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Spatial contagion: Gardening along the street in residential neighborhoods

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ABSTRACT

Urban nature, including residential gardens, can promote biodiversity and increase human wellbeing. Understanding factors that encourage the spread of gardening within cities may help planners facilitate healthier and more biodiverse urban communities. This study characterizes the spatial distribution and attributes of gardens found in easement areas of Ann Arbor, Michigan. Spatial analyses of these privately managed public spaces provide evidence of clustering for both presence of gardens and their esthetic quality. Data collected on the location and attributes of easements from 22,562 properties during summer of 2009, show that 11% of these properties held an easement garden. Results of multiple spatial analyses, each targeting a different aspect of garden distribution, show that (a) the most intense easement garden clustering occurs among neighbors with direct visual access to nearest neighbors' easement areas; (b) it is 2.4 times as likely that a property holds an easement garden if a property within 30 m holds one; (c) although clustering is measureable for all neighborhood sizes up to 610 m from home, peak clustering happens within 91 m of home; and (d) clustering of easement gardens are clustered in terms of quality (appeal), and greatest clustering occurs between pairs of adjacent neighbors. While larger scale factors may play a role in where a garden cluster is initiated, the dominant occurrence of relatively small cluster sizes indicates that social contagion is in play. The potential value of social contagion is discussed as a mechanism for spread sustainable behaviors that support ecological resilience in urban areas.

1. Introduction

Residential gardens make up a significant portion of urban green space (Gill et al., 2008; Goddard, Benton, & Dougill, 2010; Mathieu, Freeman, & Aryal, 2007) and are considered important for conservation (Doody, Sullivan, Meurk, Stewart, & Perkins, 2010) and healthy urban ecosystem function (Sperling & Lortie, 2010). As designed and managed components of the urban environment, residential gardens are increasingly seen as important in urban conservation efforts (Gaston, Warren, Thompson, & Smith, 2005; Loram, Warren, & Gaston, 2008), and the collective impact of privately managed gardens across urban space is known to support urban biodiversity (Aurora, Simpson, Small, & Bender, 2009; Lortie & Sperling, 2008; Rudd, Vala, & Schaefer, 2002). Moreover, the presence of gardens and the act of gardening both support human health and well being (Gross & Lane, 2007; Maller, Townsend, Pryor, Brown, & St Leger, 2006), neighborhood identity, and community cohesion (Comstock et al., 2010; Kurtz, 2001).

Understanding the factors that encourage the spread of gardening within cities may help planners facilitate healthier and more biodiverse urban communities. Previous work has established that the form and content of urban gardens are influenced by those of close neighbors (Zmyslony & Gagnon, 1998, 2000), and homeowner preferences are influenced by local style (Nassauer, Wang, & Dayrell, 2009) and the ecology of prestige (Grove et al., 2006). Here, we report spatial clustering in the occurrence and esthetic quality of easement gardens at multiple spatial scales within a city. An easement garden is a privately installed garden within the property's easement area, the street-side space that is owned and regulated by local government.

During an evaluation of urban forest quality in Ann Arbor, Michigan (Hunter, 2011a), we observed a high and clumped occurrence of easement gardens. The clustering seemed to occur in small patches within an array of neighborhood types from those with modest to expensive homes. The presence of these gardens in so many types of neighborhoods is notable in that adjoining property owners choose to put time and money into creating gardens on public land, even while their own front yard offers more space and control for gardening. Additionally, easement areas are susceptible to disturbance from roadwork, winter snow and salt, increased urban pollution, and the unpredictable need for underground utility access. Although adjoining property owners do not own the easement area, they are often required by ordinance to install or maintain some type of ground cover on this public land to control soil erosion in residential areas. Turf grass is the dominant choice

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and the reason for colloquial synonyms like lawn extension (US) and (grass) verge (UK and NZ).

Like many other places, the City of Ann Arbor has an ordinance governing plantings in the easement area. It states that adjacent owners are responsible for grading, planting, mowing and raking the extension. The grass cannot be above 12 inches in height while other ground cover vegetation must have an average height not in excess of 36 inches above the adjacent road surface. This prescription ensures a safe line of sight for pedestrians and drivers. The ordinance is enforced by ticketing (http://library2.municode.com/mcc/DocView/11782/1/46).

Our initial observations of apparent spatial clustering of easement gardens led us to quantify the pattern of spatial distribution. Spatial clustering, the occurrence of easement gardens in proximity of other easement gardens, was assessed over a range of spatial scales to address the possibility that clustering has a component of social contagion. We define social contagion as a form of social facilitation that yields a spatially clustered outcome. The social facilitation may be the result of imitation, competition, status, advocacy, etc. This study does not address the multi-faceted nature of social contagion, only the possibility of its presence.

We tested the hypotheses that (a) easement (=street-side) gardens are spatially clustered within the city, (b) the extent of easement garden spatial clustering can be defined explicitly, and (c) those gardens with appeal are themselves clustered. The extent of this study moves well beyond the magnitudes of existing studies about the role of private gardens in the quality of urban greenspace, with personal visitation to over 20,000 properties, including all properties citywide except institutional and governmental lands. Our results about the pattern of easement garden clustering and the scale of clustering are used to consider the potential impact of the social contagion for garden installation on urban ecosystem health in light of published research findings. This research adds to existing knowledge about the presence and attributes of gardens in public view. It also adds to the discussion of fast and affordable ways to amplify the culture of sustainability behavior in urban areas.

2. Methods

We surveyed all private properties within the city limits of Ann Arbor ($n = 22{,}562$) for the presence and attributes of easement gardens ($n = 2562$). Because some of the garden traits assessed had a subjective component, the streets were scouted by the same pair of researchers working together on foot or by bicycle, and occasionally, by car. To ensure continuity in interpretation of assessment criteria over time, we used an iterative process of conducting solo assessments, comparing the results, discussing the reasons for discrepancies to better define internal criteria, and re-testing until a common ground was established. When an easement garden was encountered, it was identified by street address, photographed (portrait orientation), and evaluated for the characteristics described in Table 1. The location of each easement garden was geocoded by street address over the property parcel layer of a GIS database generously provided by the City of Ann Arbor. Data on garden characteristics were entered on the attribute table for each property. A photograph of each property with an easement garden was attached by address so that rollover viewing on the GIS map was possible.

2.1. Variable definition and scoring

Attributes of easement gardens were recorded in the field using criteria described in Table 1.

An easement was delimited by property boundaries, estimated by typical human markers of property management such as lawn maintenance habits or property line plantings. An easement garden was delimited by the space which held non-lawn plantings and/or other garden design elements such as ornamental rock. Gardened area was estimated by visual evaluation of the proportional contribution of gardened area to the total easement. The protocol described in Figs. 1 and 2 applies to all easement conformations except one: when a gardened area occurred as a narrow collar around the base of a street tree, its contribution was valued at 5%. The proportional measures of gardened area were subsequently translated to square meters after measuring the length and width (minus driveways) of the easement area from aerial photos found at the Bing website (www.bing.com/maps/).

The most subjective measurement was esthetic appeal. To maximize continuity, methods development included an initial assignment of esthetic value for 100 gardens using a Likert scale ranging from 1 to 5, where 1 was" very poor appearance" and 5 was "outstanding appearance." The basis for a ranking was discussed among lab members after viewing photos of the gardens. This helped the pair of field workers objectify components of their esthetic response. In general, the ratings were based on a gestalt perception of visual engagement, care, and health. The initial 100 gardens were re-scored after the intuitive criteria were articulated and shared. Thereafter, the same two field workers provided all appeal ratings.

Table 1
Field measured attributes of easement gardens.

Gardened area – given as a proportion of the easement; see Figure A
Spatial arrangement – position of gardened area within the easement; see Figure B
Sidewalk – present or not
Extension – a gardened area flanking other side of sidewalk, similar in style of easement garden
Weedy – weeds are readily seen in the easement garden (yes/no)
Appeal: visual impact rating: 1 = very poor 2 = poor, 3 = average, 4 = good, 5 = outstanding
Garden content:
Ornamental grass – proportion of garden with non-turf grass species
Herbaceous plants – proportion of garden with flowering perennials and annuals
Shrubs – proportion of garden with woody bush species
Shrub type: C = coniferous, D = deciduous, CD = both types present
Vegetables – proportion of garden with fruits, vegetables, or herbs
Ground fill: M = mulch; R = rock, M + R = mulch + rock
Ornamentation: 0 = none; 1= one ornament; 2 = more than one but not as extensive as 3; 3 = impressive display with lots of owner effort
Border: presence of garden perimeter markings; Y/N; materials (noted) included brick, fence, plastic, rock, and wood
Street tree number – number of street trees in easement area

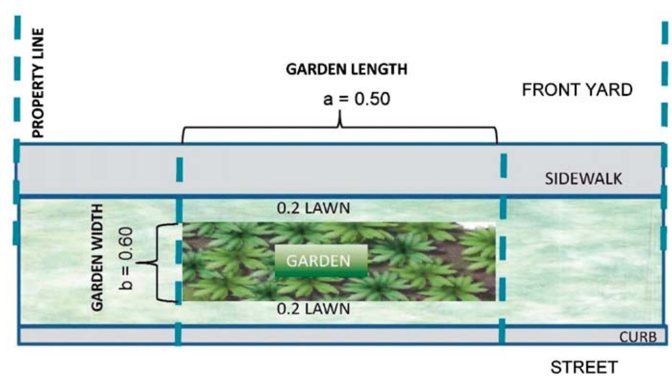

Fig. 1. Visual assessment of relative gardened area: a = proportion of easement length that was occupied by a gardened area (e.g., 0.5); within this length, b = proportion of easement width that was occupied by a gardened area (e.g., 0.6); if the delimited area included turf grass, the % contribution of grass to total gardened area was estimated. Relative gardened area was calculated as: $(a \times b)$ – proportion of lawn inside garden area, e.g., $(0.5 \times 0.6) - 0 = 0.3$ of easement was gardened.

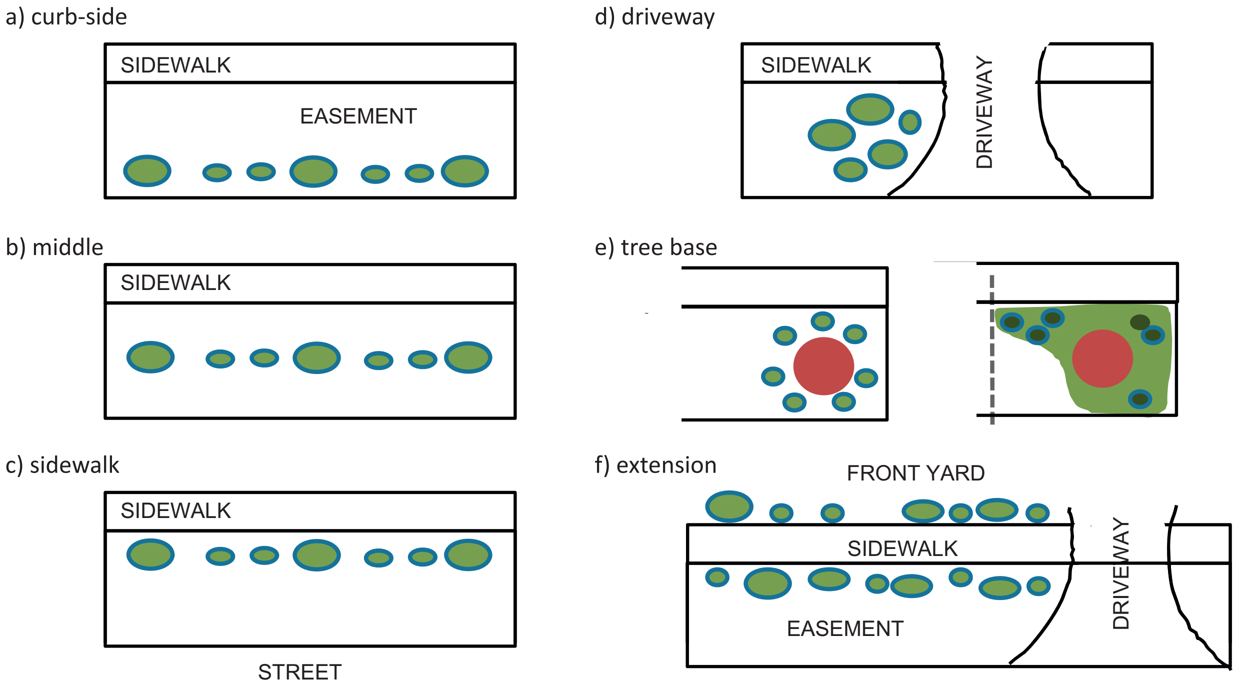

Fig. 2. Position of easement garden: full-entire easement is gardened; (a) curb – area along easement closest to the road; (b) middle – area in longitudinal center of easement; (c) sidewalk – area nearest sidewalk edge; (d) driveway – area next to driveway; (e) tree base: 1 = only a narrow gardened collar; 2 = more extensive garden around tree base, gardened area measured with standard protocol; (f) extension-gardened area that flanks other side of sidewalk and is similar in content and style of easement garden; note-multiple designations are possible.

2.2. Data analysis

The hypothesis that easement gardens are spatially clustered was tested with several statistical approaches and at different spatial scales. The scale of spatial clustering is defined specifically for each statistical test. Because familiarity with easement gardens may play a role in social contagion, the criteria for neighborhood delimitation ranged from immediate visual access to an easement garden (for example, across the street from "home") to simple physical proximity (for example, in the neighborhood).

2.2.1. Global test: frequency distribution of cluster size based on direct visual adjacency

This analysis measured the frequency distribution of visually adjacent clusters of easement gardens by size because visual exposure can be a component of social contagion (Rendell et al., 2011). For example, neighbors sharing back fences were often spatially closer than neighbors three doors down the street, but back fence neighbors are less likely to see one another's easement area unless they walk, drive, or bike around the block. Since most trips to and from home involve passage from the front of the house, the most frequently viewed easement areas will be next-door neighbors and those across the street from a reference property. Therefore we focused on the clustering of easement gardens that were visually accessible from the front yard.

We tabulated the sizes of visually adjacent clusters of gardens by manually inspecting the 2562 easement gardens in the geocoded data base created in ArcGIS. Whenever two or more easement gardens occurred in a visually adjacent cluster (i.e., where two or more gardens were in view of each other and there were no properties without easement gardens in-between), the total number of visually adjacent gardens in the cluster was counted and recorded. Visually adjacent properties included next-door neighbors, neighbors directly and/or diagonally across the street and, for cul-de-sacs, any easements visible from the front of the reference property. Once a property with an easement garden was included in a cluster, it was never counted again. This method focuses on a more local scale than subsequent spatial clustering analyses (below) where visual adjacency of easement gardens from the front of the property was not required.

To enable significance testing, the same criteria for garden adjacency were applied in a simulation to test the deviation of the observed pattern of gardens from a random pattern. The simulation allowed us to compare the observed patterns to random patterns on a spatial grid that approximated the spatial structure of visual adjacencies on city streets, and involved creating a 150 by 150 grid with a total of 22,500 parcels. The cells on the grid were assigned to streets that ran horizontally along the boundaries of cells in every other row. The visually adjacent neighbors of each cell were defined as those on the left and right side, as well as the three across the street. We randomly located 2560 easement gardens on the grid, produced 100 realizations of this random pattern, and tabulated for each realization the numbers of clusters of each size. These random runs were used to interpret 95% confidence intervals for each cluster size, and determine whether the observed numbers of clusters of various sizes were different from random.

Because some of the parcels in Ann Arbor were in non-residential uses, and therefore not likely to participate in imitation behavior related to gardens, this simulation over states the observed clustering relative to random (i.e., the observed pattern will have more clustering than the random simulation simply by virtue of the fact that residential parcels exhibit a greater degree of clustering in the city than the random pattern assumed in the simulation). Because we know that non-residential parcels were not likely to be randomly located within the city, we also ran an alternative simulation, in which non-residential parcels were all clustered in a separate part of the city from the residential parcels. This alternative simulation provides a conservative test of the robustness of the findings, because the observed pattern will tend to have less clustering than this case by virtue of the fact that there is some degree of interspersion of residential and non-residential parcels within the city (i.e., the actual pattern of intermixing of residential and non-residential parcels likely falls somewhere in between the initial simulation and this alternative case). For this test, we randomly located 2560 gardens on a grid of 132 by 132 cells (i.e., the small grid represents the grouping of all residential parcels within the city, which are spatially separated from the non-residential parcels), for a total of 17,424 parcels (77.4% of the cells in the original simulation to approximate the number of residential parcels), and tabulated the frequencies of cluster sizes across 100 runs. We report the results from the simulation on the larger grid because we believe that the actual pattern of intermixing of residential and non-residential parcels is closer to random than completely clustered, but also report differences between the two simulations to test the robustness of the results to this assumption.

2.2.2. Global test: case–control analysis with increasing neighborhood size

The next analysis provided additional information about the spatial position of nearby gardens relative to a reference property. We used the Cuzick and Edwards (1990) test in the ClusterSeer (TerraSeer® 2009) program because it can be used to detect global spatial clustering for individual-level case–control data. A case is defined as a property holding an easement garden ($n = 2562$). Control is obtained by comparing known cases of easement gardens (the "condition") with properties that are garden free. The dataset was prepared in ArcGIS by creating a shape file containing all properties ($n = 22{,}562$), coded as 0 = without garden and 1 = with garden. The analysis produced a test statistic based on the number of each case's k nearest neighbors that had easement gardens (also cases), summed across all cases (Cuzick & Edwards, 1990). When the p-value was less than 0.05, the null hypothesis (H_o) of random distribution was rejected and the alternative hypothesis (H_1) of a clustered distribution was accepted. The analysis was done at the spatial scales of 5 and 10 nearest neighbors, because these two scales bracket the range of larger scales than the previous test over which we hypothesize visual interaction and social contagion might operate. Use of a nearest neighbor distance criterion reduced the impact of variation in property size across the city.

2.2.3. Clustering evaluations with logistic regression and contingency analysis

Clustering was also evaluated with contingency analysis (SAS for Windows 9.2) to assess the form of the relationship between density of nearby gardens and neighborhood size (PROC FREQ). In addition, likelihood estimates for garden occurrence based on nearby garden density were generated with logistic regression (PROC LOGISTIC) in order to evaluate the magnitude of the effect of neighboring garden density on the occurrence of easement gardens. For these tests, new variables were created to describe the density of easement gardens within a specified radius from a property. Circular neighborhood sizes of 30, 61, 91, 122, 152, 305, 457, and 610 m in diameter were defined for each property in the study. The smallest neighborhood size (30 m diameter) approximated typical distances of nearest neighbor properties. The largest neighborhood size (610 m diameter) fell within the range of preferred walking distance in public transit studies – 402–805 m (Dittmar & Ohland, 2004). A nearby garden density variable for all properties was defined for each circular neighborhood size using the following method. A point distance matrix generated in ArcGIS held the distance (in meters) between each easement garden property and all other properties citywide ($2562 \times 22{,}562$ matrix). From this, a new binary (0/1) matrix was generated for each neighborhood size based on the occurrence of an easement garden at the specified distance. The nearby garden density variable for each neighborhood size was valued as the sum of all "1"s for each address citywide.

2.2.4. Clustering of attractive easement gardens

If a homeowner is influenced by the presence of a nearby easement garden, then its attractiveness may also influence the form of emulation. We tested the hypothesis that gardens with high visual appeal were randomly distributed (H_o) or clustered (H_1) relative to less appealing gardens. The original values for esthetic appeal ranged from not appealing (=1) to most appealing (=5). The majority of gardens (56%) got higher marks for visual appeal with 40% rated 'very appealing' and 16% rated 'extremely appealing'. The remaining gardens were rated as 'OK' (37%), 'poor' (6%), and 'really bad' looking (1%). Consequently, appeal was re-coded for two classes – highly appealing for esthetic ratings of 4 or 5 ($n = 1447$) and less appealing for esthetic ratings of 3 or less ($n = 1115$).

Case–control analysis, described above, provided a global test of the hypothesis for neighborhood sizes of 5 and 10 nearest neighbors. Cluster-Outlier analysis located significant points of clustering and dispersion of appealing gardens; Hot Spot analysis located places in the city with high marks for clustering or dispersion of appealing gardens that were themselves surrounded by other points with the same extreme attribute (ArcGIS 9.3). These local tests were chosen because they allowed us to focus on specific local effects of appealing easement gardens. The local analyses were done at neighborhood sizes of 5 and 10 nearest neighbors, as well as a fixed distance of 372 m from "home," selected because z-scores were highest at this distance among multiple distances tested. Use of a fixed distance criterion helped equalize travel time for potential encounter with an appealing garden. Analyses at each neighborhood size yielded z-scores and p-values for test statistics – Cluster-Outlier analysis (Local Moran's I) and Hot Spot Analysis (Getis-Ord Gi) for each property in the study ($n = 2562$).

3. Results

Easement gardens occurred at a frequency of 11% ($n = 2562$) of all property types citywide ($n = 22{,}562$). The gardens were associated with residential properties nearly exclusively (98%), although residential properties made up only 77% of those surveyed. We first describe the characteristics of easement gardens and their appeal, and then evaluate the levels of clustering.

3.1. Easement garden characteristics

The average size of a gardened easement was 37.5 square meters (SE −4.55). Gardens occupied 5–100% of this area and 49.6% on average. There was no relationship between size of an easement and the proportion gardened. On average, gardens were larger (occupied a greater proportion of the easement) when there were more nearby properties with easement gardens ($p < 0.0001$, $n = 2558$, Pearson's $r = +0.18$).

The most dominant spatial arrangement of a garden within an easement was full coverage by non-turf plantings (44%, $n = 1128$), followed by a garden confined to base of the street tree (23%, $n = 591$), the driveway edges (14%, $n = 350$), or along the easement's longitudinal center (11%, $n = 272$). The remaining easements (8%) held gardens in additional and combined spatial arrangements. Lawn was nearly always the ground cover in non-gardened areas of gardened easements.

The structural diversity of easement gardens was measured by the diversity of plant types (herbaceous perennial, shrub, etc.) within a single garden. Three quarters of all gardened easements were dominated by a single plant type (constituting 75–100% of all plants in the garden). The most common was the flowering herbaceous perennial (91% of the time), followed by shrubs

(6% – half of which were deciduous only, 32% coniferous only, the remaining a mixture of the two), ornamental grass (2%), and edible plants (1%). The remaining 25% of gardened easements were more structurally diverse holding greater mixtures of these plant types.

Sixty-seven percent of gardened easements held at least one street tree. Of these, 82% held 1 tree, 15% held 2 trees, and 3% held 3 or more trees. Length of an easement strip was not strongly related to the number of street trees it held ($r = 0.10$, $p = <0.0001$, $n = 2562$). On average, easements without street trees had devoted a greater percent of space to gardens: 56% versus 46% (t-test value = 6.13, $p < 0.0001$, $n = 2562$).

The design components of easement gardens included non-plant items. The addition of ornaments such as statues or reflective balls occurred in 15% of all gardens. The addition of a border (rocks, bricks, rubber edging) around the gardened area occurred in 29% of all gardens. Thirty-five percent of all gardens added materials to cover bare earth (94% as mulch, 6% as decorative stone).

The overwhelming majority of easement gardens had average to high appeal (36.5% as average, 40.5% as good, 16% as outstanding), with only 7% rated as poor or very poor. To investigate the components of "appeal", several design attributes were considered. The presence of street trees was not related to appeal; average appeal rating on a 1–5 scale was 3.62 and 3.69 for easements with and without a street tree. However, presence of weeds influenced appeal rating with 2.98 versus 3.77 average ratings, with and without weeds (t-test, $p < 0.001$, $n = 2562$). There was a significant correlation between appeal and number of ornaments placed in the easement ($r = 0.21$, $p < 0001$), the gnome syndrome – proclivity for finding garden art appealing, regardless of its quality, because it shows distinct signs of effort and care.

3.2. Spatial distribution of easement gardens

Sixty-four percent of all easement gardens (1638 out of 2562) had visual adjacency with at least one other garden when considered from the front of a property. There were a total of 512 garden clusters based on visual adjacency rules. Of these, 50% were composed of two visually adjacent gardens ($n = 513$ properties), 25% were composed of three visually adjacent gardens ($n = 384$ properties), and 25% were linkages of 4 or more visually adjacent gardens ($n = 742$ properties). The largest cluster size class involved 16 properties (Fig. 3). A comparison of observed and expected cluster sizes, based on simulations with random placement of easement gardens, showed that the observed distribution was non-random (Table 2). We observed significantly more large-sized clusters than would be expected by chance alone. For cluster sizes of 1 (no nearby easement gardens) and 2 (1 nearby garden), the observed value fell outside the lower limit because easement gardens were less likely to be in small clusters than in large clusters.

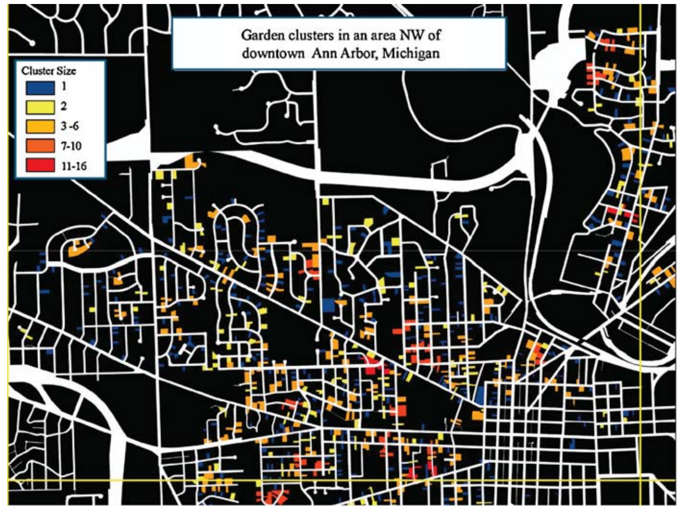

Fig. 3. Spatial distribution of easement garden clusters along streets for a portion of Ann Arbor based on the visual access criteria described in text. Cluster size is indicated by color coding; the cluster size category of 1 indicates a property with an easement garden but no visually adjacent easement gardens.

The results were similar when the analysis omitted non-residential parcels, to represent the assumption of complete clustering of residential and non-residential parcels in the city and for a total sample size of 17,424 parcels. The simulations that were run on a smaller grid were generally consistent with results that included all parcels; cluster sizes 1 and 2 were significantly less frequently observed than expected and cluster sizes 5 through 12 significantly more so. The only differences showed up at cluster sizes 3 and 4, which were no longer significantly different from random on the smaller grid. This suggests that the results are somewhat sensitive to assumptions about the distribution of non-residential parcels in the city, but the overall conclusion that easement gardens occurred more frequently in large clusters (greater than five gardens) than might be expected with a random distribution was robust to the assumption about distribution of residential and non-residential parcels.

Case–control analyses revealed that the presence of an easement garden significantly increased the probability that a property in nearest neighbor positions of 1 through 10 would also have an easement garden (Table 3a).

Table 2
Comparison of observed and expected cluster size for properties with easement gardens as well as visual access to visually adjacent easement gardens; 95% confidence limits (CL) for expected distribution ranged is based on the assumption of random distribution; observed cluster size frequencies fall outside the 95% confidence range for all cluster sizes.

Cluster size	Observed Garden Clustering			Expected clustering under random distribution			
	# Nearby gardens	Frequency	% of all clusters	Mean	Std. Dev.	Lower 95% CL	Upper 95% CL
1	None	924	–	1408	28.5	1352.0	1463.9
2	1	256	50.0	372	16.3	339.6	403.6
3	2	128	25.0	92	8.1	76.2	107.9
4	3	47	9.2	23	4.6	13.9	31.8
5	4	30	5.9	6	2.3	1.2	10.3
6	5	18	3.5	2	1.1	−0.7	3.8
7	6	12	2.3	0	0.6	−0.8	1.6
8	7	6	1.2	0	0.2	−0.4	0.5
9	8	6	1.2	0	0.0	0.0	0.0
10	9	2	0.4	0	0.0	0.0	0.0
11	10	2	0.4	0	0.0	0.0	0.0
12	11	3	0.6	0	0.1	−0.2	0.2
16	15	2	0.4	0	0.0	0.0	0.0

Table 3
Probability that a property in a specific nearest neighborhood position relative to a reference property would also hold (a) an easement garden or (b) an appealing easement garden (Cuzick and Edwards test) at two spatial scales – 5 and 10 nearest neighbors (NN). Probability values for the proximity of a nearest neighbor from closest to furthest position of clustering for (a) easement gardens in relation to non-garden properties ($n = 22{,}562$) and (b) most appealing easement gardens in relation to less appealing gardens ($n = 2562$).

NN position	Neighborhood size	
	5-NN	10-NN
(a) Garden or not		
1	0.001	0.001
2	0.001	0.001
3	0.001	0.001
4	0.001	0.001
5	0.001	0.001
6		0.001
7		0.001
8		0.001
9		0.001
10		0.001
(b) Appealing or not		
1	0.001	0.001
2	0.143	0.153
3	0.100	0.105
4	0.178	0.210
5	0.066	0.055
6		0.203
7		0.318
8		0.705
9		0.071
10		0.012

Generally, the likelihood that a property would have an easement garden increased as the density of nearby easement gardens increased (Table 4a and b). Additionally, as the neighborhood size used to calculate density was expanded incrementally from 30 m to 610 m from a property, the predictive ability of neighboring garden density changed. The greatest clustering of easement gardens occurred at a neighborhood size of 91 m. This conclusion was based on the peak value for rescaled r-square (=0.089) and ROC curve area (=0.707), which describe the fit of the logistic regression model. The odds ratios suggest that it was 2.4 times more likely that a property would hold an easement garden if there was another easement garden within 30 m of it (Table 4c).

Contingency analyses suggest that there was a significant trend in nearby garden clustering at all neighborhood sizes from 30 m to 610 m ($p < 0.0001$, Cochran-Armitage Trend test). Neighborhood size of peak clustering was at 91 m (Table 4d). At this spatial scale, 10% of properties with an easement garden had two other gardened properties within 91 m while 54% of properties with an easement garden had 16 other gardened properties within 91 m (Fig. 4).

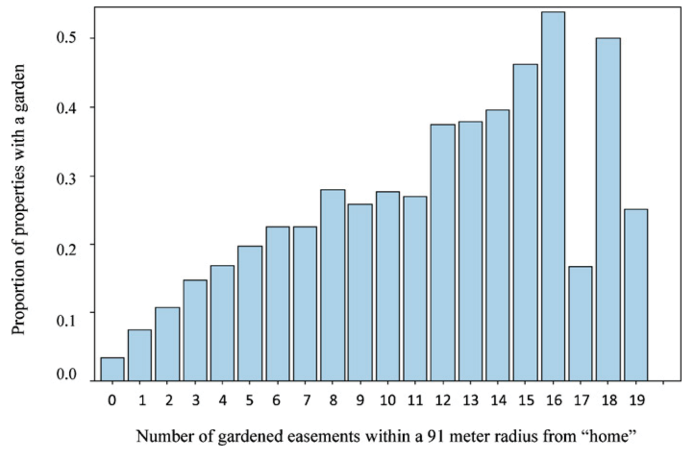

Fig. 4. Graphical representation shows a significant trend of increased occurrence of easement garden as density of nearby gardens increases for neighborhood size of 91 m; Cochran-Armitage Trend test statistic, $Z = -35.64$, $p < 0.0001$.

3.3. Spatial distribution of appealing gardens

Gardens with high visual appeal were significantly clustered in relation to gardens with low visual appeal. Case control analysis indicated that the most common cluster pattern for esthetic status involved only the closest nearest neighbor (position #1 in Table 3b). Local tests of proximity showed that significant clustering of easement gardens based on appeal for three neighborhood sizes (Table 5). Location maps showed that appealing garden clusters occurred throughout the city and there were neighborhoods where garden clustering was more pervasive (for example, see Fig. 5).

4. Discussion

Multiple processes may contribute to the patterns of easement garden clustering found in this study. Categorically, these include cultural and socio-economic factors. Cultural factors include normative views about the look of one's neighborhood (Larsen & Harlan, 2006), influence of community groups (Conway, Shakeel, & Atallah, 2011), and neighborhood incentives (e.g., civic beautification programs), all of which can contribute to social contagion. There is some evidence that these factors can influence gardening habits on private property in public view. For example, lifestyle behaviors, based on group identity and social status variables, best predicted variation in vegetation cover in urban residential settings and public rights of way (Grove et al., 2006).

Socio-economic factors include household income, property value, age of residents, and age of home. There is some evidence that these factors can influence gardening habits on private property in

Table 4
Fit statistics for significant logistic regressions where Y = presence (or not) of an easement garden and X = radius of neighborhood size; $p < 0.0001$, $n = 22{,}562$ for all neighborhood sizes. (a) C-statistic from ROC curve analysis is a concordance index that discriminates model fit; (b) re-scaled r-square. The odds (c) of having an easement garden given the density of nearby gardens within a specified neighborhood size; all Wald Chi-Square p-values < 0.0001. (d) p-values <0.0001 for all z-scores from Cochran-Armitage trend tests.

Neighborhood size (meters)	(a) C-statistic	(b) Rescaled r-square	(c) Odds ratio	95% Confidence limits: upper-lower		(d) Trend test Z-values
30	0.629	0.066	2.36	2.22	−31..51	−31.51
61	0.695	0.087	1.45	1.42	−35.61	−35.61
91	0.707	0.089	1.24	1.22	−35.64	−35.64
122	0.701	0.083	1.14	1.13	−33.82	−33.82
152	0.701	0.084	1.10	1.09	−33.91	−33.91
305	0.676	0.065	1.03	1.02	−29.01	−29.01
457	0.661	0.058	1.01	1.01	−27.22	−27.22
610	0.649	0.052	1.01	1.01	−25.64	−25.64

Table 5
Summary of significant z-score distributions for Cluster-Outlier and Hot Spot analyses showing clustering and dispersion of easement gardens based on appeal (high or low) for 2562 gardened properties; NN = nearest neighbors, FD = fixed distance of 372 m.

Analysis	Neighborhood Size	z-Score min	z-Score max	Number of properties in sphere with gardens of...	
				high appeal	low appeal
Cluster-Outlier analyses	5 NN	−6.18	6.66	141	56
	10 NN	−9.89	7.16	135	65
	FD	−8.45	9.06	204	104
Hot Spot analyses	5 NN	−3.71	3.45	152	73
	10 NN	−3.86	3.20	119	133
	FD	−3.61	4.66	283	184

public view. For example, household income predicted residents' preference for front yard landscaping style in Arizona (Larsen & Harlan, 2006) and the frequency of front yard trees in Tasmania (Kirkpatrick, Daniels, & Zagorski, 2007). After our analyses were completed, we received access to data on the tax-assessed value of all properties in the study from the City of Ann Arbor. This allowed us to make a first approximation on whether there is a relationship between house value and presence of an easement garden. There is no assumption that property value is a reliable indicator as disposable income may be unrelated to property value. That said, we found that residential properties with easement gardens had assessed values that were, on average, 2.8% greater than properties without easement gardens: gardens = $136,245 ($n = 2209$) versus no gardens = $132,555 ($n = 15,492$); Satterthwaite t-test for unequal sample size (df = 2962.2, $t = -2.49$, $p = 0.013$). Our interpretation of this result is that household economics may be a factor in the decision to install an easement garden but is not likely to be the reason for the easement garden clustering seen in this study. Clustering happened on a much smaller scale than the scale of neighborhood property values. In this study, 50% of all garden clusters were

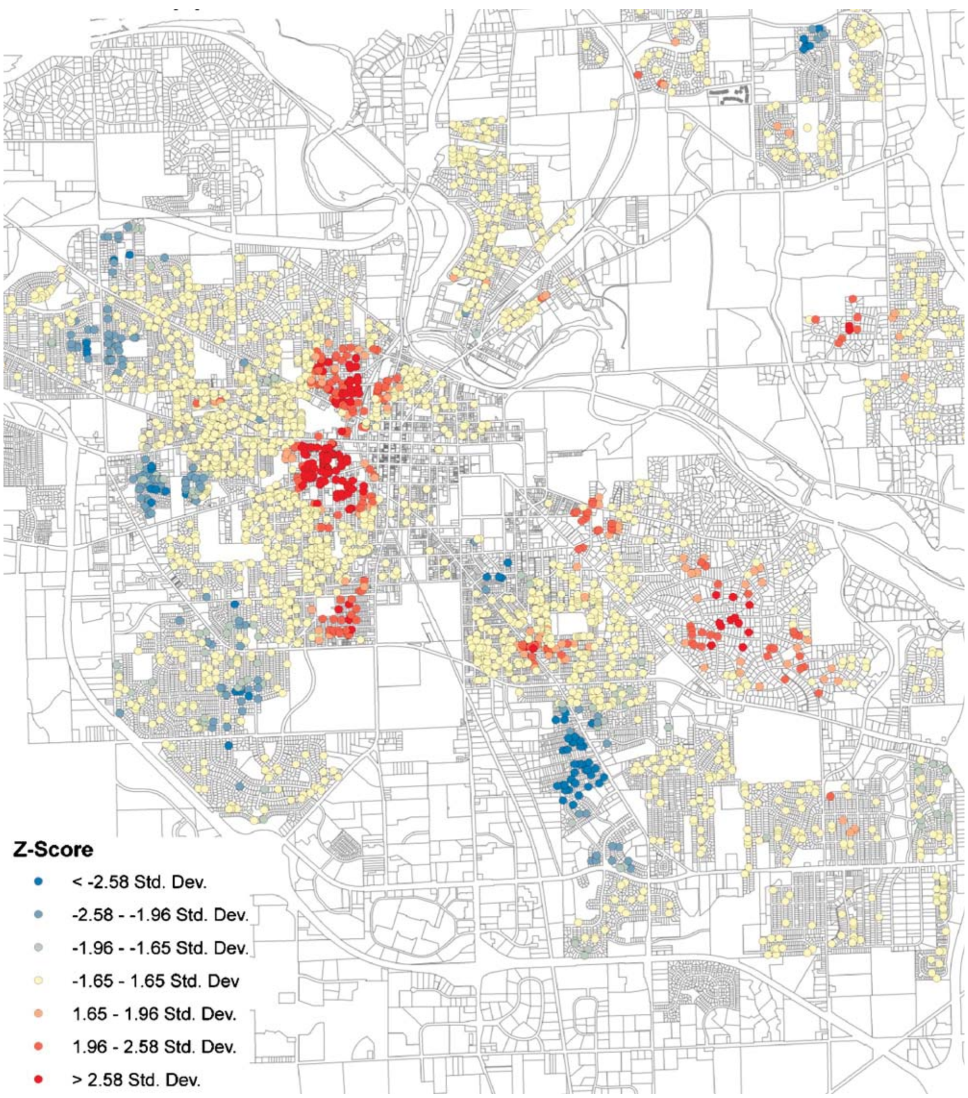

Fig. 5. Location of hot spots for easement gardens with high appeal compared to low appeal. Significant z-scores from Hot Spot Analysis for clustering are ≥+1.96, for dispersion ≤−1.96; neighborhood size is 5 nearest neighbors.

confined to 2 nearest neighbors and 90% of all garden clusters included 5 or fewer nearest neighbors. These cluster sizes are much smaller than a city block that constitutes the smallest version of "neighborhood." Property value in Ann Arbor, like most cities, is relatively constant across a city block and often much further. Further research is needed to articulate the magnitude, nature and relevance of an economic component for easement garden pattern.

While larger scale factors may play a role in where a garden cluster is initiated, the relatively small cluster sizes observed in this study suggest that some form of social contagion is in play. The importance of spatial proximity is supported by the work of Palmer (1984) who found that neighborhood attitudes about the outdoor quality of their neighborhood were significantly related to the physical quality of the street segment around the residence rather than that of the neighborhood at large; this result held across neighborhoods that differed significantly in income, education, life stage, race and property value.

4.1. Spatial clustering patterns and social contagion

Support for the interpretation that some form of social contagion is in operation emerges from the results of multiple spatial analyses, each targeting a different aspect of garden distribution. First, the most intense clustering of easement gardens occurs among neighbors with direct visual access to the easement area of nearest neighbors. Second, it is 2.4 times more likely that a property will hold an easement garden if a property within 30 m of it holds an easement garden. Third, although clustering is measureable for all neighborhood sizes up to 610 m (radius), peak clustering happens at a neighborhood size of 91 m from home. Finally, clustering of easement gardens in terms of quality (appeal) happens, but only at very local scales, with the greatest effect found between pairs of adjacent neighbors.

The contagious aspect of easement garden installation highlights the social component of gardening in visually public areas. Because clustering patterns emerged from multiple definitions of nearest neighbor in this study, multiple aspects of social contagion may be in play. Garden form can be influenced by social pressure to conform to neighborhood norms (Nassauer et al., 2009), by subscription to culturally based esthetic norms (Larson, Casagrande, Harlan, & Yabiku, 2009; Zheng, Zhang, & Chen, 2011) and by concern for property value (Robbins & Sharp, 2003). When a garden is in public view, the potential for public scrutiny can modify the level of self-expression. In Phoenix, Arizona, neighboring front yard gardens were more similar to one another than were backyard gardens (Larsen & Harlan, 2006).

Imitation, one mechanism of social contagion, emerges from admiration or desire to conform (Bonabeau, 2004). Admiration of other easement gardens is the more likely initiator of garden installation given the rarity of easement gardens (11%) citywide. Once the decision to install an easement garden is made, both admiration and conformity may come into play as evidenced by the dominant clustering of esthetically appealing gardens among closest neighbors and the clumping of appealing garden hot spots in distinct spatial areas across the city. The pattern of peak clustering of easement gardens within 91 m from a home is in keeping with other studies of imitation. In a residential district of urban Montreal, the front yards of adjacent neighbors living on the same side of the street showed a high degree of similarity in form and content (Zmyslony & Gagnon, 1998). Imitation of garden content was best predicted by proximity, with distance alone explaining 20% of the landscape variation along a street (Zmyslony & Gagnon, 2000). Imitation clusters ranged from 2 to 8 front yards with widths from 8 to 14 m (Zmyslony & Gagnon, 1998), for an imitation impact ranging from 15 to 112 m along the street. Although the sampling unit in these studies was a linear city block, their results are in keeping with what we found. By contrast, a study in Australian suburban neighborhoods of Hobart, Tasmania showed that difference rather than imitation prevailed in front garden content at a scale of 5 nearby neighbors (Kirkpatrick, Daniels, & Davison, 2009). Although properties were further apart than in the Montreal study, most to all of the five neighbors should have fallen within a 91 m neighborhood size. The lack of imitation was attributed, in part, to a social norm of independence.

4.2. Consequences of garden clustering for urban ecosystem health

There is good evidence of ecosystem services provisioning by urban gardens (Bolund & Hunhammar, 1999; Cook, Hall, & Larson, 2011; Davies et al., 2009). Easement gardens, one type of urban residential garden, occupy tougher habitat compared to most residential front and back yards. From the appeal ratings of easement gardens in this study (93% with ratings at or above average), we infer that it is possible to create healthy, functional habitat along the street edge. Street-side easement areas make up an extensive urban habitat with high ecological potential to support urban biodiversity and ecosystem services, particularly when they are occupied by a plant palette more diverse than turf grass (Fontana, Sattler, Bontadina, & Moretti, 2011; Hunter & Hunter, 2008). Even the narrow strips of turf grass along residential streets offer some ecosystem services – most notably erosion control (Mueller & Thompson, 2009), although gardened space does a better job than lawn (Kazemi, Beecham, & Gibbs, 2011). Ecosystem services are further improved with the addition of street trees which provide structural habitat diversity, carbon storage (Davies, Edmondson, Heinemeyer, Leake, & Gaston, 2011), air quality improvement, stormwater management and, depending on plant species, food for insects, birds and mammals (McPherson, Simpson, Xiao, & Wu, 2011). To the same ends, the substitution of flowering perennials, ornamental grasses, and woody shrubs for lawn expands the potential to support community diversity and environmental health.

The spatial clustering pattern of easement gardens allows consideration of additional aspects of ecosystem service provisioning – the potential for citywide linkage of enhanced habitat and ecosystem service capacity based on citizen engagement. We believe that the value of linkage has been supported by research on urban greenways (e.g., Colding, Lundberg, & Folke, 2006; Li, Wang, Paulussen, & Liu, 2005), while recognizing that efforts to promote nature conservation in urban areas are moving faster than research to validate the methods recommended (Douglas, 2011; Ernstson, Barthel, Andersson, & Borgstrom, 2010).

The results of our spatial study of easement garden distribution can be used to think about what might constitute efficient ways to amplify the culture of sustainability behavior in urban areas. The occurrence of easement garden clusters and their potential for contagious expansion along city corridors suggests a mechanism to enhance the known benefits of urban nature for human wellbeing (Brown & Grant, 2005; Jorgensen & Gobster, 2010) and environmental health (Lortie & Sperling, 2008; Van Rossum & Triest, 2010). Environmentally sound garden design and management practices by the public offers a cost-effective way to achieve such expansive goals in urban areas (Daniels & Kirkpatrick, 2006; Goddard, Benton, et al., 2010). The collective action of the public can contribute to the development of a more ecologically resilient urban green network. To achieve ecological resilience, the urban habitat network must function at three spatial scales (Goddard, Dougill, & Benton, 2010; Warren, Lerman, & Charney, 2008): the individual property (leaves personal choice intact), the neighborhood (attends to local normative values), and the city or metropolitan region (attends to continuity across the fine-grained mosaic of the highly diversified urban habitats). Collectively, street-side gardens and front yard gardens can contribute to functional connections among urban green areas by acting as corridors of a city-scale habitat network (e.g. Ignatieva, Stewart, & Meurk, 2011; Jim & Chen, 2003).

A metropolitan matrix of street-side gardens would satisfy multi-scale requirements for ecological resilience in urban areas – provided the small scale microhabitat conditions of individual properties are the starting point for garden design. As a consequence, social contagion could be counterproductive if it influences garden composition inappropriately. Interestingly, Zmyslony and Gagnon (1998) found that not to be the case in Montreal neighborhoods where the amount of shading differed dramatically from one side of the street to the other and imitation of garden form by nearby neighbors was based on matching light conditions.

There are several approaches to encourage the production of ecologically effective easement gardens, gardens that supply ecological services and are valued enough to ensure appropriate management. Each approach leaves personal choice, and thus creativity, intact but expanded. First, the presence, versus the "idea," of an esthetically pleasing and ecologically sound easement garden is essential for success. A set of model gardens could be designed for an array of typical microhabitat types of a metropolitan area; for example, sun gardens and tree-shaded gardens in dry windy areas. Model gardens, seeded throughout the city by interested parties – individuals, neighborhoods, non-profits, and local government – would offer neighbors a baseline for imitation. This idea is in keeping with those of Hunter (2011b), who devised a method of planting design to support urban ecological resilience, and Grove et al. (2006), who suggested that urban ecosystem function can be improved by developing environmental marketing strategies that appeal to the underlying household motivations for participation in local land management.

Second, establishment of ecologically effective urban gardens could be enhanced by education and encouragement programs aimed at supporting a cultural shift toward greater urban ecosystem stewardship. Existing programs to support successful urban community gardens (e.g., Alaimo, Reischl, & Allen, 2010; Milburn & Vail, 2010; Twiss, Dickinson, Duma, Kleinman, Paulsen, & Rilveria, 2003) and other forms of urban greening (Conway et al., 2011) are proactive in building the capacity of citizens to become agents of change. Professionals and community members well-versed in ecological design could offer knowledge and supporting skill sets that direct the public toward garden designs that are ecologically resilient and captivating enough to prompt imitation.

A third approach – use of social networks, employs social contagion as an accelerator for installation of ecologically effective urban gardens. Social networks are instrumental in the emergence of innovative strategies (Ernstson, Barthel, et al., 2010). They offer an efficient platform for the development and dissemination of site-specific garden design guidelines, specificity being an essential aspect of urban habitat creation owing to the great heterogeneity of urban ecosystems and the scale dependence of their processes (Pickett et al., 2001). A garden design that accommodates microclimate and ecological context has a better chance of supporting an urban green network against the stress of urbanity and the uncertainties of climate change (Gill et al., 2008; Ignatieva et al., 2011; Tzoulas et al., 2007). Social networking also offers a useful albeit challenging way to communicate, assess and coordinate information and directives for management of multi-scale urban ecosystem processes (Barthel, Folke, & Colding, 2010; Ernstson, van der Leeuw, et al., 2010). In the meantime, the spread of higher quality street-side habitat through the production of easement gardens offers an immediate and flexible avenue for enriching the urban ecosystem (Goddard, Benton, et al., 2010; Loram, Tratalos, Warren, & Gaston, 2007; Zmyslony & Gagnon, 1998), so long as what is in vogue is also ecologically sound.

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