

Assessing the homogenization of urban land management with an application to US residential lawn care

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Changes in land use, land cover, and land management present some of the greatest potential global environmental challenges of the 21st century. Urbanization, one of the principal drivers of these transformations, is commonly thought to be generating land changes that are increasingly similar. An implication of this multiscale homogenization hypothesis is that the ecosystem structure and function and human behaviors associated with urbanization should be more similar in certain kinds of urbanized locations across biogeophysical gradients than across urbanization gradients in places with similar biogeophysical characteristics. This paper introduces an analytical framework for testing this hypothesis, and applies the framework to the case of residential lawn care. This set of land management behaviors are often assumed—not demonstrated—to exhibit homogeneity. Multivariate analyses are conducted on telephone survey responses from a geographically stratified random sample of homeowners ($n = 9,480$), equally distributed across six US metropolitan areas. Two behaviors are examined: lawn fertilizing and irrigating. Limited support for strong homogenization is found at two scales (i.e., multi- and single-city; 2 of 36 cases), but significant support is found for homogenization at only one scale (22 cases) or at neither scale (12 cases). These results suggest that US lawn care behaviors are more differentiated in practice than in theory. Thus, even if the biophysical outcomes of urbanization are homogenizing, managing the associated sustainability implications may require a multiscale, differentiated approach because the underlying social practices appear relatively varied. The analytical approach introduced here should also be productive for other facets of urban-ecological homogenization.

sustainability science | land-change science | urban ecology | private land management

Changes in land use and cover have transformed the biosphere (1, 2). Land changes should remain a key influence on the global environment, although the dominant source of these transformations will likely shift from agricultural expansion to urbanization (1, 3–7). Global-scale urbanization may be homogenizing ecological structure and function (cf. refs. 8–10). The composition of plant species, soil nutrient profiles, and presence or extent of surface water bodies appears to be increasingly similar across cities, even in dissimilar biophysical settings (10–14). Such trends are potentially worrisome in sustainability terms because they suggest large-scale and possibly irreversible transformations in biogeochemical cycling and trace gas fluxes are underway. Sustainability science therefore needs an improved

understanding of the causes and consequences of urban land management (15). This knowledge should be grounded in the geographic patterning—that is, homogeneous versus differentiated—of human land management practices at household, neighborhood, metropolitan, and even continental scales (16, 17).

Sustainability, Lawn Care, and Urban Ecological Homogenization

The environmental management of an expanding private urban land base is not well understood. Of primary concern are residential lawn and yard care, due to the apparently widespread practice of excessively fertilizing and irrigating turfgrass (18–20). Such behaviors are concerning because lawns not only cover a larger extent of land than any other irrigated crop in the United States (19, 20), but also are expected to expand in coming decades (21). Thus, the potential homogenization of residential lawn care has emerged as a major concern for carbon, nitrogen, phosphorus, and water flows (22–24). The conventional wisdom asserts that a singular human–environment process—urbanization—is generating similar human behaviors (such as lawn care

Significance

This paper offers conceptual and empirical contributions to sustainability science in general and urban-ecological studies in particular. We present a new analytical framework for classifying socioecological measures along a homogenization–differentiation spectrum. This simple 2×2 matrix highlights the multiscale nature of the processes and outcomes of interest. Our application of the conceptual framework produces needed empirical insights into the extent to which land management appears to be homogenizing in differing biophysical settings. Results suggest that US lawn care behaviors are more differentiated in practice than in theory. Thus even if the biophysical outcomes of urbanization are homogenizing, managing the associated sustainability implications may require a multiscale, differentiated approach.

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practices), regardless of the biophysical setting, that produce similar environmental outcomes. This relationship (sometimes implicit), the so-called “homogenization hypothesis” (9, 10, 25–27), has yet to be rigorously tested regarding lawn care practices. The production of similar landscapes in differing biophysical settings might be associated with different, not similar, behaviors. Producing the same English manor-style yards from the native landscapes in Phoenix and Boston would require different activities (adding or removing trees, respectively) due to the differing initial conditions.

In general, residential landscapes of varied baseline biophysical conditions (e.g., climate) may exhibit similar ecological characteristics (e.g., soil carbon levels), despite being potentially produced by different land management practices (e.g., high versus low lawn fertilization) and preferences (e.g., social pressures favoring or discouraging native vegetation aesthetics). The presence of homogeneity should be tested, not assumed. A full understanding of continental-scale human–environment processes must, *contra* the conventional wisdom, allow for the plausible cases where either similar biophysical outcomes across differing environmental conditions are the product of differing human behaviors, or where differing biophysical outcomes are the product of similar human behaviors. Coupled with the homogenization hypothesis, these alternative propositions of differentiation collectively represent a major and under-studied research agenda in urban ecology. To date, the social and natural sciences literatures on lawn care have tested for the homogeneity of biophysical outcomes from lawn care practices, assuming—not testing—an underlying homogeneity of lawn care practices (9, 10, 25–27).

As a first step toward testing the homogenization hypothesis regarding both lawn care practices and associated outcomes, this paper formally examines lawn care practices across biophysical and social gradients. A multiscale analytical framework is presented, which should be applicable to urban ecological topics beyond lawn care. The framework classifies land management patterns as either similar or not within cities (i.e., along a social gradient holding biophysical conditions constant), and as either similar or not between cities (i.e., along a biophysical gradient holding social classification constant) (see refs. 8, 9, and 27). The research design thus permits a dual scale analysis (within and across cities) of the extent to which residential land management practices are or are not homogenizing. The multivariate framework is applied to two residential land management practices measured by a nationally representative telephone survey ($n = 9,480$) of US residents with yards.

An Analytical Framework for Investigating Socioecological Homogenization and Differentiation

If homogenization is present, then land management practices should not be statistically linked with biophysical or social factors. This broad framing suggests that an empirical analysis could

take several different forms. One could correlate a biophysical measure with a measure of land use or land cover. For example, comparing relative humidity in a city’s irrigated neighborhoods to nearby native ecosystem locations might indicate that lawn humidity measures are similar across the irrigated neighborhoods but different from the city’s native setting. This result would suggest urban homogenization at the city scale. If the irrigated humidity measures across multiple cities vary less than do their associated native ecosystems, then homogenization would be present at the multicity scale. One could also associate a biophysical measure with a measure of land management, or integrate a measure of social conditions with a measure of land management in varying biophysical settings. For instance, if, holding biophysical conditions constant (i.e., at the local-scale), fertilization is more common among households with high income than with low income, then a preliminary inference is that fertilization cost produces a differentiated landscape of land management behaviors—there is no homogeneity. Similarly, if, holding household income constant, fertilization is more common in some cities than in others, then a preliminary explanation is that climate or soil quality differentiates land management at the multicity scale.

There are four potential combinations of homogenization or differentiation (see cells A–D Table 1). Two scales of analysis are highlighted in each case because at any given point in time an urbanization process—even one that is homogenizing—may generate different patterns at different scales (15). Cell A reflects the case where land management appears similar at both the city- and multicity scales. This case would present *prima facie* evidence supporting the homogenization hypothesis. In cell B, a city presents internal similarities but important differences compared with the other cities. For instance, regardless of income class, a substantial majority of city 1 survey respondents might report that they irrigate their lawns, whereas the same proportion in city 2 might report not irrigating, again regardless of income class. The conclusion would be city-scale homogenization but multicity differentiation. The remaining two possible combinations, cells C and D, represent cases exhibiting local differentiation. Cell C cities exhibit differences locally, but similar differences are observed in other cities. The same within-city differentiation of fertilization behaviors across a population density gradient might be observed in both cities 3 and 4. By contrast, in cell D there is no apparent association at either scale. In this case land management practices differ within and between cities, thereby providing evidence for both city-scale and multicity differentiation.

Materials and Methods: Comparing Fertilization and Irrigation Practices Across Biophysical and Social Gradients

This paper illustrates the utility of the analytical framework (Table 1) by examining associations among social characteristics, biophysical conditions, and land management practices in six US cities. Since the cities (Boston,

Table 1. Analytical framework for classifying types and drivers of urban homogenization and differentiation

		Similarity across cities?	
		Yes	No
Similarity			
within city?			
Yes	A: Multicity and local homogenization. City exhibits similarities locally and with at least one other city.	B: Multicity differentiation and local homogenization. City exhibits similarities locally but differences with other cities.	
No	C: Multicity homogenization and local differentiation. City exhibits differences locally and similarities in the differences with at least one other city.	D: Multicity and local differentiation. City exhibits differences locally and with other cities.	

This general form of the table should be replicated for each measure. Within each table, a city is placed in exactly one cell of the table based on the results of two statistical tests of association: a within-city test comparing survey responses across social variable classifications, holding location constant (compare with the six tests shown in Fig. 1); and a between-cities test comparing survey responses across locations, holding social variable classification constant.

contrast, it is not intuitively apparent why self-reported fertilization practices are statistically indistinguishable by life stage for cities of differing climates (Boston and Miami; cell A in Table 2). Such findings suggest the need for additional research into the multiscaled influences on residential land management (15).

Second, using this matrix permits analysts to work productively with cases of no statistical association. Cases classified in cells A, B, or C have at least one test that fails to reject the null hypothesis of no association. The framework presented here renders such results meaningful: a nonsignificant association suggests that the land management behavior is not driven by the specified social factor.

Third, the matrix formally identifies the extent to which the homogenization-differentiation patterns vary by spatial scale (cf. refs. 15 and 40–42). Even though cases of complete homogeneity or differentiation in lawn care practices do not exhibit differences across scales, the other cases (cells B and C) do exhibit scale-specific differences. Thus, scale matters, but not in all cases.

Fourth, the matrix can accommodate biophysical, social, and combinations of biophysical and social data. In this paper the biophysical measures were implicit, but one could specify explicit biophysical measures. The matrix can also accommodate different sources of extensive and intensive data. An example of an intensive data source is ethnographic surveys of homeowners to understand psychological and sociocultural factors affecting lawn care practices (cf. refs. 19, 26, 27, and 43–47). An example of extensive data is landscape metrics derived from high-resolution remotely sensed imagery, which can be used to characterize biophysical features that shape or reflect the lawn care decision-making process (cf. refs. 30, 35, 36, 48, and 49). Several of these data types have been collected and incorporated (9, 17), which adds to the present analysis of lawn care practices an associated analysis of lawn care outcomes.

Conclusions

Advancing toward urban sustainability in the 21st century will require understanding the extent to which urbanization may be producing socially and environmentally homogeneous or differentiated landscapes at neighborhood, metropolitan, national, and continental scales. This paper introduces and applies a formal analytical framework for detecting socioecological homogenization or differentiation at two spatial scales. This approach carries significant potential for advancing sustainability science. To fully realize this potential, the framework needs to be animated with repeated observations. Robust inferences about trends in homogenization or differentiation over time are not possible without observations over time. This framework should be able to detect whether a place is trending toward or away from homogenization (or is stable). The urban ecological homogenization hypothesis implies that cases exhibiting a combination of similarities and differentiation today will exhibit only similarities tomorrow. Cases classified in cells B and C today would be expected to migrate to A in the future. However, the emergence of locally tailored urban sustainability policies and practices may lead to lead to less not more homogenization (e.g., refs. 18, 39, and 50–53). From this perspective, *contra* the homogenization hypothesis, cities classified in cells B and C may migrate to D not A. Applying the framework presented here to repeated measures can identify the presence (if any) and direction of trends.

This call for repeated observations of both biophysical and social variables is not new (cf. refs. 54–56). Cross-sectional analyses such as the one presented here are common out of necessity, for cost reasons. Long-term monitoring of biophysical variables is relatively rare, with the US National Science Foundation (NSF) Long Term Ecological Research (LTER) (<http://lter.net>) program being an outstanding exception to this rule. The repeated collection of social measures relevant for urban ecosystems is even less common. However, understanding the social and ecological dynamics that lead to urban homogenization

or differentiation requires a sustained program of repeated observations of urban land use, land cover, and land management. Establishing such a monitoring program is therefore a pressing need for the next generation of sustainability science program development.

Sampling and Data Collection. To reflect the theoretical interests in population density, SES, and life stage, the first sampling stage identified types of neighborhoods shared among all cities that reflect as much variation as possible in these three variables. Each city was stratified using the PRIZM scheme (30, 37, 38, 57), which classifies all US Census Block Groups (CBGs) based on an analysis of the CBG's population density, SES, and life stage. Fourteen PRIZM segments were chosen based on the PRIZM data available in July 2011. CBGs included must have $\geq 90\%$ of its surface area within the city's boundary. The selected PRIZM segment codes are: 02, 06, 07, 10, 11, 13, 14, 15, 20, 25, 29, 34, 54, and 61. Each segment is a collection of CBGs in the United States that share three characteristics: similar population density (classified based on the original continuous measure in declining order of density as urban, suburban/second city, or town and rural), SES (high or low), and life stage (younger years, family life, or mature years). For practical reasons, the sampling frame does not contain all possible pairwise combinations of classes from the three social dimensions. The six selected combined social groups in the sampling frame include: urban–family, urban–mature, suburban–family, suburban–mature, rural–younger, and rural–family. Accordingly, the sample excludes groups representing urban–younger, suburban–younger, or rural–mature. The six groups vary on the SES measure as follows: for population density, urban high and low SES, suburban high and low SES, and rural high SES; and for life-stage, younger high SES, family high and low SES, and mature high SES.

Using these selected social groups, >100,000 households were contacted between November 21 and December 29, 2011, across the six cities. Institutional Review Board approval was obtained on May 5, 2011 for project CHRBS: B11-205, from the University of Vermont Committee on Human Subjects. Of the contacted households, 13,590 qualified: the respondent was over 18 y of age, and his/her single-family home has a front- or back-yard. The response rate, after informed consent was obtained, for the computer-assisted telephone survey (37 multipart questions) was $\sim 70\%$; the city-specific response rates ranged from 66% to 73%. The resulting 9,480 completed surveys are roughly equally distributed across both the six social groups and six cities. At the 95% confidence level, survey responses can be generalized to the broader population of continental US single-family home residents with a precision ranging from $\pm 0.44\%$ to $\pm 1.01\%$, depending on the observed responses for a given survey question.

Data Analysis. χ^2 tests of association were performed both within each city and across cities. A test that fails to reject the null hypothesis of no association ($\alpha = 0.05$) supports homogenization at the scale of the test, either local or multicity. The criteria for determining cell placement for each combination of city, social variable, and survey question are:

A: within-city test, $P \geq 0.05$; and for ≥ 2 cities the across-cities tests for each social category, $P \geq 0.05$;

B: within-city test, $P \geq 0.05$; and for all across-cities tests for each social category, $P < 0.05$;

C: within-city test, $P < 0.05$; and for ≥ 2 cities the across-cities tests for each social category, $P \geq 0.05$; and

D: within-city test, $P < 0.05$; and for all across-cities tests for each social category, $P < 0.05$.

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