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Urban vacant land typology: A tool for managing urban vacant land

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ABSTRACT

A typology of urban vacant land was developed, using Roanoke, Virginia, as the study area. A comprehensive literature review, field measurements and observations, including photographs, and quantitative based approach to assessing vacant land forest structure and values (i-Tree Eco sampling) were utilized, along with aerial photo interpretation, and ground-truthing methods, to identify and catalog vacant parcels of land.; The following types of urban vacant land were identified: 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 can be important resources that support urban ecosystem health; the most effective ecosystem benefits occur in natural sites based on their per-ha value. The redesign of post-industrial sites could build a city's image, while transportation-related sites can contribute a green infrastructure network of open spaces across a city. This typological study could have significant implications for policy development, and for planners and designers seeking to utilize urban vacant land to the best advantage.

1. Introduction

Urban development and economic and industrial processes can produce waste products in the form of urban vacant land (Kim & Kim, 2012). Urban processes such as decentralization resulting from demographic change, urban sprawl, de-industrialization, and people's preferences for new types of residential choices, as well as housing foreclosures, subsequent abandonment and demolition, all create vacancies (Johnson, Hollander, & Hallulli, 2014; Kremer, Hamstead, & McPhearson, 2013) that become "urban voids" or negative spaces in the urban fabric. Vacant land presents a particular challenge for older finically distressed cities such as Detroit, Michigan, and Buffalo, all of which have significant amounts of vacant land located within the city limits. Vacant and derelict land, which often includes abandoned buildings and is frequently used as a dumpsite, is very discouraging for residents and conveys negative images about their community. 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, Jensen, & Reiskin, 2001). This reduces the quality of life and property values for the whole neighborhood, further reducing redevelopment and investment, suppressing local tax bases, and stressing municipal budgets due to the administrative and maintenance costs incurred (Crauderueff, Margolis, & Tanikawa, 2012; U.S. Government Accountability Office, 2011).

Vacant land suffers from both political and economic problems (Németh & Langhorst, 2014). Most urban vacant land in the U.S. is viewed only in terms of its current highest and best use from an economic perspective. If it is not developable it is ignored. 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). Many federal policies (including Community Development Block Grants) focus on the creation of new infrastructure and new development rather than rehabilitation or infill development (Jackson, 1987). Ever since the 1950s, the transformation of the national economic base from an industrial to a service economy, coupled with the expense cleaning up environmentally degraded land, suburban migration, mobile workplaces, and weak neighborhood economics, have resulted in a vicious cycle of decline and disinvestment in infill vacant land and increasing vacancy rates (Goldstein et al., 2001;

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Németh & Langhorst, 2014). Declining property values are part of the cycle of abandonment, but at the same time, speculation has increased property values in other areas (Goldstein et al., 2001). Speculation is an inevitable part of a competitive free market, but it can also lead to increased land vacancy and abandonment (Kivell, 1993).

The approach to transforming abandoned or derelict city lots has often focused solely on economics and litigation (Greenstein & Sungu-Eryilmaz, 2004). There are, however, opportunities to redevelop vacant land by improving its ecological and social value, leading many design professionals and scholars to study aspects such as its the planning and design potential (Hollander & Németh, 2011; Johnson et al., 2014; Kim & Kim, 2012; Németh & Langhorst, 2014; Oswalt, 2008; Schilling & Logan, 2008; Schilling & Mallach, 2012). Berger coined the term "drosscape" (Berger, 2006) to indicate that otherwise wasted urban space could be (land) "scaped" and reprogrammed for adaptive reuse. Corbin (2003) took a different approach by examining the cultural meaning of vacancy, redefining it from both cultural and social viewpoints using everyday language and contemporary design to identify what vacancy means to people and develop new ways of thinking about design frameworks for urban landscapes, while Forman (1995) studied the ecological values of these spaces. Urban vacant land can actually improve urban ecological diversity by allowing vegetation to grow freely, thus providing sanctuaries for wildlife in urban areas (Kim & Kim, 2012). These ecological and cultural values of vacant land are often externalities in the normative economic approach taken by many cities today. These parcels are often seen as suspended in limbo, unworthy of any planning or consideration until such time as a new use becomes available. 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).

Many of these research studies discuss urban vacant land as if it were all the same, largely because there is a limited systematic categorization of different types of vacant land and few comprehensive studies into how different types of vacant land can collectively contribute, to the urban landscape. Due to this dearth of knowledge regarding the potential uses of different types of urban vacant land, it is often overlooked and not fully valued as part of the urban landscape, despite its potential ecological and social values. The design, planning and management of vacant lands have been minimal, both in the short and long term, thus neglecting a valuable resource. The purpose of this study was to identify and develop a useful typology of urban vacant land to help planners, developers and residents better utilize these areas, using the City of Roanoke, Virginia, as a case study. This research will fill some gaps in our understanding of the potential utility of various types of urban vacant land to improve urban design, planning and management. The classification of different categories of urban vacant land based on their physical, biological and social characteristics will provide a useful way to assess their potential value in the urban landscape. This new typology will enhance comprehensive vacant land management that: 1) does not focus solely on economic value but proactively seeks other uses while waiting for higher uses to become available; 2) recognizes the synergistic value of planning that treats all forms of vacant land as a coherent whole; and 3) recognizes the barriers or limitations and potential opportunities inherent in the use of vacant land.

1.1. Vacant land definitions

Interest in urban vacant land has grown in recent years, but the definition of vacant land is often unclear. Although urban vacant 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, 2012). Urban vacant 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).

The term of vacant land is broad and diverse, but it is usually defined as under-utilized lands including bare soil, derelict land, abandon buildings and structures, brownfields, greenfields, uncultivated land or marginal agricultural land and recently razed land (Bowman & Pagano, 2004; Pagano & Bowman, 2000). Northam (1971) identified five different types of vacant land in U.S. cities which includes 1) remnant parcels often irregular shape or small size; 2) physical unfit for development land due to steep slopes and flood hazards; 3) corporate reserve parcels for future expansion; 4) transitional land for speculations and 5) land in institutional reserve for future development. The National Land Use Database (NLUD) in the UK defined vacant land as previously developed land which is now vacant and could be developed without special treatments, such as demolition, clearing and levelling (NLUD, 2003). In New York City, the Department of Finance defined vacant land as "on which no lawful structure exists and which is not otherwise being used for any purpose for which it may lawfully be used" (City of New York, 2010). According to The American Planning Association (APA), there are two definitions of vacant land: a) "lands or buildings that are not actively used for any purpose," and b) "a lot or parcel of land on which no improvements have been constructed" (Davidson & Dolnick, 2004). In practice, cities created the definitions of vacant land and it is diverse among jurisdictions (Kremer et al., 2013).

1.2. The condition of vacant land

There is relatively little research on the physical characteristics of vacant land, or the barriers or limitations and potential opportunities inherent in the use of vacant land. The most recent comprehensive research on vacant lots in U.S. cities was conducted by surveying city officials, usually planning director between 1997 and 1998 from 99 cities with populations of 100.000 more (Bowman & Pagano, 2004). The survey results showed that vacant land has different existing conditions and characteristics. Most vacant lots are small, odd-shaped and in wrong location that deter its potential development. Table 1 summarizes seven different vacant lot conditions in U.S. cities that include: 1) vacant parcels not large enough to develop; 2) odd-shaped parcels of

Table 1
Vacant land conditions in U.S. cities.

Condition	No. of Cities
Vacant parcels not large enough	97
Odd-shaped parcels of vacant land	75
Vacant land in "wrong" location	72
Other conditions[a]	60
Vacant land is in undersupply	58
Parcels have been vacant too long	45
Vacant land is in oversupply	43

Source: [a]Other conditions: Real estate speculation, perceived contamination, steep slopes, infrastructure problems, or wetlands (Bowman & Pagano, 2004, p.8).

vacant land; 3) vacant land in "wrong" location; 4) other conditions; 5) vacant land in undersupply; 6) parcels that have been vacant too long and 7) vacant land in oversupply (Bowman & Pagano, 2004). Other conditions include land that is vacant due to real estate speculation, perceived contaminations, steep slopes, infrastructure problems, or wetlands.

These condition may be influenced by complex or unknown ownership, zoning restrictions, and political issues. Some vacant lands have physical constraints by various environment conditions, such as drainage areas, wetlands, hillsides, railroad or motorway verges, river banks and river flood plains. Other vacant lands are empty and inactive for many years pending development until land values increase as a competitive assets for implementing economic development strategies: creating jobs, increasing tax revenue, improving transportation infrastructure, and attracting residents (Taylor 2008; Hough, 1994). As the result of industrial growth, decline in economic conditions and technology changes, there is an increasing number of abandonment of old transportation networks or factories, such as power plants, landfills, brownfields, water treatment plants, military sites and airports. According to the NLUD definition, these vacant land conditions can be defined as derelict land, which is land so damaged by previous industrial or other development that it is incapable of beneficial use without treatment (2003). Land with physical/environmental limitations and some of the remnant parcels are likely to remain unbuilt to into the future, thus will continually supply permanent vacant land.

2. Methods

Three steps were required to develop and test the proposed comprehensive typology: 1) a literature review on existing urban vacant land typologies; 2) a broad field assessment of vacant land in Roanoke to develop a vacant land typology; and 3) a detailed field assessment of the different types of vacant lands using on-the-ground measurements (i-Tree Eco random sampling) to test the new vacant land typology.

2.1. Study area

The City of Roanoke was selected as the site for this study as the city's age and industrial heritage provide a useful opportunity to identify and explore a range of typologies of urban vacant land. Due to economic and technological changes, many of the city's traditional manufacturing operations and industries have become obsolete and closed in recent years, leaving many industrial corridors with underused or derelict properties. The city has a population of 97,032 (U.S. Census Bureau, 2010), and an area of 42.9 square miles. Its climate is subtropical and humid, with 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 41.24 inches (1047.7 mm) (NowData – NOAA Online Weather Data, 1981–2010).

2.2. A field assessment of vacant land

To assess vacant land types, a list of observational variables was created based on comprehensive literature review. The variables were categorized in terms of their physical, biological and socio-cultural characteristics. Vacant parcels in Roanoke were cataloged using public data sources, aerial photo interpretation and ground-truthing methods.

A field assessment of vacant land characteristics in the area of the central Roanoke River was conducted during the 2013 leaf-on season (June) 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, socio-cultural characteristics were recorded (Table 2). Important socio-cultural characteristic variables were also quantitatively determined based on publicly available data sources (e.g. municipal statistics, historical records, previous land use, crime, property assessor data and GIS land parcel information) (Blakeman, Brown, Fitzpatrick, Shaw, & Williamson, 2008). These distinguishing variables were then compared and grouped based on their similarities and differences, to develop a list of criteria (Table 3), leading to the development of a vacant land typology (Fig. 1). The vacant land in Roanoke was categorized into 5 types: post-industrial sites, derelict sites, unattended with vegetation sites, natural sites, and transportation-related sites that are described below.

2.3. Types and amounts of urban vacant land in roanoke

The current status of the city's urban vacant land was evaluated using i-Tree Canopy. This tool allows users to quickly and easily estimate cover classes such as trees, grass, buildings or roads over large areas using sampling of random points (e.g., Nowak & Greenfield, 2010). At each point, the user classifies the type of cover class at each point on the Google Map image. The program automatically provides an estimate of the percentage and standard error for each cover class (i-Tree Canopy Technical Notes, 2011). In this study, 1000 random points were assessed within the Roanoke city boundary. Each point was identified as to the type of urban vacant land. Overall, percent of the points were classified as vacant land (Table 4). Among the points classified as vacant land, 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%).

2.4. i-Tree Eco random sampling

To assess the forest structure, functions and values in the five different types of vacant land in Roanoke, the i-Tree Eco model (www.itreetools.org) was used. This software used standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak et al., 2008). Plot measurements include the percent of plot tree cover, shrub cover, plantable space, ground cover types and data on each trees, including tree species, total height, Diameter at Breast Height (DBH; 4.5 ft), crown width (N-S, E-W), percent of canopy missing and dieback, crown light exposure, and trees near buildings (distance and direction from trees) (Nowak et al., 2008). In the City of Roanoke, 113 (0.04 ha) plots were randomly sampled across five different types of vacant land: post-industrial sites (15 plots), derelict sites (15 plots), unattended with vegetation sites (53 plots), natural sites (15 plots), and transportation-related sites (15 plots). Plots were assigned proportionate to the land area of each stratum, with a minimum sample size of 15 plots for each class (Table 5). Plots on both public and private property were assessed. All field data were collected during the 2013 leaf-on season (June–July) to properly assess tree canopies.

3. Results

3.1. Typological classification

The vacant land typology presented here 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 lends itself to the categorization of project-appropriate vacant land into 5 types: post-industrial sites, derelict sites, *unattended with vegetation* sites, natural sites, and transportation-related sites (Fig. 1). 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. Different types of urban vacant lands can be categorized in terms of their potential uses. Fig. 2 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

Table 2
Vacant land's distinguishing variables identified during field-based data collection.

Physical characteristics	Biological characteristics	Socio-cultural characteristics
Structure present	Large number of trees (more than 5 trees per 0.04 ha)	Previously developed land or Previously undeveloped land
No structure present	Small number of trees (less than 5 treess per 0.04 ha)	Public ownership
Size − smaller than 0.8 ha or larger 0.8 ha	Large tree canopy cover (more than 30% of the area)	Private ownership
Slope − gentle slope less than 5% or steep slope more than 5%	Small tree canopy cover (less than 30% of the area)	High property value
Shape − rectangular, irregular, or linear	Large plantable space (greater than 50% of the area)	Low property value
Soil − permeable or nonpermeable	Small plantable space (less than 50% of the area)	Safe
Visible maintenance	Ground cover − cement, bare soil, grass, or water	Not safe
No visible maintenance	Diverse tree species (more than 3 species per 0.04 ha)	High crime level
Presence of debris	Few tree species (less than 3 species per 0.04 ha)	Low crime level
No presence of debris		Illegal activity
Contamination level-contamination or no contamination		No illHistorical siteegal activity
		Not a historical site
		Community asset
		Not a community asset
		Significant structure
		No significant structure

Table 3
List of criteria for assessing vacant land: Natural and cultural attributes that was mapped at the vacant land site.

NATURAL FACTORS		CULTURAL FACTORS
Physical characteristics	Biological characteristics	Socio-cultural characteristics
Structure	Tree number	Land use/Zoning
Size	Tree canopy cover	Ownership
Shape	Tree species	Property value
Slope	Tree health	History of site
Soil	Tree height	Safety of site
Maintenance	Tree D.B.H	Crime level
Waste	Plantable space	Illegal activity
Contamination	Ground cover type	Community asset
	Biodiversity	Significant structure (Landmark)

developed land or 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 contain no remnants of building structures. Depending on the contamination level, history and the quality of vegetation on 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. 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. Depending on the quality of vegetation on the site, previously undeveloped land may be suitable for environmentally sensitive use, unlimited development, ecosystem conservation and ecosystem enhancement (Fig. 2).

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. Fig. 2 depicts the typology of urban vacant land to illustrate the types and characteristics of urban vacant land.

3.2. Forest structure on Roanoke's vacant land typology

Among the categories of vacant land, the highest tree densities occur on natural sites, followed by *unattended with vegetation* sites and derelict sites (Fig. 3). However, *unattended with vegetation* sites make up the majority of the urban vacant land (17.3 km^2), so these may be particularly important resources that can have a significant impact on urban ecosystem health in Roanoke (Table 5). "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). Among the five categories of urban vacant land in the city, *unattended with vegetation* sites contain about 121,300 trees, which is the most trees relative to other types. These *unattended with vegetation* sites play host to 33 tree species, which is again the most relative to other types. The highest biodiversity occurs in *unattended with vegetation* sites, followed by natural sites and derelict sites (Table 5). 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 water quality. Trees and vegetation ground cover types reduce storm water impacts by intercepting rainfall, slowing water movement, and increasing infiltration in the ground. Vacant land forest structure can be a cost-effective way of reducing the need for expensive storm water management infrastructure such as retention tanks and sewer system, as

Category	Image	Example	Characteristic
Post-industrial sites		By-product of rapid urbanization and urban sprawl types by: e.g.,) power plants, landfills, brown-fields, water treatment plants, military sites, airports	Size: 242 m^2 Ownership: Municipal Zoning: I-2 (heavy industrial district) Tree number: 21.4 per ha Contamination: Petroleum inventory
Derelict sites		Building or house remains empty or unused. Previously developed land that is now vacant and often wasted or unused sites: e.g.,) unsafe, place for illegal activity, abandoned buildings or structures	Size: 136 m^2 Ownership: Unknown Zoning: R-7 (residential single-family district) Tree number: 61.8 per ha Contamination: None
Unattended with vegetation sites		Vacant land sites that are empty and inactive. The site may contain natural vegetation and contain ecosystem value that has a relatively high potential for development: e.g.,) unimproved vacant parcels, unimproved natural forest, conservation areas	Size: 183 m^2 Ownership: Private Zoning: R-3 (residential single-family district) Tree number: 69.9 per ha Contamination: None
Natural sites		The sites have physical constraints by environment conditions: e.g.,) drainage areas, wetlands, hillsides, river banks/river flood plains	Size: 10,521 m^2 Ownership: Municipal Zoning: ROS (recreation and open space district) Tree number: 90.1 per ha Contamination: None
Transportation-related sites		Spaces are related to transportation systems: e.g.,) railroad tracks, highways, conservation areas	Size: 687 m^2 Ownership: Municipal Zoning: I-1 (light industrial district) Tree number: 56 per ha Contamination: Hazmat waste

Source: Vacant land typology images are tooken by author during field observation and measurement in central Roanoke River. Data for size, ownership and zoning of each vacant lot were collected from Roanoke GIS vacant land parcel information (http://www.roanokecountyva.gov/FormCenter/GIS-4). Data for tree number was collected from i-Tree Eco smaping during 2013 and contamination level was collected from the Environmental Data Resources (EDR's) comprehensive survey (Blakeman et al, 2008)

Fig. 1. Categories of vacant land in Roanoke, VA.

Table 4
Current urban land area and percentage with completed plots for the City of Roanoke (total area: 111.34 km^2).

Typology of urban vacant land	Existing urban vacant land				Number of plots selected for analysis
	km^2	± SE	% of total area	± SE	
Post-industrial sites	3.34	± 0.60	3.0%	± 0.54	15
Derelict sites	4.01	± 0.66	3.6%	± 0.59	15
Unattended with vegetation sites	17.3	± 1.27	15.5%	± 1.14	53
Natural sites	2.78	± 0.55	2.5%	± 0.49	15
Transportation-related sites	5.01	± 0.73	4.5%	± 0.66	15
Non-vacant land	78.9	± 1.60	70.9%	± 1.44	0
City total	111.34		100%		113

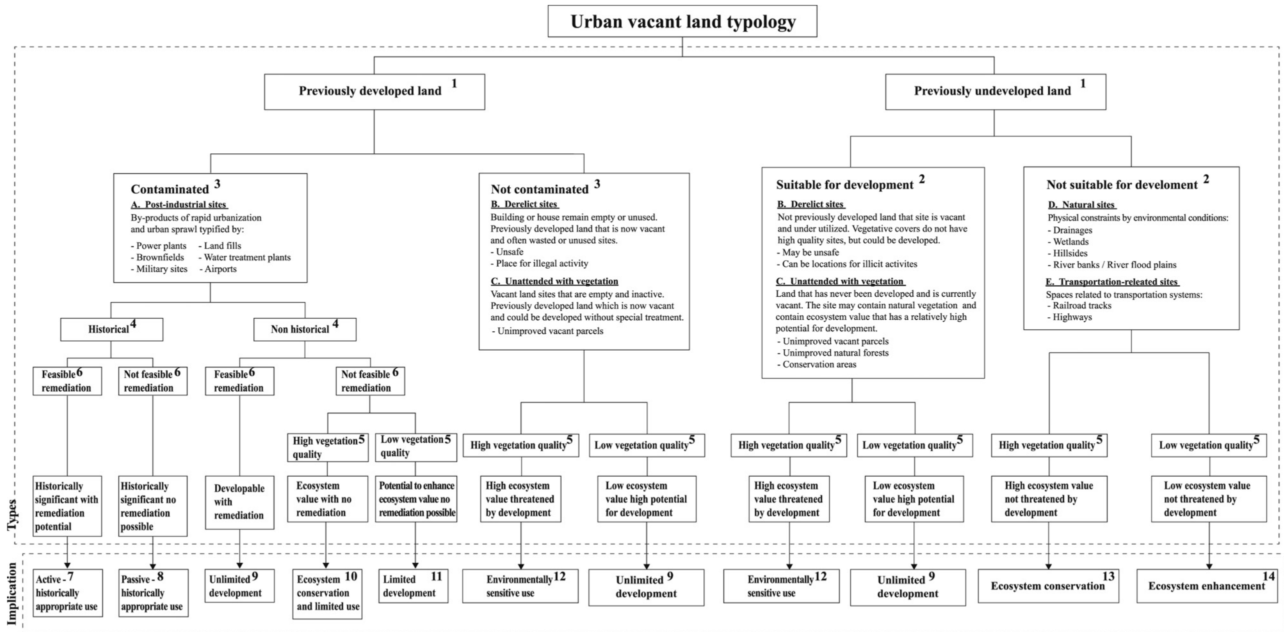
± SE = Standard error of the total.

Table 5
Comparison of urban forests: Percentage tree cover, number of trees and biodiversity in urban vacant land by category. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model.

Category	km^2 (SE)	Percent tree cover (SE)	Number of trees (SE)	Number of trees per ha (SE)	Number of tree species (SE)
Derelict	4.01 (0.66)	32.5 (6.7)	25,730 (6354)	61.8 (15.2)	18 (4)
Natural	2.78 (0.55)	48.2 (6.9)	26,510 (4861)	90.1 (16.5)	24 (4)
Post-industrial	3.34 (0.60)	13.5 (6.1)	7490 (3460)	21.4 (9.80)	6 (3)
Transportation-related	5.01 (0.73)	40.6 (6.5)	28,920 (6029)	56.0 (11.6)	13 (3)
Unattended with vegetation	17.3 (1.27)	27.7 (3.7)	121,260 (21,510)	69.9 (12.3)	33 (6)

SE = Standard error of total.

vegetation can capture or reduce storm water run-off. The current forest structure on vacant land can help manage urban storm water to reduce flooding, filter polluted water running off impervious paving areas, such as parking lots and road systems, and help recharge ground water systems. Vacant land is an important component of urban green infrastructure systems that can affect the health of the local urban ecosystem, providing enduring value for the community. Among the



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]**:** Conatmination 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.

Fig. 2. Development of the proposed typology of urban vacant land.

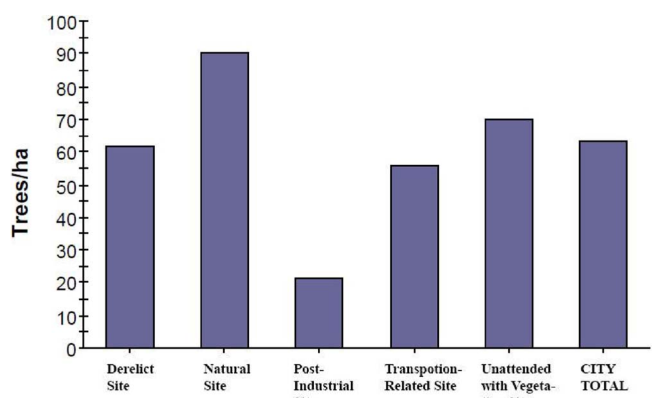


Fig. 3. Number of trees per ha growing on urban vacant land by typology, City of Roanoke, Virginia.

categories of urban vacant land, the highest plantable space occurs on *unattended with vegetation* sites, followed by transportation-related sites and natural sites (Table 7). 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). *Unattended with vegetation* sites support 71.3% of the plantable space, which is the highest relative to other types (Table 6). *Unattended with vegetation* sites also have 55.9% of the wild grass, which is again the highest relative to other categories. Thus *unattended with vegetation* sites can be strategically used as part of the urban green storm water infrastructure. Most *unattended with vegetation* sites consist of previously developed land that is now vacant with no structures, although some sites contain a natural forest structure, which means that *unattended with vegetation* sites can be easily built upon and there are no environmental and physical constraints to redeveloping those spaces. In addition, *unattended with vegetation* sites are the most common types of urban vacant land category (17.3 km^2) (Table 5), so they can be easily managed for redevelopment as green infrastructure, such as small parks, urban agriculture and community gardens in the future. *Unattended with vegetation* sites have a high potential value as green infrastructure that can be used to provide ecosystem services for city residents.

3.3. Ecosystem services provided by Roanoke's vacant land typology

Urban vacant land typology provides different ecosystem services, such as, carbon sequestration and storage. Trees on urban vacant 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. Trees store and sequester carbon dioxide through their growth processes in their tissue. The carbon storage and carbon sequestration values used was $78.5 per metric ton of carbon (Interagency Working Group on Social Cost of Carbon United States Government, 2010). Among the categories of urban vacant land, the carbon sequestration of trees on *unattended with vegetation* sites is about 1336 t per year, which is highest relative to other types (Table 7). The carbon storage on these vacant sites is about 66,000 t, which is also the highest relative to other vacant types (Table 7). *Unattended with vegetation* sites make up a major percentage of the urban vacant land, so they represent one of the most important vacant resources for carbon storage and sequestration. However, the highest tree densities occur in natural sites, followed by *unattended with*

Table 6
Comparison of urban forests: City totals for percent of coverage in urban vacant 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.

Table 7
Comparison of urban forests: City totals for tree's functional and structural values in urban vacant land by typology. Summary data are provided for the City of Roanoke and analyzed using the i-Tree Eco model.

Category	Percentage tree cover (SE)	Number of trees (SE)	Carbon storage (t) (SE)	Carbon storage value (US$) (SE)	Carbon sequestration (t/yr) (SE)	Carbon removal value (US$) per yr (SE)	Structural value (US $) (SE)
Derelict	32.5 (6.7)	25,725 (6354)	12,974 (5608)	1,023,550 (442,428)	220 (62)	17,430 (4912)	20,894,595 (6,904,317)
Natural	48.2 (6.9)	26,514 (4861)	9468 (4445)	746,905 (350,654)	249 (80)	19,667 (6318)	17,675,472 (6,608,554)
Post-industrial	13.5 (6.1)	7488 (3460)	546 (263)	43,132 (20,776)	34 (16)	2719 (1279)	1,720,407 (834,790)
Transportation-related	40.6 (6.5)	28,923 (6029)	7721 (2593)	609,080 (204,551)	233 (57)	18,389 (4498)	17,505,068 (5,499,140)
Unattended with vegetation	27.7 (3.7)	121,613 (21,510)	66,025 (14,381)	5,208,723 (1,134,519)	1336 (262)	105,449 (20,679)	111,115,757 (21,684,099)

SE: Standard error of the total.

Table 8
Comparison of urban forests: Per-ha values of tree' functional and structural values in urban vacant 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 ha (SE)	Carbon storage (kg/ha) (SE)	Carbon storage value (US$) per ha (SE)	Carbon sequestration (kg/yr/ha) (SE)	Carbon removal value (US$) per ha (SE)	Structural value (US$) per ha (SE)
Derelict	61.8 (15.2)	31,404 (13, 467)	2,449.5 (1,050.4)	534.8 (150.7)	41.7 (11.7)	50,175 (16,580)
Natural	90.1 (16.5)	32,436 (15,109)	2530 (1178)	854.1(274.4)	66.6 (21.3)	60,076 (22,462)
Post-industrial	21.4 (9.8)	1576 (754.5)	122.9 (58.8)	99.4 (46.7)	7.8 (3.6)	4920 (2387)
Transportation-related	56.0 (11.6)	15,070 (5022)	1,175.5 (391.7)	454.9 (111.2)	35.5 (8.6)	33,898 (10, 649)
Unattended with vegetation	69.9 (12.3)	38,271 (8270)	2,985.1 (645.1)	774.8 (151.9)	60.4 (11.8)	63,897 (12,469)

SE: Standard error of the total.

vegetation sites and derelict sites (Table 8). The carbon sequestration in the *unattended with vegetation* sites is about 775 kg of carbon per ha annually and the accumulated carbon storage is about 38.300 kg of carbon per ha, which is high relative to other types (Table 8). *Unattended with vegetation* sites 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. Trees in Roanoke's vacant land have a structural value, just as other infrastructure in the city. This value is based on the cost 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, Crane, & Dwyer, 2002). The number and size of healthy trees contribute to the increased structural and functional value of an urban forest. Among the categories of urban vacant land, the *unattended with vegetation* sites have a particularly high value for carbon storage, carbon sequestration, and structure, relative to other types (Tables 7 and 8). *Unattended with vegetation* sites make up the majority of vacant land, with many healthy trees in natural stand conditions. These sites can thus be one of the most effective land use types, providing ecosystem services in a city.

4. Discussion

Unattended with vegetation sites dominate the vacant land in Roanoke, covering 53 percent of all vacant land and containing 58 percent of the vacant land tree population. This type of vacant land provides the most ecosystem services among the vacant land types and could provide even more in the future, as this vacant class also has the most potentially plantable space, with over 70 percent of the land classified as plantable. All the vacant land types provide some level of ecosystem services and values that could be enhanced in the future. However, each vacant land class comes with differing potentials and limitations.

4.1. Post-industrial sites as public amenities

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. Post-industrial sites are generally the result of industrial growth and decline, changing zoning policies, or of the abandonment of old infrastructure elements

VACANT LAND CHARACTERISTICS / VACANT LAND CLASSIFICATION								NATURAL FACTORS													CULTURAL FACTORS							
								PHYSICAL								BIOLOGICAL					SOCIO-CULTURAL							
								Elements					Condition			Vegetation Structure					Legal			Sensory			Historic	
								Vacant land					Vacant land			Vacant land					Vacant land			Vacant land			Vacant land	
land use history	stage of development	contamination	history	remediation	vegetation quality	implication	type	Structure	Size	Shape	Slope	Soil	Maintenance	Waste	Contamination	Tree number per ha	Tree canopy cover	Plantable space	Ground cover	Tree species diversity	Zoning	Ownership	Property value	Safety of site	Crime level	Illegal activity	Community asset	Significant structure (Landmark)
PREVIOUSLY UNDEVELOPED LAND	NOT SUITABLE FOR DEVELOPMENT	Not contaminated	Not a historical site	No remediation need	High vegetation quality, Low vegetation quality	Ecosystem conservation, Ecosystem enhancement	Transportation-related sites ex) railroad tracks, highways, conservation areas	no structure present	687 m²	linear or irregular	gentle slope (< 5%)	permeable paving	no visible maintenance	dumped debris	hazmat hazard	56.0 per ha	40.6%	51.8%	cement: 0.9% bare soil: 3.3% grass: 39.7% water: 0%	13	I-1 (light industrial district)	municipal	low to high	not safe	low	low	low to high	no structure present
							Natural sites ex) drainages, wetlands, hillsides, river banks / river flood plains	no structure present	10,521 m²	linear or irregular	gentle (< 5%) to steep (>5%)	permeable paving	no visible maintenance	no dumped debris	no contamination	90.1 per ha	48.2%	51.5%	cement: 1.2% bare soil: 10.3% grass: 32.6% water: 5.9%	24	ROS (recreation and open space district)	municipal	high	safety	low	low	high	no structure present
	SUITABLE FOR DEVELOPMENT	Not contaminated	Not a historical site	No remediation need	High vegetation quality, Low vegetation quality	Environmentally sensitive use, Unlimited development	Derelict sites ex) may be unsafe, can be locations for illicit activities	no structure present	136 m²	square	gentle slope (< 5%)	permeable	no visible maintenance	dumped debris	no contamination	61.8 per ha	32.5%	49.4%	cement: 13.2% bare soil: 6.1% grass: 2.9% water: 0.6%	18	R-7 (residential single family district)	unknown	low	not safe	high	high	low	no structure present
							Unattended with vegetation ex) unimproved natural forest, conservation areas	no structure present	183 m²	square	gentle slope (< 5%)	permeable	no visible maintenance	no dumped debris	no contamintion	69.9 per ha	27.7%	71.3%	cement: 0.9% bare soil: 4.5% grass: 55.9% water: 0%	33	R-3 (residential single family district)	private	high	high	low	low	high	no structure present
PREVIOUSLY DEVELOPED LAND	SUITABLE FOR DEVELOPMENT	Not contaminated	Historical site / Not a historical site	Not a feasible remediation	High vegetation quality, Low vegetation quality	Ecosystem conservation and limited use, Limited development	Derelict sites ex) abandoned structures and buildings	structure present	178 m²	square	gentle slope (< 5%)	impermeable	no visible maintenance	dumped debris	hazmat hazard	28.8 per ha	16.5%	22.4%	cement: 33.2% bare soil: 3.5% grass: 1.9% water: 0%	9	MX (mixed use district)	private or municipal	low	not safe	high	high	low	significant or no significant
				Feasible remediation	N/A	Unlimited development	Unattended with vegetation ex) unimproved vacant parcels	no structure present	156 m²	square	gentle slope (< 5%)	permeable	no visible maintenance	no dumped debris	no contamination	35.9 per ha	13.7%	80.2%	cement: 0% bare soil: 3.5% grass: 75.9% water: 0%	16	R-12 (residential single family district)	private	high	high	low	low	high	no structure present
		Contaminated	Historical site	Feasible remediation / Not feasible remediation	N / A	Active historically appropriate use / Passive historically appropriate use	Post-industrial sites ex) power plants, land fills, brownfields, water treatment plants, military sites, airports	structure present or not	242 m²	square	gentle slope (< 5%)	permeable or impermeable	no visible maintenance	dumped debris	petroleum inventory	21.4 per ha	13.5%	28.5%	cement: 9.7% bare soil: 4.3% grass: 6.7% water: 0.7%	6	I-2 (heavy industrial district)	municipal	low	not safe	high	high	low to high	significant or no significant

Fig. 4. Typology of urban vacant land framework.

(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. Post-industrial sites often have few trees, little plantable space, and may have large amount of impervious cover (building, cement, and rock). The general perception of post-industrial sites conveys negative images that decrease the quality of life of nearby residents (Figs. 5 and 6), 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 and sometimes contaminated 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.

4.2. 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 (Fig. 4). Derelict buildings are an indicator of neighborhood decline, reducing sense of community and discouraging investment (Figs. 7 and 8). 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

Fig. 5. Post-industrial factory located near the railway, City of Roanoke, Virginia.

Fig. 6. Wild vegetation growing on a post-industrial factory site, City of Roanoke, Virginia.

sites. Increasing occupancy of these buildings usually improves the property value, lowers illegal activities improves safety, and decreases the municipal budget devoted to the maintenance of derelict buildings. A good strategy for managing derelict buildings is for cities to acquire the derelict buildings through foreclosure, 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. Encouraging investment and boosting home ownership rates for derelict buildings can support neighborhood stability. Private market could be encouraged to acquire and reuse derelict sites.

4.3. Unattended with vegetation sites as natural assets

Unattended with vegetation sites have significant potential as natural assets. The two predominant ground cover types on *unattended with vegetation* sites are maintained grass and unmaintained grass. These two types are permeable, which means that these sites can be strategically used to control urban storm water and provide readily available space for more trees. This vacant land type offers the largest area to increase Roanoke's tree canopy cover.

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

Fig. 7. Derelict residential building, City of Roanoke, Virginia.

Fig. 8. Two adjacent derelict residential buildings, City of Roanoke, Virginia.

species of pioneer trees and shrubs that have a significant landscape impact (Taylor, 2008). Ideally, these sites could be self-sustaining with minimal maintenance costs. These sites could also be developed in a manner that protects ecosystem values (Fig. 9).

4.4. Natural sites and transportation-related sites as green networks

Natural sites and transportation-related sites have a potential to act as connectors within a larger green network. These sites tend to be long and narrow as they lie alongside rivers, railroads lines or high ways (Figs. 10 and 11). Thus they can provide a useful corridor to support the movement of urban wildlife, improve biodiversity city-wide; increasing the city's wildlife viewing opportunities, and boost the local urban ecology. Natural sites are of particular importance as they have the highest tree density and percent tree cover among the vacant land types, and thus have the greatest carbon sequestration values per hectare. Like *unattended with vegetation sites*, natural sites and transportation-related sites are dominated by permeable ground cover, which can be used to control urban storm water and readily increase three cover.

In strategic, city-wide planning, these in-between spaces can combine to create a wider green infrastructure network of open spaces (Kamvasinou, 2011). 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). Natural and transportation-related sites can serve as a valuable ecological green network system that provide high value ecosystem benefits for city residents.

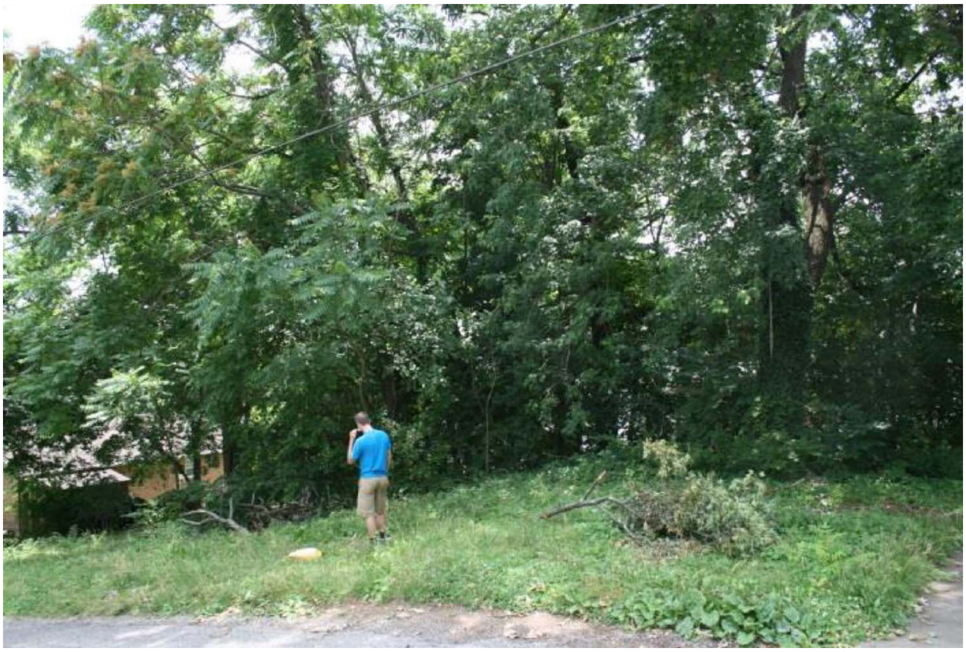


Fig. 9. Unimproved natural forest in a residential neighborhood, City of Roanoke, Virginia.

Fig. 10. Natural site − river bank, City of Roanoke, Virginia.

4.5. Planning and policies on vacant land

Urban vacant land is common in today's cities and represents part of the urban fabric. However, due to a lack of public interest, policies, and economic investment, many urban vacant sites become wasteland that are often underused or under-appreciated. Financial issues are major obstacles for redevelopment of vacant land. Most cities lack adequate economic incentives designed to support vacant land and abandoned buildings, which could be maintained and improved. Tax foreclosures and enforcement codes increase the already large amounts of vacant land that is not maintained. Unmaintained vacant land and abandoned buildings negatively impact both local property values and the quality of life in surrounding neighborhoods. Maintenance has value in itself, which can encourage redevelopment in the future. Municipalities could provide vacant land investment policies, such as tax incentives, tax credits and rehabilitation abatement on vacant land and abandoned buildings. Without financial investment, stabilizing neighborhoods is difficult. Government regulatory strategies such as enforcement codes on vacant land could help control these problems; vacant property enforcement codes could include maintenance requirements and registration fees for vacant properties to encourage the owners to improve their properties and make their surroundings secure.

Numerous potential options exist that could enhance the usefulness of vacant land for urban society.

A lead planning agency could be specifically designated to play a key role in advancing redevelopment plans for different types of urban vacant land to support the design, implementation and maintenance of site-specific green infrastructure. Special programs to manage vacant land could be created using funding from special tax levies, family foundations, personal funds, and endowments from private donations. These programs could promote neighborhood stabilization, economic well-being and improve quality of life. Programs, such as a land bank,

Fig. 11. Wild vegetation growing along the railroad tracks, City of Roanoke, Virginia.

could acquire vacant lands 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.

The public maintenance of vacant land could be instituted, or governments support could private maintenance by issuing green infrastructure credits for environmental benefits and training neighborhood residents to conduct site inspections regarding violation of property maintenance code. Community volunteers and green organizations could be also encouraged to maintain vacant sites.

The typology developed for this study show that a comprehensive examination of vacant land using a typology may facilitate planners, designers and policy makers to engage in more effective planning for vacant land. Local, state and federal government agencies could create program goals for urban vacant land encouraging the use of: 1) post-industrial sites as public amenities, 2) derelict sites as potentially useful community assets, 3) *unattended with vegetation sites* as natural city assets, and 4) natural and transportation-related sites to enhance a green network system.

5. Conclusion

The overall aim in the study was to develop a useful typology that will support a better appreciation and understanding of the potential benefits of vacant land within an urban landscape. This study represents the first attempt to conduct comprehensive survey of the current condition of urban vacant land in cities and develop a means to support city policies designed to use or reuse urban vacant land. The urban vacant land matrix framework created for this study can assist planners and city managers seeking to engage in more effective planning and design processes for vacant parcels in terms of their ecological and social benefits. These sites can offer alternative, creative ways to envision urban open spaces and landscape designs in cities. Urban vacant land can be redefined as an important resource when considered as a potential redevelopment opportunity. The typology developed in this study may have important implications for policy development, and is expected to help practitioners better understand urban vacant land, thus leading to more appropriate use of these areas.

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