How Sprawl Shapes Public Parks in an Urban System: Spatial Analysis of Historical Urban Growth in Orlando Metropolitan Region, Florida, USA

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Abstract: Public parks are defined by historical changes in land use and land cover (LULC). Influences of broader urban processes, like sprawl, are visible consequences of these processes, sometimes including the dysfunction of amenities and facilities in parks, and the decrease of multi-functional open space on a regional scale. When planners and designers are preparing solutions for public parks in specific sites and areas, the lack of credible regional understanding has become a research gap that can be potentially bridged by applying the geodesign framework. Our goal is to comprehensively explore the historical development of urban systems and the impacts of this development on public parks in the Orlando Metropolitan Region, Florida, USA today. A prior study recorded some initial results based on the land use changes from 1970 to 2011 demonstrating how significant sprawl patterns emerged in this system. We now study how this influenced the form and distribution of public parks within the urban system. We standardized land-cover data between 2001 and 2016 and used public parks as an interpretive indicator through which to enhance the geospatial understanding of sprawl. Our findings include the following: We observed significant decreases in the natural area and found that the majority of non-urban lands have been converted to urban growth within our study boundary. Such results indicate the needs of urban growth have been centered on residential lands. In addition, we superimposed sprawl buffers and examined the ratio of urban land area to public parks per count and per unit area. We concluded that the inconsistent and unbalanced distribution of public parks is correlated with sprawl. Specifically, in the range of 6 to 12 miles, sprawl has greatly influenced park form and distribution. Finally, we discussed the implications of this study for future geodesign, landscape, and planning applications.

Keywords: Sprawl, public parks, land cover changes, Orlando Metropolitan Region

1 Introduction

This is a descriptive paper and includes some initial findings for landscape resources in the process of the dynamic and complex urban systems. Specifically, we focus on studying how sprawl shapes parks in the urbanization process. Due to the length of this paper, we have emphasized the regional scale in documenting the territorial and vegetation changes between 2001 and 2016 and overlaying the distribution of public parks within the study boundary. Instead of detailing the findings associated with specific settlement patterns, we focus on the distribution of sprawl in rings around the metropolitan region that influence the numbers and sizes of public parks in the study location. Through spatial analysis in GIS, we aim to identify the necessity of a regional understanding in order to guide future geodesign applications.

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1.1 Stage of Knowledge

Urban sprawl, a phenomenon of urbanization, has brought much attention to urban issues in the fields of urban and landscape planning. To accommodate a booming population, metropolitan growth has amplified urban sprawl through increased urban development in areas with lower population density and increased low-density LULC (SETO & REENBERG 2014). Beyond the urban fringe, the establishment of human-dominated environments by sprawl has altered the continuity of the land cover, eliminating the possibility of preserving large open spaces where a large number of people can spread out at a lower density (EWING 2008). Some observations have been conducted on a community scale, revealing repetitive sprawl patterns at the street level, and with private home sites encroaching on a variety of open space areas and limiting the space available for parks (SCHNEIDER 1970). Under the conditions of decreased natural resources in exchange for urban growth, the study of public parks associated with sprawl is becoming more significant. Simply put, the form and distribution of public parks have been influenced by historical patterns of urban growth. Parks, which are influenced by the outcomes of urban sprawl, can be referred to as positive or negative responses to environmental conditions and historical LULC change processes (FORTIN & DALE 2005).

Previous studies attempting to increase our geospatial understanding of public parks have focused on the specific sites and functions of parks (KACZYNSKI et al. 2008). However, a few have examined public parks as an interpretive indicator, using them to understand the urbanized context in terms of development trends in parks. Historical settlement patterns shape regional landscapes by opening up some opportunities to accompany housing but constraining others in the review of park design and planning. This is a classic case of studying human adaptation within the living environment, reflecting the dynamic relationship between land-use decisions and settlement patterns. Actions from local residents and people surrounded by amplify humans' modification of natural resources in their living environments (OLDING-SMEE et al. 2013, MURTHA 2015). Thus, it is necessary to emphasize long-term spatial and temporal perspectives to reveal human-nature interaction (DEARING et al. 2010). The measurement of kinds, distributions, and patterns of LULC from the past serves as a platform for studying the interacting social, physical, and ecological systems of parks (TURNER et al. 2007). Thus, in this study, we want to learn how public parks are influenced by urban growth and in particular sprawl. Such an evaluation of parks also offers information to think about the geodesign framework and how recreation systems can be integrated within broader geodesign themes.

1.2 Study Design and Findings

We conducted a case study in central Florida to describe the spatial and temporal dynamics of urban development in land-cover changes, urban sprawl, and landscapes during critical periods of the urban system. In our pilot study, the necessity of understanding public parks was established by sprawl patterns resulting from historical changes in LULC analysis from the 1970s to the 2010s (MURTHA et al. 2019). This paper supplements and reinforces the pilot study's results with further investigation of settlement and vegetation changes in the past decade to explicitly examine the recent effects of land-cover changes on public parks between 2011 and 2016.

The objectives and major findings of this study include the following. First, we explored the types of land morphology that characterize parks. We documented the forms and distribution

of land-cover changes in the Orlando Metropolitan Region from 2001 to 2016. We found that with relatively stable changes, urban lands still increased significantly over those 15 years, demonstrating that urban growth is continuing. Second, we sought to determine what major changes had occurred and under what conditions they occurred. We found that most forested or natural lands had declined, thereby increasing the proportion of urban lands. More importantly, our investigation of urban land conversion revealed evidence of rising rates of residential land alongside declines in open-space urban lands. Third, we worked to understand how sprawl affects the regional conditions of surrounding public parks. We found that the ratio of developed lands to public parks, both per count and per unit area, was distributed inconsistently, but not randomly. Some of the findings showed that the public parks located at distances of 6–12 miles from the city center and on the periphery had a clear influence over the number and size of accessible parks. Given this interpretation, some of the results from these crossed temporal-dynamic comparisons illustrate that current park opportunities are insufficient, which offers potential room for future decisions about planning and design for public parks.

2 Materials and Methods

We standardized several data sources, including land-cover data that was obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium [1] and public park and county boundaries data from the Florida Geography Data Library (FGDL) [2]. Within the Orlando Metropolitan Region, land-cover data were processed first for each of the following years: 2001, 2006, 2011, and 2016, in ArcMap. Major land-cover types included: shrub, cultivated crops, herbaceous, evergreen forest, deciduous forest, hay/pasture, open water, woody wetlands, mixed forest, developed land (including open space, and of low, medium, and high intensity), barren land, and perennial snow. In addition, we quantified land-cover conversions via the combine tool in ArcMap for the periods 2001-2006, 2006-2011, and 2011-2016. Third, guided by our pilot study on sprawl, we investigated the relationship between public parks and the sprawl buffers in each year, focusing specifically on the distance from the city center; our sprawl buffers ranged from two to eighteen miles. Finally, we used ratio analysis to compare urban land areas by years to the public parks at the alignment of the sprawl buffers.

3 Results

The results of our analysis can be summarized under three key headings: (1) land-cover distribution analysis, (2) land-cover conversion, and (3) sprawl and public parks. Our results reveal how major land cover was distributed, what land conversion happened between non-urban and urban lands, and how sprawl shaped public parks from 2001 to 2016.

3.1 Land Cover Distribution Analysis

We observe land-cover changes in the Orlando metropolitan region between 2001 and 2016 (Table 1). We observe a declining trend in the land-cover types of deciduous forest, evergreen forest, mixed forest, and hay pasture. Hay pasture decreased the most, with 2% of lands in which areas of 8,087 hectares changed. Evergreen forests were converted or lost, around

4,091 hectares of land, which amounted to a 1% change. However, despite the stable changes of land cover over 15 years, we still found a significant rise in developed (urban) lands. In total, the developed lands from open space, including low intensity, medium intensity, and high intensity developments, increased from 34% in 2001 to 38% in 2016. When we analyzed them separately, the types of developed land that increased the most were medium intensity by 1.84%, while high intensity developed land had the smallest increase rate of 0.65% from 2001 to 2016. The remaining developed land from open space, including low intensity, accounted for increased rates of 1.43% and 0.85% from 2001 to 2016. For the other types of lands, unstable changes happened. In particular, barren lands, cultivated crops, woody wetlands, and emergent herbaceous wetlands eventually dropped below their 2001 numbers. Not surprisingly, in the Orlando Metropolitan Area, there has been a significant and steady decline in natural or forested areas associated with population growth.

Table 1: Land cover analysis in years of 2001, 2006, 2011, and 2016 in Orlando Metropolitan Region

Code	Land cover	2001%	2006%	2011%	2016%
11	Open Water	9.32	10.00	9.69	9.72
21	Developed, Open Space	14.81	15.11	15.31	15.66
22	Developed, Low Intensity	11.59	12.07	12.65	13.02
23	Developed, Medium Intensity	5.40	6.11	6.87	7.24
24	Developed, High Intensity	1.71	1.95	2.24	2.36
31	Barren Land	0.42	0.35	0.36	0.39
41	Deciduous Forest	0.05	0.06	0.05	0.04
42	Evergreen Forest	7.35	6.74	6.24	6.18
43	Mixed Forest	1.00	0.86	0.83	0.80
52	Shrub/Scrub	2.16	1.75	1.91	1.57
71	Herbaceous	0.75	1.17	0.91	0.98
81	Hay/Pasture	11.98	10.96	10.25	9.66
82	Cultivated Crops	0.77	0.80	0.71	0.61
90	Woody Wetlands	26.87	26.05	25.97	26.09
95	Emergent Herbaceous Wetlands	5.80	6.03	6.02	5.68
	Total	1	1	1	1

3.2 Land Cover Conversion

While we observed significant decreases in natural areas, what those lands become is potentially more important than simply the decline in natural areas. To investigate these changes, we analyzed patterns of nonurban lands that were converted to urban lands between 2001 and 2016 (Fig. 1), and measured conversion of specifically non-urban land types to developed (urban) lands. We then calculated the total area of land conversion that occurred from 2001 to 2016 (Table 2). We observed that the most converted non-urban land was hay/pasture, which contributed 6,452 hectares to urban land growth. The second largest land conversion was evergreen forest and woody wetlands which both dropped by more than 2000 hectares. Deciduous forest and emergent herbaceous wetlands had the smallest increase, around 50 hectares. To sum up, a total area of 16,612 hectares of non-urban lands were converted to urban lands.

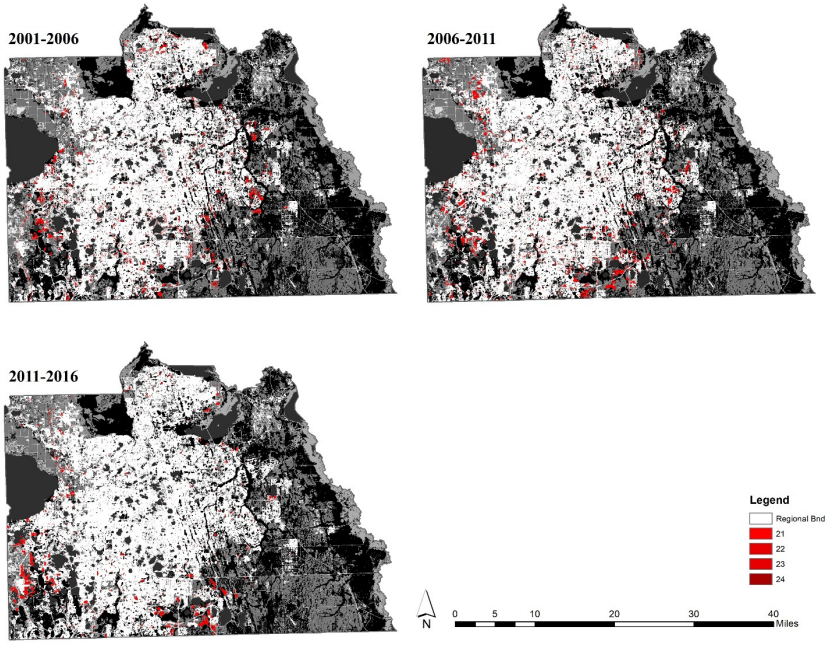

Fig. 1: Land cover conversions from 2001 to 2006, 2006 to 2011, and 2011 to 2016 in Orlando Metropolitan Region. Note: Numbers in legend refer to land cover code on table 1, represents the consequences of non-urban lands converted urban lands.

Table 2: Land conversion summary: non-urban lands to urban lands between 2001 and 2016 in Orlando Metropolitan Region

Non-urban lands	**To urban lands: 2001-2006 (ha)**	**To urban lands: 2006-2011 (ha)**	**To urban lands: 2011-2016 (ha)**	**Sum: 2001-2016 (in ha)**
Open Water	100.53	130.1661	21.42	252.12
Barren Land	174.6	96.93	112.68	384.21
Deciduous Forest	26.19	16.83	1.8	44.82
Evergreen Forest	1691.19	804.78	494.01	2989.98
Mixed Forest	363.6	140.4	89.19	593.19
Shrub/Scrub	439.47	318.6	218.07	976.14
Herbaceous	245.16	979.47	136.08	1360.71
Hay/Pasture	1965.51	2299.32	2186.91	6451.74
Cultivated Crops	113.04	247.23	314.1	674.37
Woody Wetlands	753.21	1142.37	438.93	2334.51
Emergent Herbaceous Wetlands	139.86	205.2	204.93	54.99
Total	6,012.36	6,381.296	4,218.12	1,6611.78

In addition, our analysis reveals that land conversion occurred in four types of developed lands: open space, low intensity, medium intensity, and high intensity. Because we found that the open space of developed lands was not equal to or covered up by public parks, it is necessary to study how functional lands such as open space have been affected by urban land conversions, and how residential areas were interchanged with each other. From 2001 to 2016, no open space was gained overall, but more areas were converted to other residential patterns. For example, the open space lands converted the most from 2006 to 2011 amounted to 1559.97 hectares and contributed to a medium-intensity increase of 961.56 hectares. When we measured housing settlement patterns, we found evidence of low intensity areas converted to higher density patterns, but none of the areas converted back. For example, from 2001 to 2011 low and medium housing patterns were converted to medium and high patterns, whereas the existing high intensity patterns did not change. Moreover, from 2011 to 2016, none of the housing patterns changed; we observe only that open space continually changed for residential needs.

3.3 Sprawl and Public Parks

This historical study has quantified land conversion, illuminating assumed patterns for regions experiencing rapid urbanization. Orlando has witnessed increasing residential areas in urban growth and a decline in nonurban lands. Specifically, the most significant declines have been in natural and forested lands. Because of these historical trends, we wanted to document and understand how these patterns might have shaped public parks. For example, were these patterns of urbanization coupled to shifts in the form and distribution of public parks?

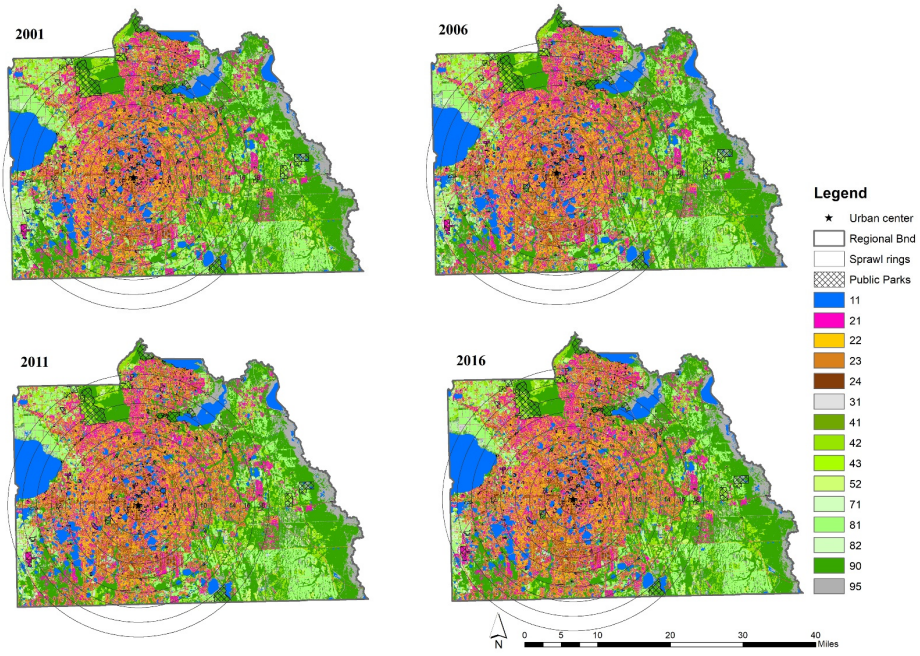

Fig. 2: Land cover distribution and sprawl buffers between 2001 and 2016 in Orlando Metropolitan Region. Note: numbers in legend refer to the land cover code in Table 1.

Or were public parks limited in their size and distribution? Guided by our pilot study of sprawl in the Orlando Metropolitan Region, we overlaid available data about public parks over a series of concentric sprawl buffers that document patterns or intensity sprawl (low density residential) development from the urban center to the periphery. Our analysis first quantified the distribution of key land-cover categories in each ring from 2001 to 2016 (Fig. 2). We designed the buffers to range from two to eighteen miles from the urban center. We observed key distribution and proportions of all land-cover types across the buffers. In detail, we observed that woody wetlands occupied a greater proportion of land in the buffer rings of 12 – 18 miles. Developed open space, developed low, and developed medium accounted for most of the area between 6 and 12 miles. Open water, hay pasture, evergreen forest, and evergreen herbaceous wetlands occupied large areas between 14 and 18 miles.

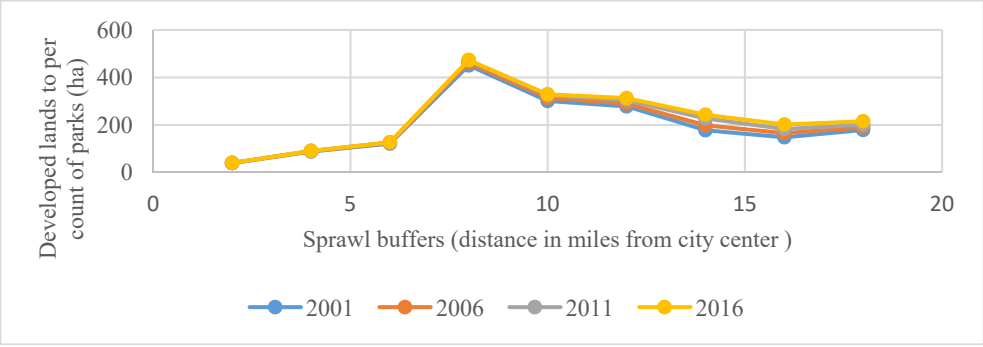

Fig 3: Ratio analysis: developed lands to per count of parks

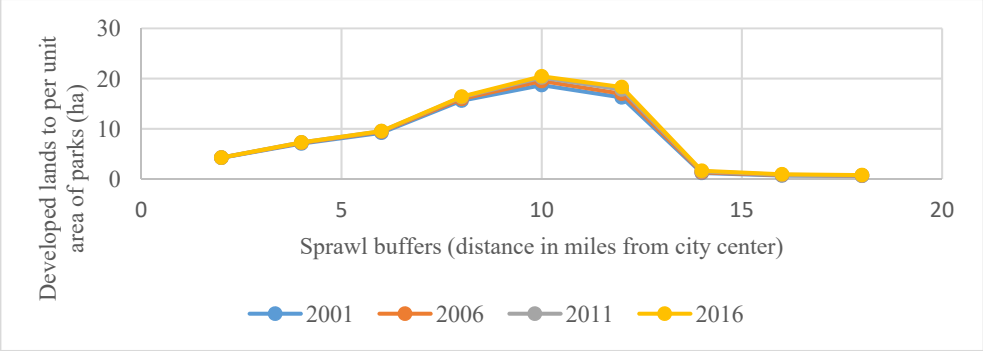

Fig 4: Ratio analysis: developed lands to per unit area of parks

Because we identified an upward trend in urban areas, we are curious about how urban development has shaped the formation of public parks. We performed a ratio analysis of each buffers' urban area to the count and the area of parks. Specifically, we combined four categories of developed land into one because we wanted to know the overall relationship between developed lands and public parks. Our analysis of the ratio of developed lands to parks identified the 8-mile sprawl buffer as the turning point that is between two opposite trends: the climbing trend within the 8-mile buffer, and a declining trend beyond it (Fig. 3). We also

examined the ratio of developed land to unit area of parks. In Figure 4, we show that the of 10-12 miles contains the highest proportion of urban land. At the periphery of the Orlando metropolitan region, the lowest proportion of urban lands was found per unit area of parks.

4 Discussion and Outlook

This study delineates several major consequences of urban growth in relation to land cover, sprawl, and public parks in the Orlando Metropolitan Region. First, urban lands have maintained rapid growth, growing faster than other land-cover and vegetation categories. Second, we gathered evidence of the fact that not only the majority of non-urban lands have been converted to urban lands, but that urban lands of open space and lower density residential areas have been correspondingly converted to medium- and high-density housing patterns. Most importantly, at a regional scale, the ratio of urban lands to parks and park area in regions outside the urban core is inconsistent and unbalanced.

Notably, public parks in a rapidly urbanizing context have been at the center of guiding the spatial organization of Central Florida. As reflected in our findings, buffers of more than 6 miles show that urban growth and sprawl patterns have played important roles in the change. For example, we found the greatest area of urban land lies between the 6- and 12-mile buffers, indicating population pressure and the need for public facilities such as parks. These needs are also reflected in the number and area of parks from 6- to 12 miles, with each individual park facing human-dominated activities due to urban growth. In addition, at the periphery, our study reveals the consequences of urban sprawl on landscape resources. Because the lowest number of public parks appears between the 14- and 18-mile buffers, each park has been confronted with increasing residential lands, but still less than in the inner regions. This seems logical because people in the inner regions live in single houses with backyards, reducing the demand for public parks.

However, some limitations have restricted our understanding of landscape resources in urban systems. For a comprehensive urban systems analysis, we plan to investigate the exact land-use and land-cover changes between the critical distances of 6 and 12 miles. We will adapt the methods of historical image analysis and statistical summary for our future work.

Our study of how sprawl shapes public parks uses an explanatory research design, showing potentially valuable aspects of landscape planning and design for future urban growth. It suggests that we rethink urban issues from a long-term perspective and in a landscape dimension in order to prioritize parks in the land system. Our study offers several lessons for alternatives in future geodesign. For instance, in the case of smaller parks that serve larger urban areas, we suggest several solutions: (1) expanding areas by land-use decisions, (2) enhancing the functionalities of parks, and (3) designing the parks to be part of the green infrastructure, such as corridors to connect the public park system. As a result, the planning and design of parks will better serve the local region and fit the intertwined natural and human contexts.

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