Using GIS to Measure the Impact of Development on Urban Green Spaces in D.C.

Angela T. Chang, MGIS Candidate
Advisor: Dr. Justine Blanford
Department of Geography
Pennsylvania State University

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ABSTRACT

Washington, D.C. has experienced a steady surge of growth over the past 10 years, with increases in jobs, development and a changing demographic, leading the way. The gentrification of "Chocolate City" – the historical term affectionately used for decades by black-Americans to reference the nation's capital city – has been welcome to many, but the pace, the location, and the equity of development and both public and private resources has not been without contention and controversy.

The loss of open space, especially of public green spaces, including parks, forests, sporting fields and community gardens, often accompanies urban population growth and development efforts (McDonald *et al.*, 2010), and often disproportionately affects the poor and already-disenfranchised (Heynen *et al.*, 2006). But efforts to improve green spaces in low-income and park-poor neighborhoods can also have a paradoxical affect – improving the appeal of neighborhoods and increasing property value encourages gentrification and can lead to the displacement of the original residents that the green space was meant to benefit in the first place (Wolch *et al.*, 2014).

This project will utilize a geographic information system (GIS) to examine the impact of urban population growth and development on public urban green spaces in D.C. and two surrounding areas of interest, Arlington and Alexandria counties. The objectives of this project are to identify if and where green spaces have been impacted by demographic change and development (commercial and residential), and to observe whether there are any relationships or patterns of behavior between these demographic changes and the availability and access to public green spaces. In approaching this analysis with a social justice lens, the intent is to demonstrate how GIS can be used a barometer to measure (amongst other items) the equality of access to public goods and resources, particularly in a rapidly developing and changing city landscape.

BACKGROUND

Changing American Cities

American cities are changing. In 2010, over four-fifths, or 83.7 percent, of the U.S. population lived in one of the nation's 366 metropolitan areas (Census Briefs, 4) – defined as a core urban area with a population of 50,000 or more (Metropolitan and Micropolitan Statistical Areas Main). Over the last decade, these metropolitan areas grew almost twice as fast as micropolitan areas – a core urban area with a population of at least 10,000 but less than 50,000 – 10.8 percent compared to 5.9 percent respectively (Census Briefs, 4).

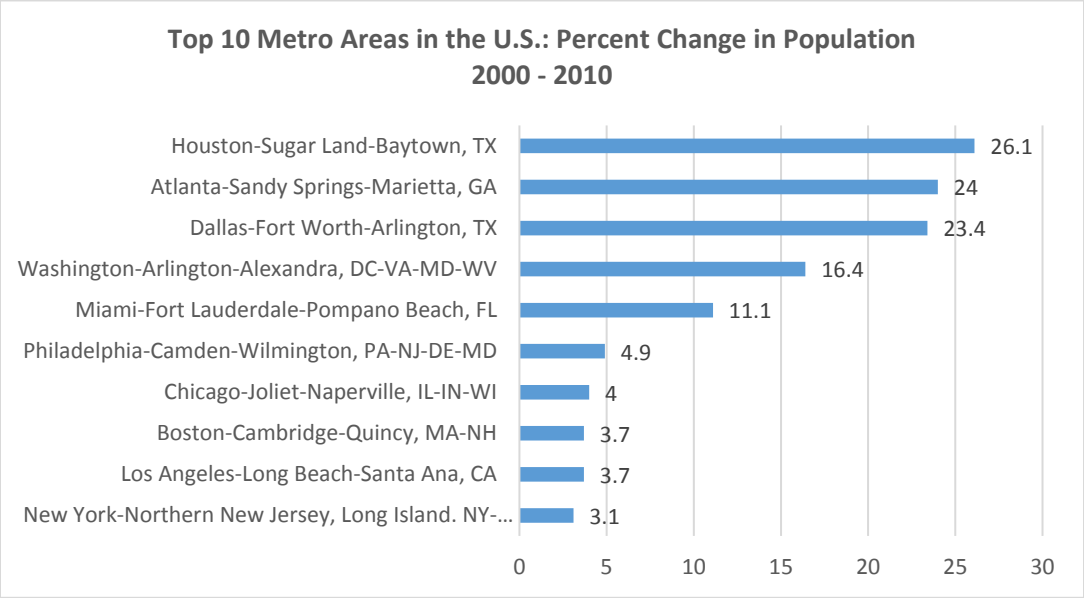
This rapid growth is well-documented by the 2010 Census which found that the ten most populous metropolitan areas in the U.S. – New York, Los Angeles, Chicago, Dallas-Fort Worth, Philadelphia, Houston, Washington D.C., Miami, Atlanta, and Boston – all experienced an increase in population growth between 2000 and 2010 (Census, 4).

Population Change for the Ten Most Populous Metropolitan Statistical Areas: 2000 to 2010

METROPOLITAN STATISTICAL AREA	POPULATION		CHANGE	
	2000	2010	Number	Percent
New York-Northern New Jersey, Long Island. NY-NJ-PA	18,323,002	18,897,109	574,107	3.1
Los Angeles-Long Beach-Santa Ana, CA	12,365,627	12,828,837	463,210	3.7
Chicago-Joliet-Naperville, IL-IN-WI	9,098,316	9,461,105	362,789	4.0
Dallas-Fort Worth-Arlington, TX	5,161,544	6,371,773	1,210,229	23.4
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	5,687,147	5,965,343	278,196	4.9
Houston-Sugar Land-Baytown, TX	4,715,407	5,946,800	1,231,393	26.1
Washington-Arlington-Alexandra, D.C.-VA-MD-WV	4,796,183	5,582,170	785,987	16.4
Miami-Fort Lauderdale-Pompano Beach, FL	5,007,564	5,564,635	557,071	11.1
Atlanta-Sandy Springs-Marietta, GA	4,247,981	5,268,860	1,020,879	24.0
Boston-Cambridge-Quincy, MA-NH	4,391,344	4,552,402	161,058	3.7

(Data Source: 2010 Census Brief)

Of the top ten most populated metro areas, half of these metro areas, including two in Texas, Georgia, Florida, and Washington, D.C. saw double-digit percent changes in population growth.



(Data Source: 2010 Census Brief)

The growth and demographic shift to major metropolitan cities and their surrounding suburbs has notably been driven by job-seeking millennials, the term used to define the generation of young professionals between the ages of 25 to 44 (Dure, 2014). A 2014 analysis of Census data from 2007 to 2013 performed by RealtyTrac, a comprehensive housing data and analytics firm, found that millennials generally moved from lower-priced to higher-priced markets for both buying and renting property, with the tradeoff being more economic job opportunities (lower unemployment) and higher median incomes (RealtyTrac, 2014).

Urban Green Space

Urban green space in its broadest context includes areas such as parks, forests, green roofs, streams, and community gardens – all of which are considered to be critical ecosystem services that can greatly impact the general health and well-being of an urban population (Wolch *et al.*, 2014). Public green spaces – areas that are open and accessible to anyone – include parks and nature conservation areas, sporting fields, riparian areas like streams and river banks, greenways and trails, community gardens, and street trees, along with less conventional spaces such as green walls, alleyways, and cemeteries (Roy *et al.*, 2012). Unlike natural ecosystems, the green spaces in urban ecosystems possess unique characteristics – where the type, amount, composition and distribution of a system's climate, soils, vegetation, and ecological relationships is dependent upon human decision-makers (Dobbs *et al.* 2011) and the non-natural, built-up infrastructure.

A comprehensive understanding of this built environment has become especially critical to urban and city planners, particularly as the growth of urban populations greatly reduces open and green space in and around cities (McDonald *et al.*, 2010). Within the past two decades, numerous studies have demonstrated the strength of the positive relationship between the amount of and access to urban green spaces, and to public health (Wolch *et al.*, 2014).

Urban Green Space: A Public Health Issue

In 2003, Dutch researchers found a positive correlation between self-reported health status of a population and the amount of green space in their living environments (de Vries *et al.*, 2003). Green spaces such as parks often function as settings for health promoting physical activities and behaviors that are associated with overall health and reduced risk for all-cause mortality and various chronic disease and illnesses (Anon, 1996). In 2010, a study conducted by researchers at Florida State University found a significant correlation between the amount of green space within defined distances of all census tracts in a county, and the overall mortality and cardiovascular mortality rates in that county. The researchers used GIS to examine the relationships between the amount of and distance to green spaces by census tracts within all counties in Florida – their findings suggest that accessibility to green space support positive health outcomes (Coutts *et al.*, 2010).

Parks and green spaces not only provide physical space for healthy physical activities, but they also serve to encourage and support mental health (Barton and Pretty, 2010) and stress relief as social interaction within these spaces can help to encourage and strengthen neighborhood bonds and social ties in the area (Kuo *et al.*, 1998).

As discussed above, urban green spaces not only contribute to the public health of urban populations (Groenewegen *et al.*, 2006), but also function as a critical component in maintaining the ecological integrity of a city (Wolch *et al.*, 2014). Vegetation in green spaces help to filter and remove air pollution (Nowak *et al.*, 2006), manage storm and ground water resources (Escobedo *et al.*, 2011), reduce noise, and regulate temperature (Cummins and Jackson, 2001) – especially in highly-populated urban environments.

Urban Green Space: A Social Justice Issue

As awareness of the importance and beneficial impact of green spaces in urban environments has grown over the past two decades, so has the recognition that the inequitable distribution and uneven accessibility to these spaces represent an important environmental justice issue. A myriad of interrelated factors have informed the distribution of green space in urban environments thus far – differing philosophies of park design, changing perceptions about leisure and recreation, the history of land development and its intertwining relationship with class, ethno-racial inequality, and government oppression (Byrne, 2012 and Byrne and Wolch, 2009).

In the United States, the inequality of green space between the urban core and their suburban counterparts is starkly interwoven with the economic and racial demographics of the population. People of color and low-income wage earners typically occupy the core of cities and the low-income inner ring of suburbs, where green space is both scarce and most often poorly-maintained. In contrast, green space is typically abundant and well-maintained in the suburban periphery where wealthier households often reside (Heynen *et al.*, 2006).

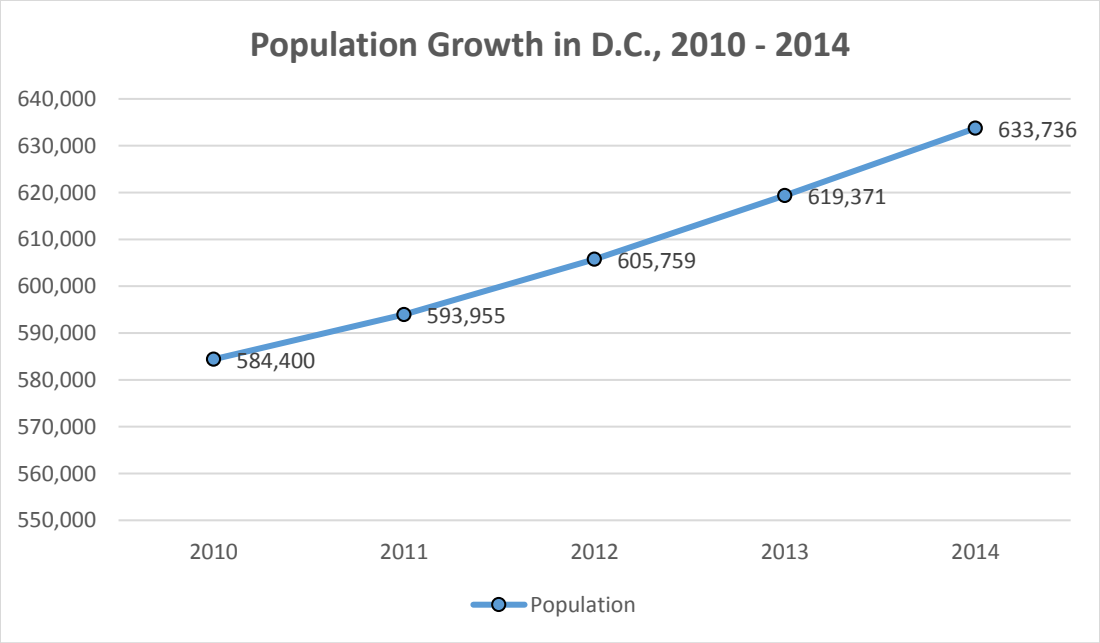
The recognition of this environmental and social injustice has become a priority for urban planners and city officials, leading to efforts to redress park-poverty in communities of color and strategies to deploy underutilized urban land for additional green space (Wolch *et al.*, 2014). The High Line Park in New York City is a fascinating example of how the successful effort to turn a 1.45 mile-long elevated section of abandoned railway into an elevated park and aerial greenway, spurred new real estate development the revitalization of the Chelsea neighborhood.

The paradox here is that the addition of public green spaces in park-poor neighborhoods can be so successful in helping to increase neighborhood health and curb-appeal, that the increase in housing costs and property values can lead to gentrification and the displacement of the original residents that the green space was meant to benefit in the first place (Wolch, *et al.*, 2014). In the case of the High Line, the New York City Economic Development Corporation found that before redevelopment, the residential properties surrounding the High Line were valued 8 percent below the overall median. In the time period during/after redevelopment, between 2003 and 2011, surrounding property values near the park increased by 103 percent (NYCED, 2011). Sadly, the success of the High Line Park has not come without the consequences of gentrification – many working-class residents and businesses that have

lived and worked in the area for decades have been forced to close (Moss, 2012). In most cases, the loss of the traditional neighborhood customer base and skyrocketing rent, have been to blame (Moss, 2012).

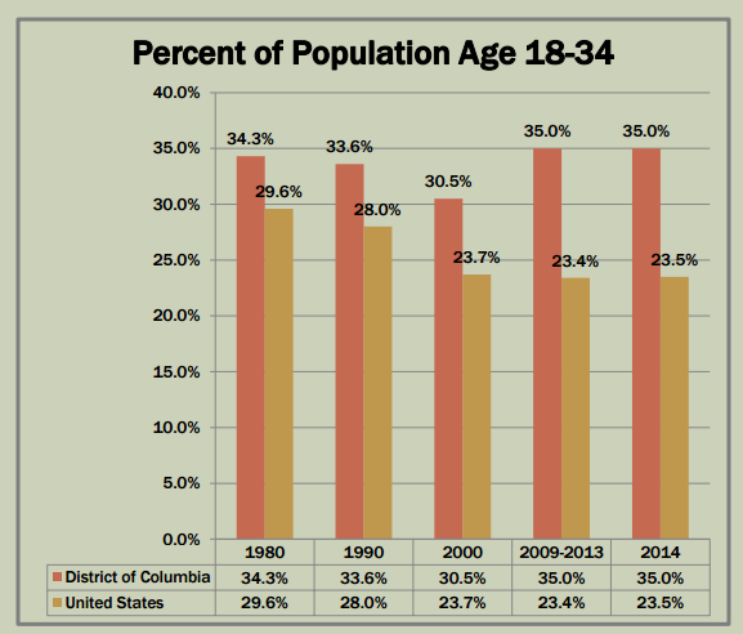
A CLOSER LOOK: Demographic Changes & Development in Washington, D.C.

The nationwide trend toward urbanization, and the physical, environmental and demographic impacts of such a change, has not been lost on D.C. From 2000 to 2010, the Washington metropolitan statistical area (including the District of Columbia, Arlington, and Alexandria), grew by 16.4% and since then, the District of Columbia in particular has continued to experience an increase in the rate of change of population growth (2010 Census Briefs, 6).



(Data Source: American Community Survey, 2014)

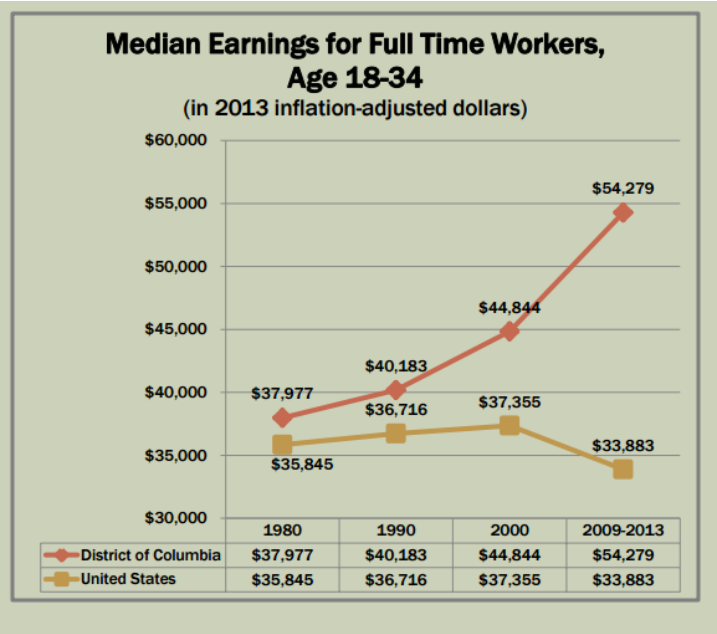
Between 2000 and 2010, the District of Columbia itself grew by 5.2 percent, the first decennial population increase since the 1940s (2010 Census Brief, 3). Not surprisingly, millennials account for a significant percentage of the population growth in D.C. – representing 32.7% of the population in 2005 to 36.8% of the population in 2014. While the percent change may not appear significant over the change in time, what is most notable is the five-year period between 2009 and 2014, where the increase of millennials in D.C. as a segment of the total population grew by 22% (WDCEP, 9).



(Data Source: D.C. Office of Planning, 2014)

In D.C.'s nearby suburbs of Arlington County and Alexandria, Virginia, millennials also spearheaded population growth. Between 2007 and 2014, the number of millennials grew by 82 percent, ranking Arlington/Alexandria as the top destination for millennials in the U.S. during that time. Not surprisingly, both Arlington and Alexandria boasted impressively low unemployment rates – 3.2 and 3.6 percent respectively, well below the national average at the time (RealtyTrac, 2014).

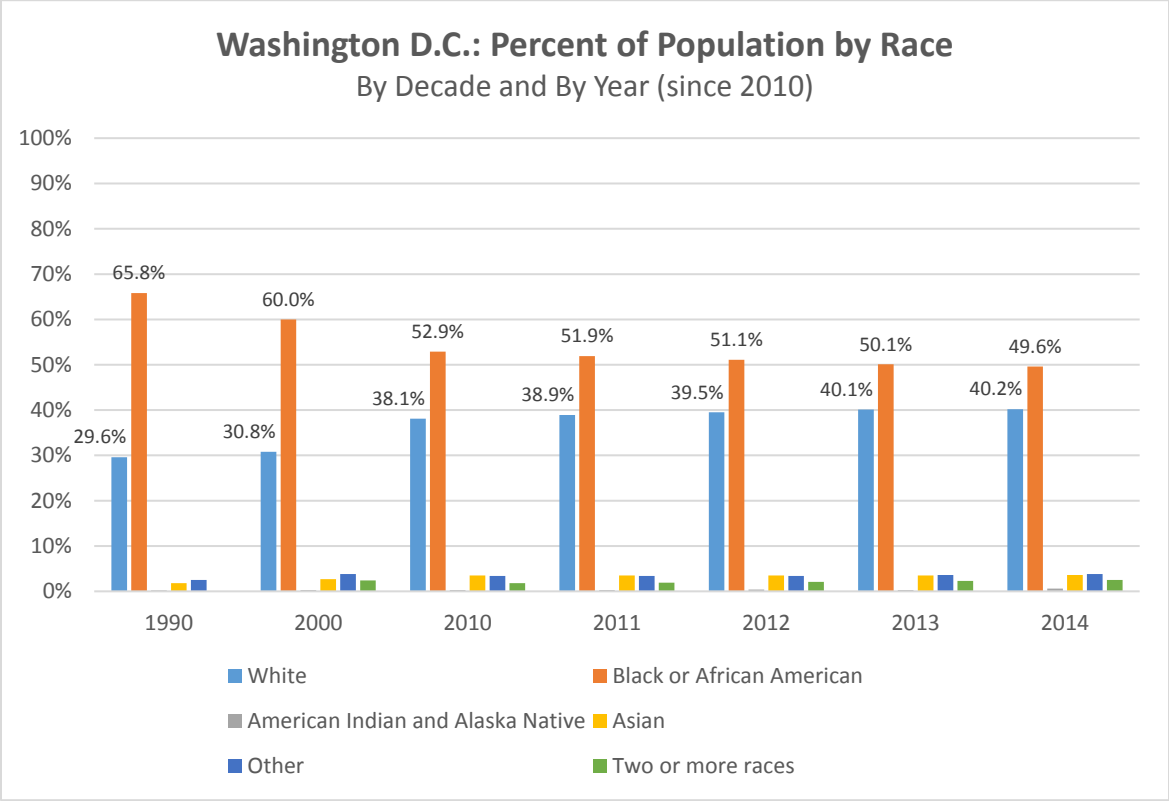
Within the District, the number of employed millennials has remained relatively on-par with the national average since the 1980s, an average of approximately 66 percent employed and 68 percent employed respectively (D.C. Office of Planning, 2014). Yet while the rate of employment in D.C. has remained in line with the national average, the median income of millennials in D.C. has increased significantly within that same time period, increasing by nearly 43 percent in comparison to the national average for median income of millennials, which actually decreased by 5 percent (D.C. Office of Planning, 2014).



(Data Source: D.C. Office of Planning, 2014)

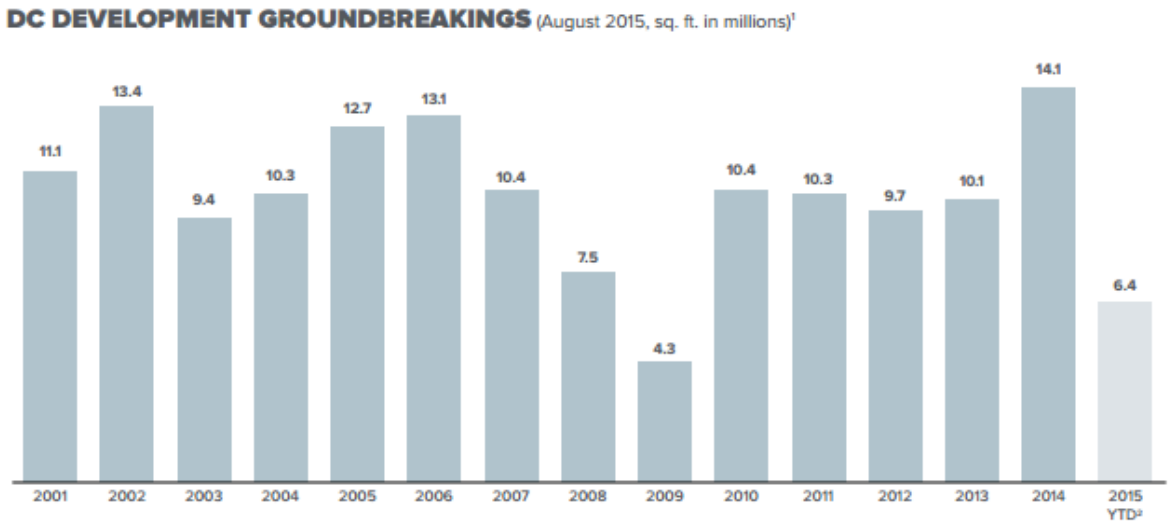
Also significant to this study is the change in racial demography that has accompanied D.C.'s growth and transition. A 2011 National Public Radio (Kellog, 2011) report looking at cities in transition throughout

the U.S. found that while most big cities in the U.S. have seen and continue to see an increase in black, Hispanic and Asian populations, Washington has experienced just the opposite – falling from a peak of 71 percent black in 1970, to just 53 percent black in 2009 (Kellog, 2011). The U.S. Census Bureau's American Community Survey 5-year estimates found that the decrease in black or African American population within the District of Columbia has continued since then, falling to 49.6 percent in 2014 (American FactFinder, 2014).



(Data Source: American FactFinder, 2014)

At the same time, and likely as a result of the aforementioned increase in population growth, residential and commercial real estate in D.C. also increased significantly in the 2000s. The Washington D.C. Economic Partnership began tracking development projects in D.C. beginning in 2001 and since then, has tracked the completion of over 153.2 million square feet of development as of August 2015, with another 12.3 million square feet slated for delivery in 2016 (WDCEP, 18).



(WDCEP, 18)

GOALS AND OBJECTIVES

Over the past two decades, D.C. has experienced significant population growth – spurring massive commercial and residential development and changing the historic fabric and landscape of the capitol city. This project will examine one aspect of this change – whether the surge in population and development has impacted the growth or the decline of public urban green spaces, and if so, seek to observe whether there are any spatial or demographic patterns and trends that are associated with the impacted areas.

DATA

Demographic Data

Demographic data for this project will come from the 2000 and 2010 United States Census. The data from these censuses sufficiently cover the time period of this study – notably, the decennial census in 2010 represented the most massive participation by households in the United States to date, with approximately 74% of households returning their census forms. In addition to the census data, demographic data on the District of Columbia and the other study areas of interest, will be collected from the 2010 – 2014 American Community Survey's 5-year data profile, a subset of data collected in between census years.

Census tract boundaries for the study area will be obtained from the Census Bureau's online TIGER/Line shapefile portal, and county and ward-level administrative boundaries for D.C., Arlington, and Alexandria are accessible from each county's respective online GIS portal.

Land Use Data

National Land Cover Data (NLCD) developed by the U.S. Geological Survey's Multi-Resolution Land Characteristics Consortium will be used to identify the land cover type and the land cover change within the study area. NLCD data from 2001 and 2011 will be used together with data from the 2000 and 2010 Censuses to observe changes in land use and demography. In addition to the national land cover data, detailed vector data on the specific locations of green spaces and resources within D.C. and the surrounding areas of interest – parks, swimming pools, recreational fields, conservation areas, trails, greenways, etc. – will be compiled from the county GIS portals.

ANALYSIS

As discussed above, green space can include a lot of different features but for the purposes of this project, the focus was on public green spaces – communal areas that are free, open and ostensibly accessible to everyone in the community. This included public parks, community gardens, recreation and activity areas – sports fields, playgrounds, tennis courts, basketball courts, swimming pools, etc. – and riparian areas such as riverbanks, trails, and greenways. Some of the key considerations used in determining what would be included in a comprehensive green space data set for this project involved examining whether the area is publicly accessible and whether the area was developed or maintained for public use.

The DC GIS team generously provided the following data sets:

Feature	2000	2010	2015
District Revitalization Areas (2003 only)	✓		
Community Gardens		✓	
All Parks (NPS and DCPS)	✓	✓	
Recreation		✓	
Recreation Outdoor		✓	
Outdoor Recreation Amenities			✓

Waterbodies	✓	✓	✓
Ortho Photos	✓	✓	✓
Demographic Data (US Census 2000 and 2010)	✓	✓	✓

Based off of the availability of data, the anticipated methodology was revised to in order to focus on collecting and then tracking change in public green spaces between 2000 and 2010.

GREEN SPACE IN 2010

To calculate the change in public green space between 2000 and 2010, two comprehensive layers for each of the respective years, were created. Because the data for 2010 was most complete, this data layer was created first by combining the following layers together:

1. **Recreation + Recreation Outdoor + Community Gardens**

The *Recreation, Recreation Outdoor* and *Community Gardens* data sets from 2010 were merged together, after identifying and editing overlapping and intersecting features.

2. (Recreation + Recreation Outdoor + Community Gardens) + **All Parks**

The output layer from merging *Recreation, Recreation Outdoor* and *Community Gardens* together was checked against the *All Parks* data set for overlapping and intersecting features, which were then edited and/or removed, before the two data sets were merged together.

3. (Recreation + Recreation Outdoor + Community Gardens) + All Parks + **Outdoor Recreation Amenities**

The only available *Outdoor Recreation Amenities* data set available was from 2015 and after comparison against historic 2010 imagery, was found to contain additional details on public green spaces that may have in fact been present in 2010 and prior, but not included in any previous data sets. So as a first step, the *Outdoor Recreation Amenities (2015)* data set was compared against the most recent merged output layer ([*Recreation + Recreation Outdoor + Community Gardens] + All Parks)*, and overlapping or intersection features were identified and erased. Then, the updated *Outdoor Recreation Amenities* data

layer was compared against imagery from both 1999 and 2010 on a feature-by-feature basis, creating a new *Outdoor Recreation Amenities* dataset with updated feature data for those years where none had previously existed.

In comparing the *Outdoor Recreation Amenities* feature dataset against imagery, the following rule set was used and applied on a feature by feature basis, to ensure data "best fit" within the project boundaries:

- Tennis courts in what appear to be private, residential areas (next to private pools and houses, one court vs. multiple courts) are deleted.
- Empty lots are marked as green space if:
    - There are pathways leading to or from it
    - Grass or other manmade material looks to be maintained (vs. an empty concrete lot)
    - The surrounding area appears to be residential

4. (Recreation + Recreation Outdoor + Community Gardens) + All Parks + Outdoor Recreation Amenities = **All Public Green Space in 2010**

The data sets above – having been checked and cleared of overlapping features and new features identified from satellite imagery – are then merged together to comprehensively represent all public green space features in 2010, as defined by the project parameters.

GREEN SPACE IN 2000

To create the data set for 2000, the features in the newly created dataset for 2010 will be checked against existing data sources and imagery from 2000. Because the only relevant and available data set from 2000 is the Parks layer, the methodology here will be to work backwards from the data available from 2010.

1. All Public Green Space in 2010 – **(Parks + Outdoor Recreation Amenities in 1999) = Public Green Space in 2000 (*to be verified)***

The output here represents all of the public green space features present in 2010 (recreation, recreation outdoors, and community gardens) that have to be checked against imagery from 1999 to determine

whether they existed during then too. Features found to not be present in the imagery were deleted from the data set and conversely, "new" features were added to the data set as well.

2. Public Green Space in 2000 (*verified*) + Parks + Outdoor Recreation Amenities in 1999 = **All Public Green Space in 2000**

After editing and verifying public green space features from 2010 against imagery from 1999, merge the park and outdoor recreation amenities features from 1999 back in to the data set. The final output is a comprehensive data set representing all public green space features in 2000 (approximately), as defined by the project parameters.

CHANGE IN GREEN SPACE BETWEEN 2000 AND 2010

To calculate the change in public green space between 2000 and 2010, two difference layers are calculated – the difference between subtracting the 2000 layer from the 2010 layer (to identify new features in 2010) and the difference between subtracting the 2010 data from the 2000 layer (to identify the loss of features in 2010). The union of those two layers represents a true difference layer that captures both the losses and gains in green space between 2000 and 2010.

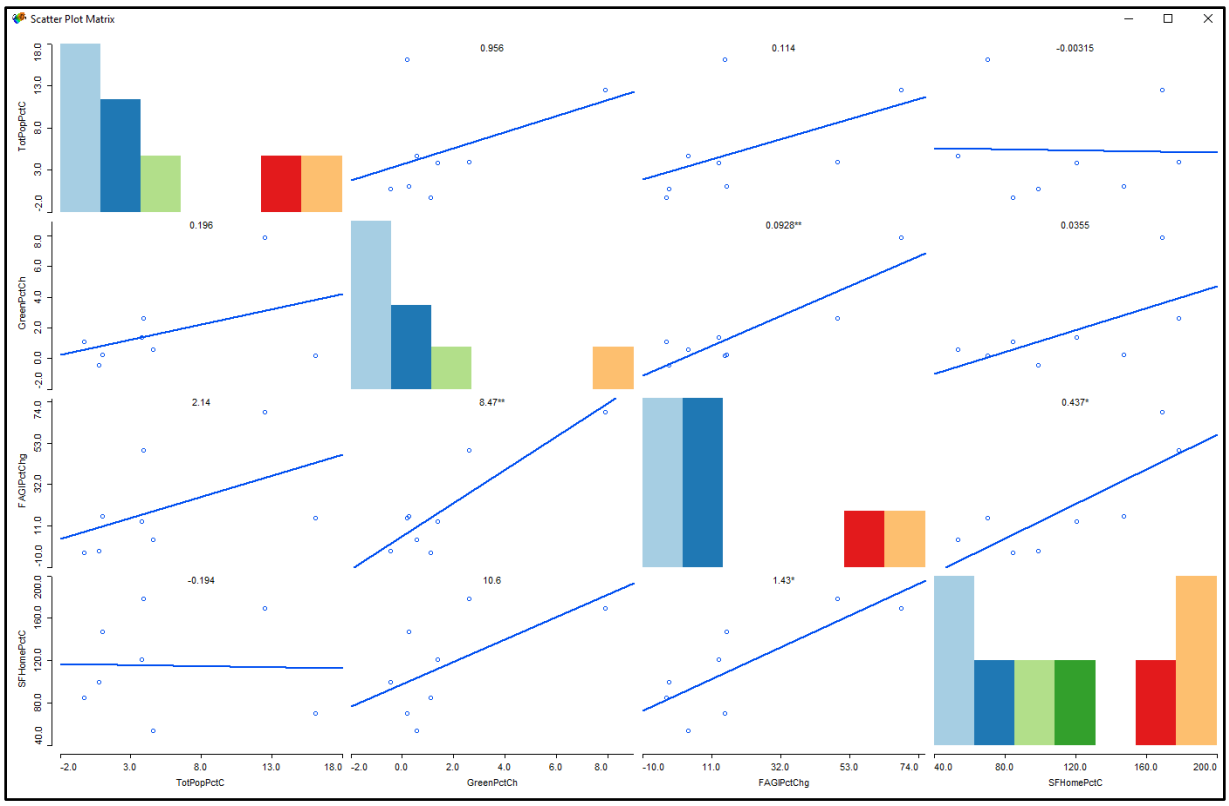
CHANGE IN GREEN SPACE BY WARD

Because the wards in D.C. represent political boundaries, and because ward size and shape area vary greatly, the decision was made to measure the percent change in green space by ward, rather than comparing simple increases or decreases in area. The following formula was used to calculate percent change:

(New Area – Old Area) / Old Area

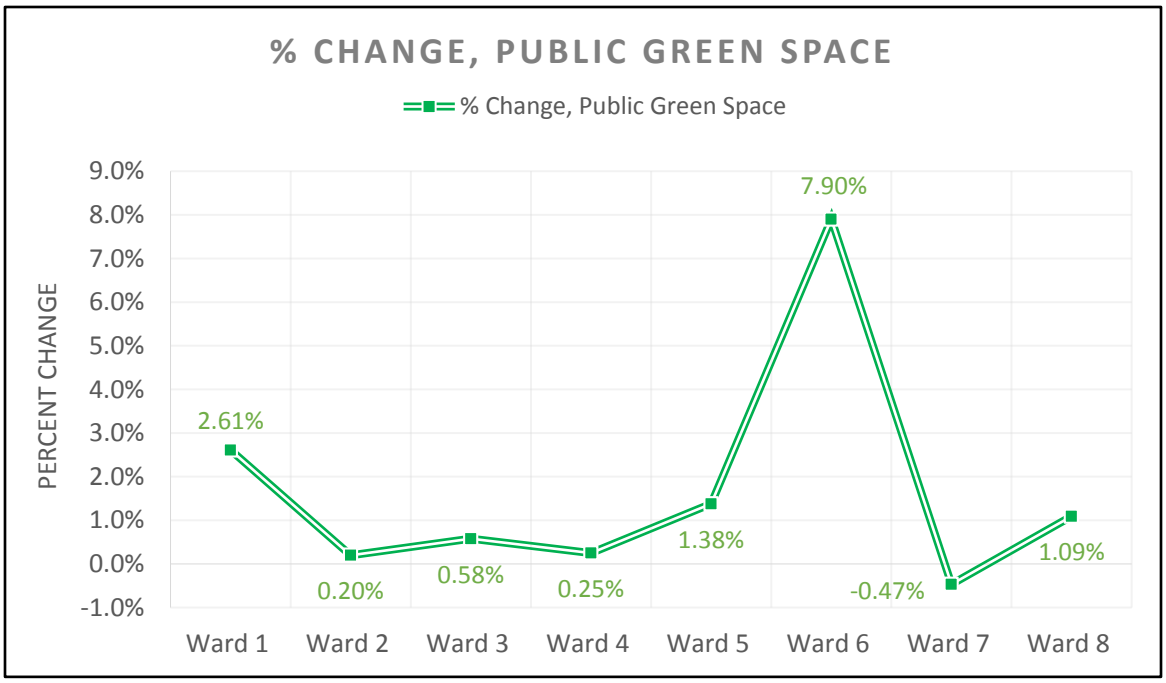
FINDINGS AND DISCUSSION

Between 2000 and 2010, there was an increase of 212,149 square meters of public green space. Despite the high number, in actuality this represents less than a 1 percent change in public green space. But with a population increase of 5.2 percent change (nearly 30,000 people) between that same time period, there is actually a loss in public green space of 2.41 square meters per capita between 2000 and 2010.

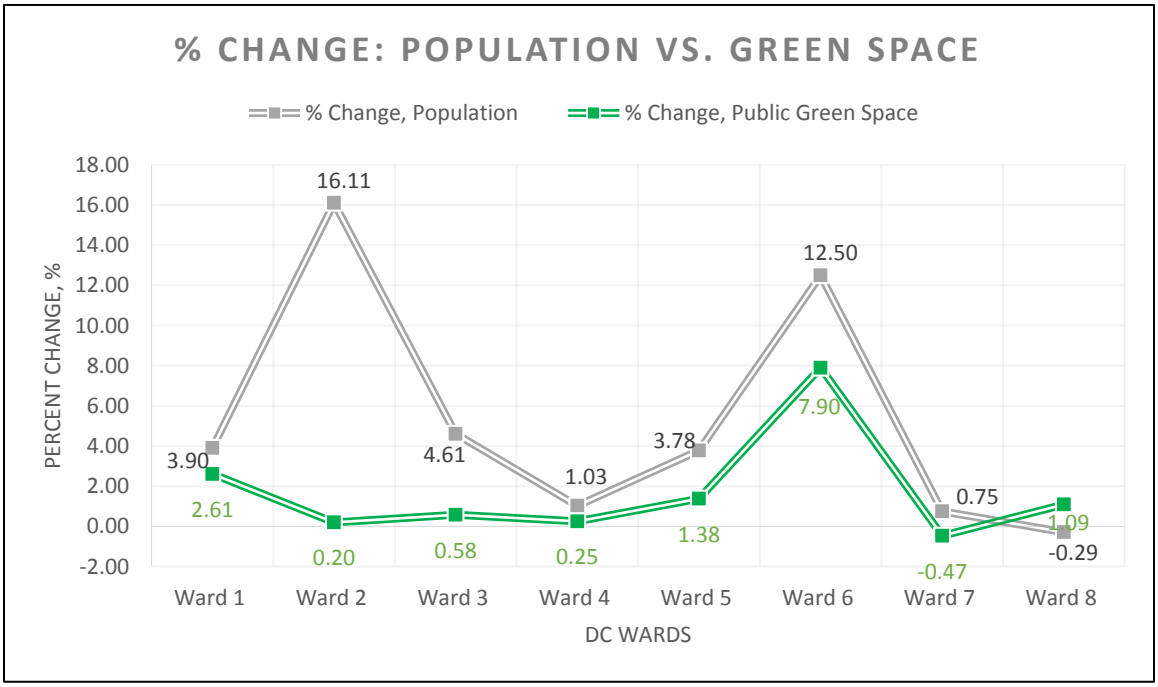


Using a scatter plot matrix to examine possible dependencies between key demographic variables – percent change in total population, green space, average family income, and the median sale price of a single-family home – there are three important observations to note:

- Strong positive correlation between change in average income and green space;
- Strong positive correlation between change in average family income and median home value;
- Moderate positive correlation between population change and green space.

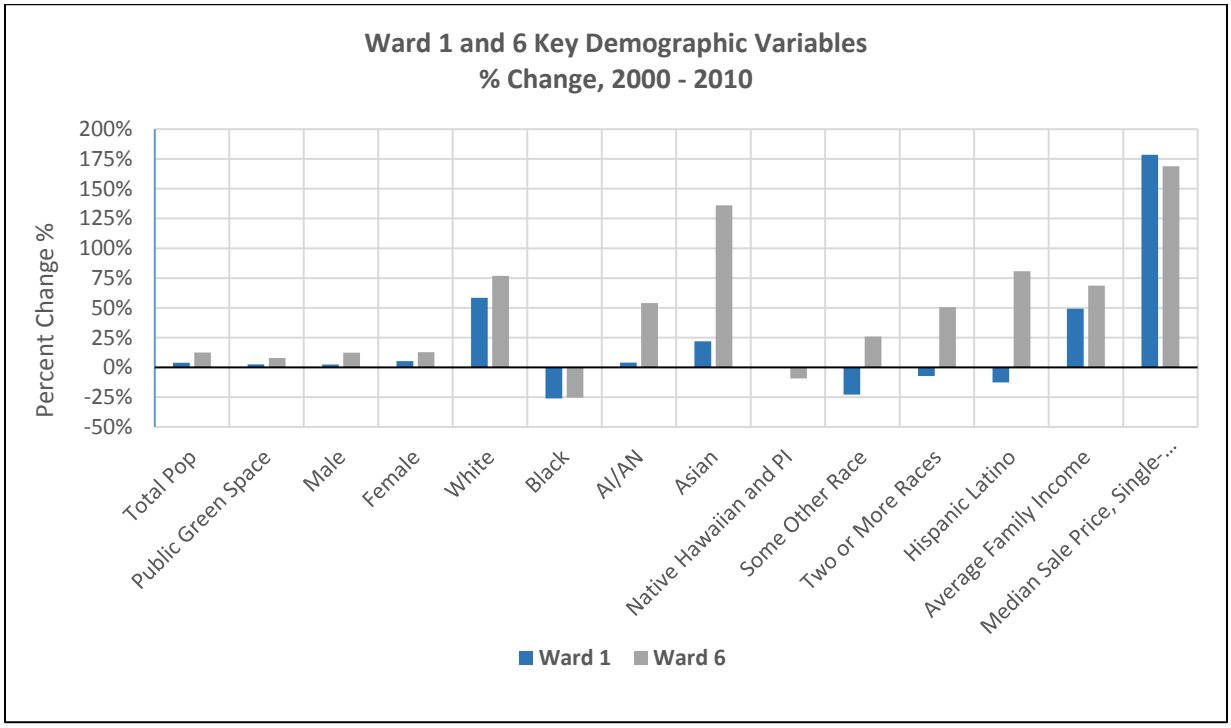


Between 2000 and 2010, Ward 1 and Ward 6 experienced the greatest percent change in public green space, 2.61% and 7.9% respectively.



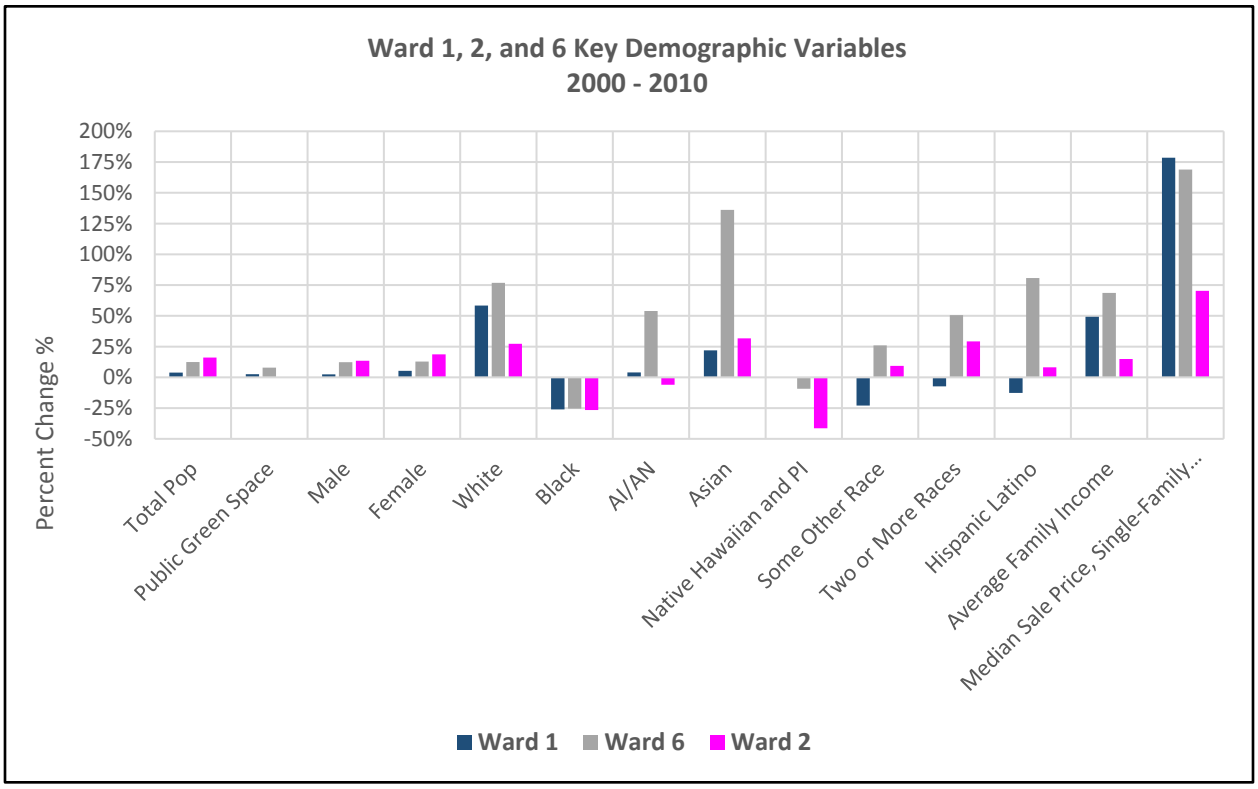
When compared against ward-level population changes over the same period of time, both Wards 1 and 6 have the greatest percent change increase in green space and appear to have relative percent changes

in population growth. Ward 2 stands out, as it appeared to have the highest and most significant percent increase in population, with very little to no change in green space.



A further examination of key demographic data for Wards 1 and 6 reveal a number of interesting similarities between the two wards:

- Significant increases in white population
- Notable decreases in black population
- Varying but significant increases in Asian population
- Significant increases between both wards in average family income (over 50% increase), and the median sale price of a single-family home (over 150% increase).



Ward 2 experienced the greatest percent increase in population between 2000 and 2010, and also became the most populous ward in 2010, jumping up from second to last in 2000. The changes in racial demographics appear to be mostly consistent with the changes observed in Wards 1 and 6 – increase in white and Asian populations, and a consistent rate of decrease in black population. As noted previously, unlike Wards 1 and 6, Ward 2 did not experience any significant increase in public green space (little to null, in fact) and while the ward did experience increases in both average family income and median sale price of single-family home values, the changes were not nearly as drastic or significant as found in Wards 1 and 6.

Interesting follow-up questions for future research? The way the data appears to play out leads me to wonder whether the park paradox is at play here: did efforts to improve green space (and increase home values, curb and neighborhood appeal, etc.) end up displacing the original residents within the ward, that the green space was meant to benefit in the first place? Or did green spaces improve and increase only AFTER the demographic changes to the area?

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