

A Continuous Approach to Evaluating Vegetation and Built-up Dynamics in a Fast Growing Desert City

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Problem Statement

Urban growth, from regional sprawl to global urbanization, is the most rapid, drastic, and irreversible form of human modification of the Earth's surface. Accurate and updated knowledge of the spatiotemporal pattern of urbanization is an important step in understanding the impacts of urbanization on the socio-ecological processes.

A combination of image time series, continuous spatial indices, and non-parametric regression permits spatially explicit, pixel-based assessment of landscape pattern change across the urban landscape, improving our understanding of the human impacts on the natural environment, which is of paramount importance for sustainable urban development in the context of rapid global change.

Research Questions

Question 1: How do the abundance and spatial arrangement of vegetation and manmade features change in the last two decades over the Phoenix metropolitan area?

Question 2: What is the spatiotemporal pattern of urbanization for major municipalities in the region?

Study Area

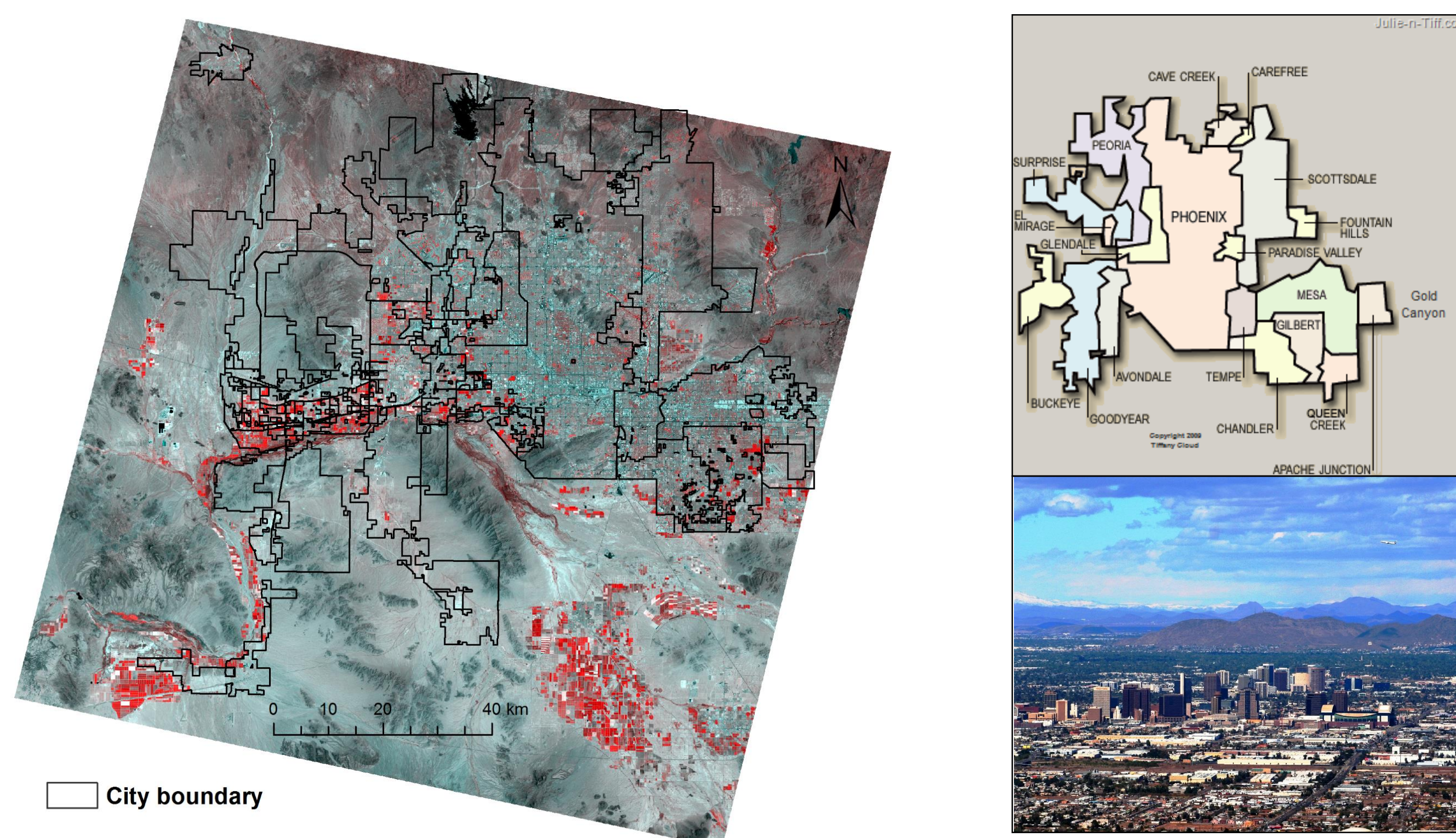
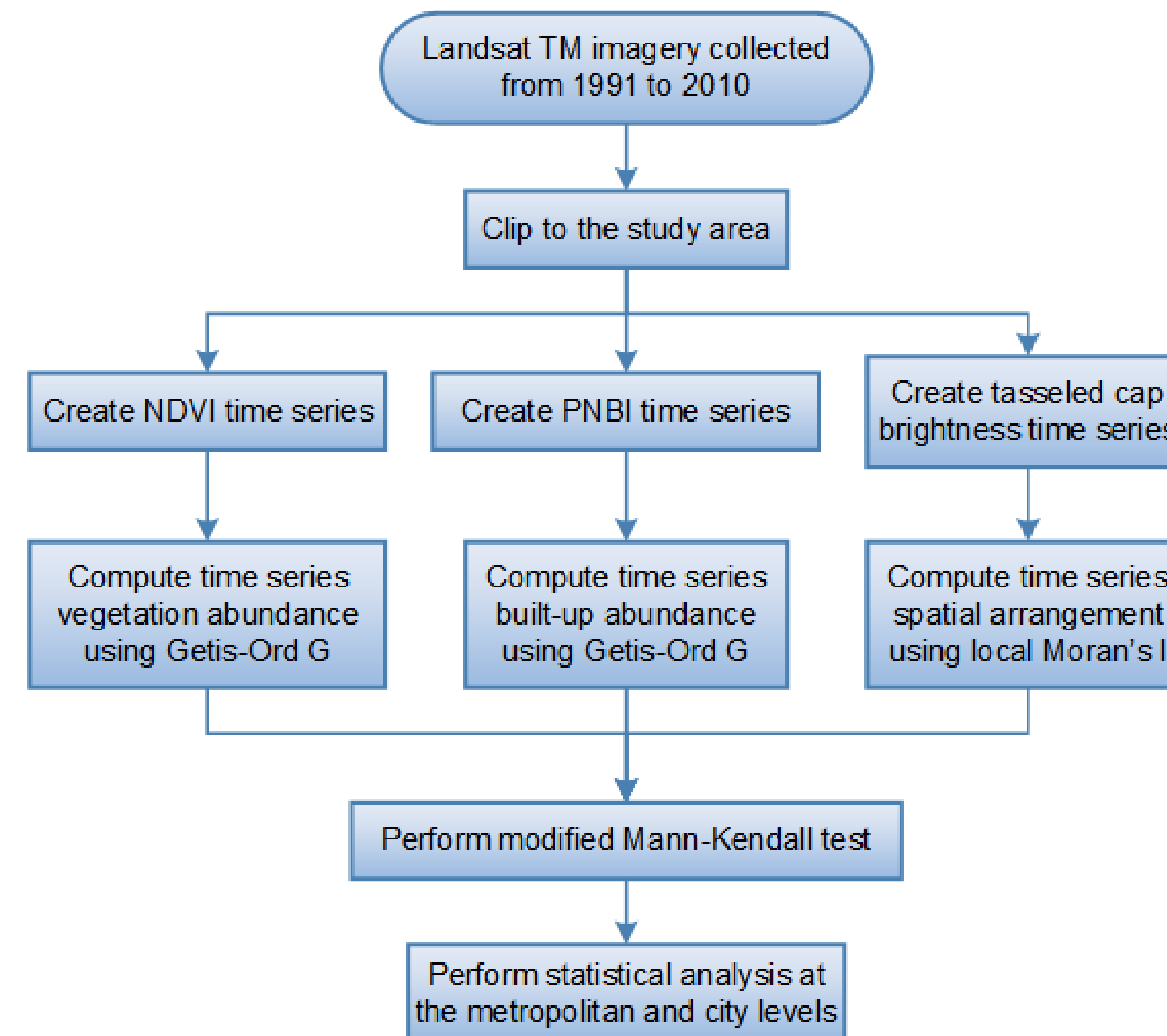


Figure 1. Study site located in the Phoenix metropolitan area.

Our study area is the Phoenix metropolitan area located in the northern part of the Sonoran desert in Arizona. The average annual temperature is 22 °C, with the average summer and winter temperature 40 °C and 3 °C, respectively. This region receives an average of 32 days of precipitation each year, and the average annual rainfall is 229 mm.

This area consists of 23 cities and is home to more than four million residents. It is also among the fastest growing metropolitan areas in the nation.

Research Design



Land cover index	Spatial autocorrelation index	Modified Mann-Kendall test
<u>Vegetation index</u>	<u>Getis-Ord G</u>	<u>Test statistic</u>
$NDVI = \frac{B4 - B3}{B4 + B3}$	$G_i^* = \frac{\sum_j w_{ij}(d)x_j}{\sum_j x_j}$	$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(x_j - x_k)$
<u>Built-up index</u>	<u>Local Moran's I</u>	<u>Variance</u>
$PNBI = \frac{PCA1 - B4}{PCA1 + B4}$	$I_i(d) = \frac{n(x_i - \bar{x})}{\sum_i (x_i - \bar{x})^2} \sum_j w_{ij}(d)(x_j - \bar{x})$	$\text{var}_m(S) = \text{var}(S) \cdot \frac{n}{n_s}$

Land use change at metropolitan level

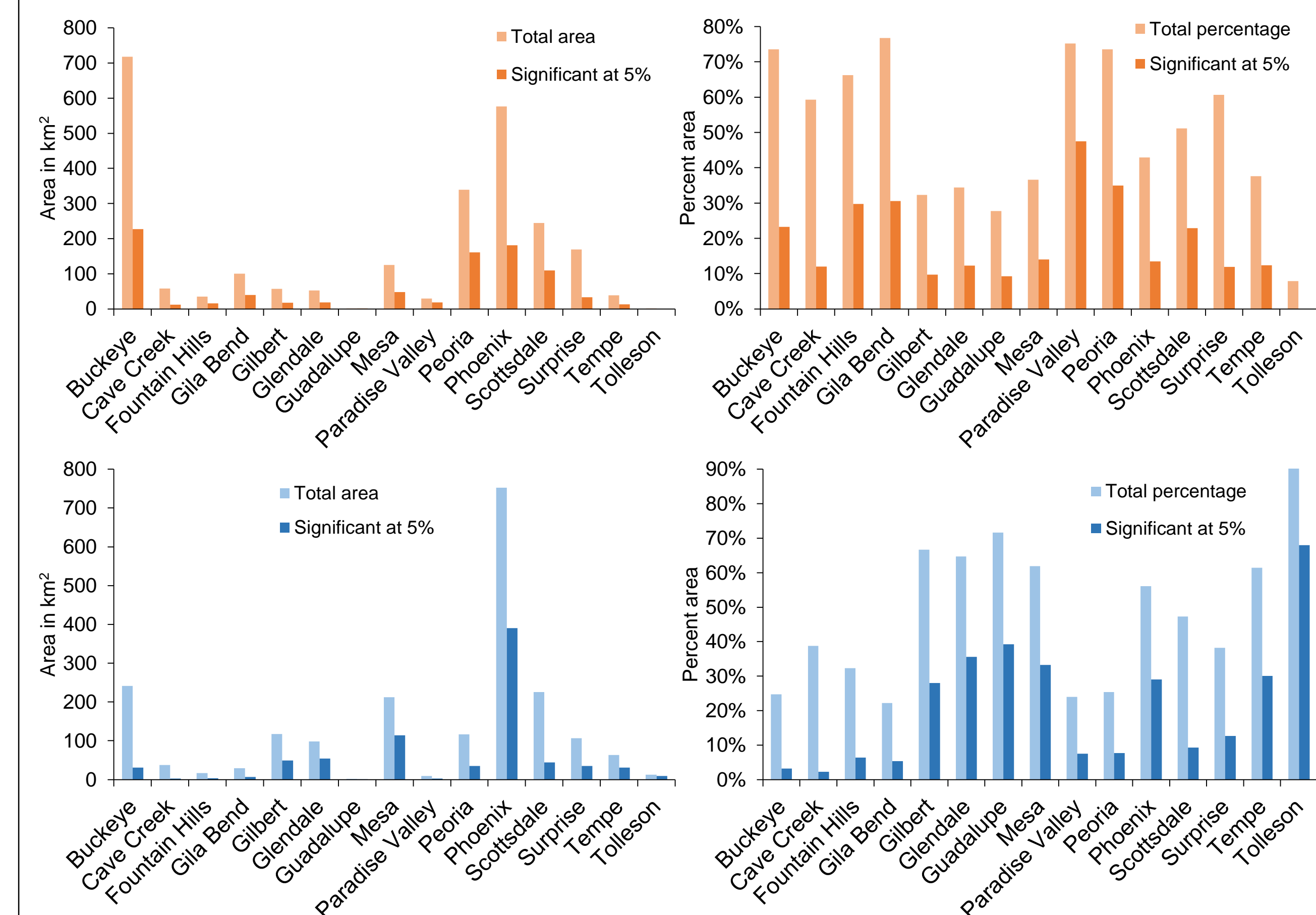
Spatial index	Increasing		Significantly increasing	
	Area (km ²)	Percent (%)	Area (km ²)	Percent (%)
Getis-Ord G for NDVI	1353.7	41.12	531.67	16.15
Getis-Ord G for PNBI	1631.2	49.55	601.62	18.27
Local Moran's I	1434.75	43.58	507.33	15.41

Spatial index	Decreasing		Significantly decreasing	
	Area (km ²)	Percent (%)	Area (km ²)	Percent (%)
Getis-Ord G for NDVI	1938.63	58.88	922.49	28.02
Getis-Ord G for PNBI	1661.12	50.45	724.47	22.01
Local Moran's I	1857.57	56.42	726.15	22.06

16.15% and 18.27% of the urban area in 2010 has a significant increasing trend in the quantity of vegetation and built-up areas, respectively. 28.02% and 22.01% of the urbanized land in 2010 shows a significantly declining pattern in the concentration of vegetation and built-up areas.

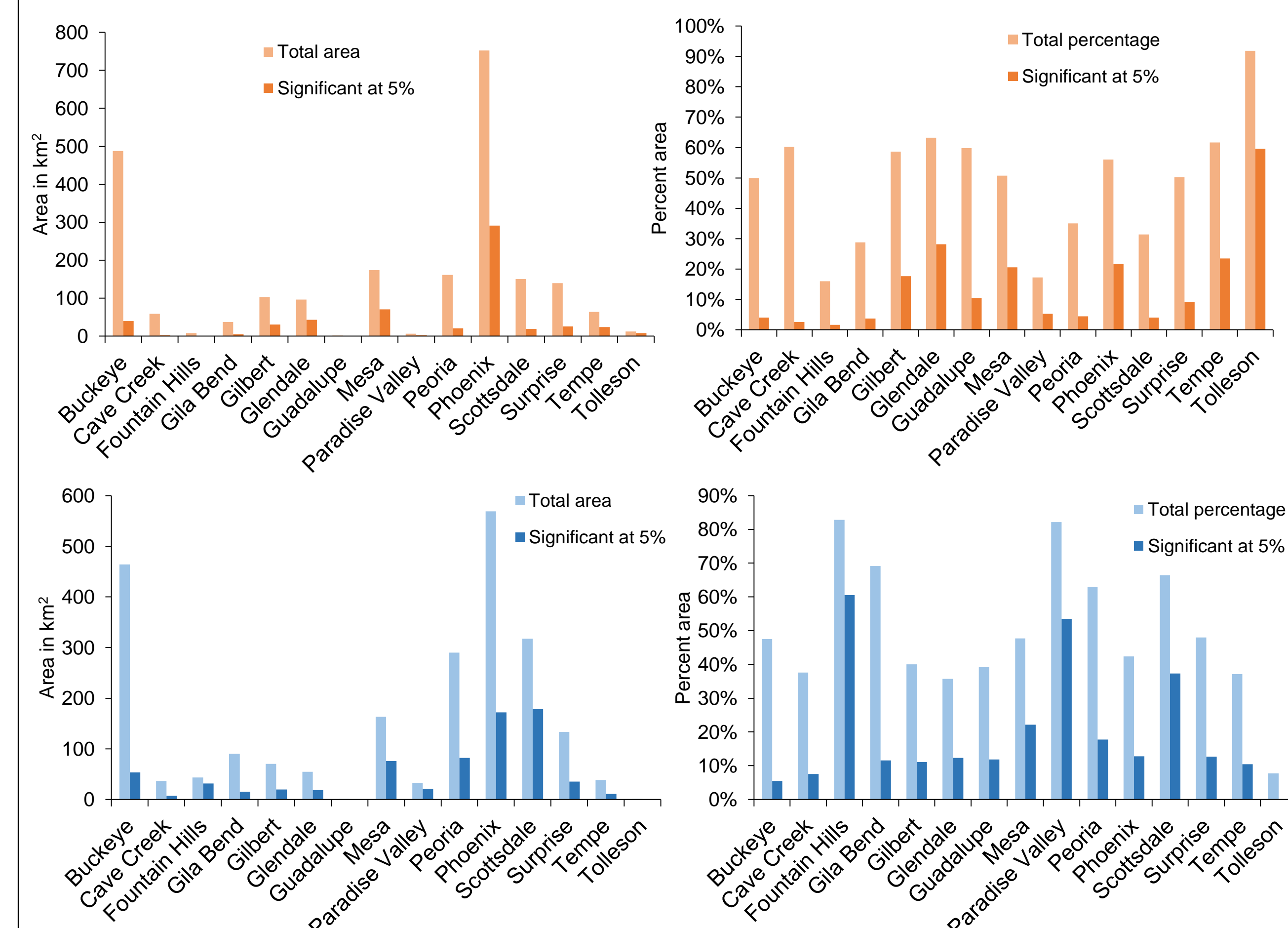
Land use change at city level

Vegetation dynamics



Cities in the Phoenix metropolitan area show an average of 170 km² increase and 136 km² decrease in the vegetation abundance. Buckeye and Tolleson are the two cities with the most and least amount of vegetation increase over the last two decades. Phoenix loses 390 km² vegetation to urban land whereas Guadalupe only loses 0.81 km² of its vegetated land to urban land use.

Built-up dynamics



The increasing pattern in the concentration of built-up areas echoes the decreasing pattern in the vegetation abundance, indicating a replacement of agricultural land by manmade features. Again, Phoenix and Guadalupe have the largest and smallest built-up area increase. Tolleson features a typical case of urbanization where all of its current urban land comes from agriculture and none from desert lands.