CAUSES OF SPRAWL: A PORTRAIT FROM SPACE

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Motivation

- According to a 2000 survey by the Pew Center for Civic Journalism, about 1/5 of Americans said Urban sprawl and land development were the most important issue facing their local community (tied with crime and violence).

- **Little is known about the spatial development patterns**
  - We have some understanding of what determines urban growth (see, e.g., Glaeser, Scheinkman, and Shleifer [1995], Overman and Ioannides [2001], and Black and Henderson [2003])
  - and the decentralization of economic activity within cities [Glaeser and Kahn 2004].
  - However, we know almost nothing about the extent to which development is scattered or compact, how this varies across space or what determines that variation.

- **This paper is concerned with this key aspect of sprawl**

Motivation

- **We construct a new data set by merging high-altitude photographs from around 1976 with satellite images from 1992**
  - At level of cells of 30x30 meters, we know whether land was developed or not around 1976 and in 1992, as well as details about the type of developed or undeveloped land.
- **We calculate the percentage of undeveloped land in the immediate square kilometer**
  - Averaging this measure across all developed cells in a metropolitan area gives us an index of sprawl for the metropolitan area: the percentage of open space in the square kilometer surrounding an average residential development.
- **We find that only 1.9 percent of the United States was built-up or paved by 1992**
  - Only 0.3 percent of 1992 residential development is more than one kilometer away from other residential development.
  - Our measure of sprawl shows that 43 percent of the square kilometer surrounding an average residential development is undeveloped.

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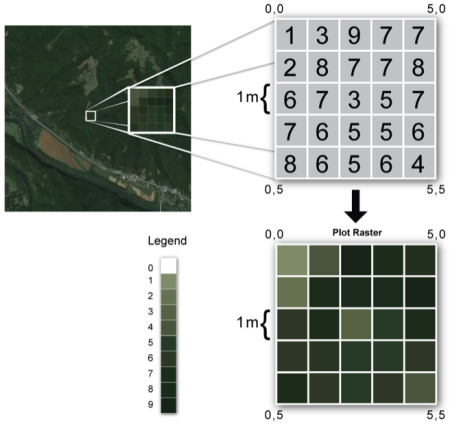
Data

- **We construct our core data from two remote-sensing data sets**
  - The most recent, the 1992 National Land Cover Data [Vogelmann et al. 2001].
  - The earlier data set, the Land Use and Land Cover Digital Data, derives mainly from high-altitude aerial photographs taken circa 1976.
- **Land cover was classified as follows**
  - First, a computer algorithm was used to find clusters of contiguous 30-meter cells with a similar set of reflectance values over the electromagnetic spectrum.
  - Next, analysts used high-altitude aerial photographs and other census and remote sensing data to match these clusters to land cover classes, to refine the boundaries of these clusters, and to make finer distinctions between land cover classes.
- Our resulting data set has 8.7 billion cells (30 x 30 meters) that make up the conterminous United States, we know the predominant land cover and land use circa 1976 and in 1992.

What is a raster?



Tomado de: https://www.neonscience.org

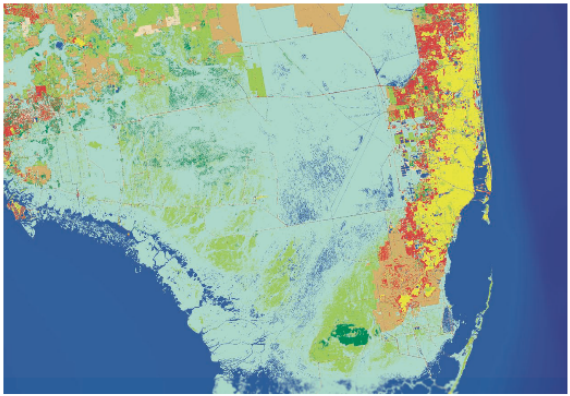
Methodology

- **We start by checking how often residential development leapfrogs over more than one kilometer of undeveloped land**
  - Only 0.3 percent of all residential development was more than one kilometer away from other residential development in 1992.

- **We measure the extent of sprawl, for each 30 meter cell of residential development, we calculate the percentage of open space in the immediate square kilometer**
  - We identify cells that were not developed in 1976 but were subject to residential development between 1976 and 1992, calculate the percentage of land not developed by 1992 in the square kilometer containing each of these cells, and average across all such newly developed cells in the metropolitan area.

- This provides a very intuitive index of sprawl: the percentage of undeveloped land in the square kilometer surrounding an average residential development.

Urban Land in Miami, FL



Function of 1976 and 1992 U. S. Residential Land across Areas with Different Degrees of Sprawl

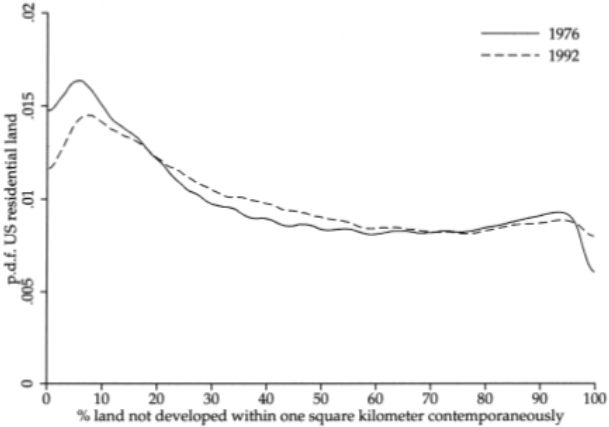


TABLE II

SPRAWL INDICES FOR METROPOLITAN AREAS WITH POPULATION OVER ONE MILLION

Metropolitan area	Sprawl index for 1992 residential land	Sprawl index for 1976 residential land	Metropolitan area	Sprawl index for 1992 residential land	Sprawl index for 1976 residential land
Atlanta	55.57	57.77	Minneapolis-St. Paul	32.07	31.34
Boston	47.64	44.72	New Haven	39.11	38.68
Buffalo	39.92	37.87	New Orleans	32.29	33.92
Charlotte	52.73	51.12	New York	28.75	28.47
Chicago	31.76	31.21	Norfolk	40.82	44.07
Cincinnati	47.79	47.45	Orlando	40.02	39.39
Cleveland	36.84	36.24	Philadelphia	42.51	43.03
Columbus	41.20	41.59	Phoenix	27.54	34.94
Dallas	28.08	26.65	Pittsburgh	57.70	56.71
Denver	28.63	28.63	Portland	44.90	43.38
Detroit	33.28	30.47	Rochester	48.80	48.11
Greensboro	52.94	51.45	Sacramento	34.93	30.72
Hartford	41.34	42.23	Salt Lake City	31.90	32.88
Houston	38.15	38.93	San Antonio	32.77	29.58
Indianapolis	39.66	37.68	San Diego	45.63	45.40
Kansas City	35.32	34.33	San Francisco	30.48	29.81
Los Angeles	35.41	32.95	Seattle	46.97	45.03
Memphis	27.40	28.72	St. Louis	43.44	40.62
Miami	20.73	20.03	Tampa	36.01	34.84
Milwaukee	35.33	33.85	Washington-Baltimore	49.81	50.68

Each sprawl index measures the percentage of undeveloped land in the square kilometer surrounding an average residential development in each metropolitan area in the corresponding year (1992 or 1976). For instance, the sprawl index for 1992 residential land is computed by calculating the percentage of land not developed by 1992 in the square kilometer containing each 30-meter cell classified as residential land in 1992 and averaging this percentage across all cells classified as residential land in 1992 in the metropolitan area.

Correlation with Other Measures of Sprawl

TABLE III
CORRELATION MATRIX FOR VARIOUS METROPOLITAN AREA SPRAWL MEASURES IN THE 1990S

	Sprawl (scatteredness) index	Median lot size	Miles driven per person	% Employment over 3 miles from CBD
Sprawl (scatteredness) index	1.000			
Median lot size	0.521	1.000		
Miles driven per person	0.271	0.187	1.000	
% Employment over 3 miles from CBD	−0.070	0.011	−0.073	1.000

The sprawl (scatteredness) index is the measure of sprawl used throughout this paper: the percentage of undeveloped land in the square kilometer surrounding an average residential development in each metropolitan area in 1992. Median lot size compiled from the metropolitan data contained in the American Housing Survey 1994–1998. Average number of miles driven per person calculated from the 1995 Nationwide Personal Transportation Survey [U. S. Federal Highway Administration 1995]. Share of employment located more than three miles away from the central business district in 1996 from Glaeser and Kahn [2001].

- **The Monocentric City Model and Its Generalizations**
  - Assumes that all employment in the city takes place at a single center, the CBD.
  - Cities specializing in sectors where employment tends to be more centralized will be more compact.
  - Lower transport costs within a city will result in more dispersed development.
  - Cities that have been growing faster will tend to experience less sprawl.
- **When Space Is Not a Featureless Plain**
  - The existence of large indivisible public facilities.
  - Nature can also contain sprawl through physical barriers hindering urban expansion.
  - For example, in places where water-yielding aquifers are pervasive, developers can sink a well instead of connecting to the municipal or county water supply.
- **Political Geography**
  - There are a possible relationship between jurisdictional fragmentation and the restrictiveness of zoning.
  - For example, the monopoly could restrict the supply of land and increase property values.

The review of literature suggests that cities will sprawl more if:

- They specialize in sectors where employment is not typically located close to the city center.
- They were built around the car rather than around public transport.
- They have experienced slow population growth.
- There is greater uncertainty regarding their future population growth.
- Aquifers underlie a greater fraction of their urban fringe.
- They are not surrounded by high mountains.
- Terrain in their urban fringe is rugged.
- Their climate is temperate.
- They begin with substantial unincorporated areas on the urban fringe.
- Local taxpayers pay a smaller share of local government expenses.

Model

We test these predictions by regressing our sprawl index for new development in individual metropolitan areas on initial metropolitan area characteristics:

$$y_{\mathrm{i}} = \phi \boldsymbol{Control}_i + Census_i + \varepsilon_i$$

* y_{i} is the percentage of undeveloped land in the square kilometer around an average 1976–1992 residential development in metropolitan area i.
* $\boldsymbol{Control}_i$ is a vector of initial metropolitan area characteristics.
* $Census_i$ is a Census division fixed effects.

TABLE IV
THE DETERMINANTS OF SPRAWL

	Regression results				Summary statistics	
	(1)	(2)	(3)	(4)	Mean	St. dev.
Centralized-sector employment 1977	−1.270 (0.517)**	−1.194 (0.526)**	−0.922 (0.599)	−0.462 (0.489)	22.65	1.14
Streetcar passengers per capita 1902	−1.723 (0.507)***	−1.918 (0.553)***	−1.762 (0.520)***	−1.822 (0.535)***	21.53	62.54
Mean decennial % population growth 1920–1970	−6.072 (1.854)***	−5.528 (1.839)***	−6.241 (2.187)***	−4.686 (1.367)***	24.54	22.42
Std. dev. decennial % population growth 1920–1970	3.169 (1.315)**	3.208 (1.210)***	3.419 (1.424)**	2.482 (1.005)**	15.72	23.42
% of urban fringe overlying aquifers	1.222 (0.473)***	1.090 (0.507)**	0.945 (0.539)*	1.720 (0.484)***	30.43	37.96
Elevation range in urban fringe (m.)	−1.609 (0.946)*	−1.166 (1.023)	0.914 (1.117)	−1.731 (0.815)**	542.43	737.02
Terrain ruggedness index in urban fringe (m.)	1.252 (0.746)*	1.267 (0.746)*	1.108 (0.767)	2.195 (0.741)***	8.84	10.10
Mean cooling degree-days	−6.512 (1.562)***	−5.415 (1.657)***	−6.440 (2.359)***	−6.157 (1.564)***	1348.43	923.13
Mean heating degree-days	−4.986 (1.341)***	−4.768 (1.381)***	−3.051 (2.632)	−6.966 (1.360)***	4580.79	2235.66
% of urban fringe incorporated 1980	−1.363 (0.455)***	−1.558 (0.451)***	−1.708 (0.464)***	−1.629 (0.422)***	5.21	5.05
Intergov. transfers as % of local revenues 1967	1.075 (0.633)*	1.070 (0.682)	1.136 (0.679)*	2.206 (0.596)***	37.17	10.65
Bars and restaurants per thousand people		0.176 (0.783)		1.51	0.41	
Major road density in urban fringe		−0.179 (0.698)			0.87	0.36

Conclusions

- Our main findings are concerned with whether development is sprawling or compact.
- We measure sprawl as the amount of undeveloped land surrounding an average urban dwelling.
- Commercial development has become somewhat more sprawling during the study period, but the extent of residential sprawl has remained roughly unchanged between 1976 and 1992.

The extent of sprawl does vary dramatically across metropolitan areas

- **We find that sprawl is positively associated with**
  - The degree to which employment is dispersed.
  - The reliance of a city on the automobile over public transport.
  - Fast population growth.
  - The value of holding on to undeveloped plots of land.
  - The ease of drilling a well.
  - Rugged terrains and no high mountains and temperate climate.
  - The percentage of land in the urban fringe not subject to municipal planning regulations.
  - Low impact of public service financing on local taxpayers.