Cities and the Environment (CATE)

Volume 4 | Issue 1 Article 6

July 2011

A Multi-Scalar Approach to Theorizing Socio-Ecological Dynamics of Urban Residential Landscapes

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Urban residential expansion increasingly drives land use, land cover and ecological changes worldwide, yet social science theories explaining such change remain under-developed. Existing theories often focus on processes occurring at one scale, while ignoring other scales. Emerging evidence from four linked U.S. research sites suggests it is essential to examine processes at multiple scales simultaneously when explaining the evolution of urban residential landscapes. Additionally, focusing on urbanization dynamics across multiple sites with a shared research design may yield fruitful comparative insights. The following processes and social-hierarchical scales significantly influence the spatial configurations of residential landscapes: household-level characteristics and environmental attitudes; formal and informal institutions at the neighborhood scale; and municipal-scale land-use governance. While adopting a multi-scale and multi-site approach produces research challenges, doing so is critical to advancing understanding of coupled socio-ecological systems and associated vulnerabilities in a dynamic and environmentally important setting: residential landscapes.

Keywords

Urban ecology, Land cover, Household decision-making, Institutions, Coupled socio-ecological systems, Residential landscapes

Acknowledgements

This material is based upon work at Plum Island Ecosystem (PIE-LTER) supported by the National Science Foundation (NSF) REU Site programs under Grants No. BCS-0948984, BCS-0709685 and SES-0849985; at CAP-LTER supported by Grant No. DEB-0423704; at FCE-LTER supported by Grant No. DEB-9910514; and BES-LTER supported by Grant No. DEB-0423476. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

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I. INTRODUCTION

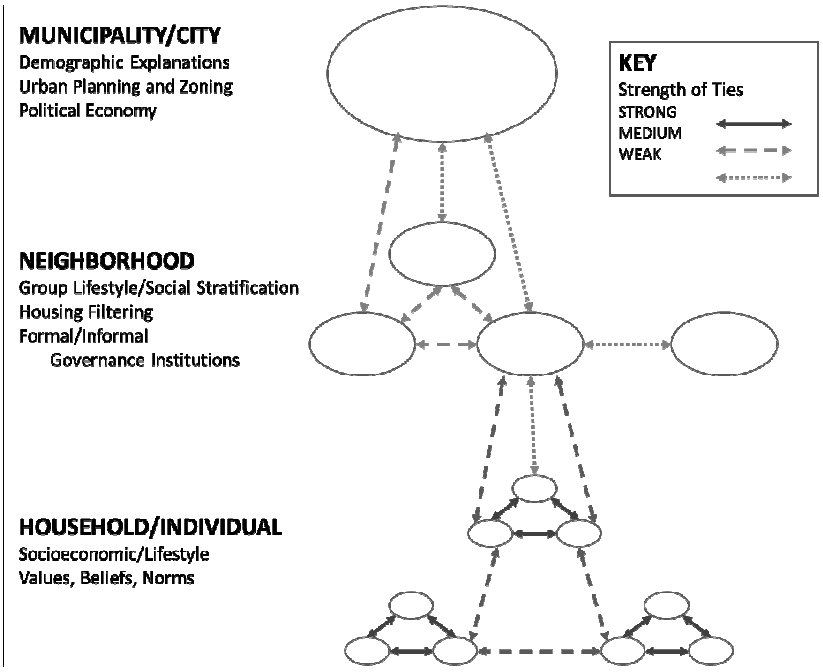
Social structures, local decisions and ecological factors interact in complex ways to shape urban environments at multiple scales. Developing urban areas worldwide reflect state, private, communal and other property ownership structures, however, in the United States, urban and suburban landscapes are dominated by private land ownership and residential land use. Understanding these landscapes depends on adequately integrating their multi-scalar, socio-ecological dynamics, but past studies have generally focused on individual scales of analysis (e.g., social neighborhoods, municipal governance), or on either social or environmental aspects. A deeper, integrated understanding is especially critical given the spatial pervasiveness of residential landscapes. Lawns are now a dominant "crop" covering over 16 million hectares, exceeding corn as the most extensive irrigated crop in the US (Milesi et al. 2005). The rapid expansion of residential land covers is driven by complex interactions among socioeconomic, political and environmental factors. Within the US, losses of agricultural and forested land to urban and suburban use are among the greatest sources of anthropogenic landscape change in the 20th century, a concern intensified by the large ecological footprints of urban areas as they mobilize resource, commodity and material flows affecting agricultural, forested and other nonurban landscapes (Munroe et al. 2005). Since World War II, urban land expansion outpaced population growth in many US cities (Otto et al. 2002). These trends accelerated in the past twenty-five years: urban areas expanded by 34% between 1982 and 1997, extending over 1.4 million sq. km. and housing over 80% of the US population (Brown et al. 2005). According to the 2000 census, suburban growth surpassed growth in cities regardless of city-specific population or economic trajectories (Katz and Lang 2003). While expanding residential spaces are embedded with personal and social value (e.g., recreational, aesthetic and property values), they also affect ecological structure (e.g., habitat fragmentation) and function (e.g., nutrient flows), creating a "self-imposed burden and hazard" (Robbins 2007, p. xx; Fissore et al. 2011). These dynamic, multi-scalar social spaces and their deep ecological impacts spur the need for theories and methods to deepen our social-ecological understanding of (sub)urban landscapes.

This paper presents a multi-scalar approach to the study of residential landscapes, grounding theories of urban and residential land use within a set of illustrative vignettes from four long-term socio-ecological research projects. In particular, we synthesize distinct *mid-level theories,* i.e., theories grounded within empirical research (supported by evidence derived from direct observation or experience, and subject to either quantitative or qualitative analysis), as opposed to a higher level of abstraction (Merton 1968; Wallace 1969). This enables us to anchor our approach in actual historical and contemporary processes of residential land management in the study locations we draw from. We examine mid-level theories that explain environmental decisions at varying spatial scales, ranging from individual behavior to broader forces at neighborhood, city and state scales. Our synthesis is built upon an examination of theoretical approaches, empirical findings and knowledge gaps from four Long Term Ecological Research (LTER) sites, each of which examines the social-ecological dynamics of residential landscapes.

The multi-scalar approach is motivated by theoretical concerns. A primary theoretical rationale lies in diverse, contradicting or complementary mid-level social science theories relevant to residential land management (Figure 1) that address various aspects of structure or agency. Land management is ultimately a local expression of the desires, constraints, abilities

and decisions of individuals, reflecting localized choices and capacities for action. Yet, non-local actors and broader political-economic or social structures influence local agency and socio-environmental impact in significant ways. Thus, landscaping decisions may be tied to residents' aesthetic values, experience, and economics, but they are also nested within progressively wider hierarchical structures, such as neighborhood norms and covenants, watershed-level ecological context, land and commodity markets, and municipal, state and national-level policies. A key goal in this paper is to reveal how mid-level theories may complement rather than conflict with one another, explicitly mapping how they address processes operating at multiple scales, and thereby illuminating the complex sociocultural, political-economic and environmental dynamics that shape socio-ecological relations. We thus link residential land management to distinct but overlapping theories of (sub)urban development and change (Grove and Burch 1997; Vogt et al. 2002). We do this while addressing socio-ecological dynamics at key analytical scales, contributing to the multi-scalar integration of socio-ecological theories describing urban ecosystems (Grove et al. 2005; Pickett et al. 2005; Cadenasso et al. 2006).

Figure 1. Example social science theories of urban-environmental dynamics at multiple scales (adapted from Grove et al. 2005).



Recent technological and methodological advances provide further impetus for a multi-scalar, social-ecological approach to residential land dynamics. First, recent high spatial-resolution (e.g., <1 m pixel) remote sensing of urban regions offers new possibilities for parcel scale analyses (Grove et al. 2006). Until recently, only coarse geospatial data (e.g., 30m resolution Landsat Thematic Mapper) have been available. Previous analyses therefore only examined broad-scale land cover in relation to US Census block-group or tract data, aggregating 200-400 or 2,500-8,000 households respectively. Second, the proliferation of high-resolution imagery has also been accompanied by digital cadastral information, allowing integration of rich social and ecological data within geographic information systems (GIS). For instance, social

surveys of residents' landscaping practices can now be linked to ecological information at the parcel scale. Integration at multiple spatial scales, from the detailed parcel to broader neighborhoods and regions, thus enable novel analytical and theoretical advances.

The following sections describe an approach to the study of residential landscapes illustrated in a set of research vignettes emerging from four diverse LTER sites: the *Baltimore Ecosystem Study (BES)*, *Central Arizona-Phoenix (CAP)*, *Florida-Coastal Everglades (FCE)*, and *Plum Island Ecosystem* (*PIE;* Table 1). Suburbanization is well underway in each site (Figure 2), but is tied to varying regional contexts and socio-environmental drivers, which help shape land cover choices and outcomes in residential parcels. Figure 3 depicts just four examples of landscapes in these four sites, though it should be noted that there is great diversity of yard forms, management and vegetative cover within any individual site. Drawing from these complementary long-term socio-ecological research projects, we derive a research framework with two overarching goals: (1) to understand the complex, multi-scalar drivers and feedbacks of residential landscapes, including lawns and "lawn people" (Robbins 2007), *and* (2) to develop spatially explicit theories of these patterns and processes. In doing so, we approach urbanization as an integrated social-ecological process constituted by social, political, economic, ecological and climate interactions. Ultimately, this work reflects a commitment to trans-disciplinary environmental science and LTER research priorities targeting land- and water-use dynamics (Collins et al. 2007; Fissore et al. 2011).

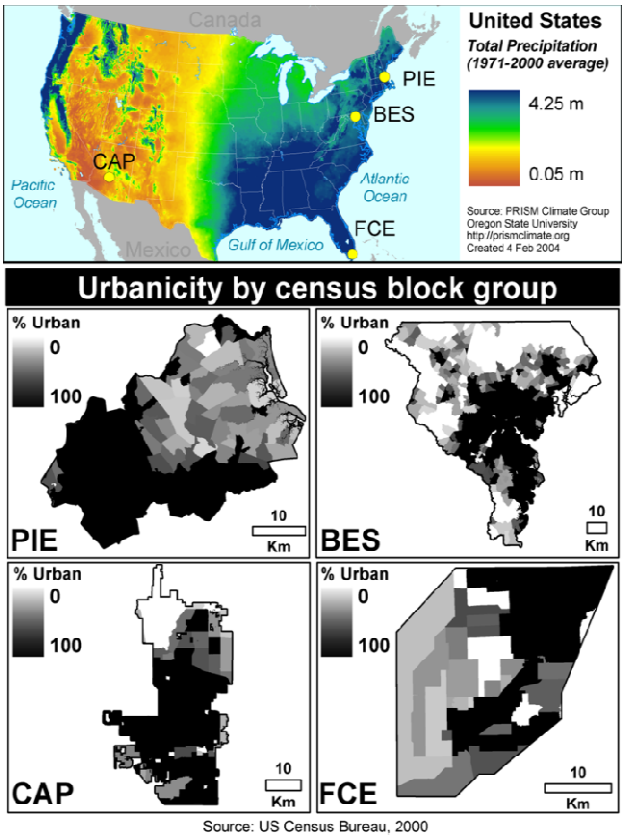
Table 1. Socio-ecological research at four LTER sites

The Baltimore Ecosystem Study (BES) LTER (http://www.beslter.org/) The BES-LTER site spans the Baltimore Metropolitan Statistical Areas (MSA), including Baltimore City and several surrounding counties. Originally an agricultural port on the Chesapeake Bay, Baltimore's population expanded significantly between 1900 and 1960 due to immigration and industrialization, and has declined since 1960 due to declining immigration and manufacturing jobs, and a transition to a service economy. Far-reaching land-use and zoning regulations, including the Urban-Rural Delineated Line, constrain urban growth of Baltimore City. The Baltimore MSA straddles the Piedmont and Coastal Zone geologic regions and has easily delineated watersheds studied in BES research. Because of land-water connections to the Bay, a policy goal to increase urban tree canopy from 20% to 40% over 30 years has been implemented in Baltimore City, where most land available for increasing vegetation lies in private, residential areas. Understanding social and ecological motivations, capacities, and pathways for land management on private parcels is an important BES science and policy issue.
The Central Arizona-Phoenix (CAP) LTER (http://caplter.asu.edu/) The CAP-LTER site encompasses the City of Phoenix, more than 20 municipalities, and nearly 4 million residents. Phoenix is situated in the Sonoran Desert with only ~190 mm/year of rainfall, yet water use has enabled its rapid growth. Severe groundwater overdraft led to the 1980 Groundwater Management Act, but high water use persists, partly a result of weak municipal regulations. While the Phoenix region continues to be promoted as a lush oasis, land use changes and recent drought have led to water scarcity and residential landscaping alternatives, such as rock-based yards with drought tolerant plants. Focused primarily on household and neighborhood scales, CAP integrates social and ecological methods to examine the human drivers of urban-ecological structure, land-management practices, and associated ecosystem functions and services.

Table 1, *Continued*.

The Florida-Coastal Everglades (FCE) LTER (http://fce.lternet.edu/) The FCE-LTER study site in the greater Everglades watershed spans a mosaic of land uses, including wetlands, rural towns, agriculture, and the greater Miami urban corridor. Seven and one half million people including in-migrants, Spanish speakers, and elderly and seasonal residents live in the region. Wetland drainage and land conversion have profoundly altered the natural system, and agricultural and undeveloped lands are being lost as residential and exurban developments fragment the landscape. Aside from the socio-economic consequences, the ecological impacts of land conversion are of particular concern – as these lands buffer urban Miami-Dade and three national parks and reserves (Everglades, Big Cypress and Biscayne). FCE scholars combine geospatial and ethnographic analyses to uncover how zoning, socio-demographics, and climate events (hurricanes and sea-level rise) impact land-use and land-cover at household to regional scales.
The Plum Island Ecosystem (PIE) LTER (http://ecosystems.mbl.edu/PIE/) The PIE-LTER project includes 26 Massachusetts towns intersecting the Ipswich and Parker River watersheds, and the Plum Island Sound estuary. The area receives ~1200 mm/year of precipitation, and river flow is greatest during spring snowmelt and low in summer and fall when evapotranspiration, sewage and municipal water withdrawals exceed rainfall and river flow. Overall water quality and fisheries production is high, but the estuary's upper reaches frequently experience eutrophic conditions during summer. The estuary has been economically productive for centuries, while land use change and human population (~500,000 in 2000) have increased dramatically in recent decades. Population and associated sprawling land-use changes are driven by: high home prices forcing some residents to outlying areas; high-income residents who develop coastal areas for seasonal recreation; and fragmented decision-making where one town's decisions directly affect development pressures and outcomes in neighboring towns.

Figure 2. Geographic context and urbanicity of the four LTER sites



Source: US Census Bureau, 2000

Figure 3. Examples of residential landscapes in the four LTER study regions.

II. APPROACHING MULTI-SCALAR RESIDENTIAL ECOLOGIES

In this section, we present theories, empirical findings, and methodological approaches to residential landscapes research conducted at three fundamental social-organizational scales: individual/household decisions, neighborhood-level processes, and regional-scale policy institutions. We draw from distinct theoretical domains and approaches including: demographic explanations, social stratification, lifestyle-based characteristics, and property regimes (e.g. land ownership and tenure rules), to describe the diverse scalar processes influencing urban and suburban form.

What socioeconomic and cultural factors explain residential land choices at the individual/household parcel scale?

Individual households, the fundamental local-scale residential land managers, maintain yards in particular ways for a variety of reasons, affecting ecosystem structure and function (Baker et al. 2007). For instance, residential lawn fertilization rates, when combined with household diets, account for the majority of total household nitrogen fluxes in the Minneapolis-St. Paul metropolitan area in Minnesota, USA (Fissore et al. 2011). Household fertilization rates also

determine watershed nutrient budgets (Law et al. 2004). These land management practices and ecological outcomes are fundamentally linked to households' socioeconomic and biophysical characteristics. Understanding household-scale decision drivers is thus critical to grounded theories of residential landscapes and socio-ecological dynamics.

Theorizing environmental behavior: Agency and attitudinal factors

Household land management takes place in both public front yards and private backyards, with distinct behavioral drivers in social vs. personal spheres (Stern 2000). In the Phoenix region, CAP-LTER research reveals that landscape preferences in front and backyards are explained by distinct factors: backyard preferences align closely with actual landscaping, and are not linked to household income, whereas household income and house age best explain front yard preferences and landscapes (Larsen and Harlan 2006). A prominent theory of environmental behavior, the Value-Belief-Norm model, posits that individual environmental behavior is influenced by value-based cognitive judgments, or "attitudinal" factors, including: *values* aligning with individualistic or altruistic orientations and conservative or change-oriented inclinations; *beliefs* ascribing responsibility and outcomes to particular actors and actions; and *norms* defining the social expectations for desirable behaviors and people's inclinations to meet them (Stern 2000). Based on people's varying views and priorities, self-transcending altruistic values combined with biocentric orientations may encourage pro-ecological behaviors (Stern et al. 1999), such as reduced pesticide use in yards. On the other hand, conservative values, beliefs in benign or positive outcomes, and long-standing norms could underpin the traditional American lawn (Jenkins 1994; Steinberg 2007).

The empirical evidence for value-based hypotheses is mixed. A CAP survey of residents in one neighborhood found that while anthropocentric values (emphasizing the rights of people to use and control nature) significantly influenced preferences for 'mesic' or water-intensive lawns, biocentric orientations (stressing the rights and protection of nature) did not affect land-cover preferences for drought-tolerant, 'xeric' landscapes with rock groundcover or other yard choices (Yabiku et al. 2008). However, a more recent study in diverse Phoenix neighborhoods indicated that biocentric value orientations led to watering of grassy landscapes as people construct 'nature' in their yards (Larson et al. 2008; Larson et al. 2010), while residents chose xeric landscapes if they prioritized ecologically practical (low-impact and low-maintenance) yards. However, landscaping decisions were influenced less by individual's values than by the historical context of neighborhoods. For instance, intensified pesticide use prevailed in newer, xeric yards compared to lawns in older areas. These findings suggest the need to consider a variety of agency-based and other (e.g., historical) factors as drivers of residential land management.

While Larsen and Harlan (2006) found that environmental concerns did not influence land-cover choices in some Phoenix neighborhoods, other (non-LTER) studies have shown that environmental concerns (Robbins et al. 2001) and activism (Templeton et al. 1999) are associated with *increased* pesticide usage. Varying explanations have been proposed for such disconnects. Some scholars ascribe the prevalence of lawns to residents' desire to be surrounded by 'nature' in their homes (Templeton et al. 1999; Larson et al. 2009a). On the other hand, Robbins (2007) and colleagues (2001) explain that residents consume the ideal of the lawn (and

the products needed to sustain it) as a result of neighborhood social pressure and broader institutional and political-economic forces (addressed in following sections). Yet more research is needed on how behavioral and normative beliefs, in addition to values, alter landscaping decisions relative to other factors.

Social stratification and lifestyle groups

Beyond attitudinal factors, some mid-level theories of residential landscapes have invoked an "ecology of prestige" (Grove et al. 2006, Troy et al. 2007), noting that land management is centrally determined by the socioeconomic characteristics of households. For instance, BES-LTER surveys indicate that differential yard expenditures by Baltimore residents are linked to their income, age and household size (Grove et al. 2006, Zhou et al. 2009), although both yard expenditures and greenness also varied with housing age. Unobserved variables not related to lawn expenditure, such as irrigation methods, labor inputs, or community greening efforts, may significantly influence lawn greenness as well. Such measurement challenges complicate the socio-ecological analysis of residential landscapes.

CAP-LTER research also reveals the salience of residents' socioeconomic characteristics in the Phoenix area. Higher-income residents prefer desert-style xeric options over mesic lawns (Larsen and Harlan 2006). As well, the gendered division of household labor significantly shapes landscape preferences; women's roles in house and childcare were linked to their dislike of xeric yards, perceived to increase the likelihood of injuries to children (Yabiku et al. 2008; Larson et al. 2009a). Furthermore, socialization processes and the tenure of residency influences landscape choices (Martin 2008); recent empirical evidence suggests that long-time Phoenicians strongly prefer the mesic lawns to which they have become accustomed (Larson et al. 2009a), while newcomers prefer more desert-like, xeric landscaping (Martin et al. 2003; Yabiku et al. 2008).

While household characteristics clearly drive land management decisions, material aspects of the parcels and dwellings also influence landscape choices. For instance, housing age affects landscaping in Phoenix, where historic neighborhoods often contain lush grassy landscapes while new developments increasingly include xeric front yards (Larsen and Harlan 2006). In Baltimore, residential grass and tree cover increase non-linearly with housing age, with a peak at 40-50 years (Grove et al. 2006, Troy et al. 2007, Boone et al. 2009a). Spatial and economic aspects of parcels are also fundamental. For instance, house-to-lot size ratios, setback and frontage are linked to the possible extent of lawns and impervious surface on individual properties (Robbins and Birkenholtz 2003; Stone 2004), while housing values are linked to residential fertilizer applications (Zhou et al. 2008).

In sum, attitudinal factors, household demographics, and parcel characteristics combine in complex ways to produce residential landscapes at the local scale through value-based judgments, social lifestyle preferences, and structural urban characteristics. Since outcomes at these disaggregate scales are partly a function of broader-scale processes, it is essential to consider neighborhood and larger-scale dynamics in a multi-scalar approach to residential landscapes research.

How do social/structural forces at the neighborhood scale mediate residential land management, use and cover patterns?

Individual and household land management is strongly affected by shared social characteristics at the neighborhood level. Key aspects of neighborhood social dynamics critical to the evolution of residential landscapes include formal and informal neighborhood governance, social stratification or group lifestyle characteristics, and processes of neighborhood-scale housing transitions or filtering.

Formal and informal neighborhood institutions

Neighborhoods are governed in multiple ways, ranging from formal institutional rules in privately governed communities, to informal social mores among neighbors. Formal neighborhood governance institutions include covenants, codes, and restrictions (CCRs) associated with residential community associations (RCAs) and homeowner associations. New residential developments are witnessing a resurgence of private covenants, historically the means of land zoning in the US before the advent of municipal zoning in the early 20th century (Deng 2003). CCRs often control visible front yards rather than backyards in Phoenix (Larsen and Harlan 2006), and help explain the divergence between residents' stated yard preferences and actual yard management (Martin et al. 2003; Larson et al. 2008). Even neighborhoods lacking RCAs often mobilize voluntary neighborhood associations to enforce municipal ordinances.

In addition to formal institutions, informal social norms define what is acceptable in yards, and residents commonly cite neighbors in connection with their yard maintenance strategies (Nielson and Smith 2005). Scholars have connected such norms to the economic imperatives of the lawn-chemical industry (Robbins and Sharp 2003a), producing a "moral economy of the lawn" and a "collective culture of redistributive obligation" in which community is constructed and reinforced through collective monoculture practices (Robbins and Sharp 2003b). Not surprisingly, resistance to neighborhood lawn care regimes also occurs (Robbins and Sharpe 2003b), or may simply take the form of disinvestment or passive yard management. Odland (1982) and Massey and Denton (1993) highlight, respectively, how disinvestment can expand through spatial lag effects, and how the lack of maintenance of residential properties can lower neighbor's incentives as well.

Neighborhood norms are subject to social stratification and group lifestyle effects. When town elites organize to shape local development, resulting outcomes tend to cater to elite interests (Logan and Molotch 1987). Thus, urban spatial segregation related to lifestyle group clustering in neighborhoods may produce distinct landscape patterns. Such outcomes are of great interest in environmental justice, a field that has long focused on the distribution of environmental risks such as atmospheric pollution, but is moving to critically (re)evaluate the social allocation of environmental amenities, such as urban tree canopy cover. For instance, urban vegetative patterns correlate strongly with varying levels of investment in green infrastructure, in turn linked to relative power and wealth differences in neighborhoods (Heynen et al. 2006). Political ecological approaches trace how the social production of urban ecology leads to an uneven distribution of amenities such as green space, or vulnerabilities to changes such as drought and water policy (Swyngedouw 2002; Desfor and Keil 2005). Prevailing models

of capitalist development embed urban areas in local-global networks, commodifying nature in cities for consumption and exchange (Robbins et al. 2001). For instance, the privatization of environmental management, specifically urban forestry, has intensified residential canopy cover inequities in Milwaukee (Heynen et al. 2006).

Neighborhood turnover, social and spatial mobility

Alongside wealth disparities, broader differences in group identities and social status may represent various lifestyle niches (Jenkins 1994) and influence neighborhood landscape dynamics. Commensurate with stratification and lifestyle group affinity theories, the "ecology of prestige" effect in Baltimore relates higher social status with higher neighborhood biodiversity and vegetation cover (Grove et al. 2006; Troy et al. 2007). Yet, long-term land use legacies complicate such socio-ecological relations. For instance, Baltimore neighborhoods with high proportions of African Americans show lower expenditure on planting and yard maintenance, but higher tree densities, possibly explained by past tree plantings or processes of "natural" succession on vacant lots, or both (Grove et al. 2005, Troy et al. 2007). In Phoenix, present-day canals based on the ancient Hohokam agricultural irrigation system continue to deliver water to flood irrigation systems in older residential neighborhoods. Finally, past decisions, such as the promotion of Phoenix as an "oasis" in which "the desert is a myth", can create cultural legacies wherein long-time residents of historic neighborhoods prefer the mesic landscapes to which they have become accustomed (Larson et al. 2009a). These cases exemplify the importance of long-term legacies in continuing to shape contemporary residential landscapes.

Social mobility, the ability of individuals and groups to increase their social status, has been linked to neighborhood turnover over time. For instance, the housing filtering model suggests that neighborhoods of aging (Muth 1969) or smaller (Bond and Coulson 1989) housing structures "filter down" to lower income residents as households of increasing/higher wealth move to suburbs with newer construction, larger lots or better public services. BES-LTER research illustrates lifestyle theory, social stratification and housing filtering in Baltimore, where homes are more likely to have more extensive areas of vegetative (lawns, shrubs or tree) cover if they are located in neighborhoods with considerable public green space (Grove et al. 2005, Boone et al. 2009b). Consistent with social stratification and housing filtering theory, high-density neighborhoods with smaller lots, more impervious surfaces and less plantable area are typically located in older, central urban regions that are more densely settled, with larger minority populations and lower incomes (Troy et al. 2007).

Social mobility not only drives neighborhood transitions, it is critical in short-term responses to stress, and to long-term social resilience. Theoretical approaches in political ecology and vulnerability research reveal how social contexts mediate community responses and coping capacities in the face of environmental change (Blaikie et al. 1994; Eakin and Luers 2006). These insights are particularly germane in south Florida, where urban households and land parcels exposed to periodic shocks from extreme weather events such as hurricanes, vary in their capacities to recover, in part due to uneven social and power relations. Accordingly, FCE-LTER research is investigating how residents in neighborhoods of varying economic marginalization respond to hurricanes, evaluating social-ecological resilience to extreme events or sudden, "pulsed" changes. The recent real estate collapse is another example of a pulse event or system

"shock" that is more anthropogenic in flavor, also being explored. Initial analyses indicate that residents' spatial mobility (their ability to relocate) and their residential land use/cover outcomes depend upon access to top-tier home insurance policies (Peacock and Girard 1997), in turn conditioned by neighborhood racial and economic characteristics. These examples illustrate how spatial mobility is inextricably linked with social mobility.

In summary, neighborhood-scale processes influencing urban landscapes range from formal governance institutions and codes to informal social norms, and regionally differentiated processes of urban social and spatial mobility. Such processes not only affect residential land management at the household scale, but also the viability of neighborhood survival and resilience in the event of sudden pulse disturbances or system "shocks", whether political/economic or ecological. Both household and neighborhood scale dynamics are fundamentally affected by regional policies, development dynamics, and municipal governance institutions.

What are the implications of regional development and institutions, including municipal and state-level governance, for residential land management?

Development and land management in parcels and neighborhoods unfold within regional political, economic and ecological contexts. Thus, vegetative change at local scales is linked to regional development and municipal or state-level policy and governance.

Regional urban development and density theories

The determinants of urban development and density have been analyzed in urban economics, geography and planning (e.g. Muth 1969; Mills 1979; Alperovich 1982). At the regional scale, urban development has been linked to "pull" factors such as employment and amenities, and "push" factors such as crime and expensive land. Existing building densities and residential management emerge from these processes over multiple time scales; for instance, many city centers developed from the clustering of industrial-transportation infrastructure and differential diffusion processes (e.g., Geyer and Kontuly 1993; Antrop 2004). Construction shifted towards the suburbs as reduced transportation costs and communication technologies released businesses from their dependency on city centers. These factors have driven a widespread decentralization of urban populations and suburban expansion, although new evidence suggests the growth of suburban regions and populations may be declining in several US cities (Mieszkowski and Mills 1993; Henrie and Plane 2006).

Land use planning and zoning institutions

Strategies to manage suburban sprawl and land fragmentation at larger scales include land use planning, zoning ordinances and open space preservation policies (Karasov 1997; Razin 1998; Croissant and Munroe 2002). Zoning regulations are strongly linked to the patterns of residential development, with implications for landscape change (Munroe et al. 2005; McConnell et al. 2006). For instance, larger minimum lot size zoning has been linked to higher landscape fragmentation in Maryland (Irwin and Bockstael 2007) and lower land use diversity in Indiana (Munroe et al. 2005). Levia (1998) found that lot size, distances to town centers, and

transportation networks significantly drove farmland conversion to residential development in Massachusetts. While zoning policies can reduce land fragmentation and sprawl, they may also prevent investments in environmental amenities. For example, municipal ordinances in Milwaukee prevent the public establishment of urban forest in low-income, private residential lots where owners may be financially unable to realize such environmental stewardship (Heynen et al. 2006).

Inconsistent zoning may produce spatial externalities wherein land uses are displaced or "spill over" to adjacent regions in the face of zoning discontinuities (Carruthers 2003). Additionally, municipal zoning often reflects feedbacks from social and ecological changes, and broader-scale state-level mandates. Thus, zoning can be an endogenous response to the realities of land markets (Wallace 1988) and environmental risks, such as hurricanes in Florida. Such factors motivate state-level growth management planning mandates (e.g., the Florida Growth Management Act 1985), and inform zoning policies in vulnerable regions (Deyle et al. 2008).

The politically negotiated and transient nature of zoning is frequently reflected in local histories of zoning variances and exemptions, which can alter the relationship between formal zoning codes and observed land use/cover (Libby 1994; Cordes 2002; Duke and Lynch 2006). FCE-LTER research in rapidly urbanizing Miami-Dade County is analyzing archival land use and zoning data to test the hypothesis that zoning changes are more likely to occur in land parcels whose market valuation diverges significantly from their current land use. Such a divergence between land use and market valuation can trigger land cover changes and environmental impacts through landscape fragmentation, increased water demand, and changes in wildlife habitat availability. Initial analyses suggest (1) requests for exemptions and changes to parcel zoning exhibit significant spatial clustering, and (2) property damage associated with sudden events such as hurricanes can drastically lower assessed home values, and then trigger rapid transformations in area demographics, land use and land cover. Both types of phenomena through time may be linked to changes in zoning.

Broad-scale resource use restrictions and conservation initiatives

Residential land management is also affected by municipal and/or state conservation initiatives and resource (e.g., water) use restrictions. PIE-LTER research examines how town zoning, land-use boards and state water-use regulatory structures affect suburbanization and homeowner lawn care and water management in central and eastern Massachusetts (Hill and Polsky 2005, 2007; Guha 2009; Polsky et al. 2009). State development policies (e.g., 1994 Smart Growth Zoning and Housing Production Act; 2000 Community Preservation Act) shape residential patterns by encouraging high-density growth. Massachusetts' Regional Planning Commissions lack binding authority, but influence resource management policies by assisting towns with "open space" funding applications by providing maps, models and predictions of land and resource use. State water management legislation, including the 1963 Wetlands Protection Act and 2004 Water Policy, target both demand- and supply-side water management with per capita daily residential consumption limits. The net effect of such legislation has been a more restrictive regulatory environment in Massachusetts than in arid regions such as Phoenix, where no watering restrictions have been imposed despite a long-term drought (Larson et al. 2009b).

Scalar disconnects in governance are apparent between state-level structures and town level implementation. PIE-LTER interviews reveal that even though town land-use planners and state-level water managers are aware of potential synergies, many report being institutionally unable (i.e., under-staffed) to capitalize on them. For example, survey results indicate that the two sets of decision makers agree about the drivers (e.g., residential lawn care behaviors) of local water stress, suggesting the opportunity for pursuing integrated land and water policy actions. Interestingly, however, these two communities diverge on which policy solutions they support. Compared to land-use planners, water managers are more supportive of policies to find and purchase new water sources, and less supportive of policies to restrict residential outdoor water consumption (Guha 2009). Conflicting views about governance, also exemplified in a Phoenix study of policy professionals, residents and academics (Larson et al. 2009c), may constrain the ability of towns to enact adaptations for expected future water challenges (Hill and Polsky 2005, 2007; Polsky et al. 2009).

In sum, town, municipal and state regulatory structures respond to processes and predictions of urban growth, and impose resource use restrictions that shape residential landscape management at the neighborhood and household scale. Regional-scale policies are in turn influenced by national and broader-scale dynamics and institutions, including market fluctuations, federal policies, and the global economy. For instance, Miami residential land value and use are linked to regional and international land markets, while national disaster insurance markets influence the ability of neighborhoods, with varying policy coverage, to recover from hurricanes. Such dynamics are difficult to quantify, yet important to land cover and management dynamics. While tracing the impacts of such broader processes is outside the current scope of this article, it is critical to recognize and evaluate how these forces may manifest at the various scales and influence local land management.

III. CONCLUSION: COMPARATIVE INSIGHTS, EMERGENT CHALLENGES, FUTURE DIRECTIONS

The theoretical insights and quantitative and qualitative evidence we have presented illustrate multi-scalar processes of decision-making and landscape change in urban socio-ecological systems. At the scale of individual residential parcels, land management decisions are linked to residents' attitudes and values, socio-economic and lifestyle factors and constraints, and parcel biophysical characteristics. Household residential actions are further shaped by diverse formal and informal institutions at the neighborhood-scale and processes of socio-spatial mobility—respectively, the ability of individuals and households to increase their socio-economic status or relocate to neighborhoods perceived as reflecting such status—among neighborhoods. Household and neighborhood vegetation structure are in turn affected by municipal and state regulatory structures, including land use zoning and water use restrictions.

Rather than exhaustively document site-specific research on residential landscapes to illustrate the above scalar dynamics, the vignettes presented here illustrate a common set of research approaches to deal explicitly with multi-scalar processes affecting residential land use. The vignettes also reveal a set of theoretical insights as well as challenges emerging from: political-ecological contexts (e.g., neighborhood marginalization and hurricane recovery in south Florida); the importance of cultural attitudes and historical legacies (e.g., in explaining

yardscaping outcomes in Phoenix); prevalence of nonlinear dynamics (e.g., between housing age and land cover outcomes in Baltimore); and scalar disconnects (e.g., between state vs. town-level governance in the Boston area). Each of these vignettes, and residential landscapes in general, also illustrate difficult challenges in determining causality. While cross-sectional data collected in short time-frames (two-three years) may point towards associations among diverse social and ecological variables, the analysis of cause-effect relations requires investment in long-term data collection, as also advocated by leading researchers of socio-ecological change (e.g., Yarnal et al. 2009; Redman and Foster 2008). Furthermore, cause-effect or endogeneity relations between local social and ecological characteristics may vary across social groups and/or spatial and temporal scales. Such considerations require time-series and multi-scalar data and analyses.

Addressing these challenges is essential to developing mid-level theories of residential landscapes and bridging individualistic theories of environmentally relevant behavior with structural theories of human-environment interactions. Residential landscapes can be a site of constant tension between managers' desires and actions and broader structural-institutional forces (Robbins 2007). Thus, assessing the discrepancies between residents' preferences, abilities, management practices and land use/cover can contribute to a better understanding of realized urban residential form and ecological patterns; past legacies and time-lags; supra-local constraints/forces, or natural succession processes; and the relative importance of each driving process within and across diverse scales. Approaching this understanding across multiple sites within an explicitly multi-scalar organizational framework stands to contribute valuable insights to advancing socio-ecological theories of urban landscape change under diverse biophysical, social and scalar contexts.

LITERATURE CITED

Alperovich, G. 1982. Density gradients and the identification of the central business district. Urban Studies 19:8.

Antrop, M. 2004. Landscape change and the urbanization process in Europe. Landscape and Urban Planning 67:9-26.

Baker L., A. Brazel, L. Byrne, A. Felson, J.M. Grove, H. Hill, K.C. Nelson, J. Walker and V. Shandas. 2007. Symposium: Effects of human choices on characteristics of urban ecosystems. Bull Ecol Soc Am 88(4):404–9.

Blaikie, P., T. Cannon and B. Wisner. 1994. *At risk, Natural hazards, people's vulnerability and disasters*. London: Routledge.

Bond, E.W. and N.E. Coulson. 1989. Externalities, filtering and neighborhood change. Journal of Urban Economics 26(2):231-249.

Boone, C., M.L. Cadenasso and J.M. Grove. 2009a. Landscape, vegetation characteristics, and group identity in an urban and suburban watershed: Why the 60s matter. Urban Ecosystems 13(3):255-271.

Boone, C.G., G.B. Buckley, J.M. Grove and C. Sister. 2009b. Parks and people: An environmental justice inquiry in Baltimore, Maryland. Annals of the Association of American Geographers 99(4):1-21.

Brown D.G., K.M. Johnson, T.R. Loveland and D.M. Theobald. 2005. Rural land-use trends in the coterminous United States, 1950-2000. Ecol Appl 15:1851–63.

Cadenasso, M.L., S.T.A. Pickett and J.M. Grove. 2006. Dimensions of ecosystem complexity: Heterogeneity, connectivity, and history. Ecological Complexity 3(1):1-12.

Carruthers, J.I. 2003. Growth at the fringe: The influence of political fragmentation in United States metropolitan areas. Papers in Regional Science 82(4):475-499.

Collins, S., S.M. Swinton, C.W. Anderson, B.J. Benson, J. Brunt, T.L. Gragson, N.B. Grimm, J.M. Grove, D. Henshaw, A.K. Knapp, G. Kofinas, J. J. Magnuson, W. McDowell, J. Melack, J.C. Moore, L. Ogden, L. Porter, J. Reichman, G.P. Robertson, M.D. Smith, J. Vande Castle and A.C. Whitmer. 2007. *Integrated Science for Society and the Environment: A strategic research initiative*, p. 35. Albuquerque, NM: LTER Network Office.

Cordes, M. 2002. *Agricultural zoning: Impacts and future directions. Protecting farmland at the fringe: Do regulations work?* Columbus, OH: OSU Swank Program in Rural-Urban Policy.

Croissant, C. and D. Munroe. 2002. Zoning and fragmentation of agricultural and forest land use on residential parcels in Monroe county, Indiana. Geography Research Forum 22:91–109.

Deng, F.F. 2003. The rebound of private zoning: Property rights and local governance in urban land use. Environment and Planning A 35:133-149.

Deyle, R.E., T.S. Chapin and E.J. Baker. 2008. The proof of the planning is in the platting: An evaluation of Florida's hurricane exposure mitigation planning mandate. Journal of the American Planning Association 74(3):349-370.

Duke, J. and L. Lynch. 2006. Farmland retention techniques: Property rights implications and comparative evaluation. Land Economics 82(2): 189–213.

Eakin, H. and A.L. Luers. 2006. Assessing the vulnerability of social-environmental systems. Annu. Rev.Environ Resourc 31:365-394.

Fissore, C., L.A. Baker, S.E. Hobbie, J.Y. King, J.P. Mcfadden, K.C. Nelson and I. Jakobsdottir. 2011. Carbon, nitrogen, and phosphorus fluxes in household ecosystems in the Minneapolis–Saint Paul, Minnesota, urban region. Ecological Applications 21(3):619-639.

Florida Growth Management Act. 1985. 1985 Fla. Laws chapter 55.

Geyer, H.S. and T.M. Kontuly. 1993. A theoretical foundation for the concept of differential urbanization. Int. Reg. Sci. Rev. 15:157-177.

Grove, J.M. and W.R. Burch Jr. 1997. A social ecology approach and applications of urban ecosystem and landscape analyses: A case study of Baltimore, Maryland. Urban Ecosystems 1(4):259-275.

Grove, J.M., W.R. Burch and S.T.A. Pickett. 2005. Social mosaics and urban forestry in Baltimore, Maryland. In *Communities and forests: Where people meet the land*, R.G. Lee and D.R. Field (eds.), pp. 248-273. Corvalis: Oregon State Univ. Press.

Grove, J.M., A.R. Troy, J.P.M. O'Neil-Dunne, W.R. Burch, M.L. Cadenasso and S.T.A. Pickett. 2006. Characterization of households and its implications for the vegetation of urban ecosystems. Ecosystems 9(4):578-597.

Guha, A. 2009. Adapting to suburbanization-induced water stress in Eastern Massachusetts: Opportunities and constraints for integrated land-use and water resource management. Unpublished Master of Arts Thesis, Graduate School of Geography, Clark University, Worcester, MA.

Henrie, C.J. and D.A. Plane. 2006. Decentralization of the nation's Main Street: New coastal-proximity-based portrayals of population distribution in the United States. Professional Geographer 58(4):448-459.

Heynen, N., H.A. Perkins and P. Roy. 2006. The political ecology of uneven urban green space: The impact of political economy on race and ethnicity in producing environmental inequality in Milwaukee. Urban Affairs Review 42(1):3-25.

Hill, T. and C. Polsky. 2005. Suburbanization and adaptation to the effects of suburban drought in rainy Central Massachusetts. Geographical Bulletin 47(2):85-100.

Hill, T. and C. Polsky. 2007. Development and drought in suburbia: A mixed methods rapid assessment of vulnerability to drought in rainy Massachusetts. Environmental Hazards: Human and Policy Dimensions 7:291-301.

Irwin, E.G. and N.E. Bockstael. 2007. The evolution of urban sprawl: Evidence of spatial heterogeneity and increasing land fragmentation. Proceedings of the National Academy of Sciences of the USA 104(52):20672-20677.

Jenkins, V.S. 1994. *The lawn: A history of an American obsession*. Washington DC: Smithsonian Institution Press.

Karasov, D. 1997. Politics at the scale of nature. In *Placing nature: Culture and landscape ecology*, J.I. Nassauer (ed.), pp 123-138. Washington DC: Island Press.

Katz, B. and R.E. Lang, eds. 2003. *Redefining cities and suburbs: Evidence from census 2000*. Volume I. Washington DC: Brookings Institution Press.

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

Larson, K.L., E.M. Cook, S.J. Hall, B. Funke, C.A. Strawhacker and V.K. Turner. 2008. *Social-ecological dynamics of residential landscapes: Human drivers of management practices and ecological structure in an urban ecosystem context*. Final Report from an Interdisciplinary Graduate Workshop, Fall 2008. Global Institute of Sustainability, Arizona State University.

Larson, K.L., D. Casagrande, S. Harlan and S. Yabiku. 2009a. Residents' yard choices and rationales in a desert city: Social priorities, ecological impacts, and decision tradeoffs. Environmental Management 44(5):921-937.

Larson, K.L., A. Gustafson and P. Hirt. 2009b. Insatiable thirst and a finite supply: Assessing municipal water conservation policy in greater Phoenix, Arizona, 1980-2007. Journal of Policy History 21(2):107-137.

Larson, K.L., D. White, P. Gober, S. Harlan and A. Wutich. 2009c. Divergent perspectives on water resource sustainability in a public-policy-science context. Environmental Science and Policy 12:2012-2023.

Larson, K.L., E.M. Cook, C.A. Strawhacker and S.J. Hall. 2010. The influence of diverse values, ecological structure, and geographic context on residents' multi-faceted landscaping decisions. Human Ecology 38(6):747-761.

Law, N.L., L.E. Band and J.M. Grove. 2004. Nutrient input from residential lawncare practices in suburban watersheds in Baltimore County, MD. Journal of Environmental Planning and Management 47:737-755.

Levia, D.F. 1998. Farmland conversion and residential development in North Central Massachusetts. Land Degradation and Development 9(2):123-130.

Libby, L.W. 1994. Conflict on the commons: Natural resource entitlements, the public interest, and agricultural economics. American Journal of Agricultural Economics 76(5): 997–1009.

Logan, J. and H.L. Molotch. 1987. *Urban fortunes: The political economy of place*. Berkeley, CA: Univ. of California Press.

McConnell, V., M. Walls and E. Kopits. 2006. Zoning, TDRs and the density of development. Journal of Urban Economics 59(3):440-457.

Martin, C. 2008. Landscape sustainability in a Sonoran desert city. Cities and the Environment 1(2):1-16.

Martin, C., K.A. Peterson and L.B. Stabler. 2003. Residential landscaping in Phoenix, Arizona, USA: Practices and preferences relative to covenants, codes and restrictions. Journal of Arboriculture 29(1):9-17.

Massey, D. and N. Denton. 1993. *American apartheid: Segregation and the making of the underclass*. Cambridge, MA: Harvard Univ. Press.

Merton, R.K. 1968. *Social theory and social structure*. New York: The Free Press.

Mieszkowski, P. and E.S. Mills. 1993. The causes of metropolitan suburbanization. The Journal of Economic Perspectives 7(3):135-147.

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

Mills, E.S. 1979. Economic analysis of urban land-use controls. In *Current issues in urban economics*, P. Mieszkowski and M. Straszheim (eds.), pp 511-541. Baltimore: Johns Hopkins Univ. Press.

Munroe, D.K., C. Croissant and A.M. York. 2005. Land use policy and landscape fragmentation in an urbanizing region: Assessing the impact of zoning. Applied Geography 25:121-141.

Muth, R.F. 1969. *Cities and housing: The spatial pattern of urban residential land use*. Chicago: Univ. Chicago Press.

Nielson, L. and C.L. Smith. 2005. Influences on residential yard care and water quality: Tualatin watershed, Oregon. Journal of the American Water Resources Association 41(1):93-106.

Odland, J. 1982. A statistical model for the development of spatial patterns: Applications to the spread of housing deterioration. Geographical Analysis 14:326–39.

Otto, B., K. Ransel, J. Todd, D. Lovaas, H. Stutzman and J. Bailey. 2002. *Paving our way to water shortages: How sprawl aggravates the effects of drought*. American Rivers, the Natural Resources Defense Council and Smart Growth America. Online: http://www.americanrivers.org/index.php?module=HyperContent&func=display&cid=1010.

Peacock, W.G. and C. Girard. 1997. Ethnic and racial inequalities in hurricane damage and insurance settlements. In *Hurricane Andrew: Ethnicity, gender and the sociology of disasters*. W.G. Peacock, B.H. Morrow and H. Gladwin (eds.), pp. 171-190. London: Routledge.

Pickett, S.T.A., M.L. Cadenasso and J.M. Grove. 2005. Biocomplexity in coupled human-natural systems: A multi-dimensional framework. Ecosystems 8:1-8.

Polsky, C., S. Assefa, K. Del Vecchio, T. Hill, L. Merner, I. Tercero and G. Pontius. 2009. The mounting risk of drought in a humid landscape: Structure and agency in suburbanizing Massachusetts. In *Sustainable communities on a sustainable planet: The human-environment regional observatory project*, B. Yarnal, C. Polsky and J. O'Brien (eds.), pp.229-250. New York: Cambridge University Press.

Razin, E. 1998. Policies to control urban sprawl: Planning regulations or changes in the 'rules of the game'? Urban Studies 35(2):321-340.

Redman, C. and D.R. Foster (Eds). 2008. *Agrarian Landscapes in Transition: Comparisons of Long□Term Ecological & Cultural Change*. Oxford University Press.

Robbins, P. 2007. *Lawn people: How grasses, weeds and chemicals make us who we are*. Philadelphia, PA: Temple University Press.

Robbins, P., A. Polderman and T. Birkenholtz. 2001. An ecology of the city. Cities 18(6):369–80.

Robbins, P. and T. Birkenholtz. 2003. Turfgrass revolution: Measuring the expansion of the American lawn. Land Use Policy 20:181-194.

Robbins, P. and J.T. Sharp. 2003a. The lawn-chemical economy and its discontents. Antipode 35(5):955-979.

Robbins, P. and J.T. Sharp. 2003b. Producing and consuming chemicals: The moral economy of the American lawn. Economic Geographer 79(4):425-451.

Steinberg, T. 2007. *American green: The obsessive quest for the perfect lawn*. New York: W.W. Norton and Co.

Stern, P. 2000. Toward a coherent theory of environmentally significant behavior. Journal of Social Issues 56(3):407-424.

Stern, P.C., T. Dietz, T. Abel, G.A. Guagnano and L. Kalof. 1999. A value-belief-norm theory of support for social movements: The case of environmentalism. Human Ecology Review 6(2):81-98.

Stone Jr., B. 2004. Paving over paradise: How land use regulations promote residential imperviousness. Landscape & Urban Planning 69:101-113.

Swyngedouw, E. 2002. Urban water: A political-ecology perspective. Built Environment 28(2):124-137.

Templeton, S.R., S. J. Yoo and D. Zilberman. 1999. An economic analysis of yard care and synthetic chemical use: The case of San Francisco. Environmental & Resource Economics 14(3):385-397.

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

Vogt, K.A., J.M. Grove, H. Asbjornsen, K. Maxwell, D.J. Vogt, R. Sigurdardottir and M. Dove. 2002. Linking ecological and social scales for natural resource management. In *Integrating landscape ecology into natural resource management*, J. Liu and W.W. Taylor (eds.), pp 143-175. Cambridge: Cambridge Univ. Press.

Wallace, N.E. 1988. The market effects of zoning undeveloped land: Does zoning follow the market. Journal of Urban Economics 23(3):307–326

Wallace, W.L. 1969. *Sociological Theory*. p. 296. Chicago: Aldine Publishing Company.

Yabiku S., D.G. Casagrande and E. Farley-Metzger. 2008. Preferences for landscape choice in a Southwestern desert city. Environment and Behavior 40(3):382-400.

Yarnal, B., C. Polsky and J.O'Brien (Eds.). 2009. *Sustainable communities on a sustainable planet: The human-environment regional observatory project*. Cambridge University Press, Cambridge, England.

Zhou, W., A.R. Troy and J.M. Grove. 2008. Modeling residential lawn fertilization practices: Integrating high resolution remote sensing with socioeconomic data. Environmental Management 41:742-752.

Zhou, W., J.M. Grove, A.R. Troy and J.C. Jenkins. 2009. Can money buy green? Demographic and socioeconomic predictors of lawncare expenditures and lawn greenness in urban residential areas. Society & Natural Resources 22:744-760.