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Inventorying Land Availability and Suitability for Community Gardens in Madison, Wisconsin

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Problem: Planners, politicians, organizations, and citizens in many cities recognize community gardens as a vital part of urban food production. To fulfill community or organizational goals, it is helpful to systematically identify and assess urban vacant land that could be used as potential garden sites.

Purpose: The technical purpose of this project was to demonstrate how stakeholder input could be combined with expert opinions and applied to available data to create an inventory of undeveloped land potentially available for community gardens. In the specific context of Madison, WI, it provided information relevant to the city's planning and land use goals.

Methods: We developed a community garden site suitability index based on criteria including size, location, and site conditions. The characteristics of existing community gardens in Madison, WI and the preferences of current gardeners were used to specify suitable value ranges. The multiple step process for identifying criteria and determining acceptable suitability values based on stakeholder input is an advance over similar efforts in other cities that relied primarily on expert judgments. After review and validation by local community garden managers, this framework was applied to publicly available data about undeveloped land, land tenure, land use, and biophysical conditions with a geographic information system. The result was a map and corresponding database of potential parcels or portions of parcels suitable for community gardens.

Results and Conclusions: The GIS-based approach provided a way to combine stakeholder input with expert judgment to create a synoptic inventory of potentially available land for community gardens. This inventory revealed 640 parcels and 1065 acres of potential suitable vacant land parcels for community gardens; this represents about 1.3% of the city land base.

Takeaway for practice: Given the City of Madison's goal of 4% of its land base dedicated to food production, this publicly accessible database is helping move community gardening from a tolerated and temporary activity to a planned long term use of vacant land.

Keywords
community gardens, urban agriculture, land suitability, land inventory

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INTRODUCTION

As issues of food security and food deserts continue to gain traction in both the public policy arena and the academic literature, community gardens (CGs) have been increasingly touted as an integral part of local food production. Feagan (2007: 27) contends that CGs are part of a local food system that is intended to achieve "a more embedded set of relationships between producers and consumers, and the place and provenance of food grown." CGs and other forms of urban agriculture (UA) are increasingly recognized as legitimate parts of regional food policy and land-use plans (Desjardins et al. 2011). The city of Madison, a mid-sized urban area located in south-central Wisconsin, serves as a prime example of this trend, and provides both the geographical context and impetus for this study.

In February 2011, the Madison Common Council ratified a comprehensive sustainability master plan intended to set actionable goals for making the city more ecologically and socially sustainable. Among several focus areas, the plan highlights the promotion and fostering of local food systems as one of its four planning and design goals. In particular, the plan calls for "support[ing] existing community gardens and find[ing] places to establish new ones," with the intention of committing 4% of the city's total land area to some form of UA by 2020 (Fey et al., 2011: 19). While this 4% commitment also includes private back-yard gardens and small-scale market operations, CGs have been and will continue to be a popular and effective component of UA in Madison, due in part to the known multifunctional benefits they confer to both gardeners and the surrounding communities. Moreover, some of these benefits, discussed below, squarely align with some of the sustainability master plan's goals for social and economic well-being, making CGs an elevated priority both as a form of UA and among broader regional food system planning goals. However, despite a recognition that city-owned land must play a part in meeting the master plan's 4% UA goal, the plan does not provide any guidance for how potential garden sites might be identified, or what share of the land base ought to support CGs.

In order to inform the development of additional CGs in Madison — both at the municipal planning level and among a variety of CG advocates — we undertook an effort to systematically identify and assess vacant land parcels within the city that could serve as potential sites for CGs. Two objectives guided the project:

(1) To build a publicly accessible map and database of potential CG sites that meet minimum suitability criteria, in order to better understand the possible contribution of CGs to the city's 4% commitment to UA; and

(2) To make a methodological contribution to the *process* of inventorying vacant land in order to more broadly inform similar efforts in other cities in the future.

This article reports on and critically evaluates the success of these objectives, including their relevance to possible to users, including various city agencies, CG-supporting NGOs, ad hoc garden groups, and neighborhood organizations, both in Madison and in other municipalities. We first provide some background on CGs, including their purported benefits, challenges, and relationship to broader food system planning. We then discuss some of the notable land inventory precedents that informed our own approach, followed by a description of our methods and their results. We finish with a discussion of the strengths and weakness of our approach, and suggest several considerations that would enhance our work, both in Madison and in other cities undertaking similar efforts.

BACKGROUND

CG benefits and challenges in food system planning

Although CGs assume numerous forms and structures across varying urban landscapes, Glover (2003: 191) has defined CGs as "organized initiatives whereby sections of land are used to produce food or flowers in an urban environment for the personal use or collective benefit of their members, who, by virtue of their participation, share certain resources, such as space, tools, and water." A small but growing literature over the last 15 years has sought to identify and, where possible, quantify the multifunctional roles that CGs play in their respective communities. Among other benefits, the sharing of garden space has been shown to increase social capital (Glover et al. 2005; Alaimo et al. 2010) and contribute positively towards neighborhood revitalization, urban renewal and environmental justice (Glover 2003; Ferris et al. 2001; Teig 2009). Shinew et al. (2004) found that CGs are unique spaces that positively promote interracial interaction, while Saldivar-Tanaka and Krasny (2004) describe gardens as places where immigrants can link to their cultural past. Beyond their potential effects on neighborhood and community health, CGs have positive demonstrable impacts on food security (Reid 2009); personal health (Armstrong 2000, Wakefield et al. 2007); nutrition (Litt et al. 2011; Alaimo 2008); quality of life (Twiss et al. 2003); and improved contact with nature (Kingsly et al. 2009). Voicu and Been (2008) showed that CGs have significantly positive impacts on adjacent or nearby property values, which five years after garden installation rose on average 7.4% more than similarly priced properties over 1,000 ft away from that same garden. As Lawson (2004) contends, CGs have also been repeatedly championed by both planners and public officials in the U.S. since at least the 1890s, largely on the claims that CGs would variously constitute: a temporary measure for providing poverty relief; an educational tool for promoting self-sufficiency, work ethics, and civic participation; a bulwark against hunger and unemployment during times of war or economic crises (e.g. Victory Gardens of WWII); and as a way for local governments to enact progressive visions of open space, ecological restoration, and urban renewal.

Despite their numerous contributions to public and individual well-being, the proliferation of CGs has at times produced conflict. Describing CGs on public parkland in Montreal (Quebec, Canada), Bouvier-Daclon and Senecal (2001: 507) described CGs as "socially ambiguous" spaces, where land is considered public, but ultimately used by a limited number of people. Similarly, Schmelzkopf (1995: 380) considers CGs to be "contested spaces," when gardens' perceived use value (to CG advocates and users) conflicts with developers who only consider the land's exchange value. Smith and Kurtz (2003) documented numerous controversies that have arisen in New York City over garden spaces being auctioned off for development. Land use conflicts associated with community gardens can make garden establishment and protection into a political issue. Indeed, in a recent literature review of all English-language peer-reviewed publications on community gardens, Guitart and colleagues (2012) assert that the most frequently cited challenge faced by community gardens is insecure land tenure.

Matters pertaining to land use, access, and tenure would ordinarily seem like issues squarely within the purview of planners. But the relationship between CGs and planners is in fact much more fraught with ambiguity, and as a result CGs are "still relatively marginal within planning institutions—although [they are] becoming less so at a rapid pace" (Thibert 2012: 353).

Speaking broadly of urban agriculture (UA), Thibert (2012: 353) contends that the reasons for this ambiguous relationship vary among planners and locales, but generally include: the perception that UA runs counter to long-held planning notions of a clear delineation between urban/rural and commercial/residential; the fact that UA is not definitively part of any established planning sub-discipline, including sustainability planning (though this is rapidly changing); the traditional, if ebbing, perception among planners that food and food policy is/was beyond their purview, or not something that they felt trained to engage with; and the possibility that some planners are "still not willing to accept that [UA] is a 'valid' approach to urban development." Addressing the historical relationship between planners and CGs specifically, Lawson (2004: 152) describes how planners have variously "encouraged, benignly ignored, or discouraged" CGs. This lack of a coherent stance, Lawson contends, is in part due to the multifunctionality of CGs; they are at once physical sites that provide shared gardening space, but also are, depending on the case, endeavors that promote a variety of social and/or environmental agendas, and may involve both community members and professionals with differing visions for what the garden will accomplish. Furthermore, the lack of a consensus among planners about whether or not CGs constitute a "public good" only complicates the planner's question regarding the degree to which public support (e.g. technical, financial, promotional, or land) should be directed towards CGs. For example, are CGs that are located in public parks or other municipally owned open spaces viewed as communal and accessible spaces, or as places for limited, private gain? Should planning departments consider CGs as a "highest and best use" of vacant land, or merely as temporary placeholders for future development? How should the positive externalities associated with CGs, which vary tremendously and may be difficult to definitively quantify across a given urban extent (e.g. potential personal health benefits, nutritional gains, food security mitigation), be weighed against more readily quantifiable variables like a vacant lot's development potential? Finally, Lawson asserts that the bottom-up, participatory nature of CGs presents a paradox to planners: "To designate a green square on a plan as a 'community garden' embraces the idealism of 'if you build it, they will come' and does not address the control needed by those who are expected to maintain it" (Lawson 2004: 170).

Despite this ambiguity, the policy landscape is changing at the municipal level, presenting planners with opportunities to move towards a more "municipally enabled agriculture" (Condon et al. 2010: 106). Thibert (2012), for example, notes that there were over 150 food policy councils in U.S. cities as of November 2010. Campbell (2004) and de Zeeuw & Dubbeling (2007) both advocate for integrating UA into cities' comprehensive land use plans and amending municipal zoning regulations to more readily permit agricultural uses, efforts that are already under way in numerous cities (e.g. Mukherji 2009, Goldstein et al. 2011, and Neuter et al. 2011). Among other recommendations, Mougeot (2000) suggests that planners ought to support gardening entities in identifying and brokering available vacant land, and ensuring that land's suitability. Echoing this, Thibert (2012) calls for planners to develop inventories of municipally owned land and arrange renewable, multi-year leases with interested community groups. Though a full accounting of the ways in which planners can support CGs is beyond the scope of this article, these last planning recommendations — identifying and classifying vacant urban land suitable for CGs — provide part of the theoretical context for the land inventory case study presented in this article.

Table 1: A comparison of select North American vacant land inventories.

	Land type considered	Data sources	Inventory methods
Portland, OR	Public (parcels owned and considered vacant by bureaus of Environmental Services; Parks and Recreation; Transportation; and Water)	*Municipal:* vacant parcel polygons, impervious surface grid, environmental overlay zones, water mains, street centerlines, sidewalks, parks developed areas, transit *Federal:* FWS wetlands, USGS 10' elevation contours	virtual parcel interpretation with aerial photography; comprehensive ground-truthing; spatial analysis to apply proximity criteria and exclusionary land-use conflicts
Vancouver, BC (Canada)	Public (parcels owned and considered vacant by Vancouver Dept. of Engineering Services; federal Dept. of Public Works)	*Municipal:* vacant parcel addresses, aerial photography via VanMap *Federal:* vacant parcel addresses	virtual parcel interpretation with aerial photography; selective ground-truthing (30 of 77 sites)
Seattle, WA	Public (parcels owned and considered vacant by city of Seattle; also, schools, parks, and public rights-of-way)	Vacant parcel polygons from the City of Seattle Property Management Area Shapefile; aerial photography	geospatial analysis to exclude candidate sites not meeting minimum site selection criteria; virtual parcel interpretation with aerial photography to assess shade, buildings, and surface; spatial analysis to apply proximity criteria
Oakland, CA	Public (vacant or underutilized parcels owned by city of Oakland	Parcel polygons from Alameda County Tax Assessor; 1-m NAIP satellite imagery; 10-m digital elevation model	virtual parcel interpretation to determine vacant or underutilized potentially arable areas; geographically representative ground-truthing (34% of all potential sites)
New York City, NY	Public, private, flat rooftops	*Municipal:* vacant parcel polygons from NYC Dept. of City Planning NGO: community garden polygons from Design Trust for Public Space *Federal:* FWS wetlands	vacant parcels culled from city databases; virtual site inspection for tiny fraction of all allegedly vacant parcels (12% found to be not vacant); no ground-truthing
Madison, WI (this article)	Public (vacant or underutilized parcels owned by city, county, or state), some private land (e.g. churches)	Parcel polygons from city of Madison tax assessor's office; water mains, street centerlines, transit, and average solar exposure grid from city of Madison engineering office	virtual parcel interpretation to verify accuracy of vacant parcel database; spatial and site-specific analysis of existing Madison CGs to determine thresholds for suitability criteria application of criteria to exclude non-suitable parcels; all parcels ground-truthed

Land Inventory Precedents

Researchers and practitioners have compiled several vacant land inventories in a handful of U.S. cities over the last decade (Table 1). Perhaps the most notable precedent is Portland's (OR) Diggable City project, which inventoried vacant land owned by several municipal agencies and preliminarily assessed and categorized each for potential UA suitability (Balmer et al. 2005). The city of Vancouver (British Colombia, Canada) followed a similar methodological strategy in order to "support land use decision making, to serve as a public resource to build awareness, to support the city's existing sustainability commitments, and to contribute to a citywide UA strategy" (Mendes et al. 2008: 443). Vancouver's study also advanced the intention that the inventory would provide a practical resource and impetus for developing a municipal community garden program. McClintock and colleagues (2010; 2013) developed an inventory of public land in Oakland, CA that was either vacant or underutilized (e.g. portions of public parks). Other inventories demonstrate an expanding spectrum in terms of municipal goals, scope of the project, methods, and land suitability criteria. Seattle's inventory sought to identify potential CG sites on publicly owned rights-of-way, school grounds, and parks (Horst 2008). Ackerman (2012) analyzed the UA potential of public and private land and rooftops in New York City. The Cleveland-Cuyahoga Food Policy Council's inventory considered only taxable, nonexempt vacant land parcels, both in the urban core and peri-urban fringe with the intention of influencing the zoning of urban garden districts, and informing ordinances pertaining to farm animal and bees (Taggart et al. 2009). Still other inventories have attempted to map the distribution and productive capacity of urban backyard gardens in both Madison, WI (Smith et al. 2013) and Chicago, IL (Taylor and Lovell 2012), as well as the productive capacity of all possible growing locations in Toronto (Ontario, Canada)(MacRae et al. 2010). The inventory described in this article applied a mix of the core methodological approaches used in the aforementioned inventories, with some notable differences and additions, which we explicitly explore in the discussion section.

METHODS

The creation of an inventory of potential CG sites in Madison included three progressive stages: (1) developing site suitability criteria; (2) virtually identifying and interpreting candidate sites for subsequent analysis; and (3) ground-truthing and analyzing all remaining sites. We developed suitability criteria from three sources, including previous vacant land inventories, analysis of existing community gardens in Madison, and input from both local experts and area community gardeners. Virtual site selection significantly narrowed the number of sites under consideration. Ground-truthing — the process of making in-person site visits in order to validate landscape characteristics that are otherwise interpreted remotely — provided necessary verification of and spatial amendments to parcels inspected during the virtual interpretation phase, as well as an opportunity to reliably account for additional suitability criteria unable to be interpreted remotely.

The coupling of expert-derived criteria with spatial analysis has a well-established track record in land-use planning. Pereira and Duckstein (1993), for example, proposed multi criteria decision making (MCDM) as a valid approach to GIS-based land suitability evaluations, particularly in urban planning. Jeering and Musy (2000) and Joerin and colleagues (2001) applied multi criteria decision analysis (MCDA), a similar evaluative approach. Both MCDM and MCDA have

Table 2: A comparison of site suitability criteria across select North American vacant land inventories.

	Portland	**Vancouver**	**Seattle**	**Oakland**	**New York**	**Madison**
Size	>1,000 ft^2	>653 ft^2 (0.015 ha)	>2,000 ft^2	>500 ft^2	N/A	>2,500 ft^2
Surface	pervious & impervious	attributed on site-by-site basis	pervious & impervious	pervious & impervious	N/A	pervious only
Slope	<10%	<10%	<40%	<30%	N/A	<20%
Water access	water mains within 100’	N/A	N/A	water meter within 10’	N/A	fire hydrants, adjacent houses, water mains
Solar access	allowed full tree canopy coverage	attributed on site-by-site basis	<75% tree canopy cover-age or build-ing shade	excluded all areas shaded by vegetative canopy or buildings	N/A	>8 hrs/day of full sun
Land use conflicts	wetlands, flood plain, zoning re-strictions	attributed on site-by-site basis	streams and wetlands; known future development plans	N/A	wetlands, cemeteries, recreational uses (e.g. baseball field)	identifiable recreational uses, cemeter-ies, develop-ment potential
On-site ve-hicular ac-cess	N/A	N/A	N/A	N/A	N/A	small truck access from adjacent street
Proximity (often used as additional site attrib-utes, not al-ways as ex-clusionary criteria)	within 1/2 mile of bus stop or bike route, and 50’ from a side-walk	attributed on site-by-site basis: access to parking, bike routes, transit, nearby density of potential users	at least one on-site or ad-jacent parking space; within 1/4 mile of bus stop and 50’ of side-walk; school-sand commu-nity garden	within 1/4 mile of bus stop and/or school	N/A	within 1/4 mile of bus stop or bike lane/path

been adapted and applied extensively over the last two decades to help planners answer the spatial question of “what must be done and where should it be realized?” (Joerin et al. 2001: 154). Both approaches use stakeholder input to assign parameters and relative weights to various suitability criteria, which are subsequently applied in a geoprocessing environment to optimize and or rank alternative sites. We should be clear that even though our methodological approach draws upon the stakeholder input and parameterization aspects of MCDM/MCDA, our final inventory does not attempt to rank potential garden sites, instead opting for including all sites that meet minimum suitability criteria. In that sense, our approach is more akin to the ultimate environmental threshold (UET) approach, an adaptation of MCDA that represents “the basis for a ‘plan of the environmental preconditions’ to be adopted during the planning process (Senes and Toccolini 1998: 117).

Identifying Criteria for Evaluating Suitability of Open Space for Community Gardens

Many of the criteria used for CG site selection are generally intuitive and self-evident; considerations such as solar exposure and water availability, for example, are vital for any outdoor garden. Some considerations, such as garden aspect, geographic density, and minimum solar exposure, can be found in the garden design literature (e.g. DeKay 1997, Lawson 2004). However, identifying their relative importance, determining what value ranges are appropriate, and developing procedures for analysis of available data depend on the unique social and biophysical context of a given community. We used three approaches to identify criteria for inclusion in our analysis and justify their inclusion. Selection criteria from published, peer-reviewed land inventories in Oakland, CA and Portland, OR provided initial suitability criteria and procedures for locating vacant land, as well as a basis for comparing what was done in other communities with similar goals. Second, a spatial analysis of Madison community gardens was used to validate and provide upper and lower parameters for criteria in the Madison context. Finally, input from local UA experts and CG managers was used to vet the proposed suitability criteria, and provide insights to ground the criteria in Madison's social and biophysical context.

Initial suitability criteria input came from conversations with contributors to land inventories in Portland and Oakland. Subsequent land inventories have adopted many of the criteria set forth in Portland's and Oaklands, but often use different thresholds for criteria like minimum parcel size or water access. Table 2 presents a comparison of the main site selection criteria and thresholds across some of these inventories. Portland's inventory used one-foot digital orthophotos to preliminarily assess sites, including an assessment of shading, subjective site suitability, water accessibility, size, and surface type (Balmer et al. 2005). Oakland's *Cultivating the Commons* (McClintock and Cooper 2010) employs similar selection criteria, but also includes an assessment of slope, proximity to public transportation and schools, and existing zoning allowances for agriculture. Both inventories, however, consider only public land (McClintock 2010). Vacant land owned by private individuals, entities, or religious or other non-profit institutions was not considered. Our Madison inventory was only able to assess a portion of privately owned land — parcels larger than ordinary residential lots that encompass significant pieces of open land but due to development on a portion of the parcel, are not considered as "vacant" on the tax rolls. That acreage comprises a significant portion of all of the land included in the final database. And while paths to stable, long-term tenure may indeed differ among privately and publicly held parcels, the inclusion of private vacant land represents a valuable and significant departure from inventories in other cities (the exception to this is Ackerman et al. [2012], who considered all land considered vacant by New York City, but only was able to virtually assess a small portion of these parcels — 12% of which either had buildings or were otherwise incompatible with gardening — and did not ground truth any).

To understand how the initial set of criteria would be applied in Madison, twenty-four existing Madison community gardens were evaluated, both virtually with Google Earth and ArcGIS, and with ground-truthing site visits. The following workflow represents the combination of ArcGIS processing and field observations used to create maximum and/or minimum thresholds for various suitability criteria that were subsequently applied to identified vacant and underutilized land.

Parameters such as parcel size and water accessibility were determined from geospatial data, while characteristics such as site access and surface/vegetation were initially observed in the field. The Near tool in ArcGIS was used to determine that the average and maximum distances from a water main to the nearest edge of a community garden parcel. Slope parameters were based on an analysis of the maximum slope present in area community gardens. A 1-meter digital elevation model, clipped to the community gardens layer and analyzed with the Slope tool, indicated slopes in gardens ranging from 0 to 16% across all community gardens. For the sake of inclusivity — and since NRCS soil mapping units contain a 12-20% slope classification category — this inventory includes parcels containing slopes up to 20%. Above this slope, gardeners would need to employ significant erosion-control measures.

In order to further assess the justification for including various suitability criteria, we convened two advisory meetings with seven local UA experts and five CG managers. These individuals were purposively recruited based upon their extensive experience with and knowledge of CGs (and UA more generally) in the Madison area, and collectively represented the following entities: garden-related NGOs, the city's planning and parks departments, the City Council's CG committee, university researchers and cooperative extension employees, and a variety of local UA farms and CGs. Experts vetted the suitability criteria in their entirety, and were influential in encouraging an approach that relied upon identifying as much land as possible based upon minimum suitability criteria rather than attempting to rank and potentially exclude usable land parcels via a complex MCDA model. More specifically, experts provided crucial contextual knowledge about comparative garden development costs (e.g. different water sources), and opportunities and challenges associated with varying land ownership arrangements, solar access, and surface and vegetation types.

As a result of considering previous vacant land inventories, Madison-area CG characteristics, and input from area CG experts, criteria used in this inventory include the following: water access, solar access, size, vehicular accessibility, land-use conflicts, surface vegetation, development potential, and geophysical context (e.g. a grass median in a busy road). All are discussed in greater detail in the next two sections, and comparatively displayed in relation to other land inventories in Table 2.

Potential site identification and interpretation

Parcels of vacant land were initially identified from parcel-based tax assessment data provided by the City of Madison Tax Assessor's office. We considered undeveloped public land including parkland, institutional grounds, storm-water retention areas, public rights-of-way, and transportation corridors. Private land owned by religious institutions and businesses with extensive areas of open space was also included in the inventory, which constitutes a key additional consideration compared to prior inventories. The consideration of private land arose as a result of the analysis of existing Madison-area CGs (see above), in which it was noted that several gardens are located on land owned by either churches or corporations.

Using ArcGIS, an initial total of 3,650 vacant parcels were extracted from the city-wide database of 59,939 parcels and overlaid onto six-inch digital orthophotos. Parcels from this first cut were evaluated by air photo interpretation and excluded from further consideration according to the following criteria:

- if parcel was already developed, implying a misclassification on the part of the city;
- if parcel was owned by a development corporation and located adjacent to other similarly platted lots in what appeared to be a future residential development;
- if parcel was owned by a non-development entity (e.g. a private individual or family) but located within a relatively new subdivision;
- if incompatible land uses were readily identifiable (e.g. cemetery or golf course);
- if parcel was readily identifiable as part of a densely shaded area;
- or if parcel was a median strip in a busy road or a grassed island in a cul-de-sac.

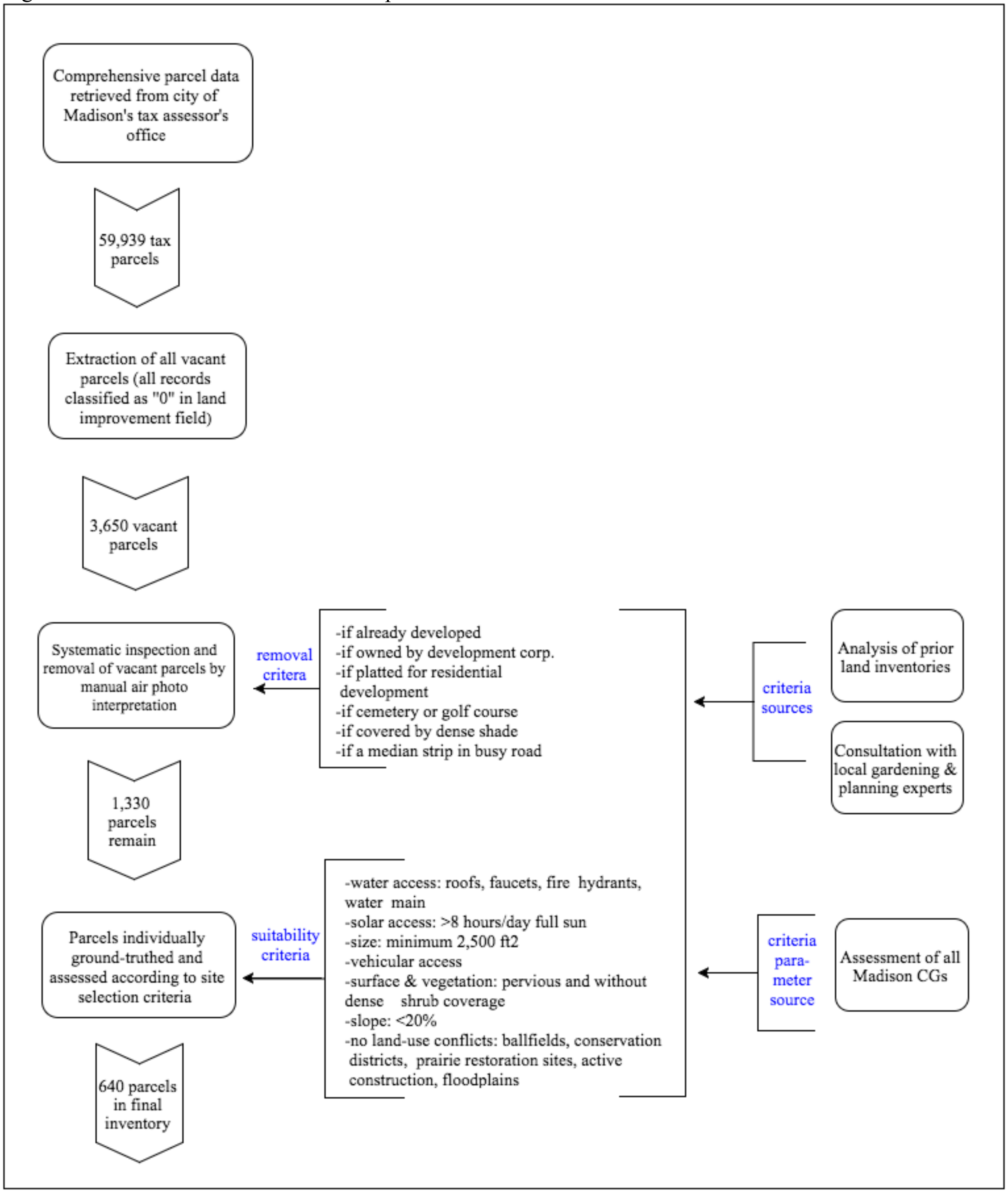
This method of virtually identifying and analyzing vacant land has been applied and validated in previous inventory efforts (e.g. Taylor and Lovell 2012; McClintock et al. 2013), and has proven to be highly accurate, as verified by subsequent ground-truthing. Though both of these studies found the method to be time-consuming, Taylor and Lovell (2012) still assert that automated or semi-automated attempts to remotely sense suitable UA areas, which would include potential CG sites, is difficult and often results in levels of accuracy that are suboptimal, due largely to the high inter- and intra-parcel heterogeneity, as well as shadows from buildings and trees. Virtual interpretation, they note, has additional advantages in that it can be done with free imagery (e.g. Google Earth), and non-experts can contribute, thereby potentially reducing associated costs and making the project more participatory. We would add that our process of virtual interpretation and elimination saved significant time during the subsequent ground-truthing phase, as it pared down by almost two-thirds the original number of parcels the tax data deemed vacant.

Ground-truthing and analysis

Ground-truthing is a common and well-documented strategy employed for verifying the accuracy of remotely sensed or interpreted phenomena, with wide applications found across geographic, planning, and terrestrial and aquatic ecology disciplines. It has proven particularly useful to urban food system researchers, since the urban built environment is both heterogeneous and subject to rapid change, and data sources like aerial photos or tax rolls may be incomplete or not fully up to date (Rossen et al. 2012; Leise et al. 2010; Cummins and Macintyre 2009; Bader et al. 2010). Previous vacant land inventories employed ground-truthing to varying degrees, with researchers often visiting a random subset of inventoried parcels to validate their data sources and virtual interpretation (Mendes et al. 2008; McClintock et al 2013). Other inventories relied only upon secondary data sources (e.g. Horst 2008; Ackerman 2012; Taggart et al. 2009). Though unarguably time-consuming, we chose to ground-truth every site determined to be vacant in the virtual identification phase. In addition to the foregoing justifications, our decision to ground-truth every site was based on the fact that not all suitability criteria could be fully interpreted virtually (e.g. adjacent water sources, vehicular access, potential land-use conflicts) and a desire to make the inventory as thorough and complete as possible.

After eliminating unsuitable parcels during the virtual site identification process, 1,330 of the original 3,650 parcels remained. Of these, 790 were publicly owned and 540 privately owned. Parcels ranged from less than one tenth of an acre to over eighteen acres in size, and averaged just short of two acres per parcel. These were individually ground-truthed, involving an

Figure 1: Overview of CG site selection process



in-person site visit and assessing each according to the following selection criteria:

- Adjacent water sources: Supplemental water access is crucial for successful community gardening. Water was considered accessible if gutter downspouts from on-site or parcel-adjacent building roofs allowed for the development of a rainwater collection system, or faucets from on-site or parcel-adjacent buildings allowed for a stable water-sharing or purchasing arrangement, or fire hydrants that could be tapped and metered were on the parcel or an adjacent parcel.
- Solar access: Root and fruiting vegetables require full sun -- often defined as eight hours of direct sun exposure at the height of the growing season -- in order to reach maturity. Though leafy greens can tolerate less light exposure, nine of the ten most popularly grown vegetables in American gardens require full sun (Butterfield 2009). Sun exposure was visually estimated during site visits by hand-digitizing tree canopy and other obstructions onto orthophoto printouts of each parcel. These initial edits were improved by a subsequent overlay of the City Sustainability Office's Solar Radiation map, which uses LiDAR data to determine average daily solar exposure for any point in the city. When clipped to the vacant parcel boundaries, this raster dataset was able to consistently demarcate areas of parcels *not* receiving minimum sunlight exposure, which were excluded from the inventory. After making edits in ArcMap, parcels not containing 2,500 contiguous square feet of ground with full light exposure were excluded.
- Size: Parcels smaller than 2,500 ft^2 (232 m^2) were automatically excluded from the inventory, since the fixed and marginal upfront costs associated with garden establishment are difficult to justify for spaces much smaller than this threshold.
- Vehicular access: Most disturbed urban soils are either contaminated, compacted, or lack indigenous fertility sufficient for robust plant growth, thus necessitating off-site amendments in the form of topsoil or compost. Truck accessibility is therefore crucial during garden establishment, as well as for ongoing maintenance, including plant waste removal and the addition of soil amendments. A parcel was considered to be vehicle-accessible if a path, roadway, or public right-of-way (wide enough for a small pickup truck) was readily identifiable between a public street and the portion of a parcel that could be gardened, or that portion was adjacent to a street.
- Surface & vegetation: The soil permeability and type of vegetation present on a given parcel are both basic indicators of the investment necessary for installing a garden. Parcels with extensive pavement, impervious materials, or highly compacted soils will likely incur significant costs associated with either breaking up and/or removing those materials. Likewise, lots containing dense shrubs, small trees, or tall weeds/grasses will also require greater monetary and time outlays than a similarly sized parcel with a pervious, cleared surface. Parcels were attributed (but not excluded) in the final database according to the following surface types, ordered from most to least hospitable: mowed grass, unmowed grass, gravel and/or partially paved, perennial weeds and shrubs.
- Land-use conflicts: Parcels were either flagged or excluded according to observed or anticipated land-use conflicts. City-owned parkland was flagged -- but not excluded -- along with parcels contiguous to active railroad lines. A 15' buffer was applied to bike path centerlines in order to accommodate minimum safety and mowing guidelines. Land comprising conservation parks, prairie restoration sites, wetlands, or densely forested natural habitats was excluded, along with parcels exhibiting active construction or a for-sale sign, indicating a high likelihood

of future development. Portions or the entirety of parcels characterized by steep slopes or a high likelihood of flooding, defined as all contoured areas within four vertical feet of a perennial or intermittent waterway, were also excluded, along with golf courses, cemeteries, and parking lots.

All candidate site polygons were compiled and edited in ArcMap 10.1, and joined to an attribute table displaying additional characteristics (e.g. surface vegetation, water access options) for each site.

RESULTS

Land Inventory

Based on criteria outlined above, we identified 640 parcels for inclusion in the current inventory, totaling 1,065 acres (650 ha). All 640 parcels were reviewed and verified as potentially suitable by site visit. This represents 1.3% of Madison's current land base (Figure 2). An electronic map depicting the size and geographic distribution of vacant parcels in this inventory is publicly available via ArcGIS Online at the following address: http://arcg.is/1CpcKqa

Parcels range in size from 2,500 ft^2 (232 m^2) to over eighteen acres (7.3 ha) and average 1.8 acres (0.73 ha) per parcel. Among the different ownership classifications, average parcel size ranges from 0.7 acres/parcel (0.3 ha) among land owned by homeowners associations, to 2.2 acres/parcel (0.9 ha) among land owned by Dane County. Publicly owned land comprises 715 acres (289 ha), just over 67% of the total and 383 of the 640 unique parcels. At 387 acres (157 ha), city parkland makes up the largest share of public parcels. Land owned by the city's engineering department ("City other" in Figure 2, below) represents the second largest share of public land, and includes parcels managed by that department's Stormwater Utility, Streets, Water Utilty, Sewage, and Walkways & Bike-paths divisions.

Privately owned land makes up just under one third of the total acreage in the inventory, and is predominantly comprised of land owned by businesses, faith-based organizations, and homeowners associations. Non-profit organizations and a varied assortment of individuals, estates, and trusts make up a much smaller but still significant share of the total private land base. The inclusion of privately owned land in this inventory represents a significant departure from similar inventories in other cities, which tend to focus on public parks and rights-of-way as the most readily available and tenure-secure sources of vacant land.

Figure 2. Distribution of vacant land according to total parcels and acres within various ownership classifications.

DISCUSSION

Full appreciation and utilization of this inventory is predicated upon an understanding of the assumption that, since establishing community gardens is an inherently political and social endeavor, this report makes no recommendations for where gardens should be located. Rather, this inventory represents a first attempt to systematically collect and organize information about vacant land within Madison that could be used for CGs. As Taylor and Lovell (2012: 58) point out, mapping of existing or potential food production sites can help food system stakeholders "identify gaps in the spatial distribution of sites — where urban agriculture is not occurring but possibly should be because of poverty, lack of food access, or public health problems." Ultimate site selection will depend upon a satisfactory confluence of garden demand, biophysical conditions, financial resources, land tenure, and support from the surrounding community. In this section we first review the strengths and limitations of our methodological approach, including its advances upon prior land inventory projects and possible applications in other cities. We then suggest additional considerations that would enhance both this and future inventories,

Strengths and limitations

As described earlier and illustrated in Tables 1 and 2, this projects draws upon and extends the work of others who have published similar work in the growing land inventory literature. Specifically, one notable advance we offer is the calibration and validation of site suitability criteria by way of assessing the characteristics of Madison's existing CGs. In other inventories, expert-derived thresholds for criteria like size, slope, and water access provide a useful starting point, but can be somewhat arbitrary (e.g. suspiciously round numbers like a 5,000 ft^2 size minimum) and bereft of consensus, both among contributing experts and across projects in the inventory literature. In our case, after considering local gardens' spatial characteristics, thresholds for size, slope, and water accessibility criteria were expanded to capture a wider set of potential sites. Other advances this project makes relative to other inventories include the following: the consideration of private land, particularly parcels owned by religious institutions; a systematic approach to identifying underutilized open space in places like public parks, as discussed below in the section "Consideration 2: CGs in underutilized open space" (though it should be noted that McClintock and Cooper 2010 tested a similar approach); comprehensive ground-truthing; and the use of LiDAR data to systematically assess solar access.

While the site selection criteria as presented in this article are calibrated to the context of Madison, the approach is adaptable and applicable to other urban environments. Issues like water access, solar availability, accessibility, surface and soil conditions, and tenure are central to successful CGs in any location. Creating parameters to represent relevant criteria, in addition to characteristics like size and proximity to transportation routes, is where the vagaries of a certain city will influence the particularities of the methods. Such flexibility is the key to ensuring that the suitability criteria adequately responds to the priorities and motivations of the individuals and groups on the ground; finding workable sites that meet their needs and specifications is ultimately what matters most, as argued by many authors (e.g. Lawson 2004; Colasanti et al. 2013; Thibert 2012).

The particularities of the site selection process will vary from one city to another, as the inclusion and parameters of specific criteria depend on the social and geographic context of any given place. Cities in more arid climates, for example, might more explicitly prioritize water access in general, and specifically rule out the possible contribution from rainwater collection. Other criteria like the requirement of pervious surfaces could be expanded in other locales if sufficient funds were consistently available to meet the higher infrastructural costs associated with raised-bed gardening and/or site remediation. Still other criteria — particularly a parcel's proximity to various transportation options, schools, or certain neighborhood demographics — will likely vary even within a city, and ultimately depend on the specific needs and interests of stakeholders involved in the establishment of actual gardens. But the means of validating a site-selection process — including the analysis of previous inventories, assessing the spatial characteristics of existing and functional community gardens in the area, and surveying the priorities and perceptions of a subset of community gardeners — are widely applicable, regardless of urban context.

Our site selection process could be improved, however, by a more synoptic view of open land. Land initially included in the Madison inventory was identified using tax assessment data, so only parcels coded as "unimproved land" were flagged initially for further assessment. In the process of ground-truthing, eighteen additional vacant parcels were identified and assessed according to this study's site-selection criteria, but that process was incidental and by no means systematic. Identification of these underutilized parcels occurred haphazardly in the field, often as a result of these parcels' adjacency or close proximity to parcels ideintified as vacant in the tax assessment data. Many corporate and industrial entities own vacant or rarely used land beyond their immediate building(s) and are not readily viewed from streets. For example, employees from a major insurance company headquartered in Madison recently negotiated for the establishment of a half-acre CG in the middle of the company's campus (Feyan 2011, personal communication). Developing a tool for systematically identifying vacant land within these otherwise-developed parcels seems like a logical next step, as this category of land represents a potentially significant untapped resource. For example, using city-wide street and building footprint data, combined with systematic virtual interpretation of an entire urban extent — following the protocols tested by Taylor and Lovell (2012) — could help locate additional vacant or underutilized land. So, too, could building a database that collected crowd-sourced, on-the-ground observations of vacant land. Though the expansion of CGs onto private land may encounter different constraints relative to public land — in terms of lease negotiation, potential liability requirements, and the acceptability of people not affiliated with the institution using the land — we believe that private land has great potential, and ought to receive more systematic consideration in the innovatory literature going forward.

In terms of limitations, conducting a land inventory elsewhere by these methods will likely require significant time investments, though collaboration among some combination of universities, public agencies, and community organizations can mitigate the investment made by any single entity. Ground-truthing and virtually assessing vacant parcels constitute a significant time commitment in comparison to data processing and mapping, which are relatively straightforward and expeditious steps and can be completed with basic GIS skills. For this project, ground-truthing covered between five and twelve parcels per hour. Geospatial data necessary for an inventory such as this one are quite likely to be maintained and made available at no cost by public agencies.

Additional analyses and site-selection considerations

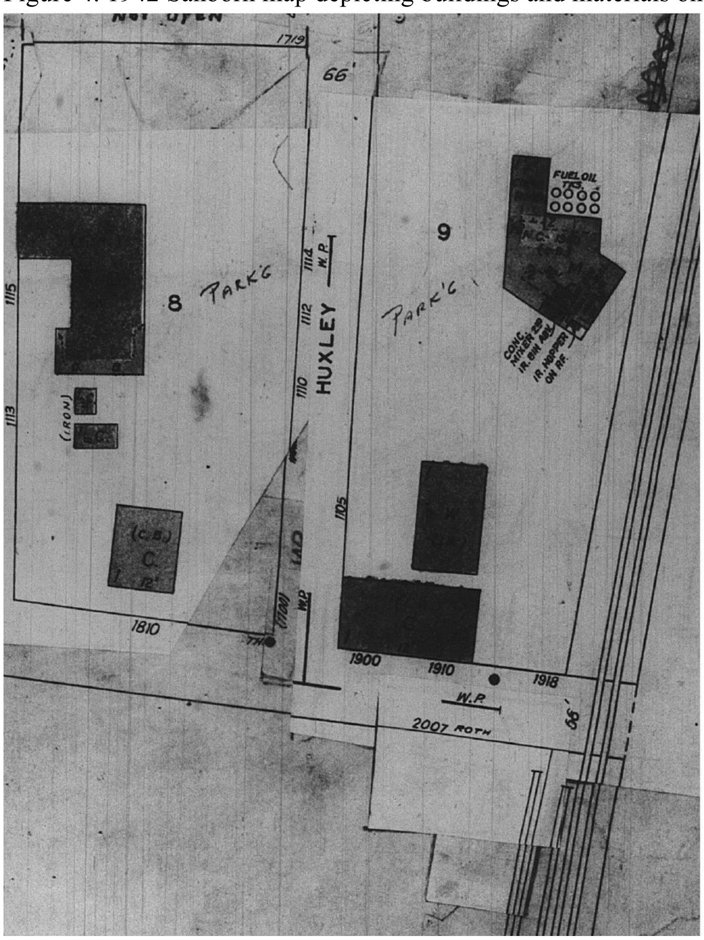
Additional steps, including both site-specific considerations and generalizable analyses, are necessary for refining parcels sites identified in this inventory into shovel-ready sites. These include, but are not limited to the following, which are discussed in greater detail below: (1) soil analyses, for nutrients, texture, and potential contamination; (2) a possible approach for identifying underutilized land potential suitable for CGs; and (3) implications of including gardener preferences into CG-siting criteria.

Consideration 1: soil analyses

Testing urban soils for heavy metals, PAHs, PCBs, and other volatile organic compounds is a necessary precursor to the safe establishment of a garden site in urban areas. Since contamination tests for a single site can easily cost hundreds of dollars, contaminant testing is often preceded by a site history analysis. Deemed a "Phase 1" soil test by the U.S. Environmental Protection Agency, site history analyses attempt to predict both the presence and approximate location of contamination. We compared several of the potential CG sites in our inventory with digitized Sanborn insurance risk maps, first drawn up for municipalities in an effort to determine the fire insurance liability of urban buildings, and date back to the 19th century in some parts of the city. Figure 3 shows a side-by-side orthophoto comparison of 1910-1938 Roth Street on Madison's north-east side. While the site is currently vacant -- as depicted by the most recent orthophoto on the right — it had various buildings on-site as recently as the 2006 orthophoto. A Sanborn map from 1942 (Figure 4) shows various buildings belonging to the C.E. & P.A. Roth Coal & Fuel Company. The building in the northwestern quadrant of the parcel was a concrete block factory

Figure 3. Aerial photographs of 1910-1938 Roth St from 2006 (left) and 2011 (right)

Figure 4. 1942 Sanborn map depicting buildings and materials on the site of 1910-1938 Roth St



comprised of a concrete floor, wood trusses, and hollow cement blocks. Several 30’-tall concrete tanks, which contained coal, abutted the northern edge of the building. The map also depicts two metal-clad storage tanks to the east of the concrete block factory, along with a metal-clad pump house and six fuel-oil tanks. Finally, the map shows a tiled storage tank and, in the southernmost portion of the parcel, a brick-veneered office building and three large areas designated for storing piles of coal and building materials. Soil testing should, accordingly, be concentrated to the areas of the parcel where these structures once stood, and would need to include testing for volatile organic compounds because of historical land uses, in addition to ubiquitous urban contaminants.

Consideration 2: CGs in underutilized open space

Though several underutilized parcels not already classified as vacant were identified incidentally in the field (as noted in the previous section), the majority of underutilized open space included in our final inventory consisted of public land classified on the tax rolls as vacant, but primarily existing for recreational or educational purposes (e.g. parks and schools). Several researchers have suggested that many of these areas contain underutilized open space – such as fringe areas in schoolyards and public parks – that are suitable for CGs (e.g. Middle et at. 2014; Freestone and Nichols 2004; McClintock et al. 2013). Indeed, five CGs in the city of Madison are located in public parks, and the city is amenable to following this precedent with others. To our knowledge, only McClintock et al. (2013) and Horst (2008) have attempted to include such underutilized sites in existing vacant land inventories, though the methods for systematically doing so are not well specified. Figures 5, 6, and 7 depict an example of the process of refining parkland in this inventory with park master plans, incorporating the principles laid out above. Figure 5 shows a digital orthophoto of Rennebohm Park, located on Madison’s west side, overlaid by a master plan depicting current and projected uses.

Figure 5. Orthophoto of Rennebohm Park overlaid by a Parks Dept master plan.

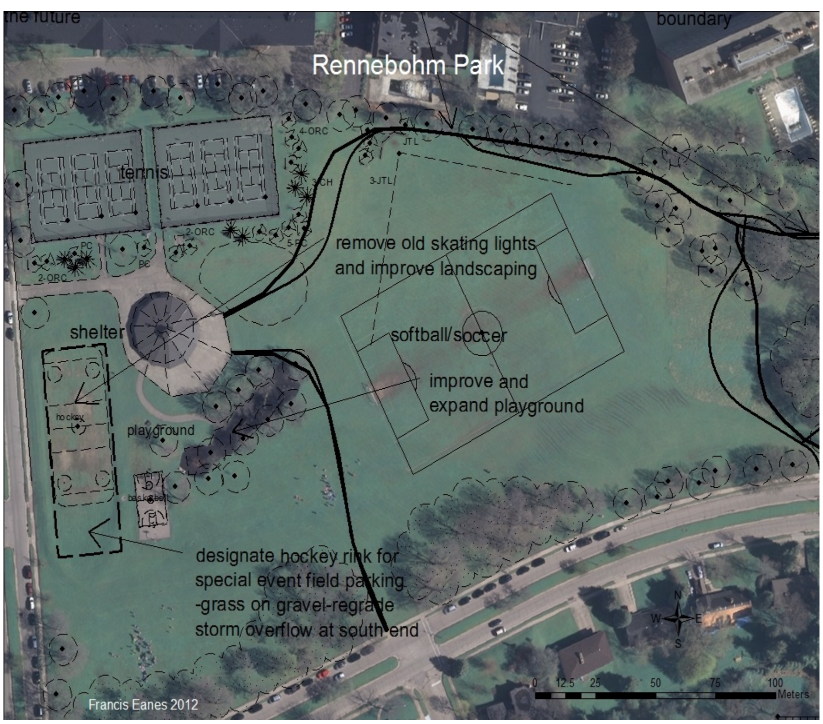


Figure 6. Rennebohm Park and master plan, overlaid with sites deemed suitable for community gardening

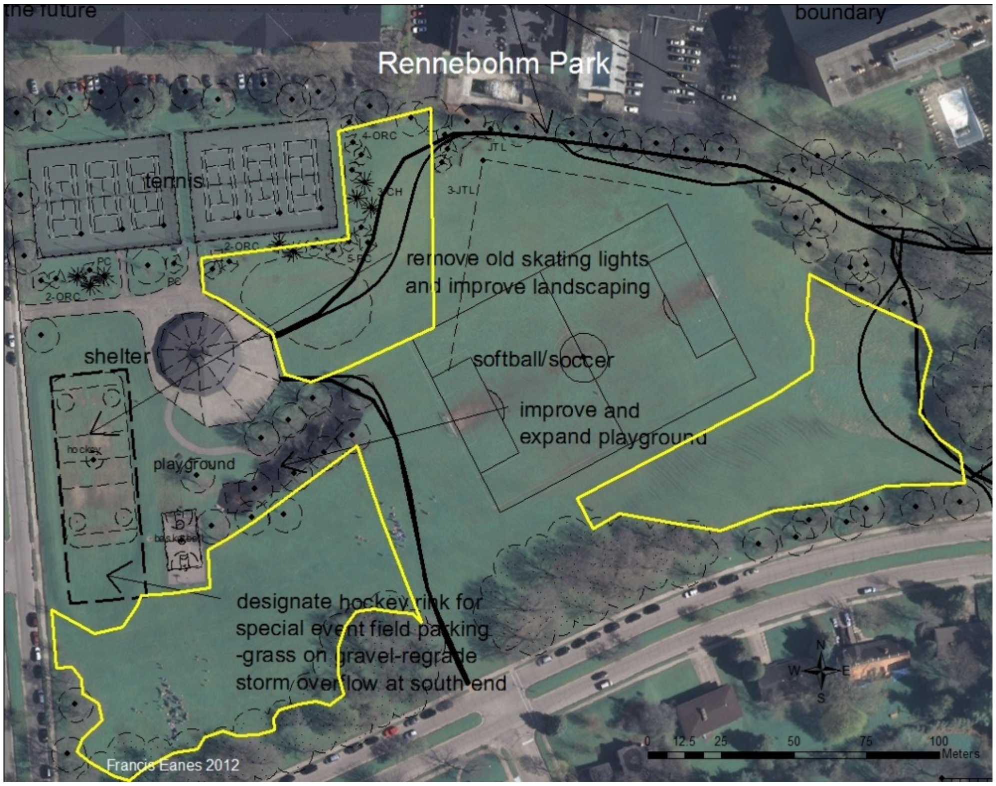


Figure 7. Potential garden site locations, scrubbed to meet siting restrictions and existing land-use conflicts.

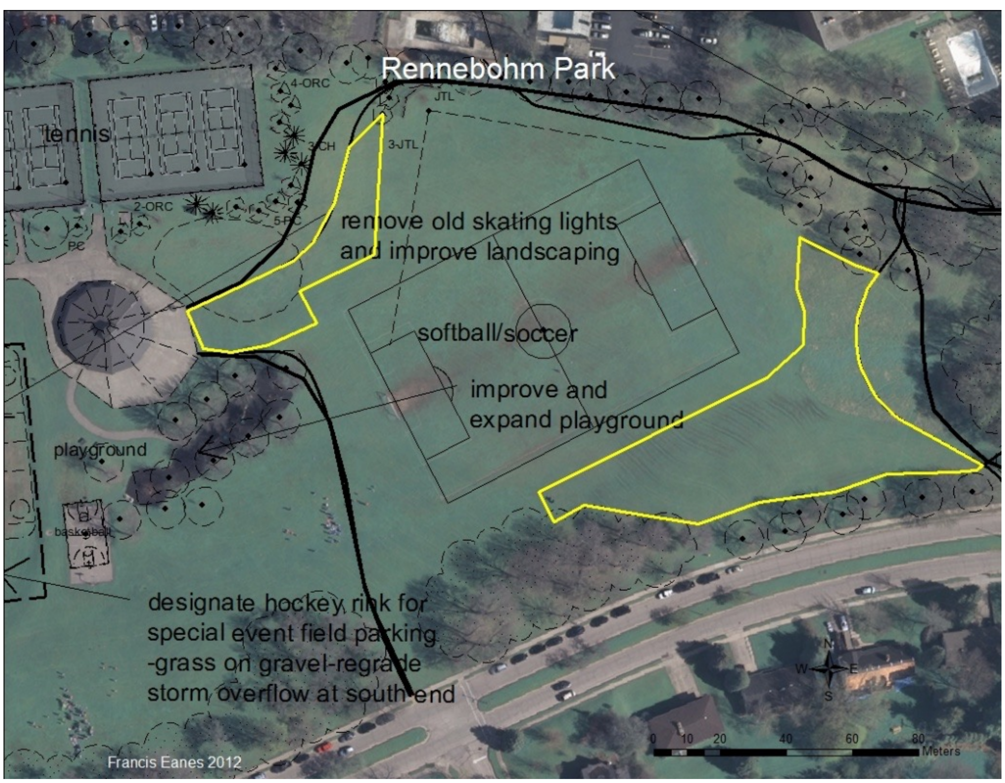


Figure 6 adds three boundaries of land parcels deemed suitable for community gardening after an initial ground-truthing analysis. Figure 7 is the result of scrubbing the original garden site polygons according to a network of proposed paths delineated in the master plan. Additionally, the potential garden site located in the park's southwestern quadrant (in Figure 6) has been removed in Figure 7, since in subsequent conversations with the Parks Department, the site was identified as a location for regular open-air community concerts in the summer. This example illustrates the limitations of reconciling the differences between this inventory and parks master plans with a simple overlay; while doing so provides a consistent first-cut of usable space, only further conversations with knowledgeable staff can reliably identify all competing claims on the available land. Based on initial conversations with city parks staff, though, general principles we established for siting gardens in parks included:

- a 30 ft (9 m) minimum buffer around playing fields, including the construction of a short barrier fence (though if space allows, a 50 ft fenceless buffer is preferable);
- an arrangement such that planned or existing paths do not cut through potential garden spaces
- a title search by the city attorney's office for deed restrictions that might preclude the establishment of a garden, since gardens are considered to be an "exclusive use";
- a preliminary check with the Parks Department to determine whether the proposed space hosts regularly programmed events that, due to their intermittent or permitted use, do not show up on a master plan (e.g., areas used for outdoor summer concerts, or areas used in the winter for sledding);
- a call to the Digger's Hotline in order to check for buried utilities that may or may not be accurately portrayed by existing utility maps or plan maps.

We would like to note, however, that these guidelines have yet not been validated. They do, however, constitute a starting point for site-specific conversations. In addition to these technical considerations, which will likely vary among municipalities, such a conversation should thoughtfully explore the degree to which CGs constitute a public good and an exclusive/inclusive land use (Lawson 2004).

Consideration 3: spatially integrating gardener preferences

Near the outset of the project we conducted a survey of area community gardeners, with the intention of using their preferences to help generate spatial criteria — such as CG proximity to various transit options and CG visibility, for example — that could be used to build a site-ranking or -optimization model, as described by Joerin et al. (2001) and Pereira and Duckstein (1993). However, three issues complicated our effort in doing so, and ultimately led us to develop an inventory that simply included all sites that met minimum selection criteria (as described above). First, we received an unacceptably low number of responses from half of the ten CGs sampled. (Respondents were recruited to take a written survey using the intercept method during regular CG workdays; though individual gardens' response rates ranged from 25% to 62%, and a total of 200 surveys were completed, low workday attendance at five of ten gardens resulted in three or fewer responses from those gardens.) Second, the survey instrument did not ask for the location of gardeners' place of residence, preventing us from making any sort of gardener-to-CG clustering analysis. Both of these limitations made it statistically dubious to make spatial inferences about the association between respondents' preferences and optimum CG spatial characteristics for the whole city. These, however, could be overcome by more intensive outreach efforts to increase survey response rates, and by adding greater detail to the survey instrument itself.

The third complicating factor arose from the results of the survey itself, which were at times conflicting and inconclusive. Some gardeners, for example, reported a preference for a more secluded garden location in order to lessen the perceived likelihood of food theft from pedestrian passersby. A similar share of respondents, however, reported a preference for garden visibility, in part to reduce the incidence of food theft. Similar inconclusiveness emerged over the issues of access to public transportation. Thirty-eight percent of respondents reported primarily accessing their CG by car, followed by those who regularly bike (31%), walk (27%), and take the bus (4%). Should we then assume that bike-and car-accessibility ought to eclipse bus accessibility when ranking potential CG sites? Or should a potential CG site that is located on a high-traffic street, which may not be bike-friendly to all gardeners, be excluded or down-ranked in a final inventory? We think not.

The inconclusiveness of the survey effort may call into question its methodological usefulness, but we argue that it can and ought to play a role in the refinement of a vacant land inventory. Validly translating gardener preference data — even from a well-constructed survey instrument — into an outranking or site optimization model for an entire urban area may prove difficult, such an approach could be useful in a smaller geographic extent. For example, future research could investigate the possibility of using block-level survey data from potential community gardeners to inform the ranking of three or four sites clustered within the same neighborhood. Alternatively, gardener preference data could be used to generate and display "what if" distributions of potential CGs based on different weighting of preferences. Ultimately, as Colasanti et al. (2013) point out, planners must recognize that urban residents and CG practitioners and advocates hold a wide variety of goals, visions, and assumptions about CGs, some of which directly impact the location, configuration, and permanency of potential garden endeavors. Incorporating these diverse views through site-specific surveys and design considerations, as opposed to treating CGs as uniformly undifferentiated goods, is something that is essential for ensuring the long-term viability of gardening in the city. Such perceptual and site-by-site variability, we felt, justified our methodological decision to include as many potential CG sites in the final inventory without attempting to rank them.

CONCLUSIONS

Our multi-pronged approach was helpful for developing a site-selection process that was both thorough and robust. Input from developers of existing land inventories was particularly instructive for developing the initial framework of the inventory, such as data sources, baseline criteria, and data processing operations. The consideration of privately owned land, comprehensive ground-truthing of candidate sites, and the inclusion of accessibility, solar access, and land-use conflicts as selection criteria all represent improvements upon previous inventories. The geospatial analysis of existing community gardens in Madison proved to be the most effective means of imposing upper and lower bounds on the site selection criteria such as sunlight, water access, slope, and size. This refinement and validation process was the key to making the existing land inventory as relevant to the Madison context as possible. Finally, even though the survey of Madison area community gardeners did not lead to the site-ranking model that we initially envisioned, it did provide some helpful input to general garden siting guidelines. Though the survey data did not directly impact the systematic inclusion or exclusion of parcels, the process of recruiting survey respondents helped to build awareness of the inventory project, and has lead to subsequent conversations at the municipal level about gardeners' needs and preferences. A more robust survey, including a greater number of respondents from some of the smaller gardens, would be necessary in order to statistically correlate response trends with the spatial characteristics of those respondents' gardens.

Taken collectively, our methodology constitutes an adaptable and coherent approach to the garden-siting process. Variability among municipal goals, researcher/labor capacity, and physical characteristics will undoubtedly result in inventorying approaches that differ from city to city. To date, vacant land inventories have arisen out of formal commitments to UA or CGs on the part of individual cities. A formal commitment notwithstanding, cities may still find utility in assessing their vacant land resources. Rust Belt cities like Dayton, OH or Detroit, MI have vast amounts of vacant land on their tax rolls, parcels which they come to manage as a result of abandonment, foreclosures, and existing tax liens (Pagano & Bowman, 2000). With development pressure in these areas relatively low, a land inventory may provide a helpful starting point for divesting properties and making them available for CGs or some other form of UA, which in turn could result in benefits beyond food production such as neighborhood revitalization, job creation, and crime deterrence.

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