Groundwater N concentrations greater than 10 mg / L have been measured discharging directly from groundwater to the Farmington River



[a] Mullaney, J.R., 2007. U.S. Geological Survey Scientific Investigations Report 2006-5278 Nutrient Loads and Ground-Water Residence Times in an Agricultural Basin in North-Central Connecticut

Mapping and measuring groundwater inputs to streams and rivers

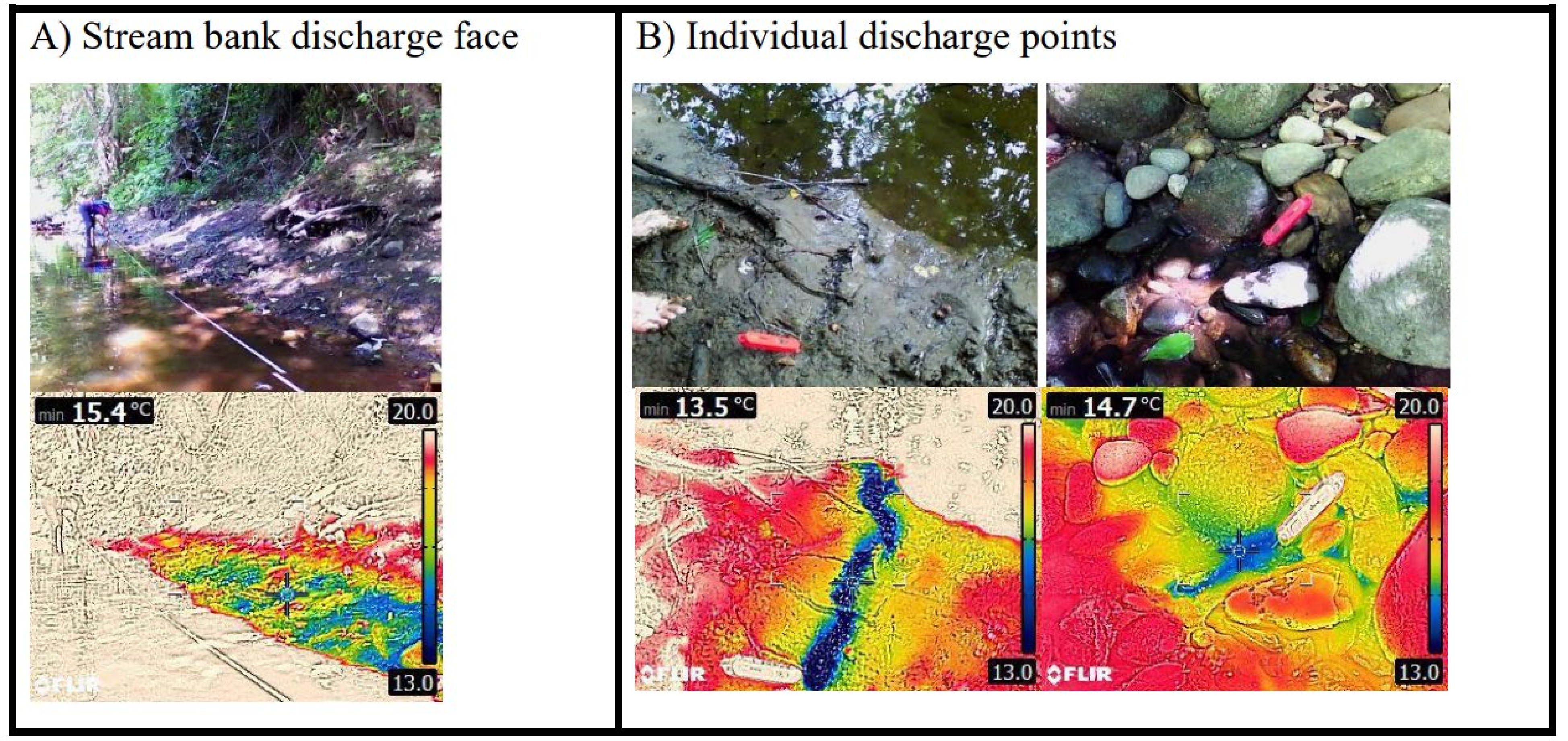
1. Map preferential groundwater seeps with thermal infrared imagery



2. Measure chemistry of discharging groundwater

Challenge: "Seeing" Groundwater Discharge

Thermal Infrared (TIR) gives a **picture of the surface temperature**



Barclay et al. In Review

Challenge: “Seeing” Groundwater Discharge

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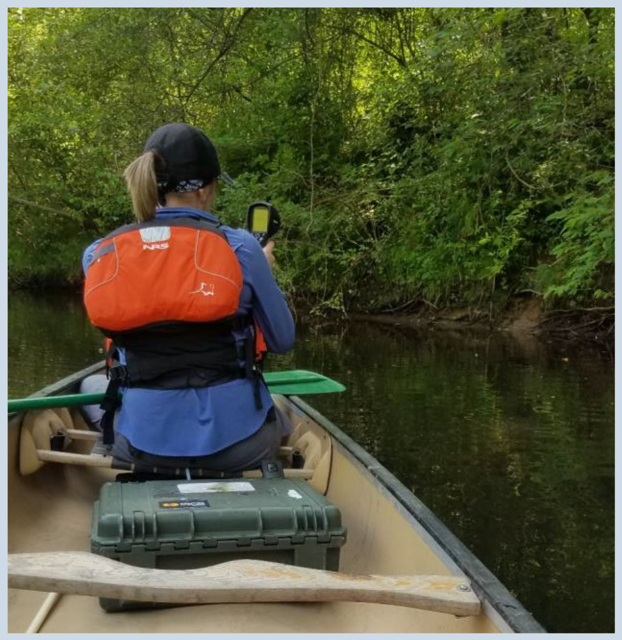
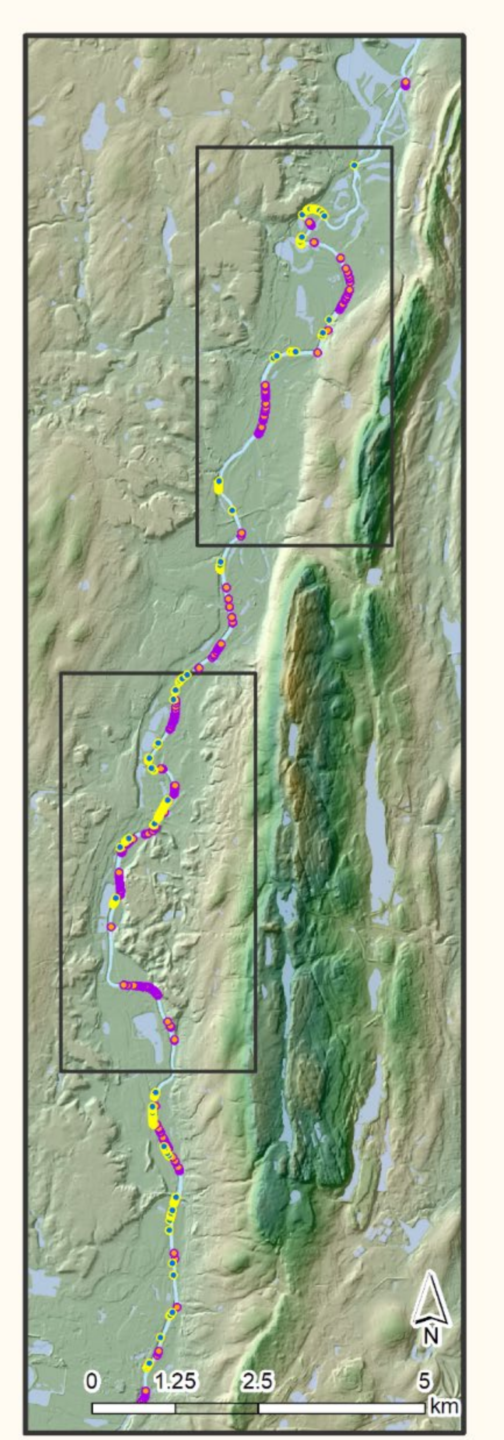


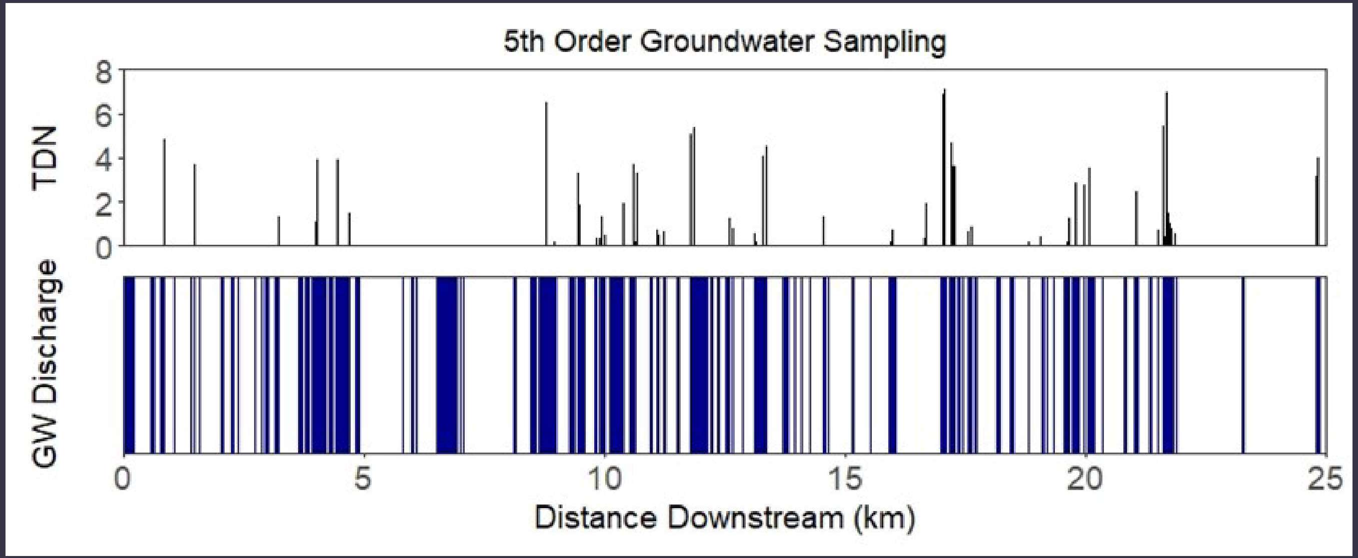
Survey Results – Map of Preferential Groundwater Discharge

- 27 km, 162 groundwater discharge locations (2019)
- Ranging from point seeps to 10s of meters in length
- GW discharged occurred along 1.52 km of river left and 2.43 km of river right



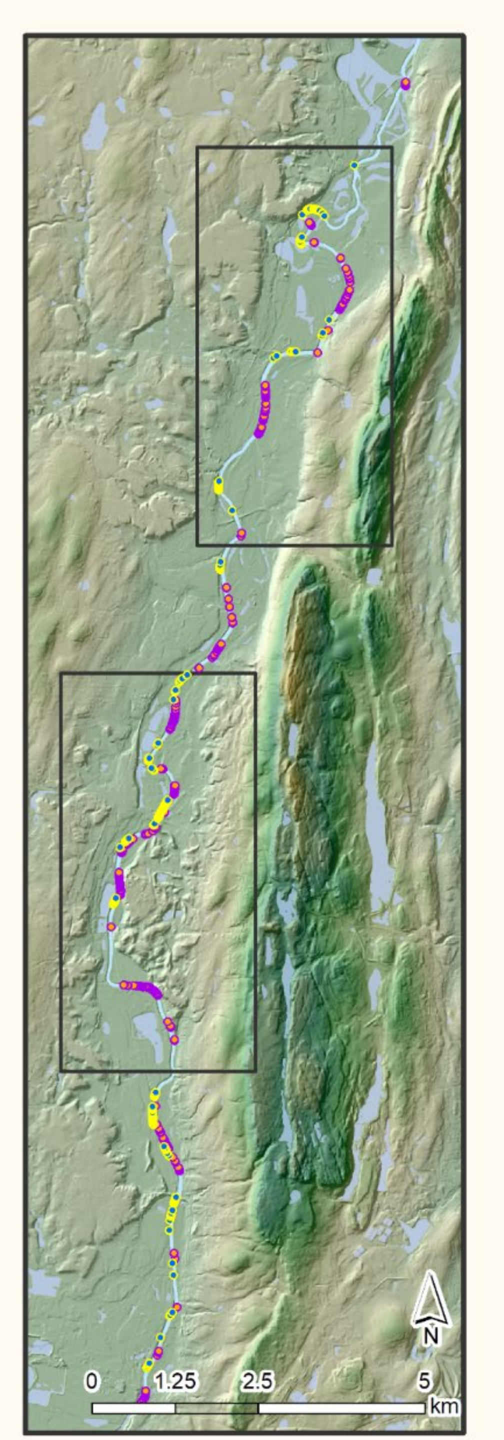
Jackson et al In Prep

Survey Results – Nitrogen Dynamics



Moore et al. In Preparation

- Nitrogen discharging from groundwater is highly variable (even within meters of stream)
  - Watershed source
  - Groundwater flux
  - Aquifer & near stream processing



Jackson et al In Prep

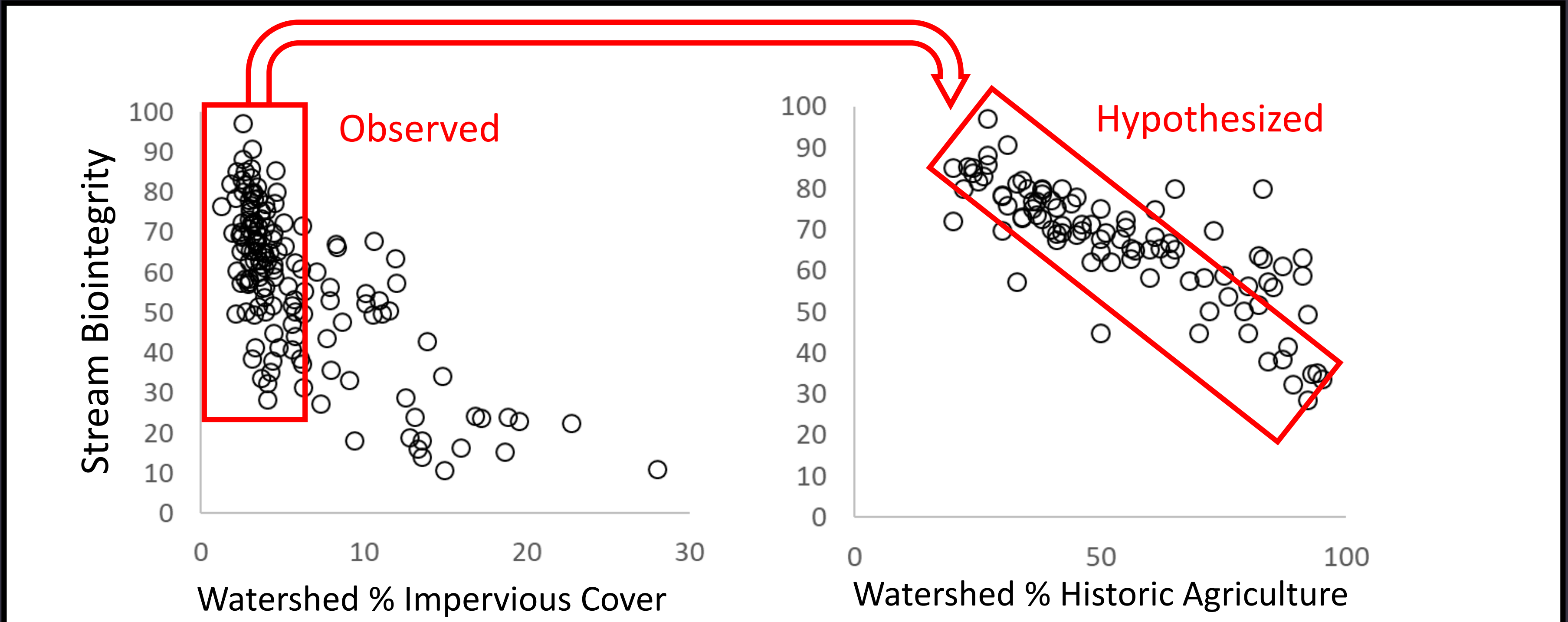
What about structural legacies? Some evidence-based hypotheses…

1. Observation: CT watersheds with a high proportion of core forests (less patchy forest land cover) have better water quality than similarly forested watersheds (Barclay et al. 2016. https://doi.org/10.1016/j.jenvman.2016.08.071)

    - Hypothesis: Core forests are less likely to be associated with legacy agricultural land use and thus lack signal and structural legacies that negatively influence water quality.

What about structural legacies? Some evidence-based hypotheses…

2. There is a large amount of unexplained variability in the biointegrity of streams that drain forested watersheds in CT.



Bellucci et al. 2011. Characteristics of macroinvertebrate and fish communities from 30 least disturbed small streams in Connecticut. Northeastern Naturalist 18(4), 411-444.

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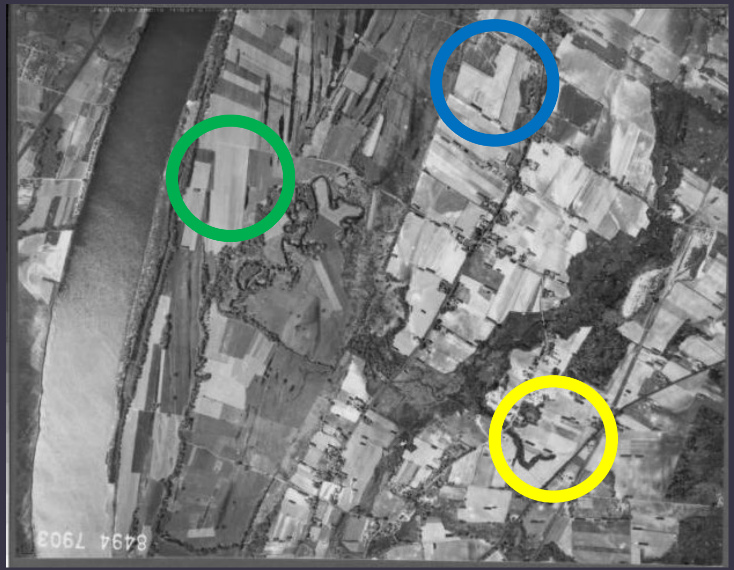
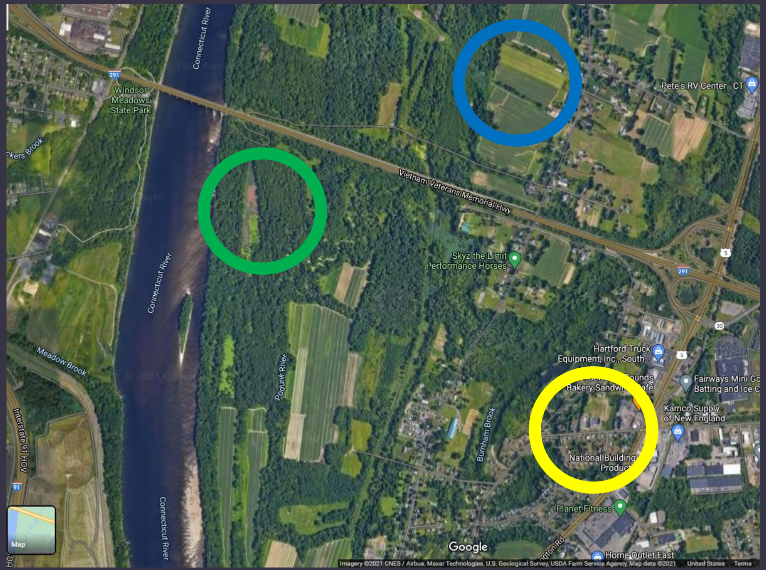
Project Objectives

- Geospatial classification of legacies in LIS watershed
- Relationships between land use legacies and water quality
- Land use legacies as a guide for watershed management

Develop a geospatial classification scheme of vulnerability to watershed land use legacies

1. Agricultural land that has been agricultural land for decades
2. Reforested agricultural land
3. Development of historic agricultural land
4. Changes in sewage infrastructure on developed land

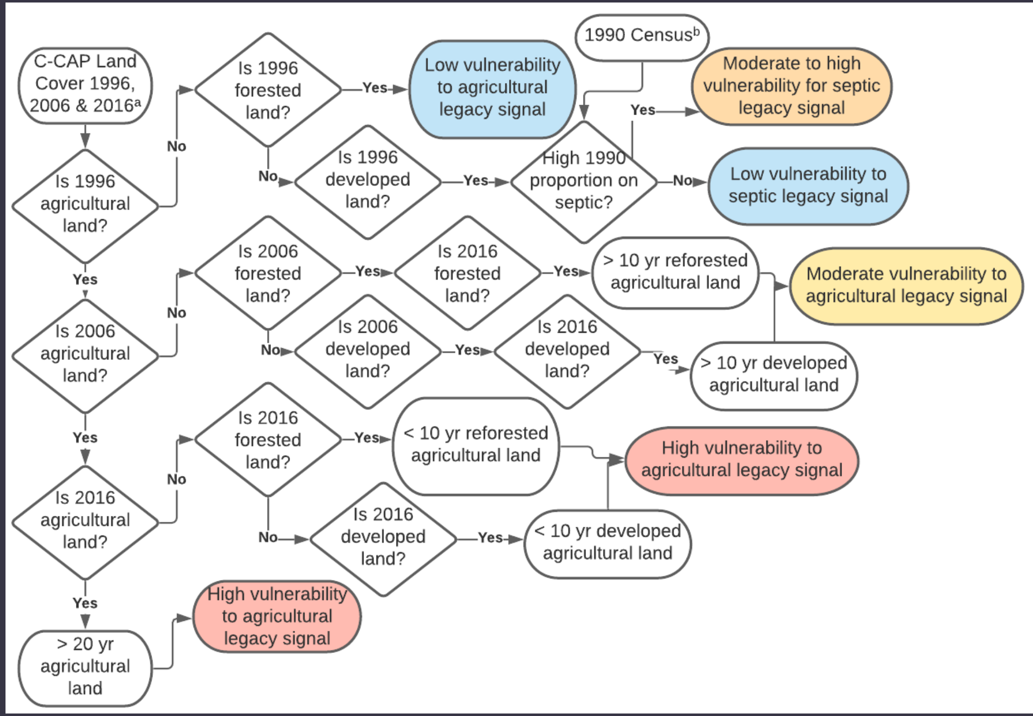




Develop a geospatial classification scheme of vulnerability to watershed land use legacies

- Develop vulnerability classification for land use legacies across LIS watershed
  - C-CAP land use / land cover dataset
  - Estimates of watershed residence times
  - Census datasets
  - Other continental datasets
    - USA Soils Farmland Class
    - Nitrogen TRENDS & fertilizer application rates
    - Historic agricultural land cover (since 1900s)

Initial decision tree for legacy classification



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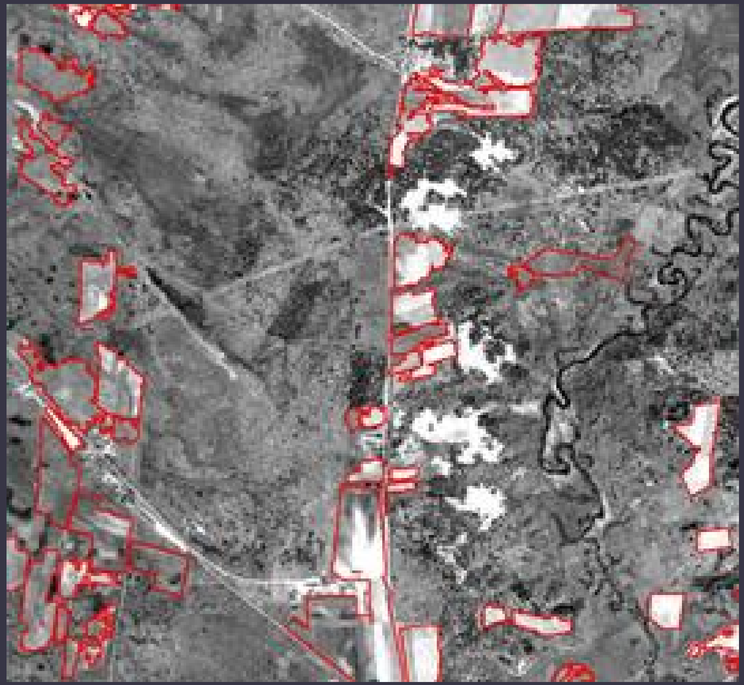
    - Nitrogen TRENDS & fertilizer application rates
    - Historic agricultural land cover (since 1900s)
  - Within CT include higher resolution by delineating aerial imagery and using local sewer information
- Output: Land use legacies GIS available publicly online

Example delineation of 1934 farm fields



Quantify the influence of watershed land use legacies on present-day water quality.

- Do watershed land use legacies improve broad-scale relationships between water quality and contemporary land use?
  - Approach: Use existing datasets across the LIS watershed and pair with land use legacy map.

- What are the chemical signatures of land use legacies, and do they affect aquatic ecosystem structure (biointegrity)?
  - Approach: Use land use legacy map to select small streams to measure surface water chemistry, discharging groundwater chemistry, and macroinvertebrate & diatom biointegrity indices.

- Outcome: Refined water quality – land use / land cover relationships that incorporate land use history.

Engage the public and resource managers in how understanding land use legacies can guide better watershed management decisions.

- Tools: Land use legacies GIS & story maps; refined land use / land cover relationships

- Approaches: Roadmap for how to consider and measure the impacts of land use history in your watershed

- Learning to manage our expectations – the ghost of land uses past:
  - Incorporating time lags & structural legacies into planning

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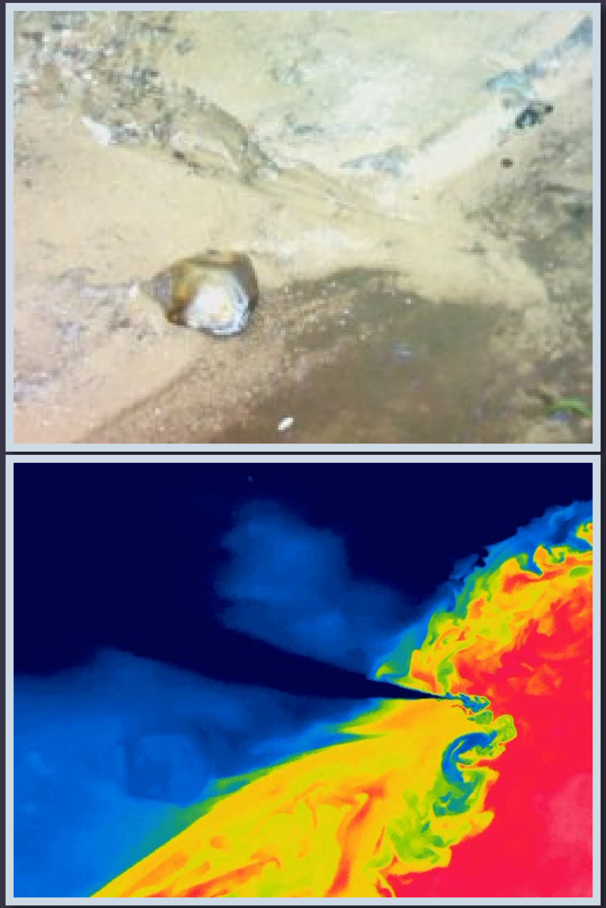

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