Landscape and Urban Planning 132 (2014) 37–46

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Exurban residential household behaviors and values: Influence of parcel size and neighbors on carbon storage potential

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HIGHLIGHTS

- Parcels >0.53 ha (just over 1 acre) (LP) have proportionately less mown lawn.
- LPs have more big trees, more trees planted, and less fertilization or irrigation.
- LP owners are less concerned that their yard fits neighborhood norms.
- Demographic variables alone do not account for differences in landscape behaviors.
- Large exurban lots may provide more carbon storage than smaller lots.

ARTICLE INFO

Article history:
Received 3 September 2013
Received in revised form 31 July 2014
Accepted 6 August 2014

Keywords:
Landcover
Urban forest
Ecosystem services
Residential landscape
Urban ecology
Web survey

ABSTRACT

To learn how household characteristics might affect carbon storage on exurban residential parcels, we conducted a web survey of 126 southeast Michigan exurban homeowners. We measured several behaviors that may affect carbon storage: the proportion of parcel mown (or left unmown with woody vegetation), the number of large trees retained, the number of trees planted, how leaf litter was managed, the use of fertilizer, and the use of irrigation. We investigated whether these behaviors might be related to parcel size, homeowners' concern for having a yard that fits neighborhood norms, or household demographic characteristics. We found that owners of large (>0.53 ha) parcels were consistently different from small and medium parcel owners in their management behaviors. Large parcel owners mowed a smaller proportion of their parcels. They also were less likely to fertilize and irrigate, had planted more trees, and had more large trees on their parcels. In addition, they reported being less affected by a desire for their yard to fit neighborhood norms. Our results suggest that parcel size and neighborhood norms together affect landscape behaviors that affect carbon storage. We conclude that for large parcels, size alone may promote carbon-storing management behaviors. However, for smaller parcels, governance should promote appropriate design at the scale of whole blocks or subdivisions in order to drive adoption and acceptance across neighborhoods.

1. Introduction

Residential landscapes can be considered as social-ecological systems with interactions among ecology, legacy effects, multiscalar human drivers, and design and management (Cook, Hall, & Larson, 2012; Fissore et al., 2011; Grimm et al., 2008; Pickett, Cadenasso, McDonnell, & Burch, 2009). Exurban residential landscapes, which we define as "low-density settlements that are contiguous with metropolitan urbanized areas but disconnected from city services of sewer and water" (An, Brown, Nassauer, & Low, 2011), are of particular interest as socio-ecological systems because of their extent and continued growth. In 2007, about 5% of the U.S. land area—41.7 million ha—was estimated to be in nonfarm, rural residential uses, while there were only 24.7 million ha in all urban land uses (including residential) (Nickerson, Ebel, Borchers, & Carriazo, 2011). This study of household behaviors is part of a larger project investigating carbon storage in exurban landscapes in southeast Michigan as coupled natural and human systems.

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http://dx.doi.org/10.1016/j.landurbplan.2014.08.004
0169-2046/

We investigated drivers of household behaviors that may enhance landscape carbon storage including: aesthetic preferences (Nassauer, 1988, 1993; Peterson et al., 2012), ease of maintenance (Carrico, Fraser, & Bazuin, 2012), neighborhood norms (Chowdhury et al., 2011), and parcel history (Donnelly & Evans, 2008).

We investigated these behaviors:

- Proportion of the parcel mown, which in southeast Michigan implies that the remaining proportion of the parcel is in forest or brush.
- Irrigation.
- Fertilization.
- Retention on the parcel of leaves, needles, and lawn clippings.
- Retention of large trees that appear to pre-date construction of the residence.
- Planting of trees by the current homeowner.

Our overarching research questions were:

- Is parcel size, which is determined in the development process, related to these behaviors?
- Does concern about fitting in with neighborhood-scale norms for landscape appearance affect these behaviors?
- Do demographic characteristics, including respondent age, number of children, income, and house age, affect these behaviors?

The remaining sections of the introduction review relevant literature regarding parcel size legacy effects, neighborhood-scale norms, demographics, and household carbon storage behaviors.

1.1. Parcel size

Several studies suggest that parcel size, which is a legacy of past development decisions, may be related to residential land cover or landscape management behaviors. Zhou, Troy, and Grove (2008) studied fertilization behavior of 73 Baltimore County, MD, households, and they found that owners of larger parcels applied larger total amounts of fertilizer N but less per unit area. This relates to their observation that homeowners with larger parcels manage the lawn near their house (the "primary lawn") very intensively, while leaving the rest of the parcel untended in tall grass or fields (Zhou et al., 2008). While this study did not specify the size of "very large lawns" or the "primary lawn," it included parcels ranging from less than 0.25 ha to larger than 1 ha. Further supporting the idea that parcel size affects residential vegetation, a comparison of land cover in two Morgantown, WV, suburbs with small parcels (0.12 ha and 0.04 ha), found that larger parcels had a higher proportion of land covers that were not bare or impervious (Kim & Zhou, 2012). A study of 360 homeowners in the Twin Cities, MN, area sampled a more complete gradient of housing density in which area in turf grass ranged from 0.02 ha to 3.76 ha, with a mean turf area of 0.15 ha; it found carbon storage to be related to the number of trees and parcel size, with larger parcels having more trees (Fissore et al., 2012).

Studying land cover of exurban townships in southeast Michigan, Robinson (2012) found that the proportion of parcel mown decreased with increasing parcel size, while the proportion in forest cover increased exponentially with increasing parcel size. He concluded that there may be limits to anthropogenic management with large parcel size. Based on homeowner interviews and site sampling of southeast Michigan exurban residential parcels, Nassauer et al. (2014) defined the mown area that extends continuously from the house as the "Zone of Care" (ZOC). They concluded that a threshold effect may occur at approximately one acre (0.45 ha): parcels smaller than approximately one acre have a proportionately larger ZOC than larger parcels. The area beyond the ZOC typically is wooded in the temperate forest biome of southeast Michigan, storing more carbon per unit area (Hooker & Compton, 2003). Further, Nassauer et al. (2014) suggest a typology of exurban homeowner behaviors that implies that parcel size and neighborhood norms interact to affect residential landscape behaviors (Table 1).

1.2. Neighborhood norms

Several studies have shown that homeowners' landscape management decisions may be influenced by conformity with neighborhood norms. While broad cultural norms for residential landscapes to look neat or tidy may affect homeowners' decisions, the influence of their neighbors, including homeowners' beliefs about their neighbors' opinions, may have an even stronger effect (Peterson et al., 2012; Nassauer, Wang, & Dayrell, 2009). A survey of 487 Perth, AU, residents largely confirmed Nassauer's et al. (2009) finding that neighborhood-scale social norms have a significant impact on preferences (Kurz & Baudains, 2012). Grove et al. (2006) note that residential landscape management decisions may be influenced by a desire to express membership within "lifestyle groups" in Baltimore, MD. In Nashville, TN, Carrico et al. (2012) found that when residents were strongly identified with a community having specific social norms, residential landscape decisions were partly motivated to conform to surroundings. A study of Miami, FL, Boston, MA, and Phoenix, AZ, found that "in all locations. . .neighborhood standards function as a constraint on management decisions, often driving yard management choices that households' report would not be their own preferred choice" (Harris et al., 2012, p. 743). In Leeds, UK, a mixed methods study involving 533 respondents concluded that keeping front yards neat was very important in part as a response to neighborhood standards (Goddard, Dougill, & Benton, 2013).

Spatial aggregation or "clumping" of similar home landscape styles also suggests that homeowners may be responding to norms implied by the appearance of nearby neighbors' yards. For example, Hunter and Brown (2012) identified a contagion effect in front yard easement gardening styles among adjacent neighbors in Ann Arbor, MI. In addition, Henderson, Perkins, and Nelischer (1998) observed that similar styles of residential landscapes (e.g., lawns that were managed in an unconventional or "alternative" style) tended to be spatially aggregated in Guelph, ON.

Neighborhood-scale influence on parcel management can also be codified through neighborhood and homeowner associations (Lerman, Turner, & Bang, 2012). With varying levels and types of control, these associations can control plant height, lawn management, and numerous other management techniques with implications for ecosystem services (Fraser, Bazuin, Band, & Grove, 2013; Cook et al., 2012).

1.3. Demographic characteristics

Several studies have investigated the relationship between household landscape behaviors and demographic characteristics (e.g., income, education, age), but no significant relationships have been found consistently, and results from different studies sometimes contradict one another. Some studies have grouped demographic variables to explore their relationship with residential land cover (Boone, Cadenasso, Grove, Schwarz, & Buckley, 2010; Giner, Polsky, Pontius, & Runfola, 2013; Troy, Grove, O'Neil-Dunne, Pickett, & Cadenasso, 2007). "Lifestyle groups" (defined by the proprietary PRIZM measure) were found to predict percent realized stewardship within ZIP code areas of Baltimore, MD (Troy et al., 2007). Giner et al. (2013) used the same lifestyle group variables in their study of suburban Boston. Analyzing at the scale of census block groups, they found no relationship between "social stratification" variables—income, home value, education, ethnicity, or

Table 1
Homeowner behavioral typology from Nassauer et al. (2014).

Parcel size (acres)	Neighborhood norms	Zone of care (acres)	Homeowner behavioral type
Small parcel (0.0–0.5) (0.0–0.2 ha)	Strong concern	0.0–0.5 (0.0–0.2 ha)	Neat neighbor Lakeshore owner Nature neighbor
Medium parcel (0.6–1.0) (0.2–0.4 ha)	Some concern	0.6–1.0 (0.2–0.4 ha)	Tree planter
Large parcel (>1.0)	Little concern	0.0–1.0 (0.0–0.4 ha)	Improver
(>0.4 ha)	Little concern	>1.0 (>0.4 ha)	Viewer

housing age—and the percentage of land cover in lawn. They conclude that other variables, such as "lawn care practices," should be examined in order to fully understand residential land cover.

1.4. Household behaviors that affect carbon storage

Existing literature describes some household behaviors that may affect exurban landscape carbon storage. Mown turf stores less carbon per area than unmown woodland in the temperate forest biome of our Michigan, USA, study area where forest cover typifies unmown areas on exurban residential parcels (Nassauer et al., 2014; Robinson, 2012). Excluding agricultural uses like grazing or crop cultivation that rarely occur in southeast Michigan exurban residential areas, a smaller mown area implies a larger proportion of the parcel in forest or brush in temperate forest biomes, where carbon is stored in soil and foliar, root, and woody litter (Watson et al., 2000). Consequently, retention of leaves, needles, and lawn clippings on residential parcels may retain more carbon in soil and vegetation. Davies, Edmondson, Heinemeyer, Leake, and Gaston (2011) examined above-ground carbon storage in the British city of Leicester and attributed an estimated 97.3% of the carbon stored above ground to trees. Fissore et al. (2012) found that trees were the most important source of carbon inputs and accumulation in residential landscapes in St. Paul, MN. Larger trees store much larger amounts of carbon, but planting trees is an important legacy investment in future carbon storage (Caspersen et al., 2000; Rhemtulla, Mladenoff, & Clayton, 2009).

While both irrigation and fertilization of residential landscapes are well-known to consume water and energy resources and to be a source of water pollution, both practices may affect carbon storage in vegetation and soils. Areas that are irrigated may produce more biomass and store more carbon in soil (Hutchins, 2010). More carbon also is stored where fertilization produces more biomass above and below ground (Fissore et al., 2012).

2. Methods and analysis

In 2011 we conducted a web survey of homeowners who had previously responded to our 2005 web survey (Nassauer, Wang, & Dayrell, 2009) of exurban homeowners. 2005 respondents had volunteered to participate in web surveys and lived in a 10-county region (207 ZIP codes) in southeast Michigan that included the Detroit, Ann Arbor, Flint Metropolitan Statistical Area (MSA). The ZIP codes selected for our sample included municipalities that did not provide municipal sewer or water services and used large-lot zoning. In June 2011, we post mailed invitations to participate in a web survey to 1301 addresses: all 494 addresses provided by 2005 survey respondents, as well as two additional addresses randomly drawn from the same streets as those addresses (identified from an on-line phone book, www.yellowpages.com/whitepages). Respondents were entered into a drawing for a free home landscape design consultation. The post office returned 122 postcards (9.4%) as undeliverable. In October 2011, we sent a reminder postcard, with an incentive of a drawing for a $100 cash prize to all nonrespondents. We received 126 usable responses (response rate of 10.7%), 75 of which were from addresses of respondents to our 2005 web survey. This response rate from other addresses was proportionately lower. Our low combined response rate may have been affected by postal mail recipients' reluctance to respond to a web survey. We developed our image-based questionnaire on a Qualtrics platform (http://www.qualtrics.com/), and downloaded the web survey responses directly from Qualtrics into SPSS 20 and 21 for analysis. This survey methodology was in compliance with standards of our institution's Institutional Review Board.

To categorize respondents as "exurban," we used respondent reports about whether their homes had a well, a septic system, or both; if they did not have full municipal sewer and water services, we classified them as exurban. Parcel size varied significantly ($n = 123$, Fisher's Exact Test = 61.90, $p < 0.05$, Pearson Chi-Square = 53.17, $p < 0.05$) between respondents who were and were not exurban by our definition. Overall, 56 respondents (44.4% of our sample) had full municipal sewer and water services, and 70 (55.6%) did not. Since some areas of appropriately selected ZIP codes fell outside exurban municipalities, our sample included some households that were nearby exurban conditions, but were served by municipal services. Consistent with the widely used regulatory rationale that exurban large lots are required in order to accommodate wells and septic systems, 84.8% of respondents with parcels 0.12 ha (0.3 acres) or smaller had full municipal sewer and water services, while only 1.9% with parcels larger than 1.09 ha (2.7 acres) had these services.

To assess the representativeness of our sample, we compared our sample demographics with census data on income, age, and presence of children (Table 2) for all county subdivisions (townships and cities) with populations below 50,000 within the Detroit, Ann Arbor, Flint MSA. Compared with these data, our sample

Table 2
Comparison of surveyed respondents and 2010 US census data for townships and cities in southeast Michigan.

	Survey data (%)	Census data (%)
Income level		
<$49,000/year	43.06	17.65
$50–74,999/year	19.04	15.69
$75–99,999/year	13.87	27.45
$100–149,999/year	14.71	21.57
$150 or more/year	9.32	17.65
Have children 18 or under	30.22	38.89
Age		
Under 35	43.33	8.70
35–44	13.86	16.70
45–54	16.59	29.40
55–64	13.08	31.70
65 and older	13.14	13.50

Source: US Census Bureau (2010, 2011).

over-represented people between 45 and 65, and under-represented those under 35. It also under-represented households earning less than $49,000 per year, and over-represented those earning more than $49,000. However, our sample demographics are consistent with the subpopulation that we sampled: homeowners, who are on average, older and have higher incomes than those who do not own homes. Our survey slightly over-represented households with children in the home, also possibly related to our homeowner subpopulation.

In our questionnaire and subsequent analysis, we operationalized our research variables in the following way:

- -*Parcel size*: We measured parcel size as a categorical variable, in which each class was described in acres and by comparison with the size of an American football field, an areal measure with which we expected our population would be familiar. For example, respondents could describe their parcel as: *larger than* 1/2 *but smaller than 1 football field (0.7–1.3 acres) (0.28–0.52 ha).* For analysis, we aggregated parcel data into classes that were relevant for our finding that, in our sample, 84.8% of parcels 0.12 ha (0.3 acres) or smaller had full municipal services, and relevant for observing whether parcels larger than approximately one acre would cross a ZOC threshold (Table 3), as found in Nassauer et al. (2014). The 0.53 ha (1.3 acre) parcel size class in our data set was closest to the approximately one acre threshold identified in Nassauer et al. (2014) as shown in Table 1. To validate self-reports of parcel size, we also asked respondents to choose from four visualizations depicting subdivisions with different typical parcel sizes and proportions of forest cover (Table 4) the one that most closely resembled their own neighborhood.
- -*Neighborhood norms*: We measured fit with neighborhood norms using a five-point Likert scale response to: "How much does having a home that fits in well with the neighborhood affect your yard care choices?"
- -*Demographic variables*: We collected interval scale responses on several demographic variables, including the age of the respondent, the length of time they had lived in their home, the number of children 18 or under, the age of their home, and their income.

We operationalized household landscape behaviors in the following ways:

Proportion of parcel mown: To represent the ZOC for analysis, we aggregated responses on proportion of parcel mown into "less than half mown" ($n = 36$) and "more than half mown" ($n = 74$).

Irrigation and fertilization: Respondents reported the number of hours they or someone else spent irrigating their lawn or applying fertilizer in the month of June 2011. We aggregated responses to represent irrigation and fertilization as individual binominal variables.

Leaf removal: In response to a multiple choice item, respondents reported the method they used most for tree and leaf disposal in the fall of 2010.

Large trees: Respondents reported the number of large trees (larger than 12″ diameter at breast height) present on their parcel in a multiple choice question.

Tree planting: Respondents reported the number of trees they had planted and the number they had removed on their parcel in a multiple choice question.

3. Results

Our results support a conclusion that both parcel size and homeowner concern for neighborhood norms are related to homeowner behaviors that are likely to affect carbon storage on exurban residential properties. Furthermore, owners of parcels larger than 0.53 ha (1.3 acres—the approximately one acre threshold suggested by the ZOC concept) mow a smaller proportion of their properties and tend to be less concerned about neighborhood norms. Finally, our results do not support a conclusion that demographic variables are significantly related to homeowner behaviors, independent of parcel size and homeowner concern for neighborhood norms.

3.1. Parcel size

3.1.1. Parcel size validation

Respondents identified neighborhood types (Table 4) consistent with their self-reports of parcel size ($n = 122$, Fisher's Exact Test = 63.93, $p < 0.05$, Pearson Chi-Square = 65.67, $p < 0.05$). Most of the small parcel owners (53.1%) identified the smaller lot conventional subdivision as most like their own neighborhood, the medium-sized parcel owners most frequently (43.8%) selected the medium-parcel subdivision with less forest cover, and nearly all large parcel owners (total of 92.8%) selected either the heavily wooded large parcel subdivision or the rural individual large lot development as most like their own.

3.1.2. Proportion of parcel mown: zone of care

We found a significant difference among parcel sizes in the proportion of parcel mown ($n = 108$, Pearson Chi-Square = 6.83, $p < 0.05$) (Table 3). Mowing less than half the parcel was typical of large parcels (47.5%), but not medium (21.4%) or small (26.9%) parcels. To further validate the "proportion of parcel mown" as a measure of landscape care, we compared proportion of parcel mown with proportion of parcel in other land cover types that were visibly maintained (such as flower and vegetable gardens and pruned shrubs), as well as land cover types that were not visibly maintained (unmaintained understory and unmown herbaceous areas). There was no relationship between proportion of parcel mown and areas in flowers, gardens, or pruned shrubs. However, proportionate area beyond the ZOC was negatively correlated with the mown area ($n = 109$, Pearson's $R = -0.32$, $p < 0.05$ (1-tailed)), meaning that respondents with more than half their parcel in lawn were likely to have smaller areas in unmaintained land cover types. We concluded that proportion parcel mown validly represented the ZOC concept for subsequent analyses.

3.1.3. Irrigation

Significantly fewer large parcel owners irrigated their properties in June 2011 ($n = 110$, Pearson Chi-Square = 7.04, $p < 0.05$), with 51.2% not irrigating at all, compared with only 38.5% of small and 23.3% of medium parcel owners (Table 3). Considering the proportion of parcel mown, there was no significant difference between those who irrigated and those who did not ($n = 110$, Pearson Chi-Square = 0.64, $p > 0.05$).

3.1.4. Fertilization

Fewer respondents ($n = 50$) reported fertilizing than irrigating. Large parcel owners were significantly different from others ($n = 110$, Pearson Chi-Square = 6.74, $p < 0.05$), with about 70.7% of them not fertilizing at all compared with less than half of smaller parcel owners. Considering the proportion of parcel mown, there was also a significant difference between those who fertilized and those who did not ($n = 110$, Pearson Chi-Square = 6.74, $p < 0.05$). 72.2% of those who mowed less than half of their property did not fertilize, while only 45.9% of those who mowed more than half of their parcel did not fertilize (Table 3).

3.1.5. Leaf litter management

Respondents managed leaf litter in several ways, but large parcel owners were significantly more likely ($n = 103$, Fisher's

Table 3
Parcel size related to landscape management behaviors and values about neighborhood norms.

	Parcel size			
Number of respondents	Small: 0.12 ha (0.3 acres) or smaller (% of small parcel owners) $n = 33$	Medium: 0.16–0.53 ha (0.4–1.3 acres) (% of medium parcel owners) $n = 48$	Large: >0.53 ha (1.3 acres) (% of large parcel owners) $n = 42$	Total n
Behavior				
Proportion of parcel mown				
Less than half	7 (26.9%)	9 (21.4%)	19 (47.5%)	35
More than half	19 (73.1%)	33 (78.6%)	21 (52.5%)	73
Total	26 (100%)	42 (100%)	40 (100%)	108
Irrigation				
No	10 (38.5%)	10 (23.3%)	21 (51.2%)	41
Yes	16 (61.5%)	33 (76.7%)	20 (48.8%)	69
Total	26 (100%)	43 (100%)	41 (100%)	110
Fertilization				
No	12 (46.2%)	19 (44.2%)	29 (70.7%)	60
Yes	14 (53.8%)	24 (55.8%)	12 (29.3%)	50
Total	26 (100%)	43 (100%)	41 (100%)	110
Leaf litter disposal				
Carbon conserving				
Nothing/left in place	4 (12.1%)	2 (4.2%)	15 (36%)	21
Composted/moved	6 (18.2%)	16 (33.3%)	13 (31%)	35
Mulching mower	5 (15.1%)	11 (22.9%)	6 (14%)	22
Total of carbon conserving	45.5%	60.4%	81.0%	
Carbon dispersing				
Curb	8 (24.2%)	7 (14.6%)	1 (2.4%)	16
Burned	1 (3.0%)	3 (6.3%)	5 (11.9%)	9
Missing	9 (27.3%)	9 (18.8%)	2 (4.8%)	20
Total	33 (100%)	48 (100%)	42 (100%)	123
Number of large trees				
0	7 (26.9%)	9 (20.9%)	4 (9.8%)	20
1–9	16 (61.5%)	26 (60.5%)	15 (36.6%)	57
>10	3 (11.5%)	8 (18.6%)	22 (53.7%)	33
Total	26 (100%)	43 (100%)	41 (100%)	110
Trees planted				
0	10 (38.5%)	6 (14.0%)	6 (14.6%)	22
1–9	14 (53.8%)	26 (60.5%)	14 (34.2%)	54
>10	2 (7.7%)	11 (25.6%)	21 (51.2%)	34
Total	26 (100%)	43 (100%)	41 (100%)	110
Mean years lived in this home (standard deviation)	12.08 (9.60)	15.59 (9.40)	18.37 (12.33)	107
Neighborhood variables				
Neighborhood association member?				
Yes	12 (36.4%)	21 (43.8%)	4 (9.5%)	37
No	21 (63.6%)	27 (56.3%)	38 (90.5%)	86
Total	33 (100%)	48 (100%)	42 (100%)	123
Neighborhood norms				
Affects very little	4 (15.4%)	4 (9.5%)	17 (41.5%)	25
Affects somewhat	7 (26.9%)	12 (28.6%)	13 (31.7%)	32
Affects very much	15 (57.7%)	26 (61.9%)	11 (26.8%)	52
Total	26 (100%)	42 (100%)	41 (100%)	109

Exact Test = 23.88, $p < 0.05$, Pearson Chi-Square = 23.83, $p < 0.05$) to dispose of their leaves in a way that would increase carbon storage (81.0%): leaving litter in place, composting it, or using a mulching mower (Table 3). Considering proportion of lawn mown, there was not a significant difference in leaf litter management ($n = 102$, Fisher's Exact Test = 2.06, $p > 0.05$, Pearson Chi-Square = 1.86, $p > 0.05$).

3.1.6. Trees

Owners of large parcels had significantly more large trees than others ($n = 110$, Fisher's Exact Test = 17.54, $p < 0.05$, Pearson Chi-Square = 18.27, $p < 0.05$). In addition, they were significantly more likely to have planted 10 or more trees. About a quarter of both small and medium parcels had no large trees. However, owners of small parcels were different: many more (38.5%) had not planted any trees, and about 85% of owners of medium parcels had planted at least one tree. Owners of large parcels tended to plant more trees, with more than half having planted 10 or more (Table 3). There was no significant difference among parcel sizes in the number of trees that respondents had removed from their properties ($n = 110$, Fisher's Exact Test = 3.91, $p > 0.05$, Pearson Chi-Square = 4.09, $p > 0.05$). Considering the proportion of parcel mown, there was no significant difference in the number of large trees present on the parcel ($n = 110$, Fisher's Exact Test = 3.94, $p > 0.05$, Pearson Chi-Square = 4.12, $p > 0.05$) or the number of trees planted ($n = 110$, Fisher's Exact Test = 3.82, $p > 0.05$, Pearson Chi-Square = 3.78, $p > 0.05$).

We also considered age of the home related to the number of large trees present, and how the length of time respondents had lived in their home related to the number of trees planted. Controlling on parcel size in a linear regression with large trees as the dependent variable, we found that house age did not add significant predictive power to the model (df = 104, $R^2 = 0.23$, $p < 0.05$) (Table 5). Using the same approach with trees planted as the dependent variable and controlling on parcel size, we found that the length of time respondents had lived in their homes significantly predicted the number of trees planted: those who had lived in their home longer had planted more trees (df = 106, $R^2 = 0.22$, $p < 0.05$).

Table 4
Exurban subdivision types from Nassauer et al. (2014).

Aerial image	Neighborhood type	Parcel size of respondent			
		Small	Medium	Large	Total
	**Smaller Parcel Conventional Subdivision**	17 (53.1%)	10 (20.8%)	0 (0.0%)	27
	**Horticultural Subdivisions:** Medium-sized parcels with less forest cover	3 (9.4%)	21 (43.8%)	3 (7.1%)	27
	**Remnant Subdivisions:** Wooded larger parcels	10 (31.2%)	15 (31.2%)	20 (47.6%)	45
	**Rural Lots:** Individual large-parcel development	2 (6.2%)	2 (4.2%)	19 (45.2%)	23
	Total:	32 (100%)	48 (100%)	42 (100%)	122

Table 5
Regression models: parcel size with tree dependent variables.

Model	R^2	n	Variables in model	B	Std error	t
Model 1 (Large trees present)	0.234^{*}	105	Parcel size (3-level)	0.856^{*}	0.153	5.581
			House age (interval)	−0.003	0.004	−0.839
Model 2 (Trees planted)	0.216^{*}	107	Parcel size (3-level)	0.521^{*}	0.149	3.501
			Years in home (interval)	0.034^{*}	0.011	3.162

* Levels of statistical significance are $p < 0.05$.

Interestingly, the mean number of years homeowners had lived in their homes increased with parcel size (Table 3).

3.2. *Neighborhood characteristics and concern for neighborhood norms*

3.2.1. *Fit with neighborhood norms*

Owners of large parcels were significantly less concerned about fitting neighborhood norms than owners of small or medium parcels (Table 3). 84.6% of small parcel owners and 90.5% of medium parcel owners reported their yard care choices were affected (somewhat or very much) by a desire to fit in, compared with only 58.5% of large parcel owners ($n = 109$, Fisher's Exact Test = 15.93, $p < 0.05$, Pearson Chi-Square = 16.28, $p < 0.05$).

3.2.2. *Neighborhood associations*

While only 31.7% of respondents reported being in a neighborhood association, membership was significantly related to parcel size ($n = 123$, Fisher's Exact Test = 14.40, $p < 0.05$, Pearson Chi-Square = 13.32, $p < 0.05$). Few large parcel owners (9.5%) belonged to a neighborhood association, while 43.8% of medium parcel owners and 36.4% of small parcel owners belonged. However, we did not find a significant difference between those who did and did not belong to a neighborhood association in the proportion of parcel mown ($n = 110$, Pearson Chi-Square = 1.89, $p > 0.05$).

3.3. *Parcel size and neighborhood norms*

We used logistic regression to test whether, together, parcel size, and concern for fitting neighborhood norms predict proportion of parcel mown. Logistic regression is an effective way to test the relationship between variables with a dichotomous dependent variable (Kleinbaum & Klein, 2010).

Our first model tested parcel size and concern for neighborhood norms as independent variables entered individually (Table 6). This model was significant ($n = 107$, Cox & Snell $R^2 = 0.06$, Nagelkerke $R^2 = 0.08$, $p < 0.05$), but neither of the independent variables alone was significant ($p > 0.05$). We then created dummy variables that combined neighborhood norms and parcel size in the following five variables: (1) large parcel owners who stated that neighborhood norms affected their yard care very little, (2) small and medium-sized parcel owners who stated that neighborhood norms affected their yard care very little, (3) all parcel owners who stated that neighborhood norms affected their yard care somewhat, (4) small and medium-sized parcel owners who stated that neighborhood norms affected their yard care very much, and (5) large parcel owners who stated that neighborhood norms affected their yard care very much. This model was statistically significant ($n = 107$, Cox & Snell $R^2 = 0.09$, Nagelkerke $R^2 = 0.12$, $p < 0.05$) with greater predictive power than Model 1.

3.4. Demographic variables: income, children, and age

We used logistic regression to test the relationship between proportion of parcel mown and demographic variables (income, respondent age, and having children under 18). The first model included each of the three demographic variables as independent variables and the proportion of parcel mown as the dichotomous dependent variable. This model was not significant ($n = 105$, Cox & Snell $R^2 = 0.04$, Nagelkerke $R^2 = 0.05$, $p > 0.05$) (Table 7). We then used a similar method as employed above for assessing concern for fitting into the neighborhood, controlling for parcel size, and using dichotomous independent variables with proportion of parcel mown as a dichotomous dependent variable. Though parcel size was significant ($n = 93$, Wald = 4.43, $p < 0.05$), this model was not significant ($n = 93$, Cox & Snell $R^2 = 0.08$, Nagelkerke $R^2 = 0.11$, $p > 0.05$).

3.4.1. Income

Income did not significantly predict proportion of parcel mown ($n = 95$, Cox & Snell $R^2 = 0.00$, Nagelkerke $R^2 = 0.00$, $p > 0.05$) (Table 7). Controlling on parcel size, the regression model was not significant ($n = 93$, Cox & Snell $R^2 = 0.06$, Nagelkerke $R^2 = 0.09$, $p > 0.05$), nor was the dichotomous income variable (more or less than 100k) ($n = 93$, $p > 0.05$, Wald = 0.43). The model that included income, parcel size, and the interaction between income and parcel size was also not significant, nor were any of the variables ($n = 93$, Cox & Snell $R^2 = 0.07$, Nagelkerke $R^2 = 0.09$, $p > 0.05$).

3.4.2. Children

Our next model (Table 7) included children living at home as the only independent variable, and it significantly predicted proportion of parcel mown ($n = 110$, Cox & Snell $R^2 = 0.040$, Nagelkerke $R^2 = 0.06$, $p < 0.05$). However, controlling on parcel size, “children” was not significant ($n = 108$, Wald = 2.29, $p > 0.05$), but parcel size was significant ($n = 108$, Cox & Snell $R^2 = 0.08$, Nagelkerke $R^2 = 0.11$, $p < 0.05$). Our next model used the interaction between parcel size and having children at home, along with parcel size and children, as the independent variables. The model was significant ($n = 108$, Cox and Snell $R^2 = 0.10$, Nagelkerke $R^2 = 0.14$, $p < 0.05$), as was the children variable ($n = 108$, $p < 0.05$, Wald = 4.30), but neither the interaction term nor parcel size were significant. In our sample, the presence of children appears to affect proportion of lawn mown.

3.4.3. Age

Age alone did not significantly predict proportion of parcel mown ($n = 110$, Cox & Snell $R^2 = 0.00$, Nagelkerke $R^2 = 0.00$, $p > 0.05$) (Table 7). Controlling for parcel size, the model was significant ($n = 108$, Cox & Snell $R^2 = 0.06$, Nagelkerke $R^2 = 0.08$, $p < 0.05$), but age was not ($n = 108$, Wald = 0.09, $p > 0.05$). The next model using the interaction between age and parcel size was significant ($n = 108$, Cox & Snell $R^2 = 0.08$, Nagelkerke $R^2 = 0.11$, $p < 0.05$). Homeowners younger than 45 tended to own smaller parcels.

4. Discussion

We found that parcel size is related to household landscape behaviors that may affect carbon storage: proportion of the parcel mown, use of irrigation, use of fertilizer, retention of leaf litter on the parcel, presence of large trees on the parcel, and planting of trees. Compared with others, owners of parcels larger than 0.53 ha (1.3 acres) more typically mowed a smaller proportion of the parcel (allowing a larger proportion of their parcel to be forested or in brush) and retained leaf litter on the parcel. They also tended to have more large trees and plant more trees. While the presence of recently planted trees may have little immediate affect on carbon storage, the legacy effect could be significant. Notably, owners of medium-sized parcels were likely to plant more trees than owners of small parcels (0.12 ha [0.3 acres] or less). However, they were very similar to owners of small parcels in their other behaviors and in their attention to neighborhood norms. For example, owners of medium-sized and small parcels typically irrigated or used fertilizer. While these behaviors have well-known environmental costs, they also may enhance carbon storage in some ecoregions. Overall, our findings support Nassauer et al.’s (2014) identification of an approximately one acre parcel size threshold, beyond which several behaviors that promote woody vegetation increase. These findings also are consistent with observations in Baltimore, MD (Zhou et al., 2008), that larger residential parcels included a less tended area that was more distant from the house. They also support Robinson (2009) suggestion that increasing parcel size may limit management of exurban residential land. This is important because the proportion of a parcel in mown turf may store less carbon per area compared with forest cover without a turf understory, or deep-rooted perennial herbs.

We also found that concern for fitting neighborhood norms is significantly related to parcel size. Large parcel owners were less concerned about fitting neighborhood norms than were owners of either small or medium-sized parcels. The size and spatial configuration typical of large parcels in southeast Michigan often results in wooded visual buffers between neighboring yards, and this may reduce perceived pressure to fit in with neighborhood landscape styles. At the same time, those who are less concerned about fitting neighborhood norms may sort themselves by choosing large parcels. Regardless, concern about neighborhood norms may drive the higher proportion of mown turf, removal of leaf litter, and more frequent irrigation and fertilization behaviors that characterize small and medium-sized parcels.

Importantly, we found that parcel size combined with concern for neighborhood norms significantly predicts proportion of parcel mown. This supports the exurban homeowner behavioral typology (Table 1) developed by Nassauer et al. (2014), which describes owners of large parcels as mowing a proportionately smaller area and being less concerned about fitting neighborhood landscape norms, compared with owners of small and medium-sized parcels. The typology describes small parcel owners as tending to be more concerned about neatness and mowing nearly all their parcel, medium-sized parcel owners as planting more trees but also having high concern for neatness, and large parcel owners as

Table 6
Logistic regression models: parcel size and concern about fitting into the neighborhood with proportion of parcel mown as dependent variable.

Model	Cox and Snell R^2	Nagelkerke R^2	n	Variables in model	B	Wald
Model 1*	0.058	0.081	107	Parcel size (small, medium, large)	−0.415	2.031
				Neighborhood norms (does not affect, somewhat affects, affects very much)	0.212	2.446
Model 2*	0.085	0.119	107	Norms no affect and small/medium parcel	0.539	0.274
				Norms no affect and large parcel	−0.560	0.487
				Norms somewhat affect and small/medium/large parcel	−0.356	0.255
				Norms affect and small/medium parcel	1.021	1.844
				Norms affect and large parcel (not entered)	–	–

* Levels of statistical significance are $p < 0.05$.

Table 7
Logistic regression models: parcel size and demographic variables with proportion of parcel mown as dependent variable.

Model	Cox and Snell R^2	Nagelkerke R^2	n	Variables in model	B	Wald
Demographics1	0.037	0.051	95	Income (more or less than 100k)	−0.030	0.005
				Children (present or not)	0.899	3.031
				Age (interval-level)	0.006	0.076
Demographics2	0.077	0.106	93	Income (more or less than 100k)	−0.287	0.358
				Children (present or not)	0.645	1.445
				Age (interval-level)	0.007	0.099
				Parcel size (large or not large)	−1.005*	4.431
Income1	0.000	0.000	95	Income (more or less than 100k)	−0.029	0.004
Income2	0.062	0.085	93	Income (more or less than 100k)	−0.312	0.430
				Parcel size (large or not large)	−1.117*	5.703
Income3	0.065	0.089	93	Parcel size (large or not large)	−0.389	0.077
				Income (more or less than 100k)	−0.095	0.024
				Income (more or less than 100k) BY parcel size (large or not large)	−0.533	0.300
Children1*	0.040	0.055	110	Children (present or not)	0.901*	4.220
Children2*	0.079	0.110	108	Children (present or not)	0.688	2.290
				Parcel size (large or not large	−0.978*	5.067
Children3*	0.100	0.140	108	Parcel size (large or not large)	−0.507	0.952
				Children (present or not)	1.330*	4.303
				Children (present or not) BY Parcel Size (large or not large)	−1.474	2.444
Age1	0.003	0.004	110	Age (interval)	−0.010	0.307
Age2*	0.059	0.083	108	Age (interval)	−0.006	0.094
				Parcel size (large or not large)	−1.073*	6.310
Age3*	0.076	0.106	108	Parcel size (large or not large)	−3.867	3.356
				Age (interval)	−0.029	1.259
				Age (interval) by parcel size (large or not large)	0.053	1.850

* Levels of statistical significance are $p < 0.05$.

tending to mow a smaller proportion of their parcel and being less likely to irrigate or fertilize.

In predicting proportion of parcel mown, we also found a significant interaction between parcel size (comparing large parcels with all others) and some demographic characteristics including age and having children at home. However, our study supports results of previous studies that have found that demographic and socioeconomic characteristics alone are not sufficient to predict homeowner parcel management and residential land cover.

5. Conclusion

Our results suggest that parcel size is a legacy decision that affects future carbon storage in woody vegetation of exurban residential landscapes. In our study area, a temperate forest biome characterized by row crop agriculture, undeveloped agricultural land has a lower proportion of forest cover than exurban development overall (An et al., 2011). Consequently, if households that own residential parcels larger than approximately one acre manage their properties in ways that store more carbon per area than households in denser development patterns, as our results suggest, then land use policy could account for their carbon storage ecosystem service. Especially given that exurban residential development is the dominant form of metropolitan land use, governance of landscapes designated for low-density development could promote development patterns that store more carbon. Our results suggest that where large lot zoning is already used to maintain rural character or protect drinking water sources, a governance strategy common in exurban America, a minimum parcel size of approximately one acre or larger would deliver more carbon storage per area than smaller parcel sizes in temperate forest biomes of the US. Where exurban residential landscapes already exist, governance strategies might target large parcel owners, who are less concerned with neighborhood norms and own more property beyond the conventional one acre ZOC, as likely participants in programs for reforestation and wetland restoration to enhance carbon storage.

At the same time, the carbon costs of motorized travel and the related benefits of less extensive residential development patterns are well known (NRC, 2009). Where governance encourages relatively more dense exurban residential development and household behaviors that enhance carbon storage are desired, subdivisions might be designed differently to promote those behaviors.

Our results suggest a strong desire among small and medium parcel owners to conform to neighborhood norms, which has been typified by a weed-free green turf lawn. Implying possibilities for moving beyond such norms even on smaller parcels, Nassauer et al. (2009) found that exurban homeowners prefer to have landscapes that look like their neighbors—even where their neighbors' yards look somewhat unconventional compared to broad cultural norms for extensive turf lawns. Rather than relying only on adoption by individual homeowners, governance that promotes ecological design in "clumps" or large connected patches of neighbors—within entire blocks or across entire subdivisions of smaller parcels—may achieve wider adoption of carbon storing landscape behaviors. Developers' interactions with governance through zoning ordinances, planning or design approvals, and formation of neighborhood association rules are opportunities to engineer "clumps" of ecological design innovation on smaller parcels. Another opportunity might come in the form of financial incentives to homeowners for retrofitting existing exurban parcels to enhance carbon storage, in much the same way that household renewable energy retrofitting has been incentivized by state and federal governments in the USA. Our research contributes to a suggestion that homeowners may be more responsive to financial incentives if they are offered on large parcels or if they are offered on entire blocks or subdivisions of smaller parcels.

While our study focused on carbon storage, the governance strategies that we describe here would affect other ecosystem services as well, including habitat, air quality, human activity and well-being, surface and ground water quality and management and nutrient flows. Each of these ecosystem services should be considered in governance and design strategies for a multi-functional exurban landscape.

Acknowledgments

We gratefully acknowledge the support of the National Science Foundation Collaborative Research Program for our project, Spatial Land-Use Change and Ecological Effects (SLUCE): Interactions of Exurban Land Management and Carbon Dynamics (Grant #GEO-0814542), and the Environmental Protection Agency STAR Fellowship (Assistance Agreement FP91750901-1). We thank all of our collaborators including Scott Page, Derek Robinson, Shipeng Sun, Rick Riolo, Sarah Kiger, Ayehlet Cooper, and Meghan Hutchins.

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