

A 'People-Based' Perspective on Population Density

With Applications to:
Recent U.S. Metropolitan
Population Distribution and
Change, 'Return to the City'
Residential Development,
and Coastal Population
Vulnerability

Fellows Address,
North American
Meetings of the RSAI,
Ottawa 2012

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Introduction

- The conventional measure of population density for, e.g., a city or metro area is an areal-based average of the more local-scale densities at which people live
- An alternative, “people-based” perspective is to calculate average densities on a per capita basis
- Population-weighted average density is often more revealing than conventional, overall density
- This work stems from recent research with the staff of the Population Distribution Branch of the U.S. Census Bureau

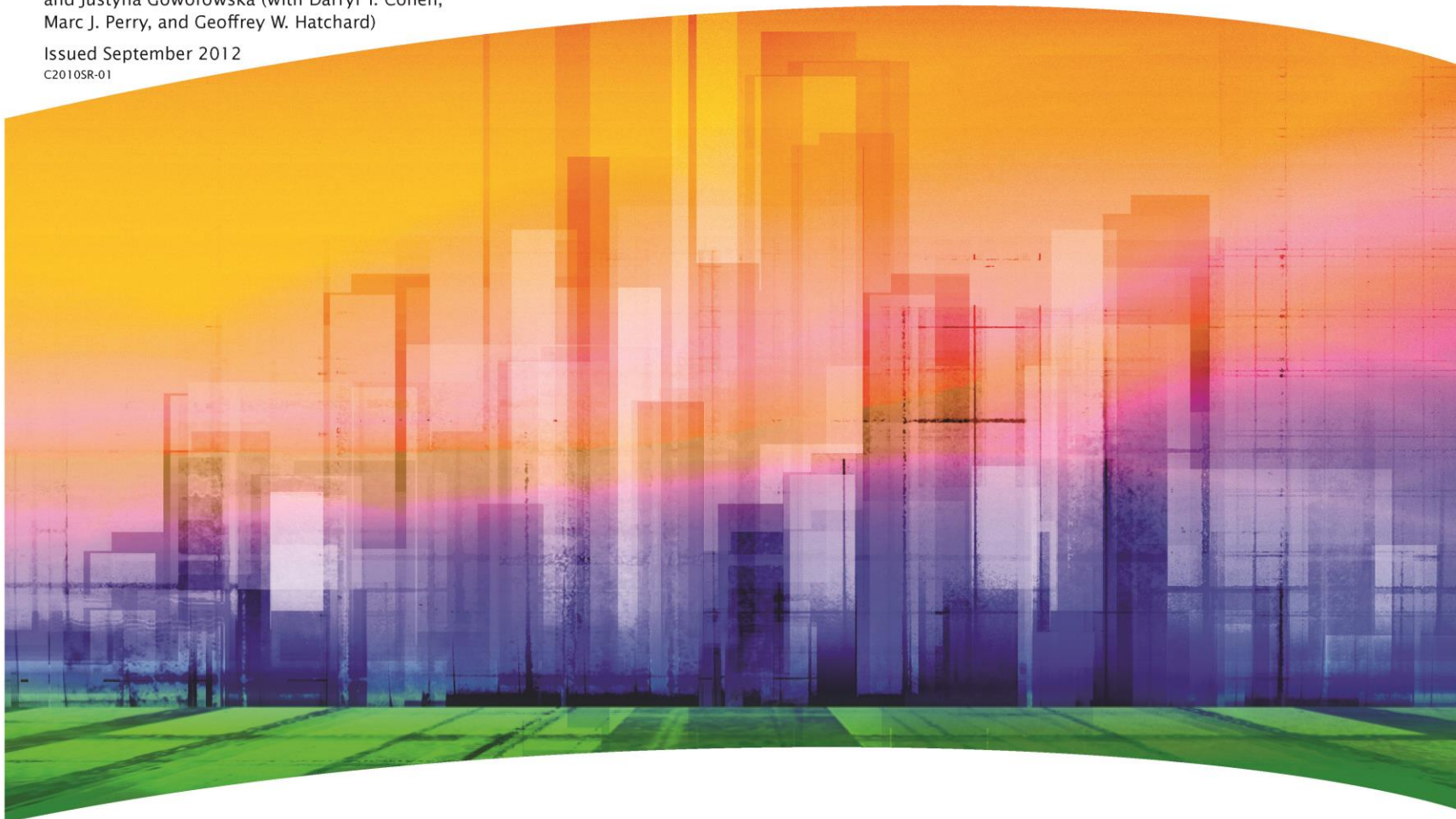
Patterns of Metropolitan and Micropolitan Population Change: 2000 to 2010

2010 Census Special Reports

By Steven G. Wilson, David A. Plane, Paul J. Mackun, Thomas R. Fischetti,
and Justyna Goworowska (with Darryl T. Cohen,
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Issued September 2012

C2010SR-01



U.S. Department of Commerce
Economics and Statistics Administration
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Overview of the talk

- Patterns of 2000-2010 population distribution and change at two scales
 - Across the landscape of U.S. metropolitan / micropolitan statistical areas
 - At the neighborhood scale within individual metro areas (using census tracts, the closest Census proxy to urban neighborhoods)
- Density “profiles” of U.S. metro areas
 - Population-weighted density for one-mile-wide distance bands from the largest principal city’s “city hall” (a consistent basing point for metro areas’ historic cores)
 - Results demonstrate the recent revival of downtown residential development in the main principal cities of many U.S. metro areas.

Overview (cont.)

- Maps of tract-level density and population change
- Population-weighted density analysis at nationwide scale
 - Regional results
 - Density trends for U.S. coastal populations:
Climate vulnerability—a timely topic!
- Thoughts for further extensions
 - Continuous density measures
 - 3-D density measures

Population-Weighted Density

- Conventional population density is an attribute of *land*:

$$d = P / A$$

- John Craig (1984) "Averaging Population Density," *Demography*
 - Any region's density statistic is inherently an areal average of the densities of more localized areas:

$$d_i \equiv P_i / A_i \quad d = \sum (A_i d_i) / \sum A_i$$

- He proposed using, instead, the geometric mean of the population weighted density of subareas
- Our "people-based" or population-weighted measure is the arithmetic mean of each and every metro area resident's tract density:

$$d_{AM} = \sum (P_i d_i) / \sum P_i$$

where P_i is the population of tract i and d_i is its density

'Perceived Densities' and a 'Concentration' Ratio

Gary Barnes (2001), Minnesota travel behavior study:

- Used weighted population and employment densities at traffic zone level to derive 'perceived densities' of urbanized areas (UAs).
- 'Concentration' ratio:

$$CR = \text{population-weighted density} / \text{overall density}$$

- Measures extent to which actual local densities at which people live diverge from average density of all UA land
- If all land developed at same density: $CR = 1$
- Overall density of Los Angeles UA greater than New York UA
 - But, New York's concentration index: 6.29
 - Los Angeles: 1.78
 - Greater disparity of density levels in New York, with its high-rise apartment core, but low density outlying suburbs.

“Weighted densities straighten out a lot of other counterintuitive ‘facts.’”

Austin, Texas blogger, Chris Bradford
 (“The Austin Contrarian”):

Weighted densities straighten out a lot of other counterintuitive “facts.” Austin and Tampa are not really denser than Boston (as the standard density figures suggest), and the sprawling suburbs of Riverside County are not actually denser than Chicago. Note that Portland's urbanized area is less dense than Houston's.

Table 3.1.

Population Density by Core Based Statistical Area (CBSA) Status and Population Size Category: 2010

(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)

CBSA status and CBSA population size category ¹	Population	Land area in square miles	Population density ²	
			Overall	Population- weighted
United States	308,745,538	3,531,905.4	87.4	5,369.0
Inside core based statistical area	289,261,315	1,649,928.4	175.3	5,720.4
In metropolitan statistical area	258,317,763	912,992.1	282.9	6,320.8
5,000,000 or more	75,886,632	60,103.4	1,262.6	13,328.3
2,500,000 to 4,999,999	42,266,846	89,888.9	470.2	5,549.9
1,000,000 to 2,499,999	48,933,937	128,131.3	381.9	3,489.4
500,000 to 999,999	35,655,887	146,113.5	244.0	2,985.5
250,000 to 499,999	28,724,493	180,814.0	158.9	2,321.4
Less than 250,000	26,849,968	307,973.7	87.2	1,597.0
In micropolitan statistical area	30,943,552	736,936.3	42.0	708.0
100,000 or more	6,003,660	72,775.3	82.5	723.5
50,000 to 99,999	13,572,401	259,472.7	52.3	777.7
Less than 50,000	11,367,491	404,688.3	28.1	616.5
Outside core based statistical area	19,484,223	1,881,977.0	10.4	152.1

¹ Size categories based on 2010 Census population data.

² Population density expressed as average number of people per square mile. Population-weighted density is an average density of all census tracts in each area.

Note: CBSAs (metropolitan and micropolitan statistical areas) defined by the Office of Management and Budget as of December 2009.

Source: U.S. Census Bureau, 2010 Census.

“Top 5 / Bottom 5” Table

For Overall Density

Table 3.2.

Core Based Statistical Areas (CBSAs) With Highest and Lowest Overall Population Density: 2010

(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)

CBSA ¹	Population	Land area in square miles	Population density ²
METROPOLITAN STATISTICAL AREA			
Highest Density			
New York-Northern New Jersey-Long Island, NY-NJ-PA	18,897,109	6,686.9	2,826.0
Los Angeles-Long Beach-Santa Ana, CA	12,828,837	4,848.5	2,646.0
San Francisco-Oakland-Fremont, CA	4,335,391	2,470.5	1,754.8
Trenton-Ewing, NJ	366,513	224.6	1,632.2
Honolulu, HI	953,207	600.7	1,586.7
Lowest Density			
Flagstaff, AZ	134,421	18,618.9	7.2
Fairbanks, AK	97,581	7,338.2	13.3
Casper, WY	75,450	5,340.4	14.1
Anchorage, AK	380,821	26,312.6	14.5
Lake Havasu City-Kingman, AZ	200,186	13,311.1	15.0
MICROPOLITAN STATISTICAL AREA			
Highest Density			
Oak Harbor, WA	78,506	208.4	376.6
Thomasville-Lexington, NC	162,878	552.7	294.7
Lexington Park, MD	105,151	357.2	294.4
East Stroudsburg, PA	169,842	608.3	279.2
Statesville-Mooresville, NC	159,437	573.8	277.8
Lowest Density			
Bishop, CA	18,546	10,180.9	1.8
Kodiak, AK	13,592	6,549.6	2.1
Elko, NV	50,805	21,345.5	2.4
Pahrump, NV	43,946	18,181.9	2.4
Ketchikan, AK	13,477	4,858.4	2.8



• Areas with highest density.

• Areas with lowest density.

¹ Among CBSAs in the 50 states and the District of Columbia.

² Population density expressed as average number of people per square mile.

Note: CBSAs (metropolitan and micropolitan statistical areas) defined by the Office of Management and Budget as of December 2009.

Source: U.S. Census Bureau, 2010 Census.

“Top 5 / Bottom 5” Table

For Population- Weighted Density

Table 3.3.

Core Based Statistical Areas (CBSAs) With Highest and Lowest Population- Weighted Density: 2010

(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)

CBSA ¹	Population	Land area in square miles	Population-weighted density ²
METROPOLITAN STATISTICAL AREA			
Highest Density			
New York-Northern New Jersey-Long Island, NY-NJ-PA	18,897,109	6,686.9	31,251.4
San Francisco-Oakland-Fremont, CA	4,335,391	2,470.5	12,144.9
Los Angeles-Long Beach-Santa Ana, CA	12,828,837	4,848.5	12,113.9
Honolulu, HI	953,207	600.7	11,548.2
Chicago-Joliet-Naperville, IL-IN-WI	9,461,105	7,196.8	8,613.4
Lowest Density			
Jefferson City, MO	149,807	2,247.7	522.7
Rocky Mount, NC	152,392	1,045.7	525.7
Brunswick, GA	112,370	1,286.4	539.0
Morristown, TN	136,608	715.9	554.2
Anniston-Oxford, AL	118,572	605.9	566.6
MICROPOLITAN STATISTICAL AREA			
Highest Density			
Athens, OH	64,757	503.6	2,950.8
Key West, FL	73,090	983.3	2,614.9
Laramie, WY	36,299	4,273.8	2,499.3
Rexburg, ID	50,778	2,332.7	2,470.5
Sunbury, PA	94,528	458.4	2,423.6
Lowest Density			
Prineville, OR	20,978	2,979.1	19.6
Evanston, WY	21,118	2,081.3	48.5
Silverthorne, CO	27,994	608.4	54.7
Mountain Home, ID	27,038	3,074.7	56.7
Weatherford, OK	27,469	988.8	70.2



- Areas with highest density.
- Areas with lowest density.

¹ Among CBSAs in the 50 states and the District of Columbia.

² Population-weighted density is an average density of all census tracts in each area.

Note: CBSAs (metropolitan and micropolitan statistical areas) defined by the Office of Management and Budget as of December 2009.

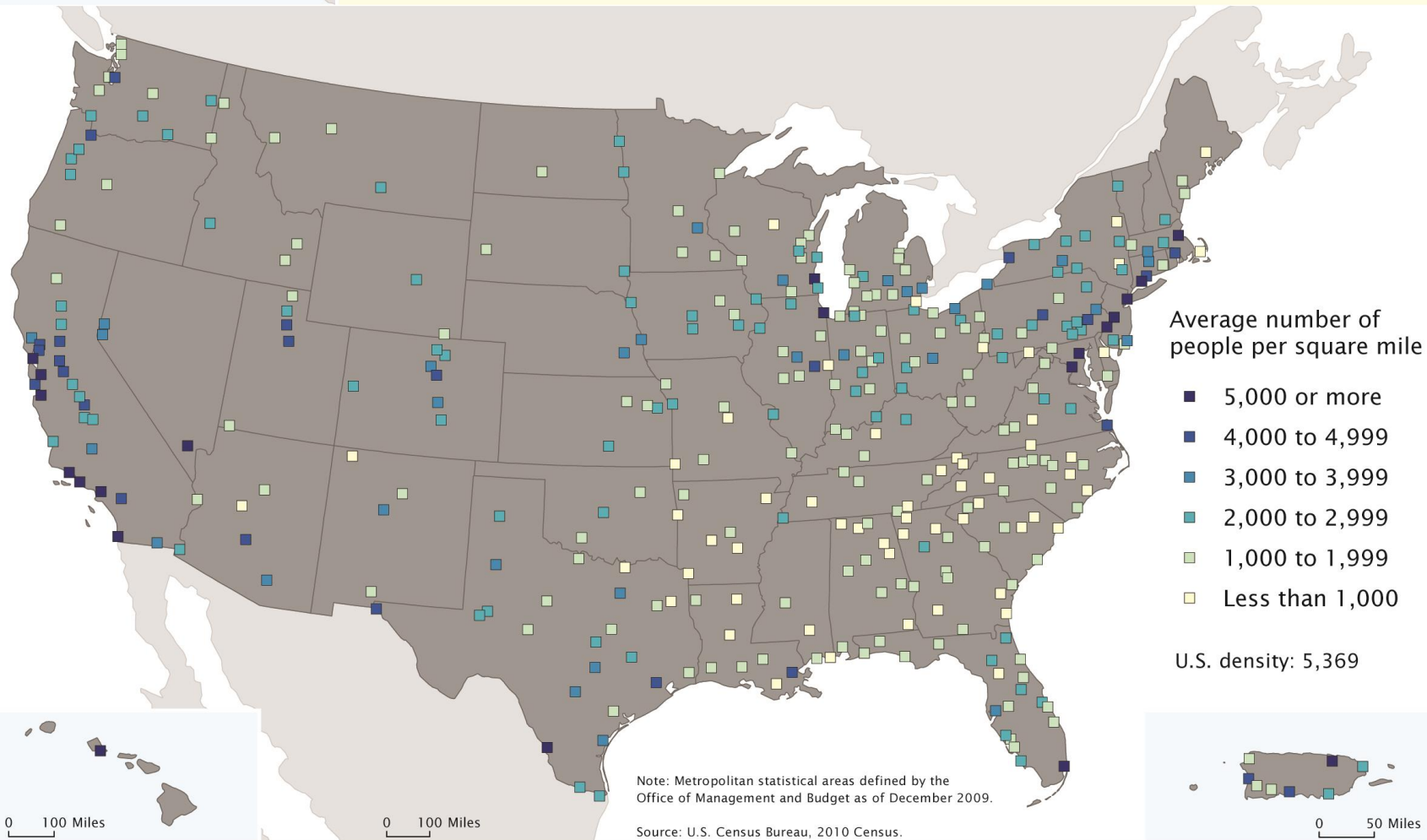
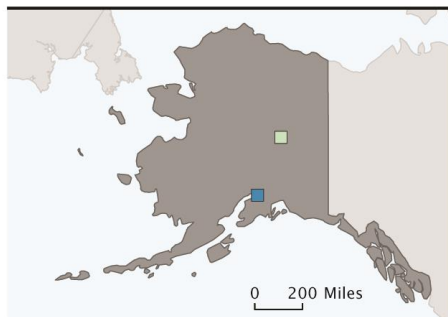
Source: U.S. Census Bureau, 2010 Census.

Metros Ranked by Overall Population Density	People per square mile		Metros Ranked by Population- Weighted Population Density	People per square mile
Highest Density			Highest Density	
1. New York	2,826.0		1. New York	31,251.4
2. Los Angeles	2,646.0		2. San Francisco	12,144.9
3. San Francisco	1,754.8		3. Los Angeles	12,113.9
4. Trenton	1,632.2		4. Honolulu	11,548.2
5. Honolulu	1,586.7		5. Chicago	8,613.4
Lowest Density			Lowest Density	
1. Flagstaff, AZ	7.2		1. Jefferson City, MO	522.7
2. Fairbanks, AK	13.3		2. Rocky Mount, NC	525.7
3. Casper, WY	14.1		3. Brunswick, GA	539.0
4. Anchorage, AK	14.5		4. Morristown, TN	554.2
5. Lake Havasu-Kingman, AZ	15.0		5. Anniston-Oxford, AL	566.6

Population-Weighted Density by Metropolitan Statistical Area: 2010

Population density expressed as average number of people per square mile of land area. Densities calculated on a population-weighted basis across all census tracts included in the metro areas.

(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)



Population-Weighted Density Profiles

- ◉ Colin Clark's (1951) seminal article, "Urban Population Densities"
- ◉ Density Gradient (aka, Density Profile, Density-Distance Profiles) have been our primary tool for visualizing population distribution within metro area
- ◉ Ground zero: heart of the historic, pedestrian-city downtown core of the metro's largest principal city
- ◉ Clark fit negative exponential functions to overall densities of each mile-wide ring (calculated from tract data)
- ◉ Newling's (1969) modification for 'central crater effect'
- ◉ Population-weighted density provides an alternative measure of the densities at which people live in each ring

Population-Weighted Density¹ in Metropolitan Statistical Areas by Distance From City Hall and Population Size Category: 2010

(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)

Population size category ²	Distance to city hall (miles) ³										
	All distances	Less than 2	2 to 4	5 to 9	10 to 14	15 to 19	20 to 29	30 to 39	40 to 49	50 to 59	60 or more
All U.S. metro areas	6,320.8	5,485.6	3,272.1	1,860.8	1,245.1	915.4	614.8	334.5	156.9	98.3	41.1
5,000,000 or more	13,328.3	25,358.8	20,329.4	15,426.7	9,735.4	5,898.3	4,161.7	3,119.9	2,019.6	1,684.7	665.0
2,500,000 to 4,999,999	5,549.9	15,086.5	9,820.7	6,590.4	4,821.5	3,519.1	2,902.6	1,791.0	698.9	559.2	342.6
1,000,000 to 2,499,999	3,489.4	7,429.2	5,673.7	3,865.9	2,781.5	2,032.2	1,253.1	650.9	354.3	48.4	97.0
500,000 to 999,999	2,985.5	6,687.6	3,904.8	2,347.2	1,819.3	1,313.7	1,036.0	437.5	179.4	45.3	24.7
250,000 to 499,999	2,321.4	4,969.9	2,969.7	1,604.3	937.1	821.6	430.8	241.4	107.4	108.8	6.7
Less than 250,000	1,597.0	3,444.9	1,559.9	527.0	314.1	243.9	148.3	61.6	12.6	7.9	1.2

¹ Population-weighted density is an average density of all census tracts in each area. Population density is expressed as average number of people per square mile.

² Size categories based on 2010 Census population data.

³ Based on spherical ("straight-line" or "crow-fly") distances between the city hall or similar main municipal building of each metropolitan statistical area's first-named principal city and the 2010 population centroids of the metro area's census tracts. Average tract-based densities within each distance category are averaged across all metro areas in each population size category.

Note: Core based statistical areas (metropolitan and micropolitan statistical areas) defined by the Office of Management and Budget as of December 2009.

Source: U.S. Census Bureau, 2010 Census.

...The population-weighted density within two miles of City Hall for metro areas of under 250,000 is about the same as the density 30–39 miles out in metros of 5 million or more

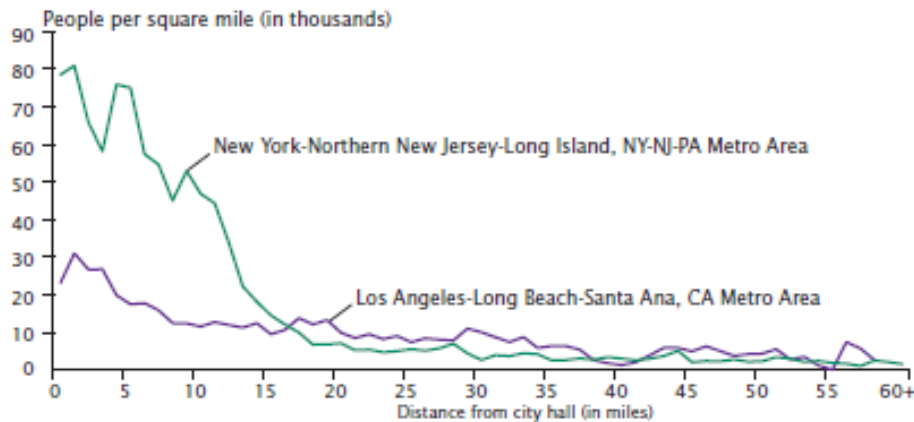
Report includes both density by distance and population by distance profiles.

The on-line content includes a fun, interactive, metro comparison tool

Figure 3.2a.

Population-Weighted Density by Distance From City Hall: 2010

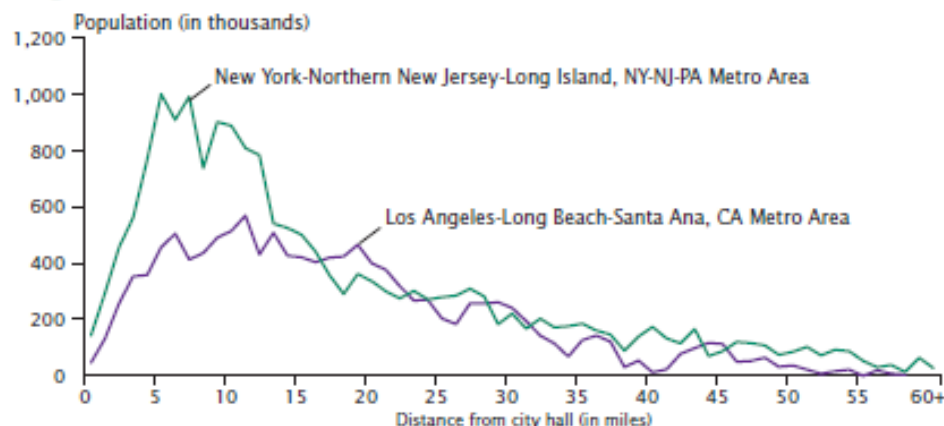
(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)



Metropolitan statistical area	Population		Population-weighted density ¹	
	Total	Percent change: 2000–2010	All census tracts	Numeric change: 2000–2010
New York-Northern New Jersey-Long Island, NY-NJ-PA Metro Area. . . .	18,897,109	3.1	31,251.4	–432.2
Los Angeles-Long Beach-Santa Ana, CA Metro Area.	12,828,837	3.7	12,113.9	–328.1

¹ Population density calculated on a population-weighted basis across all census tracts (using 2010 boundaries) included in the metropolitan statistical area.

Population by Distance From City Hall: 2010



Note: Population density expressed as the average number of people per square mile of land area. Distances are measured to the city hall or similar municipal building of the metro area's first-named principal city. Metropolitan statistical areas defined by the Office of Management and Budget as of December 2009.

Source: U.S. Census Bureau, 2010 Census and Census 2000.

...Land availability is a factor that strongly mediates the relationship between density and accessibility.

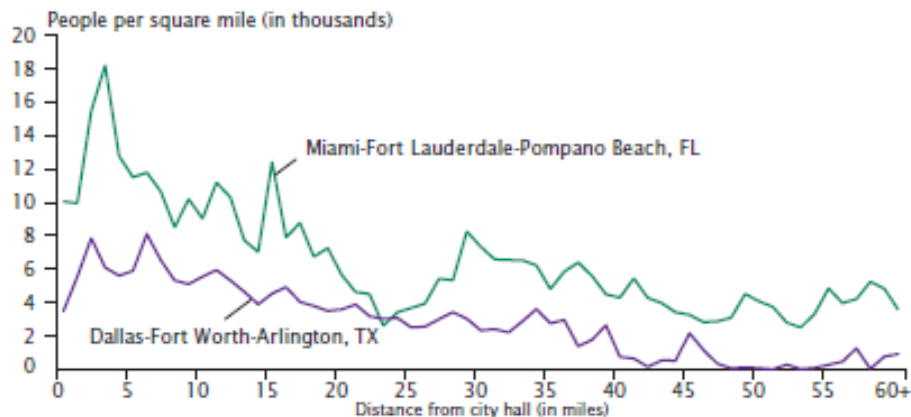
Miami and Dallas-Ft. Worth have approximately same total population

But Miami is denser in almost every distance band from City Hall

Figure 3.2b.

Population-Weighted Density by Distance From City Hall: 2010

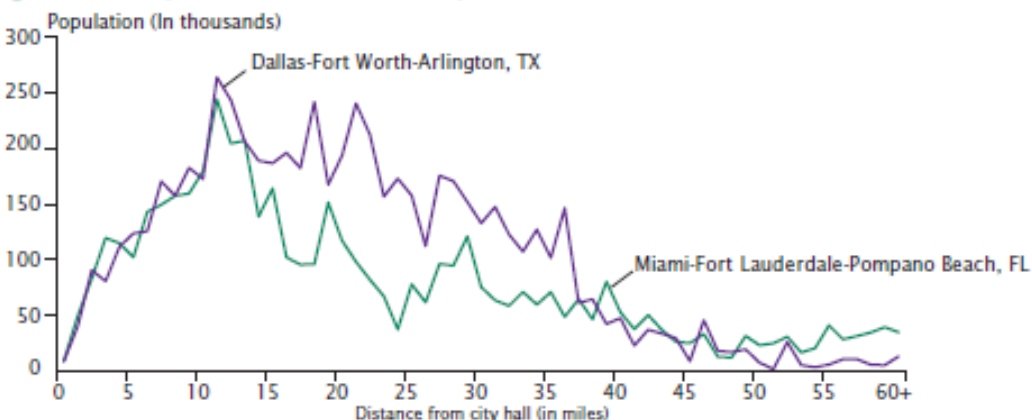
(For Information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)



Metropolitan statistical area	Population		Population-weighted density ¹	
	Total	Percent change: 2000–2010	All census tracts	Numeric change: 2000–2010
Dallas-Fort Worth-Arlington, TX Metro Area	6,371,773	23.4	3,909.3	-385.9
Miami-Fort Lauderdale-Pompano Beach, FL Metro Area	5,564,635	11.1	7,395.3	158.7

¹ Population density calculated on a population-weighted basis across all census tracts (using 2010 boundaries) included in the metropolitan statistical area.

Population by Distance From City Hall: 2010



Note: Population density expressed as the average number of people per square mile of land area. Distances are measured to the city hall or similar municipal building of the metro area's first-named principal city. Metropolitan statistical areas defined by the Office of Management and Budget as of December 2009.

Source: U.S. Census Bureau, 2010 Census and Census 2000.

Metro Areas with Highest Numeric Change in Population within 2 Miles of City Hall: 2000–2010

Rank	Metro Area (Largest Principal City)	Numeric Change	Percent Change
1.	Chicago	48,288	36.2
2.	New York	37,422	9.3
3.	Philadelphia	20,769	9.7
4.	San Francisco	19,712	5.9
5.	Washington, DC	19,502	14.2
6.	Portland, OR	14,857	22.3
7.	Boston	14,776	8.8
8.	Oxnard, CA	14,637	16.3
9.	Seattle	14,006	15.3
10.	Los Angeles	12,381	7.4



CHARTS

It's Official: Downtowns Are Booming

NATE BERG SEP 27, 2012 9 COMMENTS



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Big city downtowns are becoming people places – again or, for some, for the first time. [New figures](#) [PDF] out from the U.S. Census Bureau show that downtown areas saw huge jumps in

Numeric Change in Population by Census Tract: 2000 to 2010

(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)

Numeric change

● Increase

● Decrease

1 Dot = 25 people

— Metro area

— Largest principal city

--- County or equivalent

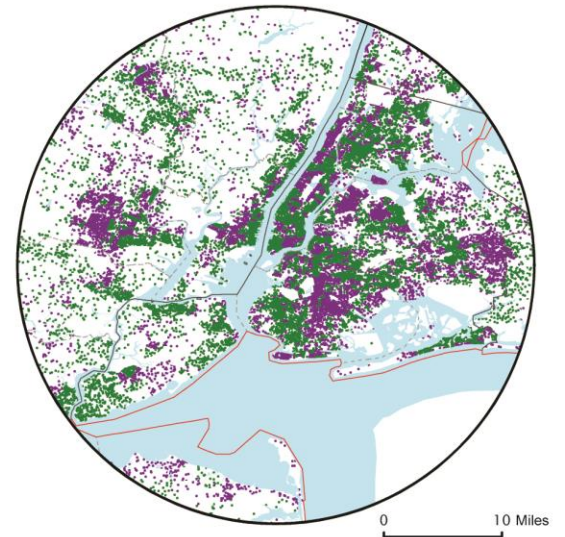
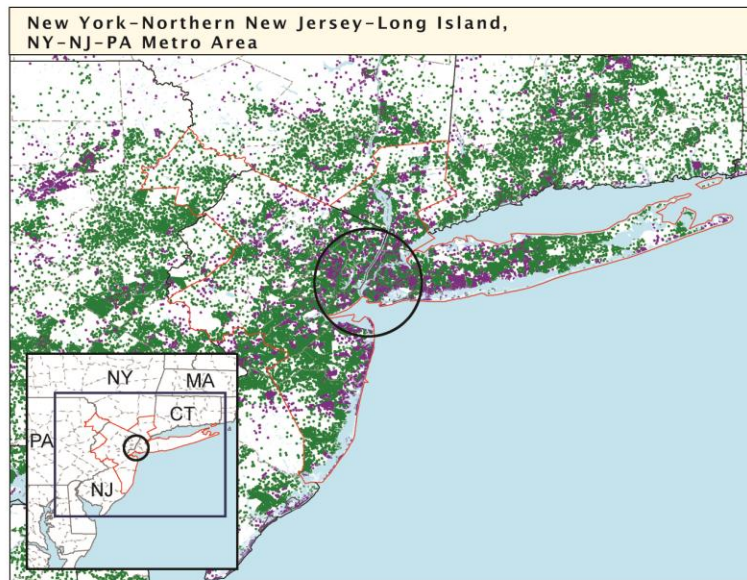
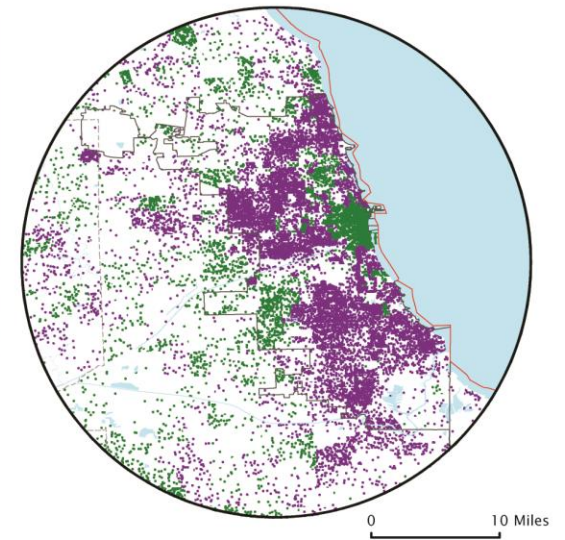
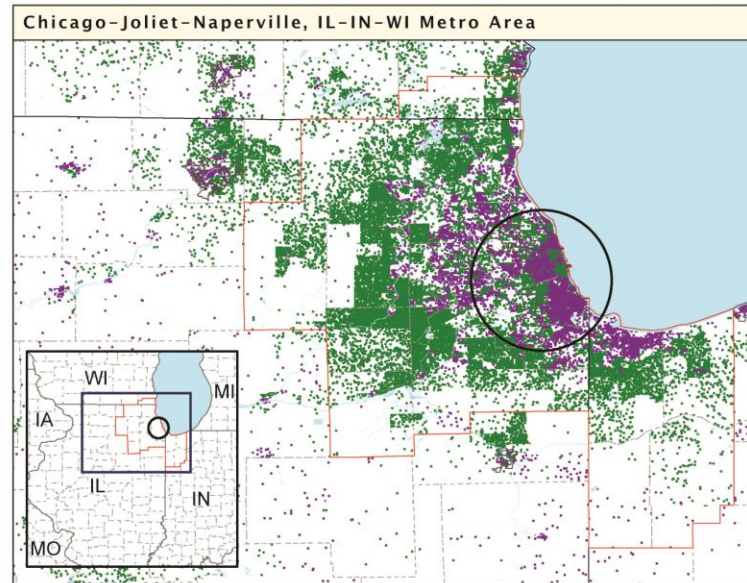
— State

Water

Chicago metro area

change: 362,789

U.S. change: 27,323,632



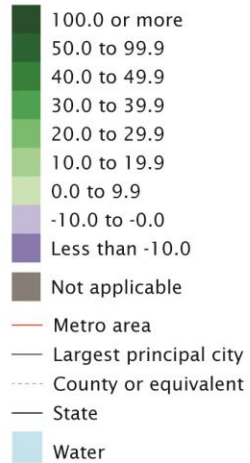
New York metro area

change: 574,107

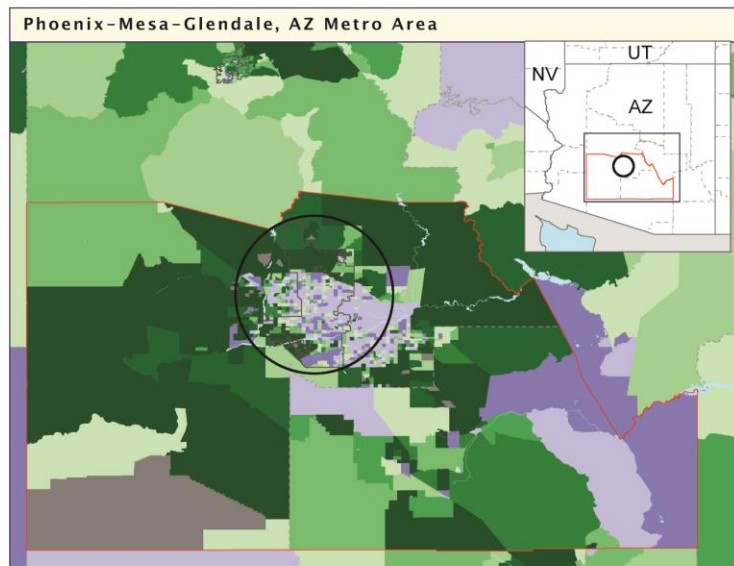
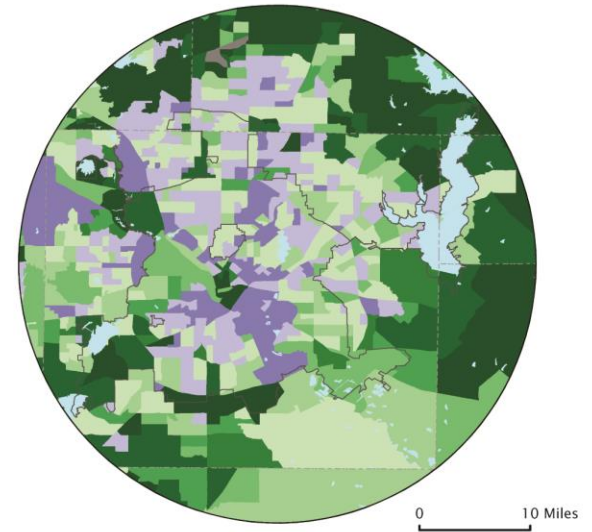
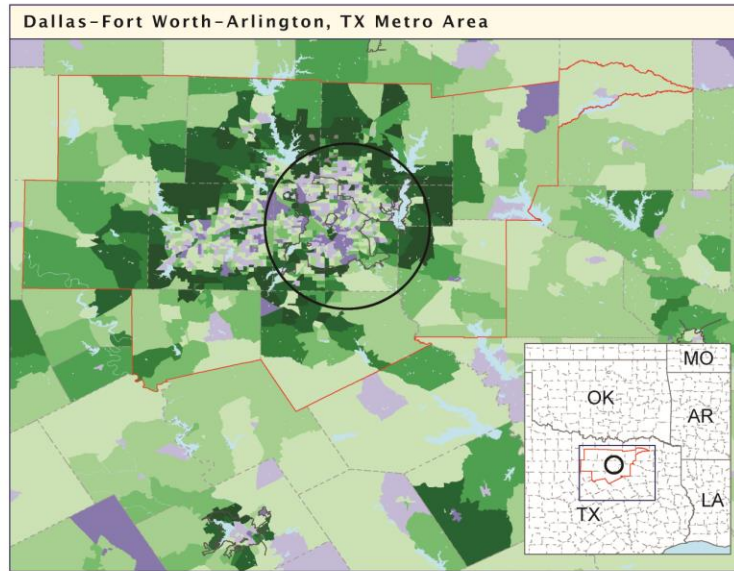
Percent Change in Population by Census Tract: 2000 to 2010

(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)

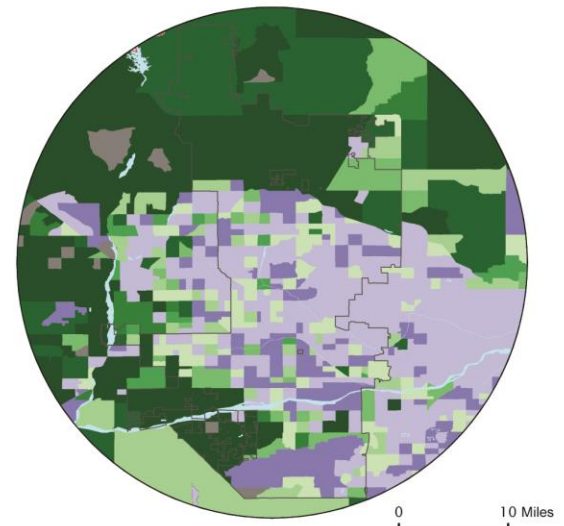
Percent change



Dallas metro area
change: 23.4
U.S. change: 9.7



Phoenix metro area
change: 28.9



Note: Metropolitan statistical areas defined by the Office of Management and Budget as of December 2009.
Source: U.S. Census Bureau, 2010 Census and Census 2000.

Regional trends in population-weighted density

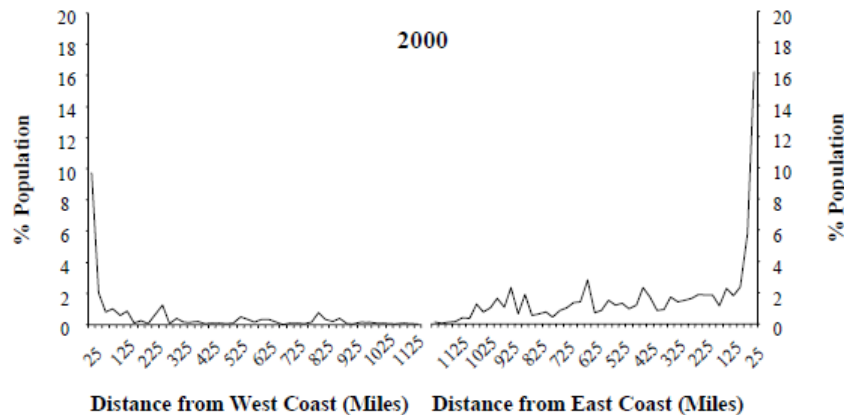
- Due to population growth, overall density necessarily increased
 - Nation's overall density grew from 51 (in 1960) to 87 (in 2010)
- But population-weighted density decreased substantially
 - Using counties as subunits, it declined from 3,012 (in 1960) to 2,132 (in 2000) and to 2,096 (in 2010)
 - At the tract scale for 2000-2010 it went down from 5,654 to 5,369
- Regional differences are quite striking
 - 2010 overall density of the West: 41, versus 132 for the South
 - But population-weighted densities are the opposite!
 - If counties used, West more dense than South: 1,117 versus 903
 - At tract scale, huge difference: West 5,924 vs. 2,491 South
 - West's population-weighted density also higher than the Midwest's

Regional trends in population-weighted density

- All four Census regions had increased population and thus higher overall density in 2010 than in 2000
- At the tract scale, however, all four registered *lower* population-weighted density in 2010
- At the county-scale the trends were highly variable:

Region	1960-2000 trend	2000 to 2010 trend
Northeast	Decrease	Increase
Midwest	Decrease	Decrease
South	Increase	Increase
West	Increase	Increase (slight)

Coastal Population Growth



Source:

Henrie and Plane (2006) Decentralization of the Nation's Main Street: New Coastal-Proximity-Based Portrayals of Population Distribution in the United States, 1950–2000. *Professional Geographer* 58: 448–459

Percentage Growth Rates, 2000-2010

United States	9.71
In Coastline County	6.10
Atlantic	7.11
Gulf of Mexico	13.73
Pacific	6.67
Great Lakes	-1.76
Not in Coastline County	11.74

Overall and Population-Weighted Density by Coastline County Status: 1960, 2000 and 2010

Geographic Area	Overall Population Density			Population-Weighted Density				
				County-Based			Tract-Based	
	1960	2000	2010	1960	2000	2010	2000	2010
United States	50.5	79.6	87.4	3,012.0	2,131.6	2,096.2	5,654.7	5,369.0
By Coastline County Status								
In Coastline County	96.5	161.0	171.7	6,782.1	4,661.5	4,620.3	11,202.6	10,708.9
Atlantic	446.0	652.8	699.2	13,588.5	8,828.3	8,690.9	17,296.8	16,608.0
Gulf of Mexico	121.0	273.2	310.8	805.6	1,183.0	1,287.7	3,541.6	3,266.4
Pacific	40.1	70.4	72.2	1,628.6	1,952.0	2,007.9	9,238.6	9,007.7
Great Lakes	277.9	297.6	292.4	3,009.9	2,708.9	2,558.5	6,864.7	6,120.6
Not in Coastline County	39.7	62.0	69.3	848.5	708.7	748.1	2,534.2	2,517.1

- Overall population density: only decreased on Great Lakes, where there was 2000 to 2010 population loss
- But population-weighted density
 - at census tract scale, *decreased* on all coasts for 2000 to 2010
 - at county scale *decreased* on coastlines overall, on Atlantic, and Great Lakes, but *increased* on Gulf of Mexico and Pacific Coasts

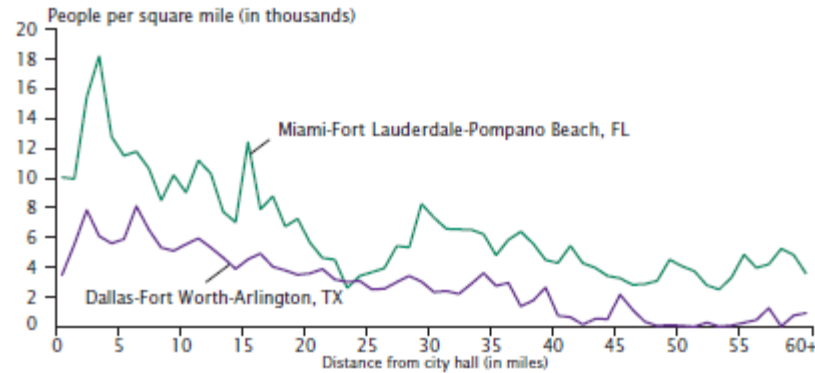
Thoughts for further extensions

- Continuous density measures
 - Geocoded micro data increasingly common
 - 2010 Census housing unit addresses geocoded
 - Imagine “2-mile” or “50-mile” point densities mapped as continuous surfaces
- Debates in planning circles on optimal type of density
 - How best to incorporate 3rd dimension into density measures?

Figure 3.2b.

Population-Weighted Density by Distance From City Hall: 2010

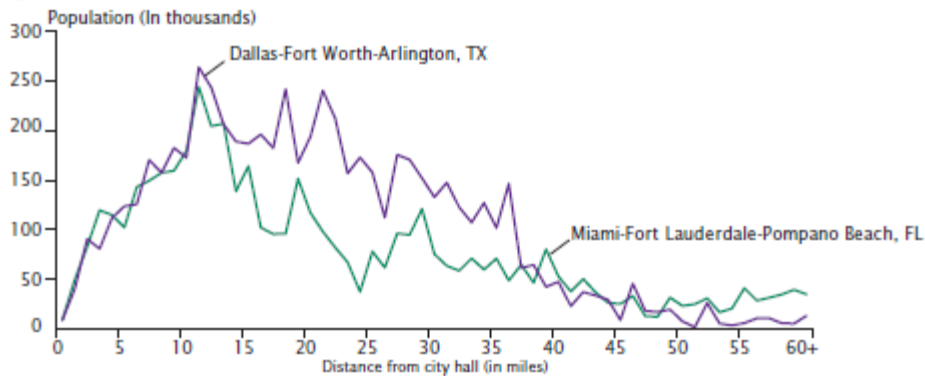
(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)



Metropolitan statistical area	Population		Population-weighted density ¹	
	Total	Percent change: 2000–2010	All census tracts	Numeric change: 2000–2010
Dallas-Fort Worth-Arlington, TX Metro Area	6,371,773	23.4	3,909.3	–385.9
Miami-Fort Lauderdale-Pompano Beach, FL Metro Area	5,564,635	11.1	7,395.3	158.7

¹ Population density calculated on a population-weighted basis across all census tracts (using 2010 boundaries) included in the metropolitan statistical area.

Population by Distance From City Hall: 2010

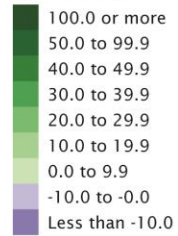


Note: Population density expressed as the average number of people per square mile of land area. Distances are measured to the city hall or similar municipal building of the metro area's first-named principal city. Metropolitan statistical areas defined by the Office of Management and Budget as of December 2009.
Source: U.S. Census Bureau, 2010 Census and Census 2000.

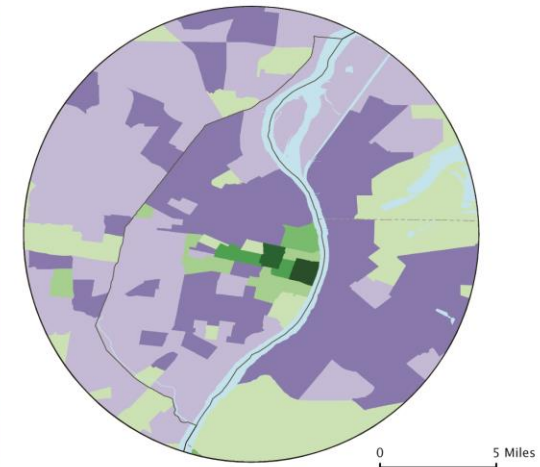
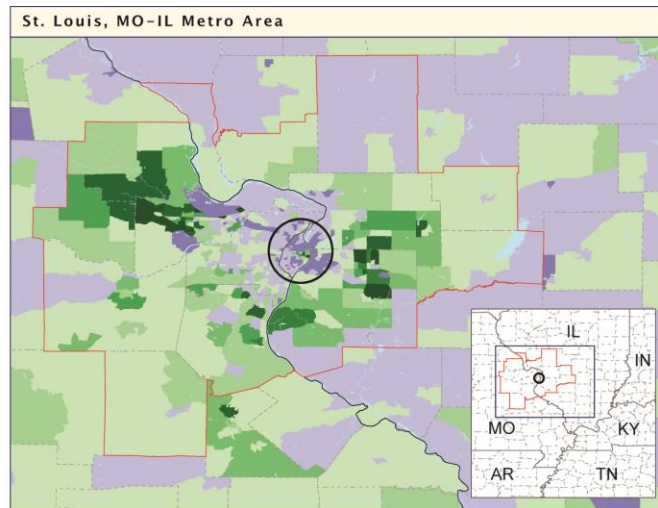
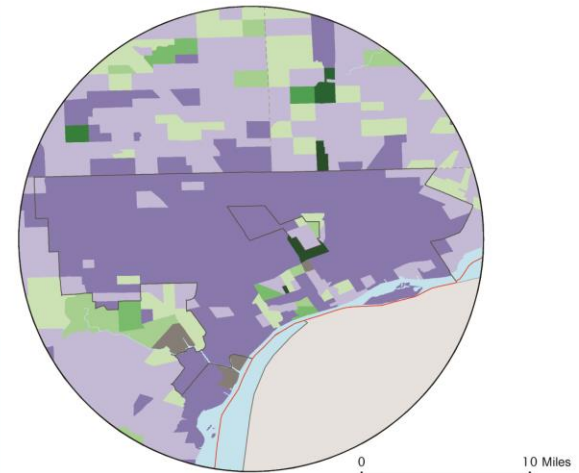
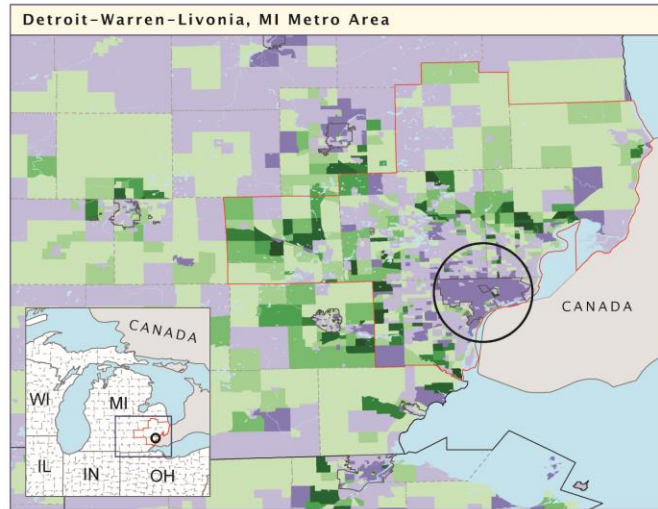
Percent Change in Population by Census Tract: 2000 to 2010

(For information on confidentiality protection, nonsampling error, and definitions, see www.census.gov/prod/cen2010/doc/sf1.pdf)

Percent change



— Metro area
 — Largest principal city
 - - - County or equivalent
 — State
 Water
 Detroit metro area change: -3.5
 U.S. change: 9.7



St. Louis metro area change: 4.2

Note: Metropolitan statistical areas defined by the Office of Management and Budget as of December 2009.
 Source: U.S. Census Bureau, 2010 Census and Census 2000.