Deforestation in the Agricultural Landscape: Impacts on Water Quality in Indiana

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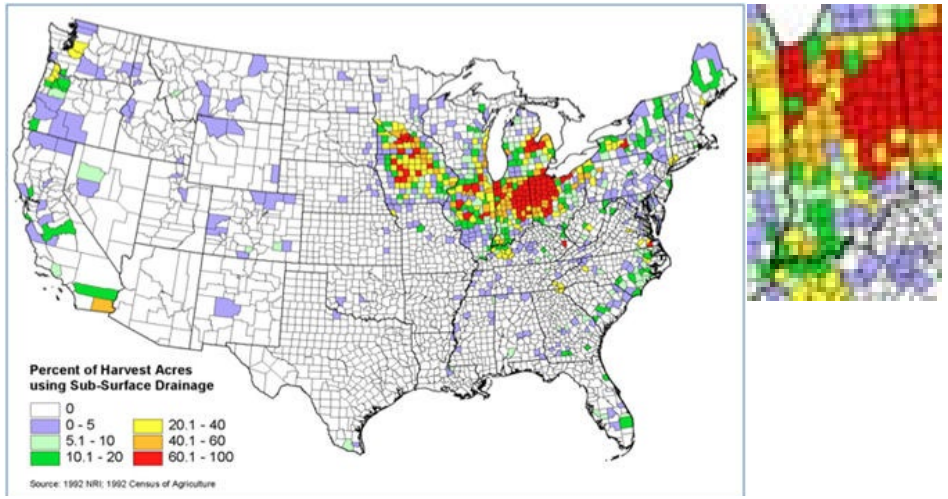
8th UF Water Institute Symposium
22nd February, 2022

Introduction

- Dominant LU types in Indiana – cropland and forests
- Cropland and forests
  - Proportions – unchanged
  - Spatial patterns – significant changes
- Cropland expansions
  - Simultaneous with reducing grasslands and pastures
  - Deforestations in the North
- Increased water pollution risks from Agricultural Runoffs
- Objective of the study
  - To map LU change – Indiana cropland and forests
  - Estimate impacts of deforestation on water quality (InVEST model)

Agricultural runoff: nutrients from fertilizers can contaminate water primarily in lands that are excessively irrigated or over-grazed.

Forests: nutrient retention and water purification → decrease AR-induced water pollution (Weigelhofer et al., 2012)



Sub-surface drainage – an example of non-point source nutrient pollution (King et al., 2015)

Land use change in Indiana

- LU data: 30m pixel level data from USDA's Cropland Data Layer (CDL)
  - CDL: 130 LU categories, 100 crop categories
  - Aggregate pixel data to specific geographic units
- Spatial heterogeneity in LU
- North – primarily cropland; South – primarily forests.
- Stable cropland and forest cover, decreasing grassland and pastures.

Land use type	2008	2010	2012	2014	2016	2018
Corn	**0.2359**	**0.2480**	**0.2612**	**0.2451**	0.2430	0.2265
Deciduous Forest	0.2347	0.2405	0.2363	0.2368	**0.2529**	0.2487
Developed/Open Space	0.0599	0.0624	0.0603	0.0588	0.0590	0.0594
Grassland/Pasture	0.1350	0.1492	0.1362	0.1299	0.0974	0.0928
Soybeans	0.2234	0.2182	0.2116	0.2252	0.2379	**0.2597**

Note: Numbers in bold refer to the LU category with the highest share of land.

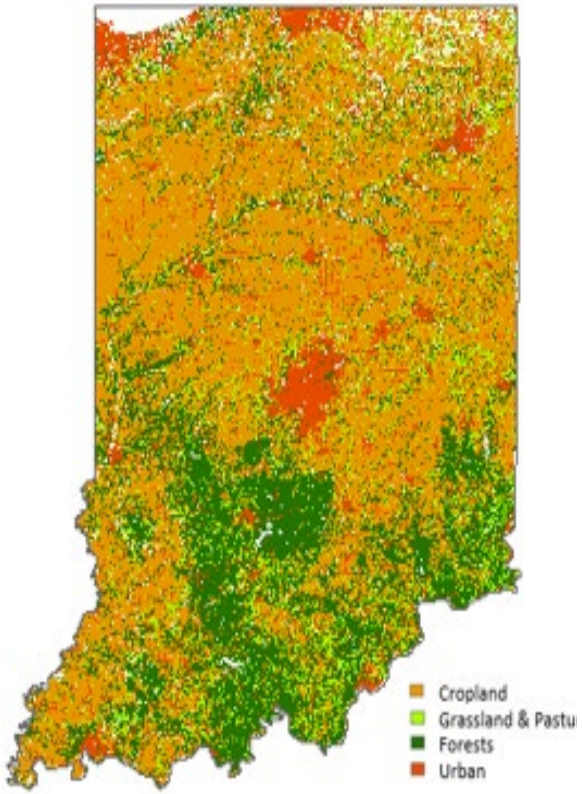


Figure 1: Land use in Indiana, 2018 (CDL)

Land use change in Indiana

- Net afforestation 2008 - 2018
- Forest cover change – spatially & temporally heterogenous
  - Forest expansion in the South
  - Cropland expansion in the North
- Cropland expansions – corn and soybean acreage expansion
- Simultaneous deforestation and cropland expansion – Wabash & Southeastern Lake Michigan watershed regions

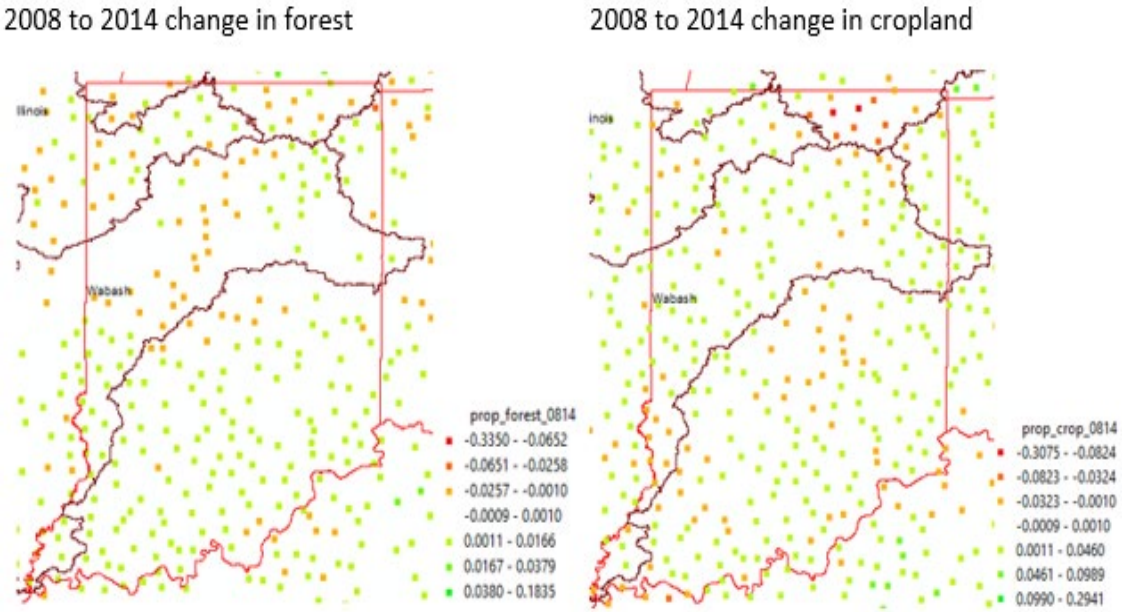


Figure 2. Change in forest and cropland between 2014-18 (CDL). Each dot represents change in proportion of forest or cropland for 10-digit watershed regions (WBD). The outlines of the 10-digit WBDs are not given in the map. Instead boundaries of the 6-digit WBDs from Northern Indiana are given. Greener dots represent positive change and redder dots represent negative change. Yellow represents small positive change.

Land use change in Indiana

- Changing LU conversion trends for forests w.r.t cropland and urban cover
  - Net afforestation w.r.t corn between 2008 and 2014
  - Net deforestation w.r.t corn, soybean, total cropland, and urban/developed between 2014-2018
- Evidence of recent deforestation w.r.t cropland expansions

From	To	2008 to 2014	2014 to 2018
Forests	Corn	-6847.8	4988.2
Forests	Soybean	1808.3	6413.9
Forests	Total cropland	-7223	11030.3
Forests	Urban/developed	-3405	213.7

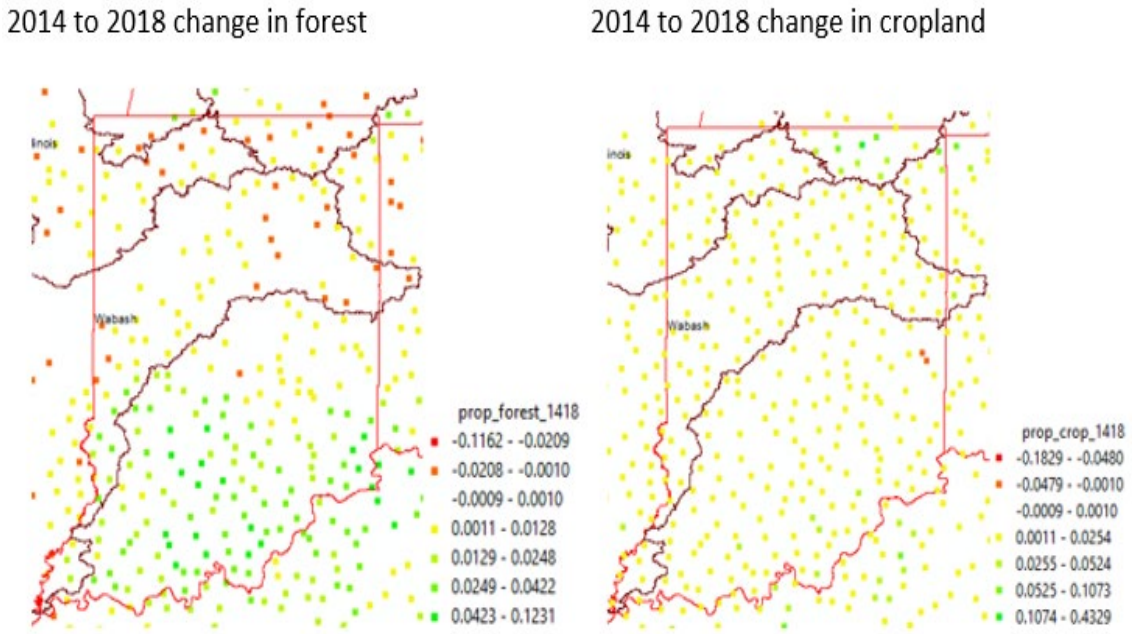


Figure 3. Change in forest and cropland between 2008-14 (CDL). Each dot represents change in proportion of forest or cropland for 10-digit watershed regions (WBD).

Indiana water quality

- Northern Indiana:
  - High hydrogeologic and aquifer sensitivity higher in the North
  - High concentrations of nitrate-nitrites and pesticide residues (Indiana Ground Water Monitoring Report, 2016)
  - High risk of non-point source pollution
- 101 major industries and water supply facilities with violations in 2018 (EPA's Enforcement and Compliance History Online (ECHO) database)
  - Majority are in the North
  - Source of point source pollution
- Contamination poses significant public health challenge

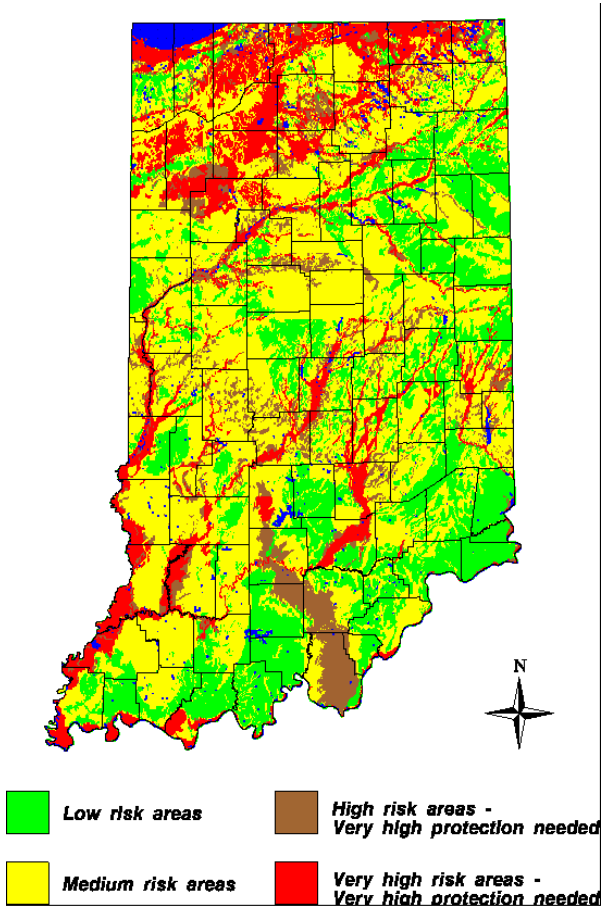
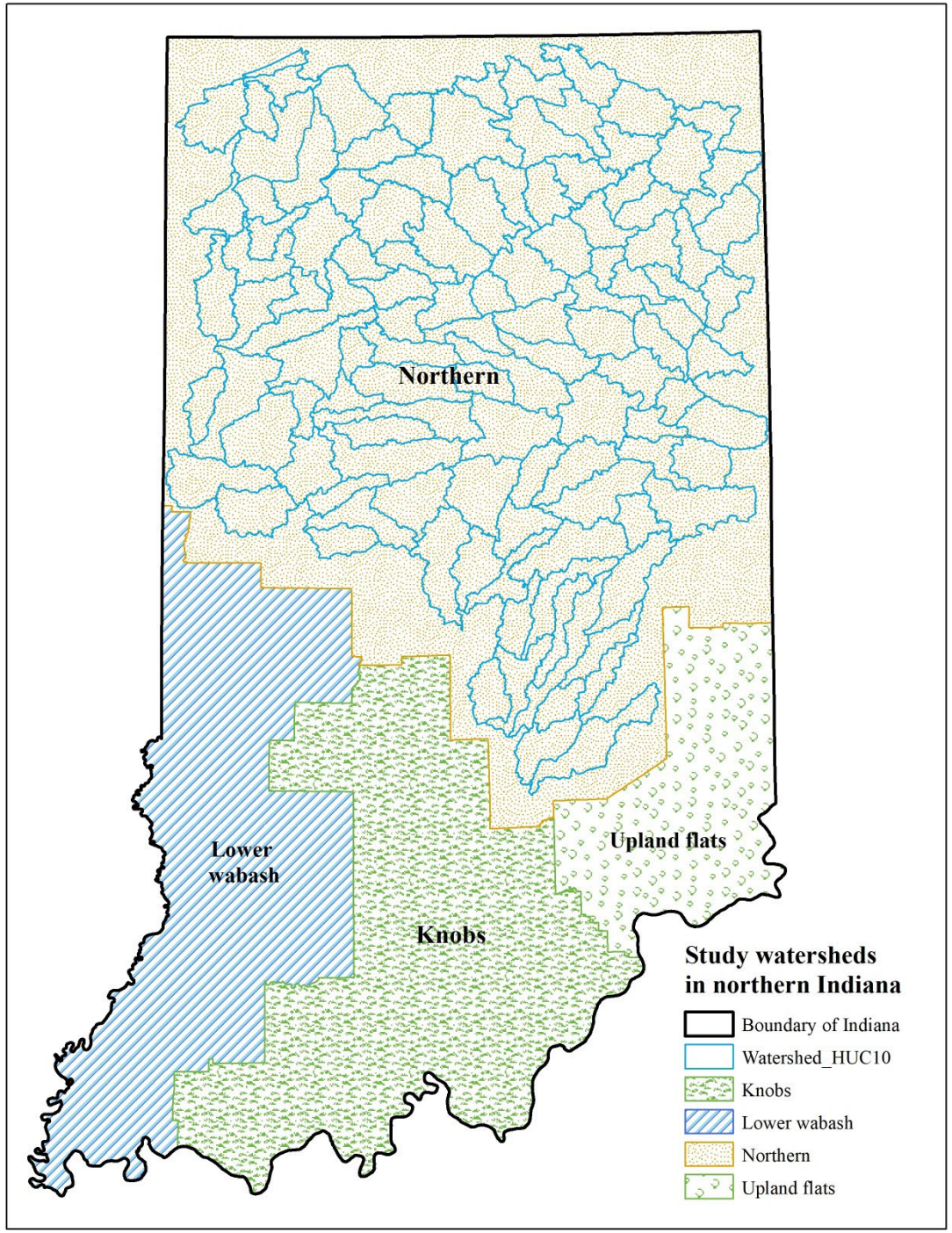


Figure 4: Hydrogeologic sensitivity (source: Brian Cooper, Purdue, 1996)



Study Area

Distribution of HUC10 watersheds in HUC2 Hydrologic Unit

Region	Watershed
Great Lakes Region	17
Ohio Region	84
Upper Mississippi Region	14
Total	115

Area statistics of HUC10 watersheds

Statistics	Area (Mi^2)
Min.	33
Max.	293
Mean	139
Std. Dev.	53

InVEST Nutrient Delivery Ratio Model

Data Requirements and Outputs (contd.)

The *InVEST* nutrient retention model *is based on* a well-known hydrological and biophysical relationship. The model estimates the contribution of vegetation and soil to purifying water resources through intercepting non-point sources nutrient pollutants from runoff.

- The model is **performed o**n an annual average basis with data formats in GIS raster grids, GIS shapefiles and tabular data .

- The first phase of the model **calculates** annual average water yield using climate data, geomorphological information, and LULC characteristics defined on ArcGIS.

- The second phase **determines** the quantity of nutrient pollutants retained based on the user defined nutrient export coefficient and filter coefficient on each pixel. And the pixel results are finally summed up at sub-watershed level.

- The biophysical output provides an insight into the dynamics of nutrient pollutant loading, filtration, and transport within the targeted sub-watersheds.

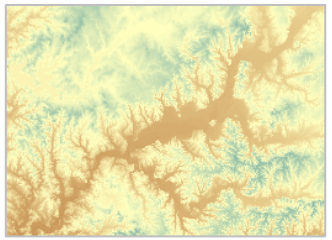
InVEST
integrated valuation of ecosystem services and tradeoffs

InVEST Nutrient Delivery Ratio Model

Data Requirements and Outputs

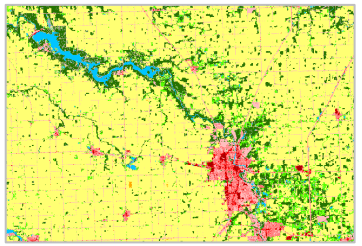
Input

GIS raster grids and shapefiles



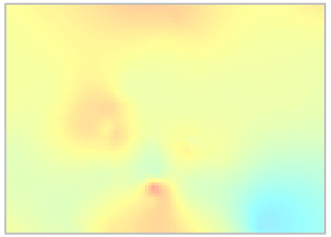
Digital Elevation Model (DEM)

National Elevation Dataset 30 meter



Land Use and Land Cover (LULC)

USDA's Cropland Data Layer (CDL)



Nutrient Runoff Proxy (Precipitation)

NOAA Climate Prediction Center (CPC)

Watersheds

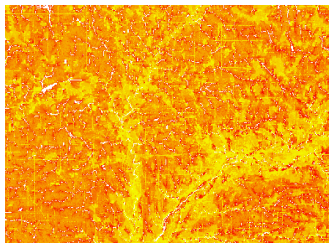
NRCS Watershed Boundary Dataset (HUC10)

Tabular data

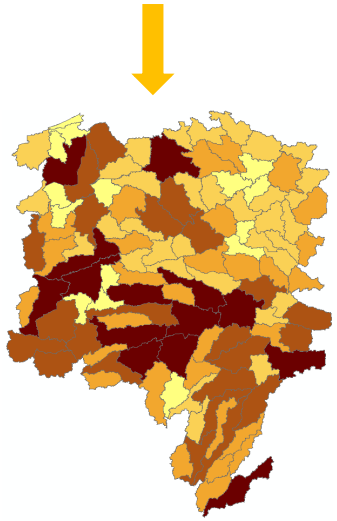
Biophysical Table: *model information corresponding to each of the land use classes in the LULC raster.*

Parameters: *threshold flow accumulation; Borselli k parameter; subsurface critical length; subsurface maximum retention efficiency*

Output

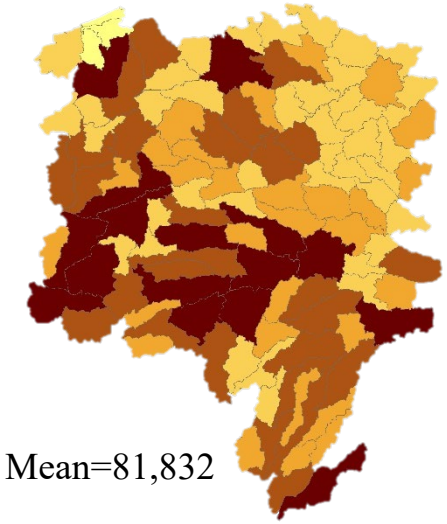
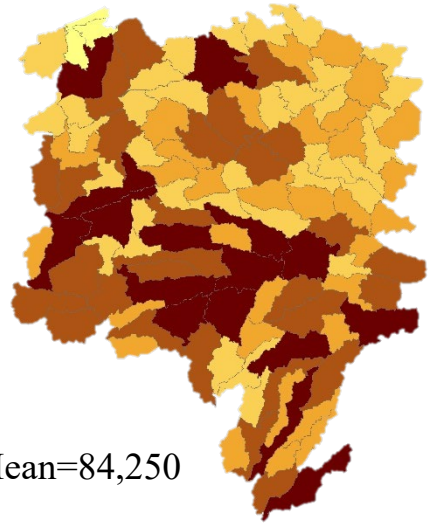
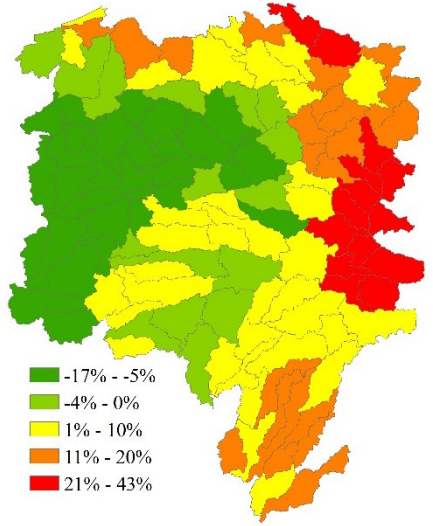
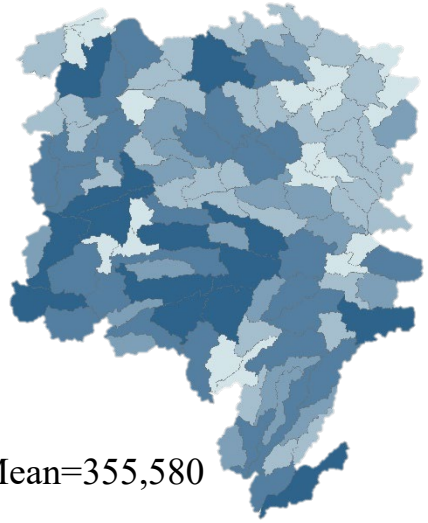
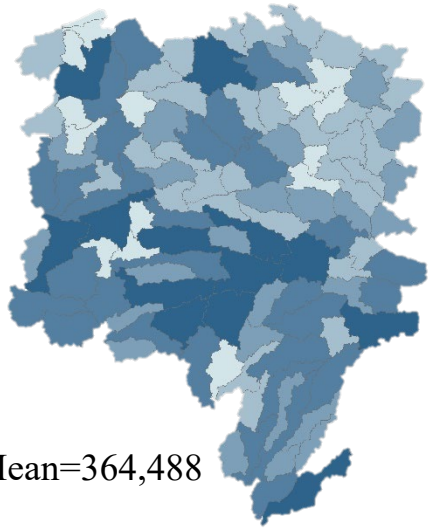
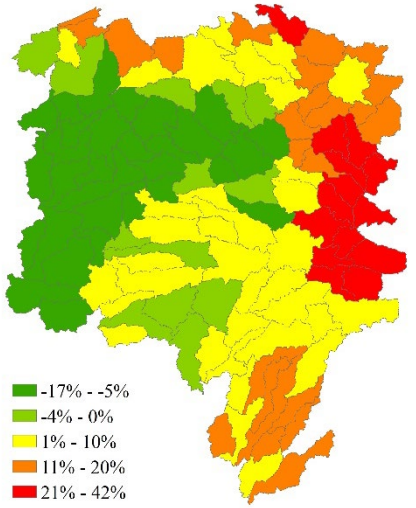


Nutrient loading (kg/pixel)



Total nutrient export from the watershed(kg/year)

Results

Total nutrient export from watershed (kg/year)	2008	2018	Change in percentage
Phosphorus	 Mean=81,832	 Mean=84,250	 71 watersheds with increased P export
Nitrogen	 Mean=355,580	 Mean=364,488	 69 watersheds with increased n export

Results

Summary statistics of nutrient export from watershed in northern Indiana

	N			P		
	2008	2018	%	2008	2018	%
Min. (kg/yr/ws)	26,221	28,854	10%	4,448	4,719	6%
Max. (kg/yr/ws)	776,961	768,185	-1%	181,668	179,614	-1%
Sum. (kg/yr)	40,891,732	41,916,075	3%	9,410,735	9,688,730	3%
Mean (kg/yr/ws)	355,580	364,488	3%	81,832	84,250	3%
Std.	173,260	167,309		40,787	39,404	

Summary

- Recent deforestation in agricultural landscape owing to cropland expansion
- As a result, increase in total nutrient exports (both N and P)
- Spatial and temporal heterogeneity in nutrient export
  - Greater positive change in watersheds with lower nutrient export at baseline (2008) levels
  - Watersheds with positive change in nutrient export:
    - 2008-2018: Marginal + change in forest, + change in cropland
    - 2014-2018: Marginal – change in forest, + change in cropland
    - Impacts driven by LU changes in recent years

Thank you! Questions?

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