Measuring the Effectiveness of Agricultural Conservation Expenditures on Water Quality

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Motivations

- Diversified agricultural conservation programs have been implemented to target the reduction of water pollution from agricultural production
- It is important to examine the cost-effectiveness of these programs for program evaluation and future policy design
- There is a dearth of statistical analysis of the relationship between agricultural conservation programs expenditure and water quality

Objectives

- Investigate how have agricultural conservation programs influenced water quality
- Measure the cost-effectiveness of these programs
- Explore the heterogeneity of the impacts of different programs on water pollution
- Control for spatial spillovers of water pollution via modeling upstream to downstream water flows

Characteristics of (surface) water pollution from agricultural production

- Pollution from agricultural production can be controlled through certain conservation practices
- Impacts of different conservation practices are heterogeneous
- Spatial spillovers
  - Upstream pollution affects downstream pollution directly
- Temporal dynamics
  - High pollution happens in March-July and Oct-Feb due to the characteristics of agricultural production
  - Pollution remains in the water system for more than one year

Methods

A spatial autoregressive model:

$$WQ_{i,t} = \sum_{j=0}^{J} \beta_j E_{i,t-j} + \gamma\left(\sum_{\omega \in \Omega_i} \psi_\omega WQ_{\omega,t}\right) + X_{i,t}\alpha + \lambda_t + \varepsilon_{i,t}$$

$WQ_{i,t}$: Measurements of nitrogen and phosphorus in March-July and Oct-Feb.

$E_{i,t-j}$: land area under conservation practice contracts

γ: strength of the spatial spillover effect

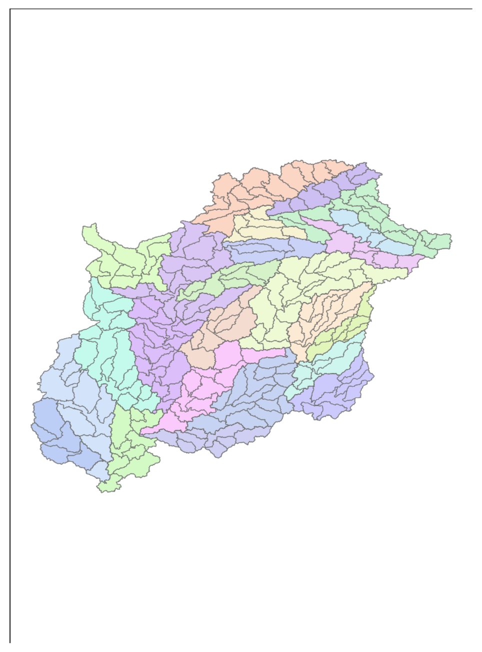
ψ_ω: spatial weight matrix, capturing the potential influence of upstream pollution to downstream

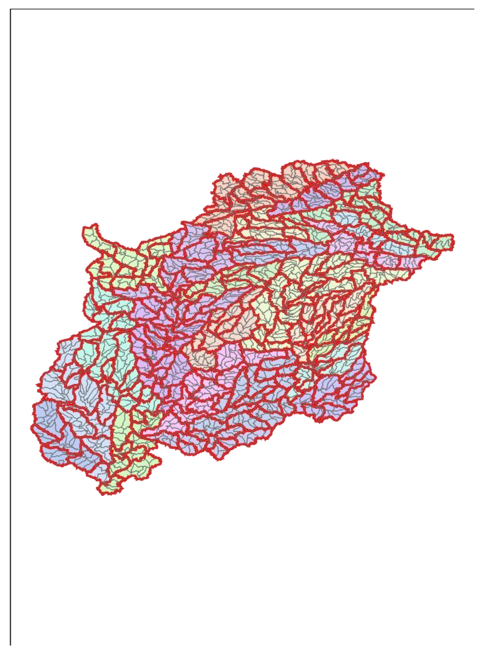
X : cropland allocation, crop rotation and other land use

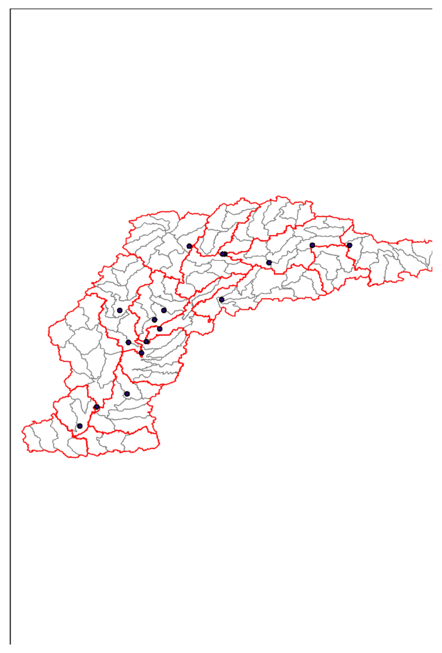
λ_t:year dummies

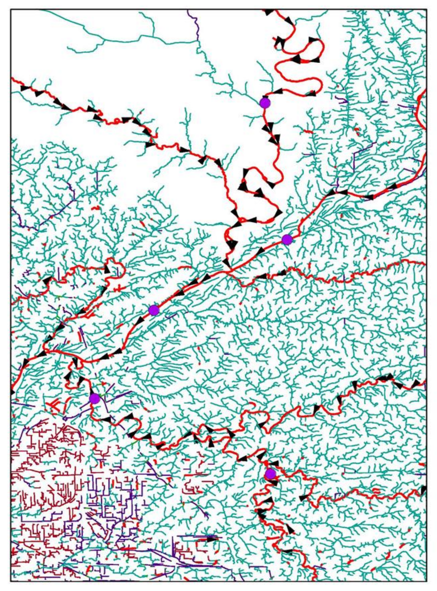
Analysis

- Wabash River Watershed
- Different levels of watershed
  - 8-digit watershed
  - 10-digit watershed
  - 12-digit watershed
- Agricultural conservation practices at watershed level in Indiana
- IDEM fixed monitoring sites
- Spatial spillovers are identified via upstream and downstream relationships









Data

- USDA NRCS agricultural conservation practices data
- Indiana Department of Environmental Management (IDEM) water quality data
- National Hydrography Dataset (NHD)
- National Watershed Boundary Dataset (WBD)
- USDA Cropland Data Layer (CDL)

Preliminary results

Table 1: 200907 Nitrogen

	Dependent variable: Nitrogen	
	HUC10	HUC12
CC	−28.228* (16.714)	−106.475* (55.521)
SC	−44.284 (28.629)	−23.446 (71.980)
OC	1.624 (49.171)	−2.460 (199.213)
CS	59.905** (25.379)	172.832** (69.583)
SS	−48.210 (35.152)	−272.719** (103.925)
OS	146.786 (125.580)	434.372 (313.399)
OTHER AGRICULTURE	−19.250 (68.758)	588.519*** (217.430)
FOREST	−5.285 (3.958)	−12.455 (13.220)
GRASS	−20.152* (10.532)	−98.569*** (36.157)
WETLAND	−178.163* (102.758)	−381.511* (209.685)
SHRUBLAND	−204.082 (558.756)	−2,938.941 (3,848.722)
DEVELOPED	−6.652 (5.080)	−11.709 (13.755)
WATER	−2.526 (56.159)	31.236 (121.497)
OTHER	383.782 (541.926)	2,385.964* (1,249.722)
CONSERVATION PRACTICES	−0.563 (1.080)	−2.542 (2.163)
Constant	5,930.827*** (586.077)	4,221.215*** (544.817)
Observations	75	93
R^2	0.442	0.489
Adjusted R^2	0.300	0.390
Residual Std. Error	1,624.242 (df = 59)	1,440.147 (df = 77)
F Statistic	3.117*** (df = 15; 59)	4.913*** (df = 15; 77)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 2: 201002 Nitrogen

	Dependent variable: Nitrogen	
	HUC10	HUC12
CC	−18.015 (13.342)	−9.346 (46.112)
SC	−26.054 (22.906)	38.269 (59.792)
OC	−9.983 (39.360)	−197.001 (166.524)
CS	36.720* (20.327)	52.567 (58.193)
SS	−47.429* (28.136)	−229.340*** (86.363)
OS	145.790 (100.589)	612.695** (261.974)
OTHER AGRICULTURE	4.820 (54.852)	205.776 (181.039)
FOREST	−4.229 (3.170)	−28.753** (10.985)
GRASS	−11.873 (8.431)	−37.602 (30.188)
WETLAND	−137.890* (82.296)	−418.028** (174.266)
SHRUBLAND	−166.189 (447.674)	−333.990 (3,205.729)
DEVELOPED	−1.732 (4.068)	−6.486 (11.416)
WATER	6.395 (44.997)	100.782 (101.024)
OTHER	64.892 (432.515)	1,008.032 (1,037.187)
CONSERVATION PRACTICES	−0.326 (0.862)	−0.772 (1.797)
Constant	4,452.200*** (469.588)	3,773.484*** (452.172)
Observations	76	93
R^2	0.366	0.378
Adjusted R^2	0.207	0.257
Residual Std. Error	1,301.416 (df = 60)	1,196.890 (df = 77)
F Statistic	2.306** (df = 15; 60)	3.122*** (df = 15; 77)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3: 200907 Phosphorus

	Dependent variable: Phosphorus	
	HUC10	HUC12
CC	−1.229 (1.240)	−4.700 (4.450)
SC	−4.472** (2.124)	−7.843 (5.770)
OC	−2.282 (3.648)	−3.248 (15.969)
CS	3.776** (1.883)	4.752 (5.578)
SS	−2.400 (2.608)	2.200 (8.331)
OS	24.615** (9.317)	17.736 (25.122)
OTHER AGRICULTURE	−6.645 (5.101)	46.666*** (17.429)
FOREST	−0.273 (0.294)	−0.205 (1.060)
GRASS	−0.606 (0.781)	−3.406 (2.898)
WETLAND	−1.194 (7.624)	−1.639 (16.808)
SHRUBLAND	−68.940 (41.456)	−461.973 (308.510)
DEVELOPED	−0.340 (0.377)	−0.475 (1.103)
WATER	0.115 (4.167)	−0.634 (9.739)
OTHER	26.970 (40.207)	231.067** (100.177)
CONSERVATION PRACTICES	−0.018 (0.080)	−0.146 (0.173)
Constant	296.884*** (43.483)	187.832*** (43.672)
Observations	75	93
R^2	0.331	0.293
Adjusted R^2	0.161	0.155
Residual Std. Error	120.508 (df = 59)	115.441 (df = 77)
F Statistic	1.946** (df = 15; 59)	2.125** (df = 15; 77)

Table 4: 201002 Phosphorus

	Dependent variable: Phosphorus	
	HUC10	HUC12
CC	−1.623 (1.358)	−3.104 (5.085)
SC	−2.850 (2.331)	−0.913 (6.590)
OC	−0.251 (4.006)	−3.210 (18.277)
CS	2.436 (2.069)	−0.485 (6.373)
SS	−3.306 (2.864)	−2.315 (9.533)
OS	19.440* (10.237)	19.644 (28.755)
OTHER AGRICULTURE	−2.251 (5.583)	33.821* (19.954)
FOREST	−0.126 (0.323)	−1.231 (1.213)
GRASS	−0.717 (0.858)	−0.0001 (3.317)
WETLAND	−2.990 (8.376)	−15.536 (19.244)
SHRUBLAND	−62.404 (45.562)	−340.363 (352.403)
DEVELOPED	0.376 (0.414)	1.445 (1.261)
WATER	−1.669 (4.580)	2.668 (11.139)
OTHER	5.736 (44.019)	118.184 (114.533)
CONSERVATION PRACTICES	−0.092 (0.088)	−0.211 (0.198)
Constant	262.276*** (47.792)	173.179*** (49.909)
Observations	76	94
R^2	0.260	0.181
Adjusted R^2	0.075	0.024
Residual Std. Error	132.451 (df = 60)	132.169 (df = 78)
F Statistic	1.407 (df = 15; 60)	1.150 (df = 15; 78)

Note: *p<0.1; **p<0.05; ***p<0.01