Spatial Models of Land Use Change – The Role of Local Spillovers as Drivers of Open Space Loss

Simanti Banerjee, Nga Phuong Nguyen,
Richard Ready

Conference on the Science and Education of Land Use:
A transatlantic, multidisciplinary and comparative approach
Washington, DC – September 24-26

Study Objectives

- Identify drivers of open space loss in rural and suburban areas
  - Physiographic
  - Socio-demographic
  - Population and population growth
- Investigate roll of spatial spillovers in open space loss

Motivation

- Widespread focus on population growth as primary driver of open space loss
  - "[Pennsylvania] developed nearly four acres of land for every new resident during this timeframe [1982 to 1997], versus the national average of 0.60 acres per new resident. This means that Pennsylvania used more land per person than every other state except Wyoming ." (GreenSpace Alliance)
- Is population growth the most important driver?
- How much control does a jurisdiction have over its open space drivers?

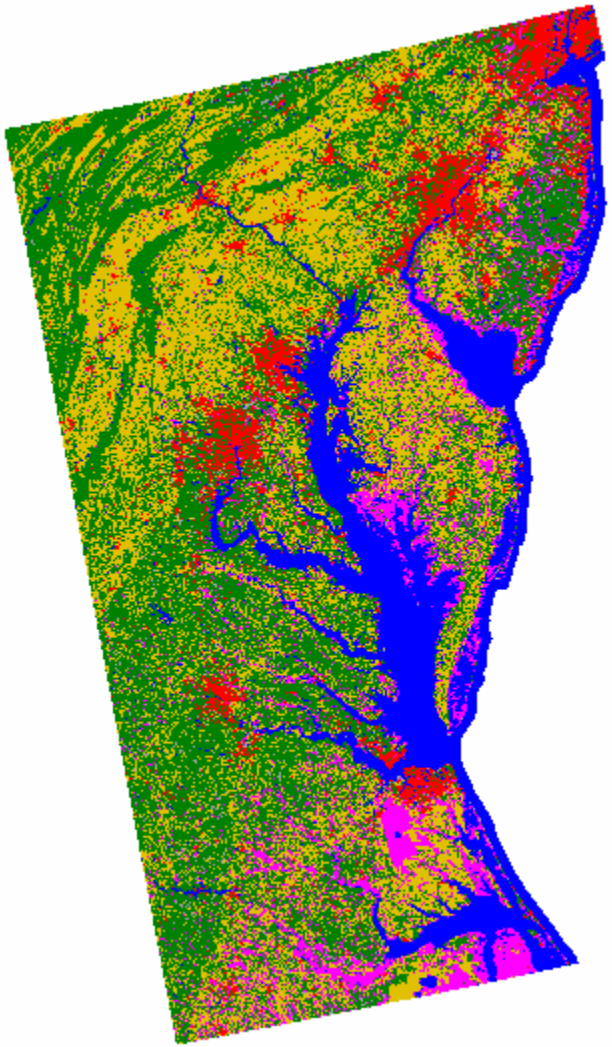
Study Design

- Objective: Empirical model of aggregate open space loss
  - Unit of Observation: Minor Civil Division (Township, City, Borough)
  - Time Period: 1992 to 2001
  - Dependent Variable: % Loss of Open Space

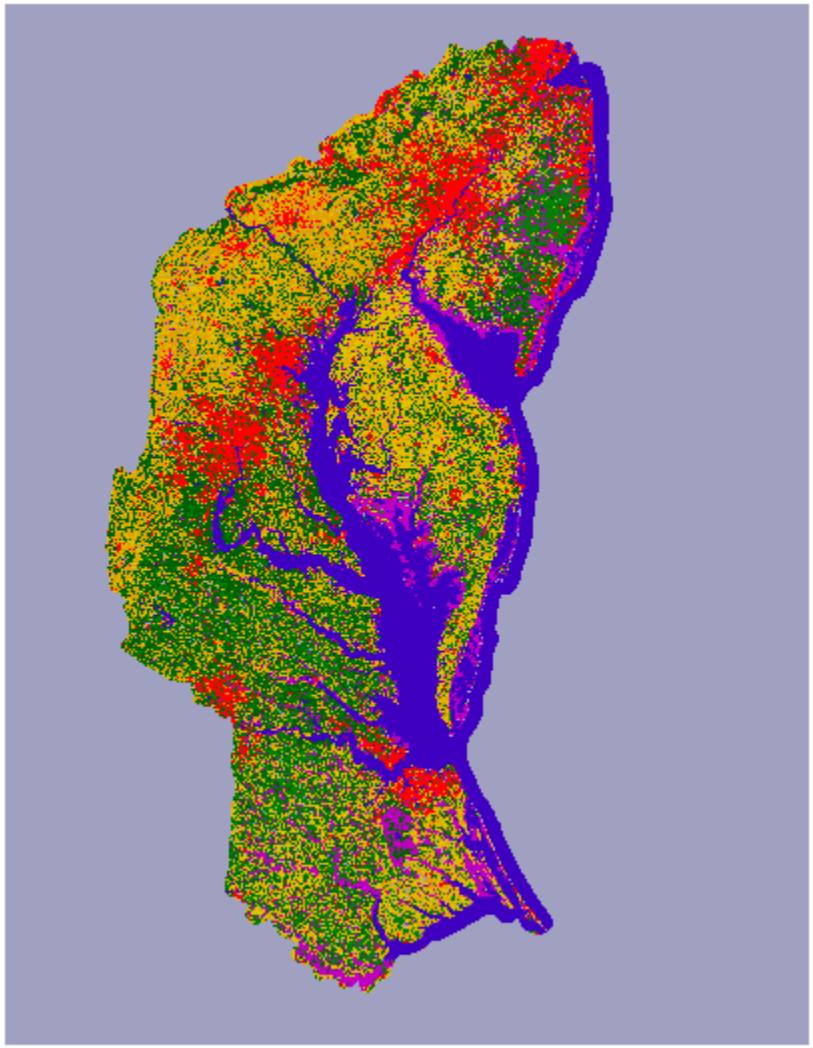
$$\frac{OS(1992) - OS(2001)}{OS(1992)}$$

  - Data Source: NLCD
  - Study Area: Mid-Atlantic U.S.

1992 NLCD



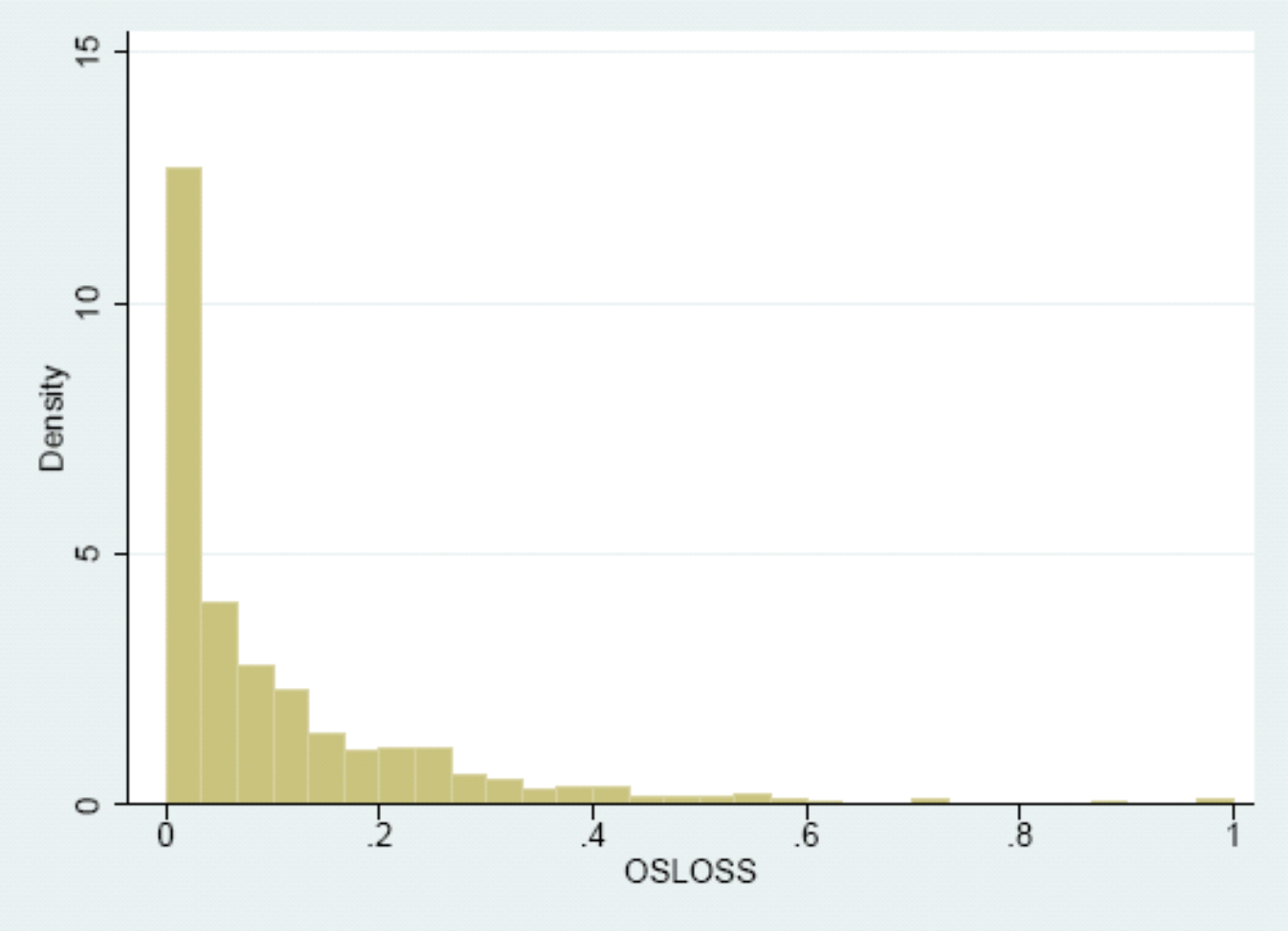
2001 NLCD



More Details

- OS defined to include forests, crops, grasslands, wetlands
- Areas protected from development excluded from analysis (GAP level 3 or higher)
- Urban MCD's (OS less than 25%in 1992) modeled separately
- Excluded MCD's where total amount of all land changed by more than 5%
- % OS Loss values constrained to interval [0,1]
- Final sample size - 1214

Histogram of Open Space Loss



Set of explanatory variables

- Physiographic Drivers
  - Initial Percentage of open space
  - (Initial Percentage of open space) squared
  - Mean distance to an interstate highway
  - Percent of initial OS with slope 10% or greater
- Socio-Demographic Drivers
  - Percentage African American
  - Median household income
  - Percentage over 65
- Population Drivers
  - Initial Population Density
  - Population Growth (increase in density)
- Is Pennsylvania Different?
  - Intercept Shifter for Pennsylvania
  - Slope Shifters for population variables

Results : OLS

Variable	Coefficient	t-statistic	Sig Level
Constant	-4.793	-5.650	0.000
Physiographic Drivers			
Initial % open space	40.592	8.406	0.000
Initial % open space (sq)	-28.573	-6.728	0.000
Distance from Hwy	-0.024	-3.614	0.000
% steep slope	-0.123	-10.334	0.000
Socio-Demographic Drivers			
% African American	-0.040	-3.628	0.000
Median HH Income	-0.046	-0.270	0.787
% over 65	0.076	2.226	0.026

Results : OLS

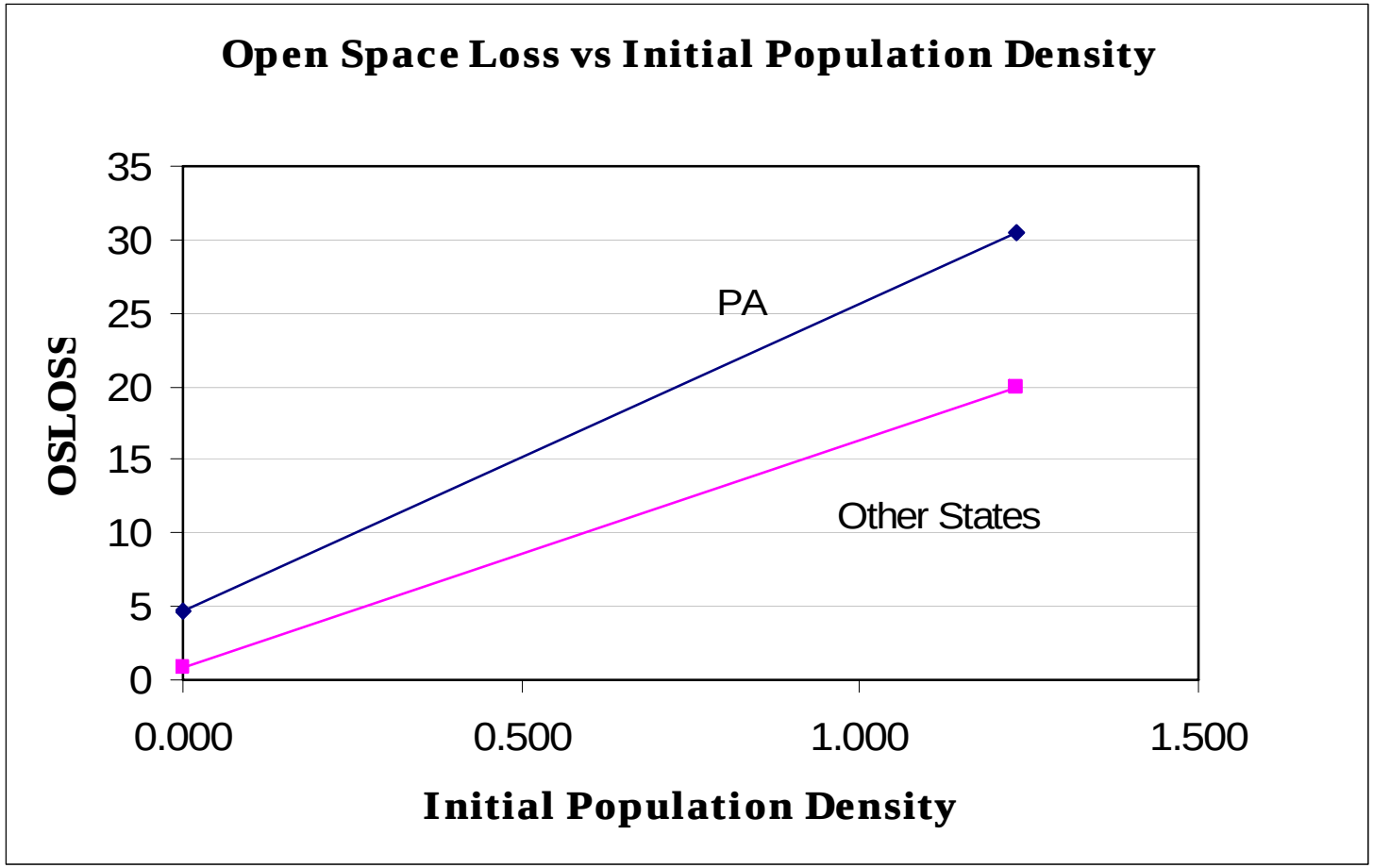
Variable	Coefficient	t-statistic	Sig Level
Population Drivers			
Initial population density	20.946	16.804	0.000
Population growth	42.305	10.214	0.000
Shifters for states other than PA			
Constant	-3.980	-7.799	0.000
Initial population density	-5.418	-4.307	0.000
Population growth	0.461	0.086	0.932

Which is more important, population growth or initial population?

Driver	Model Coeff	Mean of X	S.D. of X	S.D. * Coeff
Initial Population Density	20.946	620.9	877.1	18271.5
Population Growth	42.305	35.5	120.9	5114.7

- Initial Population Density is 3 times as important as Population Growth in determining OS loss
  - A densely populated county with no population growth experiences more open space loss than a lightly populated county with rapid growth
- "Spreading-out Effect"

Comparison of loss of open space between Pennsylvania and other states



Spatial Spillovers

- Does the “spreading out” effect spill over into neighboring townships?
  - Example: Malls, restaurants, services to support population in nearby townships
- Spatial Models
  - Spatially Lagged Independent Variables
  - Spatially Lagged Dependent Variable
  - Spatially Correlated Regression Errors

Spatially Lagged Independent Variables Model

- Spatial Weights Matrix W
  - 1st order contiguity
  - Row-standardized
  - WX = Average value of X for neighboring MCD's

$$y = X\beta + WX_s\gamma + \varepsilon$$

- Include selected spatially lagged variables in OLS model
  - Initial Population Density
  - Population Growth

Results : SLIVM

	OLS		SLIVM	
Variable	**Coeff**	**t-stat**	**Coeff**	**t-stat**
Own Population Drivers				
Initial population density	20.946	16.804	21.389	17.450
Population growth	42.305	10.214	40.923	10.003
Neighboring Population Drivers				
Initial population density			3.380	4.593
Population growth			21.773	5.140

- Population growth in neighboring townships causes OS loss in your township
- Spillovers from initial population density are less important

Spatially Lagged Dependent Variable Model

$$y = \rho W y + X\beta + \varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 I)$$

- OS Loss will be correlated with loss in neighboring townships
- Drivers in neighboring townships cause OS loss in your township, through the correlation parameter, ρ

$$y = (I-\rho W)^{-1} X\beta + (I-\rho W)^{-1}\varepsilon$$

Results : SLDVM

	OLS		SLDVM	
Variable	**Coeff**	**t-stat**	**Coeff**	**t-stat**
Own Population Drivers				
Initial population density	20.946	16.804	18.952	17.545
Population growth	42.305	10.214	36.915	10.518
Spatial Correlation Parameter				
rho			0.378993	8.109

- OS loss correlated with loss in neighboring townships
- Anything that drives OS loss in neighboring townships will cause OS loss in your township

Spatially Correlated Errors Model

$$y = X\beta + \varepsilon$$

$$\varepsilon = \lambda W\varepsilon + u, u \sim N(0, \sigma^2 I)$$

- Could be motivated by spatially correlated omitted variables.

Results : SCEM

	OLS		SCEM	
Variable	**Coeff**	**t-stat**	**Coeff**	**t-stat**
Own Population Drivers				
Initial population density	20.946	16.804	18.816	16.707
Population growth	42.305	10.214	36.928	10.184
Spatial Correlation Parameter				
lambda			0.490	21.615

- If there is something that causes your neighbors to loose OS faster than would be expected, then you will also loose OS faster than expected

Hybrid Models

- Spatially Lagged Dependent Variable Model with Spatially Lagged Independent Variables

$$y = \rho W y + X\beta + WX_s\gamma + \varepsilon$$

$$y = (I-\rho W)^{-1}X\beta + (I-\rho W)^{-1}WX_s\gamma + (I-\rho W)^{-1}\varepsilon$$

  - X_s appears twice on r.h.s.
  - Interpretation of γ not straightforward

- Spatially Lagged Independent Variable Model with Spatially Correlated Errors

Results : SLIVM with spatially correlated errors

	SLIVM		SLIVM with SCE	
Variable	**Coeff**	**t-stat**	**Coeff**	**t-stat**
Own Population Drivers				
Initial population density	21.389	17.450	19.890	17.694
Population growth	40.923	10.003	40.174	10.861
Neighboring Population Drivers				
Initial population density	3.380	4.593	2.704	3.746
Population growth	21.773	5.140	19.461	4.450
Spatial Error Correlation				
lambda			0.488	27.334

Which spatial model best captures spillovers?

- Predictive Power – R^2
  - OLS 0.59
  - SLIVM 0.61
  - SLDVM 0.60
  - SCEM 0.59
  - SLIVM w SCE 0.61

- Lagrange Multiplier Statistics
  - SLDVM 389.34
  - SCEM 237.05
  - SLIVM w SCE 223.36

Which spatial model best captures spillovers?

- Policy Usefulness
  - SLIVM allows policymakers to directly see impact of neighboring drivers on own OS loss
  - Less restrictive than SLDVM
  - SLIVM w SCE combines advantages of SLIVM and SCEM

Policy Implications

- Townships have little control over most drivers of OS loss
  - Have some control over job growth, which is primary driver of population growth in most places
  - But simply limiting population growth wont stop OS loss

- Need to pay attention to what is happening in neighboring townships
  - Correlated Errors – impacted by same forces
  - Spillover in drivers – population growth