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CONNECTING THE LOTS:

PRIORITIZING REDEVELOPMENT STRATEGIES OF VACANT LAND IN BALTIMORE CITY

by

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ABSTRACT

The changing dynamics and inequities of land uses in Baltimore City are reviewed to justify vacant land redevelopment prioritization. Areas of coincidence between vacant land and non-vegetated space are identified and vacant land within is prioritized for green space, residential, or commercial redevelopment using a Multiple Objective Land Allocation (MOLA) model tailored to Baltimore City's planning objectives. A network analysis identifies green space accessibility within the areas of coincidence. Hot spot analysis indicated the clustering of low values (cold spots) of tree canopy mainly in the downtown area along the harbor, while hot spots were clustered in the west, north, and east. Vacant land was clustered on either side of the downtown corridor with one cluster in the northwest Baltimore. This study resulted in three focus areas with prioritized vacant parcels for commercial, residential, and green space redevelopment. The largest degree of coincidence between vacancy hot spots and canopy cold spots was found in southeast Baltimore, while the areas in the southwest and northwest had moderate and low levels of coincidence, respectively. The results of the MOLA analysis suggested that 257 acres of vacant land should be prioritized for green space, 248 acres for commercial redevelopment, and 218 acres for residential redevelopment.

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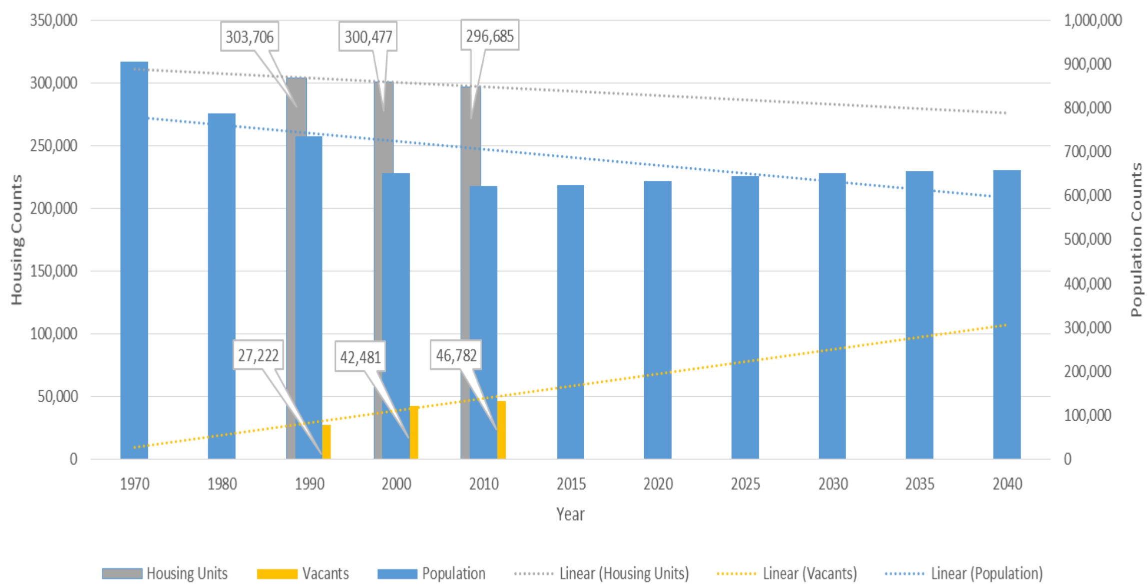
Introduction

Many major cities are experiencing a surplus of vacant properties provided by post-industrial population declines seemingly destined to continue (Frazier & Bagchi-Sen, 2015; Großman et al., 2013; Hackworth, 2014; Mallach, 2011). Baltimore City's population peaked in 1950 (949,708 people) and stabilized near the 620,000s (Maryland Department of Planning, 2014). The US Census Bureau expects this value to remain stable and slightly rise in future projections (Maryland Department of Planning, 2015). While population fell, vacant properties rose 17% (Maryland Department of Planning, 2014a; Maryland Department of Planning, 2014b; Maryland Department of Planning, 2015; see Figure 1). Such properties are in cyclic states of hazardous disrepair (Németh & Langhorst, 2014) due to the aging stock of old homes. In neighborhoods of high vacancy, housing markets cannot support the need for redevelopment (Hackworth, 2014; Pagano & Bowman, 2004), and the necessary (social) capital tends to be selectively planned away. This causes negative impacts on crime, mental health, housing prices, community cohesion, and environmental conditions.

The urbanization responsible for the construction of so many houses, of which many are now abandoned, also contributed to the continual decline of urban forests at a national rate of 40,000,000 trees per year (Nowak and Greenfield, 2012). This was not just deforestation, but a replacement of valuable ecosystem services with impervious surfaces contributing to the heat-island effect and storm-water management issues (Wu et al., 2008; Mullaney et al., 2015). A decrease in tree cover also diminishes the quality of life for residents in multiple facets that will be discussed in the next section. The prefixed "urban" in urban forests (green space and vegetation in general for that matter) elucidates a myriad of specialized and unique services that span the physical and social ecologies of the urban context. Obviously, the preservation of such should be imperative for city managers (Mincey et al., 2013). In planning for a shrinking city where green space is unequally distributed (Boone et al., 2009), it is important to discuss “decline as a development state,” in a “growth-oriented… hegemony” (Johnson et al., 2014, 162).

Figure 1: Historical and projected population and housing data in Baltimore City. (Maryland Department of Planning, 1990; Maryland Department of Planning, 2014a; Maryland Department of Planning, 2014b; Maryland Department of Planning, 2015)



Many of the negative social impacts of vacancy, such as crimes and fires, are shown to disperse with a basic demolition of the property, but “it is necessary to realize that the problems associated with decline… do not necessarily shrink along with the physical infrastructure” (Frazier et al., 2013, 60). A demolished site with no improvements does little to improve the symptoms of blight aesthetically, and in return, falls short of providing attainable community assets while potentially harboring illicit activity (Cohen, 2001; Frazier and Bagchi-Sen, 2015). These residual impacts of vacancy demolitions have been proven to be ameliorated by vacant lot greening (Branas et al., 2011; Garvin et al., 2012; Troy et al., 2016). Not only does the decline of urban green space share many negative impacts of vacancy, they share spatial similarity as they tend to occur in high density, poor, minority neighborhoods. Bottom-up strategies and temporary land-uses have the added benefit of preserving vacant land in areas with other needs.

Pearsall et al. (2014) proposed a GIS-based multi-objective land allocation (MOLA) approach as an alternative to ad-hoc redevelopment programs for vacant land management. The MOLA model prioritized vacant land opportunities holistically with exceptional results and promising translational abilities to other cities' planning efforts. Adapting from Pearsall et al.'s (2014) MOLA model, I developed a method of vacant land prioritization for Baltimore City based on current planning objectives and criteria. If successful, the results could help identify areas of Baltimore City that would benefit the most from small-scale vacant lot greening while minimizing conflicting redevelopment objectives as an alternative to strictly growth-oriented planning. In this study, I attempt to answer the following questions.

(1) To what degree is vacancy in Baltimore City clustered? This was tested with a point density analysis of features representing vacant properties in Baltimore City. The resulting density is then supported by a hot-spot analysis with p-, and z-values of significance associated.

(2) To what degree is a lack of green space clustered? This was tested with the same point density analysis and further described with a network analysis. Tree canopy areas were divided into 100 m squares from a grid, then converted to points for the point density and network analyses. The resulting density analysis is also supported by a hot-spot analysis with p-, and z-values of significance associated.

(3) Where might green space cold-spots (resulting from question 2), and vacancy hot-spots (resulting from question 1) occur simultaneously? The results from the point density analyses of questions 1 and 2 were converted from continuous data to nine classifications of integer data. A composite density raster was created from an equally weighted overlay analysis of the two inputs. Square areas containing the top three classifications of the combined weighted overlay were chosen as study areas

(4) How might the conflicting interests of vacant land redevelopment be prioritized? A series of point and line density raster datasets were created from a range of data related to Baltimore City planning objectives, environmental features, and socio-economic factors. These datasets are inputs for a series of weighted overlay analyses to determine areas best suited for competing redevelopment strategies.

Background Information

Vacancy

According to Smart Growth America (2009), vacant properties are defined as a mixture of properties that are a public nuisance resulting in potential public safety issues and property resulting from financial neglect. Being ubiquitous with former manufacturing cities (Garvin et al., 2012), vacant land is unsurprisingly one of the most important policy challenges facing municipal governments (Kromer, 2002). Vacancy is a result of urban renewal policies, job loss, bank practices (Kromer, 2002), suburbanization, disinvestment (Schilling & Logan, 2008), and population decline, which is expected to continue for many cities (Frazier & Bagchi-Sen, 2015; Großman et al., 2013; Hackworth, 2014; Mallach, 2011). The growing literature engaged in the effects of vacant properties on neighborhoods have identified increased crime, loss of real investment, decreased social capital, decreased property value, dwindling tax bases, and large maintenance costs (Accordino & Johnson, 2000; Branas et al., 2011; Branas et al., 2012; Cohen, 2001; Cui & Walsh, 2015; Dewar, 2015; Dewar et al., 2014; Foo et al., 2014; Frazier et al., 2013; Garvin et al., 2012; Garvin et al., 2013; Németh & Langhorst, 2014; Troy et al., 2016; Whitaker & Fitzpatrick IV, 2013).

This surplus of vacant properties in cities experiencing population declines creates a cycle of degradation and disinvestment (Németh & Langhorst, 2014) which cannot be ameliorated by market-based redevelopment (Hackworth, 2014; Pagano & Bowman, 2004). Often, the market of vacant or abandoned properties, with encouragement by tax incentives (Németh & Langhorst, 2014), draws predatory speculators with intentions of profit that complicate later planning efforts or renting with no improvements which do nothing to benefit the communities (Dewar et al., 2014; Dewar, 2015; Hackworth, 2014; Mallach, 2011). The effects of such actions are profound on neighborhoods but is seldom a concern during the sale (Dewar, 2015). In such light, market-only strategies tend to challenge planning efforts and erode market conditions (Hackworth, 2014). Many properties remain unsold in public ownership resulting in an overall decrease in owner occupancy (Dewar, 2015; Dewar et al., 2014). Congruently, vacancy tends to occur in areas of already low housing market value which are unable to recuperate the costs of repairs and construction (Kromer, 2002), which is where foreclosures (at least in Detroit) tend to concentrate (Dewar et al., 2014). Through deed restrictions (Glotzer, 2015), redlining and reverse-redlining (Németh & Langhorst, 2014), sub-prime lending (Rugh et al., 2015; Rugh & Massey, 2010), and land-lord sorting (Rosen, 2014), hypersegregation (Massey & Tannen, 2015) through disproportionate disadvantages in housing remain concentrated on African Americans in Baltimore City— "force[ing] them to bear the social costs of their own victimization" (Massey & Denton, 1993, 116). More critically, "the residents of several neighborhoods are being systematically displaced… into new housing: the Maryland Criminal Justice System" (Rhine, 2010, 333). To quote Harvey (2007, 41) on neoliberalism and creative destruction, "if it looks like class struggle and acts like class struggle, then we have to name it for what it is."

Citing Molotch (1976), Hackworth (2014, 7) states, "city politics are often structurally influenced by a 'land-based elite' who push a growth-first agenda to satisfy their interests as land holders in the region." This "growth-first agenda" (*ibid*) was a main instigator of urban renewal, or "slum clearance," popular in American mid-century planning (Mallach, 2011)—currently repeating itself in Detroit's vacancy planning

(Clement & Kanai, 2015; Safransky, 2014). Hackworth and Smith (2001) identify waves of gentrification increasing with state involvement and size of developers. In respect to current literature, cities like Baltimore may be riding the trough of targeted high-risk sub-prime lending wave to a new peak of concentrated vacant land ripe for development. With the neo-liberal solidification of market-based growth-oriented planning in shrinking cities, it is surprising to find there has been little effort to prioritize properties (Frazier & Bagchi-Sen, 2015) in the under-studied subject of demolition— "a powerful shaper of 21st century American cities" (Mallach, 2011, 380). This is alarming when considering the quotas set forth in Baltimore (among others) for numbers of demolitions per political terms focusing on larger contiguous vacant lands (Cohen, 2001).

Urban Green Space

There is extensive literature discussing the benefits of green space and vegetation in an urban environment regarding an overall quality of life (both physically and psychologically), crime, community, and the environment (Boone et al., 2009; Branas et al., 2011; Branas et al., 2012; Escobedo et al., 2015; Frazier & Bagchi-Sen, 2015; Garvin et al., 2012; Garvin et al., 2013; Kabisch et al., 2015; Kim et al., 2015; McPherson et al., 2011; Middle et al., 2014; Mincey et al. 2013; Mullaney et al., 2015; Nowak & Greenfield 2012; Nowak et al. 2014; Rao et al., 2014; Rupprecht & Byrne, 2014; Rupprecht et al., 2015; Schilling & Logan, 2008; van den Berg et al., 2010; Wolch et al., 2014). While grassy vegetation offers environmental services, tree plantings are one of the most cost-effective means of mitigating urban heat island effects (Wu et al., 2008). In addition, trees are capable of lowering ozone (Nowak et al., 2014) and nitrate pollution (Rao et al., 2014). Trees can also be used as an indicator of park maintenance (Solecki &

Welch, 1995), although there is a lag-time between actual neglect/maintenance, and that which is represented through trees as an indicator (Gobster, 1998).

Unfortunately, as it is true with vacancy, urban green space and park distributions are unequal among socio-economic factors (Barbosa et al., 2007; Boone et al., 2009; Byrne, 2012; Comber et al., 2008; Dai, 2011; Gobster, 1998; La Rosa, 2014; Ogneva-Himmelberger et al., 2009; Solecki & Welch, 1995; Wolch et al., 2014). There is a consensus of urban vegetation literature on the positive relationship between wealth and greenness (Pearsall & Christman 2012). Most parks belong to the public and should stand the scrutiny of equal distribution (Boone et al. 2009), just as urban greenspaces are a utility to public well-being and should withstand equal scrutiny. Boone et al. (2009, 783) found Baltimore City to contain an unequal distribution of parks: "African American and high-need populations have better walking access to parks but access to less acreage per capita than whites and low-need populations." While shorter more direct access may seem an equitable—maybe even preferable—concession to acreage, "a focus on distribution or outcome equity is not an entirely satisfactory assessment of justice," and "does not take into consideration needs, merits, or choices of the population (Boone et al., 2009, 783)."

While Boone et al. (2009) conclude disproportionate distributions of parks exist in Baltimore City, corrective policies may have a converse effect. The addition of larger green space in neglected areas create a more attractive, healthy, and functional housing location which may increase the housing cost and possibly lead to gentrification (Wolch et al., 2014). Small-scale scattered sites of urban greening may be preferable planning practices since larger civic projects tend to concentrate natural resources and possibly initiate gentrification (Wolch et al., 2014). Unfortunately, many park projects are developed with land price and development as a motive (Clement and Kanai, 2015; Middle et al., 2014; Wolch et al., 2014) rather than equality and public health. Even more worrisome is the evidence of neoliberalism as a hegemonic mode of classist accumulation (Harvey 2007) spurring increasingly state-involved gentrification (Hackworth and Smith, 2001) and settler-colonialism under the green guise of environmental consciousness (Safransky, 2014; Clement & Kanai, 2015).

Greening Vacant Lots

One example of Wolch et al.'s (2014) small-scale scattered sites is the greening of vacant lots. Vacant greening has been shown to have mixed effects on property prices and crime—both of which are negatively affected by vacancy. Escobedo et al. (2015) found that houses with mature trees sold for higher prices than similar houses without trees; brush and shrubbery had little to no impact; and grassy areas had a negative effect on house value. Furthermore, Des Rosiers et al. (2002) found that dense vegetation within visible distance of homes resulted in a lower price. Greening vacant lots has shown to decrease gun assaults, vandalism, and perceptions of crime in general while promoting public health (Branas et al., 2011; Garvin et al., 2012). Furthermore, the landscaping of Baltimore City/County yards was shown to be related with lower crime and neglected yards with higher crime (Troy et al., 2016). Trees on vacant land can help remove air pollutants, reduce temperature, and save energy while "unattended sites with vegetation" can have surprisingly high value in carbon sequestration and may be the most effective ecosystem land-use (Kim et al., 2015).

Urban greening has been found to facilitate controlled growth and maintenance of natural areas and residential yards within 100 meters (Krusky, 2015), which creates a positive feedback loop for safer streets (Troy et al., 2016). Greening vacant lots would increase the value of directly adjacent parcels by providing aesthetic vegetation and would potentially decrease symptoms of blight by increasing stewardship within a 100-meter radius. In alignment with and preceding Wolch et al. (2014), Schilling and Logan (2008) claim vacant lot greening differs from traditional open space creation: a practice which serves as a tool for managing growth. Alternatively, vacant lot greening would create community assets while aligning the supply of green space with existing and future demand with minimal socio-economic disruption.

While large parks do offer active and passive recreational benefits associated with green spaces, they are formal, public, and often aimed at organized activity which lends to a monotonous characteristic that can be largely out of step with local social and ecological needs (Middle et al., 2014). One form of vacant lot greening is community gardening. They are unique in the agricultural sense and "represent a type of public green space created outside of traditional formal planning structures… representing a citizen-led movement against the perceived failure of decision makers," and can help ameliorate the exclusion experienced by residents in the planning of parks. This type of "bottom-up" green space promotes "bridging" social ties across different groups over "bonding" social ties among similar groups (Middle et al., 2014, 639).

Another form is Informal Green Space (IGS). IGS consists of any urban space with a history of strong anthropogenic disturbances that is covered at least partly with non-remnant spontaneous vegetation (Rupprecht & Byrne, 2014). In Rupprecht and Byrne's

(2014) literature review, residents identified problems and benefits of IGS differently than authorities. Residents also preferred a medium level of human influence based on a dislike for the artificial, and appreciated the proximity, naturalness, wilderness, diversity, and mystery of IGS—qualities often lacking in formal green space (Rupprecht et al., 2015). Rupprecht et al. (2015) identify shrinking cities with growing vacant properties as possibly benefitting from the consideration of IGS in planning, and as an alternative to eco-gentrification—a previously mentioned critique of Detroit's redevelopment plan (Safransky, 2008).

All three options: vacant greening, gardening, and IGS, could be incorporated into temporary uses for vacant land (Németh & Langhorst, 2014). Vacant land is viewed by many as a problem that must be fixed, however, Németh and Langhorst argue it can and should be realized as a flexible resource for smart-growth principles reacting to spatially dynamic and increasing vacant land patterns. Temporary land uses offer a unique solution to the "problem" of vacant land. Politically, they alleviate pressure of long term, and if rushed, possibly unjust development strategies (Ibid.). They require miniscule economic risk and cost, while socially, they can catalyze communities around common goals in a "bottom-up" approach to planning granting communities their "right to the city" as "co-author[s] of the spaces and places they inhabit" (Ibid., 149). Specifically, Németh and Langhorst (2014) claim temporary uses can operate as an implementation of ecosystem services as green space—a costly process when artificially planned and created. A quote from Middle et al. (2014, 643) regarding benefits of community-based gardening illuminates the common goal of increased community social capital: "Attempts to fully formalize their creation and management are in many ways antithetical to their value as green spaces."

The shift in perception from vacant land as a problem to that of a resource has led to what could be considered a competition of uses. Pearsall et al. (2014) created a Multi-Objective Land Allocation (MOLA) model which considers socio-economic and physical factors of census tracts in Philadelphia, PA in suggesting either green space (388.33 acres), commercial (406.46 acres), and residential (477.49 acres) vacant land opportunities. Their study provides a scalable method for prioritizing vacant land opportunities. Additionally, their model utilizes weighted criteria, which can be adjusted by policy-makers in a variety of different cities. Of the total vacant land examined, 113.19 acres were found to have conflicting recommendations (Ibid.).

Measuring Access to Green Space

When performing an accessibility analysis, there are three factors to consider: the origin, the destination, and the route. In establishing destination points for green space, there is an argument for creating central points of a polygon (La Rosa, 2014; Oh & Jeong, 2007), entrance points of a polygon (Barbosa et al., 2007; Comber et al., 2008), and doing neither by establishing a buffer of the polygon outline (Boone et al., 2009; Dai, 2007; Nutsford et al., 2013). As for distances, either by route or buffer, there are three options: Manhattan distance, Euclidean distance (Boone et al., 2009; La Rosa, 2014; Nutsford et al., 2013), and network distance (Barbosa et al., 2007; Comber et al., 2008; Dai, 2011; La Rosa, 2014; Nutsford et al., 2013; Oh & Jeong, 2007). Manhattan distances best serve the grid of a city as it represents the distance traveled between two points as the two equal sides of a right triangle. Euclidean distance is the measurement of a straight line. Network distance is the distance measured by a cost, usually either time or distance, and can provide a more detailed expression of accessibility. Among the reviewed articles, network distance is most favored while Euclidean distance was used as a comparison. A summary of access studies can be seen below (Table 1).

Table 1: Accessibility Studies and Characteristics of Methodologies.

Characteristics of Green Space Accessibility Studies				
Author and Date	Green Space	Statistical Zone	Location	Distance
Barbosa et al. 2007	Entrance	UK Mosaic Database	Sheffield, United Kingdom	Network
Boone et al. 2009	Buffer	Census Block Groups and Tracts	Baltimore Metro Area, USA	Euclidian
Comber et al. 2008	Entrance	Census Output Areas (Centroid)	Leicester, United Kingdom	Network
Dai 2011	Buffer	Metropolitan Statistical Areas	Atlanta, GA, USA	Network
La Rosa 2014	Centroid	Census Tracts	Catalina, Italy	Network and Euclidian
Nutsford et al. 2013	Buffer	Mesh Block (Weighted Centroid)	Auckland City, New Zealand	Network and Euclidian
Oh and Jeong 2007	Buffer	No unit	Seoul, South Korea	Network

Creating a buffer of a polygon to measure accessibility allows for footpath shortcuts not adhering to the grid of a city and allows the polygon's outline to serve as an entry point in its entirety (Boone et al., 2009). Creating center features for the destination polygon allows for a network analysis, but in large features, the center is not representative of either an access point or features of interest within the polygon. Creating entrance points for a polygon will allow for a more accurate network analysis, but can become a tedious task of manual digitization, and cumbersome if the outline of a polygon can serve as an access point. Some of this could be automated by building a topology between the boundary layer and road network layer.

I would argue that in a highly urban area consisting of privately owned parcels adjoined to each other, one would not easily travel in many other manners than a network distance—even by foot. Additionally, while origin points can be weighted by attribute data, it might be necessary to find the median center of features within the polygon without a weight as to equally include more travel scenarios and better represent activity.

Materials and Methods

Study Area

Based on the population and housing information presented in the 2000 and 2015 U.S. Census, Baltimore City has been included in Cohen's (2001) and Dewar et al.'s (2014) studies as ranking among the top cities experiencing population decline and vacancy increase within the last 40 years. Vacant property is patterned, but not as much as other shrinking cities such as Detroit with major sections of continuous vacancy. The distribution of vacant parcels is sporadic enough in its clustering to contribute to urban green space while not creating large open spaces which would in turn transform the neighborhoods into another entity rather than improve them. Baltimore City also has large portions of green space with stark boundaries and fragments of which their connectivity would benefit from vacant lot greening. Additionally, the articles presented in the background information highlight racial and class-based segregation evident in housing and development practices as well as environmental injustice. Highlighted in Boone et al.'s 2009 (784) study were similar issues, events, and practices as a historical back-drop to the distribution analysis of parks inherited spaces revealing a pattern stated as "difficult to interpret… as environmental justice." Nearly a decade later and the city's population shows little signs of regaining its former stature while vacant lots accumulate as a new 'inherited space'.

Data

All datasets except the habitat, water bodies, and land cover data were obtained from Baltimore City's open data portal (https://data.baltimorecity.gov/). These include:

1. Vacant land was derived from parcel polygons last updated in 2013, and vacant property points, last updated on 08/14/2017. https://data.baltimorecity.gov/Housing-Development/Vacant-Buildings/qqcv-ihn5 http://planning.maryland.gov/OurProducts/downloadFiles.shtml

2. Census Block Groups. These polygon features were downloaded from the US Census Bureau's Tiger Line database https://www.census.gov/geo/maps-data/data/tiger-geodatabases.html

3. Street centerline from the US Census Bureau's Tiger Line database was used to create a transportation network data set and measure accessibility to green space.

4. Critical and Habitat Protected Areas are designated spaces of the city with strict land use ordinances restricting development. Currently there is a 2011 draft which states some Inner Harbor areas would become revitalization areas. The data used was last updated in February of 2017. https://data.baltimorecity.gov/Geographic/Critical-Area-and-Resource-Conservation-Areas/m5av-ntyv

5. Enterprise zone boundaries indicate which areas of the city offer tax incentives for businesses and commercial land use redevelopment of distressed properties. https://data.baltimorecity.gov/Geographic/Enterprise-Zone/nsuz-8g9d

6. 2014 Floodplains data, prepared by the Federal Emergency Management Agency, were downloaded from Open Data Baltimore. https://data.baltimorecity.gov/Geographic/Floodplain/5q84-2ek5

7. School locations are maintained by the Open Data portal, but do not contain metadata on currency. https://data.baltimorecity.gov/City-Services/BCPSS-School/aqpj-kgk7

8. Hospitals, libraries, police stations, and fire stations were downloaded from Open Data Baltimore. https://data.baltimorecity.gov/Health/Hospital/jbwe-hmsf

9. Crime occurrences (with victims) from 2013 to 2017 represented by points with location and crime type. https://data.baltimorecity.gov/Public-Safety/Crimes-to-date-in-2013/3h27-ehp2

10. Census Block demographic data for the year 2015 and projections of 2020 provides detailed socioeconomic factors of the block groups of the study. The data is managed and organized by the Environmental Systems Research Institute (ESRI).

11. Zoning boundaries were last updated in 2008. https://data.baltimorecity.gov/Geographic/Zoning-Boundary/idqa-6rg3

12. Hurricane Inundation Zones was downloaded from Open Baltimore and developed as part of the Hazards Analysis within the Hurricane Evacuation Study for the Maryland Western Shore. https://data.baltimorecity.gov/Geographic/Hurricane-Inundation-Zone/vanx-ubga

13. Habitat data include forest dwelling interior species modeling, targeted ecological areas, green infrastructure gaps, corridors, and hubs, and blue infrastructure. The dataset was obtained from the Maryland's Department of Natural Resources (DNR) data portal: http://dnrweb.dnr.state.md.us/gis/data/data.asp.

14. Detailed Waterbodies – Rivers and Streams are the most detailed digitizations of hydrology available for Baltimore City, and may be enhanced by the slope analysis from

the Digital Elevation Model (DEM). These data sets were downloaded from the MD iMap portal: http://imap.maryland.gov/Pages/default.aspx

15. Land Cover data were downloaded from the Chesapeake Bay Conservancy. It is high resolution raster data of land cover derived from orthoimagery of the Chesapeake Bay watershed. http://chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/land-cover-data-project/

Methods

This study focuses on the land use and land cover of Baltimore City, MD, specifically parcels designated by the city as vacant, and those designated in accordance with popular criteria as green space (see Table 2). The following section details steps that were employed to analyze the data. These include identifying green space and vacancy, identifying common concentrations of both green space and vacancy as areas of interests, evaluating green space accessibility, and developing the MOLA model to prioritize vacant land redevelopment for the City.

Green Space Classification

Land cover data from the Chesapeake Bay Conservancy were used to classify urban green space. This dataset includes low vegetation, tree canopy, and tree canopy over both impervious surfaces and roads. Low vegetation and tree canopy over impervious surfaces and roads were not included in this analysis. The former would include private and restricted property such as country clubs, private lawns, and institutional grounds, and therefore did not fulfill all the benefits of urban green space listed in the literature review. The latter was excluded to prevent false positives as a proxy for green space and to focus more on larger clusters of canopy rather than sparse plantings in parking lots and similar areas. Only the tree canopy polygons were extracted from the land cover data and defined as “urban green space.”

From the tree canopy polygons, I classified urban green space into six categories based on its size:

(a) green space smaller than 1,000 square feet;

(b) green space between 1,000 and 2,500 square feet;

(c) green space between 2,500 and 5,000 square feet;

(d) green space between 5,000 and 10,000 square feet;

(e) green space between 10,000 and 100,000 square feet; and

(f) green space larger than 100,000 square feet.

The resulting green space polygons were dissolved for each layer to create continuous areas from contiguous polygons. The purpose of multiple area-based iterations implemented here was to create a weighting factor to favor larger forested areas over smaller urban plantings. This would help in the following point density processes since larger gridded canopy areas result in uniform points which become statistically insignificant in hot-spot analyses. Furthermore, the increased density of larger forested areas would help in a point density analysis to represent the improved services they offered compared to smaller urban plantings.

1. Generating Access Points to Green Space

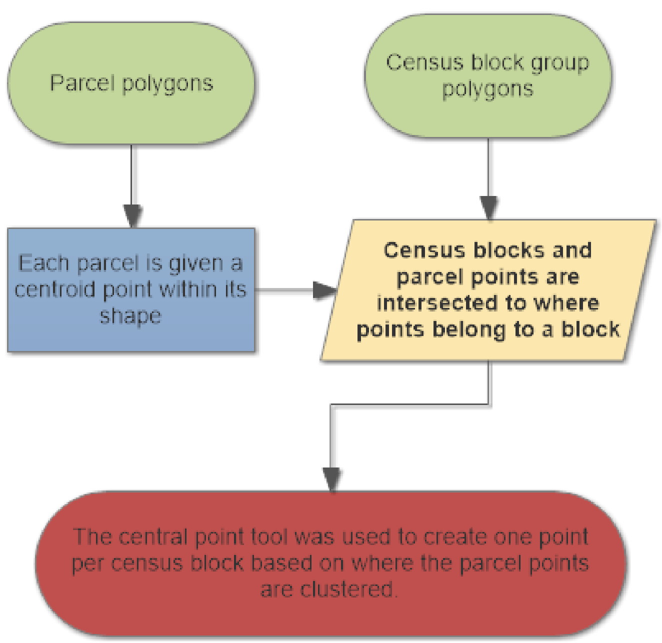
To derive points from these polygons, a grid of 100-meter squares was generated using the ArcGIS fishnet method and then overlaid onto each of the six tree canopy layers mentioned in the last section. Fish-netting green space polygons to create access points has not been a process in the methods of the reviewed literature and was applied here as a faster alternative to manual digitization – like forming a topology of roads and green space boundaries. For each of the six layers, all polygons were divided into 100-meter squares, and then all polygons were exploded, meaning that in the occasion that more than one polygon fell within one of the 100-meter squares, they would remain separate entities. With the green space polygons divided into 100-meter squares, a feature to point process was implemented. All six of the resulting point layers were merged into one file. Figure 2 illustrates the workflow of this process.

Figure 2: Workflow for creating green space points for access and density analyses

2. Determining Median Centers for Each Census Block

Block centers were created from the parcel census block data. These centroids were used in the network-based service area analysis to evaluate accessibility to green space. Parcels were converted from polygons to points, then clipped to the census block layer. A median center analysis was applied to the parcel points in each block to determine the center of structures. This process was similar to the population-weighted mesh-blocks used in Nutsford et al.'s (2013) research. However, instead of population, this method used parcels to better represent the structure and lived area of small communities. The inclusion of all parcels rather than only residential was an attempt to study the neighborhood structure entirely rather than piecemeal and should represent foot traffic of residents and non-residents visiting commercial, institutional, and public parcels not classified as residential. Median center analysis minimized the Euclidian distance between all points to find the center of a community rather than the concentration of phenomena. Block centers created in this manner would represent the different densities of parcels, thus minimizing the possibility of block centers being located within a sparsely populated area such as industrial areas or train switch-yards. Figure 3 illustrates the method used to create median centers for census blocks.

Figure 3: Workflow used to create median centers for census blocks



3. Evaluating Green Space Accessibility

Accessibility to green space was evaluated using the ArcGIS network analyst extension. A network dataset was created from the Street centerline data and two types of network analyses were conducted.

A service area layer was created from the network dataset. This allowed the cost of travel away from a point to be calculated. In this study, the cost was specified by an average willing walking distance of 400 meters (Boone et al., 2009) and the points were determined based on median parcel centers of each block group. A service area for each block group center was used to determine the walking radius. This was chosen as the boundary of analysis to assess the availability of green space and vacancy in terms of a resident's daily activities, and perceptions. Using the road network is useful since transportation and roads contribute to both chemical (Tallis et al., 2011) and thermal (Couts et al., 2016) pollution. The greening of vacant lots with trees would provide abatement for such pollution not only on the vacant lot, but to the extents of the drip lines, which would extend to the road eventually. Additionally, tree lined streets (Van Dillen et al., 2012), decreased crime, and ameliorated blight symptoms facilitate community interaction and foot traffic.

While the service areas represent the walking distance area of each block center, the closest facility analysis identifies the routes taken to the closest green space areas from the block center within 400 meters. These routes can serve as micro-corridors to small pockets of vegetation, and better facilitate habitats in urban areas. Therefore, these routes should be prioritized for road-side vegetation in areas of need of green space. The previously described park points created from the fishnet method were added to the closest facility layer as incidents. The threshold for adding them to the network was 100 meters, which was based on the grid applied to vegetation. The block centers were added as facilities with a threshold of 400 meters. The closest facility analysis was performed with the goal of routing the most number of incidents to facilities within 400 meters.

The results provided by these two processes included total lengths of the maximum amount of walking distances to tree canopies from the median center for each study area. The total lengths of closest facility routes should characterize tree-canopy accessibility classified by how large the canopy area is.

4. Cluster and Point Density Analyses

The green space data points along with the vacancy land data were inputs for hot-spot and density analyses. These analyses were two separate processes. While hot-spot analysis provides a level of confidence to the patterns observed, point density analysis provides density values and rasterized results which would be reclassified for standardized input to a weighted overlay analysis. The reclassification of tree canopy density inverted the values of canopy density, so raster analysis would identify canopy cold-spots as areas of interest. The reclassification of vacancy density was not inverted but was otherwise performed the same way. The reclassified vacancy and vegetation raster datasets were assigned discreet integer values between 0 and 10, where 0 is dispersed and 10 is clustered. The weighted overlay considered both inputs with a 50% weight and returned what were essentially isolines of coincidence intensities from values 1 (low) to 9 (high) between the two inputs. Intensity levels 9, 8, and 7 were used to determine the areas of interest for the detailed MOLA.

5. Multiple Objective Land Allocation

The MOLA model was used in Pearsall et al.'s 2014 article which prioritized vacant land redevelopment in Philadelphia. This study adopted the MOLA methodology, while the factors and constraints were developed according to current Baltimore City planning objectives, issues raised in the reviewed literature, and focused spatially via an alternative methodology. The final product of the study was an overlay raster map which identified vacant land prioritization city wide. Using the data previously described I developed constraints and factors for vacant land redevelopment (see table 2). The constraints are static binary statements of suitability such as *not developing residential or commercial land use facilities on wetlands habitat areas*. The factors are the results of point and line density analyses performed on the datasets from table 2. The point and line density rasters were reclassified to represent their suitability for their corresponding land use scenario. The reclassified integer values represent a spectrum of suitability for residential or commercial land uses such as a value increasing from 0 to 9 as its distance from a stream increases. Criteria and factors were designed in congruence with Baltimore City's planning objectives and recommendations. The density rasters and constraints were used in a weighted overlay analysis for three iterations to determine the suitability of vacant land for green space, commercial, and residential redevelopment. Finally, the weighted overlay analyses results were used in a last equally (33.33% each) weighted overlay analysis to prioritize vacant land for the three strategies.

Table 2: A list of constraints, their functions, and supporting references.

Objective	Criteria	Logic	Membership Function	Literature
Green Space	Vacant land	Should be on vacant land	Constraint	Smart Growth (2009)
	Existing Green Space	Should be in high-need areas	Increasing with distance	Smart Growth (2009)
	Hydrology	Should be near hydrology	Decreases with distance	CBPD (2011), US Forest Service (2015), BOS (2009)
	Transportation	Should be close to major transportation	Decreases with distance	US Forest Service (2015), BOS (2009)
	House Price	Stabilize and improve property values	Decrease with increasing housing price based on property value from parcel point hot-spot analysis.	US Forest Service (2015), Escobedo et al. (2015), Whitaker and Fitzpatrick (2013), Wolch et al. (2014)
	Crime	Green space can reduce crime	Decreases with distance	Branas et al. 2012, Cui and Walsh (2015), Frazier et al. (2013), Garvin et al. (2013), Troy et al. (2016)
Commercial	Vacant land	Site needs to be vacant land	Constraint	Smart Growth (2009b)
	Commercial zoning	Site needs to be in commercial zoning	Constraint	Smart Growth (2009b)
	Enterprise zone	Site should be in enterprise zone for tax benefits	Constraint	Smart Growth (2009b)
	Hydrology	Site should be farther from hydrology	Increases with distance	CBDP (2011), Smart Growth (2009b), BOS (2009)

	Floodplain and inundation zones	Not within the 100-year floodplain	Constraint	CBDP (2011), Smart Growth (2009b), BOS (2009)
	Transportation	Site should be near major streets	Decreases with distance	Smart Growth (2009b)
	Habitat and critical area	Not in habitat areas	Constraint	CBDP (2011), Smart Growth (2009b), BOS (2009)
Residential	Vacant land	Site needs to be vacant land	Constraint	Smart Growth (2009b)
	Residential zoning	Site needs to be in residential zoning	Constraint	Smart Growth (2009b)
	Hydrology	Site should be farther from hydrology	Increases with distance	CBDP (2011), Smart Growth (2009b), BOS (2009)
	Floodplain	Not within the 100-year floodplain	Constraint	CBDP (2011), Smart Growth (2009b), BOS (2009)
	Habitat	Not near habitat areas	Increases with distance	CBDP (2011), Smart Growth (2009), BOS (2009)
	Schools, libraries, police stations, and fire stations	Near all points of interest	Decreases with distance	Smart Growth (2009b), BOS (2009)

Results

Tree Canopy and Vacancy

Baltimore City has approximately the same area coverages for tree canopy and impervious surface (Table 3). Tree canopy covers 22% of the land surface, and when combined with low vegetation, shrubland, and overhanging canopy, they occupy 41% of the land cover in Baltimore City. On the other hand, a combination of impervious surfaces including parking lots and concrete, with barren land, impervious roads, and structures surpasses all vegetated areas at 47%. The remaining percentage of the land cover is composed of water and wetlands at 12%. The contribution vacant land can make to the land cover of Baltimore City is 1,446 acres, or 2.4%.

Table 3: Land Cover of Baltimore City

Land Cover	Acres	Percent
Tree Canopy	13,505	22%
Impervious Surfaces	13,094	22%
Low Vegetation	9,468	16%
Structures	9,032	15%
Water	7,093	12%
Impervious Roads	6,131	10%
Tree Canopy over Impervious Roads	760	1%
Tree Canopy over Structures	505	1%
Barren	419	1%
Tree Canopy over Impervious Surfaces	413	1%
Shrubland	34	0%
Wetlands	29	0%
Total	**60,483**	
Vacant	**1,446**	**2%**

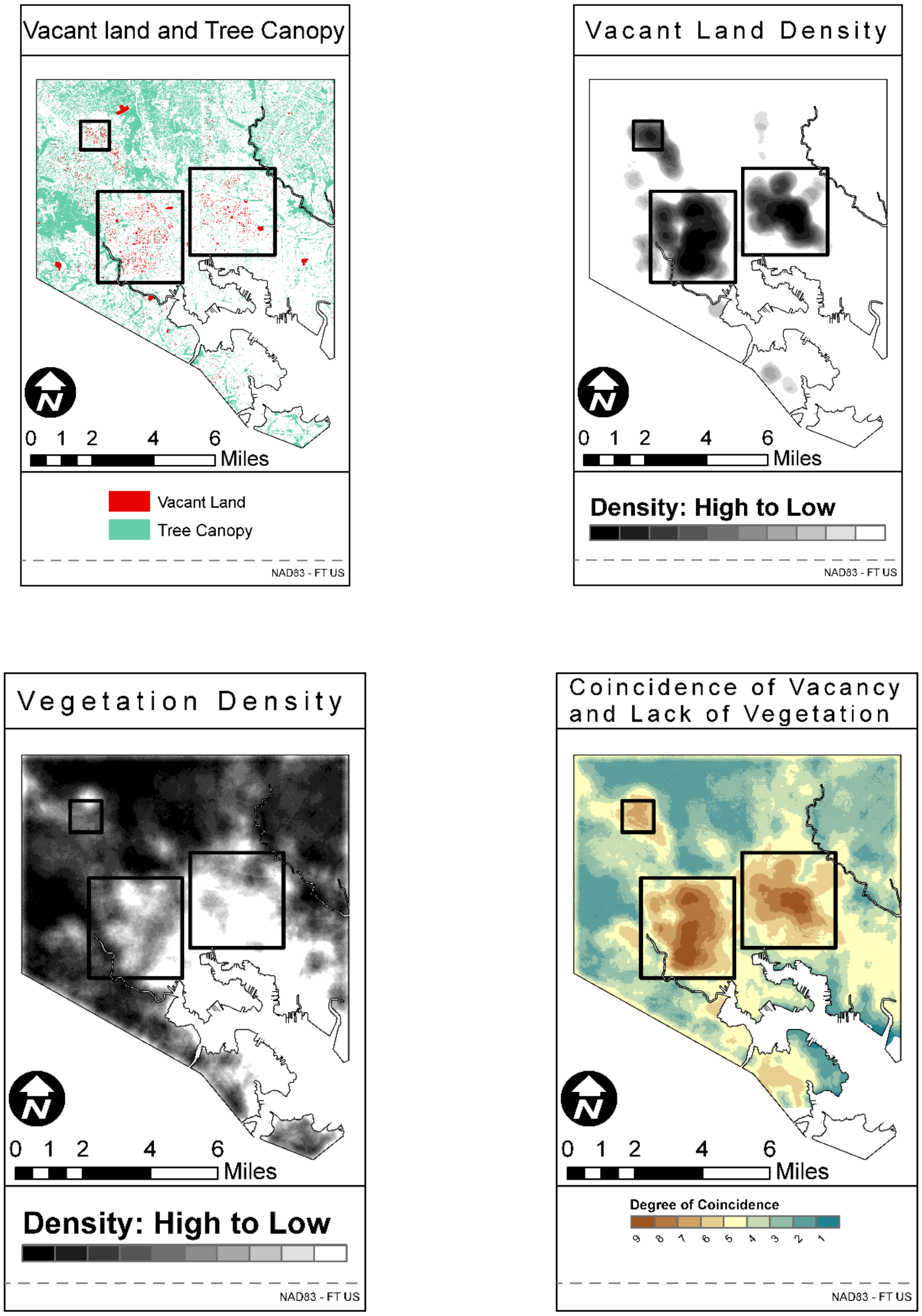
Most of the parcels in Baltimore City are residential, as are the majority of vacant parcels (Table 4). Since most of the total parcels are residential, it would make sense for most of the prioritization results to either be green space or residential rather than commercial redevelopment. The only caveats to this expectation would be larger acreage sizes of commercial parcels opposed to smaller acreage sizes of residential properties, and if those parcels classified as exempt fall within commercial zoning.

Table 4: Parcel Characteristics of Baltimore City

	Total	Percent of Total	Vacant	Percent of Vacant
Total Parcels	**222,845**	--	**16,621**	--
Residential	195,132	88%	14,439	87%
Commercial	12,790	6%	303	2%
Exempt	12,625	6%	1,990	12%
Industrial	2,298	1%	159	1%

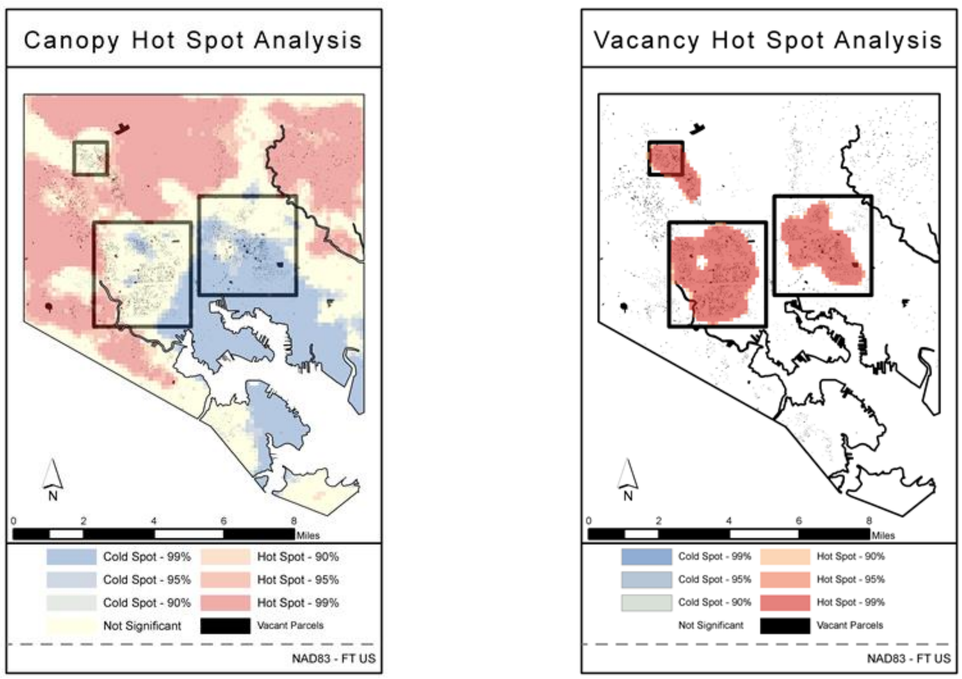
The spatial relationship of vegetation and vacancy densities is illustrated in Figure 4. Areas of interest were defined as rectangles from the top three classifications. Tree canopy is present in most of the city's periphery, while vacant land is more centered in the downtown area (Figure 4a). Vacant land is clustered on either side of the downtown corridor with one cluster in the northwest Baltimore (Figure 4b). Tree canopy is clustered in the periphery of the city, with some radial breaks, and a few patches in the downtown area (Figure 4c). The areas of interest based on the overlaid densities of vegetation cold spots and vacancy hotspots are depicted in Figure 4d. Even with the variation of density in the vegetation cold spots, the vacancy hotspots largely define the focus areas in figure 4d. The coincidence area in the northwest (Area #1) is the smallest and contains the least amount of canopy cold spots. The area in the southwest (Area #2) contains some canopy cold spots, and the area in the southeast (Area #3) mostly covers by canopy cold spots.

Figure 4: Vacant land and tree canopy of Baltimore City (figure 4a top left), vacant land density (figure 4b top right), tree canopy density (figure 4c bottom left), and the weighted overlay of figures 4b and 4c.



Figures 5a and 5b show the confidence levels of clustering for vacancy and vegetation hotspots. The mapped results show the Gi Bin value, which is determined from the p-value and z-score to determine clustering significance. The three study areas have varying levels of tree canopy cold-spots, or non-significant clustering, while the extreme clustering of vacant parcels largely determined the outcome of the weighted overlay.

Figure 5: Hot spot analysis of tree canopy (figure 5a left) and vacant land (figure 5b right)



Accessibility to Green Space

The levels of green space accessibility within the three areas of interest were assessed using network analysis. The network analysis reveals routes taken from median neighborhood centers to reach vegetated areas of varying sizes. Figures 6, 7, and 8 show the routes calculated from the median centers of Areas 1, 2, and 3, respectively. The area in northwest Baltimore (Area 1), which holds the least vegetation cold spots also has the least routes shown for all tree canopy classifications (Figure 6). The areas east of downtown Baltimore (Area 2, Figure 7) and west of downtown Baltimore (Area 3, Figure 8) are similar in size, but have different routes and route lengths. Figure 7 shows the large vegetated areas on the western edge of area 2 (Gwynn's Falls) and their accessibility from nearby median block centers. Of the three study areas, area 3 seems to have the most gaps of routes and tree canopy, which would suggest that these median block centers with fewer routes connected to them are underserved by available green space. Furthermore, median centers that have only one route that branches out in a few directions to an area of green space may suggest that green space could be stressed by over use. In all three figures (6, 7, and 8) there are plenty of opportunities along the routes shown for vacant land to become green space and intercept the route, or even contribute to adjacent green space.

Figure 6: Network analysis results of area 1

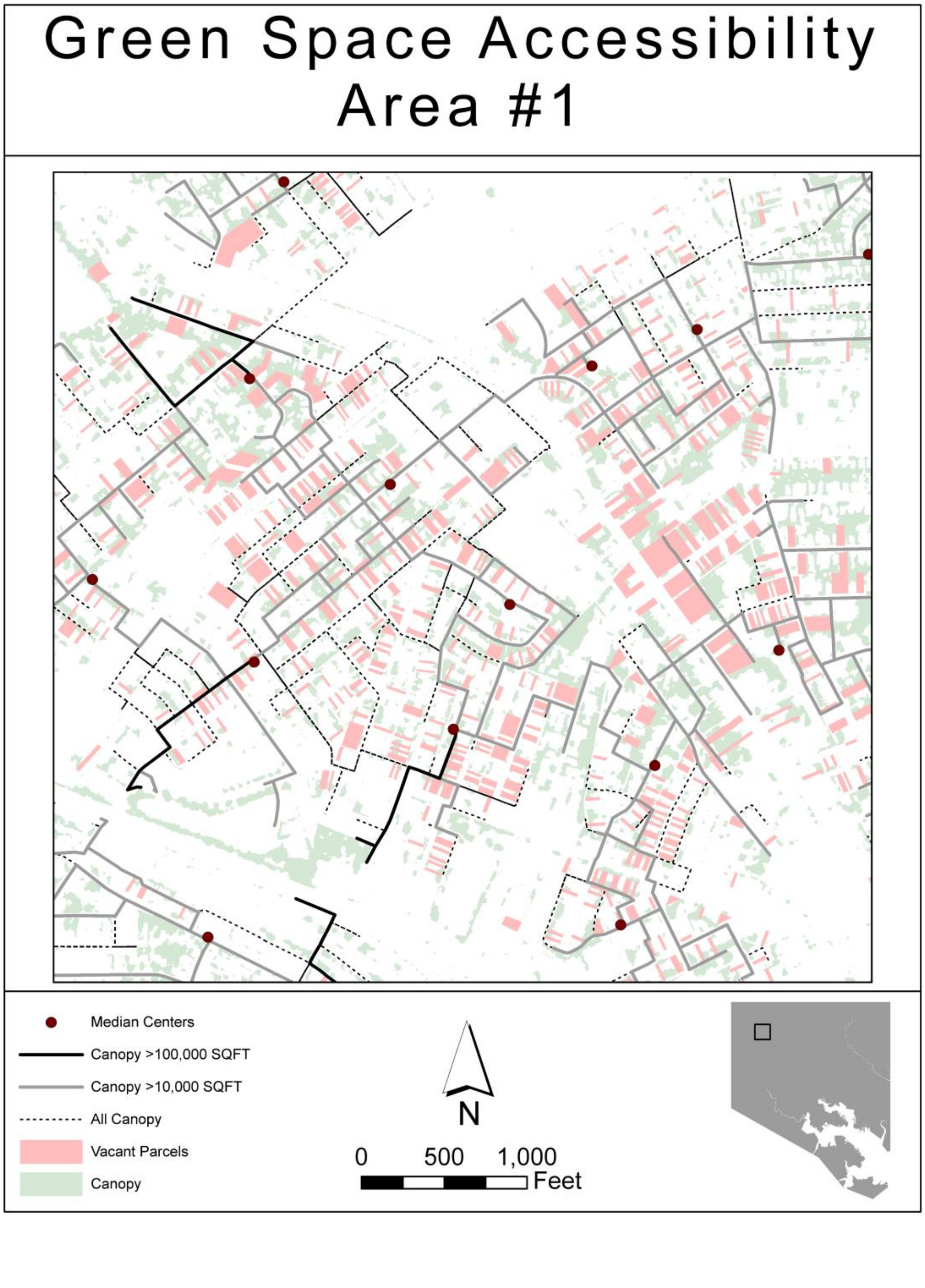


Figure 7: Network analysis results of area 2

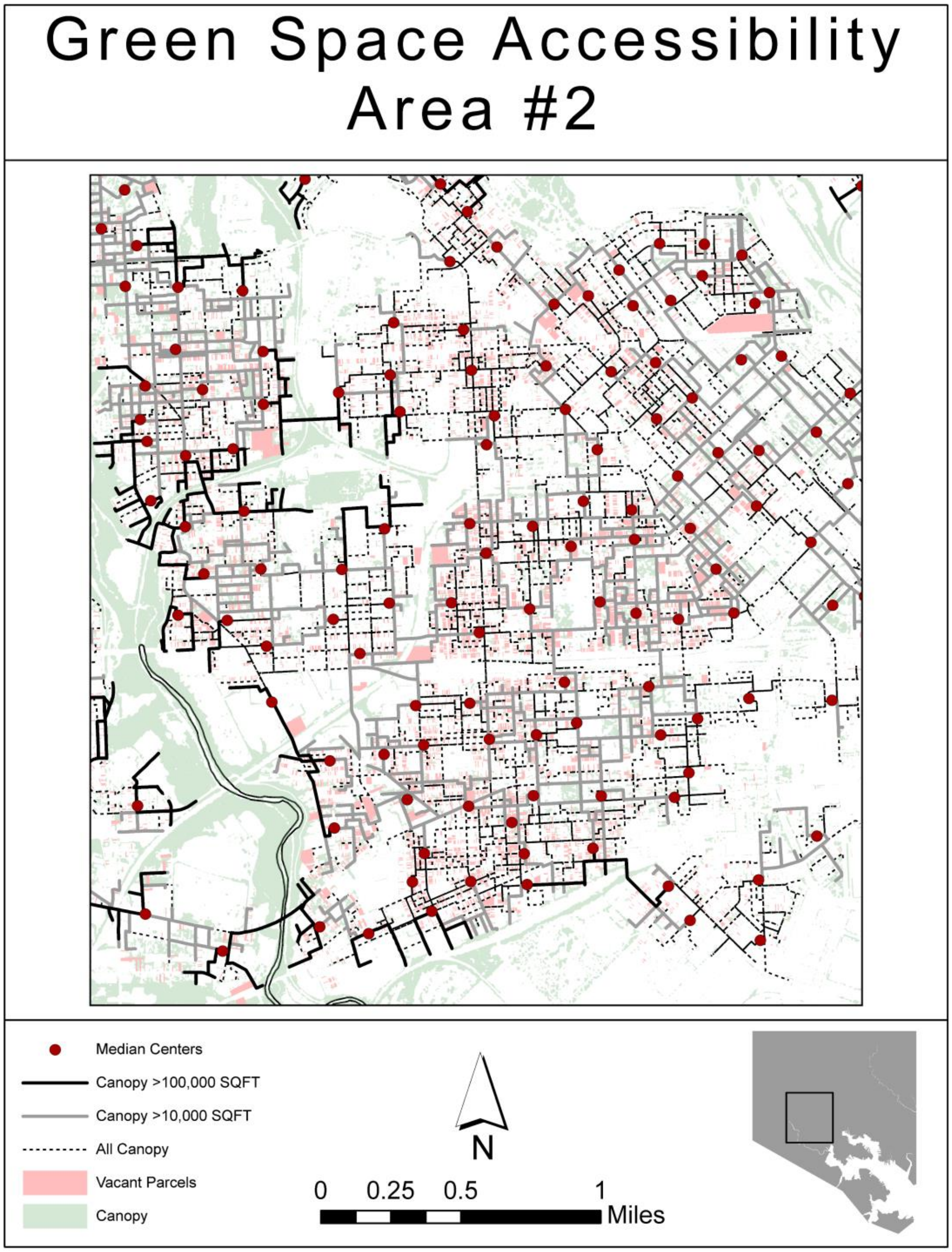


Figure 8: Network analysis results of area 3

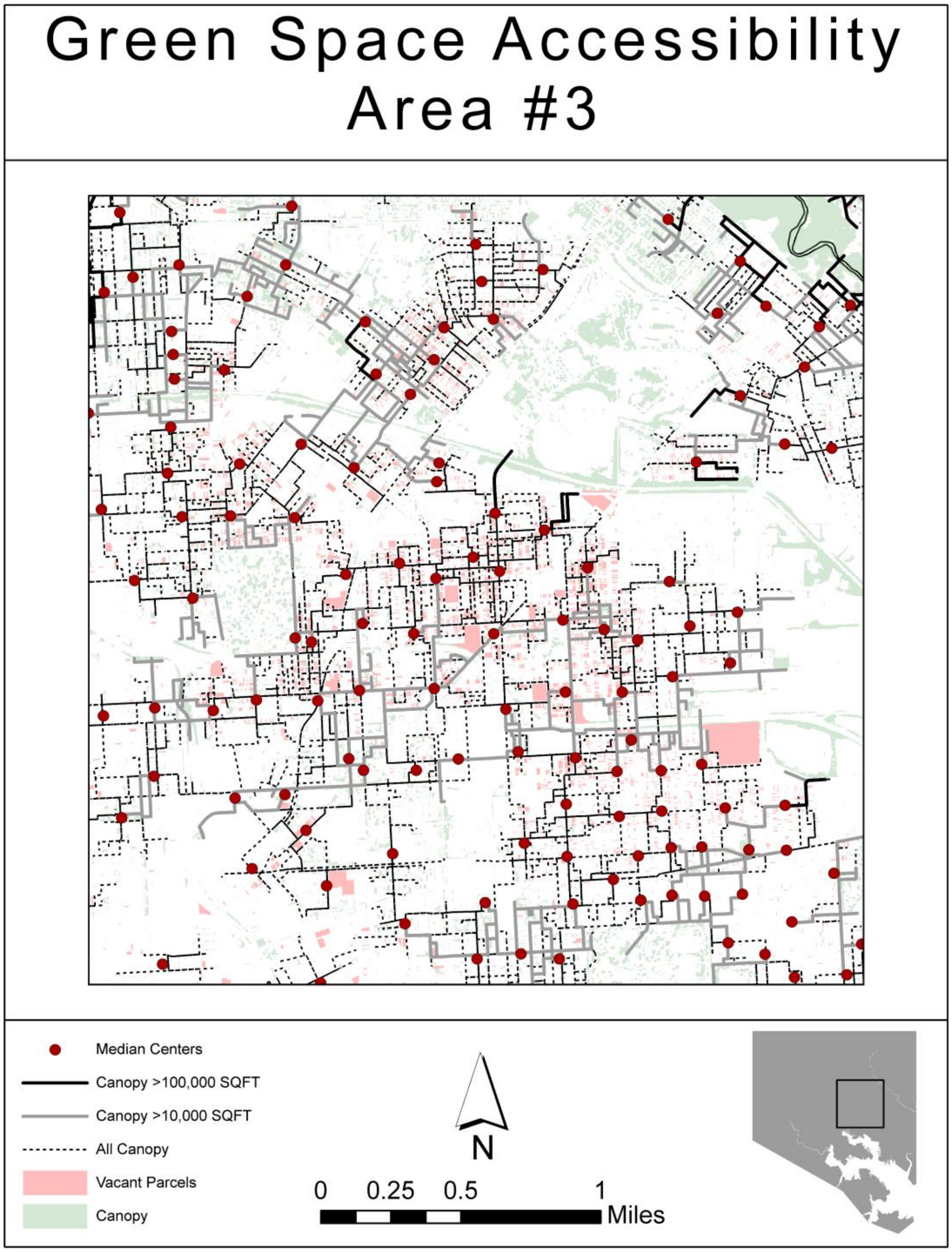
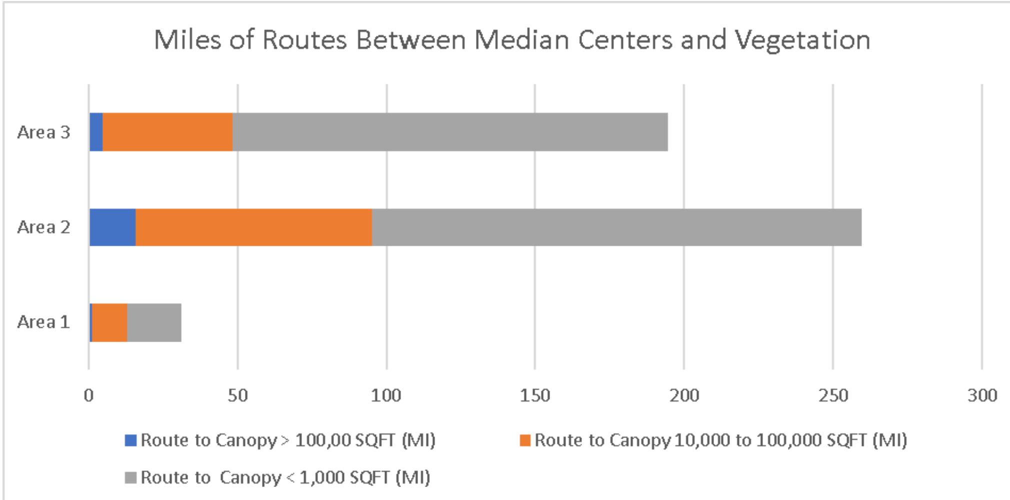


Table 5 summarizes the total length of routes between median neighborhood centers and vegetation and shows vacant parcels per area. Area #2 has the most combined miles of routes followed by Area #3 then Area #1. While Areas #2 and #3 are similar in size, Area #2 not only surpasses Area #3 in route miles, but in vacant parcels as well. The more routes that appear should inversely represent accessibility to green space. Figures 9 summarizes the lengths of routes. The composition of the route lengths as they relate to the size of the destination or green space. Since areas 2 and 3 are similar in size and area 3 has the most tree canopy cold-spots, it seems the more routes there are, the more accessible green space there is in that area. As discussed, area 2 has more large tree canopy areas which can be seen in figure 9. The composition of routes between the three areas seem proportionate.

Table 5: Summary of vacant property and route lengths per area

	Area #1 (MI)	**Area #2 (MI)**	**Area #3 (MI)**	**Total Distance (MI)**
Routes to Canopy > 100,00 SQFT	1	16	5	**22**
Routes to Canopy 10,000 to 100,000 SQFT	12	79	44	**135**
Routes to Canopy 1 to 1,000 SQFT	18	164	146	**329**
Total	**31**	**260**	**195**	**486**
Vacant Parcels	**61**	**394**	**268**	**723**

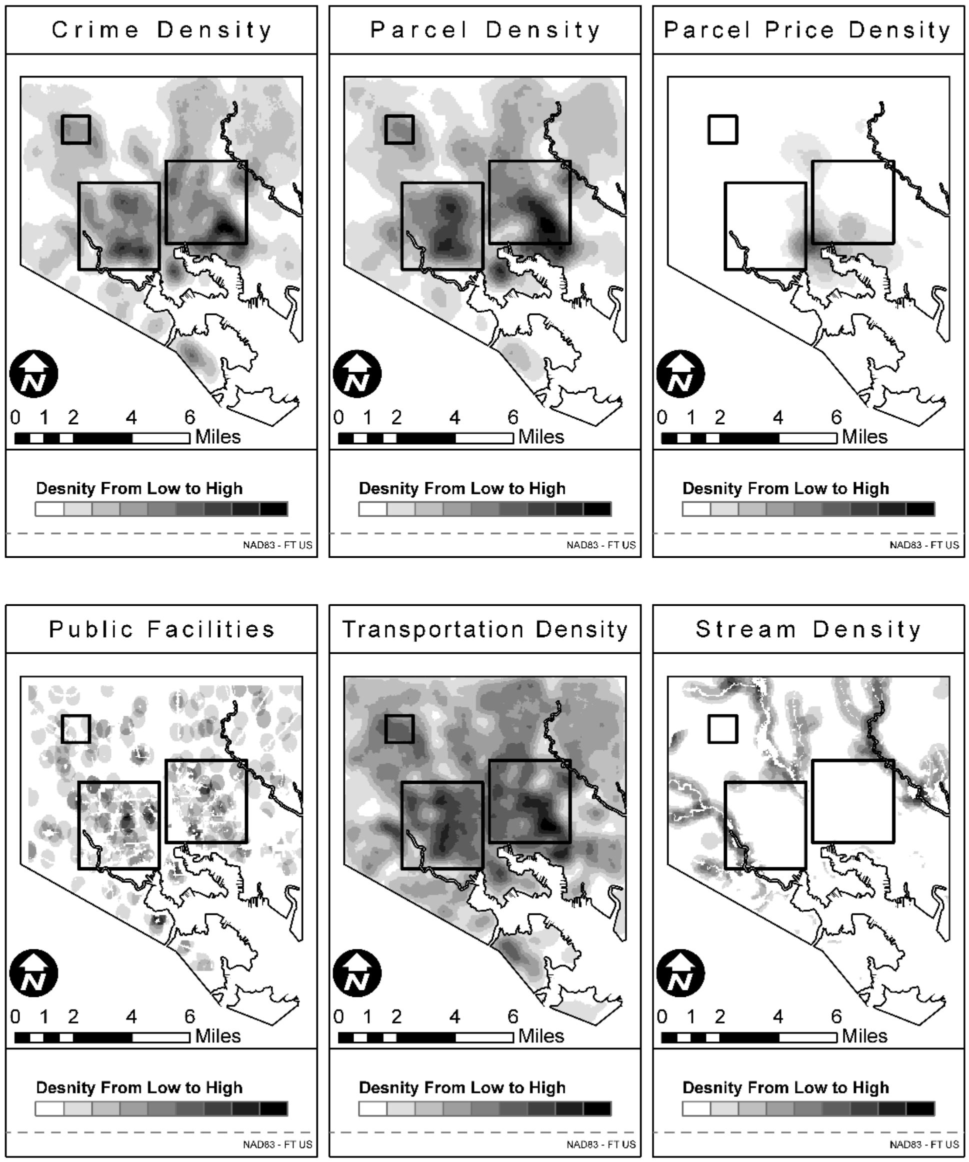
Figure 9: Summary of route lengths and types per area



Weighted Overlay Analysis

Figure 10 shows the factor inputs for the MOLA analysis. Parcel price and hydrology intersected the least with the study areas, while crime, parcel, and transportation density played the largest factors. Public facilities represent the firehouses, libraries, and police stations which were weighted towards residential development. Not surprisingly, transportation and parcel density are very similar. Also, when compared to vacant parcel density, the same three clusters are seen in parcel, transportation, public facilities, and crime densities. Conversely, when comparing vacant parcel density and parcel price density, the opposite is true. The parcel price density appears as a corridor and spur that separates the two downtown clusters of vacant land densities. Lastly in comparing the vegetation density to the stream density, the western and central stream reaches coincide with densely vegetated areas while the eastern reach coincides with sparsely vegetated areas.

Figure 10: Density inputs for the MOLA including crime (top left), parcels (top center), parcel prices (top right), public facilities (bottom left), roads and transportation lines (bottom center), hydrology density (bottom right)



Figures 11a, 11b, and 11c illustrate the weighted overlay inputs of green space, residential redevelopment, and commercial redevelopment respectively. All three inputs were used to create the combined weighted overlay in figure 11d. Figures 12, 13, and 14 illustrate the resulting decisions of the MOLA analysis for areas 1, 2, and 3 respectively. The inputs of commercial and residential redevelopment reflect the constraints of zoning restrictions and environmental prohibition and permitting of floodplains and critical areas while the input of vegetation has no constraints and only an increase of suitability. The residential redevelopment suitability seems to be centered around the existing parcel density rather than sprawling into the periphery. Even though the commercial suitability model is constrained by zoning, it follows the same pattern of concentrating in the core of the city. The combined weighted overlay has much of the commercial zoning intact as far as redevelopment suitability, but in all the study areas we can see that portions of it prioritized for green space rather than commercial redevelopment. Additionally, since the commercial and residential redevelopment model focus on existing parcel and transportation density, the eastern stream reach has two areas on either side of it that are recommended for commercial/residential redevelopment when ideally it would have a large riparian buffer.

The results in figures 12, 13, and 14 are not very interspersed between the three land use scenarios., but the boundaries between them are not so stark either. The reason for this is due to zoning. Residential and business/industrial zoning are mutually exclusive. In study area 1, there is a large residential redevelopment zone, and a large green space zone, but in the southwest corner of the area, some mixing of residential and green space is observed. In study area 2 the green space prioritized vacant land is closer to the existing green space on the west side of the area, but there is considerable green space recommended in the central corridor, the northwest, and the southeast of the area as well. Area 3 is the most scattered with no easily defined clusters of either land use scenario. In all three areas commercial redevelopment is the most scattered, but in areas 2 and 3 it can be observed along radial roads and within the commercial zoning boundary from the weighted input.

Figure 11: MOLA weighted overlays; suitability of green space (top left), suitability of residential redevelopment (top right), suitability of commercial redevelopment (bottom left), combined weighted overlay (bottom right).

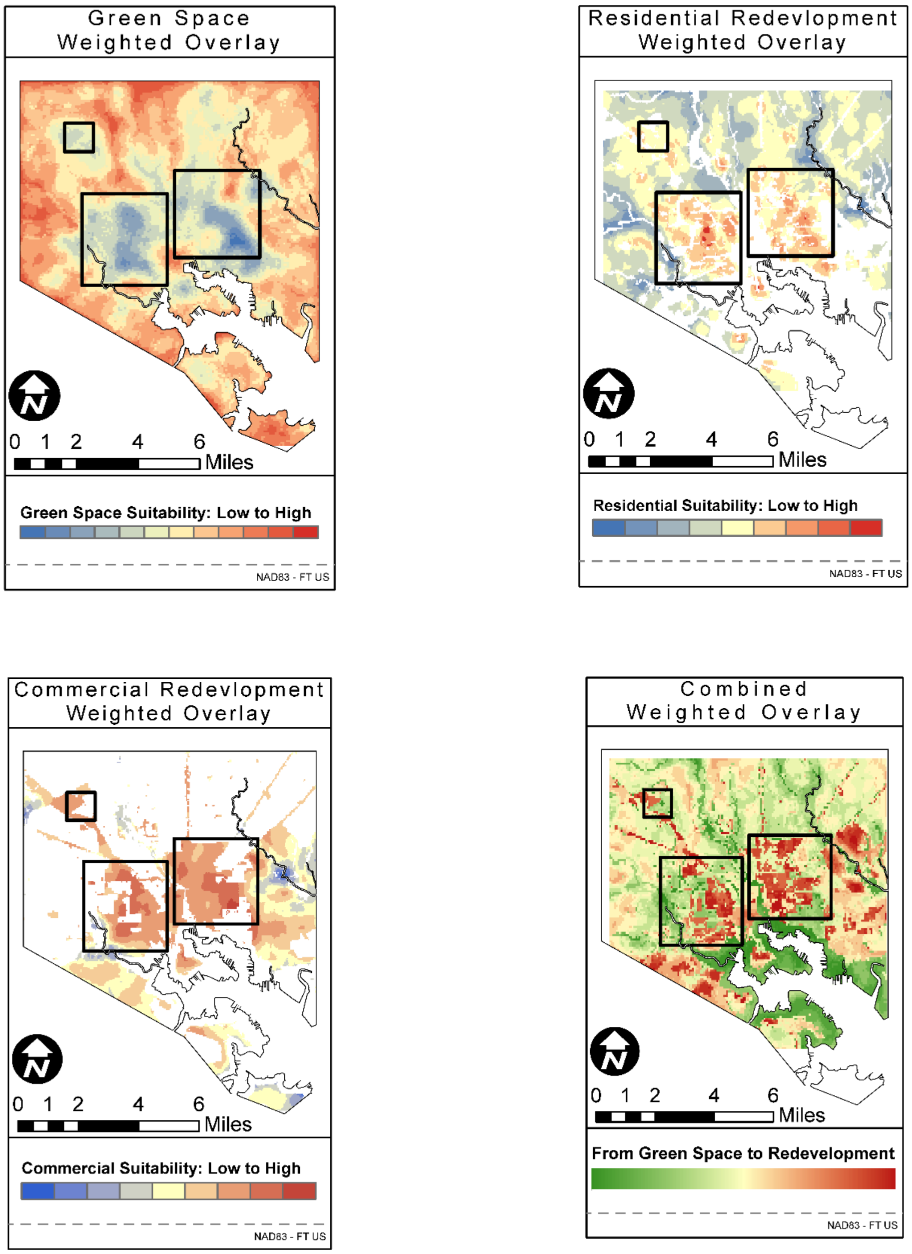


Figure 12: Land use prioritization of vacant parcels in area 1

Figure 13: Land use prioritization of vacant parcels in area 2

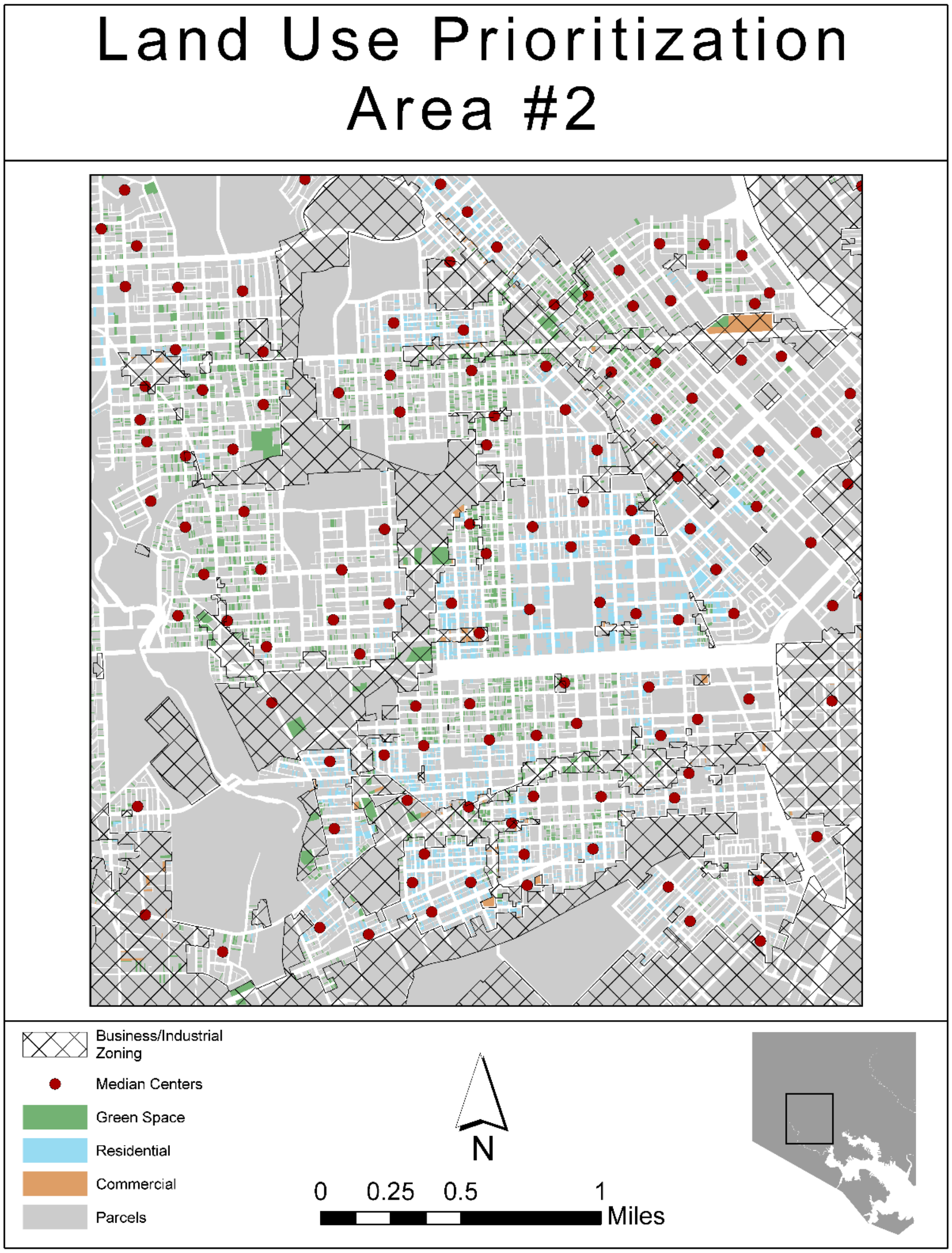


Figure 14: Land use prioritization of vacant parcels in area 3

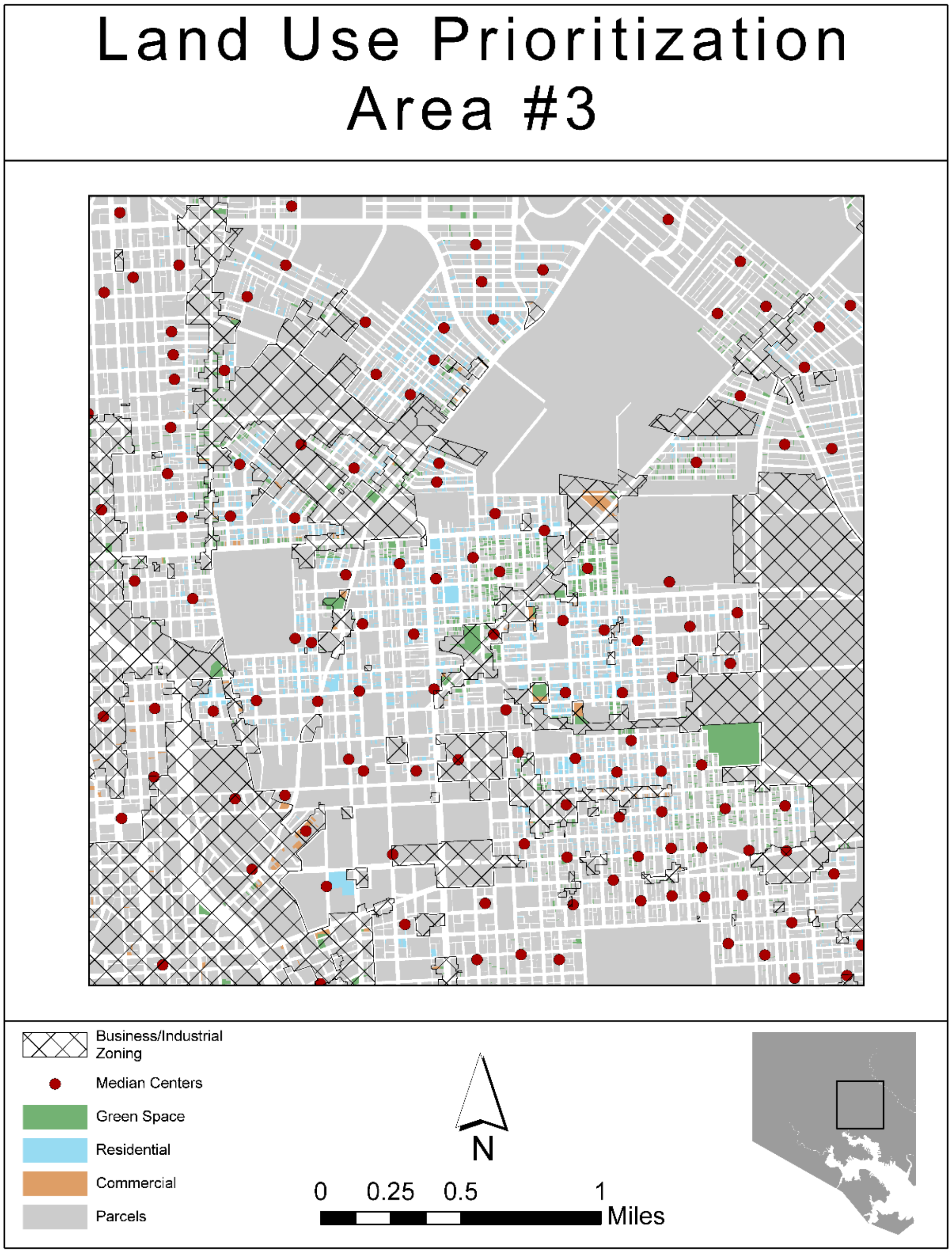
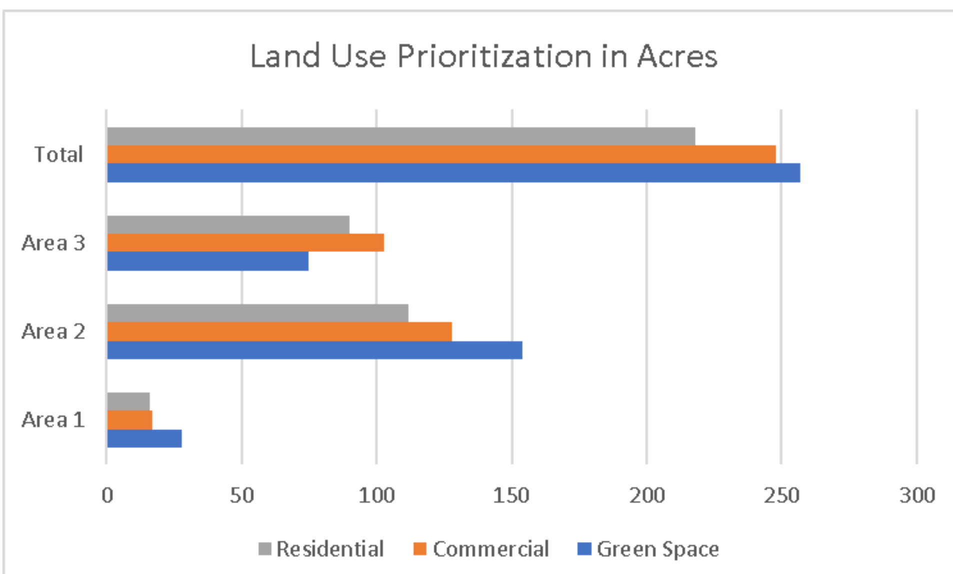


Table 6 and figure 15 summarize the results of the MOLA analysis scenarios. Green space was found to be the most favorable scenario for all areas but area 3 which favored commercial first, then residential second before green space. After totaling the scenarios for all the areas, green space was found to be the most favorable land use scenario. In all areas commercial redevelopment outweighed residential redevelopment. In all areas the three scenarios were nearly evenly distributed. Even though area 3 had the most tree canopy cold spots, more residential and commercial redevelopment was recommended over green space. Conversely, area 1 had the least tree canopy cold-spots but had the most recommended green space of the land use scenarios.

Table 6: Acreages of Land Use Prioritization

	Area 1		**Area 2**		**Area 3**		**Total**	
Green Space	28	46%	154	39%	75	28%	**257**	36%
Commercial	17	28%	128	32%	103	38%	**248**	34%
Residential	16	26%	112	28%	90	34%	**218**	30%
Total	**61**		**394**		**268**		**723**	

Figure 15: Comparison of land use prioritization acreages



Discussion

In accordance with the literature, a large degree of coincidence between vacant property frequency and vegetation absence existed within Baltimore City. While the vacant clustering was acute and well defined in three clusters, the vegetation cold spots were more diffuse with varying intensities of clustering in vacant land clusters. The three clusters of vacancy in the northwest, southwest, and southeast were essentially the focused areas in Baltimore City (Figure 4c). Each one contained either high, moderate, or low tree canopy cold spots. The methods used to create point densities of tree canopy applied weighting to large areas of canopy that would otherwise be counted as non-significant clustering. This method can be applied to vegetated areas of varying distributions and sizes by use of natural breaks classification. Since this study focused on the services rendered by green spaces in an urban setting, it made sense to weight the large contiguous canopy areas differently than small street plantings. This method allowed for accurate clustering canopy while including both extremes. Tree canopy hotspots could be easily defined by large parks in the northwest and west such as Druid Hill Park, Stony Run, and the Gwynn's Falls area. On the east side of the city riparian plantings and greenways along areas of Herring Run and landscaping plantings of lake Montebello were visible as hot spots.

Vacant parcels were distributed over most of the city, but there were some areas which did not contain as many. The clustering of vacant parcels shared similarities with that of crime density and parcel density but seemed to lack density in the clustering of higher parcel prices. Additionally, areas that were highlighted in the commercial redevelopment weighted input in the northwest corridor of the city had less vacant parcels than other areas. Tree canopy hot spots did not contain many vacant parcels, partly due to large parks where development was prohibited. The densely vegetated northern portion of the city did not have significantly clustered vacancy or higher parcel prices. In areas such as this exploratory regression analysis may provide more insight as to the nature of vacancy clustering.

By identifying study areas and analyzing routes of green space accessibility, a directional characteristic of their coincidence along network routes—an approach not seen in the literature examined—could be observed. While it is not an explicit goal of this study, results may have implications for street-tree plantings in underserved communities. This information adds another dimension to the spatial analysis of the study areas. Rather than only viewing the current land uses and proposed MOLA results, the route lines can be used to prioritize green space and increase accessibility in areas of competing MOLA results. When the lengths are summarized by the area of canopy they lead to, they can further characterize the study areas' green space accessibility and the varying densities of the vegetated and built environments. It is worth mentioning that the benefits of urban tree plantings may not be met with equally positive perceptions of residents and may be viewed as maintenance complication or nuisance. As with any planning measure, public involvement and the dissemination of information between officials, planners, and the public is crucial.

The results of the MOLA analysis were balanced in the study areas between commercial, residential, and green space scenarios. Inputs used for redevelopment, both residential and commercial, were assigned negative values and given constraints on where they could occur, but green space had no constraints and only degrees of suitability. Some inputs like transportation created competition between the three objectives since it is a favorable condition for all three. The three objectives in the study area also resemble the results city-wide. If the results were skewed towards one scenario in all study areas, that might suggest a bias in the overlay inputs. The commercial and residential development scenarios were separated from each other by zoning boundaries, but all three scenarios have degrees of suitability diverging from 0 in the positive and negative spectrum that could be used to examine larger clusters of vacant land. For summary purposes the results were dissolved into positive and negative values, then classified by zoning for negative values.

After reviewing Philadelphia's 2035 City-Wide Vison (PCPC, 2011), Land Bank Strategic Plan & Performance Report (PLB, 2017), and Five-Year Review of the Zoning Code (PCPC, 2017), there is little if any evidence of Pearsal et al.'s 2014 MOLA model results being incorporated into planning efforts. The Philadelphia Land Bank estimates of all the vacant land acquisitions 101 will be green space, 412 will be side yards, 1,121 that will be housing/mixed use, and 16 will be business expansions with similar numbers for property dispositions (PLB, 2017). The land-bank strategy is market based, but with more regulation and permitting than typical vacant land auctions as in Baltimore City to deter predatory speculation. Despite increased regulation on vacant land bank disposition, the five-year zoning review indicates an overall increase in successful zoning appeals—mostly changes in land use (PCPC, 2017). While it was not apparent if the MOLA model was used in Philadelphia's planning efforts, the initial desktop planning processes were not described in detail. It is possible that a similar analysis was performed by the planning committee, and still has potential for future planning efforts in other cities.

Future improvements and efforts would do well to apply the MOLA model on the smaller scales of the areas of interest. Doing so would make unwieldy large data more manageable to incorporate into the model such as slope and terrain, housing markets, informal green space and temporary land uses currently serving the community. Using the model on smaller areas would also increase the resolution of the density inputs, which would decrease the cell sizes of the model results, and possibly break up clustered results. Zoning boundaries play a large part in the model results. In this analysis, residential and business/industrial, or commercial, zones were treated as mutually exclusive. While this is true to a certain extent, Baltimore City does allow for mixed use residential zoning which incorporates office and commercial zoning with residential (BCDLR, 2017). In a city-wide analysis, these zones may be too small to influence the model results. However, with redevelopment, the land owner can appeal for rezoning. An alternative analysis using this model could allow for rezoning insight if zoning was excluded as constraints or factors. Using the model in this manner would allow more competition in the weighting between residential and commercial redevelopment, and when compared with existing zoning, may show areas in need of rezoning. More importantly, the subsequent steps that should be taken after using this model as a planning tool would be to gain public involvement, incorporate the historical and present needs of the communities studied, and ground-truth the available data.

Conclusion

This study answered the four questions asked in the introduction. (1) To what degree is vacancy in Baltimore City clustered? Three clusters of vacant properties were found in Baltimore City with significance greater than 99%. These included areas in northwest, southwest, and southeast Baltimore. (2) To what degree is a lack of green space clustered? Hot and cold spots of tree canopy with significance greater than 90% were found throughout the city—cold spots were mainly downtown and along the harbor with hot spots in the west, north, and east. (3) Where might green space cold spots and vacancy hot spots occur simultaneously? Within the three clusters of vacancy, high, moderate, and low levels of coincidence with tree canopy cold-spots were observed. The largest degree of coincidence was in area 3 in the southeast Baltimore. In area 2 (southwest Baltimore) there was still some cold spots, and in area 1 (northwest Baltimore), there were very few cold spots and mainly insignificant clustering or lack thereof. (4) How might the conflicting interests of vacant land redevelopment be prioritized? The MOLA analysis resulted in the recommendation of 257 acres of green space, 248 acres of commercial redevelopment, and 218 acres of residential redevelopment.

Adapting Pearsall et al.'s MOLA model to Baltimore City's planning visions and objectives was successful with some caveats. Some city-wide data were too large or required too much preparation to be used for the model. For example, to incorporate steep slopes into the model, structure elevations would have to be removed. In some cases, the MOLA results were grouped into large areas of combined vacant lots. In these areas, future studies would benefit from considering the gradation of suitability per MOLA scenario. Applying this model to a smaller scale would also result in smaller cell sizes for the weighted overlay input rasters and the final results.

In the literature reviewed, my approach to convert land-use raster data of tree canopy has not been used. As higher resolution imagery is being used to create land cover datasets with both extremely large and small features, this method can be used to generate densities not overly influenced by small features or under influenced by larger features. This study is meant to test a novel approach of popular methods in a field of rapid growth as a supplement to the urban planning toolbox and as a starting point for analyzing vacant land in shrinking cities. It should provide a quantitative foundation flexible in scope, scale, and location for more tailored investigations to adjust, and possibly an additional land use model for planners to present as a baseline for public input forums to discuss, correct, and improve.

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- Park user survey design for Baltimore City Department of Recreation and Parks – Fall 2013
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