

# Causes of sprawl: A portrait from space



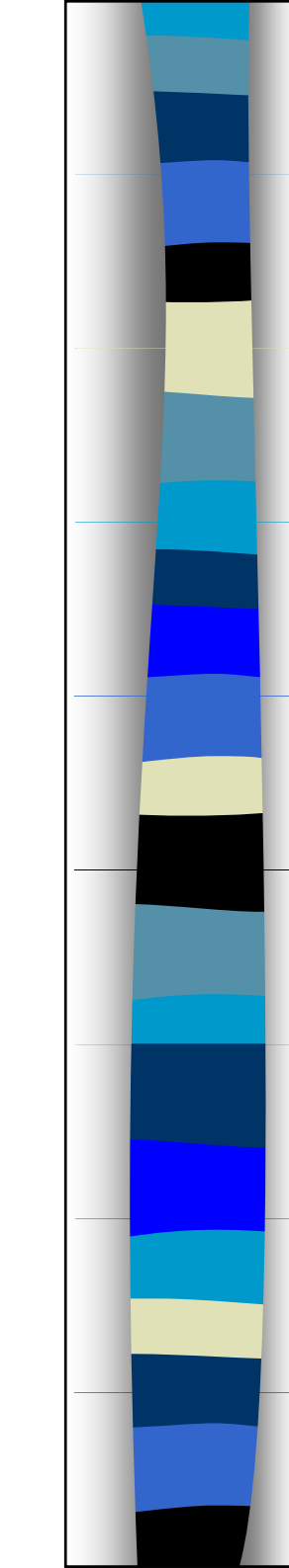
Burchfield M., Oversman H., Puga M.,  
Turner M., 2005



# I. Introduction

- Sprawl definition
  - Residential Sprawl
  - Commercial Sprawl
- Advantages and Disadvantages of Sprawl

# Urban Sprawl

- 
- **“*Low-density development beyond the edge of service and employment*, which separates where people live from where they shop, work, recreate and educate — thus requiring cars to move between zones.”** (<http://www.sierraclub.org/>)
  - ***Urban Sprawl - беспорядочно застроенная территория***

# Residential Sprawl

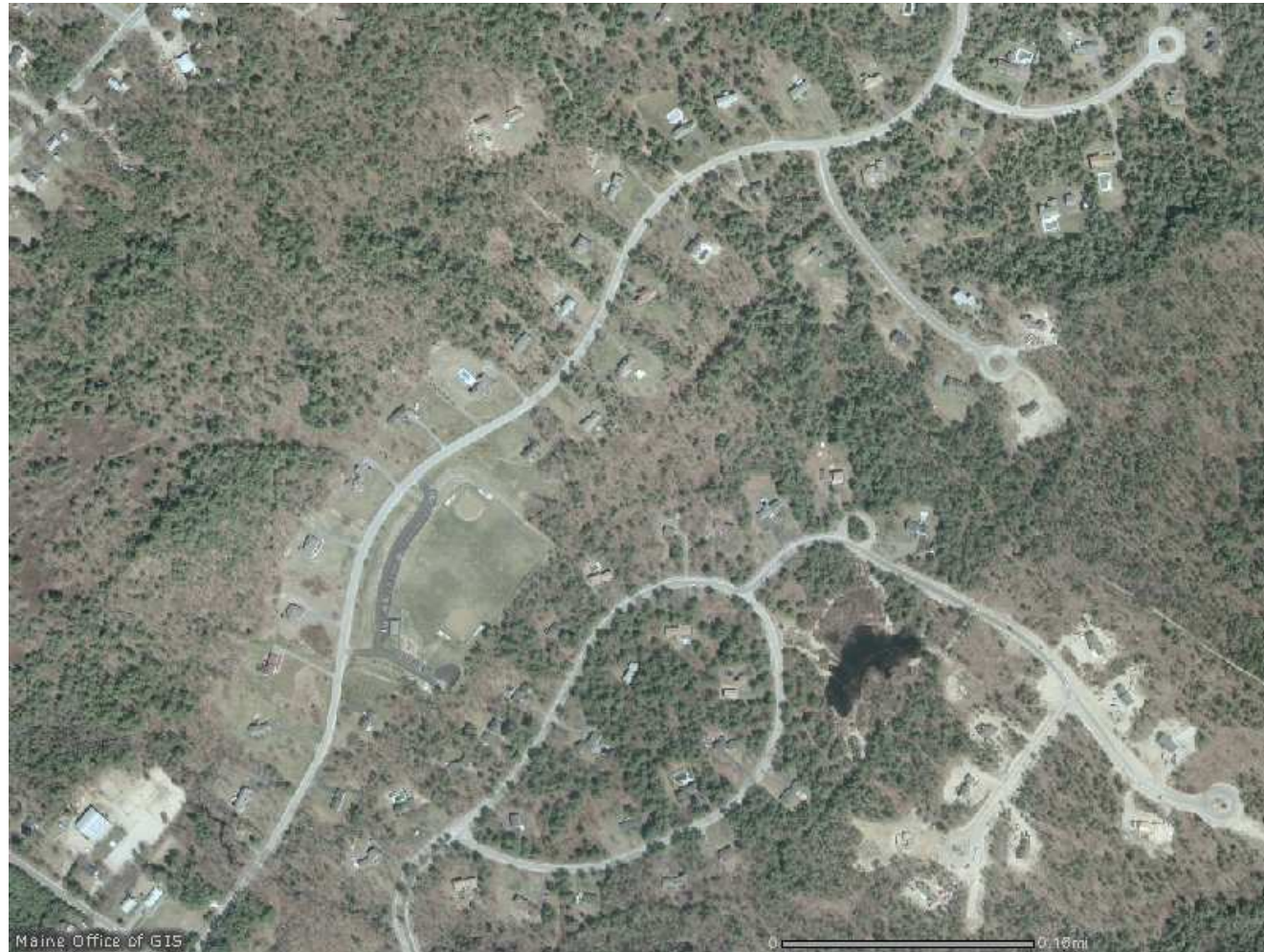


*Single-family* detached homes...

- ...occupied by *households that commute* to work, and
- ...built at *low density*
- ...beyond *walking distance* of goods and services
- ...more than *critical response time* from fire services

*Heavy reliance on private automobiles* as the primary transportation mode

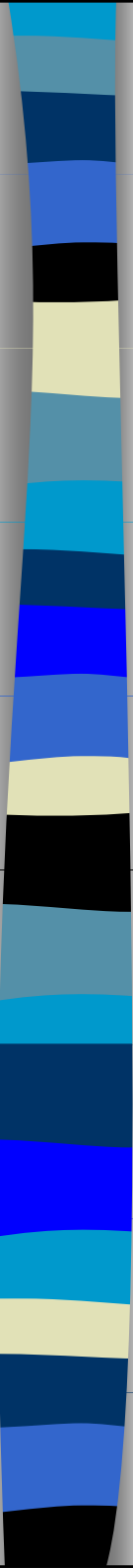
# Residential sprawl



**Low density, auto-dependent development outside compact urban and village centers, along highways and in rural countryside.**



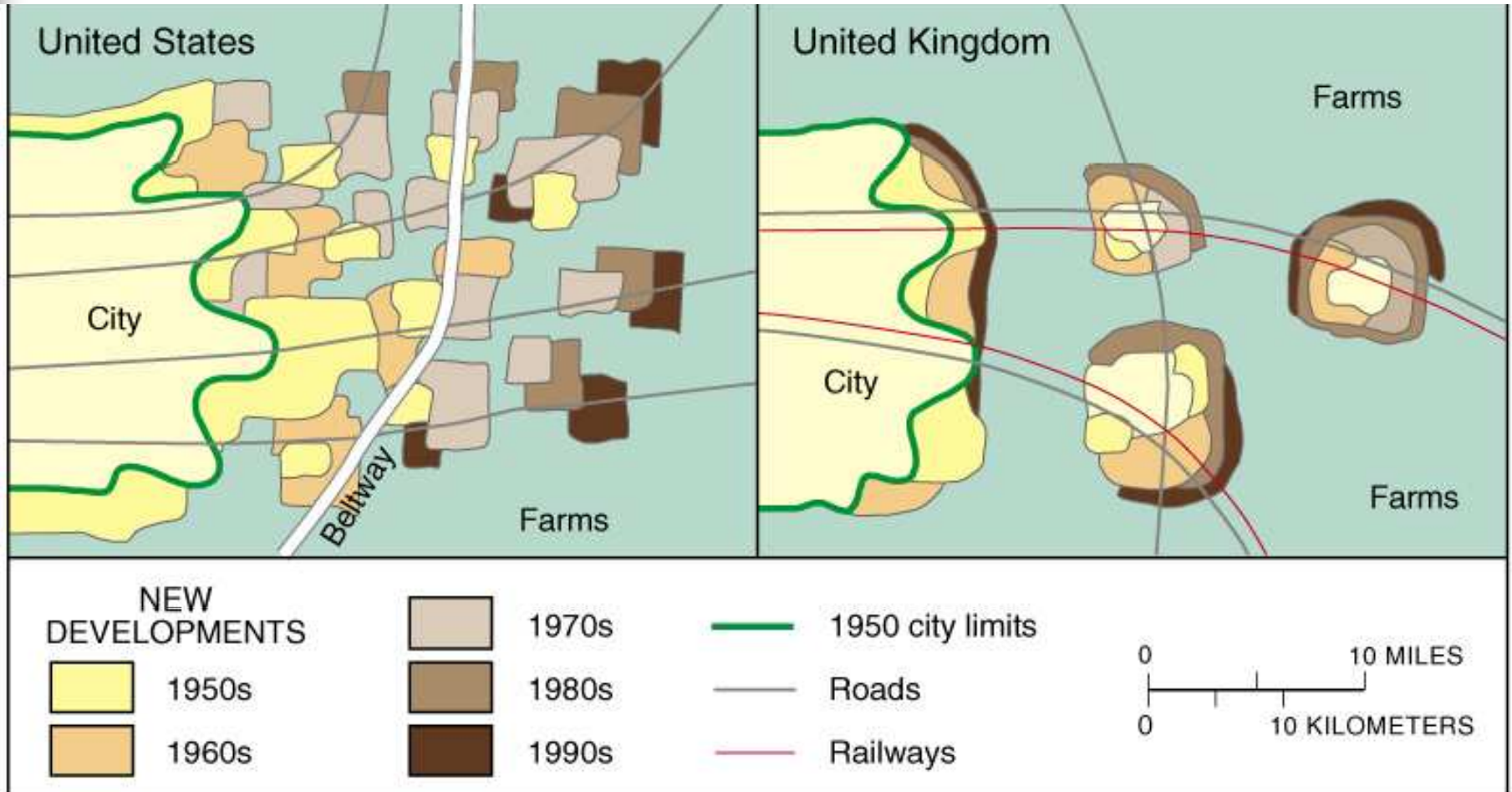
# Urban Sprawl

- 
- *No centralized planning or control* of land uses
  - *Significant fiscal disparities* among localities
  - Reliance on a “*trickle-down*” or *filtering* process to provide housing to low-income households

# Urban sprawl

- *“Leapfrog” development* which occurs when *developers* choose to build on less expensive land farther away from the city, bypassing vacant land located closer to the city

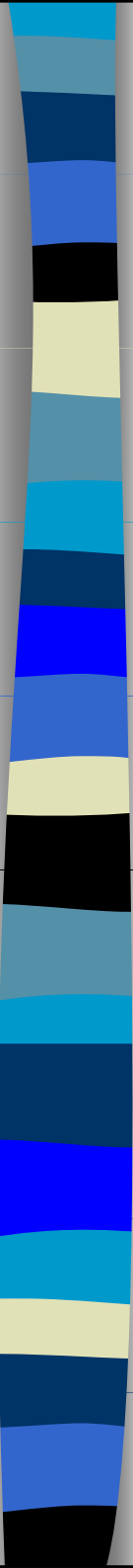
# Europe versus U.S. Cities: Sprawl



European cities, including this hypothetical U.K. example, tend to restrict suburban development, thereby concentrating new development in and around existing concentrations. This leaves large rings of open space, so-called greenbelts.



# Urban Sprawl

- 
- *Segregation of land use types* into different zones
  - *Strip or ribbon development*, which involves extensive commercial development in a linear pattern, which contributes to traffic congestion



# Commercial sprawl

*Auto-oriented* development...

...built at a *low floor area ratio*

...in *strips* along major routes or in isolated business parks

...*separated* from other land uses.

# Commercial sprawl





# ADVANTAGES AND DISADVANTAGES OF SPRAWL

- **Social**
- **Economic**
- **Environmental**
- **Health**
- ...



# ADVANTEGES OF SPRAWL

## Advantages

- **improvement of life quality in range of flat** (housing estate with block of flats vs. own detached house)
- **improvement of life quality in range of environment and landscape** (housing estate with block of flats vs. own detached house)
- **nearness of recreation space;**
- **improvement of life quality in terms of safety**



# ADVANTEGES OF SPRAWL



- **improvement of life quality in range of flat (housing estate with block of flats vs. own detached house)**



# ADVANTEGES OF SPRAWL



- **improvement of life quality in range of environment and landscape (housing estate with block of flats vs. own detached house)**
- **nearness of recreation space;**
- **improvement of life quality in terms of safety**

# DISADVANTAGES OF SPRAWL

- 
- **Social**
  - **Economical**
  - **Environmental**
  - **Health**
  - ...



# Some recent conclusions about sprawl...

- “The vast majority of metropolitan areas experienced a significant decline in metropolitan density (between 1982-1997) and therefore can be described as sprawling.” (Fulton et al. 2001)
- “Sprawl is ubiquitous and it is continuing to expand.” (Glaeser and Kahn 2003)
- “Many extended urbanized areas are very sprawl-like on some dimensions, but not so sprawl-like on others.” (Galster et al. 2005)
- **“The extent of sprawl has remained roughly unchanged between 1976 and 1992.”**  
(Burchfield et al. 2006)



## II. Measurements of Sprawl

- **Methodology**

- Analyzing Landscape Change with Satellite Remote Sensing and Geographic Information Systems

- **Data Source**

- Land Use and Land cover Digital Data (derived from high attitude aerial photography, **1972**)

- National Land Cover Data (derived from satellite imagery, **1990**)

- **Land Use Classification**

- **Urban Land**

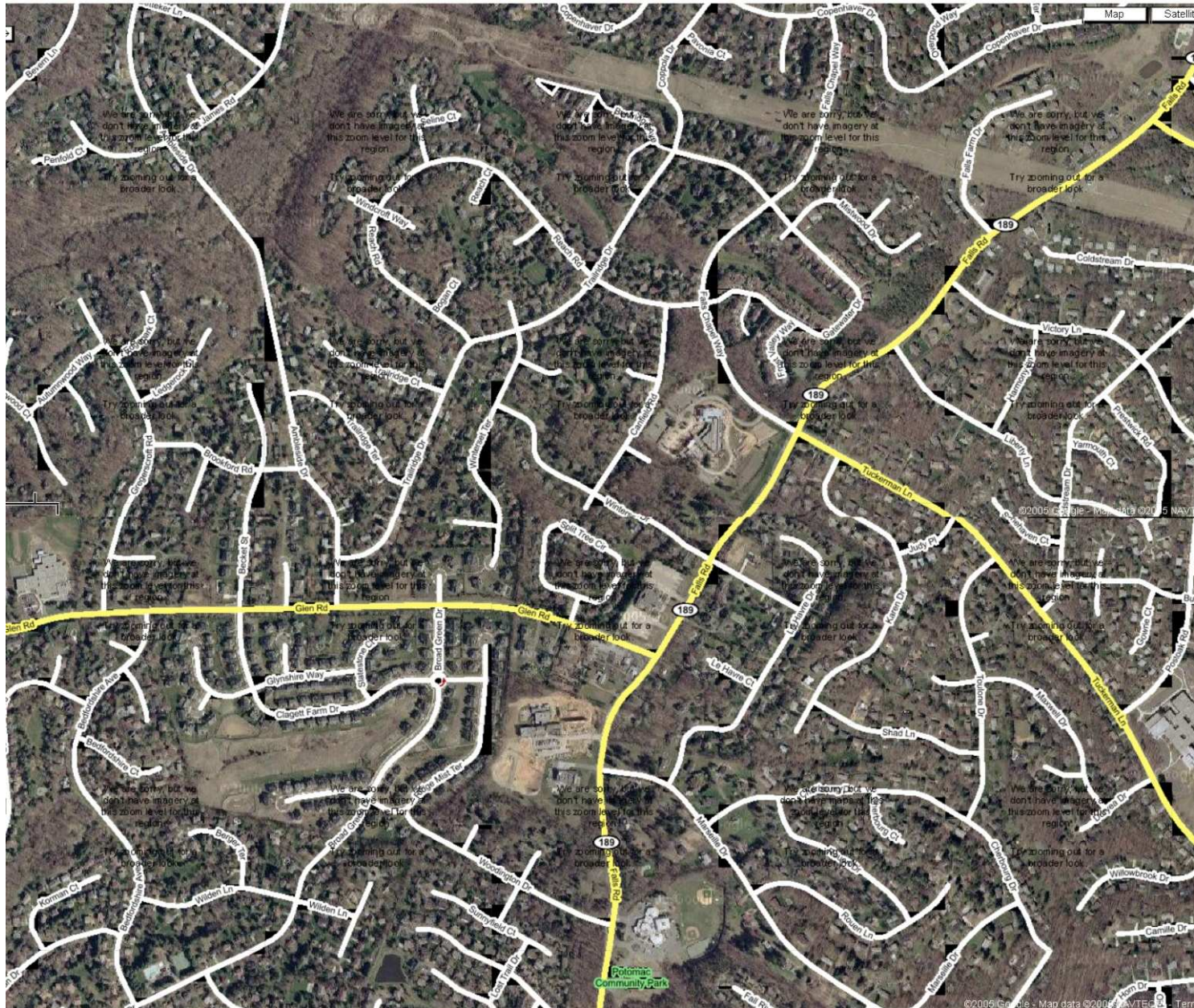
- **Sprawl Index**



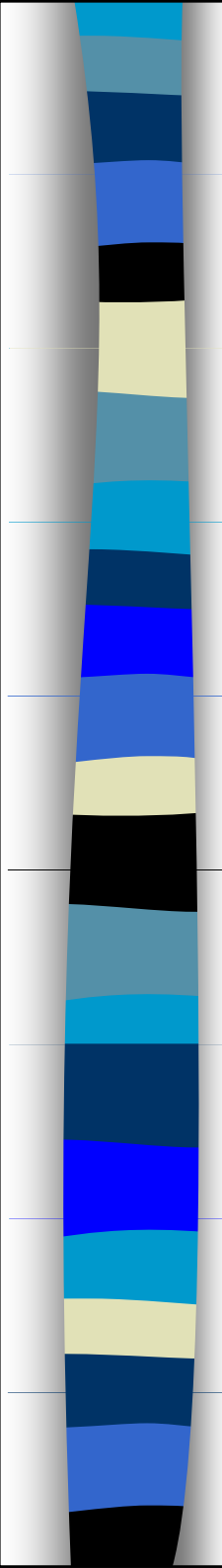
# Data Source: Satellite Imagery

North West suburb of Washington DC

0 200 m 400 m



# Data units

- 
- Square cells of 30×30 meters situated on a regular grid (8.7 billions cells)
  - For each cells predominant land cover was assigned
  - Land Cover Codes
    - *Residential development;*
    - *Commercial and industrial development and transportation networks;*
    - *Water;*
    - *Bare rock and sand;*
    - *Forest;*
    - *Range and grassland;*
    - *Agricultural land;*
    - *Wetlands*



# Urban Land in US

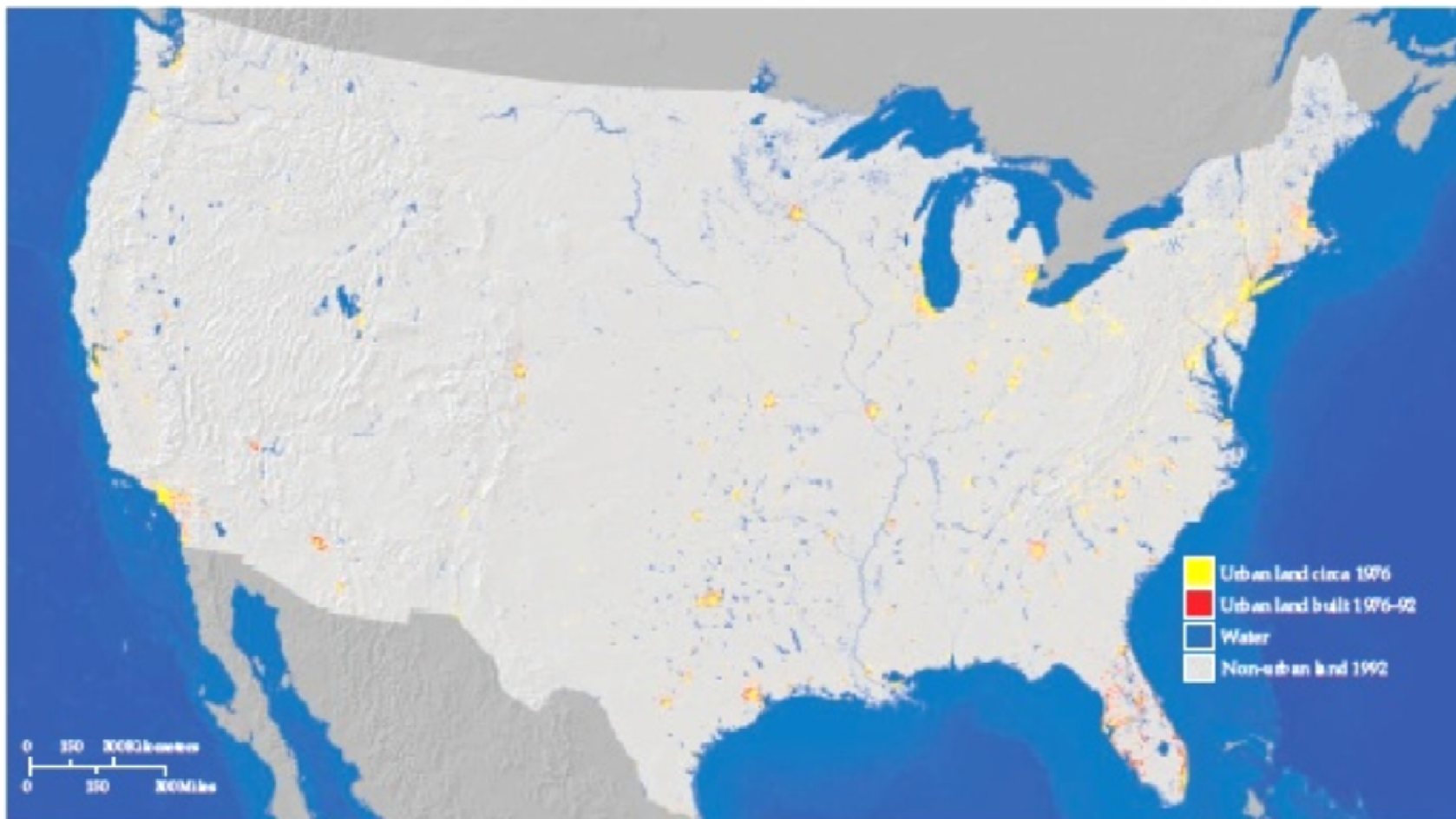


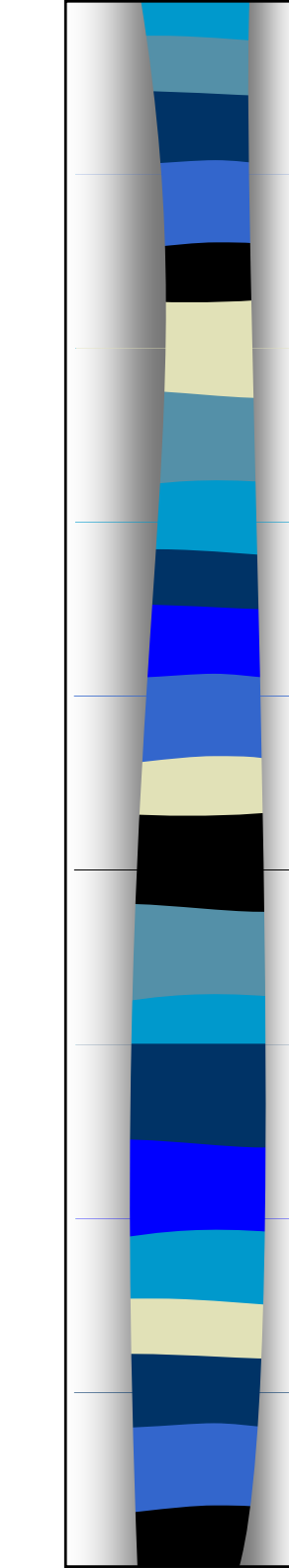
FIGURE I  
Urban Land in the Contiguous United States



# Urban Land in US

- 1.9 % of the United States was developed in 1992 (Burchfield, 2005)
  - (2.5 % of US was classified as “urban” by Census Bureau in 1990)
- two-thirds of this developed land is already in urban use in 1976
- Developed area grew by 48 percent over 16 years

# Urban Land in US: Large Differences across States



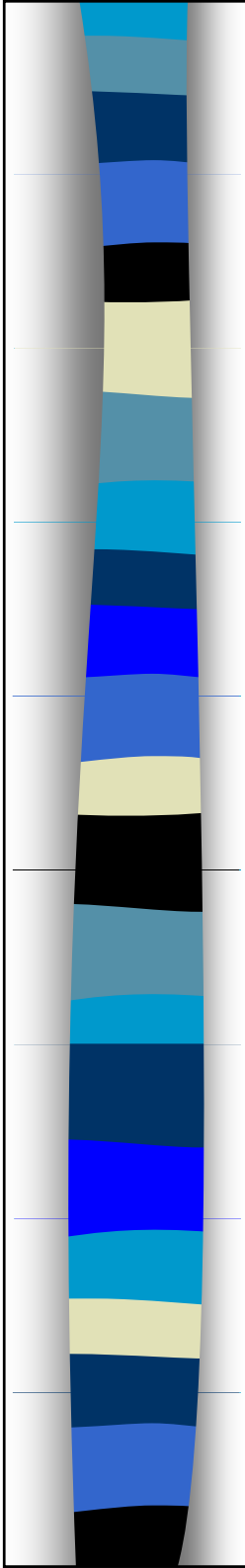
State	% of state land area urbanized by 1992	% of state non urban land urbanized by 1976-1992
Arizona	0.79	0.35
DC	68.13	2.8
Massachusetts	17.34	5.7
Wayoming	0.21	0.09



# Sprawl Index

- Cell-based measure of sprawl:

$SI = \text{average \% undeveloped land within } 1 \text{ km}^2 \text{ of residential cells in metropolitan area}$



# Sprawl Index

$$\frac{240 \text{ undeveloped pixels}}{1200 \text{ total pixels}} = 20\%$$

560 m

**Urban**  
**0-50%**

Developed pixels  
are dark gray

# Sprawl Index

$$\frac{960 \text{ undeveloped pixels}}{1200 \text{ total pixels}} = 80\%$$

**Suburb**  
**50 – 80%**

Developed pixels  
are dark gray



# Sprawl Index

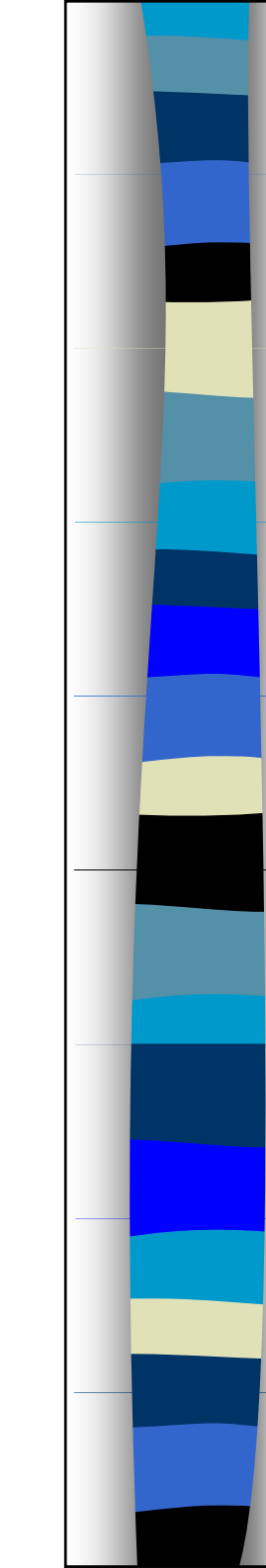
$\frac{1160 \text{ undeveloped pixels}}{1200 \text{ total pixels}} = 97\%$

560 m

**Rural**  
**90 – 100%**

Developed pixels  
are dark gray

# Sprawl Index

- 
- Spatial scale choice (1 km<sup>2</sup> - radius 560 m)
    - Only 0.3 % of residential development was more than 1 km from other residential development in 1992



# Sprawl Across United states



- *Sprawl Index (1992) = 0.43*

- Measure of sprawl shows that 43 percent of the square kilometer surrounding an average residential development is undeveloped

- *Sprawl Index (1976) = 0.42*

- Average residential development was essentially unchanged between 1976 and 1992

# Sprawl as scattered residential development

- Cell-based measure of sprawl = average %undeveloped land within 1km<sup>2</sup> of residential cells in metro

*“The extent of (residential) sprawl has remained roughly unchanged between 1976 and 1992.”*

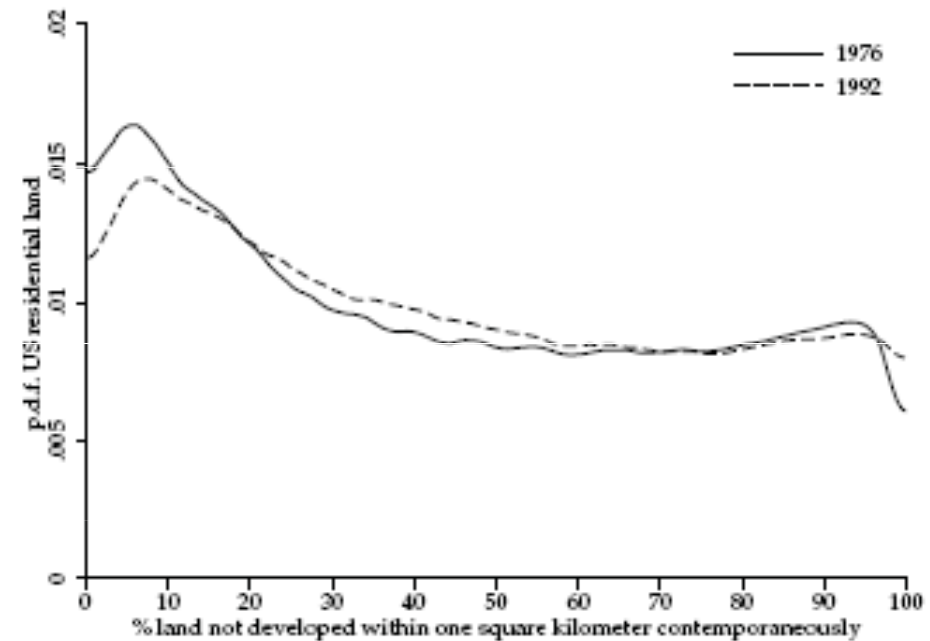


FIGURE IV  
Probability function of  
1976 and 1992 US residential land  
across areas with different degrees of sprawl

# Sprawl as scattered residential development

- Cell-based measure of sprawl = average %undeveloped land within 1km<sup>2</sup> of newly residential cells in metro

*Flow of new residential development between 1976 and 1992 was biased towards sprawling areas*

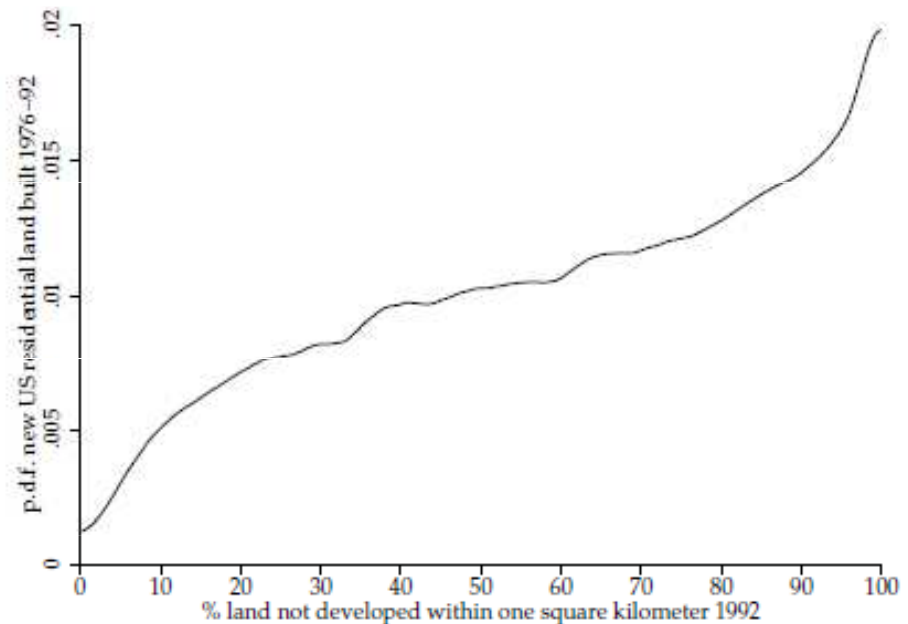


FIGURE V  
Probability function of  
1976–92 US residential development  
across areas with different degrees of sprawl

# Sprawl as scattered commercial development

- Cell-based measure of sprawl = average %undeveloped land within 1km<sup>2</sup> of **commercial** cells in metro

*Flow of new residential development between 1976 and 1992 was biased towards sprawling areas*

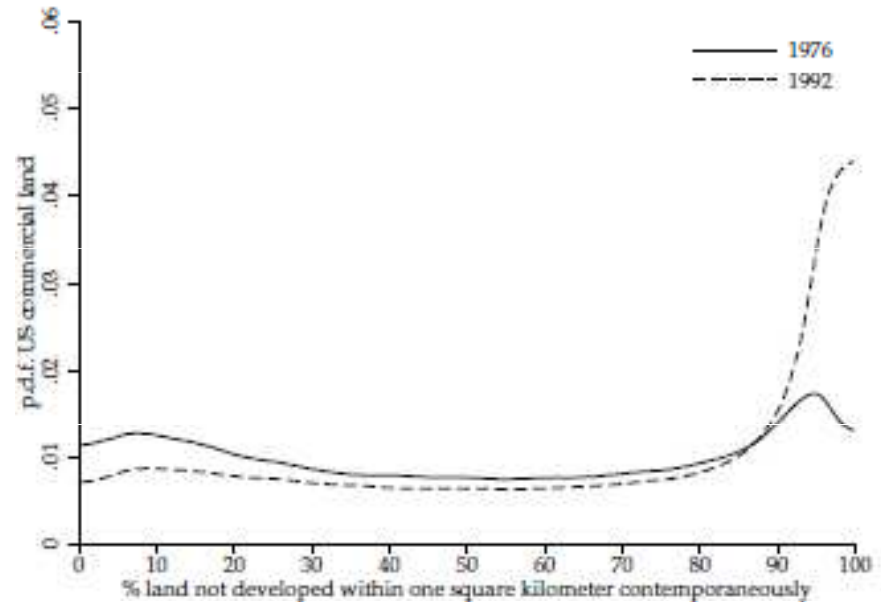


FIGURE VII  
Probability function of  
1976 and 1992 US commercial land  
across areas with different degrees of sprawl

# Sprawl Index for metropolitan areas

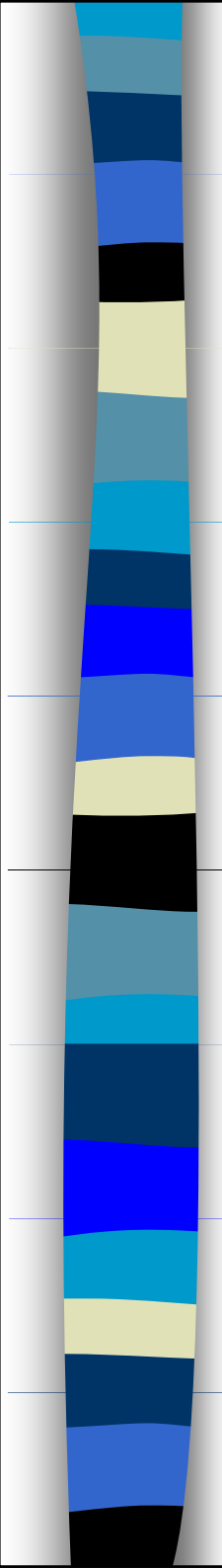
Metropolitan area	SI, 1992	SI, 1976
Atlanta	55.57	57.77
Boston	47.64	44.72
Miami	20.73	20.23
Los Angeles	35.41	32.95
New York	28.75	33.92

*“Sprawl varied dramatically across metropolitan areas.”*

*“Even at the metropolitan area level the extent of sprawl is very stable over time”*



# Another Sprawl Measures

- 
- Median Lot Size ( $S_1$ )
  - Miles Driven per Person ( $S_2$ )
  - % Employment over 3 miles from CBD ( $S_3$ )

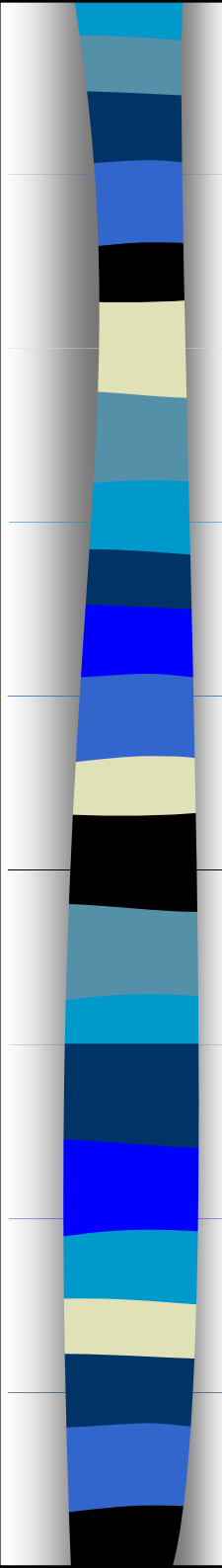
# Correlation matrix for various sprawl measures

- $S_1$  - Median Lot Size ( $S_1$ )
- $S_2$  - Miles Driven per Person ( $S_2$ )
- $S_3$  - % Employment over 3 miles from CBD – (*USA*

*Today's sprawl index published in 2001)*

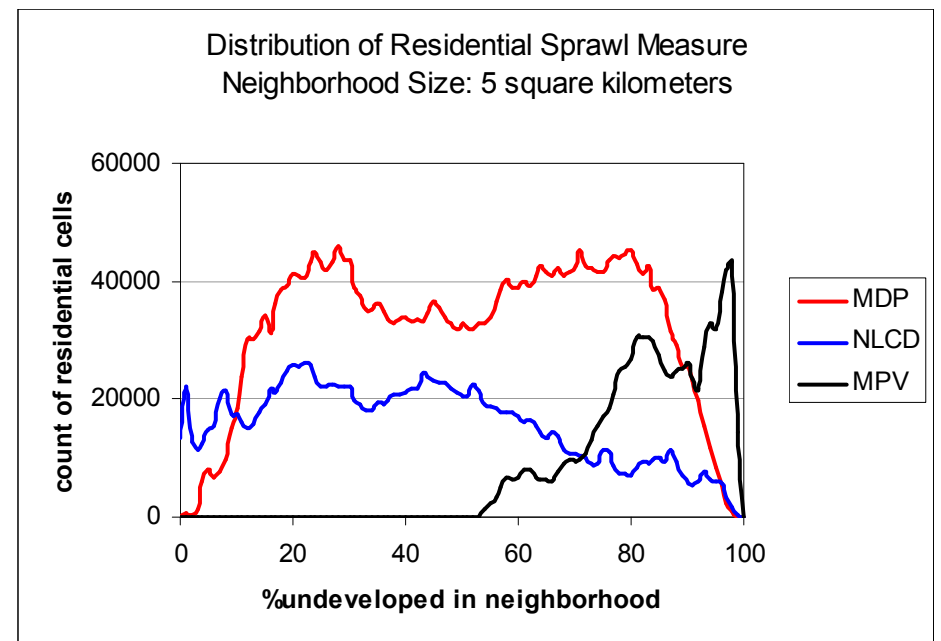
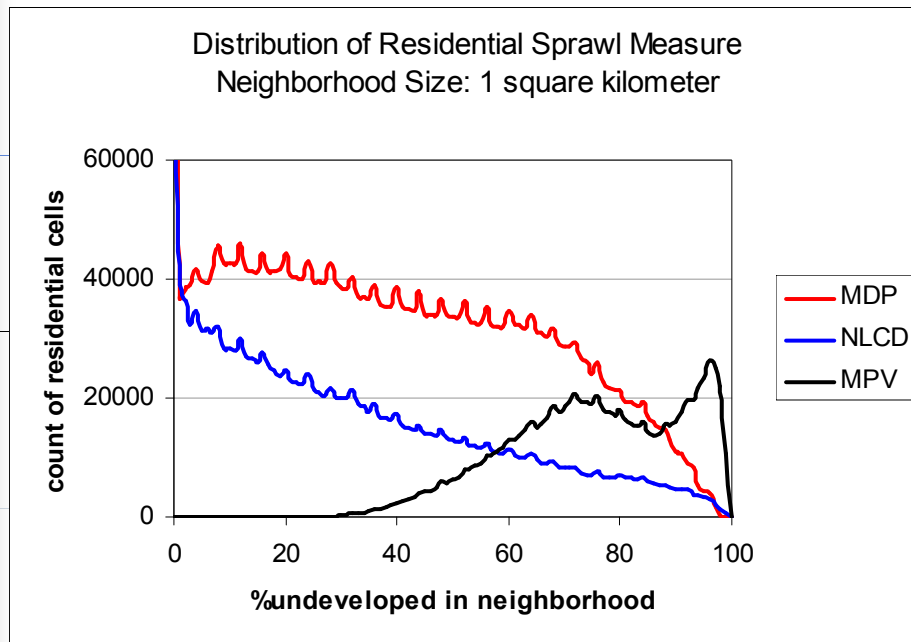
	SI	S1	S2	S3
SI	1.000			
S1	0.521	1.000		
S2	0.271	0.187	1.000	
S3	-0.070	0.011	-0.073	1.000

# Urban sprawl variables (other authors)

- 
- *Residential density*
  - Neighborhood mix of homes, jobs, and services;
  - Accessibility of the street network.
  - Overall mobility
  - Public transport
  - Road traffic
  - Accessibilities
  - Strength of activity centers and downtowns
  - ...

## Some critique (E. Irwin, N. Bockstael and H. J. Cho)

- Measurement of sprawl is highly dependent on data and spatial scale of analysis
- Aggregate pattern analysis masks important variations



# III. Causes of Sprawl

## ■ **The Monocentric City Model**

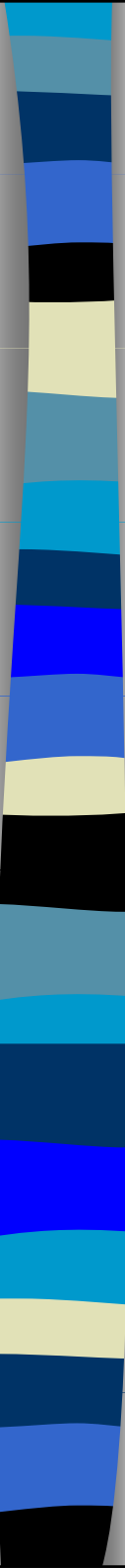
- proportion of jobs located in CBD and employment decentralization
- transport costs
- Open space & amenities

## ■ **Space is not Featureless Plain**

- Aquifers
- Physical landscape

## ■ **Political Geography**

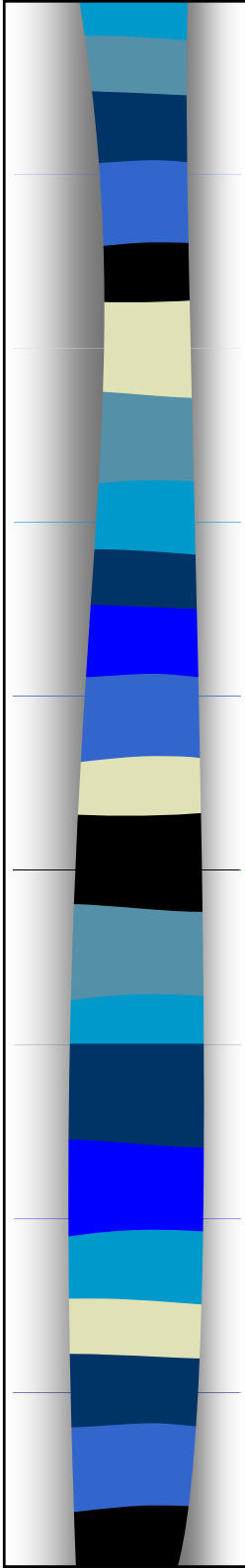
- Jurisdictional fragmentation
- Zoning



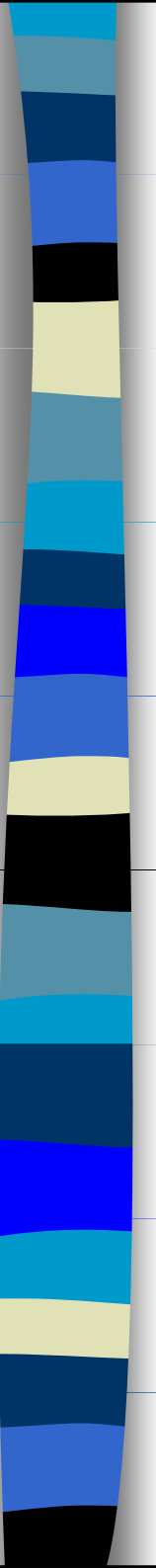


# Monocentric city

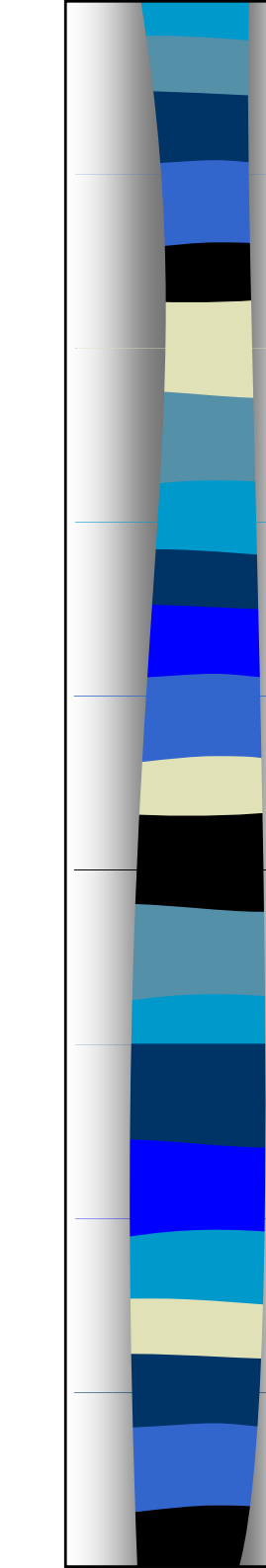
- The monocentric city model assumes that all employment in the city takes place at a single center, the central business district.
- Residential development around that center is then shaped by the tradeoff between convenient commuting close to the center and affordable housing further away.
- Substitution in response to declining land and housing prices leads to larger dwellings with lower capital to land ratios (i.e., less tall, more spacious units and larger yards) as one moves away from the center.



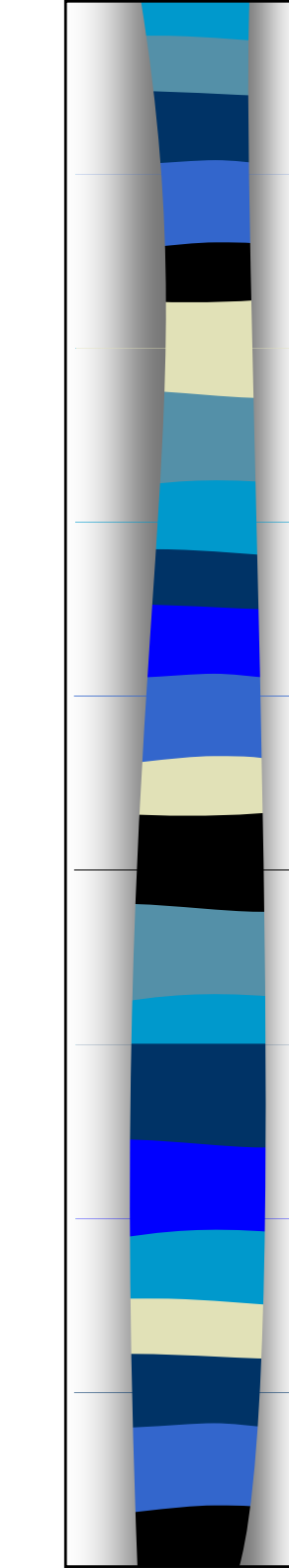
# Monocentric city

- 
- *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.*

# Monocentric city

- 
- Standard monocentric city model cannot explain leapfrog development.
  - **Amenity value of public open space:**
    - characteristics that make public open space more attractive will increase sprawl;
    - *cities that have been growing faster will tend to experience less sprawl;*
  - **Housing is durable and redevelopment costly => construction lag**
    - *leapfrogging is greater the greater the uncertainty about future urban growth*

# When Space Is Not a Featureless Plain

- 
- Example. Municipal water systems
    - *wherever aquifers underly the urban fringe, household water can be obtained without the large increasing returns associated with public water systems and this facilitates scattered development.*
    - *We would expect rugged terrain to naturally encourage scattered development.*
    - *In contrast, high mountains in the urban fringe are likely to make development more compact.*
    - *Cities with a pleasant temperate climate experience more sprawl.*

# Political Geography

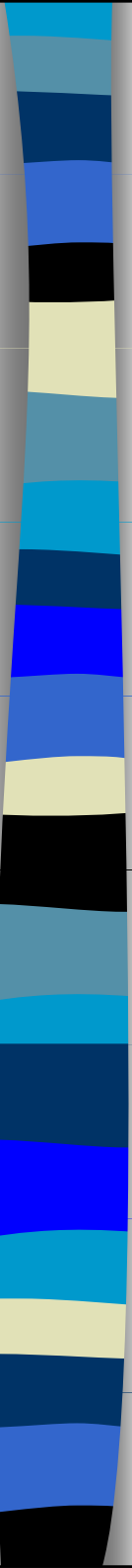
- 
- Jurisdictional Fragmentation
  - Zoning
    - *To the extent that there are unincorporated areas on the urban fringe, developers can escape municipal regulation by building outside municipal boundaries, and this facilitates sprawl.*
    - *sprawl should be more prevalent where local tax payers pay a smaller share of local government expenses.*



# Causes of Sprawl

Cities will sprawl more if:

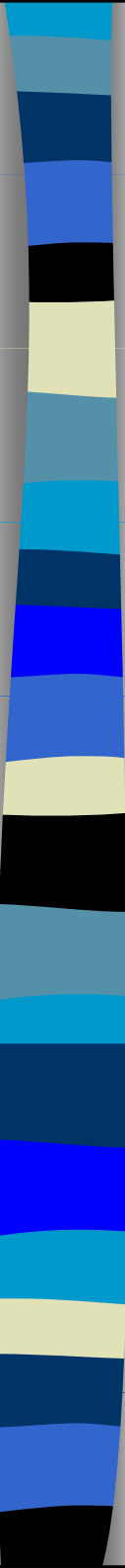
- they specialize in sectors where employment is not typically located close to the city center,
- they were built around the car rather than around public transport,
- they have experienced slow population growth,
- there is greater uncertainty regarding their future population growth,



# Causes of Sprawl

Cities will sprawl more if:

- 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 tax payers pay a smaller share of local government expenses.



# The determinants of sprawl

Sample: N=275 metropolitan areas

$SI_{newly}$  – Sprawl Index for newly developed cells 1976-1992

$SI_{1992}$  – Sprawl Index, 1992

X1 – Centralized sector employment, 1977

X2 – Steetcar passenger per capita, 1992

X3 – Mean % pop.growth 1920-70

X4 – S.d. pop.growth

X5 – % of urban fringe overlaying aquifers

X6 – Elevation range in urban fringe

X7 – Terrain ruggedness index

X8 – Mean cooling degree-days

X9 – Mean heating degree-days

X10 – % of urban fringe incorporate 1980

X11 – Intergov. Transfer, % of local revenues, 1967

# The determinants of sprawl (1)

$$SI_{newly} = 111.4 - 1.27x_1 - 1.72x_2 - 6.07x_3 + 3.17x_4 + 1.22x_5 - 1.61x_6 \\ + 1.25x_7 - 6.51x_8 - 4.99x_9 - 1.36x_{10} + 1.08x_{11}, R^2 = 0.4$$

$SI_{newly}$  – Sprawl Index for newly developed cells 1976-1992

X1 – Centralized sector employment, 1977

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X7 – Terrain ruggedness index

X8 – Mean cooling degree-days

X9 – Mean heating degree-days

X10 – % of urban fringe incorporate 1980

X11 – Intergov. Transfer, % of local revenues, 1967

# The determinants of sprawl (4)

$$SI_{92} = 75.0 - 0.46x_1 - 1.82x_2 - 4.68x_3 + 2.48x_4 + 1.72x_5 - 1.73x_6 + 2.19x_7 - 6.16x_8 - 6.97x_9 - 1.62x_{10} + 2.20x_{11}, R^2 = 0.4$$

$SI_{92}$  – Sprawl Index, 1992

X1 – Centralized sector employment, 1977

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