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Research Paper

Residential demolition and its impact on vacant lot hydrology: Implications for the management of stormwater and sewer system overflows

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HIGHLIGHTS

- Some cities have a coincident over-abundance of stormwater volume and vacant land.
- Demolition processes can alter the qualities of vacant land.
- We assessed urban vacant land soils and their hydrology.
- Data was used to show how vacant lots could be used as infiltrative green infrastructure.

GRAPHICAL ABSTRACT

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ABSTRACT

Increased residential demolitions have made vacant lots a ubiquitous feature of the contemporary urban landscape. Vacant lots may provide ecosystem services such as stormwater runoff capture, but the extent of these functions will be regulated by soil hydrology. We evaluated soil physical and hydrologic characteristics at each of low- (backyard, fenceline) and high-disturbance (within the demolition footprint) positions in 52 vacant lots in Cleveland, OH, which were the result of different eras of demolition process and quality (i.e., pre-1996, post-1996). Penetrometer refusal averaged 56% (range: 15–100%) and was attributed to high concentration of remnant buried debris in anthropogenic backfill soils. Both disturbance level and demolition type significantly regulated infiltration rate to an average of 1.8 cm h^{-1} (range: 0.03–10.6 cm h^{-1}). Sub-surface saturated hydraulic conductivity (K_{sat}) averaged higher at 4.0 cm h^{-1} (range: 0–68.2 cm h^{-1}), was influenced by a significant interaction between both disturbance and demolition factors, and controlled by subsurface soil texture and presence/absence of unconsolidated buried debris. Our observations were synthesized in rainfall-runoff models that simulated average, high- and low-hydrologic functioning, turf-dominated, and a prospective green infrastructure simulation, which indicated that although the typical Cleveland vacant lot is a net producer of runoff volume, straightforward change in demolition policy and process, coupled with reutilization as properly designed and managed infiltration-type green infrastructure may result in a vacant lot that has sufficient capacity for detention of the average annual rainfall volume for a major Midwestern US city.

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1. Introduction

The rise of vacant land as predominant land cover in many urban core areas is attributed to the decay of urban residential housing stock. These circumstances of blight have been accelerated by recent trends in foreclosure, abandonment, and tax-delinquency (Whitaker & Fitzpatrick, 2011). According to the National Vacant Properties Campaign (Smart Growth America, 2005), vacant properties are distinguished by either or both of two general features: that the property is a nuisance or poses a threat to public safety; and the landowner neglects to pay taxes, defaults on the mortgage and utility accounts, and fails to keep the deed free of liens. One outcome of this confluence of economic conditions and land use is an increased number of residential demolitions with a correspondent increase in the proportion of vacant land. Although the literature is consistent in recommending careful analysis of the social, economic, and environmental costs (e.g., disposal of rubble, dispersion of asbestos or heavy metals in dust, reduced soil quality) or societal benefits (e.g., removing blighted properties, public safety) prior to demolition (Bullen & Love, 2010; O'Flaherty, 1993; Power, 2008), there is a trend toward wholesale demolition of blighted residential neighborhoods in cities like Cleveland, OH. From a purely economic standpoint, the oversupply of vacant land can depress the value of these vacant properties (and thereby potential for redevelopment). An alternative, productive reuse of vacant land is needed to arrest devaluation. Land bank agencies have emerged as a critical force in organizing the onslaught of vacant properties and setting the stage for a more coordinated re-use of vacant land toward urban agriculture (Masson-Minock & Stockmann, 2010) and the detention of excess stormwater volume.

Just as private parcels have some capacity to manage stormwater runoff volume with stormwater management retrofits (Keeley, 2007; Mayer et al., 2012), soils in vacant residential lots may also play a role (albeit passive) as an infiltrative sink for stormwater (Shuster et al., 2011; Xiao, McPherson, Simpson, & Ustin, 2007). On a neighborhood scale, stormwater infiltration and redistribution is a potentially significant ecosystem service, and may thereby impart more value to vacant land that presently has little or no value. On a larger scale, stormwater runoff volume that enters combined sewer systems (CSSs) serves to reduce system capacity, which leads to combined sewer overflow events (CSOs). The frequency and volume of combined sewer overflows have increased over the years due to aging infrastructure (cracked conveyances that allow exfiltration, infiltration and inflow), reductions in operation and maintenance budgets that would otherwise control inflow-infiltration issues in the combined system; and that there has been no substantial change in the load on the CSS from increased directly connected impervious area and changing rainfall patterns due to climate change (Semadeni-Davies, Hernebring, Svensson, & Gustafsson, 2008). Enforcement actions aimed at repairing or otherwise reducing CSO frequency and volume have recently begun to incorporate green infrastructure (rain gardens, cisterns, green roofs, urban agriculture, etc.) as a way of keeping stormwater runoff volume out of the existing gray infrastructure (piped conveyances, inlets to CSS, a wastewater treatment plant, off-line storage, etc.). In practice, green infrastructure leverages plant–soil systems and other forms of storage to capture and detain stormwater runoff with an emphasis on the more frequent, smaller-depth storms. Green infrastructure strategies employed in this way may keep stormwater runoff volume out of the CSS, with the potential to thereby reduce CSO frequency and volume.

The substantial amount of vacant land available in these cities offers additional detention capacity for stormwater that would otherwise contribute to CSO events; with soils as the primary storage media. As Xiao et al. (2007) found, when infiltration capacity is exceeded, the production of surface runoff is initiated, and regulated by soil properties. Since there is no longer a residence on vacant lots, there is a great deal of pervious surface area for infiltration and redistribution of soil moisture, though the specifics of these processes may differ among parcels due to the influence of residential demolition processes. Furthermore, the imprinting of anthropogenic disturbance as the primary soil forming factor of vacant lot soils can alter soil properties by inversion of soil horizons, mixing of debris with fill or native soils, sealing, and compaction among other structural changes that affect site hydrology and drainage (Scalenghe & Marsan, 2009). Demolition techniques vary within a range of generally accepted practices that are designed to bring down a structure in a safe, expedient, and effective manner. An unforeseen consequence of these practices is the negative impact that demolition has on soils, which may affect infiltration and drainage patterns in vacant lots (Shuster et al., 2011). There is a dearth of data on urban soils with regard to their role in landscape hydrology, and especially for vacant lot soils, and our study has no known prior precedent. Our main objectives were to assess the soils and hydrology of vacant lots, and use this data to understand how extant conditions and demolition may modulate the suitability of vacant lots as infiltrative, passive green infrastructure. We assessed soil physical and hydrologic characteristics and how they are influenced by different levels of disturbance (as: lower (parcel area with remnant, undisturbed soils), higher (fill areas on vacant lots within the footprint of the structure)); and demolition technique (burying debris on-site versus removing debris); or if both factors influenced vacant lot hydrology. To advance the data to practical scenarios of actual and potential vacant lot hydrologic functions, we synthesized field data and findings in a rainfall-runoff model to quantify runoff volume from a typical vacant lot, and parameters were adjusted to illustrate the implications for redevelopment as green infrastructure, as one approach to decentralized urban stormwater and combined sewer overflow management in an urban core area.

2. Materials and methods

2.1. Site selection and site-level measurements

Soils and extant vegetation for a total of 52 residential vacant lots were assessed for physical, hydrologic, and chemical characteristics. This survey was conducted across the NEORSD service area in 2010 (31 sites; Fig. 1), and then in 2011 focused on a two blocks in the Slavic Village neighborhood (21 sites; Fig. 1). The parcels characterized in 2010 were selected from an overlay (Arc GIS, ver. 10, ESRI Corp. Redlands CA) of maps of vacant, publicly owned residential parcels that were within the boundary of both the corporate limits of the City of Cleveland, and within the drainage areas for relatively low volume (<60 million $l\,yr^{-1}$), high frequency (>5 activations yr^{-1}) Northeast Ohio Regional Sewer District (NEORSD) combined sewer drainages, as in Shuster et al. (2011).

For the greater Cleveland area, there are two distinct eras of standard demolition practice: The pre-1996 demolition technique involved demolishing the residence, bulldozing the entirety of the demolition debris into the basement–foundation, covering the debris with a layer of clean fill soil, and completed with seeding in order to provide permanent stabilization as turf cover. The post-1996 demolition was more extensive and entailed the demolition of the residence, basement, and foundation, removal of all of the resultant debris, backfilling the excavated area with clean fill soil, and seeding in order to provide permanent stabilization as turf cover (see: OAC Chapter 1510:15-1.B(38), http://codes.ohio.gov/oac/1501%3A15-1). In the absence of complete site histories for pre-1996 demolitions, these were distinguished from post-1996 vacant lots by a distinctive slumped fill area in the footprint of the former residence.