Urban Mapping Study of the Tulsa Region

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Abstract

The purpose of this mapping study of the Tulsa region is to increase the understanding of the urban growth pattern of the region and predict future growth trends. To this end, maps have been produced showing the region's natural open space, urban framework and temporal change of urbanized area. An additional map, showing an estimate of future growth in the year 2025, has been developed from a composite of the previous maps and projections of population growth.

Introduction

Increasingly, the metropolitan region is the basic cultural, environmental, economic and civic entity for both citizens at the local level and globally in the larger sense of the world community (Calthorpe and Fulton 6). Developing a vision for the future growth of the Tulsa region requires an understanding of the interconnected relationships between land use, infrastructure and social equity. Real estate market forces, land use regulation, transportation networks, utility grids, and the need for regional community services cross jurisdictional lines and operate on a regional level. Competition between municipalities, socioeconomic stratification and sprawling, inefficient land use threaten the quality of life for residents of many regions (Orfield 1).

The aim of this study is to begin a mapping process to better understand the Tulsa region's land use and its relationship to the many forces influencing urban growth. A series of mapping layers have been developed to understand the region's open space, urban framework, and urban growth pattern. Speculative projection of future urban growth is also attempted.

Literature Review

The mapping process used in this study is based on similar techniques used to map other regions. Calthrope and Fulton (139-158) have mapped Portland, Oregon and Salt Lake City, Utah creating composite maps showing open space; centers, districts and corridors; and infill, redevelopment and new growth areas. Keith Clarke and his colleagues at the University of California, Santa Barbara (Project Gigalopolis website) involved in the United States Geological Survey (USGS) Urban Dynamics program have developed an urban land cover modeling program using computer simulations. The SLEUTH model creates temporal maps and animations of historical and projected urban growth by applying cellular automata rules to a series of overlaid map images. SLEUTH is an acronym for the image input maps required for the simulation: Slope, Land Cover, Exclusion Zones, Urbanization, Transportation and Hillshade (Project Gigalopolis website). Researchers at the Mid-Atlantic Regional Earth Science Application Center have used SLEUTH and other techniques to model the Baltimore-Washington, DC region (RESAC website). Myron Orfield and the Metropolitan Area Research Corporation have used Geographic Information System (GIS) technology to map socioeconomic indicators including school performance, tax rates and voting results of the Minneapolis-St. Paul region and others (Orfield 16).

Mapping Method

The maps for this study have been produced using GIS ARC/INFO software, version 8.1, developed by the Environmental Systems Research Institute (ESRI). The study area is roughly 30 statute miles by 30 statute miles centered on the City of Tulsa and includes the municipalities of Broken Arrow, Bixby, Claremore, Catoosa, Sapulpa, Sand Springs, Jenks, Owasso, Skiatook, Collinsville, Coweta, Glenpool and several other smaller communities. The area includes all of Tulsa County and portions of Osage, Rogers, Creek and Wagoner Counties. It approximately coincides with the Metropolitan Transportation Management Area developed by the Indian Nations Council of Governments (INCOG) (INCOG website). This area of 900 square miles contains virtually all of the urbanized land in the Tulsa Metropolitan Statistical Area, which encompasses the total area of all five counties, approximately 5,015 square miles. A number of mapping layers were developed from a variety of data sources.

The Tulsa Region Open Space Map (Figure 1) consists of seven map layers. The gray hillshade background used on this map and the others is generated by ARC/INFO using digital elevation models (DEM) obtained from the USGS (USGS mapping website). Forty - 2 arc second DEM images are combined to produce a hillshade map of the entire region. The same DEM images are used by ARCINFO's Spatial Analyst Algorithms to generate a steep slope layer. The map depicts areas with a slope greater than 20 percent grade. Slopes with grades exceeding 20 percent present cost-prohibitive challenges to land developers including soil erosion, excessive cut and fill, and building foundation design. One hundred year floodplains and open water are mapped using data provided by the Federal Emergency Management Agency (FEMA website) as Q3 mapping data. Digital data is available for Tulsa, Osage and Creek Counties. Floodplains shown on the map for Rogers and Wagoner Counties were developed by manually interpreting Flood Insurance Rate Maps (FIRM) and interpolation of floodplains on the hillshade layer. Finally, layers showing forest, grassland or pastureland and land under cultivation are mapped using thermal data from the Earth Resources Observation System (EROS) 1992 National Land Cover Dataset with a spatial resolution of 30 meters (EROS website).

The Tulsa Region Urban Framework Map (Figure 2) consists of six map layers on a hillshade background. Arterial streets, highways, and railroads layers are 2000 Tiger\Line data from the U.S. Census Bureau (Census website). Town and activity centers are mapped with a range of circular symbols. Activity centers are defined as key geographic landmarks (KGL) including shopping centers, hospitals and institutions. Industrial districts are identified as major concentrations of primary economic activity, heavy industry and other employment districts. They have been identified by interpreting digital aerial photography from a variety of sources including digital orthophoto quadrangles (DOQ) from the USGS (NDOP website).

The Tulsa Region Urban Growth Map (Figure 3) is a temporal map showing the historical growth of urbanized area. Map layers estimating extent of urbanized area at 1920, 1950, 1980 and 2000 have been developed. For the purposes of the study, urbanized area is defined as developed land being used for residential, commercial, industrial and other non-agricultural uses with a population density typically greater than 500 persons per square mile and/or possessing significant civic infrastructure. The urbanized area for 2000 is estimated using the Land Use Land Cover (LULC) data from EROS, images from the Landsat Thematic Mapper (TM) and aerial photography. The urbanized area for 1950 and 1980 is estimated from USGS Digital Line Graphs (DLG) showing extent of urban area, as well as aerial photography and historic maps. The urbanized area for 1920 is estimated almost entirely from historic maps and data.

Map Interpretation

The Tulsa Region Open Space map (Figure 1) describes the natural elements of the region that affect and shape urban development. The predominant feature of the map is the Arkansas River Valley and its tributary watersheds (Southwest Tulsa Project 10). Floods have plagued the region in the past and remain a major concern for future development. While flooding has been ameliorated along the Arkansas River since the construction of the Keystone Dam, many areas downstream are still at risk. The Verdigris River, Bird Creek and its tributary Mingo Creek have extensive floodplains in the northern and eastern parts of the region. In the southwest, Polecat Creek is the primary flood threat. Skiatook, Oollagah and Heyburn Dams and flood control projects along Mingo Creek are examples of extensive, engineered improvements to the watershed, but flooding still is common in many of these areas.

Tulsa Region Open Space

Legend

- Surface Water
- Flood Plains
- Cultivation
- Grasslands
- Woodlands
- Steep Slopes

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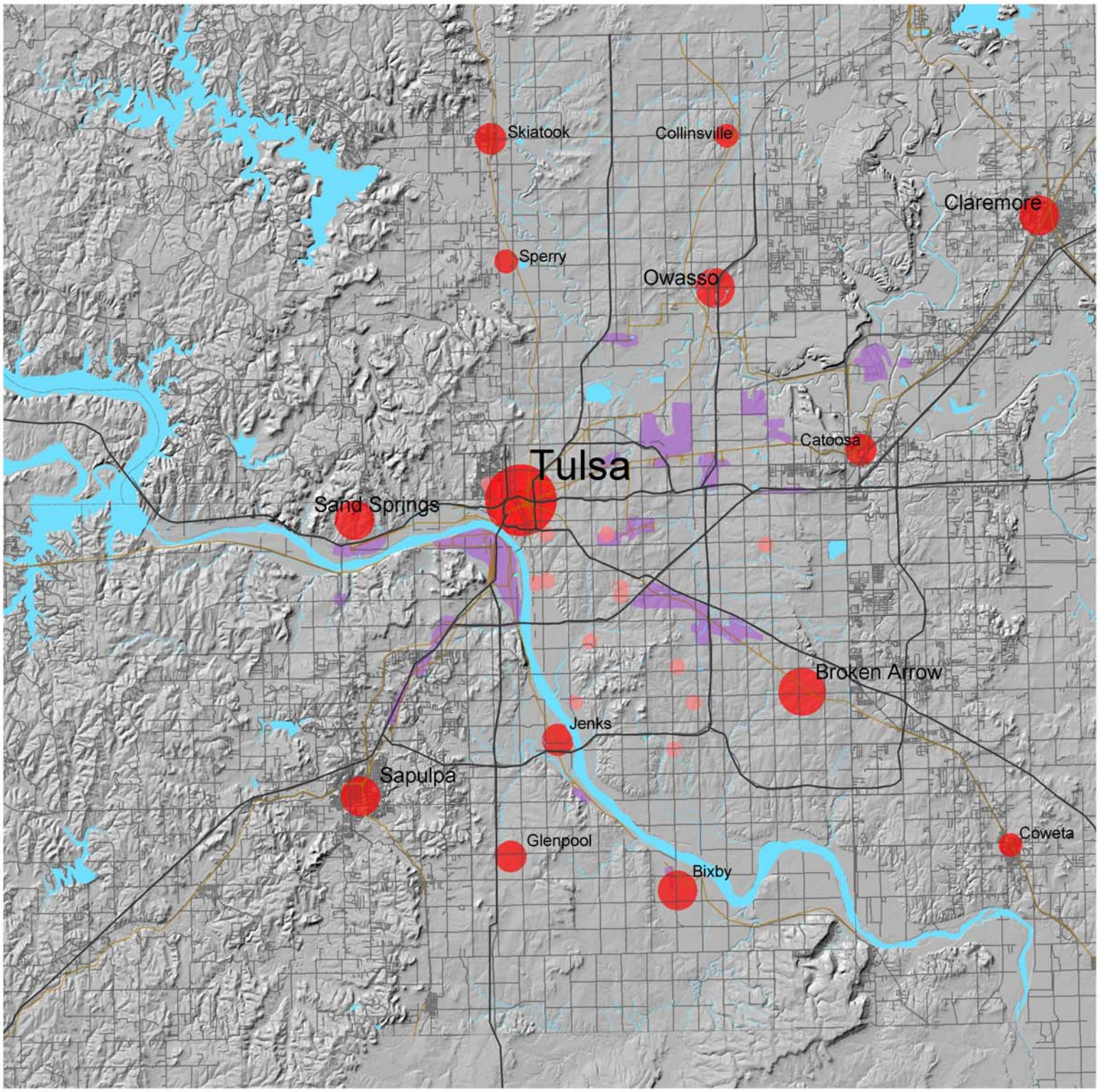

Tulsa Region Urban Framework

Legend

- Highways
- Streets
- Railroads
- Town Centers
- Activity Centers
- Industrial Districts

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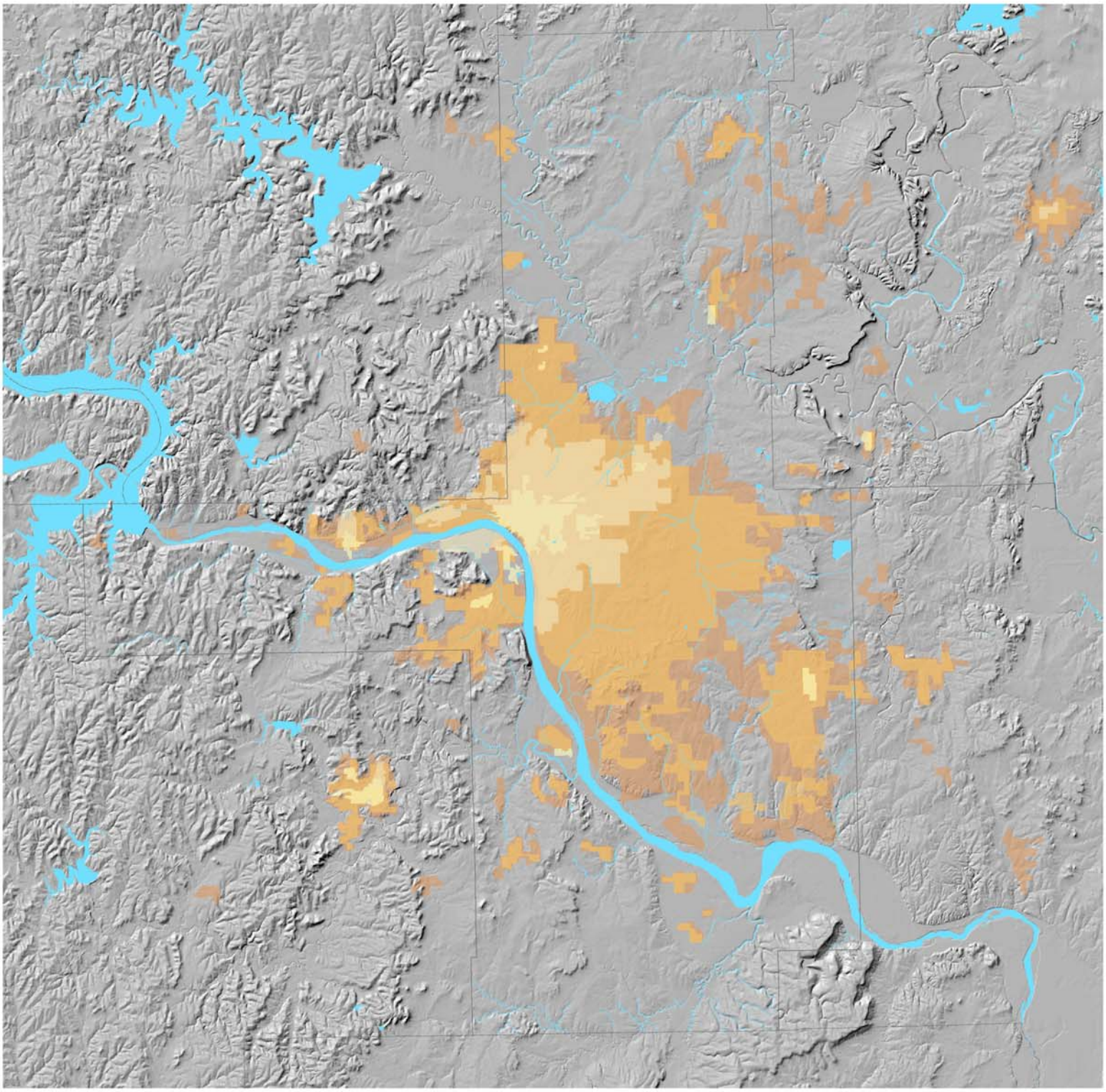

Tulsa Region Urban Growth

Legend

- 1920 Urbanized Area - 10 Sq. Miles
- 1950 Urbanized Area - 37 Sq. Miles
- 1980 Urbanized Area - 144 Sq. Miles
- 2000 Urbanized Area - 230 Sq. Miles

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An analysis of the hypsography of the region reveals a significant difference between the western and eastern halves of the region. Areas west of US Highway 75 are part of the Osage Hills landform. Geologically these hills are part of the Coffeyville Formation of shale, sandstone and coal (Southwest Tulsa Project 10). The Osage Hills are a folded landscape with many steep slopes exceeding 20 percent grade with well-drained, shallow and stony soils. In contrast, most areas east of US Highway 75 are flat plains or bottomland with deeper, sandy or clay soils. Some bluffs and significant landforms are evident along the Verdigris River in the northeast part of the region.

The Osage Hills are part of the Cross Timbers ecosystem and is heavily wooded with oak, hickory and ash. The flatter lands are grasslands used for grazing and cultivation. The river bottoms are particularly well suited for intensive agriculture.

The Tulsa Region Urban Framework map (Figure 2) uses points, lines and planes to describe the manmade systems of the region. The railroad network is one of the first and most enduring legacies of the region's early days. Many early town centers, including Tulsa, were platted by the railroads. The one-mile spaced grid of arterial streets and land divisions used by government surveyors is the next major feature superimposed on the landscape throughout the region. Controlled access highways centered on downtown Tulsa were added after World War II and continue to evolve, the latest addition being the Creek Turnpike bypassing the established urban areas to the east and south.

The region has many activity centers, including: established pre-war business districts, colleges and universities, medical centers, retail shopping centers and entertainment venues.

Industrial districts have developed in several areas. The west side of the Arkansas River contains oil refineries, power plants, rail yards, and manufacturing factories. Tulsa International Airport, Cherokee Industrial Park and the Port of Catoosa are major economic generators located to the north and northeast side. Other employment districts follow the highway system particularly at the Interstate 44 and Broken Arrow Expressway junction on the southeast side.

The Tulsa Region Urban Growth map (Figure 3) illustrates the growth of the region's urbanized area over time. Early development before 1920 tended to follow the east bank of the Arkansas River and concentrate around the railheads at Tulsa and Sapulpa. From 1920 to 1950, most of the growth took place around the central city especially to the north and east. The geographic barrier of the river slowed growth on the west bank. Rough terrain and the presence of the Osage Indian Reservation, now Osage County, discouraged growth to the northwest. From 1950 to 1980, the region's urbanized area grew predominantly to the southeast. The development centered on the newly completed highways, Interstate 44 and the Broken Arrow Expressway. Suburbs, particularly Broken Arrow and Jenks, experienced rapid growth as people relocated from the central city. Growth in the last twenty years has continued to follow the development of the highway infrastructure with further development to the southwest and new growth along the US Highway 169 corridor from Owasso south to Coweta. Few new urbanized areas have been added to the north or west sides of the region.

A map showing the Tulsa Region Composite (Figure 4) is included with all the map layers developed for the three component maps superimposed. The composite map allows an overview of all of the factors considered in the study.

Tulsa Region Composite

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Population Data

Population data was collected and analyzed in order to understand historic trends and make future projections about population growth, population density and the relationship between population and growth of the urbanized area. All population data used in the study has been obtained from the Oklahoma State Data Center operated by the Oklahoma Department of Commerce (ODOC website). The Department of Commerce summarizes and archives United States Census data since 1890, as well as making future population projections to 2030. Population statistics are available by town, county and metropolitan statistical area. Because none of these entities exactly describe the population of the study's focus, an aggregate approach is used to estimate the population in the urbanized area. For the purpose of the study the urbanized area population includes: Kellyville town, Kiefer town, Mannford town (part), Mounds town and Sapulpa city in Creek County; Prue town, Sand Springs city (part), Skiatook town (part) and Tulsa city (part) in Osage County; Catoosa city (part), Claremore city, Collinsville city (part), and Fair Oaks town (part) in Rogers County; all of Tulsa County including Bixby city (part), Broken Arrow city (part), Collinsville city (part), Glenpool city, Jenks city, Liberty town, Lotsee town, Mannford town (part), Sand Springs city (part), Skiatook town (part), Sperry town, Tulsa city (part) and the remainder of the county; and Bixby city (part), Broken Arrow city (part), Catoosa city (part), Coweta city, Fair Oaks town (part), and New Tulsa town in Wagoner County. This method includes a portion of the population in unincorporated Tulsa County, which is not part of the urbanized area and excludes a small portion of population in unincorporated areas of Creek, Osage, Rogers and Creek County, which are a part of the urbanized area. We would expect the errors introduced by this method to be relatively small, between 1 and 5 percent of the total population of the urbanized area.

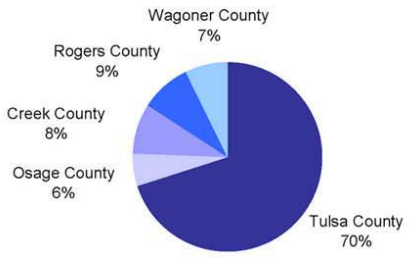
A summary of the Tulsa Metropolitan Statistical Area (TMSA) population and population density per square mile is shown in Table 1. Due to the large land area of the metropolitan statistical area the population densities are skewed and indicate lower densities then what is found in the study area. The large size and small population of Osage County particularly exacerbate this condition. Tulsa County contains 70 percent of the TMSA population (Chart 1) but constitutes only 11 percent of the TMSA land area (Chart 2). Conversely, Osage County contains 6 percent of the TMSA population but has 46 percent of the land area.

A comparison of 2000 population data and growth rates is presented in Table 2. The fastest growing parts of the region are Rogers and Wagoner Counties, growing more than twice as fast Tulsa County. Still, in absolute terms, Tulsa County will likely add twice as many residents as Rogers and Wagoner County combined by 2025. The growth of population in new and existing urbanized areas is projected to be 15.9% by 2025. While this is lower than the TMSA projected growth rate, the urbanized areas will still see 70 percent of the total population added.

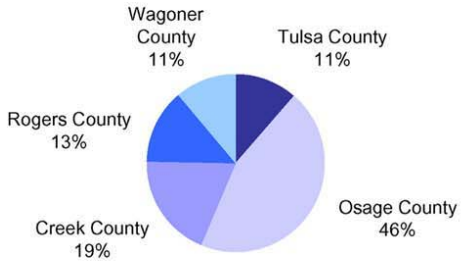
The suburbs continue to outpace the City of Tulsa in growth rate. Table 3 shows that 69% of the population of Tulsa County lives in the City of Tulsa, 25% lives in other municipalities and 6% live in unincorporated areas. Since 1950, the population of other municipalities in Tulsa County has grown from 7% to 25% while the population in unincorporated areas has dropped from 37% to 6%. This change can be explained by the rapid growth of the suburbs and the annexation of land by all municipalities.

The amount of urbanized land in the region continues to grow. The urbanized area has grown from 10 square miles in 1920 to 230 square miles in 2000 (Chart 3). As shown in Table 4 the percentage of people living in the urbanized area had stabilized by 1980 at about 79% while the amount of urbanized land has increased from .2 percent to 4.6 percent of the TMSA. The population of the urbanized area has increased from 127,551 in 1920 to 633,013 in 2000 (Chart 4).

Tulsa Metropolitan Statistical Area - Population



Tulsa Metropolitan Statistical Area - Land Area



Year	Tulsa County		Osage County		Creek County		Rogers County		Wagoner County		Total MSA	
	Population	Density	Population	Density	Population	Density	Population	Density	Population	Density	Population	Density
1920	109,023	191	36,336	16	62,480	65	17,605	27	21,371	38	246,815	49
1950	251,680	442	33,071	15	43,143	45	19,532	28	16,741	30	364,173	73
1980	470,593	826	39,327	17	59,016	62	46,436	68	41,801	74	657,173	131
2000	563,299	988	44,439	20	67,367	70	70,641	104	57,491	101	803,235	160
2025 (Projected)	646,000	1,133	52,200	23	79,100	83	94,400	140	76,000	135	947,700	189

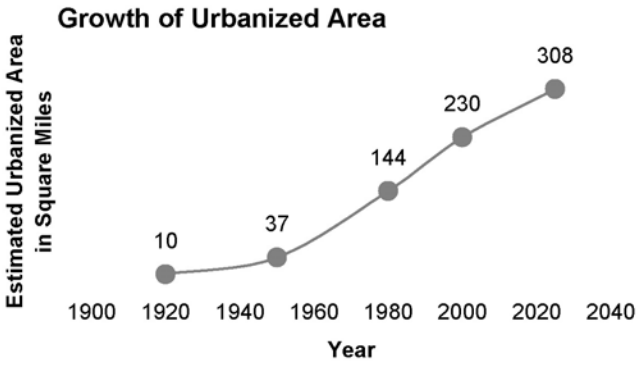
Table 1
Tulsa Metropolitan Statistical Area Population and Population Density per Square Mile

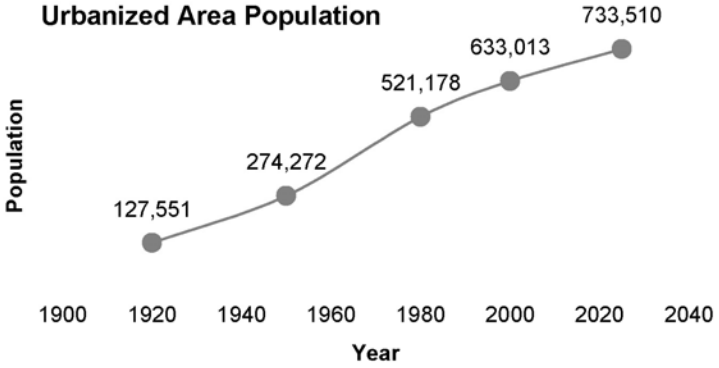
	Area in Square Miles	2000 Population	2025 Population	Growth Rate	Annual Change	Population Density per Square Mile
Tulsa County	570	563,299	646,000	14.7%	3,308	988
Osage County	2,251	44,437	52,200	17.5%	310	20
Creek County	956	67,367	79,100	17.4%	469	70
Rogers County	675	70,641	94,400	33.6%	950	104
Wagoner County	563	57,491	76,000	32.2%	740	101
Tulsa Metropolitan Statistical Area	5,015	803,235	947,700	17.9%	5,751	160
Tulsa Region Urbanized Area	230	633,013	733,510	15.9%	4,020	2,752
City of Tulsa	198	393,049	450,910	14.8%	2,314	1,985
City of Broken Arrow	40	74,859	87,090	16.3%	489	1,871
City of Sapulpa	18	19,166	22,500	17.4%	133	1,065
City of Sand Springs	18	17,172	20,020	16.6%	114	954
City of Claremore	9	15,873	21,210	33.6%	213	1,764
State of Oklahoma	68,667	3,450,654	4,081,100	18.3%	25,218	50

Table 2
Population Density and Growth Rate Comparative Summary

Year	Tulsa County	City of Tulsa	Percent of County	Other Municipalities	Percent of County	Remainder of County	Percent of County
1920	109,023	72,075	66%	15,975	15%	20,973	19%
1950	251,680	142,157	56%	17,383	7%	92,140	37%
1980	470,593	355,444	76%	82,720	16%	32,429	8%
2000	563,299	387,419	69%	141,125	25%	34,675	6%
2025 (Projected)	646,000	444,300	69%	161,930	25%	39,770	6%

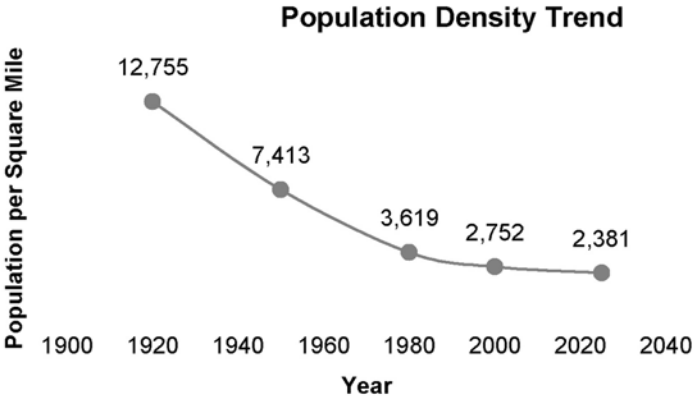
Table 3
Tulsa County Population Breakdown

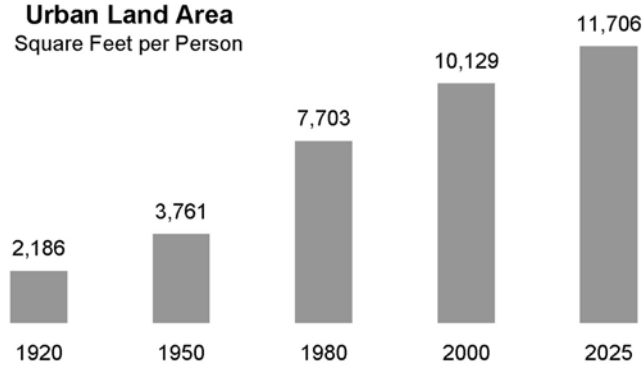




Year	Urbanized Area Square Miles	Percentage of Metropolitan Area	Population of Urbanized Area	Percentage of Metropolitan Area	Urban Land per Person Square Feet
1920	10	0.2%	127,551	52%	2,186
1950	37	0.7%	274,272	75%	3,761
1980	144	2.9%	521,178	79%	7,703
2000	230	4.6%	633,013	79%	10,129
2025 (Projected)	308	6.0%	733,510	77%	11,706

Table 4
Tulsa Region Urban Land Summary





Year	Estimated Urbanized Area Square Miles	Annualized Change Square Miles	Estimated Population of Urbanized Area	Annualized Change of Population	Population Density of Urbanized Areas	Annualized Change of Density
1920	10		127,551		12,755	
1950	37	0.9	274,272	4,891	7,413	5,823
1980	144	3.6	521,178	8,230	3,619	2,311
2000	230	4.3	633,013	5,592	2,752	1,300
2025 (Projected)	308	3.1	733,510	4,020	2,381	1,300

Table 5
Summary of Changes in the Tulsa Region: Urbanized Area and Population Density

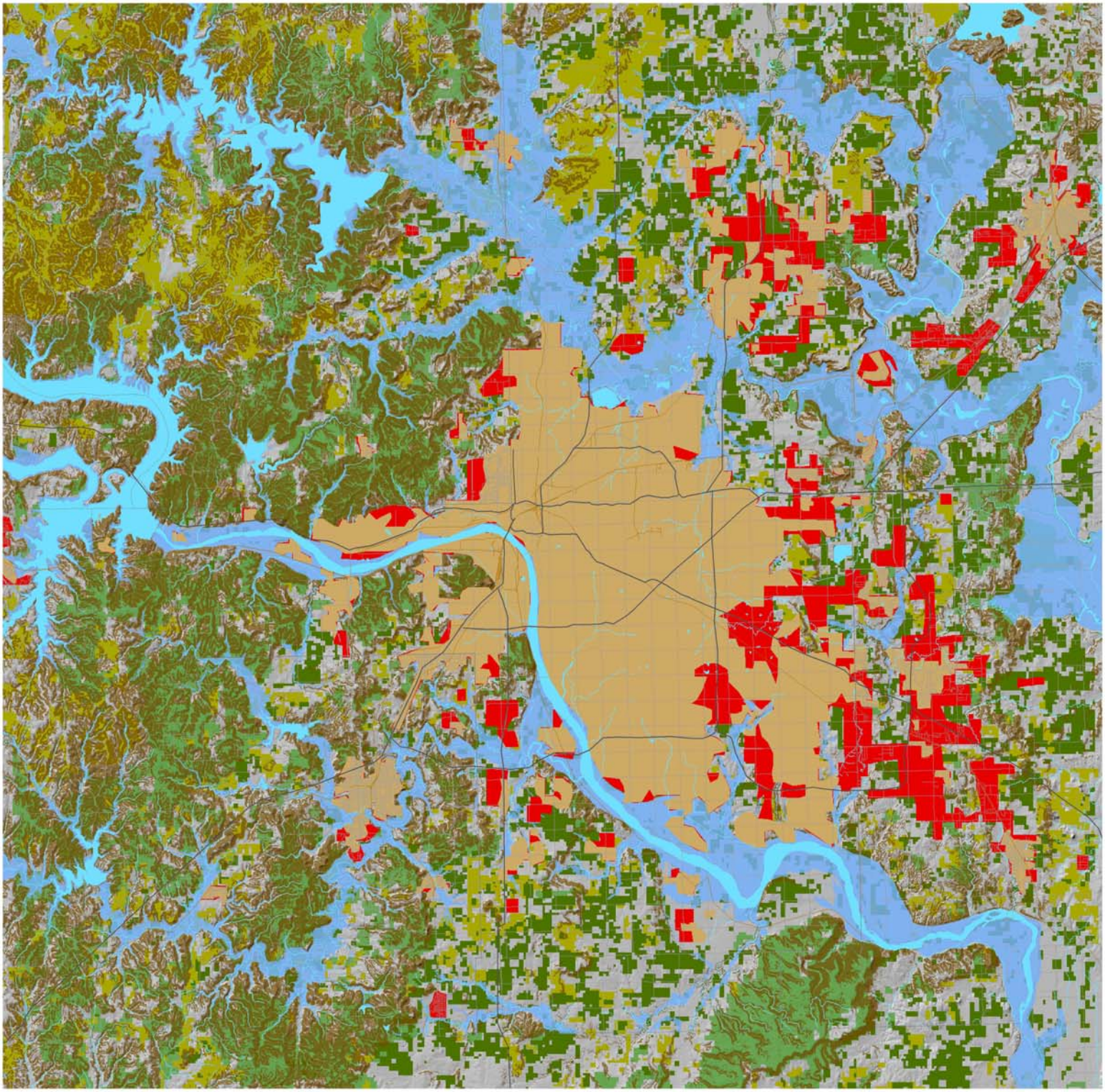
The amount of urbanized land has been growing at a faster rate than the growth rate of the population, consequently population density has been decreasing dramatically (Chart 5) and the amount of urban land per person has increased proportionally (Chart 6). Table 5 summarizes the changes of population density using densities calculated with estimated urban population and area of urbanized land. It is suggested that this gives a more accurate portrayal of the region's growth than densities calculated from the TMSA. It is also worth noting that the density of urbanized areas of the Tulsa region has declined from 12,755 persons per square mile in 1920 to 2,752 persons per square mile today. This has caused the amount of urban land per person to more than quintuple. Between 1980 and 2000, the Tulsa Region added an average of 5,592 people per year and the urbanized area grew approximately 4.3 square miles per year. This would indicate a simple density in new urbanized areas of 1,300 persons per square mile.

Using the Department of Commerce projections, the estimated population of the study area in 2025 will grow by just over 100,000 people to 733,510. If the growth takes place in the same manner as the historical trends indicate and land use regulation, infrastructure development, and taxation methods do not significantly change then an estimated 78 square miles or 3.1 square miles per year of urbanized land must be added to the region by 2025. Population density will continue to decline to approximately 2,381 persons per square mile.

Future Growth Projections

Speculation about future growth is fraught with uncertainties but essential for land use planning, designing infrastructure and budgeting of public funds. The Tulsa Region Future Growth map (Figure 5) shows a projection of the region in 2025 with 80 square miles of new urbanized area added. The new growth was added using the following heuristics adapted from the SLEUTH method. Edge growth stems from and occurs around the perimeter of existing urban areas. Spontaneous growth occurs randomly on undeveloped land often around a seed or catalytic development. Spreading growth continues growth trends and dynamics already in place. Road influenced growth takes place along transportation routes. (Project Gigalopolis website).

Future growth in the Tulsa region will most likely not be balanced growth. There are a number of both positive and negative factors influencing future growth in the region. The trend for the urbanized area to grow to the southeast will continue. There are a number of possible reasons to explain this trend. First, the river to the west and topography to the northwest will continue to slow growth in those directions. Osage County does not invest in urban infrastructure and continues to hinder growth to the northwest. The new Creek Turnpike will attract road-induced growth along its path. This growth will also be accompanied by spontaneous growth at the NSU-Broken Arrow Campus, Southcrest Hospital, the Jenks aquarium and the Renaissance Conference Center. Spreading growth patterns also contribute to this southeasterly trend with new housing and commercial construction in Broken Arrow, Jenks and Coweta. School funding and performance also fuel growth in suburban locations. The disparity of school performance should not be underestimated as a development force; it is also an indicator of socioeconomic stratification in the region. Northeastern portions of the region including Owasso, Collinsville and Claremore will also see significant growth due to the prior reason and their proximity to major employment centers on the north side. Growth in the northeast will be inhibited by floodplains and limestone deposits and may have lower densities and follow a patchwork pattern. Finally, slow perimeter growth is expected in a wide range of areas. The future growth map depicts a scenario with 55 percent of the region's growth toward the southeast, 25 percent to the northeast and the remaining 20 percent in areas of scattered perimeter and spontaneous growth.



Tulsa Region Future Growth

Legend

- Estimated Urbanized Area 2000 - 230 Sq. Miles
- Projected Urbanized Area 2025 - 308 Sq. Miles

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Discussion

The first question to consider is whether the Tulsa Region can add 80 square miles of urbanized area in the next twenty-five years. While the region has wetlands and hills that are not suitable for development and other lands that should be preserved for agriculture and recreation, there certainly is not any shortage of land for development. Even at 310 square miles, the urbanized area would only be 6 percent of the TMSA. With this in mind, the original question needs reframing to consider whether the Tulsa Region can afford to add 80 square miles of urbanized area in the next twenty-five years. The region faces the challenge of trying to maintain and upgrade 230 square miles of existing infrastructure while providing for the new growth. Roads, power, water, sewer and communication networks along with schools, police, fire protection and other community services need to be provided for the newly developed areas.

The American Farmland Trust has developed the Cost of Community Services (COCS) study method to determine the net fiscal contribution of different land uses to local budgets (American Farmland Trust website). COCS studies from more than 70 communities across the nation indicate the median cost to provide public services to residential land uses per dollar of revenue raised is $1.15. In other words, it costs 15 percent more to provide services to homeowners than residential landowners pay in taxes. Meanwhile, the median cost to provide public services to commercial and industrial land uses is $.29 or less than one third the revenue collected (American Farmland Trust website). Many suburbs develop initially as clusters of housing subdivisions. Some depend on rapid growth to add new residents and raise the tax base to outpace the costs of providing community services until they reach a critical mass capable of attracting commercial, retail and industrial development needed for long term sustained revenue. New suburban commercial and industrial development in turn can lower the tax capacity of the central city, compounding the fiscal impact of lower population growth rates due to suburban housing development (Orfield 23). Much of the growth in the last twenty years in the region's suburbs has followed this pattern. Many are feeling growing pains in areas where infrastructure and services have not been able to keep pace with development. These communities are competing with each other and the City of Tulsa for commercial development to fund their needed improvements. Adding additional land to the urban area will only reinforce these trends.

Beyond the sheer extent of growth, another issue to consider is the distribution of growth. As already pointed out the Tulsa region has experienced unbalanced growth to the southeast. Much of this growth occurred due to the location of road and highway improvements and other public works projects. Recent projects have continued to reinforce this trend. Spreading growth also makes it difficult to plan and operate a public transportation system. Transit needs well-defined centers of population and activity to be efficient and cost effective. The region needs to consider whether new growth will be a differentiated network of urban centers or an undifferentiated hypertrophy.

Finally, the decrease in population density should be considered. A typical family of four living in the Tulsa region now requires over one acre of urbanized land, yet the size of a typical residential lot has not increased significantly since the early part of the twentieth century. This suggests that housing development has not been responsible for the decrease in population density. Rather it may be due to poor land use practices. Commercial development has become larger and requires more land for buildings and surface parking. Zoning regulations and planning policies fuel lower densities with setback requirements, lower floor area ratios and no incentives for shared parking or other land conservation measures. Many sites are bypassed or underdeveloped while becoming engulfed by the urban area. Still other sites become brownfields (abandoned industrial sites) or greyfields (abandoned commercial sites) after they have served an increasingly shorter useful life. All of these trends indicate an opportunity for future growth to take place as infill by increasing density in developed areas instead of adding new urbanized land to the region.

Many regions have introduced managed growth policies to deal with these issues. The State of Oregon passed urban growth boundary legislation in 1973 that requires every city and town to establish limits beyond which urban growth is prohibited. Orange County, Florida has taken a different approach by establishing an Urban Service Area around Orlando, which describes the maximum extent of utilities and public services.
It is important to take a regional approach to the above measures otherwise development will leapfrog over local jurisdictional boundaries. Minneapolis and St. Paul have formed a Metropolitan Council, while Louisville and Jefferson County, Kentucky have actually merged governments to manage regional issues. Many other states and cities are considering similar measures (Calthorpe and Fulton 105-197).

Further Study

This study could be greatly expanded by future research. The maps themselves could be improved by obtaining data that is more detailed or measuring growth in smaller time intervals. Additional map layers could be created and analyzed using demographic and economic data. Mapping measures of tax capacity, school performance and election results would yield further insights. Completing a Cost of Community Services Study for the region would also be useful.

The dynamic display of the maps in the form of computer animations would allow a better understanding of the rate of change of urban growth. Generating projections of future growth using computer simulations, such as SLEUTH, would provide a more accurate vision of future growth and allow the manipulation of variables to generate different growth scenarios.

Lastly, identifying and locating infill development sites may be most useful for planning higher density development, transit systems and improving the existing urban framework without consuming more land.

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- To train urban design professionals through master's degree programs in architecture and urban studies
- To advance the understanding of the city through research and creative activity
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The Urban Design Studio is always looking for promising students and community partners for its endeavors.

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