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Research Paper

Parcel size related to household behaviors affecting carbon storage in exurban residential landscapes

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HIGHLIGHTS

- Cultural norms relate to how much of a parcel is intensively maintained.
- Parcels larger than 1.1 acre (0.45 ha) typically have a part that is less maintained.
- Smaller parcels are comprehensively maintained: this may affect carbon storage.
- Parcels larger than 0.5 acre (0.20 ha) have more mature trees and more trees planted.
- Adjacent property characteristics may affect small parcel land cover.

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ABSTRACT

We investigated whether exurban parcel size might be related to homeowners' behaviors that could affect carbon balance in residential landscapes. Based on data drawn from in-depth interviews and field surveys in 26 southeast Michigan exurban households, we conclude that an approximately 1-acre (0.45 ha) size may be a critical threshold for certain behaviors, such as leaving a portion of an exurban parcel in forest or old field or retaining leaf litter on the property. Tree planting is a relevant behavior that may increase when parcels are larger than 0.5 acres (0.20 ha). Yard style of adjacent properties also appears to be related to homeowners' landscape management behaviors: conventional turf-dominated yards prevail adjacent to parcels smaller than one-acre. We used our analysis of these data to develop an exurban homeowner typology to be employed in agent based models in which homeowners' behaviors that may affect carbon balance are linked to parcel size.

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1. Introduction

This paper reports our investigation of exurban homeowners' landscape care behaviors related to carbon storage in exurban residential landscapes, a pervasive, growing land use. Housing development is a primary cause of anthropogenic landscape change worldwide (Hammer, Stewart, Winkler, Radeloff, & Voss, 2004), and much of this is 'exurban' development – low-density settlements that are contiguous with urbanized areas but typically disconnected from government services of sanitary sewer and water (An, Brown, Nassauer, & Low, 2011). Exurban residential landscape dynamics operate within coupled natural and human systems (CNHS) that affect ecosystem services at local scales and aggregate to affect global processes (Hammer et al., 2004; Liu et al., 2007; Radeloff, Hammer, & Stewart, 2005; Theobald, 2005), and household-scale mechanisms are core elements of these systems (Cook, Hall, & Larson, 2012, Fissore et al., 2011). The large parcel size that characterizes exurban landscapes creates a powerful legacy effect, ensuring that exurban households occupy disproportionately large areas of land, and Americans have repeatedly expressed a preference for living in large lot residential development (Alig, Kline, & Lichtenstein, 2004; Fernandez, Brown, Marans, & Nassauer, 2005; Talen, 2001). By 2001, about 4% of the land area of the coterminous US was in exurban development, which was the fastest growing land use, increasing fivefold in the last half of the 20th century (Brown, Johnson, Loveland, & Theobald, 2005; Heimlich &

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Anderson, 2001; Vesterby & Krupa, 2002). In the Upper Great Lakes Region alone metropolitan regions doubled in size over the last 20 years, despite relatively low population growth (Pijanowski & Robinson, 2011).

We investigated whether homeowner behaviors that could affect carbon storage might be related to parcel size, and whether some of these behaviors might be related to social norms, including expectations for neatness or for matching the yard style of nearby neighbors. Behaviors we explored include: managing part of the parcel to be less neat or untended, maintaining existing trees, including canopy trees in the mown part of the parcel, planting trees, and disposing of leaf litter. We also posited that other homeowner behaviors that could indirectly affect carbon storage by encouraging more woody vegetation might vary with parcel size. These were having an enclosed backyard, having a backyard that was not extremely neat, and enjoying viewing wildlife on the property. We also investigated the used of lawn fertilizer for a possible relationship with parcels' having higher proportions of turf.

Parcel size is driven by land use controls, perceived market demand, and land development decisions by regulators and developers (Vigmostad, 2004) as well as social norms (Grove et al., 2006; Harris et al., 2012; Nassauer, Wang, & Dayrell, 2009). In addition, homebuyers sort themselves within the residential real estate market according to their preferences and buying power. Regardless of sorting behavior, homebuyers who become homeowners change their parcels, managing vegetation and sometimes changing land cover.

Our study focused on exurban areas in 10 counties in southeast Michigan that vary in population density from urban to rural. The investigation we report here is part of a larger examination of exurban residential development, which links developer choices, homeowner behaviors, land markets, and the ecological dynamics of vegetation and soils to understand drivers of exurban landscape change related to landscape carbon balance.

Exurban areas and carbon storage. Exurban areas, characterized by relatively low population density and large parcel sizes, have been described as having particular ecological effects and associated ecosystem services based on land cover types and patterns (e.g., Brown, Pijanowski, & Duh, 2000), surface hydrology (e.g., Armstrong & Stedman, 2012; Groffman et al., 2003), and terrestrial habitat quality (e.g., Hansen et al., 2005). For example, exurban residential land use may enhance nutrient cycling and downstream hydrology compared with either agriculture or denser, more impervious urban land cover (Armstrong & Stedman, 2012; Nassauer, Allan, Johengen, Kosek, & Infante, 2004), and may increase forest cover on former cropland in some biomes (Brown et al., 2008).

Compared with cropland, forest and grassland sequester more carbon (Laganiere, Angers, & Pare, 2009; Rhemtulla, Mladenoff, & Clayton, 2009). While carbon storage rates in urban forests may vary substantially from state to state (Nowak, Greenfield, Hoehn, & Lapoint, 2013), residential areas that have more forest (including canopied turf areas), as well as management that retains dead wood and leaf litter rather than burning or transporting it, may store more carbon than conventional turf-grass landscapes (Fissore et al., 2012; Milesi et al., 2005; Morris & Bagby, 2008).

Exurban land use and parcel size. Highly relevant to our investigation, Robinson (2012) found that, across the range of relatively large parcel sizes that characterize exurbia, the forested proportion of a parcel increased with parcel size. Using 10 m land cover and parcel data for three southeast Michigan townships, he found that mean patch size of forest or other "natural" area increased exponentially with increased parcel size. Large parcels with large proportions of forest were likely to be adjacent to similar parcels (Robinson, 2009), and as parcel size increased, connected habitat patch size increased. The proportion of the parcel in turf or impervious surfaces decreased with increased parcel size. Importantly, Robinson (2012) suggested that this may occur because there are "limits to anthropogenic management of land within parcels with increasing size" (p. 95).

Other studies describe a relationship between parcel size and homeowner behavior. Vermont exurban homeowners' willingness to include forests on their properties was found to be partially dependent on parcel size (Erickson, Lovell, & Méndez, 2011). In southeast Michigan, small, private forest owners were found to take a 'hands-off' approach to forest management, allowing land to revert to forest near stream and field edges (Erickson, Ryan, & De Young, 2002).

Residential behaviors, demographics, and social norms. Homeowner behaviors that affect landscape carbon storage may be related to household demographic characteristics. A Baltimore, MD, study found that while demographic characteristics alone were not strongly related to land cover, combinations of demographic characteristics (e.g., family size, education, ethnicity, marriage), aggregated within US Census blocks, were related to proportion of forest or grass cover (Troy, Grove, O'Neil-Dunne, Pickett, & Cadenasso, 2007). They inferred that household land management decisions are influenced by a desire to assert influence within a group.

This is consistent with research demonstrating that residential landscape behaviors are significantly influenced by societal and community norms (Blaine, Clayton, Robbins, & Grewal, 2012; Lovejoy, Handy, & Mokhtarian, 2010; Nassauer et al., 2009). A homeowner's property is a means of self-presentation, and it is typically intended to be viewed by others (Nassauer, 1988). Physical evidence of landscape care is critical to self-presentation as a "good neighbor". It connotes civility or neighborliness, safety, and marketability or productivity. Widely recognized evidence of care in residential landscapes includes: mown turf, trimmed trees and hedges or neat rows, colorful flowers, and visible, crisp edges of different patch types (Nassauer, 2011). While excessive mowing, paving, irrigation, or application of herbicides or pesticides have well-known detrimental environmental effects, these behaviors are motivated in part by a desire to maintain a neat landscape appearance (Nassauer, 1997). Parts of residential landscapes that store more carbon than turf-grass alone (i.e., "brushy" areas, downed dead wood, small wetlands, remnant patches) often look less well-cared-for, and consequently may be removed to conform with neatness norms (Nassauer, 1995).

In exurban residential properties, front yards exhibit a higher level of tidiness, expressing care, than do backyards (Harris & Brown, 1996; Hess, 2008; Schroeder, 1993). Backyards may be more varied in their maintenance and usage, allowing more flexible, innovative, and personal design and maintenance choices (Larsen & Harlan, 2006; Quayle & van der Lieck, 1997).

Compared with broader cultural norms, neighborhood norms may more powerfully influence homeowner yard management. A southeast Michigan study found that the land cover in adjacent neighbors' front yards dramatically affected exurban homeowner preferences for their own front yards (Nassauer et al., 2009). Local area norms also were found to strongly affect preference for habitat of residential landscapes in Perth, AU (Kurz & Baudains, 2012), and group identity was found to affect neighborhood vegetative characteristics in Baltimore, MD (Boone, Cadenasso, Grove, Schwarz, & Buckley, 2010). Finally, a study in Ann Arbor, MI, found that certain front yard garden features were more likely to be observed if a nearby property had the same features (Hunter & Brown, 2012). These studies all suggest that neighborhood norms strongly influence homeowners' choices of land covers and management regimes.

Research in social psychology (Asch, 1951; Crutchfield, 1955) and economics (Bernheim, 1994; Bikhchandani, Hirshleifer, & Welch, 1992) concludes that individuals tend to adjust their

behavior or stated preferences to conform to those of others. Conformity in behavior such as collective action or following the law (Kuran, 1990; Posner, 1998) can result either from psychological causes – to fit in, to be liked, or to signal awareness of current trends - or from economic incentives. Economists have shown that, viewing the actions of others as signals, individuals may rationally conform to match others. In residential landscapes, both psychological and economic causes likely play roles. Individuals probably do want to be liked by and fit in with their neighbors. They might also perceive that landscape decisions by others reveal information about market prices, costs, or even environmental impacts affected by behavioral choices.

2. Methods

In this exploratory study we used ethnographic techniques (e.g., Westphal, Longoni, LeBlanc, & Wali, 2008). We interviewed 26 southeast Michigan exurban homeowners at their homes and outdoors on their property. In addition, our team conducted biophysical site surveys, sampling vegetation and soils on each property. Interdisciplinary, combined quantitative and qualitative studies of residential development as socio-environmental systems are particularly needed (Cook et al., 2012; Kondo, Rivera, & Rullman, 2012). Analysis of data from a small sample can yield insights for building agent-based models (ABMs), which explore dynamics among agents in coupled natural and human systems (CNHS) (An, 2012), as well as for developing hypotheses for investigation with larger data sets (e.g., Alberti & Hutyra, 2009). Our study was subsequently used in both of these ways (Robinson et al., 2012).

Populating ABMs with research-relevant agent characteristics is a critical element in many CNHS investigations (Robinson et al., 2007; Smajgl, Brown, Valbuena, & Huigen, 2011), and analysis of our interview data was essential to characterizing agents for ABMs within our larger project. The basis for characterizing agent types within CNHS research varies widely – sometimes including expert opinion, literature reviews ethnographic small sample investigations, or representative sample surveys (Rounsevell, Robinson, & Murray-Rust, 2012). ABMs can simulate the dynamics of human behavior; representing humans as learning, adapting, and evolving agents that affect each other (An, 2012).

The analysis we report here is based on observational data from each home landscape and interview participants' reports of their own behavior. Our study area is southeast Michigan, a 10-county (Genesee, Lapeer, Lenawee, Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne) area of 15,060 km^2 with an estimated population of 5.1 million in 2010 (US Census Bureau, 2010). Our sample was drawn from addresses voluntarily provided by 600 exurban homeowners who responded to a 2005 web survey. In order to control for soil carbon storage potential related to biophysical site sampling we selected 53 addresses that were unlikely to have soils high in clay content. We mailed postcards and followed up with a phone call to request interviews. Twenty-one households agreed to participate. To increase sample size, we sent postcards (following up with a phone call) to an additional 53 addresses, each selected by drawing an address two parcels away from an initial sample address. This yielded five additional households for a total of 26 respondents (overall 25% response rate) with home site parcel sizes from 0.2 to 5.4 acres (0.08–2.2 ha).

All interviews were conducted in June–August 2009 by a pair of trained interviewers at respondents' homes. Interviews lasted 2–3 h. The questionnaire included both open-ended and forced-answer items about yard care behaviors and home landscape preferences, and also included demographic information. Interviewers accompanied each respondent into their yard to elicit information that allowed our team to delineate the parcel into areas with distinct management regimes, and these were photographed in subsequent site visits. All interviews were tape-recorded. Areas of distinct management regimes within each parcel were digitized using Arc GIS 9.3 and we employed field notes and maps to characterize land cover and site images to identify mature trees of indigenous species on the parcel. Finally, we classified adjacent properties' land cover using 2005 aerial images from the National Agriculture Imagery Program (NAIP) (2 m resolution). All data were incorporated into a database that linked parcel characteristics, neighboring parcel characteristics, homeowners' behaviors and preferences, and demographic variables for each household.

Using SPSS 20 and 21, we iteratively employed cross-tabular analyses and reexamination of primary data to explore possible relationships among parcel characteristics, household characteristics and behaviors, and parcel size (Table 1). In this exploratory study, we sought to identify possible relationships that could be tested in subsequent confirmatory studies, with the general hypothesis that parcel size is related to certain landscape management behaviors that have implications for carbon storage in residential subdivisions, and the secondary hypothesis that some of these behaviors are affected by social norms for neatness and for conformity with the appearance of neighboring properties. Below we describe the variables we measured as: parcel characteristics that are not immediately controlled by the homeowner, parcel characteristics that are affected by homeowner behaviors, reported homeowner behaviors, and homeowner demographic characteristics.

Parcel characteristics that are not immediately controlled by the homeowner (but that may have been relevant to home buying choice) included approximate decade of development and subdivision type, which we defined as conventional if the subdivision design did not include remnant ecosystems, as remnant if the design did include remnant ecosystems, and as single lots if the parcel was not part of a subdivision (An et al., 2011). To gain a sense of the strength of neighborhood design norms, we also documented neighboring yard styles compared with the sample parcel: all dominated by conventional turf, all dominated by more unconventional land covers, or varying among neighbors.

Parcel characteristics that are affected by homeowner behaviors. These characteristics focused on the Zone of Care (ZOC), a pivotal concept that emerged from our exploration of these data. The ZOC is the area of the parcel under frequent visible maintenance and extending continuously from the house. It includes areas that are regularly mown or maintained as food or ornamental gardens. We noted the proportion of the ZOC that was in wooded turf, as opposed to turf without woody canopy.

We refer to the area of the parcel not under frequent visible maintenance as the area beyond the ZOC. This area was typically forested in exurban sites in our study area. We also noted the number of mature trees (caliper > 3–4″ (7.6–10.1 cm)) on the parcel that were horticultural species (and consequently indicative of past tree planting) or indigenous species (and more likely indicative of the homeowners' choice to maintain the tree rather than remove it).

Other ZOC characteristics that are evident products of homeowner behavior specifically refer to backyard appearance. We defined the backyard as extending back from the front façade of the house, including all of the ZOC not within the front yard. Relevant backyard characteristics were:

Backyard-enclosure. Visibility from the backyard into others' property. Fully enclosed backyards are not visible from the street or other properties. Enclosure may allow homeowners to pursue more 'unconventional' landscape management choices (e.g., unmown or wooded areas) that could enhance carbon storage. In addition, trees and shrubs that achieve enclosure also enhance carbon storage.

Backyard-neatness. Apparent maintenance of the backyard, operationalized as the degree to which backyard, non-turf patches

Table 1
An exurban homeowner typology supported by analysis of parcel size, other parcel characteristics, household behaviors, and demographics.

	Parcel type					
	Small parcel, small zone of care			Medium parcel, medium zone of care	Large parcel, small zone of care	Large parcel, large zone of care
	Homeowner type					
Variables	Neat neighbor ($n = 6$)	Lakeshore property Owner ($n = 3$)	Nature neighbor ($n = 2$)	Tree planter ($n = 7$)	Improver ($n = 4$)	Viewer ($n = 4$)
Parcel characteristics						
Subdivision type	Conventional (6)	Remnant lake (3)	Remnant forest (1) Conventional (1)	Conventional(6) Single lot (1)	Remnant forest (1) Single lot (3)	Remnant forest (2) Single lot(2)
Yard style similarity with neighboring yards	Similar conventional (5) Varied (1)	Similar unconventional (1) Varied (1) Not similar (1)	Varied (1) Not similar (1)	Similar conventional (6) Not similar (1)	Similar unconventional (2) Not similar (1) No residential adjacent (1)	Similar unconventional (1) Varied (2) Not similar (1)
Time of development	1960s–80s (1) 1990s–2009 (5)	Before 1960 (2) NA (1)	1960s–80s (1) 1990s–2009 (1)	1960s–80s (4) 1990s–2009 (3)	Before 1960 (2) 1960s–80s (1) 1990s–2009 (1)	1960s–1980s (2) 1990s–2009 (2)
Parcel characteristics affected by homeowner behaviors						
Landcover beyond zone of care	None (6)	None (3)	None (1) Forest (1)	None (7)	Forest (2) Mixed (2)	Forest (2) Field (2)
Mature trees on parcel	Absent (5) Horticultural (1)	Horticultural (1) Indigenous (2)	Indigenous (2)	Absent (2) Horticultural (5)	Indigenous (4)	Horticultural (1) Indigenous (3)
Proportion of wooded turf vs. unwooded turf within zone of care	Equal proportions (3) More unwooded turf (2) More wooded turf (1)	Equal proportions (1) More wooded turf (2)	More unwooded turf (1) More wooded turf (1)	More unwooded turf (3) More wooded turf (4)	More unwooded turf (1) More wooded turf (3)	More unwooded turf (1) More wooded turf (3)
Enclosure: backyard visible from adjacent property?	No (5) Yes (1)	No (2) Yes (1)	Yes (2)	No (4) Yes (3)	No (1) Yes (3)	Yes (4)
Neatness: backyard gardens and plantings weed-free with crisp edges?	Very neat (6)	Very neat (1) Less neat (2)	Less neat (2)	Very neat (4) Less neat (3)	Very neat (1) Less neat (3)	Less neat (4)
Reported homeowner behaviors						
Planting trees	Never (3) One (1) More than one (2)	Never (3)	Never (1) One (1)	Never (1) One (2) More than one (4)	Never (1) One (2) More than one (1)	More than one (4)
Using lawn fertilizer	Yes (6)	No (1) Yes (2)	No (2)	Yes (5) Unknown (2)	No (3) Yes (1)	No (1) Yes (3)
Disposing of leaves	Removed from parcel (4) Left on parcel (2)	Removed from parcel (2) Left on parcel (1)	Left on parcel (2)	Removed from parcel (3) Left on parcel (4)	Removed from parcel (1) Left on parcel (3)	Left on parcel (4)
Enjoying wildlife on property	No (2) Yes (4)	No (3)	No (1) Yes (1)	No (3) Yes (4)	Yes (4)	Yes (4)
Homeowner demographic characteristics						
Interviewee age	<55 years (5) NA (1)	55+ years (1) 2 NA (2)	<55 years (1) 55+ years (1)	<55 years (3) 55+ years (3) 1 NA (1)	<55 years (1) 55+ years (3)	<55 years (1) 55+ years (1) NA (2)
Children at home	No (2) Yes (4)	No (2) Yes (1)	No (1) Yes (1)	No (3) Yes (4)	No (3) Yes (1)	No (3) Yes (1)

are apparently weed-free and have visibly crisp turf edges. This was relevant only to backyards because all except one front yard in our sample were neat.

Reported homeowner behaviors describe *ongoing homeowner behavior* as reported by the homeowners in the interviews. These include:

Planting trees. Whether the homeowner had planted no trees, one tree, or more than one tree on the parcel.

Using lawn fertilizer. Whether lawn fertilizer had been used in the previous month.

Disposing of leaves. Whether leaves were disposed of on the property (e.g., by mulching or moving to some area on the property) or moved off the property (e.g., by bagging or burning).

Enjoying wildlife. Whether homeowners stated that they enjoyed viewing wildlife in their yard. This could affect whether the parcel would have more woody vegetation.

Demographic characteristics of homeowners. These variables were initially examined for their possible relationship to landscape behavior: age, having children (18 or under) in the household, education, and income. With our small sample, we searched for possible clues to demographic variation that could be investigated in a subsequent, large sample survey.

3. Results

3.1. Parcel characteristics

In this section we describe parcel characteristics that may have implications for carbon storage.

Parcel size. In our sample, 8 parcels were large (>1.1 acre), 7 were medium (0.5–1.1 acre), and 11 were small (≤0.5 acre). ZOC size nearly always equaled parcel size for small and medium lots. That is, for these parcels, the entire yard was managed as a ZOC. However, for large parcels, ZOC rarely occupied the entire parcel. In these parcels, the ZOC varied widely in size but was nearly always much smaller than parcel size, frequently even smaller than the ZOC of smaller parcels (Fig. 1). Consequently, large parcels have a much larger area beyond the ZOC, absolutely and as a proportion of parcel. This result is consistent with Robinson's (2012) conclusion that larger parcels had a higher proportion of forest cover. This finding suggests that there is an approximately 1 acre threshold, beyond which there is increased variation in the size of the ZOC. Also consistent with Robinson, we found wooded or old field cover beyond the ZOC.

Zone of care and parcel size. To understand how homeowner behavior might account for the one acre threshold and to explore further how homeowner behavior might vary among parcel sizes, we categorized parcels by their size in combination with the relative size of their ZOC (Fig. 1): Small Parcels (≤0.5 acre, 0.20 ha); Medium Parcels (0.5–1.1 acre, 0.20–0.45 ha); Large Parcels (>1.1 acre, 0.45 ha) with Large ZOC (>1 acre, 0.40 ha); and Large Parcels (>1.1 acres, 0.45 ha) with Small ZOC (<1 acre, 0.40 ha) (Table 1).

Subdivision type. Large parcels were individual lots (not part of a subdivision) or were in subdivisions that included forest remnants. All medium parcels and most small parcels were in more conventional subdivisions. However, three of the eleven small parcels were lakeshore lots and two were adjacent to forest remnants, one of which was in a remnant subdivision.

Time of development. Proportionately, small parcels had somewhat more houses built after 1990.

Yard style similarity with neighboring yards. No large parcels were surrounded only by conventional yards, but nearly all medium parcels and about half of small parcels were surrounded only by conventional yards dominated by turf. Large parcels were more often surrounded only by unconventional yards not dominated by turf. Having a yard that was dissimilar from neighbors was unusual at any parcel size.

3.2. Parcel characteristics that are affected by homeowner behaviors

In this section we describe those parcel characteristics that are affected by homeowner behaviors that may have implications for carbon storage.

Wooded turf. Proportionately, the amount of wooded turf within the ZOC increased from small to medium to large parcels.

Land cover beyond the ZOC. As noted above and in Fig. 1, the area beyond the ZOC is much more extensive for parcels larger than 1.1 acre. Except for a small parcel adjacent to forest, only large parcels in our sample had any area beyond the ZOC. More large parcels with small ZOC had at least some forest beyond the ZOC, while about half of those with large ZOC were dominated by old fields beyond the ZOC.

Mature trees. More large parcels contained mature indigenous trees (70%). In contrast, no medium parcels contained mature indigenous trees, but about 30% of small parcels (all lakeshore properties) did. 70% of medium parcels had mature trees that had been planted (horticultural species), and 50% of small parcels had mature trees, most including indigenous species.

Backyard enclosure. Nearly all large parcels had enclosed backyards. Less than half of small and medium parcels were enclosed. Those that were enclosed had mature trees or were lakeshore parcels.

Backyard neatness. Most small parcels had very neat backyards. However, small lakeshore parcels or those containing mature indigenous trees were somewhat less neat. With one exception, medium parcels were very neat. Among large parcels, those with small ZOCs were somewhat neater.

3.3. Reported homeowner behaviors

In this section we describe homeowner behaviors that may have implications for carbon storage.

Planting trees. All owners of large parcels with large ZOC had planted more than one tree, and nearly all owners of other large and medium parcels had planted some trees. Only two of the eleven owners of small parcels had planted more than one tree, and seven had never planted a tree on their property.

Using lawn fertilizer. While 50% of homeowners of large parcels used lawn fertilizer (especially if they had a large ZOC), about three-quarters of all small and medium parcel homeowners (who had virtually no area beyond the ZOC) used lawn fertilizer.

Disposing of leaves. Seven of eight owners of large parcels left leaf litter on their property. The remaining homeowner burned leaves. For both medium and small parcels, about half of owners left leaf litter on their property.

Enjoying wildlife. While all owners of large parcels indicated that they enjoyed watching wildlife on their property, only about half of owners of small or medium parcels indicated this. None of the owners of lakeshore parcels indicated that they enjoyed watching wildlife.

3.4. Demographics

In our small sample, possible demographic patterns were generally too subtle to discern. While we examined income and education, only age and having children at home suggested a possible pattern related to parcel size. About half of all owners of small or medium parcels were younger than 55 and had children under 18 at home. Most owners of large parcels were over 55 and had no children at home.

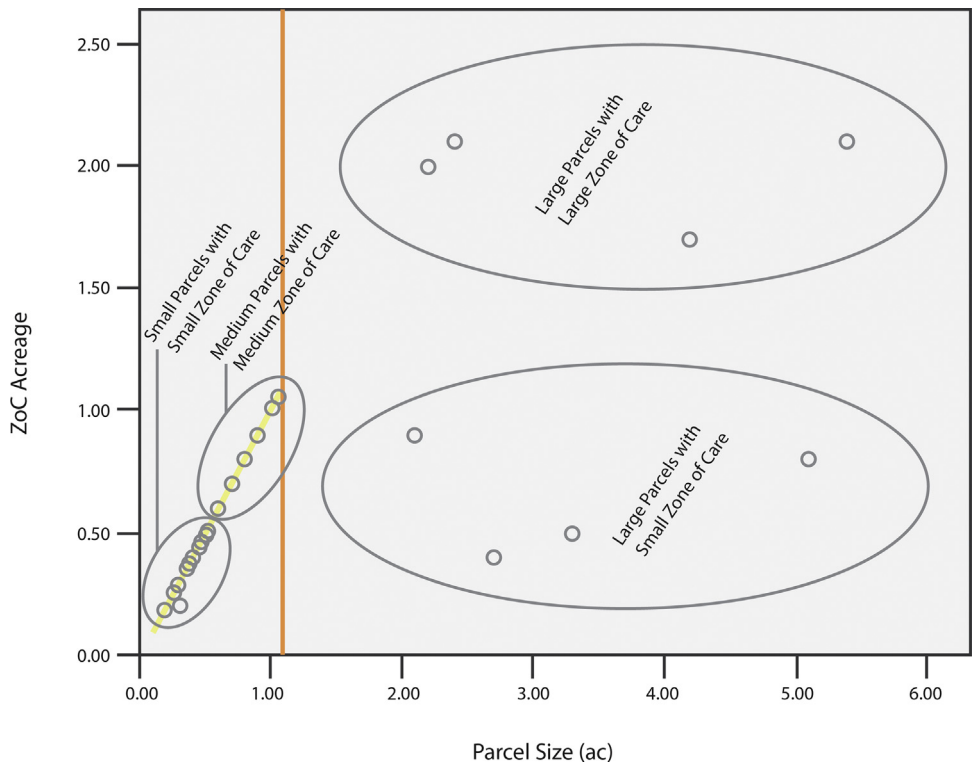

Fig. 1. Relationship between Parcel Size and the size of the "Zone of Care", the area under visible frequent maintenance that extends continuously from the house.

3.5. *A typology for use in an agent-based model*

Combining respondents' parcel size/ZOC type (Fig. 1) with variation in their parcel characteristics and homeowner behaviors and characteristics, we developed a typology of exurban homeowners (Table 1) to be employed in an agent-based model. We use excerpts from our interviews with homeowners and photographs of their yards (Fig. 2) to illustrate each of the six types:

1. *Neat neighbors* ($n = 6$) are small parcel owners who live in newer homes. They tend to be younger families with children at home. They have no mature indigenous trees on their property, only half had planted trees, and all fertilized (Fig. 2). Their backyards are very neat, and few are enclosed. Nearly all properties adjacent to those of Neat Neighbors were conventional, with turf-dominated cover. Neat Neighbors noticed their neighbors' yards and expected that their neighbors noticed theirs. One said "the neighbors appreciate the work we put in", and another noted that they "admire care in the planting areas" of their neighbors. Only the three Neat Neighbors who had planted trees and one who lived adjacent to a site with mature indigenous trees reported enjoying wildlife.
2. *Lakeshore property owners* ($n = 3$) had mature indigenous trees on their properties, but did not plant more trees (Fig. 2). Their maintenance behaviors varied. None of them lived adjacent only to properties with conventional turf-dominated cover. Most fertilized and none reported enjoying wildlife. A typical interview comment was that having more mature trees would be a "maintenance nightmare".
3. *Nature neighbors* ($n = 2$) lived on small parcels that had mature indigenous trees and were adjacent to large woodlands. They had enclosed backyards, somewhat less neat than other small parcels, and many perennial plantings (Fig. 2). Neither fertilized. Both composted all leaf litter. While neither parcel was adjacent only to properties with conventional turf-dominated cover, one homeowner who said he preferred "wild things" specifically commented on the highly manicured property of neighbors, whom he termed "fanatics." Another Nature Neighbor spoke about the beauty of "light coming through the trees so that it feels like you are in the middle of the woods."

   These results suggest that characteristics of properties adjacent to small parcels may influence homeowner behaviors that affect carbon storage. For Neat Neighbors and Lakeshore Property Owners, the most important characteristics may be cues to care that they see in neighbors' properties. For Nature Neighbors, adjacent woodlands may be more influential.
4. *Tree planters* ($n = 7$) are owners of medium parcels in conventional subdivisions (Fig. 2). All but one had only conventional turf-dominated properties adjacent to their own. None had mature indigenous trees, but most had mature horticultural trees. All but one homeowner had planted trees on their property. Consequently, wooded turf predominated in half of these parcels. Half had enclosed backyards. Nearly all owners of medium parcels used lawn fertilizer, but nearly half composted their leaves. Their interview comments indicate that, while attention to neighbors' perceptions was uppermost in some Tree Planters' minds, others aspired to a "more natural" approach to property maintenance.

   These results suggest that parcels between 0.5 and just over 1.0 acre, a common parcel size for exurban development in America, may have ecosystem dynamics that are particularly influenced by changes introduced by homeowners (like planting trees). Design and management behaviors that augment ecosystem services on parcels of this size could extensively influence the environmental functions of metropolitan landscapes.
5. *Improvers* ($n = 4$) own large parcels with a relatively small ZOC (Fig. 2). Improvers tended to use the area beyond the ZOC for recreation, making improvements like bridges, seating areas in the woods, gardens, and trails. All had a mix of forest and old field beyond the ZOC. Some had houses built before 1960, most had

Fig. 2. Typical backyards of each of the six homeowner types used to populate agent-based models.

owned their homes for at least 10 years, and most were over 55 with no children at home. Improvers indicated that they valued the autonomy afforded by a large property. Only one fertilized and removed leaf litter from their parcel. None had any conventional turf-dominated parcels adjacent to their own. All had mature indigenous trees, and all but one had planted trees. All but one had an enclosed backyard, and that less private backyard was extremely neat. Its owner indicated that, though he appreciated having wooded areas nearby, he would have preferred a more conventional sunny backyard. All stated that they enjoyed watching wildlife on their properties.

6. *Viewers* ($n = 4$) own large parcels with a relatively large ZOC (Fig. 2). Half of Viewers had at least one conventional turf-dominated residential parcel adjacent to their property. Viewers' parcels were wooded: all but one had a wooded turf ZOC and an enclosed backyard. All Viewers had planted two or more trees, but they mowed further beneath the canopy than Improvers. Like Improvers, only one had children at home. Nearly all Viewers fertilized, but all disposed of leaves on their own property. All enjoyed watching wildlife on their properties. Viewers' houses were all built after 1960, and one Viewer explained that he planted a lot of trees in his backyard so that there would be "more things in their view". Another explained the importance of keeping "junk behind the trees" to keep their property looking neat.

These results suggest that, even given similar, large parcel sizes, individual homeowners design and manage their properties in distinct ways with different implications for carbon storage. Our data suggest that large property owners who leave a relatively large proportion of their property unmown (have a small ZOC) may face more flexible neighborhood norms for property management, and may have different esthetic preferences for their home landscapes, compared with large property owners who have a larger ZOC.

4. Discussion

Our investigation suggests that homeowner behaviors that could affect carbon storage may be related to parcel size, and that some of these behaviors appear to be related to social norms. Our results support Robinson's (2012) conclusion that forest patch size increases with parcel size, and address a gap in his results, which could not account for household behaviors. Behaviors that we found to be less common on small parcels and that affect carbon storage in trees were: maintaining mature indigenous trees, planting trees, and having woody canopy extend over more than half of the ZOC (the mown part of the parcel). Some behaviors that could enhance carbon storage may be related to social norms for neatness or for matching the yard style of nearby neighbors, and behaviors that challenge social norms were more often seen on large parcels (i.e., retaining leaf litter on site, having a backyard that was not extremely neat, and leaving a higher proportion of the parcel unmown (beyond the ZOC)). Behaviors that could indirectly affect carbon storage also varied with parcel size. Having an enclosed backyard and enjoying viewing wildlife on the property might prompt maintaining or planting woody vegetation, and both behaviors were more common among owners of large parcels. We also found that the use of lawn fertilizer was less common among owners of large parcels in our sample.

Important to all of these behaviors related to parcel size is the homeowner's delineation of the proportion of the parcel maintained by regular mowing, pruning, and weeding – the "Zone of Care" (ZOC); the remainder of the parcel is in woodland or old field. Within our sample, we found the proportion of the parcel in the ZOC to be strongly related to parcel size for parcels approximately one acre or smaller, where the ZOC occupies the entire parcel. For parcels surpassing the 1 acre threshold, the ZOC varied widely but was always considerably smaller than the parcel.

Untended areas beyond the ZOC are likely to provide more carbon storage than tended areas. Essentially all the unmown forest or old field cover in our sample was beyond the ZOC on parcels larger than one acre. This may be attributable to limits on resources that homeowners expend on their landscapes as Robinson (2012) suggested. That the ZOC is nearly identical to parcel size up to an approximately one acre threshold suggests that cultural norms for ensuring that one's residential property looks well-cared-for are sufficiently powerful to encourage homeowners to expend resources necessary to achieve the look of good care even in areas as large as one acre, but that mowing areas larger than one acre may exceed cultural norms, at least in neighborhoods of parcels larger than one acre. There may have been different cultural norms for the appearance of residential property in the neighborhoods where large parcels in our sample were located. No large parcels had only neighbors with conventional mown lawns; large parcels in different development contexts could have more rigid neighborhood landscape management norms for neatness.

Underscoring the power of neighborhood norms, our typology identified Neat Neighbors, who owned small parcels surrounded by conventional turf-dominated lawns, as most consistently using lawn fertilizer and removing leaf litter. This behavior is different from other small parcel homeowners who own small parcels that are immediately adjacent to lakes or have mature indigenous trees. More Lakeshore Property Owners and Nature Neighbors conserved leaf litter on their property and did not use lawn fertilizer.

Large, indigenous trees and predominantly wooded turf were most prevalent on large parcels, which also more often had enclosed backyards that were not extremely neat. Fewer large parcel homeowners used lawn fertilizer and more of them left leaf litter on their property. Interestingly, large parcel homeowners also were more likely to enjoy viewing wildlife. These behaviors might be understood as preferences reflected in homeowners' selection of a home, or they might indicate responses to parcel characteristics. They also might be understood as responses to relaxed social constraints where neighbors are more distant, social desires to mark property boundaries, or personal desires for privacy from neighbors' views.

Tree planting and protection of existing trees appears to be related to parcel size in a different way. Those who had more space to plant trees (homeowners of medium and large parcels) nearly all did so. This behavior is particularly notable for medium parcels in our sample, which were located in conventional subdivisions with no remnant ecosystems and only homes built after 1960. These Tree Planters were like Neat Neighbors in that nearly all their yards were adjacent to at least one conventional turf-dominated lawn. Neighborhood norms may have influenced these homeowners to use lawn fertilizer, a choice quite different from owners of larger properties. However, even as they strove to maintain a neat appearance, medium parcel homeowners planted trees. The wooded turf landscapes they produced support carbon storage, despite lacking some other forest functions.

Our data cannot indicate whether the relationship between parcel size and land covers supporting carbon storage is "sorting," in which homebuyers' predilections for certain landscape-related behaviors like planting trees or watching wildlife, for example, cause them to seek parcels that allow those behaviors, or whether homeowners develop these behaviors in response to parcel size. However, our data suggest a clear relationship between parcel size and these behaviors.

5. Conclusions

This study has both substantive and methodological implications. Its findings were used to populate ABMs within our larger interdisciplinary study of exurban residential landscape dynamics in southeast Michigan as CNHS, which links developer choices, landowner behaviors, land markets, and the ecological dynamics of vegetation and soils to understand drivers of landscape change related to carbon balance (e.g., Magliocca et al., in press). The study employs ABMs to explore how homebuyer choices and homeowner behaviors might interact with developer choices to affect carbon storage. As reported here, we used ethnographic methods to gain insight into whether and why owners of residential parcels of different sizes might manage their properties differently and to derive from our analysis a typology of homeowner agents to populate our larger project ABMs. This paper's detailed description of our method and results contributes to the larger discussion of methods for populating ABMs (Robinson et al., 2007; Smajgl et al., 2011; An, 2012). In addition, findings of our ethnographic study were the basis for hypotheses that we tested in a larger confirmatory study of exurban homeowners' parcel characteristics and care behavior.

Land parcelization decisions that are part of real estate development may profoundly affect subsequent homeowner behaviors that affect landscape-based carbon storage. Substantively, our data support Robinson's (2012) finding that larger exurban residential parcels in southeast Michigan tend to have higher proportions of woodland, with associated implications for ecosystem services. Our analysis suggests that many exurban homeowners' landscape behaviors that may affect carbon storage vary with parcel size, and that cultural norms for neatness and norms to match the yard styles of nearby neighbors may affect these behaviors.

If our results are supported by subsequent investigations, they have direct implications for climate change mitigation. The extensive, popular, and growing land use of exurban residential development can supply a broader public good, carbon sequestration, if residential properties provide proportionately more woodland where lots are larger. If landscape patterns of exurban

development continue unchanged, policy that promotes parcels larger than one acre will likely promote more carbon sequestration than policy that requires smaller exurban parcels. However, the carbon costs of transportation in exurban landscapes are well known (National Research Council, 2009), and not everyone will desire or be able to afford the purchase and management of large parcels. Thus, our results also implicitly challenge residential landscapes in higher density metropolitan areas to be designed to offer increased potential for landscape carbon storage. This will require inventive designs that provide characteristics that have drawn home buyers to large exurban properties (e.g., backyard privacy), that respond to cultural and neighborhood norms for landscape appearance, and that promote carbon storage behaviors like tree planting, tree maintenance, and retention of leaf litter. For example, wooded public or quasi-public land may have a spillover effect on adjacent residential properties, promoting a more relaxed landscape management regime and more trees in backyards. Policy to promote innovative design of more dense development could support new homeowner management regimes that provide a broader array of ecosystem services while also reducing the carbon costs of transportation.

References

Alberti M., Hutyra L. *Detecting carbon signatures of development patterns across a gradient of urbanization: Linking observations, models, and scenarios*. Paper presented at the 5th Urban research symposium on cities and climate change: Responding to an urgent agenda. 2009.

Alig, R. J., Kline, J. D., & Lichtenstein, M. (2004). Urbanization on the US landscape: Looking ahead in the 21st century. *Landscape and Urban Planning*, *69*(2–3), 219–234.

An, L. (2012). Modeling human decisions in coupled human and natural systems: Review of agent-based models. *Ecological Modelling*, *229*, 25–36.

An, L., Brown, D. G., Nassauer, J. I., & Low, B. (2011). Variations in development of exurban residential landscapes: Timing, location, and driving forces. *Journal of Land Use Science*, *6*(1), 13–32.

Armstrong, A., & Stedman, R. C. (2012). Landowner willingness to implement riparian buffers in a transitioning watershed. *Landscape and Urban Planning*, *105*(3), 211–220. http://dx.doi.org/10.1016/j.landurbplan.2011.12.011

Asch, S. E. (1951). Effects of group pressure upon the modification and distortion of judgments. *Groups, Leadership, and Men. S*, 222–236.

Bernheim, B. D. (1994). A theory of conformity. *Journal of Political Economy*, 841–877.

Bikhchandani, S., Hirshleifer, D., & Welch, I. (1992). A theory of fads, fashion, custom, and cultural change as informational cascades. *Journal of Political Economy*, 992–1026.

Blaine, T., Clayton, S., Robbins, P., & Grewal, P. (2012). Homeowner attitudes and practices towards residential landscape management in Ohio, USA. *Environmental Management*, *50*(2), 257–271. http://dx.doi.org/10.1007/s00267-012-9874-x

Boone, C., Cadenasso, M., Grove, M. J., Schwarz, K., & Buckley, G. (2010). Landscape, vegetation characteristics, and group identity in an urban and suburban watershed: Why the 60s matter. *Urban Ecosystems*, *13*(3), 255–271.

Brown, D. G., Johnson, K. M., Loveland, T. R., & Theobald, D. M. (2005). Rural land-use trends in the conterminous United States 1950–2000. *Ecological Applications*, *15*(6), 1851–1863.

Brown, D. G., Pijanowski, B., & Duh, J. (2000). Modeling the relationships between land use and land cover on private lands in the Upper Midwest, USA. *Journal of Environmental Management*, *59*(4), 247–263.

Brown, D. G., Robinson, D. T., An, L., Nassauer, J. I., Zellner, M., Rand, W., et al. (2008). Exurbia from the bottom-up: Confronting empirical challenges to characterizing a complex system. *Geoforum*, *39*(2), 805–818.

Cook, E., Hall, S., & Larson, K. (2012). Residential landscapes as social-ecological systems: A synthesis of multi-scalar interactions between people and their home environment. *Urban Ecosystems*, *15*(1), 19–52. http://dx.doi.org/10.1007/s11252-011-0197-0

Crutchfield, R. S. (1955). Conformity and character. *American Psychologist*, *10*(5), 191.

Erickson, D. L., Lovell, S. T., & Méndez, V. E. (2011). Landowner willingness to embed production agriculture and other land use options in residential areas of Chittenden County, VT. *Landscape and Urban Planning*, *103*(2), 174–184. http://dx.doi.org/10.1016/j.landurbplan.2011.07.009

Erickson, D. L., Ryan, R. L., & De Young, R. (2002). Woodlots in the rural landscape: Landowner motivations and management attitudes in a Michigan (USA) case study. *Landscape and Urban Planning*, *58*(2), 101–112.

Fernandez, L. E., Brown, D. G., Marans, R. W., & Nassauer, J. I. (2005). Characterizing location preferences in an exurban population: Implications for agent based modeling. *Environmental Planning B*, *32*, 799–820.

Fissore, C., Baker, L., Hobbie, S., King, J., McFadden, J., Nelson, K., et al. (2011). Carbon, nitrogen, and phosphorus fluxes in household ecosystems in the Minneapolis-Saint Paul, Minnesota, urban region. *Ecological Applications*, *21*(3), 619–639.

Fissore, C., Hobbie, S., King, J., McFadden, J., Nelson, K., & Baker, L. (2012). The residential landscape: Fluxes of elements and the role of household decisions. *Urban Ecosystems*, *15*(1), 1–18. http://dx.doi.org/10.1007/s11252-011-0189-0

Groffman, P. M., Bain, D. J., Band, L. E., Belt, K. T., Brush, G. S., Grove, J. M., et al. (2003). Down by the riverside: Urban riparian ecology. *Frontiers in Ecology and the Environment*, *1*(6), 315–321.

Grove, J., Troy, A., O'Neil-Dunne, J. P. M., Burch, W., Cadenasso, M., & Pickett, S. (2006). Characterization of households and its implications for the vegetation of urban ecosystems. *Ecosystems*, *9*(4), 578–597.

Hammer, R. B., Stewart, S. I., Winkler, R. L., Radeloff, V. C., & Voss, P. R. (2004). Characterizing dynamic spatial and temporal residential density patterns from 1940–1990 across the North Central United States. *Landscape and Urban Planning*, *69*(2), 183–199.

Hansen, A. J., Knight, R. L., Marzluff, J. M., Powell, S., Brown, K., Gude, P. H., et al. (2005). Effects of exurban development on biodiversity: Patterns, mechanisms, and research needs. *Ecological Applications*, *15*(6), 1893–1905.

Harris, P. B., & Brown, B. B. (1996). The home and identity display: Interpreting resident territoriality from home exteriors. *Journal of Environmental Psychology*, *16*, 187–203.

Harris, E., Polsky, C., Larson, K., Garvoille, R., Martin, D., Brumand, J., et al. (2012). Heterogeneity in residential yard care: Evidence from Boston, Miami, and Phoenix. *Human Ecology*, *40*(5), 735–749. http://dx.doi.org/10.1007/s10745-012-9514-3

Heimlich, R. E., & Anderson, W. D. (2001). *Development at the urban fringe and beyond: Impacts on agriculture and rural land. (No. 33943)*. United States Department of Agriculture, Economic Research Service.

Hess, P. M. (2008). Fronts and backs: The use of streets, yards, and alleys in Toronto-area new urbanist neighborhoods. *Journal of Planning Education and Research*, *28*(2), 196–212. http://dx.doi.org/10.1177/0739456x08321799

Hunter, M. C. R., & Brown, D. G. (2012). Spatial contagion: Gardening along the street in residential neighborhoods. *Landscape and Urban Planning*, *105*(4), 407–416. http://dx.doi.org/10.1016/j.landurbplan.2012.01.013

Kondo, M. C., Rivera, R., & Rullman, S., Jr. (2012). Protecting the idyll but not the environment: Second homes, amenity migration and rural exclusion in Washington State. *Landscape and Urban Planning*, *106*(2), 174–182. http://dx.doi.org/10.1016/j.landurbplan.2012.03.003

Kuran, T. (1990). Private and public preferences. *Economics and Philosophy*, *6*(1), 1–26.

Kurz, T., & Baudains, C. (2012). Biodiversity in the front yard: An investigation of landscape preference in a domestic urban context. *Environment and Behavior*, *44*(2), 166–196.

Laganiere, J., Angers, D. A., & Pare, D. (2009). Carbon accumulation in agricultural soils after afforestation: A meta analysis. *Global Change Biology*, *16*(1), 439–453.

Larsen, L., & Harlan, S. L. (2006). Desert dreamscapes: Residential landscape preference and behavior. *Landscape and Urban Planning*, *78*(1–2), 85–100.

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., et al. (2007). Complexity of coupled human and natural systems. *Science*, *317*(5844), 1513–1516. http://dx.doi.org/10.1126/science.1144004

Lovejoy, K., Handy, S., & Mokhtarian, P. (2010). Neighborhood satisfaction in suburban versus traditional environments: An evaluation of contributing characteristics in eight California neighborhoods. *Landscape and Urban Planning*, *97*(1), 37–48. http://dx.doi.org/10.1016/j.landurbplan.2010.04.010

Magliocca, N. R., Brown, D. G., McConnell, V. D., Nassauer, J. I., & Westbrook, S. E. (2014). Effects of alternative developer decision-making models on the production of ecological subdivision designs: Experimental results from an agent-based model. *Environment and Planning B*, *41* http://dx.doi.org/10.1068/b130118p (in press)

Milesi, C., Running, S. W., Elvidge, C. D., Dietz, J. B., Tuttle, B. T., & Nemani, R. R. (2005). Mapping and modeling the biogeochemical cycling of turf grasses in the United States. *Environmental Management*, *36*(3), 426–438.

Morris, J., & Bagby, J. (2008). Reducing environmental impacts: Lawn and garden care – Case study. *The International Journal of Life Cycle Assessment*, *13*, 226–234.

Nassauer, J. I. (1988). The aesthetics of horticulture: Neatness as a form of care. *HortScience*, *23*(6), 973–977.

Nassauer, J. I. (1995). Messy ecosystems, orderly frames. *Landscape Journal*, *14*(2), 161–170.

Nassauer, J. I. (1997). Cultural sustainability: Aligning aesthetics and ecology. In J. I. Nassauer (Ed.), *Placing nature: Culture in landscape ecology* (pp. 65–83). Washington, DC: Island Press.

Nassauer, J. I. (2011). Care and stewardship: From home to planet. *Landscape and Urban Planning*, *100*(4), 321–323.

Nassauer, J. I., Allan, J. D., Johengen, T., Kosek, S. E., & Infante, D. (2004). Exurban residential subdivision development: Effects on water quality and public perception. *Urban Ecosystems*, *7*(3), 267–281.

Nassauer, J. I., Wang, Z., & Dayrell, E. (2009). What will the neighbors think? Cultural norms and ecological design. *Landscape and Urban Planning*, *92*(3–4), 282–292.

National Research Council. (2009). *Driving and the built environment: The effects of compact development on motorized travel, energy use, and CO_2 emissions. Report no. 298*. Transportation Research Board, National Academy of Sciences.

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution*, *178*, 229–236.

Pijanowski, B. C., & Robinson, K. D. (2011). Rates and patterns of land use change in the Upper Great Lakes States, USA: A framework for spatial temporal analysis. *Landscape and Urban Planning*, *102*(2), 102–116. http://dx.doi.org/10.1016/j.landurbplan.2011.03.014

Posner, E. A. (1998). Symbols, signals, and social norms in politics and the law. *The Journal of Legal Studies*, *27*(S2), 765–797.

Quayle, M., & van der Lieck, T. C. D. (1997). Growing community: A case for hybrid landscapes. *Landscape and Urban Planning*, *39*(2), 99–107.

Radeloff, V. C., Hammer, R. B., & Stewart, S. I. (2005). Rural and suburban sprawl in the US Midwest from 1940 to 2000 and its relation to forest fragmentation. *Conservation Biology*, *19*(3), 793–805.

Rhemtulla, J. M., Mladenoff, D. J., & Clayton, M. K. (2009). Historical forest baselines reveal potential for continued carbon sequestration. *Proceedings of the National Academy of Sciences*, *106*(15), 6082–6087.

Robinson, D. T., Brown, D. G., Parker, D. C., Schreinemachers, P., Janssen, M. A., Huigen, M., et al. (2007). Comparison of empirical methods for building agent-based models of land and resource use. *Journal of Land Use Science*, *2*(1), 31–55.

Robinson, D.T. (2009). Effects of land-use policy, forest fragmentation, and residential parcel size on land-cover and carbon storage in Southeastern Michigan. Unpublished doctoral dissertation, Ann Arbor, MI: University of Michigan.

Robinson, D. T. (2012). Land-cover fragmentation and configuration of ownership parcels in an exurban landscape. *Urban Ecosystems*, *15*(1), 53–69.

Robinson, D. T., Sun, S., Hutchins, M., Riolo, R. L., Brown, D. G., Parker, D. C., et al. (2012). Effects of land markets and land management on ecosystem function: A framework for modelling exurban land-change. *Environmental Modelling and Software*.

Rounsevell, M. D. A., Robinson, D. T., & Murray-Rust, D. (2012). From actors to agents in socio-ecological systems models. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1586), 259–269.

Schroeder, F. E. H. (1993). *Front yard America*. Bowling Green, Ohiio: Bowling Green State University Popular Press.

Smajgl, A., Brown, D. G., Valbuena, D., & Huigen, M. G. A. (2011). Empirical characterisation of agent behaviours in socioecological systems. *Environmental Modelling and Software*, *26*(7), 837–844.

Talen, E. (2001). Traditional urbanism meets residential affluence: An analysis of the variability of suburban preference. *Journal of the American Planning Association*, *67*(2), 199–216.

Theobald, D. M. (2005). Landscape patterns of exurban growth in the USA from 1980 to 2020. *Ecology and Society*, *10*(1), 32.

Troy, A. R., Grove, J. M., O'Neil-Dunne, J. P. M., Pickett, S. T. A., & Cadenasso, M. L. (2007). Predicting opportunities for greening and patterns of vegetation on private urban lands. *Environmental Management*, *40*(3), 394–412.

US Census Bureau. (2010). *American Housing Survey for the United States: 2010*. Washington, DC: US Department of Commerce. http://quickfacts.census.gov/qfd/states/26000.html Accessed 17.09.13.

Vesterby, M., & Krupa, K. (2002). Rural residential land use: Tracking its growth. *Agricultural Outlook - Washington*, 14–17.

Vigmostad, K. (2004). *Michigan real estate developer perspective on development, sustainability, and nature: An autoethnography* Unpublished doctoral dissertation. Lansing, MI: Michigan State University.

Westphal, L. M., Longoni, M., LeBlanc, C. L., & Wali, A. (2008). Anglers' appraisals of the risks of eating sport-caught fish from industrial areas: Lessons from Chicago's Calumet Region. *Human Ecology Review*, *15*(1), 46.