RE-IMAGINING VACANT URBAN LAND AS GREEN INFRASTRUCTURE: ASSESSING VACANT URBAN LAND ECOSYSTEM SERVICES AND PLANNING STRATEGIES FOR THE CITY OF ROANOKE, VIRGINIA

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ABSTRACT

A typology of urban vacant land was developed using Roanoke, Virginia, as the study area. Because of its industrial past, topography and climate, Roanoke provides a range of vacant land types typical of those in many areas of the Mid-Atlantic, Eastern and Midwestern United States. A comprehensive literature review, field measurements and observations analysis and aerial photo interpretation and ground-truthing methods were utilized to identify and catalog vacant parcels of land and the results were mapped using i-Tree Canopy to identify the following types of urban vacant land: post-industrial (3.34 km^2), derelict (4.01 km^2), unattended with vegetation (17.3 km^2), natural (2.78 km^2), and transportation-related (5.01 km^2). Unattended with vegetation sites are important resources as the health biodiversity found in natural sites benefits urban populations and they represent the highest plantable space. The redesign of post-industrial sites builds a city's image and transportation-related sites can contribute a green infrastructure network of open spaces. This typological study has significant implications for policy development, and for planners and designers seeking the best use for vacant urban land.

The analysis of Roanoke's urban forest revealed around 210,000 trees on vacant land, a tree cover of 30.6%. These trees store about 107,000 tons of carbon (worth $7.65 million) and remove about 2,300 tons of carbon ($164,000), and about 91 tons of air pollution ($916,000) every year, which is high relative to other land uses. Trees on vacant land are estimated to reduce annual residential energy costs by $211,000 for the city's 97,000 residents and their structural value is estimated at $169 million. The methodology applied to assess ecosystem services in this study can also be used to assess ecosystem services of vacant land in other urban contexts and improve urban forest policies, planning, and the management of vacant land. The study findings support the inclusion of trees on vacant land providing a new vision of vacant urban land as a

valuable ecological resource by demonstrating how green infrastructure can be used to enhance ecosystem health and promote a better quality of life for city residents.

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CHAPTER 1: INTRODUCTION

1.1. Background

The urban cores of many contemporary American cities are slowly becoming decentralized, with many losing significant numbers of residents, businesses, and industries between 1950 and 2010 (Hall, 2010). This loss of population has led to an increase in the number of vacant lots, often in the urban core. These vacancies become "urban voids" or negative spaces in the urban fabric. Decentralization is most common in post-industrial cities such as St.Louis, Philadelphia, and Detroit. For example, since 1950, Detroit has lost over 50% of its population, 165,000 industrial jobs, and 147,000 housing units (Hall, 2010); between 1978 and 1998, there were 108,000 demolitions and only 9,000 new buildings constructed in the city (Oswalt, 2008). As the population of Detroit continues to decline, an estimated 2,400 properties become newly vacant every year (Daskalakis, Waldheim & Young, 2001) and approximately 32% of the city's land area is now vacant property (King, 2012), more than twice the average in large U.S. cities (Bowman & Pagano, 2004). While Detroit is an extreme case, many cities have vacant land.

Since 1950, the metropolitan population of the U.S. has almost doubled, but the population density in its central cities has fallen by half (U.S. Department of Housing and Urban Development, 1995). Despite the growth in the U.S. population over the last 20 years, for every person taking up residence in a city, four other moved to the suburbs (U.S. Department of Housing and Urban Development, 1997). The populations in central cities in the Northeast declined by 10% in the 1970s and remained flat during the 1980s. Boston is indicative of this trend: the Boston metropolitan area overall grew by over 19%, but the central city population fell by close to 18% (Pennsylvania Horticultural Society, 1995).

There are numerous causes of urban land abandonment, including the decline of the local industrial base with a corresponding increase in job losses, foreclosures, increased rates of criminal activity, and the unwillingness or inability of property owners to maintain their properties (Goldstein, Jensen & Reiskin, 2001). The areas which have been worst affected include large, older cities, especially those where heavy industrial areas have become run down and local economies have been insufficiently to require the vacant land to be repurposed (Kivell, 1993). Due to declining local real estate markets in many areas, vacant land continues to exist in cities because it does not support the development or re-use of certain vacant properties (Crauderueff, Margolis & Tanikawa, 2012). The construction of highways, the lower cost of housing, and the flight of wealthier, disproportionally white, residents from the cities to the suburbs have contributed to the population loss and business decline in many U.S. cities, particularly in the Northeast and Midwest (Jackson, 1985) and urban development and economic and industrial processes can also produce waste products in the form of vacant urban land (Kim & Kim, 2012). A variety of urban processes, including decentralization due to demographic changes, urban sprawl, de-industrialization, and people's preferences for new types of residential choices have thus led to increased vacancy rates in urban areas (Kremer, Hamstead & McPhearson, 2013). Overall, declining city populations and urban sprawl are the two most important reasons for the decentralization of our cities. As people moved to the suburbs, the infrastructure provided and utilization of land decreased, leaving the urban core with remnants. Depopulation of the urban core increases vacancies in urban areas. These vacancies, also known as urban voids, then become left-over, negative spaces in the urban fabric.

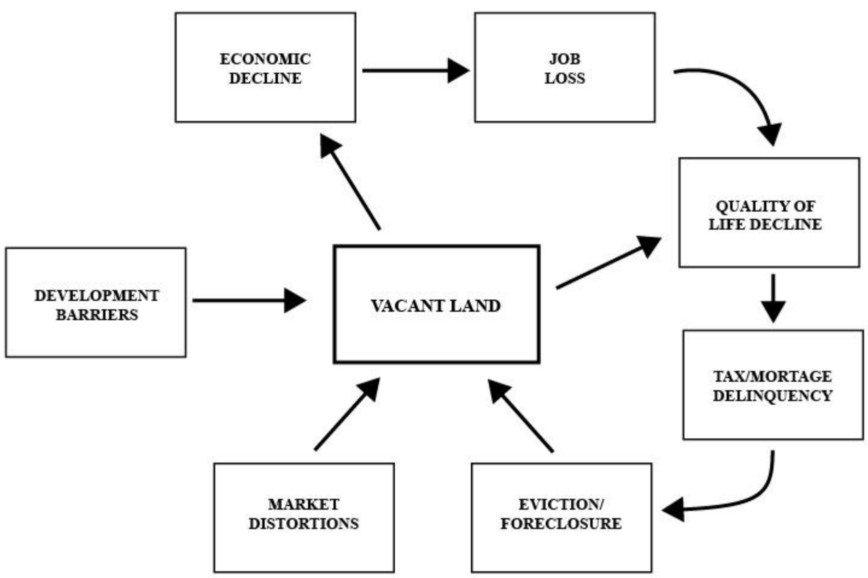

Figure 1.1 The vicious cycle of decline (Goldstein et al., 2001, p.4), permission to use granted by: James Goldstein (March. 19, 2015)

Typically, vacant urban land is considered a "blight" that conveys negative images, with a consequent effect on property values in the surrounding area (Crauderueff et al., 2012). Vacant land reduces property values and the quality of life for local residents, decreasing the desirability of developing land for housing and economic development purposes, suppressing local tax bases, and stressing municipal budgets due to the higher administrative and maintenance costs incurred (U.S. Government Accountability Office, 2011). Vacant land deters investment but imposes costs on the local community and public sector agencies to maintain vacant properties, while at the same time discouraging investment from the private sector (Crauderueff et al., 2012). For example, vacant land has been shown to decrease property values by 20% and cost the city of Philadelphia $20 million each year for maintenance alone (Econsult Corporation, Penn Institute for Urban Research & May 8 Consulting, 2010). In addition, 17,000 of the city's 40,000 vacant parcels are tax delinquent, 11,000 of them for more than 10 years. As a result, the city is losing minimum of $2 million in revenue annually (Econsult et al., 2010).

According to Kivell, "derelict and vacant land is a significant part of the overall land use pattern of most cities and amounts to a major problem in a number of them" (1993, p.175). Abandoned buildings are fire hazards, may host drug trafficking activities (Cohen, 2001), are an indicator of neighborhood decline, reduce a sense of community, and discourage investment (Goldstein et al., 2001). The physical blight of vacant land contributes to the vicious cycle of disinvestment shown in Figure 1.1. further reducing reinvestment and development (Crauderueff et al., 2012), as vacant land conveys negative images that deter potential investment and thus increases urban vacancy rates. Vacant land also requires a significant amount of financial input to pay for the associated planning, acquisition, management, and maintenance services.

Vacant urban land covers a significant amount of the urban landscape. According to a 2000 Brookings Institution study, vacant land comprised an average of 15% of the land area in seventy U.S. cities (Pagano & Bowman, 2000). This label does not differentiate between different types of vacant land, however, which can consist of anything from undistributed open space to abandoned, contaminated brownfield sites. The amount of land involved continues to rise; the 6.8 million permanent vacant land parcels that existed nationwide in 2000 had increased to 10.3 million by 2010, a 51% increase (U.S. Government Accountability Office, 2011). While this problem is especially severe in cities experiencing a population decline, many cities with growing population also experienced an increase in abandoned buildings. For example, Tucson, AZ, experienced a 6.9% increase in population but a 57.8% increase in abandoned buildings between 2000 and 2010, while Indianapolis, IN, and Las Vegas, NV, experienced population increases of 4.9% and 22% but 48.8% and 137.4% increases in abandoned properties, respectively, over the same period (U.S. Government Accountability Office, 2011).

Many abandoned buildings are potential vacant lots. Abandoned buildings frequently remain standing due to the high cost of demolition, which can range from $2000 to $40,000 per unit depending on the building's size, type, and contamination levels (U.S. Government Accountability Office, 2011). Cities, such as Chicago, IL, Detroit, MI and Baltimore, MD, simply cannot afford to demolish all their long-term vacant buildings. For example, Baltimore, a city that has a greater proportion of vacant lots to population than most cities in the United States (Pagano & Bowman, 2000), would need approximately $180 million to demolish all the abandoned buildings city wide (U.S. Government Accountability Office, 2011). These statistics indicate the extent of the vacant urban land issue in many urban areas.

1.2. Problem Statement

Vacant and abandoned property is increasingly recognized as a significant barrier to urban regeneration and renewal of city centers. However, the occurrence of urban voids is now common in contemporary cites and has become part of the urban fabric. There are many opportunities to redevelop vacant land in terms of ecological and social value, so many design professionals and scholars are becoming interested in the potential offered by vacant urban land, especially with regard to planning and design (Kim & Kim, 2012). While recent attention has largely focused on urban brownfields (contaminated industrial sites), relatively little research or policy work has considered the vast potential of the large number of different types of vacant urban land in our most economically depressed urban neighborhoods (Goldstein et al., 2001). Understanding the problems associated with vacant and abandoned land, the causes of land abandonment, barriers to the redevelopment of urban land, and innovative opportunities for redeveloping such land will enable us to develop alternative policy mechanisms that promote urban regeneration and renewal (Goldstein et al., 2001).

Previous research studies have tended to discuss vacant urban land as if it were all the same.

There is as yet no systematic categorization of different types of vacant land and there is no comprehensive research into how different types of vacant land can contribute, collectively, to the urban scene. Due to this lack of knowledge about the potential utility of different types of vacant urban land, much of it is overlooked and undervalued as part of the urban landscape, despite its potential ecological and social value. These parcels are often in limbo not seen as worthy of any planning or consideration, until such time as a new use becomes available. The design, planning and management process for vacant land has been underutilized at best, both in the short and long term, thus neglecting a potentially valuable resource. Planners and designers tend to conceive of vacant land in a very narrow way, leaving it in a kind of holding pattern until it is economically viable to develop. In this sense it is not even a land use, so it does not get planned for. Also, planners and designers are unlikely to understand the short term and long term ways that vacant land can be planned for, as they do not fully appreciate the diversity and potential of different types of vacant land. Depending on previous and current vacant urban land use structure, the existing condition and redevelopment potential of the vacant land may vary considerably and will thus require different approaches for future development. Vacant urban land has different characteristics, and it is important to understand the different potentials and obstacles to the redevelopment of these spaces. Therefore, a typology of vacant land is needed that will help planners and designers to understand and plan for vacant urban land, leading to better utilization of these spaces and opening up alternative creative approaches to envisioning space and landscape design in a city.

Re-imagining vacant urban land is critical to our disciplinary and professional commitment to traditional urban land use and we need to be more open to alternative ways to “reuse wasted land” in urban areas. Vacant land can be a valuable ecological resource, acting as green infrastructure that can be used to enhance ecosystem health and promote a better quality of life for city residents. Urban infrastructure consists of the systems that provide benefits to people and communities, traditionally referring to roads, sewers and the like, but green infrastructure not only provides these benefits but also environmental benefits. The definitions used for “green infrastructure (GI)” are numerous. According to the U.S. Environmental Protection Agency (EPA), GI is an “adaptable term used to describe an array of products, technologies, and practices that use natural systems - or engineered systems that mimic natural process - to enhance overall environmental quality and provide utility services" (USEPA, 2011). The EPA suggests that green infrastructure could include innovative ways to reduce the volume of urban stormwater runoff, for example, both providing community benefits and reducing the need for additional public spending on storm drains (Grumbles, 2007). Green infrastructure can also improve the air quality and consequently public health, cool the air by counteracting the urban heat island effect and thus reduce demand for air conditioning, and support climate change adaptation (Rosenthal, Crauderueff & Carter, 2008), all of which promote the quality of urban life. In the late 1980s, the National Science Foundation supported an urban ecology educational effort that used city parks, rights of way, and vacant lots as "nature's classrooms" (Bowman & Pagano, 1998). Similar thinking is evident in Portland Oregon's Metropolitan Greenspaces Program (Poracsky & Houck, 1994). This program changed the land use general labels to make them more positive, exchanging labels such as "vacant" or "undeveloped" to biological labels such as "greenspace" or "greenbelt" (Bowman & Pagano, 1998). Rather than being a negative symbol of urban problems, vacant land began to be considered as "fortuitous landscapes" (Hough, 1994). This new way of thinking is apparent in the title of an op-ed piece published in the *National Journal*: "Vacant Urban Land – Hidden Treasure?" (Peirce, 1995).

Vacant urban land is not normally thought of as green infrastructure, partly because the potential community benefits provided by these spaces are not widely recognized. There are relatively few studies of the ecology of vacant lands (Burkholder, 2012) and for the most part it is not managed for its environmental benefits. Most urban vacant land is viewed only from an economic perspective of highest and best use, so it just sits waiting until it is economically viable to develop it. However, vacant land does contribute ecosystem services and benefits and could potentially contribute more if managed appropriately. One way of addressing this failure is to conduct a comprehensive assessment of urban forests to estimate the environmental benefits and ecosystem services they provide and thus improve our understanding of the role trees play in creating healthy, livable and sustainable cities.

The extent to which land uses provide ecosystem services depends on their current urban forest structure. This includes tree species, species origin (native vs invasive), number of trees, percentage tree canopy cover, tree condition, and ground cover types, all of which are important components of the ecosystem services potentially provided by trees in urban areas. Different forest structure results in different green ecosystem benefits and infrastructure value for different land uses. However, land use planners lack a comprehensive set of bench marks for ecosystem productivity to apply when setting planning goals or expectations. One reasonable expectation for ecosystem benefits from the management of vacant land is that it should meet or exceed the ecosystem benefits produced by other land uses, such as commercial, industrial, and residential land. It might be reasonable to expect vacant land should at least produce similar or greater ecosystem benefits than other urban land uses. Research in the form of a comparative study is needed to determine the extent to which residential and vacant land are actually comparable, both in terms of forest structure and ecosystem benefits. Forest structure in vacant urban land refers to the amount and density of plants, the types of plants present (e.g. trees, shrubs, ground cover), the diversity of species, and tree health. Before ecosystem benefits can be assessed it is important to understand the forest structure for both other urban land uses and vacant land. Differences in ecosystem productivity will most likely be due to differences in forest structure, so determining these characteristics is a vital first step in providing the detailed evaluation needed for effective urban forest management and for estimating the green infrastructure value of a vacant site.

Therefore, a way to assess vacant urban land forest structure and ecosystem services is needed that will demonstrate how vacant urban land functions as a green infrastructure on otherwise vacant land to provide ecosystem services and add value by performing functions, such as air pollution removal, carbon sequestration and storage, and energy saving, as well as the structural value of the trees themselves. In most cities, air pollution is a major environmental problem. Carbon dioxide is the major cause of climate change and also has a strong relationship with energy consumption from power generation, while the structural value of trees on vacant land can add to our understanding of the compensatory value of vacant land and lead to better urban forest management of vacant land. The goal of understanding how forest structure and ecosystem services of vacant land differ from those provided by other urban land uses will help determine how effectively urban vacant land can function as part of a city's green infrastructure, and lead to better utilization of the vacant land. Vacant land may also offer alternative creative open spaces and landscape design, especially in an otherwise built-up city environment.

1.3. Scope of Research

1.3.1. Goal of Research

The goal of the research conducted for this dissertation has been to identify and develop a useful typology of vacant urban land and demonstrate how vacant urban land functions as a green infrastructure on otherwise vacant land to provide ecosystem services and add values by providing services such as air pollution removal, carbon sequestration and storage, and energy saving, as well as the financial value of the trees themselves, using the City of Roanoke, Virginia, as a study site. Planning and implementation strategies will be examined, including identifying the plans, policies and implementation that can be used to overcome barriers and challenges to the task of enhancing the green infrastructure value of vacant urban land. Alternative strategies to utilize these spaces more effectively for short-term and long-term uses for urban regeneration and renewal will also be suggested.

1.3.2. Methodology

In order to develop a comprehensive typology and assess vacant urban land ecosystem services and planning strategies, four tasks were performed: 1) a comprehensive literature reviews was conducted, 2) a vacant urban land typology and framework was developed, and 3) the vacant urban land forest structure and ecosystem services in the City of Roanoke were assessed, leading to 4) a set of vacant urban land planning and implementation strategies for the city. The literature review in Chapter 2 surveys the work done by previous researchers in this area to determine the status of efforts to develop a typology of vacant urban land to help develop a better understanding of the potential value of vacant land in terms of its ecological and social value, and to examine how leading cities incorporate vacant land in their long-term plans and shed new light on how the policies they implement have an impact on the barriers and challenges related to green infrastructure on vacant lots across U.S. cities. A detailed description of the research methodology employed for this research is present in Chapter 3.

The development of a vacant urban land typology and framework to identify the types and characteristics of vacant urban land are expected to assist in the future design, planning and management of vacant land. As yet, there has been no comprehensive investigation of the current condition of vacant urban land in our cities, and hence no useful assessment of city policy tools designed to use or reuse vacant urban land. Therefore, the vacant urban land matrix framework in this dissertation was designed as a tool to be used for planning and designing vacant parcels in terms of enhancing the ecological and social benefits they provide. The typological approach to vacant land will provide a categorization of project-appropriate vacant land from which the planners and designers may choose, as described in Chapter 4.

Assessing vacant urban land forest structure and ecosystem services will demonstrate how vacant urban land functions as a green infrastructure that provides ecosystem services and values to society. Vacant urban land is not normally thought of as green infrastructure, largely because the potential community benefits provided by these spaces are not widely recognized. Understanding an urban forest's structure, function and value can promote decision-making that will improve human health and environmental quality. This will demonstrate that vacant urban land is a vital resource and a useful component of the city's green infrastructure that can offer significant benefits and must therefore be managed to increase its effectiveness and minimize any negative effects. The analysis of the structure, function, and economic benefits of vacant urban land presented in Chapter 5 will be a useful reference for local authorities, landowners and regeneration professionals, as well as providing a rationale for a change in current approaches towards valuable vacant urban land. A closer examination of the green infrastructure provided by vacant land in an urban environment will quantify the value it adds through providng ecosystem services, such as air pollution removal, carbon sequestration and storage, avoided runoff, energy saving, and the structural value of the trees themselves.

A good understanding of vacant urban land planning guidelines and implementation strategies is vital for any effort to identify alternative strategies to better utilize different types of vacant land for short-term and long-term uses for urban regeneration and renewal. The research described above, especially the typological study, revealed that vacant land has different characteristics and potential in terms of both its ecological and social value. If planners are to appropriately manage vacant land to maximize its green infrastructure benefits, different types of vacant land needs to be redeveloped with different short-term, long-term planning and implementation strategies. Vacant land does contribute ecosystem services, along with other benefits, and could potentially contribute more if managed appropriately. Chapter 6 discusses how vacant urban land planning and implementation strategies related to the programs, planning policies, regulations and implementation methods involved, specifically aspects such as its administration, acquisition and transfer mechanisms, financing, and maintenance, may be needed to overcome the barriers and challenges identified through the literature review if planners are to take full advantage of the green infrastructure on vacant lots based on the new typology and ecosystem services.

1.4. Research Significance

The findings of this research will fill some of the gaps in our knowledge of the value of the green infrastructure services provided by vacant urban land to assist in the future design, planning and management of vacant land in our cities. The classification of different types of vacant urban land based on their physical and social characteristics is useful in considering its value in the urban landscape, while understanding an urban forest's structure, function and value can promote decision-making that will improve human health and environmental quality. This dissertation research captured the current structure of Roanoke's urban forest growing on vacant land and quantified a subset of the ecosystem functions and economic values it provides to the city's residents. The results of this research can be used to identify the vacant land forest structure in order to improve urban forest policies, planning and the management of vacant land, providing data to support the inclusion of trees on vacant land within existing environmental regulations and showing how trees growing on otherwise vacant land affect the environment and, consequently, enhance human health and the environmental quality in urban areas. The significance of this research is the new vision it provides of vacant urban land as a valuable ecological resource, demonstrating how green infrastructure can be used to enhance ecosystem health, and promote a better quality of life for city residents. The findings provide useful information for urban planners, architects, landscape architects and other design professionals concerned with the design and planning of the urban landscape in a manner that treats vacant land as a valuable resource that may create new open space opportunities for city residents.

CHAPTER 2: LITERATURE REVIEW

2.1. Historical Overview of Vacant Land

Vacant land presents many challenges for older financially distressed cities such as Detroit, Michigan, and Buffalo, all of which have significant amounts of vacant land. Most of these cities are post- industrial centers that have been steadily losing population and jobs since the 1950s as large areas of the U.S. economic base shifted from heavy manufacturing to technology and service-based industries and technology companies (Goldstein et al., 2001). The rapid technological development eliminated many of the traditional manufacturing jobs as industrial competitor nations such as Japan and the European countries recovered from World War II and developing countries also built industrial bases (Goldstein et al., 2001). Technology based industries such as the computer and health care required fewer workers with higher skills, but did not pay as well as the traditional manufacturing jobs had done (Kivell, 1993).

Before World War II, our city centers were the hubs of economic activity, primarily industrial activity, because the transportation options were limited and most people lived in the city center to be close to their jobs and businesses. However, as transportation improved after WWII with the construction of the nation's extensive highway systems, many people seized the opportunity to move away from city centers to find jobs and businesses in suburbia (Goldstein et al., 2001). This tendency was encouraged by lower property costs, lower taxes, and fewer regulations, often designed to tempt businesses to move to the suburbs (Kivell, 1993). This trend continues today, with more than 70% of the new jobs being created in suburban settings (Municipal Research & Services Center of Washington, 1997).

Although cities lost their industrial base they were unable to find new strategies for economic growth. As a result, their populations decreased, creating large amounts of vacant land and abandoned buildings. This type of decline in cites is not only an economic problem, but also results in the loss of their community identity (Schilling & Mallach, 2012). This decline is often accompanied by social problems and indifference on the part of government (Schilling & Mallach, 2012). The physical characteristics of vacant land, including abandoned buildings may cause residents to lose pride in their community. In addition, the social and civic infrastructure may weaken and in declining cities. Many residents of declining cities do not actively participate in the community engagement process. Because these disparate social and economic problems occurred simultaneously, many industrial cities effectively closed leaving residents to struggle with low levels of economic activity and live in undesirable urban neighborhoods with declining property values, which in some neighborhoods continues to this day (Goldstein et al., 2001).

2.2. The History of Vacant Land

Interest in vacant urban land has grown among design professionals and scholars in recent years due to their potential for redesign and adaptive re-use, both socially and ecologically. Multiple scholarly sources have discussed the meanings and design potential of vacant urban land. In "Vacancy and the Landscape: Cultural Context and Design Response", Corbin (2003) examines the cultural meaning of vacancy in everyday language. This study redefines the meaning of vacancy in terms of cultural and social viewpoints using everyday language and contemporary design, with the goal of identifying the potential value of vacancy that will help develop a new way of thinking about their place within a design framework for urban landscapes.

According to Berger (2006), the concept of *drosscape* refers to the need to find a way for dross, or waste, to be reshaped and reprogrammed for other purposes. Drosscapes are created as a by-product of the rapid urbanization described above, along with the resulting urban sprawl. Berger proposes an urban design framework that effectively treats urban areas as waster products of defunct economic and industrial processes. This approach is potentially very useful for those engaged in redesigning and re-using "waste landscapes" in the form of vacant land within urbanized regions who can utilize the concept of drosscapes to create alternative visions for space and landscape design in our cities.

Other researchers have suggested their own terms for vacant urban land. Although vacant urban lands are not officially designated as green spaces, they have often been left open to colonization by nature and thus appear to be in a semi-wild natural state (Kowarik & Körner, 2005). The term "left-over" has been used to denote their uncertain character in relation to other land uses, their apparent inactivity as opposed to being functional, productive spaces in the city; their physical form as voids amid the surrounding built environment; and their temporal dimension, as they often exist in the interval between changes in land use. Other terms used to describe them vary from the positive "urban wildscapes" to the less favorable "urban wastelands;" they may also be classified as "incidental amenity green space," or as "disturbed ground" under "other" semi-natural habitats in a proposed typology of urban green space (Dunnett, Swanwick & Woolley, 2002; Jorgensen & Keenan, 2011). Vacant urban land has also been termed "cracks in the city" and "lost space" (Loukaitou-Sideris, 1996; Trancik, 1986). These latter terms implicitly describe the particular management challenge that "spaces in-between" represent (Carmona & De Magalhaes, 2006).

2.3. The Potential Value of Vacant Land

The term "vacant land" frequently carries a negative connation – abandoned, empty, dangerous – and thus often to symbolizes disinvestment, blight and decay (Jakle & Wilson, 1992; Coleman, 1982). As a result, it is often automatically viewed as a problem in urban areas (Kremer et al., 2013). However, vacant land may also be viewed as valuable urban landscape that provides community benefits and/or opportunities for transformation via community redevelopment, as well as a source of ecosystem services that support the health and well-being of local people (Burkholder, 2012; Little, 2008). The experience of many in the U.S. suggests that vacant land represents a common and a substantial proportion of the urban landscape that is available for strategic reused in urban development policy (Bowman & Pagano, 2004). To avoid blight having an adverse impact on the surrounding community, vacant land could instead be used to provide long-term or interim beneficial services such as community gardens, wildlife gardens, public plantings and recreational areas (Bonham, Spilka, & Rastorfer, 2002). If vacant land is managed appropriately, it can contribute ecological and social benefits and more. A review of the literature regarding the potential value of vacant land in terms of its ecological and social benefits is provided in this section.

2.3.1. Ecological Value of Vacant Land

> *Vacant land can be a natural asset that creates enduring values for the community. A time when land is vacant can be an extraordinary opportunity to pause, look around, and invest in the environmental characteristics that initially attracted people to a place.*

> *Desirable environmental characteristics will be even more important in the future, as clean and abundant natural resources become rare and as more and more businesses locate where future employees are attracted to a pleasant place to live* (Nassauer & VanWieren, 2008, p.1).

Different types of vacant land habitats, such as vacant lots, abandoned industrial areas, the edges of parking lots, and alongside rail roads, highways and other right-of-ways, frequently support highly diverse plant and animal populations (Robinson & Lundholm, 2012). In Europe, many different types of vacant land have received attention, including refuse tips (Darlington, 1969), railway sites (Jehlik, 1986), road verges (Klimeš, 1987), wasteland (Sukopp, Blume & Kunick, 1979), and old town centers (Brandes, 1995) among others. In North America, remnant natural habitats are the focus of attention for urban ecologists, who look at more than uniquely urban plant communities (Hope et al., 2003). Ecological processes do take place in the vacant land in our cities (Bradshaw, 2003). Ecological succession lies at the heart of all urban landscapes, including vacant land (Alberti, 2008), although a history of local disturbance often leads to the type of successional dynamics that makes it difficult to predict future ecosystem structures and functions (Trepl, 1995) for particular restoration or planning goals. For example, some ecological studies of vacant land in Baltimore and Chicago found that the vacant land characteristics vary considerably in terms of species richness and variables such as lot age, size and level of isolation (Crowe, 1979; Tauzer, 2009). The development of different types of ecosystem services and benefits will thus inevitably also vary depending on the environmental conditions of the land, any surrounding natural habitats, the current and historical uses of the lot and the management practices utilized (Burkholder, 2012). From an urban ecology perspective, vacant urban land has a high potential as a valuable ecological resources that could take the form of agricultural land, forested areas, and open streams in urban areas (Zipperer & Pickett, 2012).

2.3.1.1. Ecosystem Services of Vacant Land

Ecosystem services are defined as the benefits people obtain from ecosystems and these can be broken down into four major areas: provisioning services (e.g. food production, water supply), regulating services (e.g. climate regulation, air pollution removal), cultural services (e.g. recreation, education), and supporting services (e.g. nutrient cycling, soil building) (Millennium

Ecosystem Assessment, 2005). A major driver for sources providing ecosystem services are land cover by vegetation and bare soil, both of which generally provide more ecosystem services related to the provision, regulation and support of ecosystem services than non-vegetated and impervious surfaces (Kremer et al., 2013). Research suggests that vacant land can provide ecological habitats for a wide range of plants, mammals, birds and insects, thus supporting biodiversity and urban wildlife health (Kamvasinou, 2011). Vacant land can also play a role in urban storm-water management and provide wetland plant communities that can help filter and disperse pollution, as well as adding to a city's green network systems by providing ecological corridors (Kamvasinou, 2011).

In the UK, Camley Street Natural Park in London is an example of this kind of function. It was created from an old coal yard in 1984 and now serves as an innovative and internationally acclaimed wildlife reserve on the banks of the Regent's Canal. In spite of its small size (2 acres), it "includes a diversity of habitats such as woodland, wildflower meadow, marsh, reed bed, garden bed and pond, which support an impressive list of plant and animal species" (Kamvasinou, 2011, p.159).

Figure 2.1 Camley Street Natural Park, UK (Source: London Wild Life Trusts, 2014 http://www.wildlifetrusts.org/reserves/camley-street-natural-park), permission to use granted by: London Wildlife Trusts (March. 26, 2015)

Also in London Gillespie Park contains different types of habitats, including a pond, woodland and natural grassland, which were created by extending an existing park onto a disused railroad, providing an unusually species-rich close to the center of the city (GLA, 2010). Traditionally, railroad tracks provide long wildlife corridor and the Northern Heights Parkland Walk through two London boroughs (Haringey Council, 2010) includes “over 200 species of wild flower and hedgehogs, foxes, butterflies and a vast array of birds recorded along the route” (Kamvasinou, 2011, p.160).

Figure 2.2 Gillespie Park, London, UK (Source: Björn Haglund, 2013 https://plus.google.com/108780968263965659960/about?gl=us&hl=en&pid=5873814854958761634&oid=103160020423874855730), used under fair use (April. 8, 2015)

Natur-Park Schöneberger Südgelände in Berlin contains a number of different types of habitats, some of which will continue to evolve over time. Other areas are maintained for their species richness, which can provide different opportunities for visitors to enjoy not only just scenery but also experience sequence of vegetation stages (Grosse-Bächle, 2005). All these examples demostratet vacant land’s potential value in terms of the ecosystem benefits it can provide, “including all the weeds, insects, and rodents which live together with men”: with minimal alterations to aid access and some signposting, many derelict spaces could become educational outdoor centers, taking over from the standard city park, which is "too specialized an environment for this purpose" (Lynch, 1995, p.407).

Figure 2.3 Natur-Park Schöneberger Südgelände, Berlin (Source: Thorsten Gall, 2011 https://plus.google.com/103573146092143554342/about?gl=us&hl=en&pid=5958908374459861074&oid=109759920116080534952), permission to use granted by: Thorsten Gall (March. 31, 2015)

Three or four years are long enough to introduce new woody species of pioneer trees and shrubs to vacant land, thus producing a significant urban ecosystem impact (Taylor, 2008). Healthy wildlife habitats can be created as safe sanctuaries where temporary wildscapes connect with a larger green infrastructure network. Taylor also points out that the colorful annuals that grow in vacant land can support large populations of insects and seasonal flocks of seed-eating birds, while herbaceous and flowering grassland areas provide an ideal habitat for small mammals and their predators. Other studies have suggested that vacant land can provide many more ecosystem services that other urban land uses such as gardens or lawns, including bio control[1] (Yadav, Duckworth, & Grewal, 2012), soil food web productivity[2] (Grewal et al., 2011), storm water retention services (Shuster et al., 2011), habitat provision services, and climate regulation and carbon capture (Robinson & Lundholm, 2012). Vacant land vegetation can be a very cost effective way of reducing the need for hard storm water management infrastructure and can also mitigate urban run-off by capturing a significant percentage of runoff (Crauderueff et al., 2012).

2.3.1.2. Vacant Land as Green Space

Historically, greening vacant lots for neighborhood improvement purposes have been conducted through a variety of policy mechanisms (Kremer et al., 2013). For example, there is a growing interest in supporting urban agriculture that encourages the planning of food crops on unproductive green spaces to foster food security and provide additional environmental benefits (Hodgson, Campbell & Bailkey, 2011; Ackerman, 2012). Vacant Lot Cultivation Associations facilitate gardening on vacant land and encourage the poor to grow food for sale and self-consumption (Lawson, 2005), and land trust lease and acquisition programs enable communities to maintain gardens (Bonham et al., 2002).In underserved neighborhoods, Cooperative Extension support for food production (Lawson, 2005) operate side-lot or "abutter" programs that encourage residents to manage the land between buildings, as well as a more recent integration of community garden and urban agriculture programs that is contributing to the creation of more sustainable planning processes (City of Philadelphia, 2010; Colasanti & Hamm, 2010; Seattle Department of Neighborhoods, n.d.).

These projects, all of which focus on the transformation of vacant land, are components of urban community comprehensive plans that also include waterfront park development, the

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[1] Biological control is a component of an integrated pest management strategy. It is defined as the reduction of pest populations by natural enemies and typically involves an active human role (Cornell University, 2014).

[2] The soil food web is the community of organisms living all or part of their lives in the soil. It describes a complex living system in the soil and how it interacts with the environment, plants, and animals (Ingham, 2014).

developments of greenways along railroads or post-industrial abandoned sites for bike and pedestrian pathways and the creation of city gateways (Bonham et al., 2002; City of Pittsburgh, 2012; The Greening of Detroit, 2012). Cities that have extensive experience of land abandonment, such as Baltimore, MD, Cleveland, OH, St. Louis, MO, and Flint, MI, have used vacant land by aggregating sites for productive uses or to create open and green spaces with the aid of government or quasi-governmental land banks (Alexander, 2005; US HUD, 2009; Wachter, Scruggs, Voith, & Huang, 2010). Green spaces provide numerous additional benefits such as improving air quality and public health, cooling the air, reducing the demand for air conditioning in hot weather, and supporting climate change adaptation (Rosenthal et al., 2008).

This literature review of the ecosystem services provided by vacant land suggests that vacant land supports many different types of ecosystem services and the benefits obtained depend on the environmental conditions, uses and management practices involved; where natural systems are established through ecological succession or intentional human intervention, ecosystem services are produced (Kremer et al., 2013). Vacant land does indeed contribute substantially to ecosystem services and the resulting benefits for local communities and could potentially contribute more if managed appropriately.

2.3.2. Social Value of Vacant Land

In most cases vacant land is viewed as a temporary economic problem by planners, designers and politicians alike. Other social and economic values of vacant land are seldom considered. Due to the general lack of knowledge about the value of vacant land, much of it remains underused and unappreciated. This situation presents especial challenges for shrinking cities such as Detroit, Michigan, and Buffalo. The potential for vacant land to provide social benefits for the surrounding community that would allow the general public to understand the importance of transforming vacant land into culturally productive landscapes is very real, however. Recent studies suggest that in shrinking cities such as Detroit, Cleveland and Philadelphia the use of vacant lots for urban agriculture has significant potential to contribute to meeting the food needs of the local population, at the same time helping to build the local economiy, and support social resilience (Colasanti & Hamm, 2010; Grewal & Grewal, 2012; Kremer, 2011). Community gardens, open spaces and other urban greening sites provide not only ecological amenities such as food, climate regulation and storm water mitigation, but also cultural value (Saldivar-Tanaka & Krasny, 2004). There is a strong relationship between ecological and social value; as communities transformed unsafe and esthetically unpleasant vacant lots into community gardens or other sites of community engagement, the resilience of the coupled social-ecological system is expected to increase and emerge in most cases (Folke, 2006; Tidball & Krasny, 2007).

2.3.2.1. Vacant Land as Public Space

Vacant land presents an alternative to contemporary public spaces because even when vacant land is privately owned, local people have easy access and it can thus "accommodate a variety of social groups, including marginalized types, creative industries and artists, or just young people hanging around in a place where they feel less under public scrutiny, families with kids enjoying some contact with nature that does not cost a fortune" (Kamvasinou, 2011, p.160). Research suggests that external space is perceived as "public" when it is easy to access; its ownership or management is irrelevant (Carmona & DeMagalhaes, 2006, p.85). Public space does not require high costs or impressive design, but rather space for people's activities, enabling them to enjoy social interactions that certain types of public spaces encourage, even if some public spaces do not have remarkable design, or are untidy and self-regulated places such as street markets (Holland, Clark, Katz & Peace, 2007; Worpole & Knox, 2008). Vacant land provides "adventure playgrounds" (Kamvasinou, 2011) and are generally favorable to "constructing, adapting, destroying and growth cycles", hence welcoming woody scrubland and activities such as climbing a tree, playing in tall grass, playing hide and seek among bushes, picking and tasting leaves, flowers or berries, all of which encourage children to take control over their environment (Greenman, 1988; Thompson, 2002; Woolley, 2003).

Gillespie Park in the UK acts as just such a social and natural hub, providing a visitor and education center that is visited by large number of schoolchildren and holding a community festival once a year with over 2000 people attending (GLA, 2010). It provides opportunities for people to engage in cultural activities, such as blackberry picking or decorating the trees with jewelery, prayers and other objects (Tylecote, 2008). Vacant land can accommodate a wide range of different activities that are not typically permitted in official public spaces, such as skateboarding, graffiti and dirt biking, as well as community gardens and urban agriculture

(Kamvasinou, 2011). Vacant land can provide creative uses such as for instance farmer's markets and garage sales, all of which add color and life to neighborhoods, with activities that "could deliver local skills and products which outlive the sites and remain as a long-term legacy" (Taylor, 2008, p.5). In other cases, the reuse of post-industrial sites occur "for commercial, artistic, athletic, leisure and community activities, with permission from owners and planning authorities but with a limited amount of renovation" for "longer term or more organized forms of occupancy" (Frank & Stevens, 2007, p.231). As a result, the social dimension of vacant land matches that of "loose space", describing people's experience of unofficial spontaneous activities in public spaces in order to appropriate them (Franck & Stevens, 2007).

2.3.2.2. Vacant Land as Open Space

Vacant land contributes open space in dense city areas, where it provides a resting area, important distant views, and a visual connection with other parts of the city in a way that is more effective than other densely planted parks or woods areas (Kamvasinou, 2011). Open space is an important component of the built environment as a "void" physical form that provides openness for accessibility in the city mass. In psychological terms, openness is "associated with freedom, a loosening of control and regulation, adventure and play" (Kamvasinou, 2011, p.161). According to Lynch, "openness of open space" is a fundamental aspect of the planning of cities, going on to explain that "open" means:

> *free to be entered or used, unobstructed, unrestricted, accessible, available, exposed, extended, candid, undetermined, loose, disengaged, responsive, ready to hear or see as in open heart, open eyes, open hand, open mind, open house, open city. Open spaces in this sense are all those regions in the environment which are open to the freely-choosen and spontaneous actions of people: public meadows and parks, but also unfenced vacant lots and abandoned waterfronts. These areas may be open to many kinds of activity, as a sandbank or a grassy slope; or kinds of movement, as a prairie or unobstructed wood; or to the roving eye, as a vista or the open sky* (1995, p.396).

In practice, vacant land can serve as an important component of urban storm water management plans, helping cities deal with the type of heavy rainfall and flooding that is becoming more common due to climate change, as well as providing more environmentally attractive options such as, for instance, "the production of nursery stock that could be used for planting the permanent landscapes of surrounding development"; at strategic scale city planning, vacant land can also contribute to a wider green infrastructure network of open spaces (Kamvasinou, 2011; Taylor, 2008). According to Lynch, "a network of relatively small spaces, well distributed within the urban system, may be more useful than the large tracts which look so well on land-use maps" (1995, p.400). For example, England had such a network that integrated brownfield sites totaling 62000 ha in 2006, with half classed as either derelict or vacant (Taylor, 2008). Rather than insisting that 72% of housing development take place on brownfield sites, some parts of this land needs to be considered in terms of their potential open space benefits (Kamvasinou, 2011). An official UK government White Paper policy document notes that land that was hitherto considered wasted space does have a potential value, advocating a goal of "bringing previously-developed land and empty property back into beneficial economic or social use, so that they contribute to, rather than detract from, the urban fabric" (DCLG, 2000, p.52).

As part of a city-wide network, vacant land provides different types of open space that "extend choice" from the "approved formal garden and manicured park" and also provide walking, bicycle or riding trails, generating an alternative way of exploring and learning about the city and its ecology (Lynch, 1995, p. 400-401, 407). However, vacant land is not always perceived as "positive", instead being thought of as a "blight on the urban landscape, or as a wasted opportunity, especially in densely populated urban areas with less open space" (Kamvasinou, 2011, p.161-162). They are often considered "high-risk areas, or wasted lands, in particular when populated by marginal social groups and evidence of neglect such as litter, dumped cars and industrial waste"; however once the dangerous conditions are removed, they can be positively repurposed "as adventure playgrounds, urban wilderness, breathing space or ecological havens" (Kamvasinou, 2011, p.162). Furthermore, with low-key intervention and light management, "which allow vegetation by and large 'to grow on its own,' they have positive economic implications compared to traditional parks and, in the current economic climate, may well present not only a sensible and aesthetically pleasing solution, but also the only financially possible way" (Gross-Bächle, 2005, p.244; Kamvasinou, 2011, p.162).

2.3.2.3. Vacant Land as Community Garden

Several cities across the U.S. have implemented greening programs on vacant lots, including New York, Detroit, Cleveland, Syracuse, Nashville, and Philadelphia. The City of Philadelphia has one of the most ambitious plans to manage greening vacant lots; the Green City, Clean Waters green storm water infrastructure plan (Crauderueff et al., 2012). Philadelphia has devoted considerable effort to rediscovering vacant land as a resource for social benefit (Bowman & Pagano, 2004). The city has tens of thousands of vacant parcels and abandoned structures and the Pennsylvania Horticultural Society (PHS) is one of the leaders in the "rethinking vacant land" movement (Bowman & Pagano, 2004):

> *Instead of blighting influence, vacant land can become an urban amenity. It can be converted into parks, community gardens, recreation areas, private yards, "commons" for new housing developments, managed fields, off-street parking, and other public open space. Vacant land can be incorporated into the fabric of neighborhoods, allowing city residents to enjoy the lower-density lifestyles sought by migrants to the suburbs* (Bonham & Spilka, 1995, p19).

The Philadelphia greening program not only focuses on converting vacant lots into community gardens, but also hopes to awaken community spirit and commitment (Bowman & Pagano, 2004) in the form of community engagement. During the process of caring for community gardens, residents are able to develop strong relationships with their neighbors and consequently feel more attachment to their community. Jane Schukoske stated that "Community gardens build social capital not only by reclaiming or preserving urban space, but also by fostering collaboration among nearby residents across racial and generational lines" (1999, p.357).

To achieve this goal, Philadelphia introduced multi-sector collaborations with the Philadelphia Water Department (PWD), the Philadelphia Parks and Recreation Department (PPR), and the Pennsylvania Horticulture Society (PHS) to manage the greening program and a land bank run by a non-profit organization. PHS's Philadelphia LandCare (LandCare) program was created to acquire, manage and dispose of the vacant land (Crauderueff et al., 2012). The Philadelphia Redevelopment Authority (PRA) provides a "one-stop shop" to coordinate the transactions related to vacant land owned by the Philadelphia Department of Public Property, the Philadelphia Housing Development Corporation, and the PRA (City of Philadelphia Redevelopment Authority, 2009). This close collaboration between multiple agencies including governmental organizations, nonprofit organizations, and community organizations are essential elements of the city's plan to manage vacant lots in the City of Philadelphia.

PWD works closely with civic groups, watershed partnerships, neighborhood organizations and the City Council to identify and prioritize the greening of vacant lot in the city. It also works with other planning bodies, such as the Planning Commission, PPR and the Mayor's Office of Transportation and Utilities (Crauderueff et al., 2012). PHS's Philadelphia LandCare program converts vacant lots to green clean spaces with the goal of improving and stabilizing neighborhoods by cleaning up vacant lots and bringing in top soil, planting grass, surrounding the lot with a three foot high post and rail fence, and maintaining the green spaces created. The LandCare program, which began in 2004, currently maintains approximately 7,000 parcels with a total of 8 million square feet and greening treatments are funded through Federal Housing and Urban Development programs which maintenance is funded by the City's general revenue funds through a contract with the Office of Licenses & Inspections (L&I) (Crauderueff et al., 2012). Three quarter of the vacant lots in Philadelphia are privately owned but PHS is granted legal access to these lots to maintain them due to L&I code violations; PHS has now greened approximately 15% of the city's vacant lots, although this is intended to be temporary. Many sites are large enough to be considered parks in their own right (a minimum of 1/4 acre in size) and between 10% and 20% of the parcels that are at least 1/4 acres in size that are maintained by PHS are utilized as general public parks. PHS has strong partnerships with numerous community groups and maintenance of the sites is carried out by landscape contractors. The Neighborhood Garden Association in the same city is a land trust that owns several community gardens, but it has not expanded its role due to the limited funding available (Crauderueff et al., 2012).

There are similar community garden programs in a number of other U.S. cities. In the 1980s, Boston's Dudley Street neighborhood was suffering from problems due to its high percentage of vacant properties, about 21% of all property (Bowman & Pagano, 2004). However, the area has now dramatically improved as a result of the creation of a community land trust to manage the vacant land as gardens. This approach is becoming very popular; for instance, Atlanta has its Community Gardening Initiative; Chicago has established Greencorps, and New York operates a Green Thumb program (Bowman & Pagano, 2004).

Atlanta Regional Commission inaugurated its Senior Community Garden Initiative in 2010, establishing 11 community gardens and providing nutrition education and cooking classes with the goal of encouraging seniors to have healthier lifestyles by increasing their access to fresh fruits and vegetables, as well as providing opportunities for elderly people to engage in more social interactions (Atlanta Regional Commission, 2014). This community garden is supported by multiple agencies, including the Federation of Southern Cooperatives Land Assistance Fund, University of Georgia Cooperative Extension, Open Hand and Aging Network. The Federation of Southern Cooperatives support planning, planting and sustaining the community gardens and each garden is funded by seed money, which supports garden soil and soil amendments, lumber and other supplies for the beds and structures needed to support the garden, plants and seeds, gardening tools, watering hoses and other irrigation equipment. The benefits of community garden include improving the quality of life for people in the garden and providing a catalyst for neighborhood and community development (Atlanta Regional Commission, 2014).

Greencorps in Chicago provides green industry jobs that include training for practical experience, academic enhancement, professional development and in a variety of environmentally-related jobs that involve skills such as horticulture, urban agriculture, tree care, landscaping, carpentry, ecological restoration, Integrated Pest Management (IPM) and many other topics (City of Chicago, 2014a). Greencorps Chicago maintains and restores natural and public spaces that are safe, healthy and sustainable to promote environmental stewardship and improve the quality of life for local residents. Public and private partnerships, along with strong government support are the important elements contributing to the success of this project and the outcome is healthier, safer and more engaged communities and individuals who can experience environmental stewardship through their field experience and train for a variety of environment related jobs (City of Chicago, 2014a). The training is delivered in cooperation with the Chicago Park District, The Forest Preserve District of Cook County and other public and community partners.

Figure 2.4 Greencorps Chicago (Source: City of Chicago, 2014a from https://www.facebook.com/254395609920/photos/pb.254395609920.-2207520000.1409944709./10152490899189921/?type=3&theater), used under fair use (April. 8, 2015)

New York City's Green Thumb program is the largest community gardening program in the nation. Due to the many private and public lots that were abandoned during the city's financial crisis in the 1970s, the Green Thumb program was created to renovate derelict land using volunteers (NYC Parks GreenThumb, 2014). The community gardens provide important green spaces, thus improving air quality, bio-diversity, and the social well-being of residents. The gardens are also important community resources and the Green Thumb program provides technical and material support to over 600 community gardens in New York City. Workshops are held every month to teach basic gardening skills, along with more advanced farming and community organizing topics (NYC Parks GreenThumb, 2014).

Nationwide, there were estimated to be over 350 community gardening programs in 1995 (Bonham & Spilka, 1995) and this number is doubtless now considerably higher. However, the success of community garden programs has resulted in another problem. As community gardens on vacant land become popular, the potential for development is also increased. For example, in 2002, New York City announced plans to sell 131 gardens for development as affordable housing sites (Gowda, 2002). As a result, community activists and gardeners protested the proposal until city officials provided a more acceptable alternative plan for community gardens. "Community garden preservation was not simply the flowers and vegetables grown in the gardens but also the social connection created by their presence" (Bowman & Pagano, 2004, p.118). Caring for the vacant land is another form of ownership that increases people's engagement to vacant land and also promotes neighborhood identity.

2.3.3. Economic Benefits of Vacant Land

Vacant land deters investment but imposes costs on the community and public sector bodies for maintaining the vacant properties (Crauderueff et al., 2012). Consider the situation in Philadelphia, where vacant land decreases property values by 20% and costs the city of Philadelphia $20 million each year in maintenance; 17,000 of the city's 40,000 vacant parcels are also tax delinquent, with 11,000 having been so for more than 10 years. As a result, the city loses a minimum of $2 million of revenue annually (Econsult et al., 2010). However, PHS's program of greening vacant lots is promoting environmental and social-wellbeing and also supporting economic development (Crauderueff et al., 2012).

According to EPA's Consent Order, the City of Philadelphia plan to invest $1.2 billion in a green infrastructure system to manage urban storm water management over the next 25 years (Crauderueff et al., 2012). This plan aims to capture the first inch of rain in a green infrastructure that covers approximately one-third of the existing pervious land in the city's combined sewage drainage areas (City of Philadelphia, Philadelphia Water Department, 2011). Approximately, 60% of Philadelphia has combined sewers (Neukrug, 2009), so if the plan succeeds, the city can effectively control very large amounts of urban storm water. The city has also developed a land bank to focus on the acquisition, management and disposition of vacant land for its Green 2015 plan, which aims to increase public open space by 500 acres by 2015. As part of this effort, Pennsylvania House Bill 1682 was signed into law to allow municipalities in the state to create land banks to manage vacant lots on October 24, 2012 (Crauderueff et al., 2012; The Pennsylvania General Assemble, 2012). According to a study by Penn Praxis (2010) although

200,000 Philadelphians do not live within a half a mile of public green space, the researchers identified 558 acres of publically owned vacant lots at least 1/4 acre in size, and a further 1257 acres of privately owned vacant parcels larger than 1/4 acre. This suggests that these vacant parcels have the potential to be transformed into public green space to achieve the goal of PPR's Green 2015 Plan to provide additional green space benefits.

Research indicates that Pennsylvania Horticulture Society (PHS)'s program of greening vacant urban land has significantly improved the economic and social well-being of local neighborhoods by encouraging reinvestment (Crauderueff et al., 2012). There has also been a statistically significant decrease in gun violence in these neighborhoods over a ten year time frame (Branas et al., 2011). An economic study by the PRA estimated that homes within 1/4 mile of one of PHS's greened vacant lots has increased in value by 2% to 5% annually, equivalent to $35,000 over five years, generating an additional $100 million in annual property taxes for the city. The study estimated that each public dollar invested in the LandCare clean and green program returns $7.43 dollars of tax revenues (Gillen, 2012).

2.4. Urban Forest Assessment

Urban forest assessment is essential for developing a baseline from which to measure changes and trends. Managing the urban forest includes tree maintenance, policy development, and budgetary decisions – all of which depend on understanding current urban forest conditions (Ciecko, Tenneson, Dilley & Wolf, 2012). This can be accomplished using indicators of forest health or structure, such as the number of plants, their location, species mix, and age distribution (Ciecko et al., 2012). Cities across the United States have undertaken urban forest assessment projects using both on-the-ground measurements and remote sensing analysis (Ciecko et al., 2012). An accurate quantification of urban forest can help to understand the various ecosystem services and values it provides (Nowak et al., 2008b). Urban forest, particularly trees, can provide numerous ecological and social benefits to improve environmental quality and human health and well-being in urban areas (Nowak et al., 2008b). These benefits include improvements in air and water quality, energy conservation, cooler air temperatures, reductions in ultraviolet radiation, and many other environmental and social benefits (Nowak & Dwyer, 2007). Given accurate information on the urban forest structure (i.e., species composition, number of trees, tree sizes and locations, tree health), managers and planners can easily understand the current ecosystem services provided by the urban forest and adjust its structure via tree plantings, species and site selections, and tree maintenance and removals) to enhance these benefits in the future (Nowak et al., 2008b). From this perspective, to assess the ecosystem services and values derived from urban vegetation, an assessment of the urban forest on vacant land is necessary to demonstrate how the vacant urban land function as a green infrastructure that provides ecosystem services and values to society.

An urban forest can be defined as the individual trees and groves that are found in and around the place we live. This includes forested parks and natural areas, as well as the trees along streets and in yards (Ciecko et al., 2012). For the purposes of the current research, vacant land is considered part of the urban forest, including trees, shrubs and ground cover types. Assessment of the urban forest can be performed to estimate the environmental benefits and ecosystem services provided, improving our understanding of the role trees play in creating healthy, livable and sustainable cities (Ciecko et al., 2012). Urban forest structure (e.g. number of trees, species composition, tree size, health, tree location) can provide useful information for estimating the total leaf area, tree and leaf biomass, and quantifying numerous ecosystem services and forest functions (Nowak et al., 2008a). Accurate urban forest assessments are critical for good urban forest management and planning to help sustain and enhance environmental health and human health and well-being in cities (Nowak et al., 2008a). Though urban forests have many functions and values, currently only a few of these attributes can be accessed due to our limited ability to quantify all of these values through standard data analyses (Nowak et al., 2011).

The most precise way to assess urban forests is to measure and record every tree on a site, but although this may work well for relatively small populations (e.g., street trees, small parks), it is prohibitively expensive for large tree populations (Nowak et al., 2008a). Thus, random sampling offers a cost-effective way to assess urban forest structure and ecosystem services for large-scale assessments (Nowak et al., 2008a). Increasing numbers of comprehensive assessments of urban forest structure are now being conducted using sampling techniques (e.g., McBride & Jacobs, 1976, 1986; Miller & Winer, 1984; Nowak, 1991; McPherson, 1998; Nowak & O'Connor, 2001). To better understand the urban forest resources and its numerous values, the U.S. Forest Service, Northern Research Station, developed the Urban Forest Effects (UFORE) model, which is now known and distributed as i-Tree Eco (i-Tree Canopy, 2011). This model was developed to aid in assessing urban forest structure, functions, and values (Nowak & Crane, 2000) and contains protocols to measure and monitor urban forest structure as well as estimate ecosystem functions and economic values (Nowak et al., 2008a). The i-Tree Eco model has been used in approximately 50 cities across the globe to assess urban forest structure and functions using a standardized approach (e.g., Nowak & O'Connor 2001; Nowak, Crane & Dwyer, 2002a; Ham, 2003). The research conducted for this dissertation utilized i-Tree Eco to assess vacant urban land forest structure and ecosystem services in the City of Roanoke, Virginia.

2.4.1. i-Tree Eco

The i-Tree Eco computer model was developed to help managers and researchers quantify urban forest structure and functions based on standard inputs of field, meteorological, and pollution data (Nowak & Crane, 2000). The model currently calculates the following parameters based on local measurements:

- urban forest structure (e.g., species composition, tree cover; tree density, tree health [crown deterioration; tree damage], leaf area, leaf biomass; information on shrub and ground cover types);
- hourly urban forest volatile organic compound emissions (emissions that contribute to ozone formation);
- hourly pollution removal by the urban forest and associated percent improvement in air quality (ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 10 microns);
- effects of trees on building energy use and carbon dioxide emissions;
- relative ranking of species effects on air quality;
- total carbon stored and net carbon sequestered annually by urban trees;
- pollen allergy rating for the species composition;
- exotic species composition; and
- tree transpiration (Nowak, Crane, Stevens & Hoehn, 2003, p.2)

i-Tree Eco analyses can be based on a sample of an area (e.g., an entire city or neighborhood) or an inventory of trees (e.g. street trees). Model outputs are given for the entire population and individual trees measured (Nowak et al., 2003). Results from the i-Tree Eco model are used to understand the urban forest structure in order to improve urban forest policies, planning, and management (Nowak et al., 2011). This data also provides support for the potential inclusion of trees within environmental regulations, and to determine how trees affect the environment and, consequently, enhance human health and environmental quality in urban and rural areas (Nowak et al., 2011). i-Tree Eco is a relatively new tool that will enable us to assess vacant urban land forest structure and ecosystem services in the City of Roanoke, Virginia.

2.4.2. i-Tree Eco Data Requirements

2.4.2.1. Field Data Collection Variables

There are four general types of data collected on a i-Tree Eco plot: 1) general plot information (Figure 2.5), which is used to identify the plot and its general characteristics; 2) shrub information (Figure 2.6), which is used to estimate shrub leaf area/biomass, pollution removal, and volatile organic compound (VOC) emissions by shrubs; 3) tree information (Figure 2.7), which is used to estimate forest structural attributes, pollution removal, VOC emissions, carbon storage and sequestration, energy conservation effects, and potential pest impacts of trees; and 4) ground cover data, which is used to estimate the amount and distribution of various ground cover types in the study area (Nowak et al., 2008a).

Variable	Description
Plot ID[z]	Unique identifier
Plot address[y]	
Date and crew	
Photo number	Used to help identify plot
Measurement units[z]	Units for all measurement in the plot; metric (m/cm) or English (ft/in)
Reference objects[y]	At least two objects that will assist in locating plot center for future plot remeasurements
Distance to reference object[y]	Distance from plot center to each reference object (ft or m)
Direction to object[y]	Direction from plot center to each reference object (degrees)
Tree measurement point (TMP)[y]	If plot center falls on a building or other surface (such as a highway) where plot center cannot be accessed, the plot is not moved; all distances and directions to trees are measured and recorded from a recorded fixed point (e.g., building corner) referred to as the TMP
Percent measured[z]	Proportion of the plot that is actually measured as portions of plot may be denied access
Land use[z]	As determined by crew in the field from a standard list of land uses
Percent in[z]	Proportion of the plot in each land use to nearest 1%
Tree cover[z]	Percent of plot area covered by tree canopies estimated to nearest 5%
Shrub cover[z]	Percent of plot area covered by shrub canopies estimated to nearest 5%
Plantable space	Percent of plot area that is plantable for trees (i.e., plantable soils space not filled with tree canopies) and tree planting would not be restricted as a result of land use (footpath, baseball field, and so on); to nearest 5%

[z]Required for UFORE analysis.
[y]Required for permanent reference of plot.
UFORE = Urban Forest Effects.

Figure 2.5 Plot Information for the i-Tree Eco Model (Nowak et al., 2008a, p. 348), Reprinted from Arboriculture & Urban Forestry, 34(6), D. J. Nowak, D. E. Crane, J. C. Stevens, R. E. Hoehn, J. T. Walton, J. Bond, A ground-based method of assessing urban forest structure and ecosystem services, pp. 347-358, Copyright (2008), with permission from the International Society of Arboriculture.

Variable	Description
Species code	Species code from standard list currently containing over 10,000 tree and shrub species
Average height of mass	Where mass is a group of shrubs species or genera of similar height (ft or m)
Percent area	Percent of total shrub cover on plot occupied by shrub mass
Percent shrub mass missing	Percent of shrub mass volume (height × ground area) that is not occupied by leaves; estimated to nearest 5%

UFORE = Urban Forest Effects.

Figure 2.6 Shrub Information for the i-Tree Eco Model (Nowak et al., 2008a, p.349), Reprinted from Arboriculture & Urban Forestry, 34(6), D. J. Nowak, D. E. Crane, J. C. Stevens, R. E. Hoehn, J. T. Walton, J. Bond, A ground-based method of assessing urban forest structure and ecosystem services, pp. 347-358, Copyright (2008), with permission from the International Society of Arboriculture.

Variable	Description
Tree ID	Unique tree number
Distance (ft/m) and direction (degrees) from plot center or TMP[z]	Used to identify and locate trees for future measurements; TMP is tree measurement point (Table 1)
Species code[y] (A, C, E, S, V)	Species code from standard list currently containing over 10,000 tree and shrub species
Number of dbhs recorded[y]	For multistemmed trees
Dbh[y] (C, S)	Diameter at breast height (in/cm) for all recorded stems
Dbh measurement height	Recorded if dbh is not measured at 1.37 m (4.5 ft)
Total height[y] (A, C, E, S, V)	Height to top of tree (ft/m)
Height to crown base[y] (A, S, V)	Height to base of live crown (ft/m)
Crown width[y] (A, S, V)	Recorded by two measurements: N-S (north–south) and E-W (east–west) widths (ft/m)
Percent canopy missing[y] (A, S, V)	The percent of the crown volume that is not occupied by leaves; two perpendicular measures of missing leaf mass are made and the average result is recorded; recorded to nearest 5%
Dieback[y] (C,E, S)	Percent crown dieback to nearest 5%
Percent impervious beneath canopy (H)	Percent of land area beneath entire tree canopy's drip line that is impervious
Percent shrub cover beneath canopy (H)	Percent of land area beneath canopy drip line that is occupied by shrubs
Crown light exposure[y] (C, S)	Number of sides of the tree receiving sunlight from above; used to estimate competition and growth rates
Distance (ft/m) and direction (degrees) to space-conditioned residential buildings[y] (E)	Measured for trees at least 6.1 m (20 ft) tall and within 18.3 m (60 ft) of structures three stories or less in height
Street tree	Y/N; used to estimate proportion of population that is street trees
Tree status	Indicates if tree is new or removed from last measurement period

[z]Required for permanent reference of plot.
[y]Required for UFORE analysis.
Variable used to assess: A = air pollution removal; C = carbon storage/sequestration; E = energy conservation; H = hydrologic effects; S = structural information; V = VOC emissions.
UFORE = Urban Forest Effects.

Figure 2.7 Tree Information for the i-Tree Eco Model (Nowak et al., 2008a, p.349), Reprinted from Arboriculture & Urban Forestry, 34(6), D. J. Nowak, D. E. Crane, J. C. Stevens, R. E. Hoehn, J. T. Walton, J. Bond, A ground-based method of assessing urban forest structure and ecosystem services, pp. 347-358, Copyright (2008), with permission from the International Society of Arboriculture.

2.4.2.2. Meteorological and Air Quality Data

Hourly weather data are collected to analyze air pollution removal by the urban forest, such as volatile organic compound emissions, air pollution removal by the urban forest, relative ranking of species' effects on air quality and tree transpiration (Nowak et al., 2003). i-Tree Eco includes default weather and air quality data for users in the U.S., Canada, and Australia so users will not need to obtain these data (Nowak et al., 2003). Hourly pollution concentration data are required to analyze air pollution removal by the urban forest and relative ranking of species effects on air quality (Nowak et al., 2003). For U.S. users, air quality and weather data are for the year 2005. Canadian Eco projects are processed with default weather and air quality data from 2010 (Nowak et al., 2003).

2.4.3. Carbon Storage and Annual Sequestration

To calculate current carbon storage, the biomass for each tree is calculated using allometric equations from the literature and measures of tree data (Nowak 1994; Nowak et al., 2002a). Equations that predict aboveground biomass are converted to whole tree biomass based on a root-to-shoot ration of 0.26 (Cairns et al., 1997). Equations that compute fresh weight biomass are multiplied by species- or genus-specific conversion factors to yield dry weight biomass (Nowak et al., 2008a). These conversion factors, derived from average moisture contents of species given in the literature, average 0.48 for conifers and 0.56 for hardwoods (Nowak et al., 2002a).

Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak, 1994). To adjust for this difference, biomass results for open-grown urban trees are multiplied by 0.8 (Nowak, 1994). No adjustment is made for trees found in natural stand conditions (e.g., on vacant lands or in forest preserves). Because deciduous trees drop their leaves annually, only carbon stored in wood biomass is calculated for these trees (Nowak et al., 2008a). Total tree dry weight biomass is converted to total stored carbon by multiplying by 0.5 (Forest Products Laboratory, 1952; Chow & Rolfe, 1989).

Multiple equations are combined to create a single predictive equation for a wide range of diameters for individual species (Nowak et al., 2008a). The process of combining the individual formulas (with limited diameter ranges) into one more general species formula produces results that are typically within 2% of the original estimates for total carbon storage of the urban forest (i.e., the estimates using the multiple equations) (Nowak et al., 2008a). Formulas are combined to prevent disjointed sequestration estimates that can occur when calculations switch between individual biomass equations (Nowak et al., 2008a).

If there are no allometric equations available for an individual species, the average for species from the same genus is used (Nowak et al., 2008a). If there is no genus equation, the average for all broadleaf or conifer equations is used (Nowak et al., 2008a). To estimate the monetary value associated with urban tree carbon storage and sequestration, carbon values are multiplied by $20.7/ton of carbon based on the estimated marginal social costs of carbon dioxide emission for 2001 to 2010 (Fankhauser, 1994).

2.4.4. Urban Tree Growth and Carbon Sequestration

Urban tree growth rate is based on the length of the growing season: urban street tree (Fleming, 1998; Frelich, 1992; Nowak, 1994), park trees (deVries, 1987), and forest growth estimates (Smith & Shifley, 1984) are standardized to growth rates for 153 frost-free days based on: standardized growth = measured growth x (153/number of forest-free days of measurement) (Nowak et al., 2008a). Average standardized growth rates for street (open-grown) trees are taken to be 0.83 cm/year (0.33 in/year) (Nowak et al., 2008a). Growth rates of trees of the same species or genera are then compared to determine the average difference between standardized street tree growth and standardized park and forest growth rates (Nowak et al., 2008a). Park growth averages 1.78 times less than street trees, and forest growth 2.29 times less than street tree growth (Nowak et al., 2008a). Base growth rates are adjusted based on tree conditions. For trees in fair to excellent condition, base growth rates are multiplied by 0.76, critical trees by 0.42, dying trees by 0.15, and dead trees by 0 (Nowak et al., 2008a). Adjustment factors are based on percent crown dieback, with the assumption that less than 25% crown dieback exerts only a limited effect on Diameter at Breast Height (DBH) growth rates (Nowak et al., 2008a). To estimate the gross amount of carbon sequestered annually, the average diameter growth from the appropriate genera and diameter class and tree condition is added to the existing tree diameter (year x) to estimate the tree diameter and carbon storage in year x+1 (Nowak et al., 2008a). Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (Interagency Working Group on Social Cost of Carbon United States Government, 2010) and converted to the local currency using user-defined exchange rates.

2.4.5. Air Pollution Removal

In most cities, air pollution is a major environmental issue and a concern related to global climate change (Nowak, Crane & Stevens, 2006). Nationally, urban trees and shrubs remove significant amounts of air pollutants and consequently improve environmental quality and human health and well-being (Nowak et al., 2006). Trees can remove gaseous air pollution via leaf stomata, through some gases are removed by the plant surface. Trees also intercept airborne particles and can absorb some particles, though most particles that are intercepted are retained on the plant surface. These particles are then either resuspended to the atmosphere or washed off by rain onto the ground. Consequently, vegetation is only a temporary retention site for many atmospheric particles (Nowak et al., 2006). To investigate the magnitude of air pollution removal by urban trees, computer modeling of air pollution removal of carbon monoxides (CO), nitrogen dioxide (NO_2), ozone, particulate matter less than 10 μm (PM_{10}) and sulfur dioxide (SO_2) has been performed for 55 U.S. cities and for the entire nation based on meteorological, pollution concentration, and urban tree cover data (Nowak et al., 2006). Air pollution removal estimates are derived from calculated hourly tree-canopy resistance for ozone, and sulfur and nitrogen dioxides based on a hybrid of the big-leaf and multi-layer canopy deposition models (Baldocchi, 1988; Baldocchi, Hicks & Camara, 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants are based on average measured values from the literature (Bidwell & Fraser, 1972; Lovett, 1994) and adjusted depending on leaf phenology and leaf area. Particulate removal incorporates a 50% re-suspension rate of particles back to the atmosphere (Zinke, 1967). Recent updates (2011) to air quality models are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi, 2011, 2012; Hirabayashi, Kroll & Nowak, 2011, 2012). National median externality costs are used to calculate the value of carbon monoxide removal and particulate matter less than 10 microns and greater than 2.5 microns (Murray, Marsh & Bradford, 1994).

2.4.6. Building Energy Effects

The seasonal effects of trees on residential building energy use are calculated based on procedures described in the literature (McPherson & Simpson, 1999) using the distance and direction of trees from residential structures, tree height and tree condition data. Distance and direction to the building is recorded for each tree within 18.3m (60 ft) of two- or one-story residential buildings (Nowak et al., 2008a). Any trees that are smaller than 6.1m (20 ft) in height or farther than 18.3 m (60ft) from a building are not considered to have an effect on building energy use (Nowak et al., 2008a). Using the tree size, distance, direction to building, climate region, leaf type (deciduous or evergreen), and percentage cover of buildings and trees on the plot, the amount of carbon avoided from power plants as a result of the presence of trees can now be calculated (Nowak et al., 2008a). As a result of tree energy effects, the amount of carbon avoided is categorized into the amount of MWh (cooling) and MBtus and MWh (heating) avoided (Nowak et al., 2008a). Default energy effects per tree are created based on each climate region, vintage building types (period of construction), tree size class, distance from building, energy use (heating or cooling), and leaf type (deciduous or evergreen), depending on the energy effect of the tree (tree shade, windbreak effects, and local climate effect) (McPherson & Simpson, 1999). Default shading and climate effect values are applied to all trees; heating windbreak energy effects are assigned to each evergreen tree (Nowak et al., 2008a). Because shading effect default values are given for only one vintage building type (post-1980), vintage adjustment factors (McPherson & Simpson, 1999) are applied to obtain shading effects values for all other vintage types (Nowak et al., 2008a). To calculate the monetary value of energy saving, local or custom prices per MWH or MBTU are utilized.

2.4.7. Structural Value

Urban forests have a structural value based on the tree themselves (e.g., the cost of having to replace a tree with a similar tree). The structure value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al., 2002b). The structural values of the trees (Nowak et al., 2002a) are based on the valuation procedures utilized by the Council of Tree and Landscape Appraisers (1992), which uses tree species, diameter, condition, and location information. Compensatory value is based on four tree/site characteristics: trunk area (cross-sectional area at DBH), species, condition, and location (Nowak et al., 2008a). Trunk area and species are used to determine the basic value, which is then multiplied by condition and location ratings (0 to 1) to determine the final tree compensatory value (Nowak et al., 2008a). Local species factors, average replacement cost, and transplantable size and replacement prices are obtained from International Society of Arboriculture (ISA) publications (Nowak et al., 2008a). If no species data are available for the state, data from the nearest state are used and condition factors are based on percentage crown dieback (Nowak et al., 2008a). According to ISA (1998), appropriate land use location factors are: golf course = 0.8; commercial/industrial, cemetery, and institutional = 0.75; parks and residential = 0.6; transportation and forest = 0.5; agriculture = 0.4; vacant = 0.2; wetland = 0.1.

2.4.8. i-Tree Eco Limitations

The main advantages of the i-Tree Eco model are that it uses locally measured field data and the best available peer-reviewed procedures to estimate urban forest ecosystem functions (Nowak et al., 2008a). Also, this program is publically available, and technical support is available through i-Tree (Nowak et al., 2008a). However, i-Tree Eco also has limitations. Urban forest ecosystem function' quantification procedures are estimated based on various algorithms and many of the ecosystem functions estimated by the i-Tree Eco model are difficult to accurately measure in the field; thus modeling procedures are needed to quantify these effects for urban forests (Nowak et al., 2008a). Due to the importance of the quality assurance of field data accuracy, the model estimates are only as good as the field data inputs; the i-Tree Eco model estimates current urban forest structure and functions and then treats this as a permanent average value for the plot (Nowak et al., 2008a). Urban forest conditions are changeable, so the model value is not absolute. The precision and cost of the estimate is also dependent on the sample and plot size. Generally, 200 plots (1/10 acre each) in a stratified random sample (with at least 15 plots per stratum) will produce a 12% relative standard error for an estimate covering the entire study area (Nowak et al., 2008b). As the number of plots increase, the standard error decreases and the method provides more accurate population estimates. However, as the number of plots increase, so does the time and cost of field data collection.

2.5. Ecosystem Services

An ecosystem is a dynamic complex of plant, animal and microorganism communities, with the nonliving environment interacting as a functional unit. Humans are an integral part of these ecosystems. Ecosystems vary enormously in size; a temporary pond in a tree hollow and an ocean basin can both be ecosystems (Millennium Ecosystem Assessment, 2005). Ecosystem functions are the physical, chemical and biological processes occurring in ecosystems that are necessary for its self-maintenance (Turner & Chapin, 2005) and are the result of the interactions between the biotic and abiotic components of the ecosystem (De Groot, Wilson & Boumans, 2002). According to Daily (1997), ecosystem services are defined by those conditions and processes through which natural ecosystems, and the species that inhabit them, sustain and fulfill human life. Ecosystem services are the benefits people gain from ecosystems. These include provisioning services such as food and water; regulating services such as the regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits (Millennium Ecosystem Assessment, 2003).

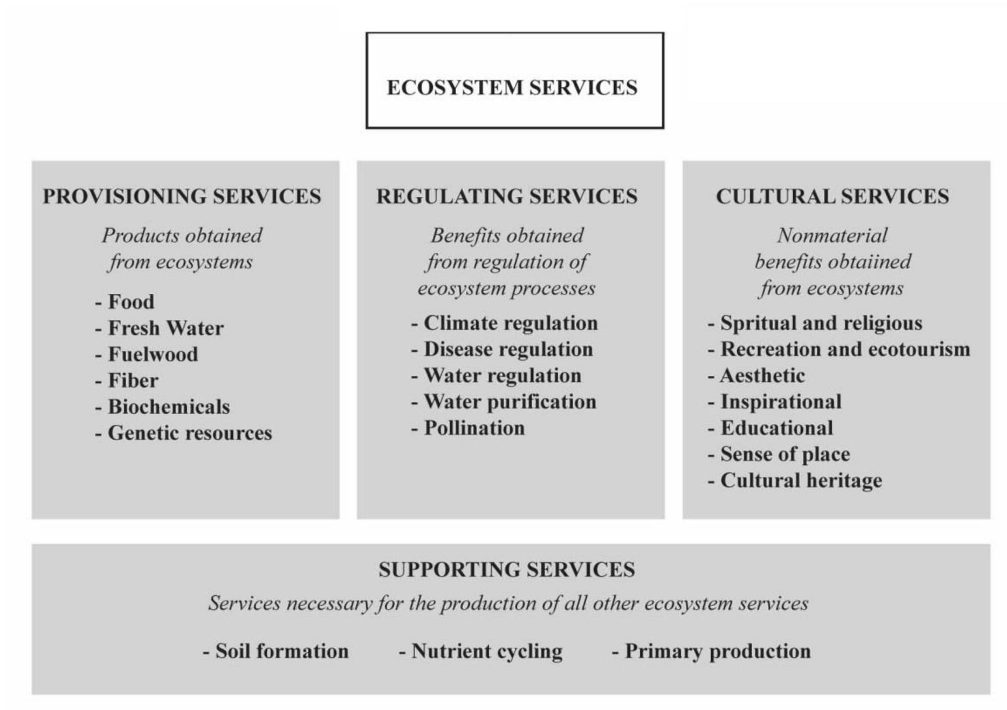

Figure 2.8 Categories of ecosystem service and examples of related services, based on Figure 2.1 (p.57) in the Millennium Ecosystem Assessment (2003), permission to use granted by: Island Press (March 19, 2015)

Regulation services are related to the improvement of well-being in urban areas and include functions such as the maintenance of air quality by decreasing air pollution and reducing ambient temperatures in hot weather (Whitford, Ennos & Handley, 2001). Another ecosystem benefit is the removal of air pollutants by trees, since decreasing the levels of O_3, SO_2 and NO_2 decreases asthma attacks, cancer, the risk of cardiac events and respiratory diseases (Bernstein et al., 2004; Sunyer et al., 2003). The maintenance of favorable climate services reduces the heat and energy needed for warming and cooling buildings (Simpson & McPherson, 1996), and avoids heat strokes in vulnerable populations, as well as generally increasing in human comfort (Fukuoka, 1997). Storm protection reduces the risk of trees falling, endangering life and property, and reducing the amount of tree debris produced, thus decreasing post-storm clean up and removal costs (Escobedo et al., 2009).

The improved drainage provided decreases runoff and minimizes the damage caused by flood (Brezonik & Stadelmann, 2002), thus preventing the accumulation of excess nutrients and heavy metals in ponds and lakes (Konijnendijk, Nilsson, Randrup & Schipperijn, 2005). The maintenance of soil quality results in decreased fertilizer use and reduced investment in soil management (Dobbs, Escobedo & Zipperer, 2011). The maintenance of healthy soils also prevents detrimental effects due to heavy metals on human health (Dobbs et al., 2011), while the filtering of dust particles reduces the risk of lung diseases (Bernstein et al., 2004) and Noise reduction due to the sound-baffling effect of vegetation decreases human discomfort and hearing problems (Koniknendijk et al., 2005).

Supporting services include habitat function related to biodiversity, which maintains all ecosystem function and supplies genetic and biochemical resources, including crops and pharmaceutical products (Millennium Ecosystem Assessment, 2005; Tzoulas et al., 2007). The provisioning services include food, fresh air, wood for fuel, fibers, biochemical, and genetic resources.

The cultural services relates to aesthetic-based opportunities for recreation and pleasure (Dobbs et al., 2011). Ecosystems provide unlimited opportunities for inspirational and educational fulfillment, reflection and spiritual enrichment (De Groot el al., 2002; Kim & Kaplan, 2004; Tzoulas et al., 2007) and are one of the highest valued ecosystem functions in cities (Konijnendijk et al., 2005; Millennium Ecosystem Assessment, 2005).

Assessments of the urban forest can be used to estimate environmental benefits, or ecosystem services, improving our understanding of the role trees play in creating healthy, livable and sustainable cities. Some of the recognized ecosystem benefits of urban forests include:

- Reducing storm-water runoff by intercepting rainfall, which reduces impacts to water quality in adjacent lakes and streams
- Lowering energy bills by reducing wind and sun exposure around buildings
- Providing habitat for wildlife

- Capturing and filtering air pollutants
- Improving the appearances of neighborhoods
- Increasing human well-being through recreation and personal restoration opportunities
- Improved public health as a result of services such as increased neighborhood walkability and clean air (Ciecko et al., 2012, p.3).

From this perspective, assessing the forest structure of vacant land in the City of Roanoke, Virginia, will enable us to demonstrate how urban vacant land functions as a green infrastructure on otherwise vacant land that provides ecosystem services and value via processes such as air pollution removal, carbon sequestration and storage, and energy saving, as well as the structural value of the trees themselves.

2.6. Planning and Policies in Vacant Land

This section summarizes how programs, planning policies, regulations and implementation methods such as program goals, planning and analysis, administration, acquisition and transfer mechanisms, financing, and maintenance can be used to overcome barriers and challenges to green infrastructure on vacant lots across U.S. cities. This literature reviews help to identify strategic alternatives for utilizing these spaces for both short-term and long-term uses for urban regeneration and renewal, described in more detail in Chapter 6, based on the typology and ecosystem services for vacant land proposed in Chapters 4 and 5. Some practices may encourage the redevelopment of vacant land in multiple contexts, and although there is no single planning and implementation strategy for vacant land, a broad range of redevelopment strategies have been identified for specific contexts (Crauderueff et al., 2012). This section presents a broad overview of the key findings across U.S. cities related green infrastructure planning and implementation strategies for vacant land and how they might be applied to particular vacant land cases in the study city. The general key findings for green infrastructure planning and implementation strategies on vacant land are organized according to the following sections: 1) program goals, 2) planning and analysis, 3) administration, 4) site use and design, 5) site aggregation, 6) transfer mechanisms, 7) ownership models, 8) maintenance models, and 9) financing.

2.6.1. Program Goals

Often cities with large amounts of vacant land do not have program goals for managing vacant land. In order to appropriately manage vacant land to achieve its full potential and maximize the green infrastructure benefits achieved, cities must develop clear management program goals for their vacant land. Recently, a number of cities around the country have begun to actively "green" their vacant lots and advance specific open space and storm water management goals, including New York, Detroit, Cleveland, Syracuse, Nashville and Philadelphia (Crauderueff et al., 2012). The City of Philadelphia is one of the most ambitious cities leading the drive to manage storm water runoff using green infrastructure and thus address the EPA's regulatory requirements with their Green City, Clean Waters green storm water infrastructure plan (Crauderueff et al., 2012). The Philadelphia Water Department (PWD) has a goal of filtering or storing the first inch of rain with green infrastructure to reduce the volume of combined sewer overflows (Crauderueff et al., 2012). As part of this effort, the city has incorporated vacant lots as part of their urban storm water management strategy by greening vacant lots as a cost effective way to reduce the amount of rainfall the drains must handle. In many of the successful cases around the country, water agencies are following their lead by greening vacant lots with program goals such as: "improving the safety of waterways for fishing and swimming; protecting drinking water supplies; and mitigating the hazardous impacts of flooding" (Crauderueff et al., 2012, p.92). Examples of these program goals and the lead agencies in the successful green infrastructure projects on vacant lots are described below.

2.6.1.1. Vacant Lots as a Storm Water Management Strategy

Several cities have established the goal of using vacant lots as part of their storm water management strategy. For example, Milwaukee, WI, has redeveloped brownfield sites such as Menominee Valley Industrial Center and implemented a vegetated "treatment train" to capture and filter storm water runoff them, while Cleveland, OH, and Detroit, MI, are both planning the greening of vacant lots by issuing Consent Orders. New York City's Staten Island Bluebelt has MS4 permits[3] to manage storm water and some of Baltimore's Watershed 263 pilot program

[3] "Polluted stormwater runoff is commonly transported through Municipal Separate Storm Sewer Systems (MS4s), from which it is often discharged untreated into local waterbodies. To prevent

projects also have MS4 credit. The City of Tallahassee and Leon County, FL, have developed the Capital Cascade Trail to mitigate annual flooding levels and improve the quality of the urban runoff that recharges the state's aquifer and the New Orleans Redevelopment Authority have developed project for greening the city's many vacant lots as a cost effective way of reducing the amount of urban storm water and thus minimize future FEMA[4] insurance claims (Crauderueff et al., 2012). As these examples of cities' plan for greening vacant lots indicate, the high potential utility of vacant lots for converting blight to a natural asset that benefits the entire local community is finally being recognized.

2.6.1.2. Storm Water Agencies Lead in Green Infrastructure on Vacant Lots

In most successful cases, water agencies are the lead agency when sustaining long-term partnerships with other public agencies, nonprofit organizations and community groups. For example, 1) The Milwaukee Metropolitan Sewerage District has long-term partnerships with the Milwaukee Department of Public Works, the Redevelopment Authority, and non-profit organizations as part of their effort to support the design, implementation and maintenance of large-scale and site-specific green infrastructure projects. Simply, the New York City Department of Environmental Protection (DEP) cooperates with a number of other agencies to support the acquisition, reclamation and maintenance of hundreds of properties for the Bluebelt program, while the Southeast Michigan Council of Governments has a technical agreement to cooperate with the Detroit Water and Sewerage Department (DWSD) to establish green infrastructure on vacant lots to achieve their Combined Sewer Overflows (CSO[5]) program. The Northeast Ohio Regional Sewer District has also identified suitable green infrastructure sites on

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harmful pollutants from being washed or dumped into an MS4, operators must obtain a NPDES permit and develop a stormwater management program" (USEPA, 2014a).

[4] The Federal Emergency Management Agency (FEMA) is an independent Federal agency. They have responsible for coordinating the Federal response to floods, earthquakes, hurricanes, and other natural or man-made disasters and providing disaster assistance to States, communities and individuals (FEMA, 2002).

[5] Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe (USEPA, 2014b).

vacant lots for its CSO program and has involved volunteers from community organizations and the Cleveland Botanic Garden as part of this effort (Crauderueff et al., 2012). From these and other examples of the many city water agencies that are taking the lead in creating green infrastructure on vacant lots, it is clear that the existence of a lead agency willing and able to play a key role is vital if these goals are to be successfully achieved.

2.6.2. Planning and Analysis

Vacant land can include many different types of open space characteristics and phenomena in terms of its physical, environment and social aspects. It is important that vacant land must be managed appropriately if its potential benefits in terms of ecological and social value are to be fully realized. However, there is little direction or guidance available for planners and managers to analyze when seeking to identify appropriate vacant land sites for specific uses. Comprehensive neighborhood plans and successful redevelopment processes for vacant lots often conflict with other agendas or incompatible functions of municipal agencies (Philadelphia Horticulture Society, 1995). The redevelopment process will be delayed without clear processes to settle title disputes and secure permits (Municipal Research & Services Center of Washington, 1997).

In addition, cities' lack of a systematic approach to tracking vacant lots and ensuringe appropriate redevelopment upon sale exacerbates the problem (Goldstein et al., 2001). Generally, political habit, short-term approaches to planning and redevelopment policy, and fragmentation of resources all act as procedural barriers to redeveloping vacant and abandoned properties (Schuman, 1994). As a result, some urban community-based organizations have reported that land acquisition for redevelopment can take up to five years (Pennsylvania Horticultural Society, 1995). Although some public agencies may be interested in competing to use vacant land, other agencies may not value it at all (Crauderueff et al., 2012).

Successful green infrastructures projects on vacant lots need regional, neighborhood and site-specific planning. Partnerships with communities can also facilitate neighborhood planning and a comprehensive spatial analysis with input from local stakeholders and site visits can help appropriate green infrastructure site selection. The role of planning and analysis for large scale green infrastructure on vacant lots on is described in the following sections.

2.6.2.1. Regional, Neighborhood, and Site-Specific Planning

Successful green infrastructure projects on vacant lots generally have regional, neighborhood and site-specific planning at the citywide level. Public agencies such as park departments, water departments and redevelopment authorities all need to become involved in an established regional planning effort if vacant lots are to be utilized as green storm water infrastructure on a large scale. Some specific neighborhood and site-specific planning must also be developed for policy mechanisms to better manage vacant land at the neighborhood scale. During the process of greening vacant lots, early cooperation among agencies provide leads agencies with better opportunities to address storm water and brown field regulations, as well as reduce the cost of the process and deal with administrative challenges (Crauderueff et al., 2012). In the early stages, NGOs can be valuable stakeholders for overcoming institutional barriers related to their own projects (Crauderueff et al., 2012).

2.6.2.2. Partnerships with Communities for Neighborhood Planning

Community based neighborhood planning is essential for the success of green infrastructure projects on vacant lots. Local residents, stakeholders, Community Development Corporations (CDCs), neighborhood associations and local businesses are all potential decision makers when it comes to reusing and greening vacant lots (Crauderueff et al., 2012). Neighborhood scale planning not only helps to identify and prioritize suitable vacant lots for greening, but neighborhood groups and community stakeholders often have a strong understanding of the history of the vacant land in their neighborhood, how it affects their well-being, and whether they will be willing to commit to long-term stewardship (Crauderueff et al., 2012).

For example, the City of Seattle is directly engaged with community groups to complete 38 neighborhood plans and the City of Chicago is working with local communities to plan the greening of vacant lots on large sites along with Openlands, a non-profit environmental organization that works with local community leaders, including neighborhood associations, block associations, businesses and elected officials to develop and implement a neighborhood-scale and site-by-site greening plan to help meet citywide greening goals. In Milwaukee, the

Redevelopment Authority of the City of Milwaukee (RACM) is working with the Menomonee Valley Partners, Inc., the Sixteenth Street Community Health Center, and other non-profit organizations and business to facilitate the conversion of Menomonee Valley Shops brownfield site (Crauderueff et al., 2012). These projects are typical of those in many other cities, where community partnerships are contributing to the successful implementation of green infrastructure on vacant lots.

2.6.2.3. Spatial Analysis and Site Visits

From practical point of view, identifying the most suitable vacant land for the many different types of redevelopment options possible may require extensive technical research and/or public consultations. Brownfield sites may require advanced scientific research to deal with potential site contamination, economic conditions, safe redevelopment options and the correct remediation process for vacant land (Crauderueff et al., 2012). Due to the lack of strategic knowledge regarding vacant land, many are wasted no functional short-term or long-term uses. Research is thus needed to provide strategic ways to select appropriate suitable vacant land sites for short-term and long-term uses.

Spatial analysis (Geographic Information System – GIS) can help planners to select potential sites where vacant lots could be greened to manage storm water at the regional, watershed and sub-watershed scales and identify the optimum way to aggregate multiple vacant lots to achieve the best possible outcome (Crauderueff et al., 2012). For example, common area-wide vacant lot projects include: 1) Watersheds or subwatersheds (Baltimore's Watershed 263 program; Cleveland; Detroit; New Orleans; NYC Staten Island's Bluebelt); 2) Areas prone to flooding (Tallahassee/Leon County); 3) Neighborhood stabilization areas with transitional housing markets (The Greening of Detroit; Cleveland; Genesee County, MI); 4) Neighborhood economic characterization and the prevalence of vacant lots (Detroit Works); 5) Area interconnection utilizing neighborhood-by-neighborhood and block-by-block assessments (New Orleans; Tallahassee/Leon County; Baltimore; Cleveland); and 6) Distance from accessible open space (Chicago) (Crauderueff et al., 2012).

Common site-specific criteria include: 1) Publicly / land bank-owned vacant lots (Chicago;

Genesee County; Cleveland; Detroit; New Orleans); 2) Vacant lots with the potential to accept inflow storm water from streets – particularly street corner sites (Detroit; New Orleans); 3) Properties near storm water inlets or bodies of water (Tallahassee/Leon County; Cleveland; New Orleans); 4) Publically owned vacant properties eligible for demolition (Baltimore's Growing Green Initiative; Chicago's CitySpace plan); 5) Tax delinquent properties with or without structures entering the foreclosure process (Chicago, Genesee County); 6) Unoccupied privately owned, tax-current vacant lots (NYC Staten Island Bluebelts; Tallahassee/Leon County) (Crauderueff et al., 2012).

Follow up site visits and enlisting the cooperation of local stake holders may help planners develop a better understanding of which vacant lots could potentially achieve green infrastructure value and community goals more effectively. The site visits may provide information on the formal and informal use of the vacant lots and their current land use condition, including the lot's surface condition and other considerations such as its proximity to power and sewer lines, whether or not the basement of any previous structures on the site were excavated and the soil conditions, including a judgment as to whether the contamination level needs to be assessed formally (Crauderueff et al., 2012).

2.6.3. Administration

Acquiring the vacant land and then shifting its official use requires time due to the need to negotiate a complex bureaucracy and engage in a public process that often requires balancing competing interests (Crauderueff et al., 2012). Systems, rules, and procedures are elements of government bureaucracy that can also act as barriers to the redevelopment of vacant land and abandoned structures, often requiring interactions between many different public departments and agencies (Goldstein et al., 2001). These make the transaction costs high, but also increase the risk of a lack of consistency and poor communication between different parts of the government. "Well-intended but misguided or poorly implemented regulations often impede redevelopment … zoning regulation can be a significant barrier to redevelopment" (Goldstein et al., 2001, p.11).

For example, zoning regulations that ensure commercial areas are separated from residential areas and encourage large sidewalks, parking lots and wide streets render compact development impossible (Cole, 1996). Community-centered, mixed-use development thus conflicts with outdated and inflexible zoning practices that were designed for a different era and economy (Kivell, 1993). Inflexible zoning practices have inhibited the construction of low-income housing, despite the need for such development (Sarazen, 1995). In addition, many redevelopment projects must comply with requirements such as parking, drainage, landscaping and infrastructure improvement (Municipal Research & Services Center of Washington, 1997).

"City governments … tend to view vacant land only as a revenue-generating commodity. Because this perspective obscures land's value as a community resource, city officials lose sight of their responsibility to manage land in ways that promote public values" (Pennsylvania Horticultural Society, 1995, p.45).

Many public agencies have not expanded or developed specialized redevelopment programs for vacant land. However, successful green infrastructure on vacant lots have all benefited from effective programs that had a narrow focus emphasizing a particular aspect of the vacant lots concerned. The development of specialized programs and organizations filled gaps in the process of greening vacant lots and the partnerships developed among specialized agencies and organizations have led to successful green infrastructure projects on vacant lots (Crauderueff et al., 2012). The role of specialized programs, organizations and collaborations among agencies are described in the following sections.

2.6.3.1. Specialized Programs

Green infrastructure on vacant lots is a specialized program and is not an existing program for any public agency. Those public agencies and nonprofit organizations that have developed and expanded new programs on vacant lots have required significant financial support for their program activities (Crauderueff et al., 2012). Funding resources may come from nonprofit organizations, family or personal funds, donations and special tax levies. Projects to green vacant lot not only involve public agencies, but also benefit from having strong relationships with multiple other organizations and NGO stakeholders who support the planning, acquisition, management and maintenance of vacant lots. These specialized strategic partnerships are critical. For example, in most cities partnerships with the Department of Parks and Recreation, the

Housing Authority, the Department of Environmental Protection and the Trust for Public Land are critical for the use of properties and the acquisition and development of vacant lots.
For example, 1) NYC public agencies and non-profits developed special programs as part of the Department of Environmental Protection's effort to create a special office to manage the Staten Island Bluebelt program, which has acquired more than 14,000 acres since the program started in 1989. The office has spent more than $72 million in the last 10 years on the acquisition of vacant lots; 2) The New York Restoration Project (NYRP) developed a land trust to acquire 52 community gardens with $1.2 million funding from the Midler family foundation and Bette Midler's personal funds. They also developed a $2.5 million endowment from private donations for financial improvements and maintenance; 3) The Greening of Detroit, a citywide non-profit organization, works with the Detroit Water and Sewerage Department; and 4) The Seattle Department of Parks & Recreation has expanded their special programs to green vacant lots using projects fund provided by special tax levies (Crauderueff et al., 2012).

2.6.3.2. New Special Purpose Organizations and Agencies

Projects to green vacant lots belong not only to existing organizations but have also led to the development of new special purpose organizations and agencies to filled the gaps in the process of greening vacant lots to achieve multiple goals (Crauderueff et al., 2012). This requires working across agencies and district lines, cooperating to overcome challenges to existing agencies and successfully supporting the planning, acquisition, management and maintenance of vacant lots (Crauderueff et al., 2012).

For example, 1) in planning, Milwaukee's Menomonee Valley Partnership, Inc., was developed to support the implementation of a regional land-use plan. This included the reuse and greening of strategic vacant sites that coordinated the contributions of NGOs, businesses and public sector agencies to redevelop the Menomonee Valley Shops site; 2) in acquisition, planning and short-term greening, the Genesee County Land Bank Authority (GCLB) in Michigan was created based on support from state laws to acquire foreclosed properties or temporarily hold properties to sell or redevelop, particularly through Sheriff's sales. GCLB coordinated with a Citizens' Advisory Committee to provide green spaces with community site managers or stakeholders for short-term greening programs; 3) In project management, the City of Tallahassee and Leon

County created Blueprint 2000, an intergovernmental special purpose agency, to support the design, acquisition, finance, and construction management of greened vacant lots through the Capital Cascade Greenway. Blueprint 2000 projects faced challenges to cooperation that crossed agency and jurisdiction lines, and program developers believed a single organization could be more effective; 4) In temporary ownership and technical assistance, the Green Thumb program in NYC was created to provide technical and material assistance to service 600 community gardens established under its regulations and facilitate license agreements with community gardeners; 5) In preservation, local land trusts have often been created to support small community managed open spaces. For instance in NYC, the Trust for Public Land developed three local land trusts: the Manhattan Land Trust, the Bronx Land Trust and the Brooklyn Queens Land Trust (Crauderueff et al., 2012).

2.6.3.3. Partnerships among Specialized Agencies and Organizations

The successful programs have generally developed and sustained partnerships among a number of specialized strategic agencies and organizations to plan, design, acquire, own and maintain vacant lots (Crauderueff et al., 2012). For example, 1) The New York Restoration Projects work with the NYC Housing Authority, the Trust for Public Land and the NYC Department of Parks & Recreation to maintain their program of community gardens and neighborhood parks; 2) when creating the NYC Staten Island Bluebelt, the Department of Environmental Protection, worked with the Parks Department as well as the New York State Departments of Environmental Conservation and Transportation during the site acquisition process and also coordinated their efforts with those of the City's legal department and the Department of Citywide Administration Services when acquiring the private properties; 3) Blueprint 2000 worked with public agency staff through a Technical Advisory Committee, and with the general public through an active Citizens Advisory Committee, and project-specific community partners; 4) Chicago's Neighbor Space, a non-profit land trust, has cooperated with the Chicago Park District, the City of Chicago and the Forest Preserve District of Cook County for the past fifteen years; and 6) The Genesee County Land Bank has worked with a Citizens Advisory Committee to provide critical feedback, and direction to the organization's program (Crauderueff et al., 2012).

2.6.4. Site Use and Design

This section considers the kinds of site use and design programs that lead to successful development, political support, and maintenance of green infrastructure on vacant lots. The successful implementation of green infrastructure on vacant lots generally involves programs with multiple goals, aiming not only at urban storm water management, but also addressing quality of life goals by incorporating multiple public uses that appeal to a wide range of stakeholders such as the creation of publically accessible green space that is suitable for both passive and active uses. This type of successful site use and design examples where multiple goals, quality of life, and open space programs are achieved on vacant lots are described in the following sections.

2.6.4.1. Multiple Goals of Green Infrastructure Programs

Three design and program challenges typically face those seeking to install green infrastructure on vacant lots. First, the public agencies may have limited funds for developing green storm water management plans, so any additional recreation-specific goals may require extra funding from some other source. Second, multiple goals may require additional time to enlist the cooperation of the multiple agencies and NGO stakeholders involved in implementing the project. Finally, lead agencies may not have specified a mission of creating open space on vacant lots while advancing storm water goals (Crauderueff et al., 2012). However, some successful projects to implement green infrastructure on vacant lots has multiple goals that advance both community interests and storm water management through some aspect of their programs. For example, the New Orleans Redevelopment Authority is seeking to identify opportunities to incorporate quality of life goals into green storm water infrastructure on vacant lots, while the Southeast Michigan Council of Governments (SEMCOG), a metropolitan planning organization supports the development of the Detroit Water and Sewerage Department’s CSO green infrastructure plan that invites community feedback when selecting suitable vacant lots for greening to improve community well-being. The Northeast Ohio Regional Sewer District will not only manage 2.1 million gallons of storm water from Cleveland’s Urban Agriculture Innovation Zone, but the zone will also provide business development and education opportunities to Cleveland residents (Crauderueff et al., 2012). Nonetheless, it is difficult to achieve multiple goals for these projects, even though opening them up to include multiple goals may ultimately lead to success for the green infrastructure projects as a result of the creative use and design of the vacant lots.

2.6.4.2. Quality of Life in Green Infrastructure by Through Multiple Public Uses

Successful green infrastructure projects on vacant lots can includes quality of life goals into their green infrastructure plan by incorporating multiple public uses that will improve the quality of of local residents through the creation of publically accessible green space that support both passive and active uses (Crauderueff et al., 2012). For example, in Milwaukee's Menomonee Valley Industrial Center a 30-acre green infrastructure storm water site is used as a floodable park that provides playing fields, canoe launch facilities and a gathering space, as well as extending the city's Hank Aaron Trail, and providing a pedestrian bridge to enable residents to access the park from the opposite side of the Menomonee River. In Tallahassee, the Capital Cascade Trail is not only used to manage storm water, but also creates open spaces that encourage community members to engage in outdoor activities together. The the third section of this trial provides pedestrian and bicycle paths alongside the storm water system. The NYC Staten Island Bluebelt project incorporated storm water BMPs[6] into existing natural areas to reduce flooding, but also expands existing natural areas, restores degraded wetlands, and provides recreational opportunities (Crauderueff et al., 2012).

2.6.4.3. Open Space Programs in Green Infrastructure

Successful green infrastructure projects are not limited to the provision of ecological services such as storm water management, air quality, urban heat island mitigation, and biodiversity, but also create open spaces for active and passive uses that improve the well-being and quality of life of the local community (Crauderueff et al., 2012). For example, in Seattle, a comprehensive plan provides a guideline for suitable site selection for parks through neighborhood planning involving community members, while the Chicago CitySpace plan has created a framework to enable the Chicago Park District (CPD) to acquire green space in priority areas by raising

[6] Stormwater BMPs are techniques, measures or structural controls used to manage the quantity and improve the quality of stormwater runoff (USEPA, 2014a).

revenues through a dedicated property tax and tax increment financing[7] (Crauderueff et al., 2012). Many of the successful open space programs on vacant lots have been supported by special programs run by local government agencies.

2.6.5. Site Aggregation

Vacant lot site aggregation provides opportunities to create extensive areas for storm water storage and treatment and can be a very cost effective way to achieve installation, maintenance, and diverse uses (Crauderueff et al., 2012). However, the complex process of acquiring the sites, especially where the ownership is unknown, is often a significant barrier when aggregating vacant lots. Even if all the land owners can be found, it can be difficult to meet their often inflated expectations of the vacant land's value. Some land owners do not agree with positive short-term interventions, such as community gardens and urban farms, and resist the idea of reusing the land, because once vacant land has public access this may impose a greater duty of care on them and increase the maintenance cost for their land (Crauderueff et al., 2012; Taylor, 2008). This issue of complex and unknown ownership, which relates to personal or individual matters, is one of the most challenging factors hindering the aggregation of vacant lots.

In order to overcome these site aggregation barriers, successful green infrastructure projects on vacant lots tend to have a single lead agency, multiple acquisition strategies, plans for interim ownership, and greenway programs on vacant lots to support aggregation. A single lead agency sustains a project's long-term planning and implementation capacity and successful programs use multiple acquisition strategies to support aggregation. Interim ownership and greenway programs can support the systematic aggregation of many smaller sites to create green infrastructure on vacant lots. Successful examples of a single lead agency, multiple acquisition strategies, interim ownership, and greenway programs on vacant lots are described in the following sections.

[7] Tax Increment Financing (TIF) is a special funding tool used by the City of Chicago to promote public and private investment across the city. Funds are used to build and repair roads and infrastructure, clean polluted land and return vacant properties to productive use, usually in conjunction with private development projects (City of Chicago, 2014b).

2.6.5.1. A Lead Agency has Long-Term Planning and Implementation Capacity

In order to achieve successful site aggregation of vacant lots, a lead agency needs to work in partnership with others to support planning and implementation efforts to acquire the vacant lots using multiple acquisition strategies. For example, the lead agencies of Blueprint 2000 in Tallahassee and Leon County coordinated the acquisition of numerous vacant lots for the Capital Cascade Trail and the NYC Department of Environmental Protection and the Genesee County Land Bank have been working together to aggregate vacant lots for more than a decade. Site aggregation methods are usually to purchase a property from its owners or through foreclosure, but some cities, such as NYC and Tallahassee, have used eminent domain to push through a deal. Intergovernmental transfers are the easiest transactions, but this process is usually not sufficient to aggregate large numbers of vacant lots (Crauderueff et al., 2012).

2.6.5.2. Multiple Acquisition Strategies

The most common vacant lots acquisition strategy for vacant lots is by direct purchase from the property owners, but foreclosed properties are another alternative. In cities with strong property markets such as New York City and Tallahassee, vacant lots often have to be acquired using eminent domain or the threat of eminent domain. The easiest acquisitions tend to be intergovernmental transfers, which can save time, negotiation, and the need to engage in a public process with the previous land owners (Crauderueff et al., 2012).

2.6.5.3. Interim Ownership and Greenways

Temporary ownership can also be a way of supporting the aggregation of vacant lots, while greenways help agencies systemically aggregate many smaller vacant lots to manage storm water. For example, Blueprint 2000 and Openlands in the City of Chicago assume temporary ownership of the land until construction is completed or the local governments can pay for the properties, while land banks in Genesee County and Cleveland can acquire vacant lots for temporary use, and then provide one year and two-to-five year leases to local residents. For leases from two-to-five years, the land bank suggests that lessees go ahead and purchase the properties concerned. The Greater New Orleans Water Management Strategy and the Pontilly Project Livability Analysis provide design examples of how a greenway can connect communities by implementing small-site vacant lot networks (Crauderueff et al., 2012).

2.6.6. Transfer Mechanisms

One of the biggest challenges for the redevelopment of vacant lots is that a significant proportion of vacant land is privately owned, particularly in post-industrial cities, and thus require the ownership to be formally transferred to either public or private agencies (Crauderueff et al., 2012). The process of ownership transfer requires time, negotiation, and engaging in a public process with the previous land owner, making the redevelopment of vacant lots more difficult and delaying the process as a result of the need to acquire grants and put in place adequate insurance coverage and responsible risk management (Crauderueff et al., 2012; Taylor, 2008). Many vacant lot landlords may not want to sell a property that will represent a financial loss or that could possibly increase in value in the future (Kelley, 2004; Setterfield, 1997). They also have very little incentive to sell because the cost of carrying the property is generally low. Municipalities are often similarly reluctant to sell property because usually redevelopment costs are less than the vacant lots' historical cost and also require payment for the cleanup, maintenance, and legal proceedings to make them attractive to developers (Goldstein et al., 2001). Sometimes, neighborhood opposition to specific redevelopment projects can seriously hinder the redevelopment process; people often protest against redevelopment projects due to their appearance, scale or potential impact on traffic, crowding, or loss of open space, especially when they have been designed without sufficient community input and fail to reflect the community's needs (Goldstein et al., 2001). Fragmented or multiple ownership acts as a further redevelopment barrier (Kivell, 1993). The next section presents different types of the most efficient transfer mechanisms in green infrastructure on vacant lots across U.S. cities including temporary-to-permanent, side lot, public-to-public, and private-to-public transfer programs.

2.6.6.1. Temporary-to-Permanent Green Spaces

The temporary use of vacant lots often leads to permanent ownership, and in smaller vacant lots, many cities support short-term uses of vacant lots for green space such as community gardens. Once vacant lots are actively used and well-maintained by members of the local community support, as is generally the case with projects such as community gardens, these vacant sites can be transferred to long-term uses relatively easily. For example, the Genesee County Land Bank provides three complementary programs: a free seasonal program that allows people to engage in short-term greening; a one-dollar annual lease of vacant lots that encourage people to commit to short-term greening or gardening projects for two to five years; and vacant land lease with option to purchase that helps open space managers to consider vacant lots for as permanent uses. Similarly, the Green Corps program in Chicago helps community garden groups to secure publicly owned properties for five years by providing supporting letters from local aldermen. Some vacant sites already have short-term agreements with the city, but others are still looking for long-term uses with NeighborSpace and the Land Trust. The Adopt-a-Lot program in Baltimore City cooperates with the city's Housing and Community Development (HCD) department to provide one year licenses to people to utilize vacant lots for greening purposes. If they successfully complete the year, they can apply for a 5 year license. Baltimore Green Space (BGS), a land trust, and the City Transfer Community also manage open spaces leased to BGS for permanent uses. NYC has a Memorandum of Agreement with the New York State Attorney General to protect several hundred community gardens from development because NYC's community gardens program was perceived as a critical community asset that should be preserved and protected from development (Crauderueff et al., 2012).

2.6.6.2. Side Lot Transfer Programs

Some cities sell publically owned side lots to interested land owners that provide the potential to create permanent green or open space, which can put these sites back on the tax rolls. For example, the Genesee County Land Bank transferred 770 vacant lots to local residents by selling them for one dollar plus a nominal processing fee ($39 in 2012) and many of those side lots are now used as adjacent gardens or lawns (Crauderueff et al., 2012). Although these side lot transfer programs do not impose any obligations on purchasers, such as restrictions or incentives to maintain the land as green space, these programs could also help to advance storm water management goals (Crauderueff et al., 2012).

2.6.6.3. Public to Public Transfer

Some cities acquire publicly owned vacant parcels from state agencies through title transfers or memoranda of understanding. The main advantage of these public transfers of vacant lots is that the financial cost tends to be waived and agreement is relatively easy to achieve compared to acquisitions of privately owned vacant parcels (Crauderueff et al., 2012). Although the transfer of the title does not cost local governments anything, the new landowners become responsible for maintaining the property, which frequently advances the mission or economic interests of state agencies (Crauderueff et al., 2012). For example, the City of Tallahassee's transfer of two brownfield sites to the Capital Cascade Park helped them to meet the state's brownfield cleanup goals. In NYC, the Department of Environmental Protection transferred between 50 and 100 acres from the NYC Department of Park & Recreation and the NYS Department of Environmental Conservations and Transportation for the Staten Island Bluebelt via memoranda of understanding. The construction of the Staten Island Bluebelt advances both city and state goals to manage storm water under the State Pollution Discharge Elimination System (SPDED), as well as preserving and restoring ecologically valuable wetlands (Crauderueff et al., 2012).

2.6.6.4. Private to Public Transfer

A significant number of the vacant lots in any project will be privately owned, particularly on postindustrial sites (Crauderueff et al., 2012). Here there are three possible transfer methods; foreclosure, direct acquisition, and condemnation. Although acquisition through foreclosure is the least expensive method of acquiring privately owned vacant lots, three successful program models, the Genesee County Land Bank, the Cleveland Land Bank, and the Chicago Tax Reactivation, that support the acquisition of thousands of properties each year through Sherriff's sales. The purchasing agency develops a list of properties that are eligible for the Sherriff's sales that will generate sufficient revenue through the development to finance the demolition of any abandoned buildings on the site (Crauderueff et al., 2012).

For example, the Department of Community Development in Chicago receives requests to commit to maintaining or supporting specific vacant lots to be greened by the Chicago Park District and NeighborSpace, while the Cleveland Land Bank acquires vacant lots in Cleveland's 15 target areas through its HUD Neighborhood Stabilization Plan, which defines the target area for the city's community Development Block Grant funds. One of the most effective approaches in the Genesee County Land Bank's arsenal is to provide groups with target lists of vacant sites to acquire, which include high potential vacant lots to develop as well as vacant lots with no development potential (Crauderueff et al., 2012).

2.6.6.5. Acquisition of Tax Current Properties

The easiest way to acquire vacant lots is from willing landowners, but in many cases it is difficult to meet landowners' unrealistic price demands. Many property owners are not interested in selling their land until property values increase as speculated. Effective transfer mechanism programs have the capacity to identify private landowners and directly negotiate with them (Crauderueff et al., 2012). For example, Blueprint 2000 has multiple strategies for acquiring privately owned properties to develop detention ponds and public parks in Tallahassee. The City of Chicago has aggregated vacant lots to create large open space in a number of cases, including wetlands, over a period of years via direct acquisitions, with the nonprofit Openlands organization providing temporary ownership of vacant lots until the City can pay for the cost of acquisition. This demonstrates that acquiring high-property sites is a long-term process, requiring the capacity to track and acquire sites over many years. The Northeast Ohio Regional Sewer District in Cleveland and the Detroit Water and Sewer Department are also trying to aggregate private properties to create green storm water infrastructure sites, along with a number of other water agencies who are attempting to purchase vacant lots strategically located adjacent to major transportation corridors. The New Orleans Redevelopment Authority's "Pontilly Project" flood mitigation plan also seeks to acquire private properties as part of their acquisition strategy (Crauderueff et al., 2012).

2.6.6.6. Condemnation

Eminent domain can be an effective way to acquire vacant lots without development potential. The NYC Staten Island Bluebelt has successfully acquired 90% of its properties through condemnation, which provides two key lessons: first, condemnation of vacant lots without development potential can be politically effective for future land use, and second, delegating both condemnation and acquisitions to partner agencies supports and enhance EDP's planning process. The city's Legal Department manages condemnations and legal transactions, and private property purchases are negotiated through the NYC Department of Citywide Administrative Services (Crauderueff et al., 2012).

2.6.6.7. Transfer of Private Properties for Demolition

Many abandoned structures are located on vacant land that then frequently remains underused due to the high cost of demolition, which ranges from $2000 to $40,000 per unit, depending on the building size, type, and contamination levels (U.S. Government Accountability Office, 2011). Many U.S. cities, such as Chicago, IL, Detroit, MI and Baltimore, MD, cannot afford to demolish all the abandoned structures on vacant lots within their city limits (Crauderueff et al., 2012). Baltimore's proportion of abandoned structures on vacant land is well above that of the average in U.S. cities (Pagano & Bowman, 2000) and it would require approximately $180 million to demolish all the abandoned structures city wide (U.S. Government Accountability Office, 2011). Due to the cost of demolishing abandoned buildings, several cities have tried to prioritize the demolition of abandoned buildings based on greening criteria.

For example, the City of Chicago acquires and demolishes abandoned buildings routinely through their Tax Reactivation Program, while the Detroit Water and Sewerage Department has paid $1 million to acquire and demolish 140 privately owned abandoned buildings to create green spaces as part of the process to implement green infrastructure in the city. Baltimore has developed and interdepartmental Growing Green Initiative that involves the city's Public Works, Housing and Community Development, Planning, and Transportation departments. These bodies work with public schools and non-profit greening organizations to identify properties containing abandoned buildings that need to be demolished and have no short-term development potential, and then choose one of six greening typologies for these sites, including green storm water infrastructure (Crauderueff et al., 2012).

2.6.6.8. Easements

Easement is not the most popular transfer method for three main reasons. First, post-industrial cities in particular have low property values that greatly lower the financial and transaction costs of an easement. Second, many cites have found that acquisition is a more effective way to preserve property for green infrastructure than easements, because changing the ownership may result in a loss of commitment to preserve the site. Finally, zoning restrictions are more efficient than easements for preserving properties for green infrastructure (Crauderueff et al., 2012). For example, Chicago changed their city policies from easements to zoning, encouraging vacant lots located along the city's waterfront to be used for storm water management and public access. The City of Tallahassee and Leon County also began by using easements to create green spaces for Segment One of the Capital Cascade Trial, but in later stages moved to a more creative design process within the public right-of-way (Crauderueff et al., 2012).

2.6.7. Ownership Models

The site ownership presents a challenge across many programs aimed at converted vacant lots to green space. Maintenance costs and liability are the two greatest concerns related to implementing green infrastructure projects on vacant lots. Usually larger greened vacant lots of at least 1.5 acres are owned by public agencies, but smaller greened vacant lots may be owned by public agencies and land trusts; privately owned side lots may provide another opportunity to advance green infrastructure on vacant lots (Crauderueff et al., 2012).

2.6.7.1. Public Ownership of Large Sites

Large vacant lots are usually owned by public agencies and have covenants related to specific storm water management purposes and other related funding supported by environmental protection grant programs (Crauderueff et al., 2012). For example, in Tallahassee, the ownership of brownfield sites was transferred from the State of Florida to the City of Tallahassee for the Capital Cascade Park project. In NYC, the Staten Island Bluebelt program is owned by the NYC Department of Environmental Protection. In Chicago, large vacant lots (more than 2 acres) are owned by the Chicago Park District, and in Milwaukee, the Menomonee Valley Industrial's green space has a deed restriction, because this site has received funding from state and federal grant programs (Crauderueff et al., 2012).

2.6.7.2. Smaller Sites Owned by Public Agencies and Land Trusts

Land trusts are nonprofit organizations set up to own vacant lots, provide liability insurance and provide technical assistance for efforts to develop vacant lots for community managed open space. They frequently have partnerships with city agencies for policymaking and the acquisition of vacant lots (Crauderueff et al., 2012). For example, in Chicago, three public agencies, namely the Chicago Park District, the City of Chicago, and the Forest Preserve District of Cook County, provide financial support and leadership for the NeighborSpace land trust, while Baltimore Green Space (BGS) has a partnership with the city's Office of Sustainability to redesign vacant lots to green space and also provide liability insurance. NYC's Green Thumb program provides technical and material support to over 600 community gardens in NYC and workshops are held every month to teach basic gardening skills and more advanced farming and community organizing topics. Green Thumb also facilitates license agreement with community gardeners (NYC Parks GreenThumb, 2014; Crauderueff et al., 2012).

2.6.8. Maintenance Models

One of the biggest challenges facing the implementation of green infrastructure on vacant lots is the maintenance model. Project planning, design, ownership, and finance all impact maintenance and the involvement of both volunteers and professional staff is important to ensure adequate maintenance occurs on vacant lots. This has been a problem in some cities; the Greening of Detroit, a non-profit organization, developed agreements with neighborhood volunteers but some volunteers were not interested in conducting maintenance, leaving a maintenance void (NYC Parks GreenThumb, 2014; Crauderueff et al., 2012). This section examines four successful maintenance program models: public, private, community, and youth summer employment.

2.6.8.1. Public Maintenance

Several cites utilize public agencies to maintain their green infrastructure on vacant lots. For example, the Capital Cascade Trail in the City of Tallahassee and Leon County is maintained by multiple city and county agencies, while in NYC, the Staten Island Bluebelt has seven full-time maintenance staff, who are supported by a $700,000 budget run through the Department of Environmental Protection and funded through ratepayer fees. The DEP has developed a Memorandum of Understanding (MOU) with the city’s Parks Department, and this has served as a model for other cites seeking to care for their green infrastructure located in the public right-of-way (Crauderueff et al., 2012).

2.6.8.2. Private Maintenance

Private maintenance on vacant lots can also be very effective. For example, the Redevelopment Authority of the City of Milwaukee (RACM) has negotiated an agreement with the Department of Public Works (DPW) to provide a 60% storm water credit against the DPW storm water fee through the easement to the Menomonee Valley Industrial Center (MVIC) businesses to maintain the above ground green infrastructure (Crauderueff et al., 2012). Because an adjacent storm water drain will manage and treat 100% of the storm water runoff from MVIC, and if MVIC fully supports funding the maintenance of the storm water drain, the businesses located on the 13 parcels in MVIC will save approximately $50,000 in storm water fees annually, which will go to the maintenance fund administered by the property owner's association. RACM has also committed to conducting or subcontracting the maintenance of the storm water drains through the funding provided by the property owner's association from the revenue received from storm water fees (Crauderueff et al., 2012).

2.6.8.3. Community Maintenance

Community maintenance of vacant lots tends to be volunteer run and is likely to be more effective for smaller vacant lots. Outside greening organizations and land trusts support community volunteers' maintenance efforts through capacity building and providing liability insurance and low-cost materials to manage the vacant lots, as well as support throughout the process of facilitating short-term and long-term uses of the vacant lots (Crauderueff et al., 2012).

2.6.8.4. Youth Summer Employment Maintenance

Employing young people form the local neighborhood to maintain vacant lots during their summer vacation offers many more opportunities to receive funding than similar programs for adults. State-based summer youth employment programs may provide additional funding for maintenance on vacant lots that extends the seasonal nature of the work throughout the summer months based on their availability (Crauderueff et al., 2012). For example, the Genesee County Land Bank's Clean and Green Program provides employment maintaining vacant lots, including mowing and trash pickup every three weeks and also administers the youth employment application process on behalf of community organizations to incorporate youth training and build their relationship with the local community. The Greening of Detroit Clean and Green program assessed vacant lots and green areas around half of the lots, all of which are cleaned by neighborhood volunteers, and planted additional vegetation such as street trees throughout the target neighborhoods. The same city's Green Corps employs about 200 local youths to conduct tree pruning, pick up trash, and perform additional maintenance for 20,000 to 30,000 trees five times each summer, along with other youth summer employment programs. In Cleveland, the Northeast Ohio Regional Sewer District (NEORSD) has worked with the Cleveland Botanic

Garden (CBG) to create youth employment opportunities for maintaining green infrastructure through ratepayer funds, as CBG has expertise in green infrastructure areas that support NEORSD's objectives (Crauderueff et al., 2012).

2.6.9. Financing

Although there is growing awareness of the potential utility of re-using vacant lots as green infrastructure, financial issues can present huge obstacles, dramatically reducing the development of green infrastructure on vacant lots. Easy access to information about the funds available in the form of grants, short-term loans and incentives, as well as other potential sources of funds, would greatly assist these efforts. The ability to rapidly assessing financial requirements and potential funding sources to implement plans are essential for the success of projects to create green infrastructure on vacant lots. Most cities lack adequate economic incentives for supporting green infrastructure on vacant lot or for maintain and improving abandoned buildings (Schilling & Mallach, 2012). Municipalities should consider offering green infrastructure investment policies, such as tax incentives, tax credits and rehabilitation abatement on vacant lots and abandoned buildings. Without financial investment, stabilizing a neighborhood is difficult or impossible. This section presents a variety of financing mechanisms for green infrastructure on vacant lots, including foundation grants, government grants, special levies, utility fees, and tax increment financing.

2.6.9.1. Planning

Foundation grants are the most common funding sources used to support the planning efforts of public agencies and NGOs (Crauderueff et al., 2012). For example, the Chicago Community Trust provides grants for the CitySpace plan, the Cleveland Foundation supports grants for the planning process to help determine how the Northeast Ohio Regional Sewer District, Land Studio, and community stakeholders could develop green infrastructure, local foundations support the Genesee County Land Bank's community planning initiative, public grants support Michigan's Section 205(j) program and EPA programs in Detroit, and HUD supports planning in New Orleans (Crauderueff et al., 2012).

2.6.9.2. Acquisition and Construction

A lead agency and specific program funding generally support the process of acquisition and construction of green infrastructure on vacant lots. For example, storm water agencies can support the process of acquisition and construction on vacant lots through ratepayer fees, parks or recreational programs may receive funding through specialized tax levies to develop acquisition and construction and place-based tax increment financing (TIF) is another significant funding source for open space programs. Government grants and loans can also provide supplementary funding to acquire and construct green infrastructure on vacant lots (Crauderueff et al., 2012).

2.6.9.2.1. Utility Fees

Green infrastructure on vacant lots is often supported by ratepayer fees through public water agencies. For example, the NYC Department of Environmental Protection spent $72 million to acquire vacant lots between 2002 and 2011, supported by ratepayer funds, and the DEP spent $50 million to develop the Staten Island Bluebelt, along with an additional $300 million to develop sewer capital projects including storm and sanitary sewering. The Detroit Water and Sewerage Department spent $1 million to demolish 140 abandoned houses along major roads as part of the city's $50 million commitment to green infrastructure through its CSO Consent Order; The Northeast Ohio Regional Sewer District will spend at least $42 million to acquire, construct and maintain vacant lots to reduce CSOs through ratepayer fees to support Cleveland's green infrastructure projects (Crauderueff et al., 2012).

2.6.9.2.2. Tax Levies

Green infrastructure on vacant lots may also be funded by tax levies. For example, the City of Seattle enacted green infrastructure levies in 2000 and 2008, with the first collecting $200 million over eight years for acquisition, development, programming, and maintenance and the second $145 million over six years for acquisition and development, but not including maintenance or programming. The Chicago Park District (CPD) receives dedicated property taxes amounting to around $30-$40 million each year for land acquisition and capital investments. The City of Tallahassee and Leon County's Blueprint 2000 organization received $198 million through a 1% local sales tax dedicated to local green infrastructure projects and the

$80 million fund for Capital Cascade Trail in Blueprint 2000 was supported by 1% sales tax. Additional funding came from the Housing and Urban Development (HUD)'s Community Development Block Grant Program, state grant programs, and private donations, while storm water green infrastructure was supported by the 1% sales tax (Crauderueff et al., 2012).

2.6.9.2.3. Place-Based Financing

There are two main types of place-based financing: tax increment financing (TIF) and an open space impact fee to support green infrastructure on vacant lots. For example, the Redevelopment Authority of the City of Milwaukee created a tax increment district (TID) to support funding $16 million for the Menomonee Valley Industrial Center, which will be repaid through future tax revenues from businesses and an additional $14 million was supported by a large range of partner collaborations, including twenty local, state and federal grants, as well as private donations and support from the Milwaukee Metropolitan Sewerage District and the Wisconsin Department of Natural Resources. The EPA also provides several hundred thousand dollars for green infrastructure on vacant lots. The Chicago Park District received support in the region of $55 million through TIF financing from 2006 to 2010 and expects this to increase to $142 million by 2016, while Chicago's Open Space Impact Fee (OSIF) program has provided $53 million for the Department of City Development to support neighborhood green space since 1998. The OSIF program requires residential developers to pay a per-unit fee for new dwelling units to create green infrastructure on vacant lots (Crauderueff et al., 2012).

All three of the above financing approaches support high value properties, but the Genesee County Land Bank utilizes TIF for low value properties, which are supported by an expansion of the Michigan state brownfield law. This law defines abandoned, tax delinquent and land bank owned properties as brownfields and thus allows land banks to redevelop these blighted properties through the state brownfield program, which is often a good strategy for low-income areas to create green infrastructure or demolish abandoned buildings in CSO areas. The Genesee County Land Bank paid back $13 million in TIF bonds from revenues received from a small number of high-value redevelopment projects and the land bank also demolished 400 buildings and rehabilitated a further 3,800 for sale, bringing additional tax benefits (Crauderueff et al., 2012).

Other place-based funding mechanisms and sources include specific types of environmental improvements and brownfield cleanup funding for specific green infrastructure and environmental projects, provided by state and federal programs. The nonprofit Openland program provides gap ownership for vacant lots that helps public agencies receive grant funding for projects by holding interim ownership, facilitating the formation of aggregation sites until public agencies can find funding to acquire the target vacant lots. An example of exceptional philanthropy is the community garden projects in NYC, but this may not be a replicable model for acquiring vacant lots in the future (Crauderueff et al., 2012).

2.6.9.3. Maintenance

Tax foreclosures and enforcement codes have increased the number of vacant lots that have not been maintained and improved for lengthy periods of time. Unmaintained vacant lots and abandoned buildings negatively impact both property values and the quality of life in their surrounding neighborhoods. Maintenance has value in itself, which can encourage redevelopment in the future. Some vacant land has well maintained vegetative structures and landscape features. This vacant land is already laid out in selling parcels and ready for new development. The owner's maintenance of the vegetative structure impacts both the property value and the quality of life in the surrounding neighborhood, and proper maintenance is an important priority. Cleaning and maintaining the land will stabilize and raise property values and hence increase tax receipts from the whole neighborhood. For green infrastructure on vacant lots, many cities have tried to develop long-term finance mechanisms for maintenance, such as ratepayer funds (Crauderueff et al., 2012).

For example, for every $1 million it devotes to capital investments, the Northeast Ohio Regional Sewer District (NEORSD) will spend $100,000 each year, approximately 10% of the construction costs, on maintenance. In Seattle, the Pro Parks Levy 2000 supported the maintenance, stewardship and programming for both existing and new parkland, of which more than $60 million went to mitigate the increased maintenance burden on the Seattle Department of Parks & Recreation (DPR). The annual maintenance costs of the newly developed parks were estimated at more than $6 million but the 2008 Levy eliminated maintenance and the Seattle DPR is now struggling to fund maintenance. In Milwaukee, private businesses are receiving storm water rebates from the City of Milwaukee Department of Public Works using an easement agreement to support funding maintenance that equals the value of their storm water rebates. The Greening of Detroit also provides annual support of $1 million for the youth-based Green Crops program through funding from public foundations and corporate sources (Crauderueff et al., 2012).

CHAPTER 3: METHODOLOGY

3.1. Study Area

The City of Roanoke, Virginia was selected as the site for this study. The city's age and industrial heritage have resulted in a range of vacant parcel types and conditions that provide an excellent opportunity to define and assess vacant land categories. The City of Roanoke became a hub for railroad and other industrial activities in the first half of the 20th century, when the city's population grew from 21,495 in 1900, to 91,921 in 1950 (Blakeman et al., 2008). However, as economic conditions and technologies changed, many traditional manufacturing operations and industries closed and ceased production in the city. As a result, there are many left-over industrial corridors with underused or abandoned properties that in some cases act as brownfields, or a blight, posing a threat to the surrounding neighborhoods and to the environment (Blakeman et al., 2008). The city has a current population of 97,032 (U.S. Census Bureau, 2010), and covers an area of 42.9 square miles (113.3 km^2). Roanoke enjoys a mild climate that is subtropical and humid, and has a monthly high temperature of 45.6 °F (7.6 °C) in January and 83.4 °F (28.6 °C) in June. It has a mean annual precipitation of 41.25 inches (1047.7 mm) (NowData - NOAA Online Weather Data, 1981-2010). The City of Roanoke is located in SW Virginia, at about 37°16'N and 79°56'W, in the valley and ridge region of the state.

3.2. Typology of Vacant Urban Land

3.2.1.Development of a Typology

Four steps were required to develop the proposed comprehensive typology: 1) a literature review was conducted to determine the status of our understanding of the related phenomena and previous attempts to develop a typology for urban vacant land (Chapter 2); 2) a field inventory was taken of vacant land characteristics; 3) a list of criteria was developed for use in vacant land design and planning; and finally 4) the vacant land typology and framework proposed here was developed. Note that the typology of vacant land proposed here is not expected to serve as an absolute typological framework for categorizing vacant land, but instead is intended to assist designers, planners, and municipalities dealing with urban vacant land. The literature review revealed little research into the possibility of developing a typology of urban vacant land, and no assessments of city policy tools designed to use or reuse urban vacant land. Therefore, there was a clear need to develop a tool for managing urban vacant land to assist planners and designers to better utilize urban vacant land in more ecologically and socially appropriate ways.

To understand the various characteristics of vacant land in an urban environment, a field inventory of the study city's vacant land was essential in order to examine the related phenomena with critical, in-person observations. A list of observational variables was therefore created to assess the relevant characteristics identified in the comprehensive literature review in terms of their ecological and social value. The distinguishing variables (Table 3. 1) identified during the field trip were then categorized in terms of their physical, biological, social and visual/spatial characteristics, and any extent development issues to develop a typology for vacant land.

Field observations were based on the researcher's visual observations of current vacant land site conditions and social characteristics and evaluated based on the researcher's perceptions of the site, including interrelated socio-cultural issues such as its safety, history, and function as a community asset. Contamination levels were estimated based on the researcher's previous experience, taking into account the land's current physical condition and assumed previous land use history. Multiple distinguishable variables were recorded for each vacant lot, including physical characteristics, biological characteristics, social characteristics, development issues, and visual/spatial characteristics (Table 3.1).

Examples of the main physical characteristics included a lot size greater or less than 2 acres, an average slope of greater or less than 5 %, and whether or not the site was likely to be contaminated based on the researcher's assessment and the assumed previous land use history. Biological characteristics in a 1/10 acre lot included vegetation that was either wild or not wild based on the maintenance of the forest structure, whether there were 5 or more trees or not, whether these trees were from 3 or more species or not, and an average plantable space on the lot of greater or less than 50 % of the area. The use of 5 as the benchmark for the number of trees was based on a previous urban vacant land forest structure study conducted for the City of Roanoke (Kim, Miller and Nowak, unpublished data). Important social characteristics included the presence of a significant structure or not, the physical condition and potential uses of any such significant structure, and visual accessibility based on visibility during the regular course of daily life in the neighborhood. Major development issues included the stage of development based on the site's current environmental and physical condition, possible development options based on its economic status and potential, and its current environmental condition to evaluate whether remediation would be required before it could be developed for different types of land use. Visual/spatial characteristics included community integrity based on a site's socio-cultural relationship with surrounding areas, vegetation quality based on the current urban forest structure, and prominent land forms based on the existing contours of the site.

The inventory of vacant land characteristics consisted of field observations in the area of the central Roanoke River, which includes many different types of vacant land due to the large number of derelict and underused industrial properties. The researcher was equipped with maps, a field book, and a camera to take notes and capture the characteristics of the different types of vacant land. The field-based observational data was collected during the 2013 leaf-on season (June ~ July) to facilitate the evaluation of the environmental characteristics of the vegetation. Sites on both public and private property were assessed and details of each site's physical, biological, social, visual/spatial characteristics and development issues were recorded (Table 3.1). These distinguishing variables were then compared and grouped based on their similarities and differences, to develop a list of criteria (Table 3.2), leading to the development of a vacant land typology (Fig. 3. 1).

Table 3.1 Vacant land's distinguishing variables identified during field-based data collection

Physical characteristics	Biological characteristics	Social-cultural characteristics	Development issues	Visual / spatial characteristics
Structure present No structure present	Wild vegetation No wild vegetation	Historical site Not a historical site	Previous development history - Previously developed land or previously unattended with vegetation land	Safe Not safe
Size – small to large	Large number of trees Small number of trees	Community asset Not a community asset	Stage of development - suitable for development or not unsuitable for development	High crime level Low crime level
Slope – gentle or steep	Large tree canopy cover Small tree canopy cover	Significant structure No significant structure	Development method – historically appropriate use, unlimited development, limited development, environmentally sensitive use, ecosystem conservation, ecosystem enhancement	Illegal activity No illegal activity
Shape – rectangular, irregular, or linear	Large plantable space Small plantable space	Accessible Non-accessible	Term of potential use – short-term use or long-term use	Prominent natural landmarks No prominent natural landmarks
Permeability– permeable or impermeable paving	Large ground cover Small ground cover	Visual access No visual access	High property value Low property value	Complex natural landmarks No complex natural landmarks
Visible maintenance No visible maintenance	Diverse tree species Few tree species		Actual land use - vacant, commercial, industrial, residential, and transportation	Prominent land forms No prominent land forms
Presence of debris No presence of debris			Adjacent land use – residential,	Complex profile Not complex profile
Contamination level- contamination or no contamination				High vegetation quality Low vegetation quality
				Landscape integrity No landscape integrity
				Community integrity No community integrity

3.2.2. Typological Criteria Applied

If a typology of urban vacant land is to be useful, it is important to use criteria that are potentially helpful for planning, design and management. Four criteria were therefore developed from the field observations to identify different types of urban vacant land, namely a site's natural, cultural, economic, and aesthetic characteristics (Table 3.2).

Table 3.2 List of criteria for assessing vacant land

Natural		Cultural	Economic	Aesthetic
Physical characteristics	Biological characteristics	Social-cultural characteristics	Development issues	Visual/Spatial characteristics
Structure	Tree number	History of site	Previous development history	Safety of site
Size	Tree canopy cover	Community asset	Stage of development	Crime level
Shape	Plantable space	Significant structure	Development method	Illegal activity
Slope	Ground cover	Accessibility	Term of potential use	Prominent natural landmarks
Permeability	Tree species	Visual access to site	Property value	Complexity of natural land marks
Maintenance	diversity		Actual land use	Prominent landforms
Presence of debris			Adjacent land use	Complexity of profile
Contamination level			Ownership	Vegetation quality
				Landscape integrity
				Community integrity

The physical characteristics represent natural elements on the site such as its structure, size, shape, slope, permeability, maintenance, and the presence of debris and contamination. These physical characteristics determine whether the redevelopment potential lies primarily in temporary short-term uses or more permanent long-term uses. For example, small parcels of vacant land with no structures can be used for short-term uses such as community gardens, pocket parks or small open spaces with natural habitats and vegetation for social gatherings, as well as permanent green re-use. Small parcels of vacant land without structures can also be valuable as elements in a green network that connects existing green spaces within a city, enhancing and expanding existing parks and open space facilities, and building recreational networks for walking and biking that offer health benefits for residents in the form of trails and greenway systems. Large parcels of vacant land without structures can be used for urban agriculture for food production, sustainable biomass energy systems, or large urban parks for recreational uses for permanent long-term use as part of the urban green infrastructure. Green infrastructure is an “adaptable term used to describe an array of products, technologies, and practices that use natural systems or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services” (USEPA, 2011). Green infrastructure can also help manage storm water, increase biodiversity, restore water quality and soils, and improve air quality for local residents.

A site’s biological, socio-cultural, and visual/spatial characteristics (Table 3. 2) represent natural, cultural, and aesthetic elements that can help residents appreciate the potential value of vacant land in terms of its ecological and social value. For example, most do not understand how vegetation is structured and functions in vacant land or know which vacant properties are safe; a high crime level can also have an adverse effect on people’s health and quality of life. The biological, social and visual/spatial characteristics of vacant land can reveal which vacant land areas will be most important or problematic in terms of ecological and social value. This can help planners prioritize the order in which vacant land should be eliminated or remediated for properties such as junkyards, derelict industrial sites and areas with a high potential for crime, as well as identify vacant land that is ripe for redevelopment as residential complexes, green space, or other infrastructure development. This information is essential if we are to realize its full potential and transform our urban vacant land into an ecologically and socially valuable asset.

The type of vacant land under consideration for redevelopment is a crucial factor for the decision-making process. The redevelopment of derelict buildings and other unattended with vegetation sites is relatively straightforward, but vacant land forest structures support a healthy living environment for the local community and so are more valuable compared to other vacant land and every effort should be made to preserve them. For example, as part of the planning process, the owners of existing vacant land forest structure who make a firm commitment to protect the site could receive utility tax credits, thus saving water utility costs. Vacant land forest structures can reduce the environmental cost of cleaning and purifying water. Urban vacant land also has a potential function as green storm water infrastructure; many cities are greening vacant lots as an important part of their storm water management strategy (Crauderueff et al., 2012).

Development issues represent economic aspects such as the stage of development, development method, term of potential use, property value, actual land use, adjacent land use, and ownership, all of which determine whether vacant properties are suitable or unsuitable for development. It is important to identify the most appropriate method for reusing vacant land, for example would it be better to demolish or rehabilitate it, wait for a while before redeveloping it, or assemble a number of small scattered vacant plots into larger parcels for future redevelopment. The conventional demolition approach is rooted in the belief that derelict properties blight their surroundings, adversely affecting property values as well as the safety, health, and quality of life of nearby residents (U.S. Government Accountability Office, 2011). Restoration can be very expensive; if it would cost more than new development, derelict properties are unlikely be restored. Demolition may also be seen as a new opportunity to carry out a rebuilding or re-use strategy, such as new development or green re-use options for short-term and long-term uses. However, historic buildings and neighborhoods are important community assets, and preserving them can create opportunities for neighborhood revitalization.

Certain sites, particularly those close to highways and railways, may have long-term potential for industrial uses that could encourage economic investment and create jobs in the future. It is important to be able to distinguish between areas where long-term uses or short-term uses are most appropriate. Short-term goals can maximize the immediate revenue from a land sale or tax receipt as cities sell the rights to vacant land foreclosures to developers, and then receive tax revenues from investors. However, if cities re-use vacant land for urban green infrastructure, a long-term use, there are few immediate cost benefits but far greater benefits in the long run. The distinction between short-term uses and long-term uses is not always clear, but is an important factor in planners' and designers' management of vacant land.

Depending on the vacant land's natural, cultural, economic, and aesthetic characteristics, the objectives of transforming it may be different, for example improving the housing market, reducing crime, or creating green spaces to improve the community's quality of life. Urban vacant land has different characteristics and so should be developed differently. Specific strategies and rationales for each type of vacant land will encourage people to better utilize these areas in the future. Through creating category recommendations for each type of land, planners and designers can more readily appreciate the obstacles, challenges and benefits related to the future development of vacant land.

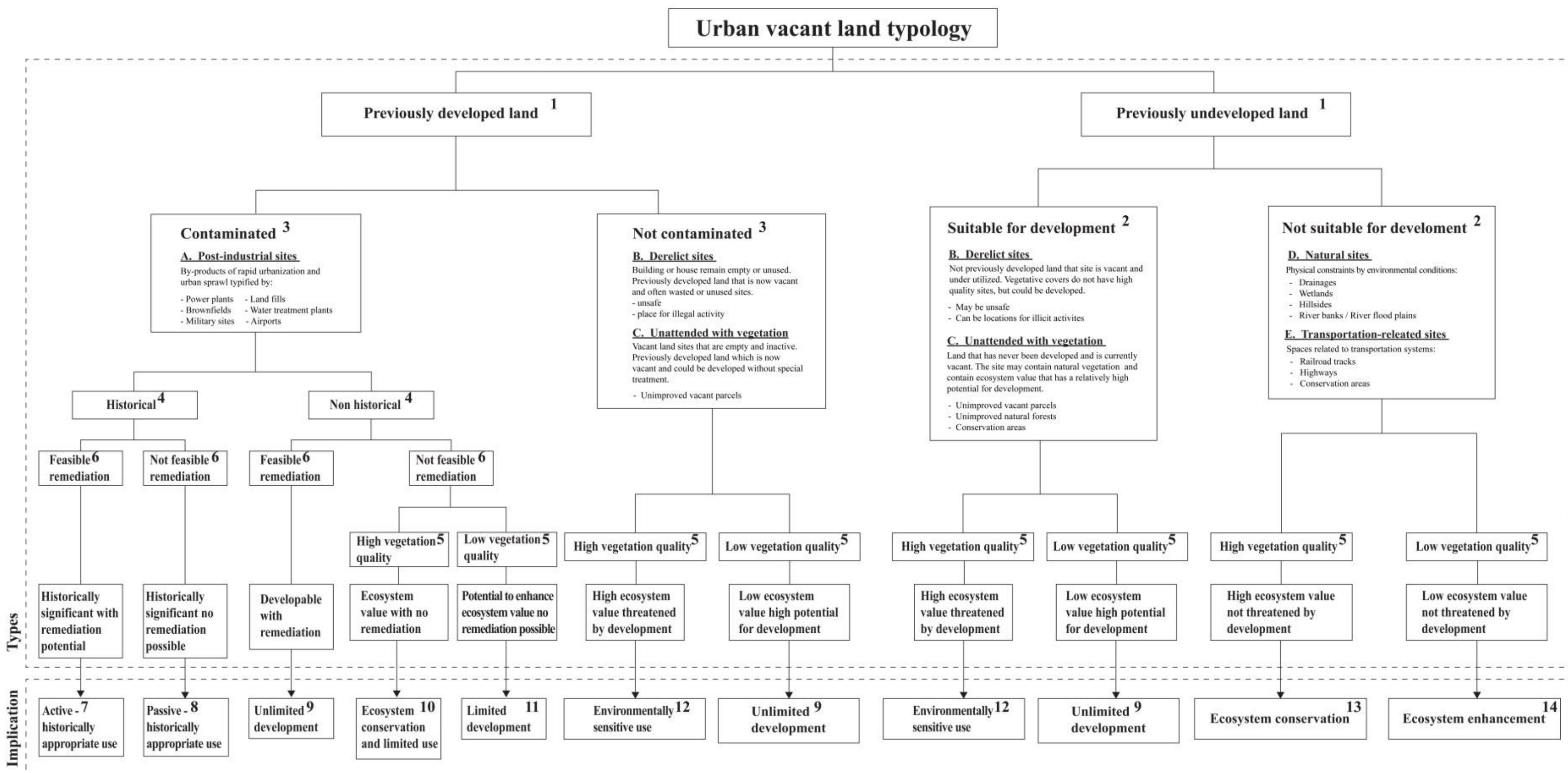
3.2.3. Typological Classification

Different types of urban vacant lands can be categorized in terms of their potential uses. Figure 3.1 outlines the various types of urban vacant lands and their characteristics, derived from the field observations. Depending on its development history, urban vacant land can be divided into previously developed land or previously undeveloped land. Previously developed land often, but not invariably, has existing building structures, while previously undeveloped land represents sites that have never been built on and so contain no remnants of building structures. Depending on the contamination level and history of the site, previously developed land may be suitable for limited or unlimited development, ecosystem conservation and limited use, and both active and passive–historically appropriate use (Fig. 3.1). Previously undeveloped land is more straightforward: it is either suitable for development, or not suitable for development depending on whether its natural and physical characteristics render it physically unfit for development.

Post-industrial sites are contaminated properties that often blight their surroundings, affecting property values as well as the safety, health, and quality of life of nearby residents. These post-industrial sites are a product of industrial growth and decline, changing zoning policies, or the abandonment of infrastructure (Kamvasinou, 2011). They are generally by-products of rapid urbanization and urban sprawl, such as power plants, landfills, brownfields, water treatment plants, military sites, and airports. Derelict sites may have buildings or houses that remain empty or unused. Some derelict sites have no structures, but are often unsafe areas that may be being used for illegal activities. These sites are effectively wasted and underused or under-appreciated sites compared to other types of vacant land.

Unattended with vegetation sites are not contaminated and the land is unimproved, with no building structures. These parcels could thus be developed without the need for special treatment such as demolition and/or remediation. Unattended with vegetation sites are empty, inactive, or awaiting development, such as unimproved vacant parcels or natural forests and conservation areas.

Natural and transportation-related sites are not contaminated but are vacant land that is physically unfit for development because of the nature of the terrain or their functional relationship with adjacent land uses. These sites often have odd shapes and are in unsuitable locations for development. Natural sites often have development constraints due to physical or environmental conditions, such as water, wetlands, hillsides, river banks and river flood-plains. Transportation-related sites include railroad tracks, highways and bridges and were originally created by urban environmental conditions or adjacent road infrastructure. Figure 3. 1 depicts the typology of urban vacant land to illustrate the types and characteristics of urban vacant land.



Foot notes

Types defenition:

Previous development history[1]: Land use development history.

Development suitability[2]: Suitable for development or not suitable for development based on current vacant land's natural and physcial characteristics (e.g. flood plain, contaminaiton level, size, slope and conservation areas) that are physically unfit for development.

Contamination level[3]: Coatmination level is based on the vacant land's current physical condition and assumend previous land-use history.

Historical site[4]: Historical significance based on the historical event or structure.

Vegetaiton quality[5]: Vegetation quality is based on current forest structure, such as tree / shrub canopy cover percent, tree / shrub species, and ground cover types (e.g. plant space, herbs, grass, bare soil, rock, and cement).

Feasible remediation[6]: Feasible remediation is based on the cost of remediation and whether it would be economically feasible.

Implication defenition:

Active - historically appropriate use[7]: Site is not contaminated and needs to be developed in a manner that preserves its historical value (e.g. Gas Works Park, WA, High Line, NY, Landschaftspark, Duisburg-Nord).

Passive - historically appropriate use[8]: Site is contaminated and should be preserved historically, but with use limited to avoid human contact with pollution.

Unlimited development[9]: Site should be redeveloped for many different types of land-use (e.g. housing, commercial, industry and green re-use options).

Ecosystem conservation and limited use[10]: Site should be developed in uses that conserve ecosystem values and provide safe level of human contact with pollution.

Limited development[11]: Site should be developed for uses that provide safe level of human contact.

Environmentally sensitive[12]: Site should be developed for a variety of uses if done in manner that protects ecosytem values.

Ecosystem conservation[13]: Site should be conserved for its high ecosystem value.

Ecosystem enhancement[14]: The current low ecosystem value needs to be enhanced.

Figure 3.1 Development of the proposed typology of urban vacant land

3.2.4. Types of Vacant Urban Land in Roanoke

Ongoing analysis and monitoring of the city's existing urban vacant land is vital to support the management of Roanoke's urban vacant land. As part of this effort, the current status of the city's urban vacant land was evaluated using i-Tree Canopy. Photo-interpreted estimates such as those provided by i-Tree Canopy can providing essential information on natural resources to facilitate development planning and policies by enabling users to quickly and easily estimate cover classes such as trees, grass, buildings or roads over large areas (Nowak & Greenfield, 2010). With the aid of Google Earth imagery, the user classifies the type of cover class at each point, after which the program provides an estimate of the percentage ground cover in each class. The system is designed to be flexible in order to accommodate the needs of its users (i-Tree Canopy, 2011). In this study, i-Tree Canopy randomly laid 1000 points across a Google Earth image of the area within the Roanoke city boundary, and then identified different types of urban vacant land via an aerial photo-interpretation process (Table 3.3) that estimates the percentages of each type of vacant land, thus providing a snapshot of the current extent of the urban vacant land in Roanoke. The following types of urban vacant land were identified: post-industrial (3.34 km^2, 10.3%), derelict (4.01 km^2, 12.4%), unattended with vegetation (17.3 km^2, 53.3%), natural (2.78 km^2, 8.6%), and transportation-related (5.01 km^2, 15.4%).

Table 3.3 Current urban land types in the City of Roanoke (total area: 111.34 km^2)

Typology of urban land	km^2	SE[1]	% of total area	SE[1]
Post-industrial site	3.34	±0.60	3.0%	±0.54
Derelict site	4.01	±0.66	3.6%	±0.59
Unattended with vegetation site	17.3	±1.27	15.5%	±1.14
Natural site	2.78	±0.55	2.5%	±0.49
Transportation-related site	5.01	±0.73	4.5%	±0.66
Non-vacant land	78.9	±1.60	70.9%	±1.44

[1]Standard error

3.3. Assessing Vacant Urban Land Forest Structure and Ecosystem Services

To assess the ecosystem services and values derived from urban vegetation, the i-Tree model (www.itreetools.org) has been developed. This software is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify the urban forest structure and its numerous effects (Nowak et al., 2008a).

Results from the i-Tree model can then be used to identify the urban forest structure in order to improve urban forest policies, planning, and management (Nowak et al., 2011). The model also provides data to support the potential inclusion of trees within environmental regulations, and determine how trees affect the environment and, consequently, enhance human health and environmental quality in urban and rural areas (Nowak et al., 2011). In this study, the i-Tree Eco model was used to assess the green infrastructure value of vacant land in the City of Roanoke, Virginia. The i-Tree Eco analysis is based on a sample of the entire study area to measure urban forest structure and ecosystem services. In most cities, the urban forest structure is not randomly distributed throughout the city, so proportional allocation in stratified random sampling can offer more accurate data about urban forest structure and ecosystem services of vacant land. This study used 5 different categories of vacant land as strata to assess the ecosystem services associated with the vacant land in Roanoke. In addition, ecosystem services were compared among vacant, commercial, industrial, and residential lands throughout Roanoke. This was done to determine whether vacant lands represent structural assets with economic value similar to that of other land uses in the city. These values are based on the cost of replacing the ecosystem services provided by the existing trees with other hard engineered methods to achieve the same environmental benefit.

3.3.1. Aerial Field Sampling of Vacant Lots

To quantify urban forest structure and ecosystem services in a city, i-Tree results are generally stratified by land use class. However, vacant land is often only one of many land use classes and is not subdivided into different classes of vacant land. As vacant urban land has different types of open space characteristics, stratifying the vacant land into smaller, more homogeneous units can help assess variations in vacant land and offer a more accurate picture of variation. The vacant land in Roanoke was therefore categorized into 5 types for this study: post-industrial sites, derelict sites, unattended with vegetation sites, natural sites, and transportation-related sites (Table 3. 4).

Table 3.4 Categories of Roanoke's vacant land

Category	Characteristics
Post-industrial sites	By-product of rapid urbanization and urban sprawl types by: ex) power plants, landfills, brownfields, water treatment plants, military sites, airports
Derelict sites	Building or house remains empty or unused. Previously developed land that is now vacant and often wasted or unused sites: ex) unsafe, place for illegal activity
Unattended with vegetation sites	Vacant land that is empty and inactive. The site may contain natural vegetation and contain ecosystem value that has a relatively high potential for development: ex) unimproved vacant parcels, unimproved natural forest, conservation areas
Natural sites	The sites have physical constraints by environment conditions: ex) drainage areas, wetlands, hillsides, river banks/river flood plains
Transportation-related sites	Spaces are related to transportation systems: ex) railroad tracks, highways, conservation areas

Within Roanoke, 1000 points on Google Maps imagery were photo-interpreted using i-Tree Canopy to estimate the amount of vacant land in the city. Each point that fell upon a vacant parcel was classified using these vacant lot categories through the aerial photo interpretation process (Table 3.5). Photo-interpreted estimates of cover classes are beneficial for providing essential information related to natural resources and development planning and policies at the local to national scale (Nowak & Greenfield, 2010). Effective planning and management of vacant land are dependent on their ongoing analysis and monitoring. The information about the percentage of existing urban vacant land supports Roanoke's urban vacant land management work by providing a snapshot of the current state of the urban vacant land. A more detailed description and rationale of the types was covered earlier in Section 3.2. After the area of vacant land was determined, field plots were laid to assess the ecosystem services derived from the trees on these vacant lands. Overall, 114 one-tenth-acre plots, located on both public and private property, were sampled using a stratified random sampling method across five vacant urban land categories. These consisted of: post-industrial sites (15 plots), derelict sites (14 plots), unattended with vegetation sites (53 plots), natural sites (17 plots), and transportation-related sites (15 plots). Plots were assigned proportionate to the land area within each stratum based on the i-Tree

Canopy results.

To select the 114 field plot locations, the city was divided into 120 grid cells (Figure 3.2) and 53 individual grid cells were then randomly selected for sampling. From the center of each grid cell, the closest vacant lot within each of the 5 vacant classes was selected based on the researcher's visual observation. Vacant parcels were categorized into one of the 5 types based on their existing and past use and potential for future development. For each selected vacant parcel, one 1/10 acre field plot was randomly selected within the parcel. If some of the vacant land classes were not present in the grid cell, additional grids cells were selected until the target sample size was attained for each vacant land class.

A sampling of 114 plots in this work is a reasonable sample size given the costs associated with measuring field plots and a goal of maximizing reduction in Standard Error (SE) of the estimates per unit cost for the city. However, five urban vacant land categories did not achieve 20 plots. This increases the uncertainty of the results within the smaller samples and the reader is cautioned regarding these results. With a small sample of less than 20, or any small sample size, the uncertainty of the estimate increases as the Standard Error (SE) increases. As a general rule, 200 plots (0.04 ha each) in a stratified random sample (with at least 20 plots per stratum) will yield a standard error of about 10% for an estimate for the entire city (Nowak et al., 2008b). In our case we used a minimum of 15 plots per stratum and the results will thus yield a higher standard error than 10% for some plots. As the number of plots increases, the standard error decreases and we can be more confident in the estimate for the population. However, as the number of plots increase, so does the time and cost of field data collection.

To compare the ecosystem services provided by vacant, commercial, industrial, and residential land, an additional 137 (0.04 ha) plots were measured using a stratified random sample of 0.04 ha plots across three land use types: commercial (14 plots), industrial (40 plots), and residential (83 plots) during 2010 using i-Tree Eco sampling protocols and analysis tools. Plots were assigned proportional to the tree canopy cover and land area within each stratum based on existing canopy data and land use zoning (Wiseman & King, 2012).

For each plot, the percentage covered by tree canopies, shrubs and other cover types was assessed. For each woody plant with a minimum Diameter at Breast Height (DBH; 4.5ft) of one-inch, the following variables were measured: species, DBH, total height, crown width (N-S, E-W), percentage of canopy missing and dieback, crown light exposure, and trees near buildings (distance and direction from trees). All field data was collected during the 2010 and 2013 additional sampling of vacant lots leaf-on seasons (June ~ July) to properly assess the tree canopies. Field data were input into the i-Tree Eco model to assess the tree structural characteristics and ecosystem services derived for each vacant land class. Details of the i-Tree Eco methods are available at the i-Tree website (www.itreetools.org) and in several publications (e.g., Nowak et al., 2003, 2008a, 2008b).

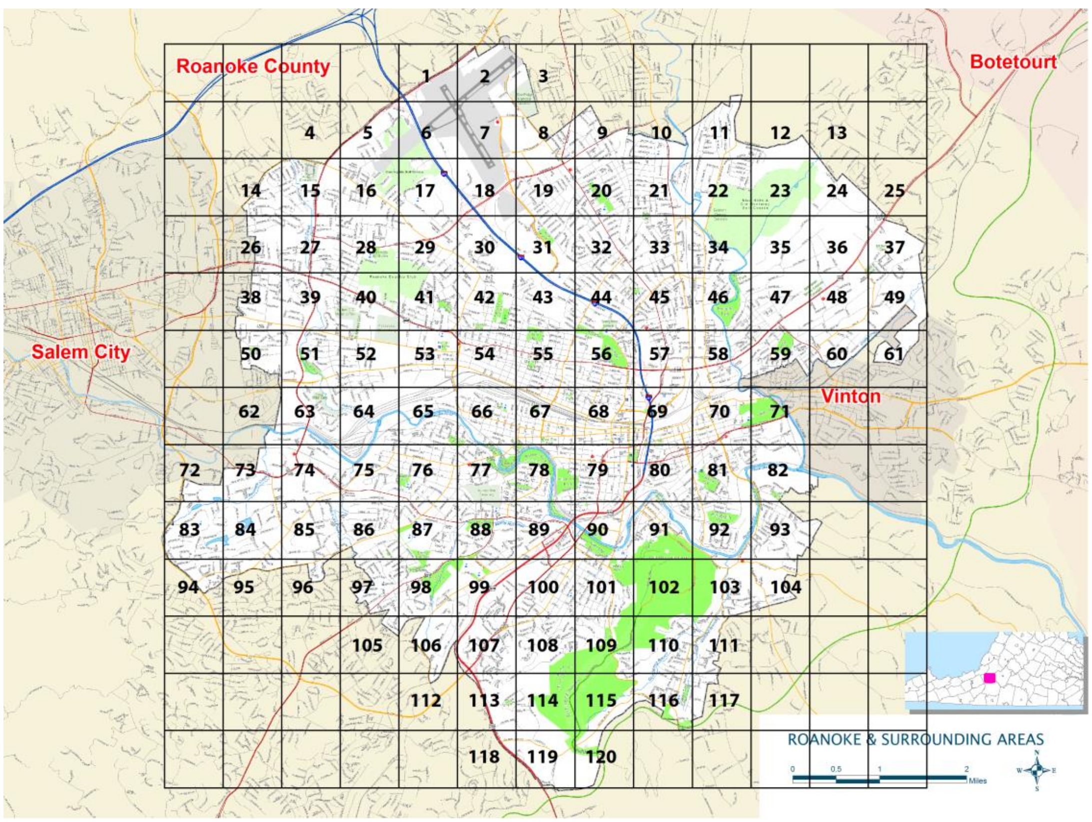


Figure 3.2 Study area and grid cells for the City of Roanoke, Virginia.

Table 3.5 Existing vacant urban land area and percentages with completed plots for the City of Roanoke, VA: summary data are provided from the City of Roanoke, analyzed using the i-Tree Canopy

Typology of vacant urban land	Existing vacant urban land				Number of plots selected for analysis
	Acres	±SE	% of total area	±SE	
Post-industrial sites	864	±4.6	3.0%	±0.54	15
Derelict sites	1,029	±607	3.6%	±0.59	14
Unattended with vegetation sites	4,297	±4898	15.5%	±1.14	53
Natural sites	727	±356	2.5%	±0.49	17
Transportation-related sites	1,276	±842	4.5%	±0.66	15
Non-vacant land	19,268	±27745	70.9%	±1.44	0
City total	27,461		100%		114

±SE = Standard error

CHAPTER 4: VACANT URBAN LAND TYPOLOGY AND FRAMEWORK

4.1. Vacant Urban Land Characteristics by Typology

The vacant land in cities is substantially different from the structure of the dominant land use in cities: residential land. The structure of land use includes its physical attributes, environmental conditions and land use issues. Depending on the previous and current urban land use structures, the existing condition and redevelopment potential of the vacant land will be different and will require different approaches for future development. It is therefore important for planners and developers to understand the potential benefits to be gained through redeveloping these spaces, but also the obstacles that first need to be overcome.

4.1.1. Post-Industrial Sites

Post-industrial sites in Roanoke usually have structures that were previously built for a particular land use such as a factory or power plant and have been since abandoned to become vacant land. Some factory sites are contaminated. Wild vegetation has grown freely over time, with no signs of maintenance, and can potentially affect people's health and decrease their quality of life. Post-industrial sites may support illegal activities and crime decreasing the surrounding property values. The lot size can vary considerably, depending on the previous land use, but they are generally rectangular in shape with a gentle slope, thus facilitating future development by avoiding the need to level the ground. Adjacent development areas of post-industrial sites are often related to industry or transportation, such as highways and railways. The examples of post-industrial factories shown in Figures 4.1 and 4.2 are now owned by the municipality, but others may be privately owned. Most post-industrial sites do not allow people to access the site without permission; boundaries are usually established by a fence, limiting access, and the site is therefore seldom used to its full potential. However, if the structures on the post-industrial sites are significant, the sites can be rehabilitated to create community assets for both short and long-term uses. Some post-industrial structures vividly convey the history of the site, supporting the identity of the site and the local area as a whole, and should thus be considered a valuable part of the city's cultural heritage and preserved for future generations. Otherwise, the site can be redeveloped for commercial use, housing, or green spaces.

Figure 4.1 Post-industrial factory located near the railway, City of Roanoke, Virginia

Figure 4.2 Wild vegetation growing on a post-industrial factory site, city of Roanoke, Virginia

4.1.2. Derelict Sites

Derelict sites in Roanoke usually include structures that are now empty and unused due to decentralization and economic decline. Some derelict sites have no structures, but are used for unsafe and potentially illegal activities thus decreasing surrounding property values. These places often convey a negative image of a neighborhood; there is no visible maintenance and wild vegetation is overgrown. Derelict sites are usually relatively small, with a rectangular shape and a moderately gentle slope; adjacent areas are often developed as residential or commercial. The most common examples of derelict sites in Roanoke are empty commercial buildings and houses that are privately owned and have become derelict for various reasons. Empty commercial buildings and houses have no public access, but can be used for anti-social activities. If the building structures are eligible for rehabilitation, they can be revitalized as community assets for long-term uses. Otherwise, derelict vacant properties can be demolished and redeveloped to make way for new development, such as housing, commercial, and green spaces.

Figure 4.3 Derelict residential building, City of Roanoke, Virginia

Figure 4.4 Two adjacent derelict residential buildings, City of Roanoke, Virginia

4.1.3. Unattended with Vegetation Sites

There are two different types of unattended with vegetation sites in Roanoke. The first consists of unimproved vacant parcels that have not been contaminated by toxic waste and contain no building structure. This previously developed or undeveloped land is now vacant and could be redeveloped without requiring special treatment such as demolition, or remediation. Most of these sites are covered with grass that was once maintained and they vary in size from small to large. In the urban core, unimproved vacant parcels are usually small, rectangular shapes surrounded by residential areas and are green spaces visible to everyone; they may be informally used as play areas for local children. The example of a residential unimproved vacant parcel shown in (Figure 4.5) is privately owned and is pending development.

The second type of unattended with vegetation sites describes unimproved natural forests without contamination (Figure 4.6). Most people consider vacant sites as empty land without building structures, but there are many unimproved natural forests in Roanoke. These sites have diverse species of trees in natural stand conditions and thus high ecosystem service values for the community, such as storm water management, air pollution removal, and carbon sequestration and storage. There is no visible maintenance, and wild vegetation is overgrown without dumped debris. The size of these areas varies depending on their location within the city, from small to large. In residential areas, these sites are usually small rectangular shapes with forest structure, but in suburban areas, they look similar to other natural sites, such as mountains or suburban forests. The slope is usually gentle, so no special treatment is necessary to develop the sites and they are usually adjacent to residential or forest land. Unimproved natural forests in a residential district are usually privately owned, but some unimproved natural forests may be municipally owned. These sites do not have boundaries, so people can access them easily. Compared to other types of vacant land, these sites do not convey a negative image so they have high potential green re-use options for green infrastructure such as urban parks for long-term use that can increase surrounding property values.

Figure 4.5 Unimproved vacant parcels in a residential neighborhood, City of Roanoke, Virginia

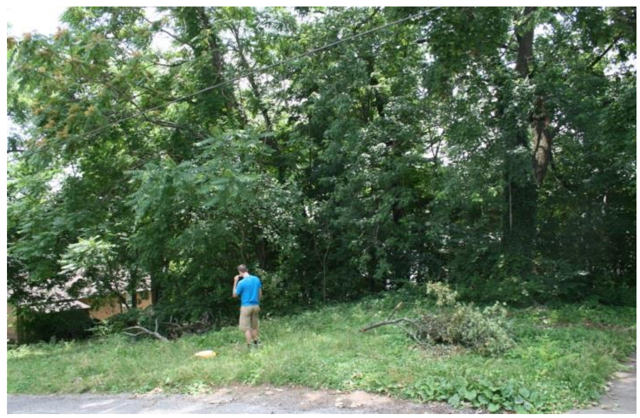


Figure 4.6 Unimproved natural forests in a residential neighborhood, City of Roanoke, Virginia

4.1.4. Natural Sites

The natural sites in Roanoke are generally not suitable for development because of the nature of the terrain and its functional relationship with adjacent land uses, such as bodies of water, rivers, and natural forests, that include drainage, wetlands, hillsides, river banks and river flood plains. There is no visible maintenance and wild vegetation is overgrown. These sites are not contaminated and are usually large, with shapes that vary from rectangular to linear or irregular. For example, river banks and river flood plains have linear shapes extending along the river, but the wetlands and hillsides contain irregular shaped land without structures. Slopes tend to be steep relative to other types of vacant land sites, reducing residents' access to the site, although they do provide an attractive visual amenity, adding aesthetic value. Adjacent areas are mountains, forests in natural stand condition, and water and rivers that can increase the vacant land's property value and also convey a positive image for the community. Usually, these areas are defined as conservation land for recreational use and urban ecosystem functions in a city.

Figure 4.7 Natural site – river bank,
City of Roanoke, Virginia

Figure 4.8 Residential drainage,
City of Roanoke, Virginia

4.1.5. Transportation-Related Sites

Transportation-related sites are generally not suitable for development because of their functional relationship with adjacent land uses, which may include highways, railroad tracks and bridges. Transportation-related sites usually have linear shapes that extend along roads or railway lines, and lack existing structures. Often there is little visible maintenance, and vegetation is overgrown, with some dumping of debris from vehicles. However, these sites are generally not contaminated. Sometimes, highway verges and interstates are managed by the city for safety reasons. Lot sizes can vary from small to large, and the shapes of the land can vary from linear to highly irregular. The slope is usually gentle, although some road system sites do include steep slopes. The adjacent area is almost invariably a transportation system, so there is no easy access to these sites, but they are highly visible to residents and passersby and so create aesthetic value that can increase neighboring property values. From an ecological point of view, these sites can provide valuable wildlife corridors within urban ecosystems and also provide ecosystem services such as rainfall interception and the removal of air pollution from vehicles. Transportation-related sites represent important urban green infrastructure for long-term uses.

Figure 4.9 Transportation-related site - bridge, City of Roanoke, Virginia

Figure 4.10 Wild vegetation growing along the railroad tracks, City of Roanoke, Virginia

VACANT LAND CHARACTERISTICS / VACANT LAND CLASSIFICATION					NATURAL													CULTURAL							
					PHYSICAL								BIOLOGICAL					SOCIAL							
					Elements					Processes			Vegetation Structure					Elements			Accessibility				
					Vacant land					Vacant land			Vacant land					Vacant land			Vacant land				
land use	development	contamination	implication	type	Structure	Size	Shape	Slope	Permeability	Maintenance	Presence of debris	Contamination	Tree number	Tree canopy cover	Plantable space	Ground cover	Tree species diversity	History of site	Community asset	Significant structure	Fence	Railroad track	Highway	Bridge	Visual access to site
PREVIOUSLY UNDEVELOPED LAND	NOT SUITABLE FOR DEVELOPMENT	Not contaminated	Ecosystem conservation, Ecosystem enhancement	Transportation-related sites ex) railroad tracks, highways, conservation areas	no structure present	small to large	linear or irregular	gentle to steep	permeable paving	no visible maintenance	dumped debris	no contamination	low to high	low to high	low to high	low to high	middle	low	low to high	no structure present	no fence present	railroad present	highway present	bridge-present	visual access
				Natural sites ex) drainages, wetlands, hillsides, river banks / river flood plains	no structure present	large	linear or irregular	gentle to steep	permeable paving	no visible maintenance	no dumped debris	no contamination	high	high	low	high	high	low	high	no structure present	no fence present	no railroad present	no highway present	no bridge-present	visual access
	SUITABLE FOR DEVELOPMENT	Not contaminated	Environmentally sensitive use, Unlimited development	Derelict sites ex) may be unsafe, can be locations for illicit activities	no structure present	small to large	square	gentle	permeable or impermeable	no visible maintenance	dumped debris	no contamination	low to high	low to high	low to high	low to high	low to high	low	low	no structure present	fence present or no fence present	no railroad present	no highway present	no bridge present	no visual access
				Unattended with vegetation ex) unimproved vacant parcels, unimproved natural forest, conservation areas	no structure present	small to large	square	gentle	permeable or impermeable	no visible maintenance	dumped debris	contamination	low to high	low to high	low to high	low to high	low to high	low	low to high	no structure present	fence present or no fence present	no railroad present	no highway present	no bridge present	no visual access
PREVIOUSLY DEVELOPED LAND	SUITABLE FOR DEVELOPMENT	Not contaminated	Environmentally sensitive use, Unlimited development	Derelict sites ex) unsafe, place for illegal activity	structure present or not	small to large	square	gentle	permeable or impermeable	no visible maintenance	dumped debris	no contamination	low to high	low to high	low to high	low to high	low to high	low to high	low	significant or no significant	fence present or no fence present	no railroad present	no highway present	no bridge present	no visual access
				Unattended with vegetation ex) unimproved vacant parcels	no structure present	small to large	square	gentle	permeable or impermeable	no visible maintenance	dumped debris	no contamination	low to high	low to high	low to high	low to high	low to high	low	low to high	no structure present	fence present or no fence present	no railroad present	no highway present	no bridge present	no visual access
		Contaminated	Active / Passive - historically appropriate use, Unlimited / limited development, Ecosystem conservation and limited use	Post-industrial sites ex) power plants, land fills, brownfields, water treatment plants, military sites, airports	structure present or not	small to large	square	gentle	permeable or impermeable	no visible maintenance	dumped debris	contamination	low to high	low to high	low to high	low to high	low to high	low to high	low to high	significant or no significant	fence present or no fence present	no railroad present	no highway present	no bridge present	no visual access

Figure 4.11 Typology of vacant urban land framework: Part I

VACANT LAND CHARACTERISTICS / VACANT LAND CLASSIFICATION					ECONOMICAL DEVELOPMENT — Elements — Vacant land						AESTHETIC VISUAL / SPATIAL — Imageability — Vacant land							Integrity — Vacant land		
land use	development	contamination	implication	type	Stage of development	Term of potential use	Property value	Actual land use	Adjacent land use	Ownership	Safety of site	Crime level	Illegal activity	Prominent natural landmarks	Complexity / natural landmarks	Prominent landforms	Complexity of profile	Vegetation quality	Landscape integrity	Complexity integrity
PREVIOUSLY UNDEVELOPED LAND	NOT SUITABLE FOR DEVELOPMENT	Not contaminated	Ecosystem conservation, Ecosystem enhancement	Transportation-related sites ex) railroad tracks, highways, conservation areas	not suitable	long-term use	low to high	transportation	transportation	municipal	not safe	low	low	not prominent	complex	not promient	complex	middle	middle	low
				Natural sites ex) drainages, wetlands, hillsides, river banks / river flood plains	not suitable	long-term use	low to high	natural forest	water, river, natural forest	municipal	safety	low	low	prominent	complex	promient	complex	high	high	middle
	SUITABLE FOR DEVELOPMENT	Not contaminated	Environmentally sensitive use, Unlimited development	Derelict sites ex) may be unsafe, can be locations for illicit activities	suitable	short term or long-term use	low	vacant	commercial or residential	private or municipal	not safe	high	high	not prominent	not complex	not promient	not complex	low	low	low
				Unattended with vegetation ex) unimproved vacant parcels, unimproved natural forest, conservation areas	suitable	short term or long-term use	low to high	vacant	residential	private or municipal	safety	low	low	not prominent	not complex	not promient	not complex	low to high	low	low
PREVIOUSLY DEVELOPED LAND	SUITABLE FOR DEVELOPMENT	Not contaminated	Environmentally sensitive use, Unlimited development	Derelict sites ex) unsafe, place for illegal activity	suitable	short term or long-term use	low	vacant	residential	private or municipal	not safe	high	high	not prominent	not complex	not promient	not complex	low	low	low
				Unattended with vegetation ex) unimproved vacant parcels	suitable	short term or long-term use	low	vacant	residential	private or municipal	safety	low	low	not prominent	not complex	not promient	not complex	low	low	low
		Contaminated	Active / Passive - historically appropriate use, Unlimited / limited development, Ecosystem conservation and limited use	Post-industrial sites ex) power plants, land fills, brownfields, water treatment plants, military sites, airports	suitable	short term or long-term use	low	industrial, vacant	industrial, transportation	private or municipal	not safe	high	high	not prominent	not complex	not promient	not complex	low	low	low

Figure 4.12 Typology of vacant urban land framework: Part II

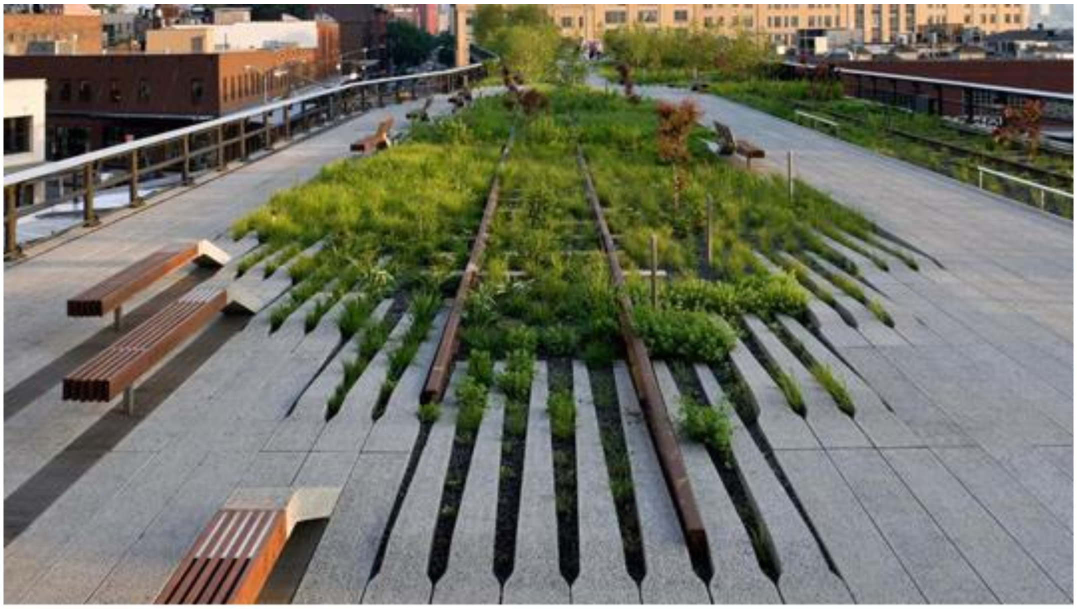
4.2. Potential Benefits of Vacant Urban Land by Typology

4.2.1. Post-Industrial Sites as Public Amenities

As the framework shown in Figures 4.11 and 4.12 demonstrates, post-industrial sites are often potential public amenities as a result of the significant structures they contain, which may represent a historically important part of the city's cultural heritage. In such cases, the post-industrial structures can be rehabilitated as public amenities such as parks for long-term uses. Post-industrial sites are generally the result of industrial growth and decline, changing zoning policies, or of the abandonment of old infrastructure elements (Kamvasinou, 2011), although sometimes a post-industrial site has been "so damaged by industrial or other development that it cannot be used beneficially without treatment" (Kivell, 1993, p.51). These sites are called brownfields. Contamination is often a serious obstacle to re-using post-industrial sites. In addition, post-industrial sites have few trees, little plantable space, and may have impervious ground cover classes (building, cement, and rock), which means that these places are not ecologically healthy and may even increase urban storm water runoff. The general perception of post-industrial sites conveys negative images that decrease the quality of life of nearby residents, and many people do not understand how derelict post-industrial sites can provide benefits to the local community. However, technology that facilitates the rehabilitation of urban sites is becoming more available and people are starting to re-think the potential value of these post-industrial sites.

Some post-industrial sites have a high potential to expand the development of new ideas related to landscape design. James Corner's Field Operations' High Line Project (www.thehighline.org) in New York City is an example of this. An elevated rail line that was originally part of the city's essential infrastructure had fallen into disuse and was redesigned as a green corridor, providing a range of community uses and at the same time preserving the transportation history of the west side of Manhattan. This project is a showcase for creativity and original thinking, demonstrating how the redesign of post-industrial sites can be used to improve a city's image. The redesign of post-industrial sites with links to the local heritage can also be harmonized with community preferences in terms of socio-cultural, and economic issues. Such concerns are key in re-purposing post-industrial sites in multiple ways, giving value to land previously considered worthless.

Figure 4.13 Landschaftspark Duisburg Nord by Latz + Partner, Duisburg, Germany (Source: http://www.landezine.com/index.php/2011/08/post-industrial-landscape-architecture/), used under fair use (April. 8, 2015)



High Line Park, NY - Photo by Iwan Baan

Figure 4.14 The High Line, New York City (Source: Iwan Baan http://www.greeningofcities.org/), used under fair use (April. 8, 2015)

If post-industrial sites contain historically significant structures with remediation potential and are not contaminated, wherever possible the sites should be developed in a manner that preserves their historical value. However, if no remediation is possible due to severe contamination, the sites should be preserved historically but with limited access for safety reasons. If post-industrial sites have no significant structure or contamination requiring remediation, they can be redeveloped for many different types of land-use, including residential, commercial, industrial, and green re-use options. Post-industrial sites with no significant structures but contamination that cannot easily be dealt with by remediation should be redeveloped to conserve the existing ecosystem values while at the same time limiting human contact with pollution to a safe level.

4.2.2. Derelict Sites as Community Assets

Derelict sites have potential as community assets because they may contain significant building structures that can be rehabilitated or redeveloped for short or long-term uses (Figures, 4.11 and 4.12). Derelict buildings are an indicator of neighborhood decline, reducing sense of community and discouraging investment. According to the National Land Use Database (NLUD) in the UK, derelict land is another side of "previously developed" and hence "available for development" land, even "Land so damaged by previous industrial or other development that it is incapable of beneficial use without treatment …" (Kamvasinou, 2011, p.159). For both short and long-term uses, municipalities could provide incentives to encourage developing these sites, such as tax abatement for infill redevelopments of derelict sites. When people are living there, poorly maintained vacant land and formerly derelict properties are usually improved, lowering the level of illegal activity and thus improving safety and decreasing the municipal budget devoted to the maintenance of derelict buildings. The most effective benefit is to halt the decline in neighborhood property values.

The positive public perceptions toward derelict land are notable, particularly "where the remains of any structure or activity have blended into the landscape in the process of time (to the extent that it can reasonably be considered as part of the natural surroundings), and where there is a clear reason that could outweigh the reuse of the site – such as its contribution to nature conservation – or it has subsequently been put to an amenity use and cannot be regarded as requiring redevelopment" (Kamvasinou, 2011, p.159) thus there are often good reasons to redevelop derelict land as a public amenity and provide additional green space.

The best strategy for managing derelict buildings is for cities to acquire the derelict buildings through foreclosure, then clean up the sites, demolish unsafe structures, and maintain the property until it can be sold. However, the process of acquiring and refurbishing derelict buildings involves significant time and cost commitments; when the city acquires derelict buildings, they provide no tax revenues and require additional maintenance costs until new residents move in. As a result, encouraging investment and boosting home ownership rates for derelict buildings can support neighborhood stability. Without a healthy housing market, the stability of a neighborhood is uncertain. Since a city may not have enough money to redevelop all its derelict properties, the private market should be encouraged to acquire and reuse derelict sites as much as possible.

Some derelict sites contain no structures but are used for unsafe and potentially illegal activities. This can be addressed by tax incentive systems that impose high taxation rates on unimproved land. A low rate or no tax at all could be levied on infill development on vacant land, and tax credits provided for vacant land forest structures and rehabilitation abatement to increase the value of vacant land. If a derelict site with high ecosystem value is threatened by development planners can ensure that it is developed in a way that protects ecosystem values. However, if the derelict site has low ecosystem value with high potential for development it can safely be developed for many different types of land-uses, such as residential, commercial, industrial and green re-use options.

4.2.3. Unattended with Vegetation Sites as Natural Assets

Unattended with vegetation sites have significant potential as natural assets, as indicated in the typology of urban vacant land shown in Figures 4.11 and 4.12, because the highest numbers of trees occur in these sites, which make up over half of all the urban vacant land in Roanoke. Many ecosystem benefits are directly proportional to the number of trees, so unattended with vegetation sites represent an important ecological resource that significantly affects the health of the city's ecosystems. The two predominant ground cover types on unattended with vegetation sites are maintained grass and unmaintained grass. These two types comprise permeable paving, which means that these sites can be strategically used to control urban storm water. The ground space these sites contain also provides additional opportunities for tree planting in areas that are not covered by impervious surfaces and are free of existing tree canopies, which given the extensive areas involved suggests that unattended with vegetation sites have a high potential for increasing Roanoke's tree canopy cover. Increasing the tree canopy cover is itself desirable as it provides other ecosystem benefits; these spaces have higher species diversity relative to other types of urban vacant land. No matter how small or apparently unimportant their role in nature, this biodiversity improves ecosystem health, supporting natural sustainability and providing a healthy ecosystem that can better withstand and recover from a variety of natural hazards (Shah, 2011).

Unattended with vegetation sites can be an important natural asset that creates enduring value for the community (Nassauer & VanWieren, 2008) by providing opportunities for residents to pause and look around, and are a good investment in the environmental characteristics that attract people to visit a place. "Both temporary and permanent green open spaces have a valuable role to play in delivering environmental protection, nature conservation, healthy recreation and higher property values" (Taylor, 2008, p.4). Green spaces can increase biodiversity, support storm water flood protection, and provide wildlife-viewing opportunities in a healthy urban ecosystem. In unattended with vegetation sites, three or four years are sufficient to produce woody species of pioneer trees and shrubs that have a significant landscape impact (Taylor, 2008). Ideally, these sites are self-sustaining and evolving; ecological processes are a key characteristic and the flow of natural processes support urban biophysical cycling. Seeding, tending growing plants, and succession planting all take time to develop, along with the introduction of new resources and the creation of wild habitats with complex environment matrix systems. If an unattended with vegetation site with a high ecosystem value is threatened by development this should only be done in a manner that protects ecosystem values. However, if the site has low ecosystem value and a high potential for development it can safely be developed for many different types of land-uses, such as residential, commercial, industrial and green re-use options.

4.2.4. Natural Sites and Transportation-Related Sites as Green Networks

As the framework in Figures 4.11 and 4.12 shows, natural sites and transportation-related sites play potential roles as components of larger green networks because the highest tree density occurs in natural sites, followed by unattended with vegetation sites and derelict sites. Similarly, the highest tree cover occurs in natural sites, followed by transportation-related sites and derelict sites. Many ecosystem benefits are directly proportional to the number of trees and the healthy leaf surface area of the plant. In Roanoke, the most effective ecosystem benefits occur in natural sites based on their per-m^2 value relative to other types of urban vacant land. The two dominant ground cover types, grass and wild grass, both serve as pervious paving, which means that these places can be strategically used as part of the city's urban storm water management plan. Both natural sites and transportation related sites tend to be long and narrow as they lie alongside a river, railroad line or highway. These sites thus provide a useful corridor to support the movement of urban wildlife, and can improve biodiversity city-wide; increasing the city's wildlife viewing opportunities also boosts the local urban ecology. A healthy urban ecosystem builds resilience, supporting the community's ability to withstand natural hazards and other incidental environmental effects. From this perspective, natural and transportation related sites can serve as a valuable ecological green network system that provides high value ecosystem benefits for city residents.

For example, in Europe, Natur-Park Schöneberger Südgelände is notable example of ant abandoned railway that has been redesigned to allow public access to the previously inaccessible wildscape in areas that provide opportunities for those who would not normally be interested in this kind of nature (Grosse-Bächle, 2005). London's Gillespie Park Local Nature Reserve utilizes an old railway track that has been converted into a wildlife park, experiencing natural vegetation grown that has generated a wealth of ecological habitats through colonization since the railway closed in the mid 1960s (Kamvasinou, 2011). Also in London, Haringey's Northern Heights Parkland Walk opened in 1984 along 4.5 miles of a disused railway line that closed down in 1971, and over a decade this rail corridor gradually changed into an urban green wildlife corridor feature, including pioneer tree species and succession vegetation where there had initially been only rail road tracks (Kamvasinou, 2011; Haringey Council, 2010).

Figure 4.15 Railway Platforms on Parkland Walk, London, UK (Source : Fezpp 2007 http://en.wikipedia.org/wiki/Parkland_Walk#mediaviewer/File:Railway_Platforms_on_Parkland_Walk.JPG), used under fair use (April. 8, 2015)

In strategic, city-wide planning, these in-between spaces can combine to create a wider green infrastructure network of open spaces (Kamvasinou, 2011). According to Lynch, “a network of relatively small spaces, well distributed within the urban system, may be more useful than the large tracts which look so well on land-use maps” (1995, p.400). In a city-wide network, spaces in-between offer alternative types of open space to the formal gardens and well-maintained parks normally found in urban areas. These alternative spaces can also be used to develop walking, bicycle or riding trails, generating an alternative way of exploring and learning about the city and its ecology (Lynch, 1995). From this perspective, natural sites such as river banks/river flood plains and transportation-related sites are valuable ecological corridors that support a city’s green networks. If natural and transportation-related sites with high ecosystem values are not threatened by development, these sites should be conserved. However, if they have low ecosystem values that will not be threatened by development, it may be possible for the current low ecosystem value to be enhanced through proper management.

CHAPTER 5: ASSESSING VACANT URBAN LAND FOREST STRUCTURE AND ECOSYSTEM SERVICES

5.1. Forest Structure on Roanoke's Vacant Urban Land

The extent to which land use provides ecosystem services depends on their current urban forest structure. Different forest structures result in different green ecosystem benefits and infrastructure values for different land uses. Assessing the forest structure of Roanoke's vacant urban land provides a picture of the current extent and condition of the vacant urban land. Forest structure in vacant urban land refers to the amount and density of plants, the types of plants present (e.g. trees, shrubs, ground cover), the diversity of species, and tree health (Ciecko et al., 2012). Understanding these characteristics provides the details needed for vacant urban land forest management and a basis for estimating the green infrastructure value. The goal of understanding the forest structure of vacant land is to aid in understanding how vacant urban land acts as green infrastructure to a great degree, leading to better utilization of vacant land. Vacant land may offer creative alternative uses for open spaces and landscape design in a city. The assessment of forest structure using i-tree Eco is described in the following sections.

5.1.1. Tree Characteristics on Roanoke's Vacant Urban Land

In the urban landscape of Virginia, other land uses and vacant land have different forest characteristics. While vacant urban land in Roanoke contains only about 210,250 trees compared to 1,626,880 on the city's residential lots, this is largely due to the difference in acreage of the 2 types of land (8,193 vs 14,319) (Table 5.1); the percentage of tree coverage was almost identical (30.6% to 31.4%). However, the number of trees per acre on residential land is greater than on vacant land. This means that while the coverage is similar there are many more trees in residential areas. Many tree benefits are directly proportional to the amount of healthy leaf surface area of the plant (Wiseman & King, 2012). The healthy leaf surface area on individual trees growing on vacant land is relatively bigger than that of individual trees on other types of land, and thus individual trees on vacant land can provide more ecosystem services to citizens than those growing on other types. The three most common species growing in this area are American elm (16.4%), tree of heaven (12.3%), and box elder (6.7%) (Figure 5.1). The overall tree density on Roanoke's vacant land is 25.7 trees per acre, which is the lowest of any of the land use types (Table 5.1).

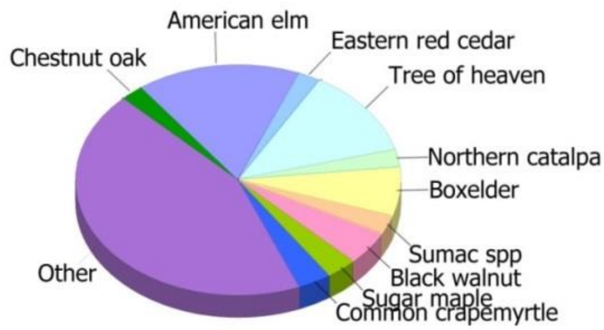


Figure 5.1 Tree species growing on vacant urban land, City of Roanoke, Virginia

Large trees provide substantially more ecosystem services, such as improving air quality and public health, cooling the air, reducing demand for air conditioning, and supporting climate change adaptation than smaller trees (Rosenthal et al., 2008). Although there are some large trees on vacant land, the much larger number of smaller trees may collectively play an important role in providing ecosystem benefits. The trees growing on Roanoke's vacant land with diameters less than 6-inches (15.2 cm) constitute 40.8% of the tree population (Figure 5.2), which suggests that these are relatively young trees and thus likely to be helpful in sustaining the urban ecosystem in Roanoke for years to come. While they are small today, they have the potential to increase in size considerably over time.

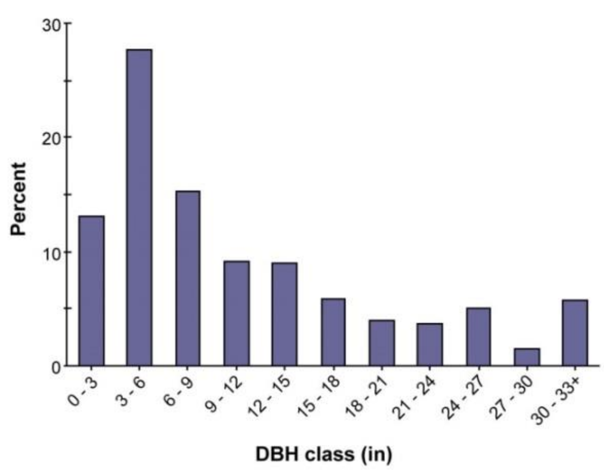


Figure 5.2 Percentage of tree population by diameter class
(DBH = stem diameter at 4.5 feet (1.37 m) above the ground line)

Table 5.1 Comparison of urban forests: Percentage tree cover and number of trees by land use. Summary data are for the City of Roanoke and analyzed using the i-Tree Eco model

Land use	Acres	Percentage tree cover	Number of trees	Number of trees per acre
Commercial	2,640	7.9	165,996	62.85
Industrial	6,057	9.7	195,355	32.25
Residential	14,319	31.4	1,626,880	113.6
Vacant	8,193	30.6	210,263	25.7

Among the categories of vacant land, the highest tree densities occur on natural sites, followed by unattended sites with vegetation and derelict sites (Figure 5.3). However, unattended sites with vegetation make up the majority of the vacant urban land (4,297 acres) (Table 5.2), so these may be particularly important resources that can have a significant impact on urban ecosystem health in Roanoke (Table 5.2).

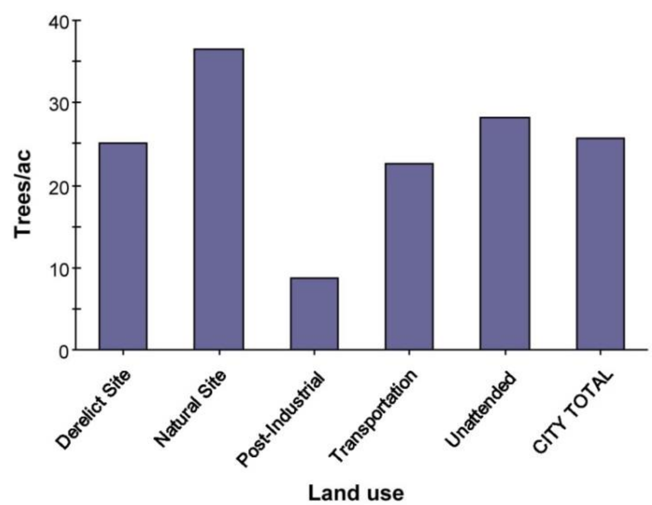


Figure 5.3 Number of trees per acre growing on vacant urban land by typology, City of Roanoke, Virginia

Table 5.2 Comparison of urban forests: Percentage tree cover and number of trees in vacant urban land by category. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Category	Acres	Percent tree cover	Number of trees	Number of trees per acre
Derelict	1,029	32.5	25,730	25.0
Natural	727	48.2	26,510	36.5
Post-industrial	864	13.5	7,490	8.7
Transportation-related	1,276	40.6	28,920	22.7
Unattended with vegetation	4,297	27.7	121,260	28.3

Urban forests are composed of a mix of native and exotic tree species, so often have higher species diversity than surrounding native landscapes (Wiseman & King, 2012). "High species diversity helps minimize ecosystem vulnerability to species-specific pests and disorders, but may also pose a risk to ecosystem health if exotic species are invasive plants that can potentially out-compete and displace native species" (Wiseman & King, 2012, p. 7). Additional exotic species may also not provide the habitat needed to support native fauna. About 69% of the trees growing on Roanoke's vacant urban land are species that are native to North America, and 60% are native to the state (Figure 5.4). Exotic species from outside North America make up 31% of the population. Most of Roanoke's vacant urban land exotic tree species are indigenous to Asia (20.2% of the species).

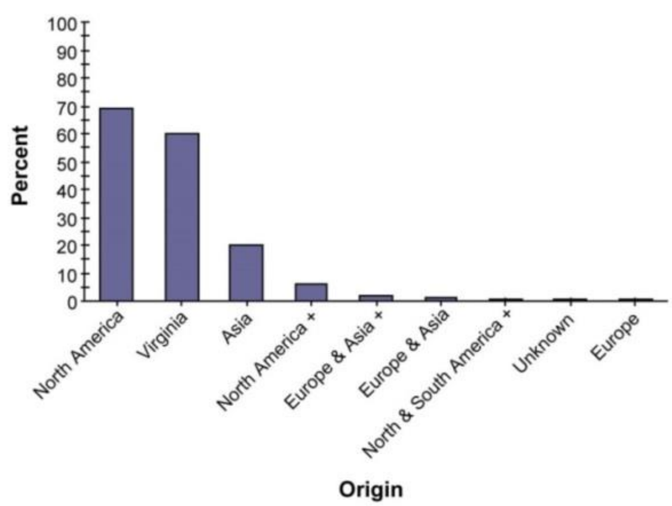


Figure 5.4 Species composition of live trees growing on vacant urban land in the City of Roanoke by geographic origin

“Biodiversity boosts ecosystem productivity where each species, no matter how small, all have an important role to play” and greater species diversity helps natural sustainability, thus providing a healthy ecosystem that can better withstand and recover from a variety of natural hazards (Shah, 2011). Roanoke’s vacant urban land contains about 210,263 trees, which is low relative to other land uses (Table 5.3). However, there are 62 species of trees growing on the vacant land, which is high relative to other land uses. The highly diverse vegetation growing on Roanoke’s vacant land will tend to provide healthy ecosystem services in a city, although in some instances this greater diversity may also cause habitat fragmentation.

Table 5.3 Comparison of urban forests: City totals for trees’ biodiversity by land use. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Land use	Percentage tree cover	Number of trees	Number of trees per acre	Number of tree species
Commercial	7.9	165,996	62.85	21
Industrial	9.7	195,355	32.25	32
Residential	31.4	1,626,880	113.6	90
Vacant	30.6	210,263	25.7	62

Among the five categories of vacant urban land in the city, unattended sites with vegetation contain about 121,263 trees, which is the highest relative to other types. These unattended sites with vegetation play host to 33 tree species, which is again the highest relative to other types: the highest biodiversity occurs in unattended sites with vegetation, followed by natural sites and derelict sites (Table 5.4). Unattended sites with vegetation also have a healthy biodiversity that may also offer high ecosystem services.

Table 5.4 Comparison of urban forests: City totals for trees' biodiversity in vacant urban land by category. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Category	Percentage tree cover	Number of trees	Number of trees per acre	Number of tree species
Derelict	32.5	25,725	25.0	18
Natural	48.2	26,514	36.5	24
Post-industrial	13.5	7,488	8.7	6
Transportation-related	40.6	28,923	22.7	13
Unattended with vegetation	27.7	121,263	28.3	33

5.1.2. Urban Forest Cover and Leaf Area on Roanoke's Vacant Land

"A major driver of the type and quantity of ecosystem services in urban areas is landcover" (Kremer et al., 2013, p. 220). The land cover of vegetation and bare soil provide more provisioning services (e.g. food production, water supply), regulating services (e.g. climate regulation, air pollution removal), and supporting services (e.g. nutrient cycling, soil building) than non-vegetated and impervious surfaces (Kremer et al., 2013; Millennium Ecosystem Assessment, 2005). In addition, many tree benefits are directly proportional to the amount of healthy leaf surface area of the plant (Wiseman & King, 2012). Tree canopy covers about 30.6% of Roanoke's vacant land area, which is moderately high relative to other land uses (Table 5.1). In Roanoke, the three most dominant tree species in terms of leaf area are American elm, black walnut, and sycamore spp (Table 5.5). Importance values (IV)[8] are calculated as the sum of relative leaf area and relative composition. To compare forest communities' composition that may differ in size, or that were sampled at different intensities, importance values are calculated using relative rather than absolute values (Kuers, 2005).

An IV over 10 may indicate that vacant urban land contains certain types of plant that are over-reliant on a particular species for structural and functional benefits, depending on the local

[8] One measure of the relative dominance of species in a forest community is called the **Importance Value (IV)**. Importance values rank species within a site based upon three criteria:

1) how commonly a species occurs across the entire forest;
2) the total number of individuals of the species;
3) the total amount of forest area occupied by the species (Kuers, 2005).

ecosystem. The functional benefits considered in this study included the air pollution removal value, carbon sequestration and storage, avoided runoff, energy saving, and structural value of trees on vacant land. Structural values are based on the valuation procedures developed by the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (e.g., the cost of having to replace a tree with a similar tree) (Nowak et al., 2002a). Roanoke's vacant urban land has four species with an IV exceeding 10, the most important of which is American elm with an IV of 42.6. Roanoke's 10 most important species of vacant urban land are listed in Table 5.5.

Table 5.5 Most important species on vacant urban land, City of Roanoke, Virginia. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Species name	Species origin	Percentage of population	Percentage of leaf area	Importance value (IV)
American elm	Native	16.4	26.1	42.6
Tree of heaven	Invasive	12.3	7.1	19.4
Black walnut	Native	4.7	9.0	13.7
Box elder	Native	6.7	3.3	10.0
Sycamore spp	Native	2.1	7.3	9.4
Slippery elm	Native	2.3	4.6	6.9
Tulip tree	Native	1.5	5.0	6.5
Silver maple	Native	2.1	4.0	6.1
Sumac spp	Native	2.7	4.0	6.1
Red maple	Native	2.0	3.3	5.3

The urban forest cover reduces the impact of impervious surfaces, such as roads, buildings and, to a lesser degree, maintained grass. Impervious surfaces reduce water infiltration and increase runoff, affecting residential water quality. Trees and vegetation ground cover types reduce storm water impacts by intercepting rainfall, slowing water movement, and increasing infiltration in the ground. The two most dominant ground cover types in vacant urban land are grass (39.5%) and wild grass (24.8%) (Table 5.6). These two dominant ground cover types are permeable, which means that vacant urban land can be strategically used to control urban storm water. Vacant land is thus potentially a very useful component of a city's storm water infrastructure and many cities are now greening vacant land as an important storm water management strategy. Vacant land forest structure can be a very cost-effective way of reducing the need for expensive storm water management infrastructure such as retention tanks and sewer systems. Vegetation uses storm water as a resource, capturing a significant percentage of the run off. The current forest structure on vacant land can help manage urban storm water to prevent residential floods and can also filter the polluted water running off cities' impervious paving areas, such as parking lots and road systems, to recharge clean ground water systems.

Vacant land is thus an important component of urban green infrastructure systems that can significantly affect the health of the local urban ecosystem, providing enduring value for the community. The three impervious ground cover classes (buildings, cement, and rock) make up 15.1% of the city's total ground area (Table 5.6). The ground space available for tree planting about 59.2% of the vacant urban land area, suggests that vacant urban land has a high potential for increasing Roanoke's tree canopy cover. As the tree canopy cover increases, this also provides other ecosystem benefits.

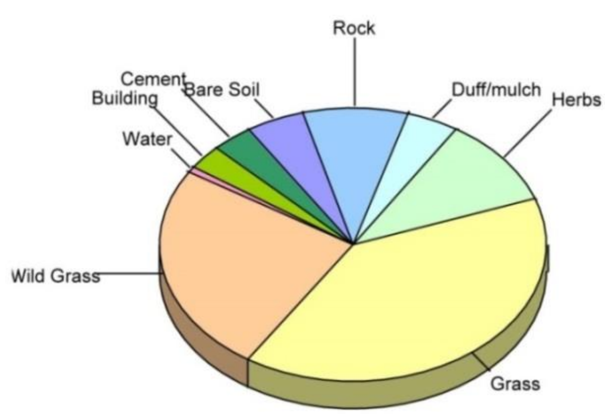


Figure 5.5 Percentage of ground cover on vacant urban land, City of Roanoke, Virginia

Table 5.6 City totals for percentage of coverage by vacant urban land. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

	Ground cover										
Land use	Plant space	Cement	Bare soil	Rock	Duff/ Mulch	Herbs	Grass	Wild grass	Water	Building	Tree
Vacant	59.2	3.4	5.0	8.8	4.4	10.5	39.5	24.8	0.7	2.9	30.6

Ground cover totals 100% and includes cement, bare soil, rock, duff/mulch, herbs, grass, wild grass, water, and buildings. Plant space and tree cover overlap with ground cover

Among the categories of vacant urban land, the highest plantable space[9] occurs on unattended sites with vegetation, followed by transportation-related sites and natural sites (Table 5.7). Unattended sites with vegetation support 71.3% of the plantable space, which is the highest relative to other types (Table 5.7). Unattended sites with vegetation also have 55.9% of the wild grass, which is again the highest relative to other categories. This means that unattended sites with vegetation can be strategically used as part of the urban green storm water infrastructure. Most unattended sites with vegetation consist of previously developed land that is now vacant with no structures, although some sites contain a natural forest structure, which means that unattended sites with vegetation can be easily built upon and there are no environmental and physical constraints to redeveloping those spaces. In addition, unattended sites with vegetation are the most common types of vacant urban land category (4,297 acres) (Table 5.2), so they can be easily managed for redevelopment as green infrastructure, such as small parks, urban agriculture and community gardens in the future. Unattended sites with vegetation therefore have a high potential value as green infrastructure that can be used to provide ecosystem services for city residents.

[9] Plantable space is not covered by impervious surfaces and is free of overhead obstructions such as existing tree canopies and utility lines (Wiseman & King, 2012).

Table 5.7 Comparison of urban forests: City totals for percent of coverage in vacant urban land by category. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Category	Ground cover										
	Plant space	Cement	Bare soil	Rock	Duff/ Mulch	Herbs	Grass	Wild grass	Water	Buildings	Trees
Derelict	49.4	13.2	6.1	11.1	3.7	14.6	2.9	42.9	0.6	5.0	32.5
Natural	51.5	1.2	10.3	1.2	1.2	25.3	32.6	22.4	5.9	0	48.2
Post-industrial	28.5	9.7	4.3	35.0	4.3	9.0	6.7	11.7	0.7	18.7	13.5
Transportation-related	51.8	1.0	3.3	10.0	8.3	17.3	39.7	20.3	0	0	40.6
Unattended with vegetation	71.3	0.9	4.5	3.9	3.9	5.2	55.9	25.1	0	0.39	27.7

Ground cover totals 100% and includes cement, bare soil, rock, duff/mulch, herbs, grass, wild grass, water, and buildings. Plant space and tree cover overlap with ground cover

5.2. Ecosystem Services Provided by Roanoke's Vacant Urban Land

Vacant urban land is a key component of Roanoke's green infrastructure, providing ecosystem services, such as air pollution removal, carbon sequestration and storage, energy saving, and the structural value of trees on vacant land. The assessment of each of these ecosystem services using i-tree Eco is described in the following sections.

5.2.1. Air Pollution Removal by Vacant Urban Land

Air quality is a major problem in most cities. It can negatively affect human health, ecosystem health, and visibility. Trees on vacant land can help to remove air pollutants, reduce air temperature (transpiration), save energy consumption in buildings, and indirectly reduce air pollution from power plants. Trees also influence ozone formation by emitting volatile organic compounds (VOCs) (Chameides et al., 1988). However, a comprehensive study suggests that urban trees, particularly low VOC emitting species, can decrease urban ozone levels in spite of their total VOC emissions, particularly through tree functions of removing air pollutant (dry deposition to plant surfaces), reducing air temperatures (transpiration), and reducing building energy and consequent power plant emission (e.g., temperature reductions; tree shade) (Cardelino & Chameides, 1990; Taha, 1996). Air pollution removal estimates are derived from calculated hourly tree-canopy resistance for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition model (Baldocchi, 1988; Baldocchi et al., 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants are based on average values from the literature (Bidwell & Fraser, 1972; Lovett, 1994). The estimate of the pollution removal value of trees was based on field data and current pollution and weather data (2011). As shown in Figure 5.6, ozone (O_3) had the greatest pollution removal value. Overall, 91 tons of air pollution (CO, NO_2, O_3, PM10, and SO_2) was removed by trees on vacant land in Roanoke in 2011 with a value of $ 916,000. Vacant land is an important component of Roanoke's green infrastructure, removing a significant fraction of the air pollution from the city's environment.

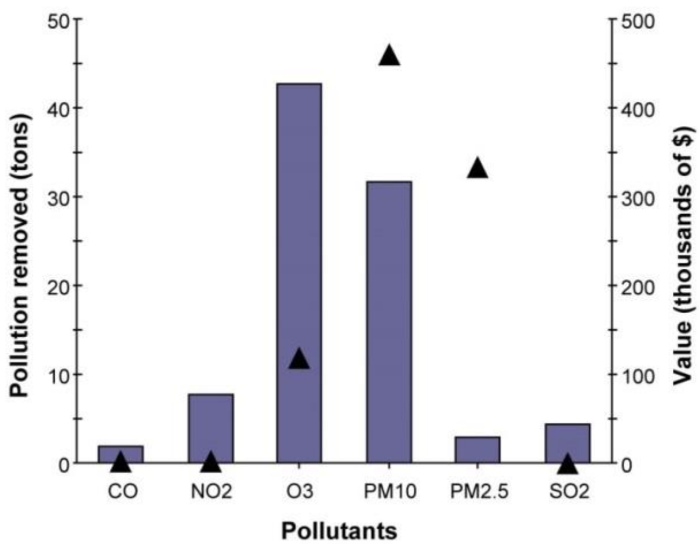


Figure 5.6 Pollution removal (bars) and associated economic value (line) for trees on vacant urban land, City of Roanoke, Virginia

Pollution removal value is calculated based on the following prices: $1,136 per ton (carbon monoxide), $2,765 per ton (ozone), $286 per ton (nitrogen dioxide), $102 per ton (sulfur dioxide), $14,500 per ton (particulate matter less than 10 microns and greater than 2.5 microns), $112,943 per ton (particulate matter less than 2.5 microns).

5.2.2. Carbon Storage and Sequestration

Climate change is a major issue across the world. Trees can remove carbon dioxide through photosynthesis in their tissue, which can help counteract climate change. Trees also alter energy consumption by reducing carbon dioxide emissions from the fossil-fuels burned by power plants (Abdollahi et al., 2000). Trees on vacant urban land reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered increases with the size and health of the trees. The gross sequestration of Roanoke's vacant urban land trees is about 2,305 tons of carbon per year (Table 5.8), with an associated value of $164,000. Net carbon sequestration (accounting for losses from carbon dioxide release through tree respiration) in vacant urban land is about 2,160 tons annually, which is high relative to other land uses (Table 5.8).

Trees store and sequester carbon dioxide through their growth processes in their tissue. Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. Carbon storage and carbon sequestration values in Roanoke are calculated based on $71 per ton (Interagency Working Group on Social Cost of Carbon United States Government, 2010). The carbon storage in the vacant urban land is thus about 107,484 tons, with an associated value of $7.65 million, which is very high relative to other land uses (Table 5.8).

The overall tree density on vacant land in the city is 25.7 trees per acre, which is the lowest relative to other land uses (Table 5.9). However, the gross sequestration of Roanoke's vacant land trees is about 0.255 tons of carbon per acre annually so trees on vacant urban land are estimated to have accumulated 11.9 tons of carbon per acre, which is high relative to other land uses (Table 5.9). Most of the trees on vacant land grow naturally so the condition of the trees on vacant land is healthier relative to other land uses, which bring additional ecosystem benefits, such as biomass and oxygen production. Biomass is a renewable energy source that can either be used directly via combustion to produce heat, or indirectly after conversion to various forms of biofuel. Oxygen production is one of the most commonly cited benefits of urban ecosystems. Vacant urban land is a valuable ecological resource that can be used to provide both biomass energy and fresh air in a city.

Table 5.8 Comparison of urban forests: City totals for tree effects by land use. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Land use	Percentage tree cover	Number of trees	Accumulated carbon storage (tons)	Gross carbon sequestration (tons/yr)	Net carbon sequestration (tons/yr)
Commercial	7.9	165,996	12,468	1,007	895.8
Industrial	9.7	195,355	19,765	1,307	1,190.4
Residential	31.4	1,626,880	235,993	14,558	10,201.6
Vacant	30.6	210,263	107,484	2,305	2,160.5

Table 5.9 Comparison of urban forests: Per-acre values of tree effects by land use. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Land use	Number of trees per acre	Accumulated carbon storage (tons)	Carbon sequestration (tons/yr)
Commercial	62.8	4.2	0.34
Industrial	32.2	2.9	0.19
Residential	113.6	14.9	0.92
Vacant	25.7	11.9	0.25

Among the categories of vacant urban land, the gross carbon sequestration of trees on unattended sites with vegetation is about 1,485 tons per year and net carbon sequestration is about 1,381 tons annually, which is highest relative to other types (Table 5.10). The carbon storage on vacant sites is about 73,362 tons, which is highest relative to other types (Table 5.10). Unattended sites with vegetation make up a major percentage of the vacant urban land, so may represent one of the most important resources that can provide ecosystem services of carbon storage and sequestration. However, the highest tree densities occur in natural sites, followed by unattended sites with vegetation and derelict sites (Table 5.11). The carbon sequestration in the unattended sites with vegetation is about 0.313 tons of carbon per acre annually and the accumulated carbon storage is about 15.4 tons of carbon per acre, which is high relative to other types (Table 5.11). Unattended sites with vegetation have healthier trees and so may be the most effective biomass energy resource; they also reduce carbon dioxide in the atmosphere by capturing carbon in new growth every year.

Table 5.10 Comparison of urban forests: City totals for tree effects in vacant urban land by typology. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Category	Percentage tree cover	Number of trees	Accumulated carbon storage (tons)	Gross carbon sequestration (tons/yr)	Net carbon Sequestration (tons/yr)
Derelict	32.5	25,725	14,416	245	223.9
Natural	48.2	26,514	10,520	277	268.2
Post-industrial	13.5	7,488	607	38	37.6
Transportation-related	40.6	28,923	8,579	259	249.5
Unattended with vegetation	27.7	121,613	73,362	1,485	1,381.4

Table 5.11 Comparison of urban forests: Per-acre values of tree effects in vacant urban land by typology. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Category	Number of trees per acre	Accumulated carbon storage (tons)	Carbon sequestration (tons/yr/)
Derelict	25.01	12.7	0.216
Natural	36.46	13.1	0.345
Post-industrial	8.66	0.6	0.04
Transportation-related	22.66	6.0	0.184
Unattended with vegetation	25.66	15.4	0.313

As trees grow, they accumulate carbon as wood; when they die and decay they release much of the stored carbon back to the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be lost if trees are allowed to die and decompose. Trees growing on vacant urban land in Roanoke are estimated to store 107,000 tons of carbon, which is valued at $7.65 million (Figure 5.8). Of all the species sampled, American elm stores and sequesters the most carbon (approximately 19.0 % of the total carbon stored and 18.8% of all carbon sequestered in trees growing on vacant land in the city).

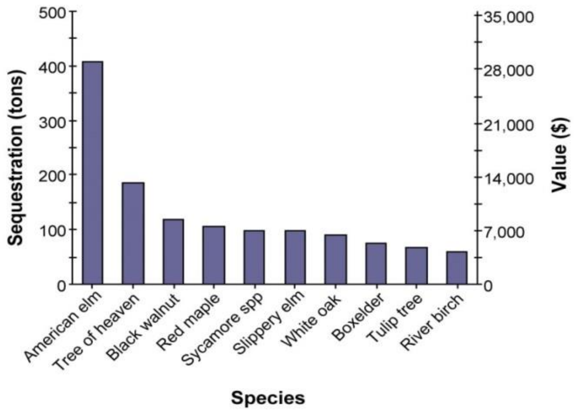


Figure 5.7 Carbon sequestration and value for the species with greatest overall carbon sequestration growing on vacant urban land, City of Roanoke, Virginia

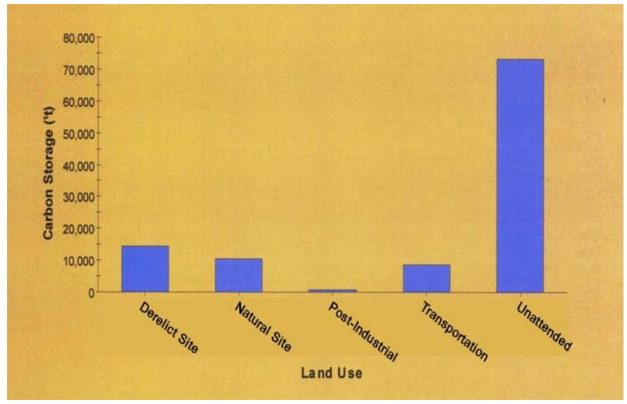


Figure 5.8 Carbon storage in vacant urban land by category, City of Roanoke, Virginia

5.2.3. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it often increases pollution in streams, wetlands, rivers, lakes, and oceans. When it rains, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the remainder reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi, 2012). In urban areas, the extensive area covered by impervious surfaces increases the amount of surface runoff. In Roanoke, vacant urban land has three impervious ground cover classes (buildings, cement, and rock), which make up 15.1% of the total ground cover in this category (Table 5.7), which is low relative to other land uses, and has 30.6% of the tree canopy cover, which is high relative to other land uses. The plantable space available on the vacant land is about 59.2%, which is highest relative to other land uses. Vacant land therefore has considerable potential to reduce surface runoff if planting of vacant lands is increased.

This suggests that vacant land may be a valuable ecological resource that can be strategically used as urban green storm water infrastructure through urban forests, including trees, shrubs and pervious ground cover classes. For example, urban trees on vacant land in Roanoke are highly beneficial in reducing surface runoff. Trees intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees growing on Roanoke's vacant land help to reduce runoff by an estimated 4,255,000 cubic feet a year, with an associated value of $283,000, as shown in Table 5.12 (U.S. Forest Service Tree Guides, n.d.). Among the categories of vacant urban land, the natural sites have less impervious ground cover classes relative to other categories (Table 5.7). The highest pervious ground cover occurs in natural sites, followed by unattended sites with vegetation and transportation-related sites. However, the transportation-related sites have a high percentage of tree and shrub cover relative to other categories (Table 5.12). Transportation-related sites are a valuable ecological resource that can slow surface runoff and contribute to ground water. The trees on transportation-related sites help to reduce runoff by an estimated 557,000 cubic feet a year, with an associated value of $37,000 (Table 5.12) (U.S. Forest Service Tree Guides, n.d.). The environmental benefits provided by transportation-related sites are seldom recognized, but the results of this study suggest that transportation-related sites can be a valuable ecological resource that can absorb much of the surface runoff in a city.

Table 5.12 Comparison of urban forests: City totals for avoided runoff for trees in vacant urban land by category. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Category	Number of trees	Leaf area (mi^2)	Avoided runoff (ft3/yr)	Avoided runoff value (US$)
Derelict	25,725	1.89	523,317	34,840
Natural	26,514	1.95	539,324	35,906
Post-industrial	7,488	0.37	101,590	6,763
Transportation-related	28,923	2.02	557,892	37,142
Unattended with vegetation	121,613	9.17	2,533,243	168,655
City total	210,263	15.40	4,255,366	283,306

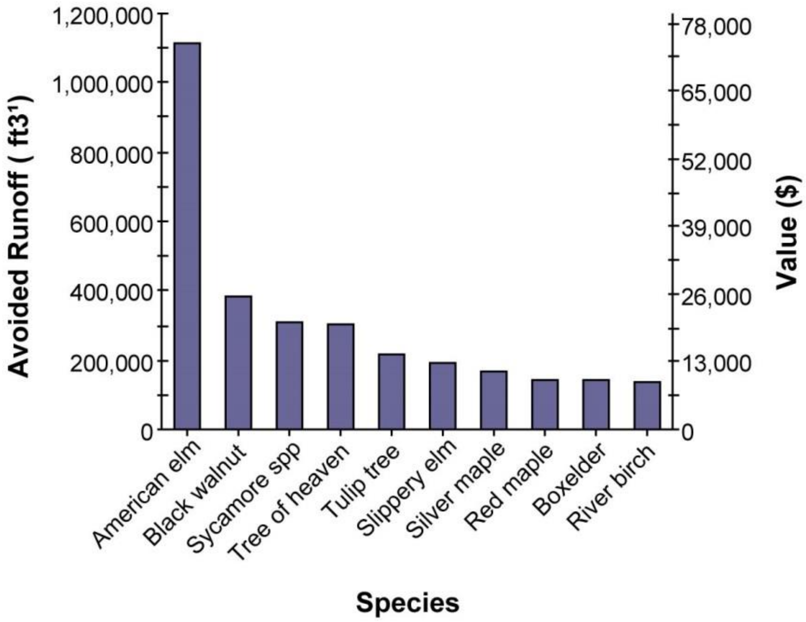


Figure 5.9 Avoided runoff and values for species with the greatest overall impact on runoff growing on vacant urban land, City of Roanoke, Virginia

5.2.4. Vacant Urban Land and Building Energy Use

Trees on vacant urban land affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds, thus reducing building energy consumption in the summer months and either increasing or decreasing building energy use in the winter months, depending on the location of the trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson & Simpson, 1999). Based on state-wide energy costs for Virginia ($106.1 per MWH and $12.26 per MBTU), the trees growing on vacant urban land in Roanoke reduced energy consumption for residential buildings by around $211,000 annually (Tables 5.13 and 5.14). Trees on vacant land also reduced the amount of carbon released by fossil-fuel based power plants (a reduction of 395 tons), with an associated value of $28,103.

Table 5.13 Annual energy conservation and carbon avoidance due to trees on vacant urban land near residential buildings in the City of Roanoke, Virginia (note: negative numbers indicate an increased energy use or carbon emission). Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

	Heating	Cooling	Total
MBTU[1]	2,127	n/a	2,127
MWH[2]	41	1,705	1,746
Carbon avoided (t[3])	41	354	395

[1]One million British Thermal Units

[2]Megawatt-hour

[3]Short ton

Table 5.14 Annual savings[1] ($) in residential energy expenditure during heating and cooling seasons (note: negative numbers indicate a cost due to increased energy use or carbon emission). Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

	Heating	Cooling	Total
MBTU[2]	26,077	n/a	26,077
MWH[3]	4,350	180,901	185,251
Carbon avoided (t)	2,905	25,199	28,103

[1]Based on state-wide energy costs for Virginia: $106.1 per MWH and $12.26 per MBTU

[2]One million British Thermal Units

[3]Megawatt-hour

5.2.5. Structural and Functional Values of Vacant Urban Land

Roanoke's vacant lands represent structural assets with economic value, just as other infrastructure in the city. This value is based on the price of replacing existing trees with other similar types of trees. In addition, they also have functional ecosystem service values (both positive and negative) based on the functions the trees perform. The structural values applied here are based on the valuation procedures laid down by the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al., 2002a). The number and size of healthy trees contribute to the increased structural and functional value of an urban forest.

The results of the comparison of urban forests effects and values by land use suggest that residential land use offers the greatest current and potential future ecosystem benefits on a per acre basis. However, city totals for Roanoke's carbon storage and carbon removal value in vacant urban land are very high relative to other land uses (Table 5.15). Trees on vacant urban land that are growing in natural stand condition have more healthy trees and thus more above-ground biomass (carbon storage) than open-grown, maintained trees located on other types of land. When comparing biomass equations for trees of the same DBH, biomass results for open-grown urban trees must be multiplied by a factor of 0.8 (Nowak, 1994), but no adjustment is necessary for trees found in more natural stand conditions (i.e. on vacant land or in forest preserves).

Table 5.15 Comparison of urban forests: per-acre values of trees' structural and functional value by land use; Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Land use	Number of trees per acre	Carbon storage (tons)	Carbon storage value (US$)	Carbon sequestration (tons/yr)	Carbon removal value (US$)	Structural value (US$)
Commercial	62.85	4.2	298	0.345	24.5	39,497
Industrial	32.25	2.9	206	0.195	13.8	24,614
Residential	113.6	14.9	1,058	0.922	65.5	97,611
Vacant	25.7	11.9	845	0.255	18.1	20,616

Table 5.16 Comparison of urban forests: City totals for trees' structural and functional value by land use; Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Land use	Number of trees	Carbon storage (tons)	Carbon storage value (US$)	Carbon sequestration (tons/yr)	Carbon removal value (US$)	Structural value (US$)
Commercial	165,996	12,468	885,266	1,007	71,474	104,290,019
Industrial	195,355	19,765	1,403,342	1,307	92,832	149,105,020
Residential	1,626,880	235,993	16,755,527	14,558	1,033,641	1,397,770,766
Vacant	210,263	107,484	7,631,385	2,305	163,655	168,911,300

Among the categories of vacant urban land, the unattended sites with vegetation have a particularly high value for carbon storage, carbon sequestration, and structure, relative to other types (Tables 5.17 and 5.18). Unattended sites with vegetation make up a major percentage of vacant urban land, with many healthy trees in natural stand conditions. These sites with can thus be one of the most effective land use types, providing ecosystem services in a city.

Table 5.17 Comparison of urban forests: per-acre[1] values of tree's structural and functional value in vacant urban land by category; Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Category	Number of trees per acre	Carbon storage (tons)	Carbon storage value (US$)	Carbon sequestration (tons/yr)	Carbon removal value (US$)	Structural value (US$)
Derelict	25.01	12.7	901.7	0.216	15.336	20,305
Natural	36.46	13.1	930.1	0.345	24.495	24,312
Post-industrial	8.66	0.6	42.6	0.04	2.84	1,991
Transportation-related	22.66	6.0	426	0.184	13.064	13,718
Unattended with vegetation	25.66	15.4	1,093.4	0.313	22.223	25,858

Table 5.18 Comparison of urban forests: City totals for trees' structural and functional value in vacant urban land by category. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model

Category	Number of trees	Carbon storage (tons)	Carbon storage value (US$)	Carbon sequestration (tons/yr)	Carbon removal value (US$)	Structural value (US$)
Derelict	25,725	14,416	1,023,550	245	17,430	20,894,595
Natural	26,514	10,520	746,905	277	19,667	17,675,472
Post-industrial	7,488	607	43,132	38	2,719	1,720,407
Transportation-related	28,923	8,579	609,080	259	18,389	17,505,068
Unattended with vegetation	121,613	73,362	5,208,723	1,485	105,449	111,115,757

The results of the comparison of urban forest effects and values in vacant urban land by categories suggest that unattended sites with vegetation could be the best vacant land type for providing ecosystem services for the city. The high ecosystem values of unattended sites with vegetation should be protected, although these sites could be developed for a variety of uses if done in a manner that protects their current ecosystem values. Less sensitive post-industrial sites that have low ecosystem values could be developed for many different types of land use (e.g. housing, commercial, industry and green re-use options) as they have the most potential for improvement and increase in ecosystem benefits. Those post-industrial sites with historical significance that have remediation potential could be developed in a manner that preserves their historical value with a historically appropriate use. If other natural sites and transportation-related sites have low ecosystem values and are not threatened by development, their current low ecosystem values have the potential to be enhanced through proper management.

5.3. Reliability and Validity

Urban forest structure is complex and it is often difficult to assess all of the tree attributes and quantify the ecosystem services of trees using standard data analyses. The i-Tree analysis utilized here has been based on a sample of an entire study area that provides a good estimate of the entire population and individual tree measurements (Nowak et al., 2003). The main advantage of the i-Tree Eco model is to estimate urban forest functions using locally measured field data and peer-reviewed literature procedures (Nowak et al., 2008a). However, the i-Tree Eco model has limitations. Ecosystem function estimates require accurate field data collection (Nowak et al., 2008a). If the field data are accurate, it provides an accurate estimate of the entire population structure and individual tree measurements, providing a good baseline from which to measure changes and trends in urban forest conditions. Also, the model only estimates current urban forest structure and functions, providing only a one-year estimate of growth and carbon sequestration. Urban forest conditions are changeable, so the model estimate will be off proportional to changes in urban forest structure through time. The precision and cost of the estimate is dependent on the sample and plot size. Generally, 200 plots (1/10 acre each) in a stratified random sample (with at least 15 plots per stratum) will produce a 12% relative standard error for an estimate covering the entire study area (Nowak et al., 2008b). As the number of plots increase from 200 to 500, the relative standard error will decrease based on the total number of trees to 7.7% (a 36% reduction) (Nowak et al., 2008b) and the method provides more accurate population estimates. However, as the number of plots increases, so does the time and cost of field data collection.

CHAPTER 6: PLANNING AND IMPLEMENTATION STRATEGIES

Vacant lots have high potential to improve the environmental quality and economic well-being of cities (Crauderueff et al., 2012). In Chapter 2, the literature review discussed the impact of planning and policies for vacant land, articulated how leading cities have developed a range of effective planning and implementation strategies to successfully implement green infrastructure on vacant lots, and analyzed early planning and implementation strategies. However, planners and designers may not fully understand the short term and long term ways that vacant land can be planned for. The diversity and potential of different types of vacant land are also not well understood by planners and designers. Therefore, adopting typologically based planning and implementation strategies could advance the efforts of cities seeking to implement green infrastructure projects on vacant lots and allow planners and designers to better utilize these spaces for short-term and long-term uses for urban regeneration and renewal. In the future, broad policy approaches and programs for different types of vacant land will be the dominant factor supporting successful green infrastructure implementations on vacant urban lots. Based on the typology and ecosystem services of vacant land presented in Chapters 3 and 4, in this chapter typological planning and implementation alternatives will be suggested that utilize these different types of vacant lots for short-term and long-term uses.

6.1. Post-Industrial Sites

6.1.1. Preparation

Assess and survey existing conditions, including historical significance and contamination level

- Identify post-industrial sites that have structures that were previously built for a particular land use, such as factories, power plants, landfills, brownfields, water treatment plants, military sites, and airports, as well as left-over spaces that do not require treatment, that have become vacant land with contamination
- Identify any historical significance based on the vacant land’s history or structure and conduct an environmental assessment of its contamination level and remediation potential based on its current physical environmental condition and previous land-use

history through the technical assistance to brownfields communities (TAB) program[10], which can help to provide scientific and technical services relating to the brownfield site assessment and remediation process

6.1.2. Preparation: Plan and Design

Propose design solutions based on the site's history and environmental conditions

- Active-historically appropriate use (i.e. the site has one or more historically significant structures with remediation potential that are not contaminated and need to be developed in manner that preserves the site's historical value, such as the Gas Works Park, WA, the High Line, NY, and the Landschaftspark, Duisburg-Nord)
- Passive-historically appropriate use (i.e. the site has significant structures but no remediation is possible due to contamination. The site should be preserved historically, but with use limited to avoid human contact with pollution)
- Unlimited development (i.e. the site has no significant structure with potential for development by remediation and so can be redeveloped for many different types of land-use, such as housing, commercial, industry, and green re-use options)
- Ecosystem conservation and limited use (i.e. the site has no significant structure, but has ecosystem value and no remediation is possible. The site should be redeveloped for uses that conserve ecosystem values and provide safe levels of human contact with pollution)
- Limited development (i.e. the site has no significant structure, but has potential for enhancing ecosystem values; no remediation is possible. The site should be developed

[10] The TAB program can "help to move brownfield sites forward toward cleanup and reuse, serving science and technology relating to brownfield site assessment, remediation, and site preparation activities, brownfield finance questions, information on integrated approaches to brownfield cleanup and redevelopment, facilitating stakeholder involvement, identifying sources of brownfields assessment and cleanup funding, understanding and complying with state brownfields and voluntary cleanup program requirements, and facilitating redevelopment activities" (USEPA, 2014d).

for uses that provide safe levels of human contact)

6.1.3. Action

Implement green infrastructure on a post-industrial site

6.1.3.1. Program Goals

- Create program goals for a post-industrial site as part of the city's public amenities to enhance the city's image through its rehabilitation, such as urban parks, for long-term uses
- Appoint a lead agency, such as city planning agency, redevelopment agency, a community development corporation (CDC), or a special purpose or special district public entities to play a key role in advancing action on a post-industrial site to support the design, implementation and maintenance of brownfield site-specific green infrastructure and also engage in strategic partnerships with other agencies and non-profit organizations to provide technical assistance for the post-industrial site to implement green infrastructure

6.1.3.2. Planning and Analysis

- Develop partnerships with communities including neighborhood associations, block associations, businesses, and elected officials to develop brownfield target-area strategies in neighborhood and site-specific planning of post-industrial site
- Geographic Information System (GIS) can help to identify neighborhood brownfield areas and site visits with local stake holders can help to better identify existing current site surface conditions, history, and contamination levels in post-industrial sites

6.1.3.3. Administration

- Create special programs and new organizations to manage post-industrial sites; raise project funds from special tax levies and support the implementation of green infrastructure with Non-Government Organizations (NGOs), businesses, and public sector agencies for brownfield revitalization

- Develop partnerships among specialist agencies and organizations related to brownfield revitalization, including public agency staff through a Technical Advisory Committee, active Citizen Advisory, and project-specific community partners in brownfields to provide critical feedback and direction to the organization's program

6.1.3.4. Site Use and Design

- Create multiple goals to guide the transformation of post-industrial sites into green infrastructure to provide ecological development education opportunities, build connections with the community, and create recreational opportunities to improve the local quality of life

6.1.3.5. Site Aggregation

- The lead agency should have sufficient long-term planning and implementation capacity to acquire a post-industrial site using eminent domain, the threat of eminent domain, or intergovernmental transfer

6.1.3.6. Transfer Mechanisms

- Public-to-public transfers could help to convert post-industrial sites to green infrastructure via appropriate memoranda of understanding to meet state brownfield cleanup goals

- Private-to-public transfer may be used to acquire post-industrial sites in brownfield target areas through the Neighborhood Stabilization Program, which could be the target area for the city's Community Development Block Grant funds[11]

6.1.3.7. Maintenance Models

- Public maintenance of post-industrial sites could be maintained by multiple city and county agencies supported by ratepayer fees
- Private maintenance of post-industrial sites may be negotiated with public sector bodies in return green infrastructure credits for environmental benefits and supporting human health and well-being

6.1.3.8. Financing

- The financial planning related to post-industrial sites could be supported by local foundations or public grants. The acquisition and construction funding may come from utility fees, tax levies, and place-based financing. The maintenance funding may be supported by capital investment, special levies, rebates from easement agreements to, or public foundations

6.2. Derelict Sites and Unattended with Vegetation Sites

6.2.1. Preparation

Assess and survey existing conditions, including abandoned, unsafe and potential illegal activities and unimproved vacant parcels or natural forests

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[11] "The Community Development Block Grant (CDBG) program is a flexible program that provides communities with resources to address a wide range of unique community development needs. Beginning in 1974, the CDBG program is one of the longest continuously run programs at HUD. The CDBG program provides annual grants on a formula basis to 1209 general units of local government and States" (U.S. Department of Housing and Urban Development, 2014).

- Identify any structures on derelict sites that are now empty and unused, such as abandoned properties, or those that contain no structures, but are areas used for unsafe, potential illegal activities
- Identify unattended with vegetation site that have no structures and are now vacant or contain unimproved natural vegetation without contamination

6.2.2. Preparation: Plan and Design

Proposed design solutions based on existing environmental conditions, including the vegetation quality of the current forest structure, such as tree/shrub canopy cover percentage, tree/shrub species, and ground cover types (e.g. plant space, herbs, grass, bare soil, rock, and cement)

- Environmentally sensitive use (i.e. the site has high ecosystem value threatened by development that can be developed for a variety of uses if done in a manner that protects ecosystem values)
- Unlimited development (i.e. the site has low ecosystem value with high potential for development and can thus be redeveloped for many different types of land-uses, such as housing, commercial, industry and green re-use options)

6.2.3. Action

Implement green infrastructure on sites that are derelict or unattended with vegetation

6.2.3.1. Program Goals

- Create program goals for derelict sites as potentially valuable community asset and unattended with vegetation site as potentially valuable natural assets for short-term and long-term uses
- Appoint a lead agency, such as a city planning agency, city community development agency, economic development agency or collaborative, redevelopment agency, community development corporation (CDC), or special purpose or special district public entity to play a key role in advancing redevelopment plans on sites that are derelict or

unattended with vegetation to support the design, implementation and maintenance of site-specific green infrastructure

- Develop partnership with other agencies to support the acquisition, reclamation and maintenance of sites that are derelict and unattended with vegetation for neighborhood revitalization/stabilization plans or vacant property-reuse strategies

6.2.3.2. Planning and Analysis

- Regional, neighborhood, and site-specific planning for sites that are derelict or unattended with vegetation may be developed by park departments, water departments, or redevelopment authorities to establish regional planning for vacant lots as green infrastructure. Encouraging cooperation among agencies and NGOs at an early stage will help lead agencies to address any issues with the green infrastructure regulations and also reduce the cost of process and administrative challenges, thereby developing effective policy mechanisms to better manage sites that are derelict or unattended with vegetation at a regional, neighborhood and site-specific scale
- Partnerships with local community leaders including neighborhood associations, block associations, businesses, and elected officials will help develop support for neighborhood and site-specific planning of sites that are derelict or unattended with vegetation
- Spatial analysis, possibly using Geographic Information Systems (GIS), can help to identify neighborhood stabilization areas with transitional housing markets, as well as characterizing neighborhood economic conditions and the prevalence of derelict sites such as publically owned abandoned properties that may or may not be eligible for demolition based on their historical structure value, tax delinquent properties with or without abandoned structures entering the foreclosure process, and unoccupied privately owned, tax-current derelict sites. This type of analysis can provide valuable information on unattended with vegetation site by identifying potential candidates for site aggregation, areas prone to flooding, and areas that are connected at a neighborhood-by-neighborhood and block-by-block scale, as well as the distance from accessible open space, publicly/land bank owned vacant lots, vacant lots with the potential to receive inflow storm water from streets, and properties near storm water inlets or water bodies

- Site visits with local stake holders may help to better understand existing conditions, including abandoned building conditions, safety issues, potential illegal activities, vegetation quality, soil quality, and other physical characteristics

6.2.3.3. Administration

- Create specialized programs and new special purpose organizations and agencies to support the strategic reuse of green infrastructure on vacant lots, as well as land trusts or land banks to manage sites that are derelict or unattended with vegetation using project funds from special tax levies or family foundations, personal funds, or endowments from private donations for the financial improvement and maintenance of sites that are derelict or unattended with vegetation. This will also support the implementation of green infrastructure by NGOs, businesses, and public sector agencies for the strategic reuse of derelict sites and unattended with vegetation sites
- Land banks may also help to acquire foreclosed abandoned properties or temporarily hold properties that are derelict or unattended with vegetation until they are sold or redeveloped, possibly through Sheriff's sales and coordinating with Citizen's Advisory Committees to provide community site managers or stakeholders for short-term greening programs. Temporary ownership and technical/material assistance could be provided to serve community gardens and local land trusts may be created to support small community managed open spaces on sites that are derelict or unattended with vegetation
- Partnerships among special agencies and organizations, such as Housing Authorities, the Trust for Public Land, the Department of Parks & Recreation, Technical Advisory Committees, Citizen Advisory panels, and project-specific community partners may assist with the maintenance and programming in community gardens and neighborhood parks in coordination with the city's legal department; the Department of Citywide Administration Services may help within the acquisition of private properties that are derelict or unattended with vegetation

6.2.3.4. Site Use and Design

- Create multiple goals for the transformation of sites that are derelict or unattended with vegetation into green infrastructure that promotes neighborhood stabilization, economic well-being and also improve the quality of life for local residents through multiple public uses

6.2.3.5. Site Aggregation

- A lead agency such as land bank may have the long-term planning and implementation capacity to aggregate a number of sites that are derelict and/or unattended with vegetation through multiple acquisition strategies. These strategies include eminent domain, the thereat of eminent domain, or intergovernmental transfer and interim ownership of the sites until construction is completed or the local government can pay for the properties. The land bank can also help to acquire sites that are derelict or unattended with vegetation for temporary use then provide leases to local residents, after which the land bank could suggest lessees purchase the sites

6.2.3.6. Transfer Mechanisms

- Temporary-to-permanent transformations of green spaces may be achieved by land banks that may then provide free seasonal programs or one-dollar annual leases for sites that are derelict or unattended with vegetation to increases residents' commitment to short-term greening or gardening initiatives and eventually offer them the option to purchase the sites, ensuring open space managers consider derelict sites and those that are unattended with vegetation for permanent use
- Green Corps Programs may also help community garden groups to secure publicly owned derelict sites by supporting green infrastructure job training. The Adopt-a-Lot Program[12]

[12] "Adopting a city-owned vacant lot can improve the living conditions in your neighborhood. You and your neighbors can create a peaceful, space for everyone to share. It not only improves

could cooperate with the Housing and Community Development (HCD) to provide short-term licenses to people to utilize sites that are derelict or unattended with vegetation for green infrastructure purposes. A Memorandum of Agreement with the State Attorney General may protect green infrastructure on these sites from development

- Public-to-public transfers may be achieved through the development of sites that are derelict or unattended with vegetation as green infrastructure in the form of memoranda of understanding to advance both city and state goals to reuse the sites for neighborhood stabilization
- Private-to-public transfers may be achieved through commitment to maintain or support specific sites that are derelict or unattended with vegetation that can then be converted into green spaces by Park District and NeighborSpace. These organizations acquire sites that are derelict or unattended with vegetation through their Housing Urban Development (HUD) Neighborhood Stabilization Plan, which can pinpoint target areas for the city's Community Development Block Grant funds and then work with land banks to develop a list of sites that are derelict or unattended with vegetation to acquire. This includes sites with a high potential for development as well as those with no developmental potential
- The acquisition of tax current properties may be achieved by multiple strategies, such as temporary ownership of sites that are derelict or unattended with vegetation by nonprofit Openlands until the city can cover the cost of these acquisitions. The aggregation of these sites can create large open spaces over a period of years, which is a potentially valuable strategy for agencies seeking to develop a flood mitigation plan for the city
- Condemnation by the city's Legal Department may successfully effect the acquisition of sites that are derelict or unattended with vegetation
- Transfer of private properties for demolition may be accomplished through a city's Tax Reactive Program and interdepartmental Growing Green Initiative. The city's Public Works, Housing and Community Development, Planning, and Transportation departments may cooperate with Public Schools and non-profit greening organizations to

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your neighborhood, it helps the City become a beautiful and productive place to live for everyone" (Baltimore Housing, 2014).

identify properties such as abandoned buildings to be demolished that do not have any short-term development potential and also suggest green re-use options for these sites

- Changing city policies from easements to zoning can encourage the use of sites that are derelict or unattended with vegetation for green infrastructure and public access
- The Department of Environmental Protection or Park District may publicly own large areas that are derelict or unattended with vegetation, enforcing the deed restrictions on green infrastructure imposed as a result of funding from state and federal grant programs

6.2.3.7. Ownership Models

- Smaller sites that are derelict or unattended with vegetation owned by public agencies such as the Park District, the city, or the Forest Preserve District may provide financial support and leadership for the land trust in partnership with the city's Office of Sustainability to redesign derelict sites to create green infrastructure and also provide liability insurance
- The Green Thumb Program may also provide technical and material support to community gardens on sites that are derelict or unattended with vegetation and hold workshops to teach basic gardening skills as well as more advanced farming and community organizing topics, such as urban farming

6.2.3.8. Maintenance Models

- Public maintenance of sites that are derelict or unattended with vegetation may be achieved by building maintenance codes and local ordinances to maintain minimum safety standards. These may include maintenance requirements for abandoned properties or vacant lot registration fees to motivate people to improve these sites and keep their surroundings secure. Building inspectors can post signs near sites that are derelict or unattended with vegetation to warn owners and prevent the need to levy fines and impose court orders to clean up the land

- Private maintenance of sites that are derelict or unattended with vegetation may be achieved by neighborhood residents who have been trained to inspect these sites and send warning notices to the owners of properties that violate the city's property maintenance codes. If the owner does not respond to the notice, an official will inspect the property and initiate enforcement action to ensure the owner complies with the requirement to improve the site
- Community maintenance of sites that are derelict or unattended with vegetation may be achieved by outside greening organizations with support from land trusts such as capacity building, liability insurance and low-cost materials to manage the sites. These organizations may also support the process of acquiring short-term and long-term uses of sites that are derelict or unattended with vegetation
- Youth summer employment programs for the maintenance of sites that are derelict or unattended with vegetation, funded by land banks, clean and green programs, or green crop initiatives. These jobs would include mowing and trash pickup, and also incorporate training for local youths, helping to build maintain the community's relationship with the sites

6.2.3.9. Financing

- The financial planning for sites that are derelict or unattended with vegetation may be supported through municipal incentives such as tax abatements, tax incentives/credits or rehabilitation incentives for infill sites. These funds may come from community trusts, city foundations, local foundations, and public grants
- The acquisition and construction financing for sites that are derelict or unattended with vegetation may be achieved through utility fees such as ratepayer funds and green infrastructure levies, dedicated property taxes, local sales tax, Housing and Urban Development (HUD)'s Community Development Block Grant Programs, state grant programs, private donations, and tax increment financing (TIF) for green infrastructure funding supported by the city or park district

- Financing the maintenance of sites that are derelict or unattended with vegetation may be achieved through enforcement codes including registration fees, or liens to cover the remuneration for maintenance services provided by the city (Accordino & Johnson, 2000). Some cities may impose fines for the maintenance of sites that are derelict or unattended with vegetation and in extreme cases may levy substantial nuisance fines (Accordino & Johnson, 2000). Clean and lien programs could also be used to impose levies on those who use sites that are derelict or unattended with vegetation as dumps or for other illegal purposes

6.3. Natural Sites and Transportation-Related Sites

6.3.1. Preparation

Assess and survey existing conditions, including physical constraints imposed by environmental conditions and transportation systems

- Identify natural sites that have structures that are not suitable for development because of the nature of the terrain and its functional relationship with adjacent land uses, such as bodies of water, rivers, and natural forests, include drainage areas, wetlands, hillsides, river banks and river flood plains
- Identify transportation-related sites that are not suitable for redevelopment, generally because of their functional relationship with adjacent land uses such as highways, railroad tracks and bridges

6.3.2. Preparation: Plan and Design

Proposed design solutions should be based on environmental conditions, including the vegetation quality based on the current forest structure, such as tree/shrub canopy cover percentage, tree/shrub species and ground cover types (e.g. planting space, herbs, grass, bare soil, rock, and cement)

- Ecosystem conservation (i.e. the site should be conserved for its high ecosystem value)
- Ecosystem enhancement (i.e. the current low ecosystem value needs to be enhanced)

6.3.3. Action

Implement green infrastructure on natural and transportation-related sites

6.3.3.1. Program Goals

- Create program goals for natural and transportation-related sites as part of a green network system supporting long-term uses
- Appoint a lead agency such as a county planning agency, metropolitan planning organization (MPO), regional planning agency, city planning agency, city community development agency, or an economic development collaboration or partnership capable of playing a key role in advancing conservation or enhancement plans on natural and transportation-related sites. This will support the design, implementation and maintenance of large-scale, site-specific green infrastructure and also seek to implement green infrastructure on vacant lots through the green network program. Having strategic partnerships with other agencies and non-profit organizations may provide technical assistance to green networks on natural and transportation-related sites for regional land-use and transportation plans, regional economic-development strategies, comprehensive plans, or vacant property strategies

6.3.3.2. Planning and Analysis

- Regional, neighborhood, and site-specific planning for natural and transportation-related sites, may be developed by economic development and housing, development services, department of transportation, department of city planning and development, department of parks, recreation and cultural resources, department of ecology, department of environmental conservation and natural resources, and water and land resources division to establish regional planning guidelines for natural and transportation-related sites as part of a large-scale green network. Early stage cooperation among agencies and NGOs will enable lead agencies to address green network regulations and also reduce the cost of process and administrative challenges, thereby developing effective policy mechanisms to better manage natural and transportation-related sites at a regional, neighborhood and site-specific scale for green networks

- Partnerships with local communities will support the planning process for green networks on large sites by involving local community leaders, including neighborhood associations, block associations, businesses, and elected officials with the neighborhood and site-specific planning of green networks on natural and transportation-related sites
- Spatial analysis, possibly using Geographic Information Systems (GIS), can help planners to identify the best potential sites for green networks on natural and transportation-related sites at regional, neighborhood, and site-specific scales and also assist with the identification of site aggregation candidates for green networks and areas. Connections at a neighborhood-by-neighborhood and block-by-block scale can be assessed, along with the distance from accessible greenways, enhancing the potential for natural and transportation-related sites to connect existing green spaces in a city. These sites can also be used to enhance and expand parks and open space facilities, providing networks of recreational opportunities for walking, riding and biking that offer health benefits for residents
- Site visits with local stake holders may help planners to develop a better understanding of existing conditions, including any physical constraints due to environmental conditions, special relationships with transportation systems, and vegetation quality

6.3.3.3. Administration

- Create specialized programs and new special purpose organizations and agencies to support the strategic reuse of greenways, trails and recreation programs (GTRP). This could involve planning, acquisition, development, rehabilitation and repair of greenways, recreational trails, open space, parks and beautification projects on natural and transportation-related sites. An intergovernmental special purpose agency could support the design, acquisition, finance, and construction management of green infrastructure on natural and transportation-related sites through greenways. In some cases a single organization may be more effective for green infrastructure implementation

- Partnerships among special agencies and organizations, such as the Trust for Public Land, the Department of Parks & Recreation, Technical Advisory Committees, Citizen Advisory bodies, and project-specific community partners may assist in the maintenance and programming process for green networks, coordinating their efforts with those of the city's legal department and the Department of Citywide Administration Services to help in the acquisition of private property for natural and transportation-related sites

6.3.3.4. Site Use and Design

- Create multiple goals for natural and transportation-related sites as elements of green networks that will improve the well-being and quality of life of the local community through multiple public uses, including large green infrastructure storm water sites that also serve as floodable parks to provide playing fields, canoe launch facilities, gathering spaces, trail extensions, and pedestrian bridges to improve access to the park while at the same time mitigating flooding. As well as creating new pedestrian and bicycle paths along the natural and transportation-related sites for active recreation, it may also be possible to expand existing natural areas and restore degraded wetlands
- A comprehensive plan for green network programs may provide guidelines for suitable site selection to further extend greenways or trails through regional, neighborhood planning involving both public agencies and community members

6.3.3.5. Site Aggregation

- A lead agency may have the long-term planning and implementation capacity needed to aggregate natural and transportation-related sites through multiple acquisition strategies, such as eminent domain, the threat of eminent domain, or intergovernmental transfer and interim ownership of natural and transportation-related sites until construction is completed or local government can pay for the properties. Land banks can also help to acquire natural and transportation-related sites for temporary use for ecosystem conservation or ecosystem enhancement based on their vegetation quality

6.3.3.6. Transfer Mechanisms

- Public-to-public transfers may facilitate the process of developing two or more natural and transportation-related sites into greenways to help meet state green network system goals and the city's Department of Parks and Recreation may accept transferred natural and transportation-related sites from the Department of Environmental Conservation and Transportation to preserve and restore ecologically valuable natural and transportation-related sites
- Private-to-public transfers may be achieved through the city's Department of Community Development to maintain or support specific natural and transportation-related sites that will be converted into green spaces by city park districts or NeighborSpace. A land bank may seek to acquire natural and transportation-related sites in a city's target areas through its HCD Neighborhood Stabilization Plan, the term used to refer to the target area for the city's community Development Block Grant funds. A land bank may also provide groups with lists of natural and transportation-related sites to acquire that includes high potential natural and transportation-related sites to develop as well as sites with no developmental potential
- The acquisition of tax current properties may be achieved by strategic purchases of sites adjacent to major transportation corridors. A flood mitigation plan could also seek to acquire private natural and transportation-related sites as a potential strategy
- Condemnation by the city's Legal Department may be another way to successfully acquire natural and transportation-related sites
- Changing city policies from easements to zoning may encourage the use of natural and transportation-related sites for greenways or trails by improving public access
- The public ownership of large natural and transportation-related sites may be via the Department of Environmental Protection or the Parks & Recreation District and be accompanied by a deed restriction on green infrastructure as a result of the funding received from state and federal grant programs

6.3.3.7. Ownership Models

- The ownership of smaller natural and transportation-related sites by public agencies and land trusts, such as the Park District, the city, or the county's Forest Preserve District may provide financial support and leadership for the land trust as well as access to assistance from the city's Office of Sustainability to redesign natural and transportation-related sites to create a green network and liability insurance
- The Green Thumb Program provides technical and material support to maintain ecosystem conservation or ecosystem enhancement on natural and transportation-related sites as well as workshops to teach basic vegetation maintenance skills and more advanced vegetation enhancement topics such as landscape planting plans

6.3.3.8. Maintenance Models

- Public maintenance of greenways or trails on natural and transportation-related sites may be achieved by multiple city and county agencies. This may involve maintenance staff supported by the Department of Environmental Protection (DEP) with funds raised through ratepayer fees. The DEP may develop a Memorandum of Understanding with the city's Parks Department to care for the natural and transportation-related sites in the green network
- In addition, vacant property maintenance codes may be specified in local ordinances to ensure minimum safety standards and the maintenance of natural and transportation-related sites, with vacant property registration fees encouraging people to improve their natural and transportation-related sites and keep their surroundings secure. Site inspectors can post signs near natural and transportation-related sites to warn owners of natural and transportation-related sites about potential fines if they do not comply with court orders to clean up the land
- Private maintenance of natural and transportation-related sites may be achieved by negotiating agreements with the Department of Public Works (DPW) to offset a certain percentage of the storm water credit against the DPW storm water fee through easements

to natural and transportation-related sites to support ecosystem conservation or ecosystem enhancement

- Neighborhood residents can be trained to inspect the natural and transportation-related sites' vegetation quality and send warning notices to the owners of properties that violate the city's natural and transportation-related sites maintenance code. If the owner does not respond to the notice, an official will inspect the property and authorize enforcement action to improve the natural and transportation-related sites
- Community volunteers can be encouraged to maintain natural and transportation-related sites for their ecosystem conservation or enhancement by outside greening organizations and land trusts that may support capacity liability insurance and provide low-cost materials to manage the sites, which may also support the process of implementing both short-term and long-term uses of natural and transportation-related sites
- Youth summer employment programs may be used to maintain the sites through land bank, clean and green program, or green crop programs that provide summer jobs for young people from the local community to maintain natural and transportation-related sites, including mowing and trash pickup, and also administer the youth employment program and incorporate youth training sessions, strengthening the relationship between the local community and their nearby natural and transportation-related sites

6.3.3.9. Financing

- Financing the planning process for natural and transportation-related sites may be through a combination of municipal incentives such as tax abatement, tax incentives/credits or rehabilitative incentives for green networks on natural and transportation-related sites, possibly including grants from community trusts, city foundations, local foundations, and public bodies
- The acquisition and construction financing for natural and transportation-related sites may be achieved through utility fees such as ratepayer funds and green network levies, dedicated property taxes, a local sales tax, Housing and Urban Development (HUD)'s Community Development Block Grant Programs, state grant programs, private donations,

and tax increment financing (TIF) for green networks. They may also be supported by an expansion of the state's green network law defining natural and transportation-related sites

- In addition, some specific types of environmental improvements and natural and transportation-related site improvements may be eligible for funding from specific green infrastructure and environmental projects such as Green Network Impact Fee (GNIF). State and federal programs may also provide support via the Department of City Development for regional and neighborhood green network systems, possibly by requiring residential developers to pay a per-unit fee for new dwelling units to fund the development of greenways or trails on natural and transportation-related sites; the nonprofit Openland organization may also help public agencies receive grant funding for green network projects by holding interim ownership to facilitate the aggregation of multiple sites until public agencies can purchase the natural and transportation-related sites
- Financing the maintenance of natural and transportation-related sites may be achieved through capital investments, a green network levy from the Department of Parks and Recreation (DPR), some green network credits from the Department of Public Works, using easement agreements to support funding maintenance, youth-based Green Crops programs through public foundation, and corporate sources

CHAPTER 7: CONCLUSIONS

The occurrence of the vacant urban land is common in our cities today and it has become a normal part of the urban fabric. However, due to a lack of public interest, policy, and economic investment, much of our vacant urban land has become a wasteland and is both underused and under-appreciated. The typology of vacant land presented in this dissertation is designed to help planners identify the types and characteristics of vacant urban land to assist in its future design, planning and management. Although people may have some understanding of the need to re-use vacant land in terms of its ecological and social value, financial struggles present major obstacles hindering efforts to redevelop vacant land. Most cities lack adequate economic incentives for supporting vacant land and abandoned buildings that could otherwise be maintained and improved. Tax foreclosures and enforcement codes add to the already large burden cities bear of vacant land that has not been maintained and improved for some time. Unmaintained vacant land and abandoned buildings have a huge negative impact on both the property values and the quality of those living in the surrounding neighborhoods. Maintenance has a value in itself, and can encourage redevelopment in the future. Municipalities should implement vacant land investment policies such as tax incentives, tax credits and rehabilitation abatement on vacant land and abandoned buildings to encourage owners to maintain their properties. Without financial investment, stabilizing neighborhoods is difficult or impossible. In addition, government regulatory strategies such as enforcement codes on vacant land could help control many of the problems associated with vacant land. Vacant property enforcement codes could maintenance requirements and registration fees for vacant properties. People should be motivated to improve their properties and make their surroundings secure.

The typology study in this dissertation shows that a more comprehensive look at vacant land made possible by using a typology to simplify the process, will enable planners, designers and policy makers to do a better job of planning for vacant land. In order to identify what needs to be done, government officials can draws on this new typology to guide the creation of a range different policies, programs and regulations tailored to each of the specific types of vacant urban land identified. Goals could be created for vacant urban land according to its types, including, for example: 1) post-industrial sites could become integral parts of public amenities such as urban parks to build the city image through their rehabilitation for long-term uses; 2) derelict site could become valuable community assets, along with unattended with vegetation site, as part of the city's stormwater control program and to improve local air quality; and 3) natural and transportation-related sites could become part of a city-wide green network system for long-term uses.

To ensure the success of these effort, an appropriate lead agency such as a city planning agency, city community development agency, economic development corporation (CDC), or a special purpose or special district public entity should be appointed to play a key role in advancing redevelopment plans on different types of vacant urban land to support the design, implementation and maintenance of site-specific green infrastructure. Government agencies should engage in successful partnerships with other agencies to support the acquisition, reclamation and maintenance of different types of vacant land for brownfield target-area strategies in neighborhood and site-specific planning of post-industrial sites, neighborhood revitalization/stabilization plans or vacant property-reuse strategies for sites that are derelict or unattended with vegetation, and neighborhood and site-specific planning of green networks on natural and transportation-related sites.

Geographic Information Systems (GIS) can be used to help identify neighborhood brownfield areas in post-industrial sites, stabilization areas in sites that are derelict or unattended with vegetation site, and to plan the optimum potential for site aggregation in green networks composed of natural and transportation-related sites. Special programs and new organizations to manage different types of vacant land should be created using project fund raised from special tax levies, family foundations, personal funds, and endowments from private donations for financial improvement and maintenance. Government agencies should encourage partnerships among special agencies and organizations that may assist in the maintenance and programming of brownfield target-area strategies required as part of the neighborhood and site-specific planning of post-industrial sites, community gardens and neighborhood parks located on derelict sites and those that are unattended with vegetation, and green networks composed of natural and transportation-related sites. In addition, creating multiple goals for transforming different types of vacant land into green infrastructure will help promote neighborhood stabilization, economic well-being and also improve the quality of life in green infrastructure by multiple public uses.

Government agencies should create a lead agency such as a land bank that has the long-term planning and implementation capacity to acquire post-industrial sites and aggregate sites that are derelict or unattended with vegetation, and natural and transportation-related sites through multiple acquisition strategies such as eminent domain, the threat of eminent domain, or intergovernmental transfer and interim ownership of different types of vacant land until construction is completed or local government can pay for the properties. Public-to-public transfer should be supported through the development of different types of vacant land as green infrastructure in the form of memoranda of understanding to advance both city and state goals to reuse post-industrial sites to help achieve state brownfield cleanup goals, derelict and unattended with vegetation site for neighborhood stabilization, and natural and transportation-related sites for greenways to meet state green network system goals. Private-to-public transfer should be achieved through the Neighborhood Stabilization Program for post-industrial sites in brownfield target areas, Park District and NeighborSpace for derelict sites and unattended with vegetation, and natural and transportation-related sites. Temporary-to-permanent green spaces should be supported through land banks, possibly by providing seasonal programs or one-dollar annual leases of different types of vacant land to increases people's commitment to short-term greening or gardening initiatives, and they should also provide different types of vacant land with an option to purchase for permanent use. Creating local Green Corps Programs may also help community garden groups to secure publicly owned vacant land by supporting green infrastructure job training. Government agencies should also provide local the Adopt-a-Lot-Programs that cooperate with the Housing and Community Development (HCD) to provide short-term licenses that enable people to utilize different types of vacant land for green infrastructure purposes.

As well, signing Memoranda of Agreement with State Attorneys General may protect green infrastructure on different types of vacant land from development. Local government agencies should acquire tax current properties through multiple strategies such as the temporary ownership of different types of vacant land by nonprofit Openlands until the city can pay for the cost of these acquisitions. They should also develop a flood mitigation plan to guide the acquisition of different types of vacant land from private owners. Condemnation by the city's Legal Department may successfully effect the acquisition of different types of vacant land. Government agencies should support the transfer of private properties for demolition through Tax Reactive Programs and by developing interdepartmental Growing Green Initiatives, including the city's Public Works, Housing, and Community Development, Planning, and Transportation departments. Public schools and non-profit greening organizations could also help to identify properties such as abandoned buildings that have no short-term development potential and should be demolished, as well as suggesting green re-use options for different types of vacant land. City governments could find it helpful to change city policies from easements to zoning to encourage the use of different types of vacant land for green infrastructure and public access. They should also support the Department of Environment Protection or Park District by supporting public ownership of large areas of different types of vacant land and enforce deed restrictions on green infrastructure that has received funding from state and federal grant programs.

Governments should support the ownership of smaller derelict sites, sites that are unattended with vegetation, natural sites, and transportation-related sites through public agencies and land trusts such as Park Districts, the city and the Forest Preserve District that may provide financial support and leadership for land trusts in partnership with the city's Office of Sustainability to redesign sites that are derelict, unattended with vegetation, natural, and transportation-related to support green infrastructure and also to provide liability insurance. Local governments should create programs like the Green Thumb Program to provide technical and material support to community gardens located on derelict sites and unattended with vegetation site, maintain ecosystem conservation or ecosystem enhancement on natural and transportation-related sites, and hold workshops to teach basic gardening skills as well as more advanced farming and community organizing topics such as urban farming, vegetation maintenance skills and more advanced vegetation enhancement topics such as landscape planning.

City governments should also support the public maintenance of different types of vacant land by multiple city and county agencies through funding supplied from ratepayer fees for post-industrial sites, building maintenance codes from local ordinances to maintain minimum safety standards, enforcing abandoned property maintenance requirements, and charging vacant lot registration fees for sites that are derelict or unattended with vegetation to support the provision of maintenance staff to care for green networks on natural and transportation-related sites. Government agencies should also support the private maintenance of different types of vacant land by providing green infrastructure credits for environmental benefits and human health and well-being from public sectors for post-industrial site; neighborhood residents trained as inspectors for the sites that are derelict or unattended with vegetation who can issue warning notices regarding violations of the city's property maintenance code; official enforcement action to improve the sites that are derelict and unattended with vegetation if necessary; and public sector incentives to provide a certain percentage of storm water credit through easements to natural and transportation-related sites for their ecosystem conservation or ecosystem enhancement. City governments should support the community volunteers who maintain the sites that are derelict or unattended with vegetation, as well as the natural and transportation-related sites for their ecosystem conservation or enhancement by outside greening organizations and land trusts for short-term and long-term uses of different types of vacant land. Youth summer employment schemes should be supported through land banks and clean and green programs, as well as green crops initiatives that provide employment maintaining different types of vacant land.

Government agencies should also provide financial support for the planning process involved for different types of vacant land through local foundations or public grants for post-industrial sites; municipal incentives such as tax abatement, tax incentives/credits or rehabilitative incentives for the infill of sites that are derelict or unattended with vegetation; and green networks of natural and transportation sites from community trusts, city foundations, local foundations, and public grants. Governments should also support the acquisition and construction financing for different types of vacant land through utility fees such as ratepayer funds and green infrastructure levies, dedicated property taxes, local sales taxes, Housing and Urban Development (HUD)'s Community Development Block Grant Programs, state grant programs, private donations, Tax increment financing (TIP) for different types of vacant land and green infrastructure project funding supported by the city or park district. Government agencies should support the maintenance financing of different types of vacant land through enforcement codes, including registration fees or fines to provide remuneration for maintenance services provided by the city or fines for the maintenance of sites that are derelict or unattended with vegetation; as well as capital investments, youth-based Green Crops program, and green network levies and credits from public sectors to support funding maintenance through easement agreements, public foundations, and corporate sources.

Professional societies and organizations such as the American Society of Landscape Architects would be well advised to utilize the new typology approach present here, and professional bodies and universities should also educate students to be aware of this methodology. The approach suggested by this typology of vacant land may be more important than the specific planning strategies themselves. Urban vacant land suffers from many socio, cultural and economic problems that are part of a complex web of urban situations. To encourage the use of these types of typologies by professional organizations such as ASLA and in our universities, government agencies need to provide adequate typology design implementations and strategies for a vacant urban land typology tool based on vacant land physical, biological, and social characteristics and conditions that also takes into account the potential benefits of each in terms of ecological and social value. Government planners should not only provide this information, but also suggest strategic ways to utilize those spaces in terms of short-term uses and long-term uses. Vacant urban land presents different characteristics and different potential values in different communities. However, many professionals and universities have limited planning and implementation strategies for different types of vacant land. As a result, people must overcome numerous obstacles when seeking to solve vacant urban land issues. Therefore, the overall aim in this dissertation has been to develop a useful typology that will advance our knowledge about the potential of the different types of vacant land typically found within an urban landscape. There has been no previous comprehensive research into the current condition of vacant urban land in cities, and no assessment of city policy tools designed to use or reuse vacant urban land. Therefore, the vacant urban land matrix framework in this dissertation was designed as a tool for use in planning and designing vacant parcels in terms of their ecological and social benefits. These places may offer alternative, creative ways to envision urban open spaces and landscape designs in cities. Vacant urban land can be redefined as an important resource when considered from a different perspective as a potential redevelopment opportunity. The typology developed in this dissertation can thus have important implications for policy development, and for practitioners seeking to develop a better understanding of the potential utility and function of vacant urban land, ultimately leading to more effective uses for these areas.

The purpose of assessing vacant urban land forest structure and ecosystem services in this dissertation was to demonstrate how vacant urban land functions as green infrastructure that provides ecosystem services and values to society. Understanding an urban forest's structure, function and value can promote decision-making that will improve human health and environmental quality. The ecosystem services identified in the vacant land study in this dissertation captured the current structure of Roanoke's urban forest growing on vacant land and quantified a subset of the ecosystem functions and economic values it provides to the City of Roanoke's residents. By capturing carbon in new growth each year, trees on vacant urban land in Roanoke store 107,000 tons ($7.65 million) of carbon, adding another 2,300 tons ($164,000/year) to this total every year, which is relatively high compared to other types of land in the city. The trees on Roanoke's vacant land also remove an estimated 91 tons ($916,000/year) of air pollution per year and the shade and shelter from prevailing winds they provide help to reduce energy-related costs from residential buildings by $211,000 annually, with an accompanying reduction in fossil-fuel power plant emissions of an additional $28,103 (a reduction of 395 tons of carbon emissions).

These results suggest that vacant urban land is a vital resource and a useful component of the city's green infrastructure that provides significant benefits and should therefore be managed so as to increase its effectiveness and minimize any negative effects. The ecosystem services provided by Roanoke's vacant urban land were analyzed using the i-Tree Eco model, which facilitates the creation of ecological design guidelines for future development. Although these spaces are now beginning to receive more attention, as yet there are no strategic plans for utilizing them more effectively. The ecosystem services provided by the vacant land in the City of Roanoke, Virginia, described in this dissertation suggest new ways to reinvigorate or revitalize these spaces in terms of their ecological value. An analysis of the structure, function, and economic benefits of vacant urban land can serve as a useful reference for local authorities, landowners and regeneration professionals, as well as providing a rationale for a change in current approaches towards potentially valuable vacant urban land.

In order to identify what needs to be done to implement such an approach that draws on ecosystem services of vacant land, government officials should support different types of vacant urban land greening strategies. The results of the current comparison of urban forest effects and values in vacant urban land by categories suggest that the unattended sites with vegetation could be the best ecological vacant land type for the city. The high ecosystem values of the unattended sites with vegetation should therefore be protected, although these sites could be developed for a variety of uses if done in a manner that protects their current ecosystem values. Less sensitive post-industrial sites that have low ecosystem values could be developed for many different types of land use (e.g. housing, commercial, industry and green re-use options) as they have the most potential for improvement and increases in ecosystem benefits. Those post-industrial sites with historical significance that have remediation potential could be developed in a manner that preserves their historical value with a historically appropriate use. If other natural sites and transportation-related sites have low ecosystem values and are not threatened by development, their current low ecosystem values have the potential to be enhanced through proper management.

Professional societies and organizations such as the American Society of Landscape Architects are highly recommended to utilize the understanding and use of ecosystem structure concepts and ecosystem benefits developed in this research in their planning for vacant land. Those in the profession and working in university settings should also educate students to be aware of the concept of urban ecosystem services related to green infrastructure, particularly urban sustainability. The science-based assessments presented here include the effect of trees on air quality, water flow and water quality, carbon storage and sequestration, and building energy use, and involve the assessment and monitoring of vegetation structure (number of trees, tree sizes, leaf area, species diversity, tree health) and risks to structure (insects and diseases; invasive plants). It is vital that students and those new to the field should be made aware of the importance of urban vegetation and its effects on environmental quality and human health, in particular the urban ecosystem services provided by green infrastructure. The specific focus of this research has been on the impact of urban forests and the value they provide for city residents (broadly defined), and, more generally, on ecosystem services. Teaching and research should focus on studying and understanding the complex interrelationships between ecosystem services and human health and well-being and seek to find solutions or alternatives in vacant urban land to support sustainable futures. The significance of assessing the ecosystem services provided by vacant land in this dissertation is the new vision it provides of vacant urban land as a valuable ecological resource, demonstrating how green infrastructure can be used to enhance ecosystem health, and promote a better quality of life for city residents.

The research described in this dissertation examine the green infrastructure value on vacant land by conducting a comparative study with other land uses, both in terms of forest structure and ecosystem benefits. The results identify differences in forest structure for vacant land and other land uses that in some cases result in fewer ecosystem services being provided by vacant land. These results provide a basis for management strategies that can be used by planners and landscape architects to improve the forest structure on vacant land in a manner that will provide similar or greater ecosystem services than that of other land uses. Therefore, the findings of the research conducted for this dissertation will fill several important gaps in our knowledge about the green infrastructure value of vacant land and suggest new planning and implementation strategies that provide better support for urban regeneration and renewal. This dissertation contributes a new vision of vacant urban lands as valuable ecological resources, acting as green infrastructure that can be used to enhance ecosystem health, and promote a better quality of life for city residents. By utilizing such sites more effectively, vacant urban land can supplement the range and variety of urban open space provision for city residents. This dissertation also outlines planning and implementation strategies to overcome the barriers commonly encountered and discusses the benefits to be gained by bringing vacant urban land back into use in detail. Overall, this dissertation will serve a useful reference for local authorities, landowners and urban regeneration professionals as well as a call for changing our current approach towards valuable vacant urban land.

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APPENDIX A. I-TREE ECO INVENTORY PAPER FORM, SHEET 1 OF 2

PLOT ID=	DATE=	CREW=	GPS COOR	PHOTO ID=
			X	
			Y	

PLOT SKETCH AND NOTES FOR PLOT RELOCATION

(Note distance and direction from plot center to fixed objects; sketch fixed objects in relation to plot center)

Plot address=
Notes:

Plot contact info:
Name and Title:_______________
Phone #______________________

LOCATING REFERENCE OBJECTS/LANDMARKS (Identify at least 1 object)
Measure Reference Object (1) description_______________________________________
Distance to Reference Object (1)______________
Direction to Reference Object (1)_____________
Measured Reference Object (2) description_____________________________________
Distance to Reference Object (2) ______________
Direction to Reference Object (2)_____________
Tree Measurement Point (TMP): Reference Object (1) used Y/N
Reference Object (2) used Y/N
Measurement Unit: M/E

Percent Measured________

ACTUAL LAND USE=	PERCENT IN=	PLOT TREE COVER (%)=	SHRUB COVER (%)=	PLANTABLE SPACE (%)=
ACTUAL LAND USE=	PERCENT IN=			
ACTUAL LAND USE=	PERCENT IN=			
ACTUAL LAND USE=	PERCENT IN=			

GROUND COVER	%BLDG	%CMNT	%TAR	%ROCK	%SOIL	%DUFF/ MULCH	%HERB/ IVY	%MAIN. GRASS	%UNMAIN GRASS	%H2O

SHRUBS	SPECIES	HEIGHT	% AREA	% MISSING	SPECIES	HEIGHT	% AREA	% MISSING	SPECIES	HEIGHT	% AREA	% MISSING

APPENDIX B. I-TREE ECO INVENTORY PAPER FORM, SHEET 2 OF 2

PLOT ID=				TREE SPECIES			DBH						HEIGHT			CROWN WIDTH							TREES NEAR BUILDINGS						
TREE ID	STAT	DR	DS	LAND	USE	HT DBH	1	2	3	4	5	6	TOT	LIVE TOP	CROWN BASE	N-S	E-W	% MISS	DB	% IMP	% SHRUB	CLE	D1	S1	D2	S2	D3	S3	TREE SITE