Sustainable Urbanism: An Integrative Analysis of Master Planned Developments as a Vehicle for Urban Environmental Sustainability

by

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ABSTRACT

Sustainable urbanism offers a set of best practice planning and design prescriptions intended to reverse the negative environmental consequences of urban sprawl, which dominates new urban development in the United States. Master planned developments implementing sustainable urbanism are proliferating globally, garnering accolades within the planning community and skepticism among social scientists. Despite attention from supporters and critics alike, little is known about the actual environmental performance of sustainable urbanism. This dissertation addresses the reasons for this paucity of evidence and the capacity of sustainable urbanism to deliver the espoused environmental outcomes through alternative urban design and the conventional master planning framework for development through three manuscripts. The first manuscript considers the reasons why geography, which would appear to be a natural empirical home for research on sustainable urbanism, has yet to accumulate evidence that links design alternatives to environmental outcomes or to explain the social processes that mediate those outcomes. It argues that geography has failed to develop a coherent subfield based on nature-city interactions and suggests interdisciplinary bridging concepts to invigorate greater interaction between the urban and nature-society geographic subfields. The subsequent chapters deploy these bridging concepts to empirically examine case-studies in sustainable urbanism. The second manuscript utilizes fine scale spatial data to quantify differences in ecosystem services delivery across three urban designs in two phases of Civano, a sustainable urbanism planned development in Tucson, Arizona, and an adjacent, typical suburban development comparison community. The third manuscript considers the extent to which conventional master planning processes are fundamentally at odds with urban environmental sustainability through interviews with stakeholders involved in three planned developments: Civano (Tucson, Arizona), Mueller (Austin, Texas), and Prairie Crossing (Grayslake, Illinois). Findings from the three manuscripts reveal deep challenges in conceptualizing an empirical area of inquiry on sustainable urbanism, measuring the outcomes of urban design alternatives, and innovating planning practice within the constraints of existing institutions that facilitate conventional development. Despite these challenges, synthesizing the insights of geography and cognate fields holds promise in building an empirical body of knowledge that complements pioneering efforts of planners to innovate urban planning practice through the sustainable urbanism alternative.

DEDICATION

In loving memory of Linda Lee Turner for her patient and selfless support of two academic careers.

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INTRODUCTION

Urbanization has always produced environmental challenges and in the 21st century those challenges will be amplified by the number of people living in mega-urban complexes (Marshall 2005). Addressing these challenges demands innovations in how we plan, build, and manage cities—urbanization processes—and novel approaches and frameworks to empirically investigate those processes. Interdisciplinary scholars have characterized cities as complex adaptive systems that are the ever-evolving manifestation of the dynamic interrelationships between the built environment and social and ecological processes (Grimm et al. 2008). This research focuses on three knowledge domains that contribute partly, but none wholly, to this conceptualization of city-nature-society relationships: (1) sustainable urbanism approaches to planning, design, and development, (2) urban ecological research on the services generated through biophysical processes, and (3) insights on the role of social institutions in shaping environmental outcomes from the environmental social science. The latter two domains, urban ecology and environmental social science, are central contributors to the city-as-complex-adaptive-system literature while sustainable urbanism, as a field of practice, has remained relatively separate from empirical nature-society relationship studies. Integrating the three holds promise in bridging an empirical-practice divide, contributing to robust empirical analysis of urban sustainability and applied solutions.

Several cognate, systems-based, areas of inquiry focused on city-nature-society relationships have emerged in interdisciplinary fields spanning the natural and social sciences. In the ecological sciences, such interdisciplinary studies ushered in a paradigm shift within the field—human systems were no longer considered separate from "nature"—and coalesced as the distinct urban ecology subfield. Ecological concepts like ecosystem services highlight the broad range of ecological processes that contribute to human-well being, trade-offs between services, and the cost of human made substitutes for those services. In the environmental social sciences, areas of inquiry such as the management of environmental commons, adaptive management, and decision-making under uncertainty grapple with the role of human institutions in structuring environmental outcomes, although not exclusively in cities. They underscore the importance of institutional fit with the social-ecological systems being managed and flexible systems of governance capable of adapting to and even anticipating change (Ostrom 2005, Folke et al. 2005, Quay 2010). A major implication of this systems-based perspective for urban planning is that the urban form alters biophysical processes and the human systems for governing and managing the built environment profoundly influences how cities are built and the urban environment is managed.

An important change to the modern urbanization process has been the rise of the master planned development—large-scale, comprehensively planned residential or mixed-use developments, typically, but not always, located on previously undeveloped sites—which integrates virtually every aspect of the development process, gives a large amount of control over the way we build our cities to national and international development firms, and generally increases the rate of urban growth and scale of cities (Weiss 1987, Seto et al. 2010). Master planned developments, therefore, have the capacity to transform biophysical and institutional landscapes rapidly and at large scales.

In the United States, this transformation has taken the form of urban sprawl, creating diffuse territories of subdivided, separate-use urban lands. Urban sprawl has been linked to myriad environmental problems including rapid land consumption, increasing outdoor water use, and declining air quality due to the auto-dominant lifestyle it necessitates (Johnson 2001).

The sustainable urbanism movement in planning attributes sprawl to the devolution of the urban planning field to the development industry and calls for a return to a normative basis for urban planning and the pursuit of good urban form (Brain 2005). It offers a set of best practice planning and design prescriptions intended to reverse the negative environmental consequences of urban sprawl. Specifically, sustainable urbanism posits that dense, mixed-use neighborhoods connected by a network of multi-modal transportation options and buffered by a variety of open space land uses will improve environmental and public health by reducing land consumption, auto dependency, and the overall impact of development on the natural system (Farr 2005). Although the movement is critical of conventional development, many sustainable urbanism projects are implemented through the conventional master planning process.

Indeed, master planned developments following the prescriptions of sustainable urbanism are proliferating globally, gaining traction in mainstream planning circles, and receiving accolades from within the planning community (Garde 2009, Mapes and Wolch 2011). Sustainable urbanism has also caught the attention of geographers who have critiqued sustainable urbanism as typical suburbia cloaked in sustainability rhetoric and pointed to failures to meet social goals such as equity and diversity (Zimmerer 2001).

Despite these critiques from geographers and embrace by the planning community, little is known about the actual environmental performance of sustainable urbanism (Conway 2009). A major reason for this paucity of evidence is that sustainable urbanism is an applied, normative, and prescriptive field of practice as opposed to an empirical area of inquiry. Another reason, however, is the failure of more empirical fields, like geography, to investigate the environmental outcomes of sustainable urbanism projects and the social processes that intervene in those outcomes.

This dissertation includes three manuscripts that examine the role of sustainable urbanism in addressing urban environmental challenges. The first manuscript, "Bridges and Borderlands: Sustainable Urbanism and the Case for an Explicit Urban Nature-Society Geography" (Chapter 2), considers the reasons why geography, which would appear to be a natural empirical home for research on sustainable urbanism, has yet to accumulate evidence that links design alternatives to environmental outcomes or to explain the social processes that mediate those outcomes. It argues that geography has failed to develop a coherent subfield based on nature-city interactions due to the disparate intellectual domains of urban and nature-society geography. It argues that interdisciplinary bridging concepts such as ecosystem services, institutional analysis, and anticipatory governance can invigorate greater interaction between the two subfields. Not only do these concepts bridge urban and nature-society geographies, they potentially link to planning practice by generating 'usable' empirical findings. The subsequent chapters deploy these bridging concepts to empirically examine case-studies in sustainable urbanism.

Chapter 3, “Do Sustainable Urban Designs Generate More Ecosystem Services? A case study of Civano in Tucson, Arizona,” uses the ecosystem services concept to measure the environmental outcomes of sustainable urbanism in the case study community of Civano in Tucson, Arizona. It uses fine-scale spatial data to quantify differences in ecosystem service delivery across three distinct urban designs: Civano I (strong emphasis on sustainable urban design), Civano II (weak emphasis on urban design), and a comparison community (typical suburban development). Results were ambiguous, revealing slight differences in micro-climate regulation, primary productivity, and provisioning of freshwater across the three urban designs, but point to the role of institutional change in weakening the emphasis on sustainable urban design between phases I and II of the development of Civano.

Chapter 4, “An Institutional Analysis of the Capacity of Sustainable Urbanism to Achieve Environmental Goals through Conventional Master Planned Development,” considers such institutional factors in contributing to the successes and failures in achieving environmental design goals through interviews with stakeholders involved in planning and developing three case study communities: Civano (Tucson, Arizona), Mueller (Austin, Texas), and Prairie Crossing (Grayslake, Illinois). It explores the extent to which conventional master planning processes are fundamentally at odds with urban environmental sustainability and highlights opportunities for innovating within that institutional framework. While the case-studies represent a range of social, biophysical, and urban planning contexts, stakeholders expressed similar concerns about working within the conventional institutional framework of master planning. They also revealed creative solutions that capitalized on particular contexts and leadership.

Chapter 5 concludes with a discussion of cross-cutting challenges associated with reconciling disparate sub-fields of geography, the project of measuring environmental outcomes of sustainable urbanism, and confronting the institutional barriers to implementation. It suggests future avenues of research implicated by the findings in this dissertation and comments on the role of sustainable urbanism in confronting the environmental problems of cities given likely future social and environmental change.

Chapter 2

BRIDGES AND BORDERLANDS: SUSTAINABLE URBANISM AND THE CASE FOR AN EXPLICIT URBAN NATURE-SOCIETY GEOGRAPHY

INTRODUCTION

Twenty-first century urbanization has large environmental consequences due to the sheer number and large size of cities, the growing affluence of urban populations, and the complexity of the urbanization process that affects global urban systems and the environment directly but also in hidden, indirect, and variable ways (Seto et al. 2010). In particular, sprawl-style development and the lifestyle it supports are linked to myriad environmental challenges including rapid land consumption, inefficient use of resources, and degradation of local environments among others (Benfield et al.2001, Gonzalez 2009). These challenges will likely be compounded in the future with the rise of the global middle class in rapidly populating developing nations and a growing demand for the resource consumptive lifestyle that sprawl supports (Kharas 2010). In short, current modes of urbanization are thought to be environmentally unsustainable and more sustainable trajectories will require innovations in how we plan, build, and manage cities.

Sustainable urbanism, a movement within planning practice, seeks to reverse the negative environmental outcomes of urban sprawl through planning and design interventions. Specifically it claims that compact development, connected through a dense network of multi-modal transportation options and buffered by green open space reduces land and resource consumption and the overall human impact on the environment (Farr 2008). Development following the prescriptions of sustainable urbanism is proliferating globally and has received accolades within planning practice despite minimal evidence that environmental goals are being met. This paucity of evidence has caught the attention of geographers and other social scientists who, early on, argued that sustainable urbanism simply propagates middle-class suburban development under the guise of environmental sustainability but later conceded a large degree of variability in the capacity of sustainable urbanism to deliver the espoused environmental benefits (Zimmerman 2001, Garde 2009, Mapes and Wolch 2011, Trudeau and Malloy 2011). Despite the popularity of sustainable urbanism among planners and the interest in empirical analysis among geographers, ambiguity remains: Does sustainable urbanism reverse the negative environmental outcomes of urban sprawl and what are the reasons for successes and failures?

This question remains largely unanswered because sustainable urbanism is a field of practice, as opposed to a domain of empirical inquiry, and geography—a discipline for which this question would appear to be of central interest—has yet to develop an explicit cadre of researchers engaging urban nature-society themes. Sustainable urbanism as currently practiced by planners is a normative, design-oriented, and prescriptive field and, therefore, does not take an empirical research approach to assess environmental outcomes (Talen and Ellis 2002, Brain 2005). Furthermore, the design-oriented approach limits the scope of environmental processes addressed and underemphasizes the role of social processes in shaping the built environment and its nature-society consequences. I argue that integrating research interests and perspectives of more empirical fields, like geography, can reduce some of these limitations and increase the capacity of sustainable urbanism to achieve current goals and generate future innovations in planning and design. Integration can be achieved by reimagining sustainable urban development as experiments in urban sustainability and analyzing them through the lens of nature-society relationships. Geography has many traditions in urban and nature-society research and has established interdisciplinary "borderlands" with fields such as ecology and the environmental science and social sciences (Zimmerer 2010, Wolch 2007; 347). Explicit linkages between urban and nature-society geography, however, remain few, especially in regard to outreach to the sustainability sciences (Kates 2001) The urban nature-society subfield would highlight the interplay between built environments, ecological functioning, and human systems contributing to an emerging international research agenda on sustainable urbanism and urban environmental sustainability more broadly (Griggs et al. 2013).

ACHIEVEMENTS AND LIMITATIONS OF SUSTAINABLE URBANISM

Sustainable urbanism is a movement within planning practice that implements a suite of planning and design alternatives to conventional, sprawl-style development posited to reduce the overall environmental impact of urbanization. Approaches to sustainable urbanism include New Urbanism or Traditional Neighborhood Development (TND), Conservation Subdivisions, and Agricultural Urbanism, among others. The core environmental argument across sustainable urbanism approaches is that sprawl-style development driven by zoning that separates land-uses undermines sense of place while driving inefficient use of resources through auto dependence and consumption of open space (Kunstler 1993). The remedy is to create compact, mixed-use communities anchored by neighborhoods, connected through densely networked streets, and buffered by greenbelts and open space (Duaney et al 2001). Although sustainable urbanism has both environmental and social goals, the environmental goals have been emphasized over the social goals (Talen 2011). Espoused environmental benefits include reducing energy consumption, limiting the environmental impact of construction, stormwater and climate regulation, and improved air quality that can be achieved by altering development regulations and processes (Ewing et al 2008, Lubell et al. 2009, Low 2010).

Sustainable urbanism offers an appealing solution to the environmental challenges associated with urban development because it does not require fundamental changes to everyday lifestyles of residents. Developments utilizing sustainable urbanism planning and design standards are proliferating in the United States and globally, and flagship projects are receiving accolades within the planning community. Yet, sustainable urbanism has been heavily criticized beyond the field of urban planning, including by geographers, as nostalgic places of social exclusion or typical sprawl-style greenfield development using environmental sustainability rhetoric without substantive improvements in environmental outcomes (Zimmerman 2001, Ellis 2002). The critiques suggest that the environmental improvements espoused are not being achieved or that those achievements are offset by substantial trade-offs with social equity or other environmental issues. Concerns about social equity are substantiated by evidence, and many developers struggle to find economically viable ways to integrate affordable housing into sustainable urbanism model (Talen 2010). The assessment that social equity failures offset environmental achievements, however, is a normative claim.

Evidence of the environmental achievements of sustainable urbanism is not sufficient to support or repudiate claims. Trudeau and Malloy (2011) examined the critique that sustainable urbanism contributes to sprawl via greenfield development and found that the majority of New Urbanist developments in the United States were infill projects that contribute to increased regional density, but that there was a large variation between regions with a disproportionate greenfield development in the Southeast and Midwest (Trudeau and Malloy 2011). Podobinik (2011) examined travel behaviors of residents of a sustainable urban community in Portland and found residents increased their use of multi-modal transportation, but still relied on cars as their primary mode of transportation. Other studies have found slight increases in environmental knowledge and values in sustainable urban communities compared to typical subdivisions (Youngentob and Hostetler 2005, Hostetler and Noiseux 2010). Such studies constitute exploratory evaluations of the environmental goals of sustainable urbanism but have yet to offer conclusive evidence because they do not directly measure links between urban design and environment consequences. Exploratory research points to variation in the capacity of sustainable urbanism to implement urban design alternatives and achieve environmental goals due to regulatory barriers and rigid development industry standards (Grant 2009, Göçmen 2013, Hostetler and Drake 2009). There is a need for an empirical line of inquiry that can interrogate the relationship between urban design, environmental outcomes, and the social processes that ultimately drive both. This line of inquiry would bridge social and natural sciences and planning practice.

GEOGRAPHIC RESEARCH TRADITIONS & INTERDISCIPLINARY BORDERLANDS

A small suite of urban nature-society hybrid geographies have begun to emerge largely through congruent research interests among urban geography, nature-society geography, and cognate fields and as a pragmatic response to the grand challenges associated with 21st century urbanization. Zimmerer (2010) characterizes interdisciplinary interactions between geography and cognate fields as “borderlands” and argues that the interactions between these multiple streams of thought contribute to a dynamic and evolving nature-society subfield. Urban geographers have many interdisciplinary ties at the borderlands as well. Table 1 summarizes the core disciplinary focus and interdisciplinary borderlands of both sub-fields identified by Zimmerer (2010) and Wolch (2007). Interestingly, while each sub-discipline contains interdisciplinary research streams with cognate fields such as ecology, environmental social sciences, and planning that address urban environmental sustainability, geography lacks a coherent urban nature-society field.

Table 1: Research Traditions and Current Interdisciplinary Borderlands in Nature Society and Urban Geography (From Zimmerer 2010 and Wolch 2007).

	Nature-Society Geography	Urban Geography
Research Traditions	• Environmental Governance and Political Ecology • Environmental Hazards, Risks, and Vulnerability • Land-Use and Land-Cover Change • Coupled Human-Environment Interactions • Environmental Landscape History and Ideas • Scientific Concepts in Environmental Management and Policy	• Chicago School (Ecological metaphors) • Neoclassical Theory (Production/Consumption) • Materialists (Marxism) • Political Ecology
Interdisciplinary Borderlands	• Earth System and Ecological Science • Broad Environmental Social Science • Environmental History	• Environmental History • Urban Ecology • Industrial Ecology • Cultural Ecology • Urban Planning • Sustainable Development

Indeed, urban and nature-society geography have remained relatively disparate due to intellectual lineages with historically different emphasis. Urban geography has strong, but separate, traditions in spatial sciences and social theory, with a particular emphasis on the economics of urban form and socio-economic relations in cities, respectively (Leitner and Sheppard 2003, Johnston 2006). Neither the spatial or social theory traditions have emphasized connections between urban form or social relations to environmental processes or outcomes, but interest in nature-city relationships is emerging. Wolch (2007) calls on urban geographers to capitalize on emergent, but disparate, nature-city scholarship, arguing that urban environmental sustainability should be a core topic of interest to the sub-field. Following through on this call will require further integration of nature-society scholarship in urban geography beyond more humanistic and critical perspectives like political ecology.

Like urban geography, nature-society geography shares dual emphasis on spatial science and social theory. Nature-society geography in the spatial science tradition (i.e.: land change science) analyzes landscape-scale system dynamics to inform global environmental change, while nature-society scholarship drawing from social theory (i.e.: political ecology) emphasizes social outcomes in predominantly rural communities to inform development (Turner and Robbins 2008). Zimmerer (2010) describes this division as scholarship on human-environment interactions, a field that is largely populated by land change science and risks-hazards scholars, from nature-society geographies with stronger ties to political ecology, environmental governance, and critical human geographies. Both traditions have strong intellectual ties to rural, poverty, and development issues and, until recently, have been largely non-urban in scope.

There are nascent attempts to apply nature-society perspectives to urban contexts. An urban political ecology has emerged that fuses urban and nature-society geographies using the political economy as a bridging concept to examine how political, economic, social, and ecological processes produce urban landscapes that are often socially unjust and environmentally unsustainable (Swyngedouw and Heynen 2004, Robbins 2012). Yet the political ecology tradition has mostly been descriptive, emphasizing representation over generalization and wary of policy prescriptions; these attributes make synthesis with natural sciences and collaborations outside the academe challenging (Blaikie 2012). Human-environment geography, on the other hand, has a strong tradition of synthesis with physical geographers and natural sciences beyond the discipline (Zimmerer 2010). That tradition of synthesis positions land change science to make significant contributions toward understanding urban system dynamics; these contributions, however, appear to be occurring in the interdisciplinary borderlands with sustainability science (Seto 2010, 2012, forthcoming). The result is that geography per se lacks a coherent urban nature-society subfield similar to urban ecology within the environmental sciences, and the contributions of geographers at large to this research arena are largely occurring outside the discipline in interdisciplinary research domains, such as adaptation to climate change and sustainability science (Kates 2001).

There are, of course, exceptions. Of particular note is the residential landscapes research stream that began with Robbins' analysis of the moral economy of the lawn and has grown to a larger interdisciplinary research project involving human-environment and nature-society geographers and scholars from natural and social sciences (Robbins 2003, Robbins 2007, Roy Chowdhury et al. 2011, Cook et al. 2012). Taking a cue from political ecology, greater interaction between urban and nature-society sub-fields can occur by identifying additional bridging concepts between the two sub-disciplines and cognate fields, particularly those that can empirically link social and natural sciences as well as planning practice and decision-making. Ecosystem services, institutions, and decision-making under uncertainty (DMUU) are three themes that can invigorate interaction between urban and nature-society geography, inspire robust analysis of urban environments, and reveal the capacity of sustainable urbanism to reverse the negative environmental consequences of urbanization.

BRIDGING CONCEPTS FROM THE BORDERLANDS: ECOSYSTEM SERVICES, INSTITUTIONS, AND DECISION MAKING UNDER UNCERTAINTY

Ecosystem Services

The concept of ecosystem services has gained traction of late because it highlights the direct and indirect connections between ecological processes and human well-being and expresses how a failure to properly account for the value of those services leads to rapid losses in ecosystem function and global biodiversity. Several insights from ecosystem services research potentially bridge urban and nature-society geographies. By calling attention to supporting and regulating services, the framework expands the range of ecosystem functions relevant to urban systems beyond those that pose an immediate concern to public health and individual livelihoods (Bolund and Hunhammar 1999). Some services, like micro-climate and flood regulation, are already part of urban and nature-society lexicons due to well established research traditions, for example, on the urban heat island effect in the American Southwest and the role of mangrove forests in adapting to climate change in coastal communities, respectively (Oke date, Tri 1998, Alongi 2008, Chow et al. 2010,). Other services, like primary productivity and nutrient cycling, are less well understood but known to be greatly altered in urban systems (Grimm et al. 2008).

The ecosystem services framework also highlights trade-offs and synergies between services and across space and time (Foley et al. 2005, Rodríguez et al. 2006). In urban systems, these may be trade-offs tied to different urban designs or the inability of human made substitutes to replace the full range of services provided by nature (Goklany 2009). For instance high albedo (white) roofs on buildings are effective in regulating temperatures but do not replace the full range of services of the vegetative cover it replaces. Urban geographers have a long tradition in quantifying urban form but few have measured the environmental outcomes associated with alternative designs (Conway 2009). The ecosystem services concept can help address this gap by linking different urban landscapes to biophysical processes. Scholars have already begun to quantify the ecosystem services tied to urban form and found a great deal of variability in the delivery of different services across different urban forms and biophysical contexts, suggesting the potential to maximize service delivery within cities through urban design and green space planning (Tratalos et al. 2007, Niemelä et al. 2010).

The ecosystem services concept it is already commonly deployed at the interdisciplinary borderlands of geography as a core area of inquiry among human-environment geographers interested in the ways humans alter their environment to appropriate resources. For example, land change scientists have deployed the ecosystem service concept to understand the proximate and distal consequence of land use change on ecosystem processes and the feedbacks to human systems (Lambin et al. 2003, Seto et al. 2012). It is also used by human environment geographers interested in urban climate adaptation to explore the role of ecosystem services in transitioning from a 'sanitary city' regulated by technological interventions to a 'sustainable city' supported by green infrastructure (Pincetl 2010, Solecki 2012). Urban land change science and climate adaptation in cities are core research interests of geographers currently explored in the interdisciplinary borderlands with sustainability science.

The ecosystem services framework also has limitations. While useful in quantifying a broad range of ecological processes associated with the built environment, resolving trade-offs requires more than refining scientific knowledge about the consequences of different development patterns on ecosystem functioning. It also involved an understanding of livelihoods and human wellbeing and processes for adjudicating the competing values of the service's stakeholders. Very little tradeoff analyses have been undertaken between ecosystem services and human impacts in cities, and much of this involves issues of urban heat islands and human health (Harlan and Rudell 2011)

Payments for ecosystem services (PES), an environmental management strategy that stems from the claim that undervaluing ecosystem services leads to degradation, posits that compensating individuals or firms for providing ecosystem services will reverse those trends. Geographers have been critical of PES and argued that they constitute the extension of neoliberal policies to environmental resource management through the privatization and commodification of natural resources. Some find PES schemes are fundamentally at odds with social goals (i.e.: poverty alleviation) while others recognize mixed success and the need for more studies with a balanced perspective on capacity of PES to deliver the co-benefits of resource management and economic development (Liverman and Vilas 2006, McAffee and Shapiro 2010, Robertson & Wainwright 2013). These limitations are tied to social processes that are better understood through the lens of social sciences.

Institutions

The concept of social institutions has bridging potential because both urban and nature society geographers have a long-standing interest in the role of institutions in structuring the urban environments and facilitating environmental outcomes. Institutions have been understood by political ecologists as the broad-scale social forces that structure decision-making at local to global scales (Pete and Watts 2002). They have chronicled problematic state interventions and the shift to even more problematic free-market, neoliberal responses (Liverman 2004, Heynen et al. 2007). Urban geographers have also explored the neoliberal turn in depth as well but have not emphasized the environmental consequences. They show that the neoliberal turn is amplified in cities in which the new spatial economy is driven by privatization that leads to exclusionary landscapes where the poor have uneven access to services and are often displaced through processes of gentrification (Smith 2012, Leitner et al. 2007). Political ecologists and critical urban geographers often tend to equate institutions with the political economy that emerges from and facilitates capitalism; a line of thinking has lead to critiques that capitalism is fundamentally at odds with environmental sustainability. There is a desire to move beyond critiques of the "commodification of nature" and to use geographic skill sets to refine metrics for valuing nature and conceive of new institutional arrangements for natural resource governance within the neoliberal framework (Liverman 2004). As Heynen and colleagues (2007, 1) comment, "Property rights—a necessary prerequisite for free market economies—also provide strong incentives to invest in resource health. Without them, no one cares about future returns because no one can be sure they will be around to reap the gains."

Institutions, as they are conceived of in environmental commons research, create an entre-point to invigorate urban nature-society scholarship within geography. Nature-society geographers have been particularly active in environmental commons research, but those contributions may be understated, in part, because they have occurred at the interdisciplinary borderlands (Brewer 2012). The study of institutions in environmental commons is, however, conceptually, and, by extension, methodologically distinct from political ecology and critical urban geography. Environmental commons researchers describe institutions as the formal and informal rules in use in society (Ostrom 1990). They eschew panaceas—one-size-fits all policy prescriptions—and instead seek to understand why some common pool resources are managed sustainably while others are not (Ostrom 2005, Ostrom 2009). Like political ecologists, environmental commons scholars attribute environmental degradation to institutional mismatch but they attribute this mismatch to issues of fit between managing institutions and the environmental context of the resource system and social context of the resource users (Ostrom 2009). Commons scholars operationalize the components of institutional design that are relevant to desirable resource management outcomes (Ostrom 1990, Ostrom 2005,). Methodologically, this approach allows researchers to collect individual case-studies while retaining the capacity to seek generalizable knowledge by comparing similarities and differences across cases (Beddoe et al. 2008) and is well suited for collaboration with natural scientist and non-academic stakeholders because it yields generalizable, and usable knowledge. In this way, environmental commons research moves beyond locating occurrences of institutional mismatch (i.e., institutional frameworks that lead to environmental degradation) and toward an understanding of the constituent parts that facilitate and constrain desirable outcomes.

Environmental commons research has overwhelmingly focused on relatively well bounded systems with single-resource streams (e.g., forests or fisheries) and tightly coupled systems in which resource users' livelihoods are highly dependent on the resource system being managed. In contrast, urban systems have highly permeable boundaries, involve multiple, interacting resource streams, and resource users' livelihoods are loosely tied to the resource system. Despite differences in system characteristics, the insights from environmental commons research may be applicable to urban systems especially given that the precursory work that informed Ostrom's framework grew out of research on the delivery of an urban public good: public safety.

This research revealed that despite perceptions of “chaos”, inefficiency, and calls for large-scale agglomeration in urban governance, the existence of polycentric governance systems—multiple public and private organizations jointly affecting collective benefits and costs—could efficiently deliver public safety (Ostrom et al. 1978). The overarching message is that single solution state or private sector interventions are appealing for their simplicity but they can have perverse environmental outcomes when tensions arise between inflexible rules and the complexity of the social-ecological system, urban or otherwise. Urban geographers could extend research on the role of urban institutions in allocating public goods and services could extend this research to the allocation of environmental goods (Turner and Ibes 2011). However, as complex systems, the decision-making processes to arrive at management systems are increasingly shrouded in uncertainty. In order to understand decision-making processes, geographers can turn to decision-science.

Decision-Making Under Uncertainty (DMUU)

DMUU links geographic research domains to scholars in sustainability science and the decision-making community, which has an emerging interest in climate adaptation. Sustainability scientists have called for novel strategies for environmental management capable of address pressing, and deeply uncertain, environmental outcomes linked to global environmental change (Lubchenco 1998). This includes novel institutional arrangements and processes for decision-making like ‘boundary organizations’—places that bring scientists and policy makers together to co-produce knowledge—enhance the credibility (scientific adequacy), salience (relevance to stakeholder needs), and legitimacy (respectful of divergent values and believes) of knowledge production (Cash et al. 2003). These deliberative exchanges are thought to improve analytic learning about urban systems as well as social learning to enhance the collaborative processes in the future (Pahl-Wostl et al 2007). One process for decision-making that is gaining traction among DMUU scholars and decision-makers working at the science-policy interface is anticipatory governance. Both communities recognize the need to confront deep uncertainties associated with the predictive capacity of climate models, inherent and unpredictable variability social-ecological system behaviors, and objective and normative disagreement over valuing environmental impacts among others (Lempert, Popper, and Banks 2003). Anticipatory governance moves away from one-shot, one-way policy making and toward more flexible and adaptive approaches to managing urban environments (Gober et al. 2010, Quay 2010). Specifically, anticipatory governance strategies develop a suite a plausible future scenarios and potential environmental thresholds to use as the basis for environmental management (Quay 2010, Polasky et al. 2011). These strategies are thought to increase resilience—the capacity to absorb shocks without fundamentally transforming states—and the capacity to adapt to accommodate change when it occurs (Quay 2010).

DMUU has bridging potential between urban and nature-society geographies because it links to established research traditions in the human dimensions of global change and risk-hazards. Geographers have long recognized the importance of communication in translating climate science to policy and public discourse and some geographers are already actively participating in ‘boundary work’ through interdisciplinary collaborative research centers focused on urban climate adaptation such as the NSF Decision Making Under Uncertainty (DMUU) sites and the Urban Climate Change Research Network (UCCRN) (Gober et al. 2010, Rosenzweig et al. 2010, Moser 2011). Geographers in the risks-hazards tradition have long articulated the failure of traditional command-and-control policies to mitigate environmental risk because they miss the social dimensions that underlie vulnerability (Cutter 2003). Geographers working on the human dimensions of global change have made similar prescriptions for communities vulnerable to climate change calling for flexible institutional arrangements to support adaptation and processes for anticipating learning opportunities when past data is insufficient to predict future change (Adger 2006, Agrawal 2010, Tschakert and Dietrich 2010).

Climate change adaptation is a critical component of any urban environmental management plan, but challenges remain due to existing institutional momentum. Despite a willingness to pursue alternative management strategies, municipal leaders face limited resources, insufficient leadership, gaps between scientific knowledge and policy, and dissonant exiting policies among others (Unwin and Jordan 2008, Rosenzweig et al. 2010, Flugman et al. 2012).

CONCLUSIONS: WHAT CAN URBAN NATURE-SOCIETY GEOGRPHAY REVEAL ABOUT SUSTAINABLE URBANISM?

Although the topic of sustainable urbanism would appear to be of core interest to geographers due to strong intellectual lineages in the urban and nature-society sub-disciplines, this review reveals historical and epistemic divisions that have kept the sub-disciplines, by-in-large, separate. As a result, multiple nascent urban nature-society geographies have emerged across the discipline but have yet to coalesce as a coherent sub-discipline of itself. Urban political ecology sits within the disciplinary core of geography having successfully leveraged the political economy concept to bridge urban and nature-society perspectives, while more systems-based perspectives have migrated to the interdisciplinary borderlands. This is a missed opportunity for geographers to leverage and synthesize the insights of two well developed areas of inquiry. Geographers can move beyond what Johnson (2006, 445) characterizes as "cockpit of competing thoughts" within the discipline and toward a robust urban nature society inclusive of both urban political ecology and more systems based urban human-environment perspectives by leveraging bridging concepts that already resonate within the field. This robust sub-discipline would build on initial critiques of sustainable urbanism as suburbia cloaked in sustainability rhetoric, gather evidence of success and failures, and explain the social processes that underlie environmental outcomes. It would also generate empirical evidence of use to urban planners and decision-makers while retaining important critiques of the sustainable urban venture.

The three bridging concepts proposed here—ecosystem services, institutions, and DMUU—link geographic perspectives on the interrelationships between the built environment and social and ecological processes. They are certainly not intended to be comprehensive list of potential bridging concepts and a number of other concepts would address additional elements of urban environmental sustainability. For instance urban metabolism and urban land teleconnections link thinking about urbanization processes across geographic sub-fields and would garner additional insights into the link between urban sites and the hinterlands (Pincetl 2012, Seto 2012). They key is identifying concepts that resonate with both more representative and more reductionist approaches (e.g., political ecology and critical urban geography versus land change science and spatial urban geographies) rather than polarizing the discipline by juxtaposing the distinct epistemic communities in the purest form.

The urban nature-society perspective advanced through the bridging concepts proposed in this review address critical empirical issues in sustainable urbanism. The concept of ecosystem services expands the range of ecological processes considered relevant to the "environment" in the city and provides a framework for gathering empirical evidence linking urban design to those processes. The role of institutions, as defined by environmental commons scholars, reveals moments of fit and discord between current planning, development, and management mechanisms and the environmental objectives of sustainable urbanism . In cities, urban planners are de-facto environmental decision-makers and, as Rosenzweig et al. (2010) assert, there is a need to make more explicit the link between urban planning and environmental processes. DMUU confronts uncertainties related to climate and other forms of socio-ecological change and can help develop urban planning strategies that anticipate the need for future adaptations. These lines of research complement critical perspectives that expose fundamental tensions between sustainable urban development and the consumptive, unsustainable tendencies of urban and suburban lifestyles by generating empirical evidence that supports or repudiates unsubstantiated environmental claims, addresses the root causes for those outcomes, and links geographic perspectives to planning practice.

Reversing the negative environmental consequences of urbanization in the 21st century will require the combined insights of geographers in both the urban and nature-society sub-disciplines. Urban planners are already addressing these challenges through sustainable urbanism, creating urban experiments that are ripe case-studies in alternative urban design. Some of the earliest attempts at sustainable urbanism are maturing and geographers have the interest as well as the empirical skill sets to measure and explain the successes and shortcomings of these case-studies. Empirical analysis of sustainable urbanism is one of many contributions that geographers are poised to make within its disciplinary core.

Chapter 3

DO SUSTAINABLE URBAN DESIGNS GENERATE MORE ECOSYSTEM SERVICES: A CASE STUDY OF CIVANO IN TUCSON, ARIZONA

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INTRODUCTION

Urban design influences ecological processes, allocation of natural resources, and the long-term sustainability of cities. Using the ecosystem services concept to quantify environmental outcomes in cities complements a long tradition of monitoring the impact of human modifications to the environment within urban environmental planning fields. Ecosystem services highlight the value of ecological processes in supporting human well-being, even if that value is hidden or indirect, and quantifies the production and consumption of natural capital in various landscapes including urban areas and service provisioning related to different types of urban design (Bolund and Hunhammar, 1999; Tratalos et al, 2007; MEA, 2008; Pataki et al, 2011).

We deploy the ecosystem services framework to quantify the environmental outcomes associated with urban design intended to increase sustainability in the planned development of Civano in Tucson, Arizona. Civano was developed in two distinct phases and adjacent to a development designed without explicit sustainability goals providing an ideal natural experiment to quantify the environmental outcomes associated with three distinct built environments. First, we utilize fine-scale spatial data to characterize the built environment of each development using landscape metrics. Then we quantify environmental outcomes for each development to determine if differences in urban design generate statistically significant differences in the provisioning of key ecosystem services in an arid environment. This research begins to address a gap in the literature empirically linking sustainable urban design to environmental outcomes (Conway, 2009).

ECOSYSTEM SERVICES AND THE BUILT ENVIRONMENT

The ecosystem services framework informs environmental planning and management because it reveals the hidden, indirect, and non-market values of healthy ecosystems for human well-being and how humans appropriate this natural capital to meet their needs (MEA, 2008). Sometimes services directly meet human needs (e.g., provisioning services), but many services (e.g., regulating and supporting) may be hidden or indirect. For example, forests provide timber for fuel and fiber directly benefitting human activities but also sequester carbon indirectly benefitting humans through climate regulation. The ecosystem services framework draws attention to those services that are overlooked, undervalued, or only partially accounted for by economic markets. The direct *and* indirect contributions of ecosystems to human well-being are critical to land planning and management.

Research utilizing the ecosystem services framework generates empirical evidence of interest to land planners by measuring stocks and flows of natural capital, generating maps and models of critical ecosystem services, and providing mechanisms for valuing services not captured by financial markets (Daily et al, 2009; DeGroot, 2002). These measurements aid the planning processes by revealing the trade-offs associated with alternative land development and management plans (Foley et al, 2005; Nelson et al, 2009). These include trade-offs between increasing provisioning services and degrading all other services and with human-made substitutes that may not deliver the full range of services provided by nature (Karieva et al, 2007; Raudsepp-Hearne et al, 2010).

The majority of ecosystem service research is conducted at the landscape scale and generates results that obscure fine-scale relationships between urban design and ecosystem services. Recently, high-resolution spatial data has been used to quantify ecosystem services in urban ecosystems (Tratalos et al, 2007; Zhou et al, 2011). For example, Tratalos et al (2010) surveyed fifteen cities in the United Kingdom and found that urban density positively corresponded to a decline in several ecosystem services but that variability within those relationships suggests potential for maximizing ecological functioning at any density. In Baltimore, Maryland, USA, Zhao et al (2011) found that fine-scale differences in landscape configuration account for differences in local microclimate after holding landscape composition constant. Linking urban design to ecosystem services at fine scales may be more appropriate for informing urban land management, which occurs at a local scale in urban planning (Alberti, 2005).

Micro-climate regulation is an important ecosystem service in arid cities experiencing the Urban Heat Island (UHI) effect (Jenerette et al, 2011). The UHI increases minimum daily temperatures, leads to longer warm periods and shorter cool periods daily during the summer, and extends the warm season (Baker et al, 2002; Brazel et al, 2007). The primary causes of the UHI are anthropogenic heat generated by energy consumption (ie: vehicles, power plants, and residential uses) and heat stored in impervious surfaces (Memon et al, 2008; Oke, 1982; Sailor, 1995). Mitigating the UHI effect through climate regulation in cities requires addressing the elements of urban design that contribute to elevated temperatures (Stone and Norman, 2006). These design elements include loss of vegetative cover, high densities of low albedo building materials, and urban designs that promote anthropogenic sources of heat (Mermon et al, 2008). Vegetative cover regulates local climate by providing tree canopy shade, cooling evapotranspiration, and introducing higher albedo material into the urban landscape (Bolund and Hunhammer, 1999). Human substitutes for vegetative micro-climate regulation such as white roofs decrease local temperatures by increasing albedo (Gaffin et al, 2012). Other adjustments to urban design such as increasing sky view factor and reducing roughness are also relevant to urban climate regulation (Akbari et al, 2009; Arnfield, 2003; Bourbia and Boucheriba 2010). Finally, urban form that encourages less energy consumptive behaviors can reduce anthropogenic heat (Memon et al, 2008). Models show that increased vegetative cover and high albedo surfaces are strongly correlated to local climate (Gober et al, 2009; Memon, 2007; Rosenfeld et al, 1995; Sailor, 1995; Stabler et al, 2005).

Regulating micro-climate is key in arid cities where small changes in temperature often produce large changes in water and energy resource. In Los Angeles, California and Atlanta, Georgia, cooling demand increases 3% and 6%, respectively, for every 1 degree Celsius increase above 18 degrees (Rosenfeld et al, 1995). In Phoenix, Arizona, every 0.5 degree Celsius increase in temperature correlates to an average monthly increase in water use of 290 gallons in single-family homes (Guhathakurta and Gober, 2007). Beyond natural resource management, micro-climate regulation has implications for quality of life, public health, and environmental justice in arid cities where high temperature "misery days" disproportionately affect vulnerable populations (Harlan and Ruddell, 2011).

Increasing vegetation for micro-climate regulation in arid environments produces the co-benefit of increasing net primary productivity (NPP): the rate at which an ecosystem accumulates biomass (photosynthesis minus respiration). NPP has been used as a surrogate indicator for a range of ecosystem services including: carbon sequestration, soil retention, soil accumulation, increasing groundwater recharge, and reducing runoff (Brauman et al, 2007; Egoh et al, 2008; Tilman et al, 1997). The latter two phenomena are especially pronounced in arid environments (Luddwig et al, 2005). Urbanization decreases NPP in the United States as a whole, however, NPP increases locally in arid environments due to the introduction of exogenous plant species like turf lawns that generate higher NPP than the surrounding desert (Buyantuyev and Wu, 2009; Imahoff et al, 2004). The efficacy of increasing vegetative cover to regulate climate and increase NPP is context dependent in arid environments. Irrigated landscapes decrease nighttime temperatures, particularly in the least vegetated neighborhoods of Phoenix, Arizona, however, temperature decreases from increased water inputs reaches a threshold such that further water input no longer ameliorate UHI effects (Gober, 2009). Vegetated landscapes that require water inputs present a trade-off between reducing energy consumption through cooling and increasing consumption of scarce water resources (Guhathakurta and Gober, 2007; Shashua-Bar et al, 2009).

Increased vegetation in arid urban environments usually requires the provisioning of local water resources and also sources beyond the geographic bounds of the city. Braumen et al (2007; 73) state that “hydrologic services are regional services,” emphasizing the interconnectedness of the hydrologic cycle within and between watersheds. In arid environments, limited water availability locally requires appropriating water from upstream sources to sustain downstream users and ecosystems. Sabo et al (2010) found that approximately 76% of stream flow in the Colorado River Basin is appropriated for human uses and projected that amount to increase to 86%. The provisioning of freshwater for human use often creates a trade-off with aquatic ecosystem health because humans alter the quantity, quality, timing, and temporal variability of stream flow (Baron et al, 2002). Not only are these supplemented supplies endangering to neighboring ecosystems, they are also not sufficient to keep up with demand under the projected conditions of growth (Sabo et al, 2010). Efforts to increase water supply have reached diminishing returns and water demand management is now paramount (Gober, 2009). Strategies such as passive cooling, stormwater harvesting, and introducing non-potable water resources decreases provisioning of freshwater resources for outdoor cooling purposes, however, reducing demand through less water intensive landscapes is key for both local and regional water management under conditions of strained supplies.

This study of the community of Civano in Tucson, Arizona quantifies ecosystem service delivery associated with alternative urban designs. The overarching goal—to increase sustainability over typical suburban development—was interpreted and implemented differently through time resulting in distinct urban designs in the two phases of development: Civano I and Civano II. Furthermore, Civano lies adjacent to another planned development that did not explicitly imbed sustainability goals into urban design. We characterize the built environment of each development using landscape metrics—percent area and patch density—derived from high-resolution class data. Then we ask: How does ecosystem service delivery differ across three distinct urban designs present in Civano I, Civano II, and the comparison community? We quantify three ecosystem services: micro-climate regulation, primary productivity, and water provisioning at the neighborhood block scale to compare delivery across the three communities.

STUDY AREA

The City of Tucson in Pima County, Arizona is experiencing rapid population growth (16.2 percent increase between 2000-2010 in Pima County) coupled with urban expansion that strains limited water resources, contributes to the urban heat island phenomenon, and leads to the loss of native biodiversity (U.S. Census, 2012). As of 2006 the municipal provider, Tucson Water, serviced approximately 80% of the population in the Tucson municipal area with supplies from groundwater , imported canal water , and reclaimed water. The municipal water sector accounts for a majority (56%) of demand (Pinal AMA, 2011). Even with augmented water supplies Tucson may not be able to serve its population given projections of growth and under conditions of climate change (Morehouse et al, 2002). Urban expansion also contributes to the UHI in Tucson where average temperatures increased 2 degrees Celsius between 1970 and 2000 (Comrie, 2000). Furthermore, urban expansion leads to a decline in local native biodiversity by removing native habitats (Germaine et al, 2001).

The planned community of Civano is situated in the southeastern edge of Tucson and was intended to increase urban sustainability through urban design (Figure 1). It was built in two phases with the first phase, Civano I, completed in 1999 and the second phase, Civano II completed in 2007. Civano I emphasized environmental design but incurred large land development costs and was sold to a large national builder, Pulte Homes, that stripped away many of the elements of environmental design in favor of energy and water efficient buildings. In this analysis, we also include a neighboring community so that we could compare the varying impacts of environmental goals and sustainable design across Civano I (strong emphasis on sustainable design), Civano II (weak emphasis on sustainable design), and a comparison community (typical suburban development). We expect that the differences in urban design will generate different environmental outcomes.

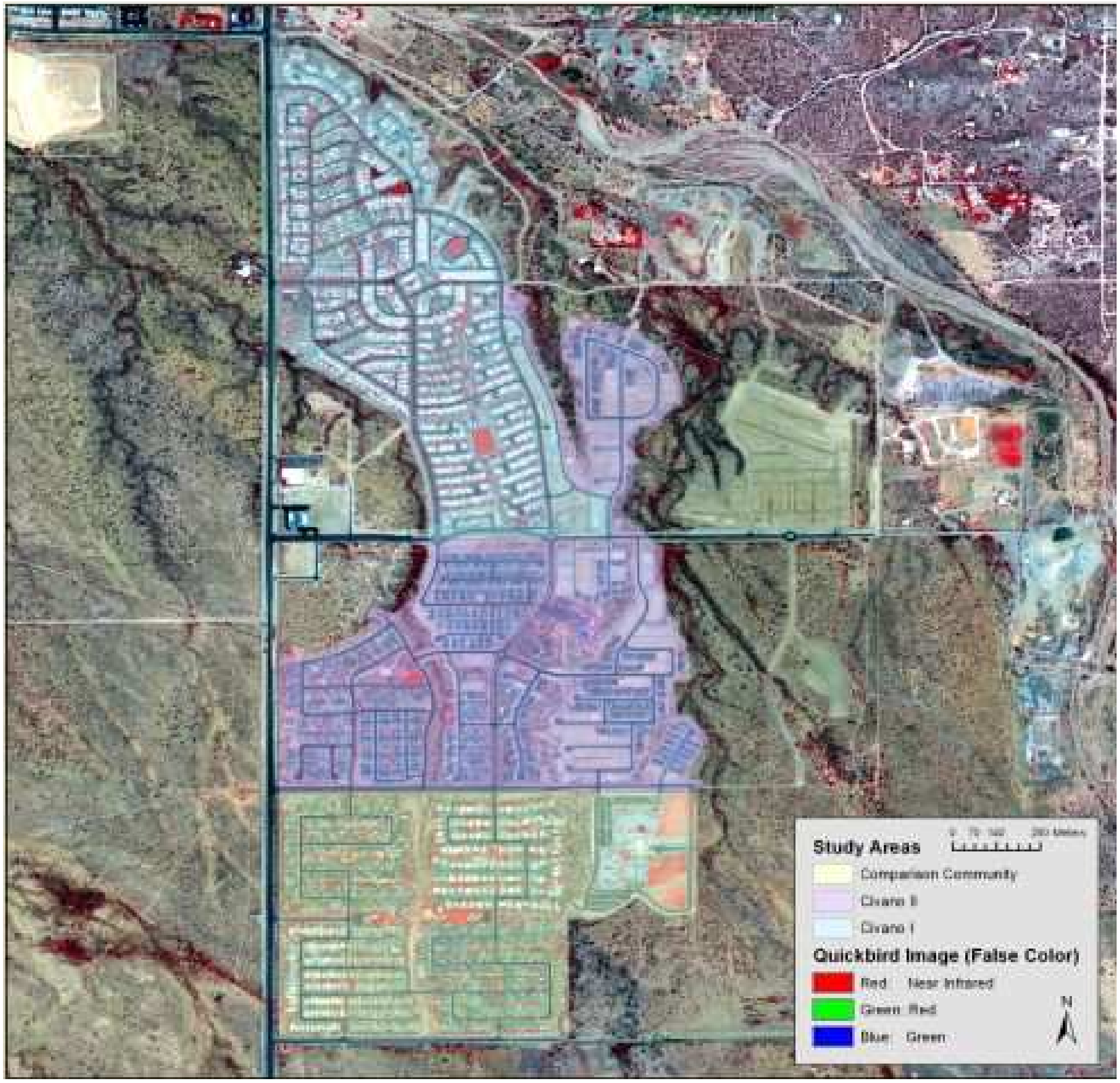

Figure 1: Map of Study Area

The three developments are similar in size, number of households, and age (Figure 1, Table 1) but differ in building area and urban design. We calculated average building area using parcel data from The City of Tucson Water to determine the total building area per lot. Average building area was smallest in Civano I (245.5 m^2) and largest in the comparison community (325.9m^2) with Civano II in between (309.7m^2).

Table 1: Size, Households, Age, and Average Building Area of Study Area Communities

Community	**Size (km^2)**	**Households**	**Age**	**Building Area (m2)**
Civano I	0.75	599	1999	245.5
Civano II	1.00	693	2007	309.7
Comparison	0.75	613	2001	325.9

Table 2: Percent Area and Patch Density for Land-Use and Land-Cover Classes in Civano I, Civano II, and the Comparison Community

	Class	Percent Composition	Patch Density
Civano I	Impervious	14.64	228.50
	Soil	36.40	1135.86
	Trees	28.11	1131.88
	Buildings	19.21	928.62
	Grass	1.57	227.17
	Pools	0.01	5.31
	Water	0.05	2.66
Civano II	Impervious	19.25	301.72
	Soil	46.79	423.96
	Trees	13.89	1086.87
	Buildings	19.43	342.47
	Grass	0.55	78.18
	Pools	0.05	14.32
	Water	0.05	3.30
Comparison	Impervious	15.36	267.00
	Soil	31.37	775.77
	Trees	23.95	1268.59
	Buildings	26.05	515.41
	Grass	3.14	273.64
	Pools	0.11	50.48
	Water	0.03	6.64

We also calculated landscape metrics—percent composition and patch density (number of patches per hectare)—for each of the following land classes: impervious surface, exposed soils, trees and shrubs, grass, pools, and other water bodies (Table 2). These are standard land classes developed to characterize urban ecosystems by the Central Arizona Project (CAP) Long Term Ecological Research project at Arizona State University (e.g. Myint et al, 2013). The urban design of Civano I is characterized by low impervious surface coverage (14.6%) and density (228.5) stemming from narrow road design and on street parking that eliminates the need for higher density parking lots. Percent building coverage is low (19.2%)—lower than the comparison community but just slightly lower than Civano II—and the building size is, on average, the smallest of the three communities (245.3 m^2). The building patch density (928.6) is quite high due to the clustering of homes and businesses in the urban design intended to increase walkability and maximize open space. Civano I has a higher percentage of grass (1.6%) than Civano II and lower percentage than the comparison community (3.1%) but with high patch density (227.2) reflecting the fact that grass—which requires water inputs—was directed to common areas in the master plan. Civano I had the highest percentage of trees and shrubs (28.1%)—which are less water intensive than grass but potentially generate cooling and other ecosystem benefits—due to the emphasis on xeriscaping. The largest percentage of land is exposed soil (36.4%), however, this percentage includes undeveloped land clustered around the western periphery of the community, which partly contributes to the high patch density (1135.9). Combined, pools and other water bodies comprise a very small percent area (less than 1%).

In contrast to Civano I, the urban design of Civano II is characterized by the highest percent coverage of impervious surface in the three communities (19.2%) with the highest patch density (301.7), reflecting the wider street design and cul-de-sacs that require more space than the grid-design in Civano I. Percent building coverage is comparable to Civano I, but the patch density is lowest in Civano II (342.5) meaning that buildings are largest and least clustered. Civano II has the lowest coverage (13.9%) and patch density (1086.9) of trees and shrubs, which may be due in part to the large undeveloped areas. Indeed, Civano II has the highest percent soils (46.8%), however, the low patch density (424.3) suggests that soils are not solely concentrated in undeveloped areas. High soil coverage may also be due to sparse tree and shrub coverage. Less than 1% of Civano II is comprised of grass, pools, and other water bodies.

Some elements of the urban design of the comparison community, such as impervious surfaces and trees and shrubs are quantitatively similar to Civano I while others, such as buildings and soils are distinct. The comparison community has slightly higher impervious surface coverage (15.4%) and patch density (267.0) than Civano I and less than Civano II. Tree and shrub coverage (23.9%) and patch density (1268.6) is slightly lower than Civano I and higher than Civano II. It has the highest percentage of building coverage (26.0%) and a patch density (515.4) higher than Civano II but lower than Civano I. The comparison community has the lowest soil coverage (31.4) with a patch density (775.8) lower than Civano I and higher than Civano II. The low soil coverage is most likely due to the fact that it is the only community that lacks undeveloped lots. Of all the communities it has the highest grass, pool, and water cover age, however, combined they constitute less than 5% of the total area.

DATA AND METHODS

Table 3: Ecosystem Service Indicators Data

Service	Indicator	Data Source	Scale	Year
Climate Regulation	Temperature	Landsat	60 m	2011
	Albedo	Quickbird	2.4 m	2011
Primary Productivity	Soil Adjusted Vegetation Index (SAVI)	Quickbird	2.4 m	2011
Water Provisioning	Potable Consumption	City of Tucson	City block	2010
	Non Potable Consumption	City of Tucson	City block	2010
Affordability	Home Full Cash Value	Pinal County Assessor	Parcel	2011

For each of the ecosystem services, indicators were selected and calculated at the city block scale (Table 3). Micro-climate regulation was represented by albedo—the extent to which short wave radiation from the sun is reflected from the surface as long wave radiation versus how much is absorbed by the surface—and day time temperature. The albedo data set was estimated from a Quickbird scene, acquired on June 13, 2010 at 18:12 GMT, by converting the raw digital numbers to reflectance and summing the squares of the reflectance values for each band on a per pixel basis. The temperature data set was estimated by using the sixth band (thermal infrared) of a Landsat 5 TM scene acquired on June 19, 2010 at 17:48 GMT. Landsat captures thermal conditions during the day that are useful for measuring micro-climate regulation (e.g. Jenerette et al. 2007) and can have implications for urban heat island effects. Primary productivity was represented by the Soil Adjusted Vegetation Index, or SAVI, (Huete 1988) which was calculated from the Quickbird scene by using the following equation:

$$\frac{(Band\ 4 - Band\ 3) * 1.5}{Band\ 4 + Band\ 3 + 0.5}$$

Band 4 covers the near-infrared portion of the electromagnetic spectrum, 760-900 nm, and Band 3 covers the red portion at 630-690 nm. Vegetation reflects more in the near-infrared part of the spectrum and absorbs more in the red because of photosynthetic activity. This makes the detection of vegetation using these two bands ideal in satellite images. SAVI was selected as the metric for vegetative cover as opposed to the more common NDVI (Normalized Difference Vegetation Index) because it minimizes the influence of soil on vegetation detection (Huete 1988, Qi et al. 1994), which is particularly useful in desert environments where soil can dominate the landscape.

Potable and non-potable water consumption indicated the provisioning of both local (groundwater and recycled) and regional (canal water) water resources. Annual water consumption data was obtained from the City of Tucson Water at the city block scale and normalized by the number of connections per city block. The provisioning of water is related to water consumption both indoors and outdoors. Potable water can be used both indoors and outdoors and is sourced from groundwater and CAP. Non-potable, reclaimed water is used outdoors. Although socio-economic status was not the focus of our analysis, we also included the full cash value (FCV) of single family homes as an indicator of socio-economic status (SES) because past research found a positive correlation between wealth and water consumption (Wentz and Gober 2007). Our intention is to link urban design to environmental outcomes and control for SES if large, significant differences in wealth between the three communities emerged. The full cash value (FCV) of single-family homes was obtained from the Pinal County Assessors' parcel scale data.

Each variable was calculated at the city block scale and used to determine means for Civano I, Civano II, and the comparison community and a multinomial logistic regression (MLR; Hosmer and Lemeshow 2000, p. 260-287) was used to differentiate the biophysical (temperature and SAVI) and social (potable water consumption, non-potable water consumption, and full cash value of the plot) covariates between Civano I, Civano II, and the comparison community. The benefit of using a multinomial logistic regression or MLR over a multiple linear regression is that the dependent variable can be categorical (e.g. Cao et al. 2011, Tremme and Verburg 2011. Unlike a standard logistic regression that uses a dichotomous dependent variable, MLR uses a dependent variable that has more than two classes. MLR can test which variables are significantly different, and thus which ecosystem services are different between the communities, by using a probabilistic framework rather than an estimation of the dependent variable (as in linear regression). MLR was used to estimate coefficients and their significance for the biophysical and social variables as way of determining how well these variables could successfully predict between the three development types, Civano I, Civano II, and the comparison community. The analysis was divided into two MLR's so that the social and biophysical covariates could be analyzed separately to keep model development parsimonious (Flack and Chang 1987, Freedman 1983, Hosmer and Lemeshow 2000 p. 120-125) and because an initial screening of the variables found that a constant was significant in the model for the biophysical parameters (SAVI and temperature) but not significant for the social (potable water consumption, non-potable water consumption, and full cash value of the plot). In the development of the biophysical model, our goal was to first determine the significant differences in SAVI and temperature. Since we measure temperature and SAVI rather than the services that lead to their outcome, we are in effect measuring the *outcomes* of micro-climate regulation and NPP. We interpret the significance values of SAVI and temperature as indicators of differences in micro-climate regulation and NPP. The model for the social variables provide insight into the significant differences related to water provisioning, furthermore it helps to determine if socio-economic status is an additional influence on water consumption by using the full cash value of single family homes as a proxy.

RESULTS

Environmental variables: temperature, albedo, and SAVI

We found small differences in climate regulation between the three communities. The mean temperature in Civano I was cooler than in both Civano II and the comparison community with the comparison community being slightly cooler than Civano II (Figure 2, Table 4). Civano I had a larger standard deviation from the mean temperature across city blocks than both Civano II and the comparison community due to an edge effect from higher temperatures in the surrounding remnant desert. After removing temperature values from city blocks around the edge the mean temperature in Civano I decreased 0.14 C to 31.59 C while temperature changes in Civano II and the comparison community were not as pronounced. In Civano II and the comparison community temperature decreased by 0.02 C each to 31.96 C and 31.91 C, respectively after negative buffering. Several elements of urban design in Civano I potentially contribute to the lower mean temperature. First, only some of the homes in the comparison community and none of the homes in Civano II utilized the light colored, high albedo roof material prevalent in Civano I. Second, homes in Civano I are more densely clustered with more contiguous high albedo areas. Third, more dense vegetation in Civano I and the comparison community generates cooler temperatures through shading and evapotranspiration. The cooling capacity of light colored roofs and vegetation combined with the clustered spatial arrangement of different land covers appear to generate the lowest micro-climate temperatures.

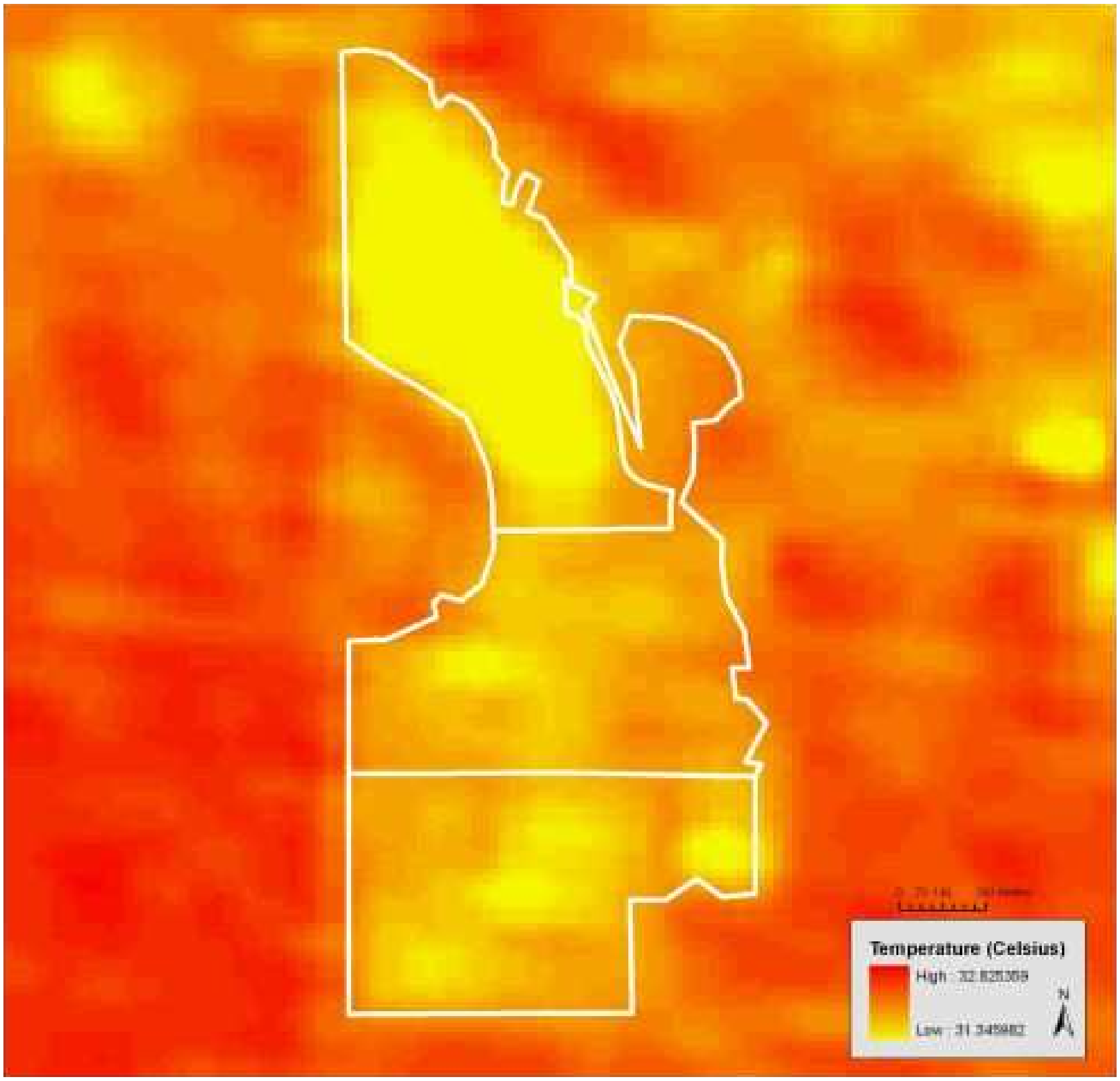

Figure 2: Temperature

Table 4: Mean Temperature

Mean Temperature Degrees Celcius				
	All Blocks		Negative Buffer	
	Mean	SD	Mean	SD
Civano I	31.73	1.70	31.59	0.97
Civano II	31.98	0.89	31.96	0.81
Comparison	31.93	0.98	31.91	0.87

Figure 3: Albedo

Table 5: Mean Albedo

Mean Albedo		
	Mean	SD
Civano I	0.130	0.164
Civano II	0.074	0.036
Comparison	0.080	0.047

Figure 4: SAVI

Table 6: Mean SAVI

Mean SAVI		
	Mean	SD
Civano I	0.262	0.240
Civano II	0.178	0.151
Comparison	0.237	0.229

As with temperature, mean albedo was higher in Civano I than in Civano II and the comparison community (Figure 3, Table 5) and city blocks in Civano I had a larger standard deviation from the mean albedo due to the edge effect from low albedo roads and desert. Differences in vegetated cover were less pronounced than differences in albedo. Mean SAVI was highest for city blocks in Civano I and the comparison community, and lowest in city blocks in Civano II (Figure 4, Table 6). All three communities are predominantly landscaped with natural desert vegetation, but the vegetation in Civano II is sparser. The presence of more mature vegetation and turf grass common areas in Civano I may account for the small difference in mean SAVI between Civano I and Civano II.

In order to empirically explore the relative cooling effect of albedo and vegetation, we performed two regressions with temperature as the dependent variable—using albedo and vegetation as independent variables—and plotted the results in two scatterplots (Figures 5 and 6). As we suspected, city blocks with high albedo ($R^2 = 0.328$) were a better predictor of city blocks with low temperatures than city blocks with dense vegetation ($R^2 = 0.258$). Figure 5 shows the link between albedo and temperature for city blocks in each of the communities. Low albedo, high temperature city blocks were present in each of the communities, however, high albedo, low temperature city blocks were predominantly located in Civano I. The correlation between SAVI and temperature was not as strong as the correlation between albedo and temperature. City blocks with low mean temperature and high mean albedo were predominantly located in Civano I. Similarly, low mean temperature, high mean vegetation city blocks were concentrated in

Civano I while the highest mean temperature, lowest mean SAVI city blocks were located in Civano II.

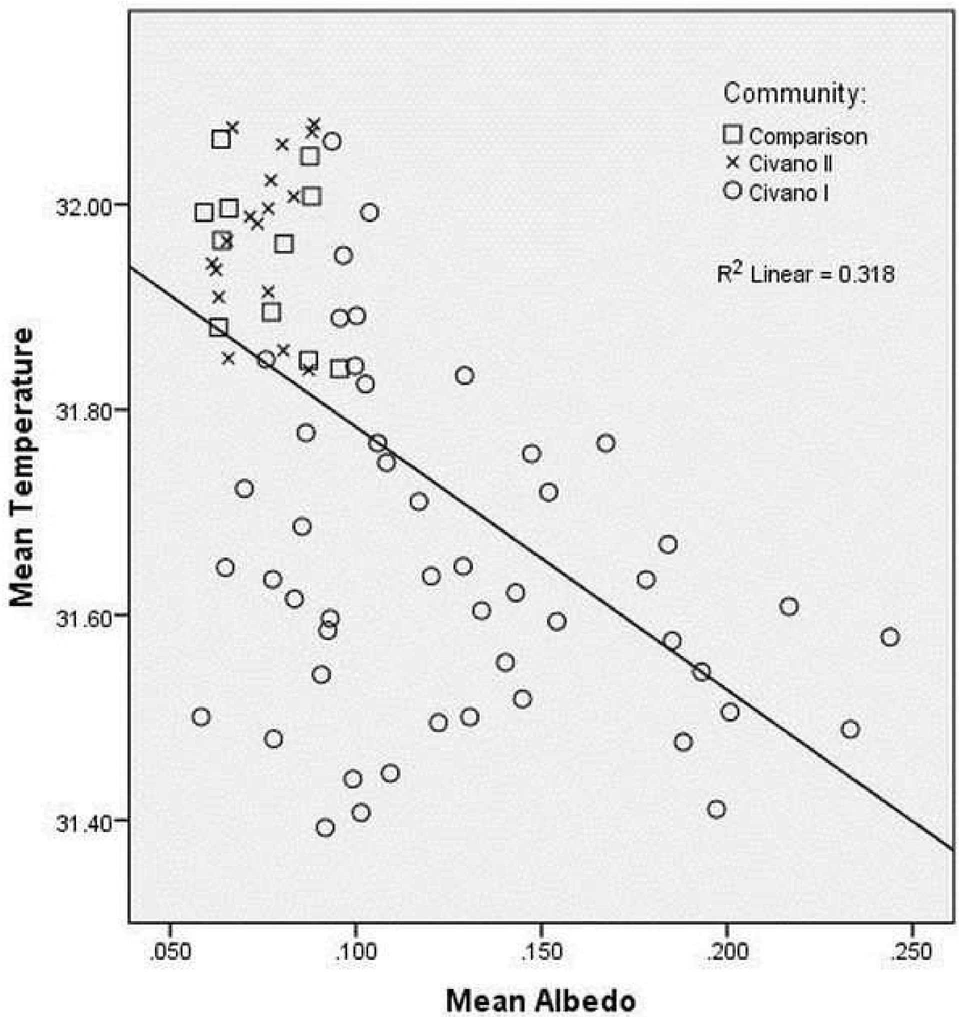

Figure 5: Scatterplot Temperature and Albedo

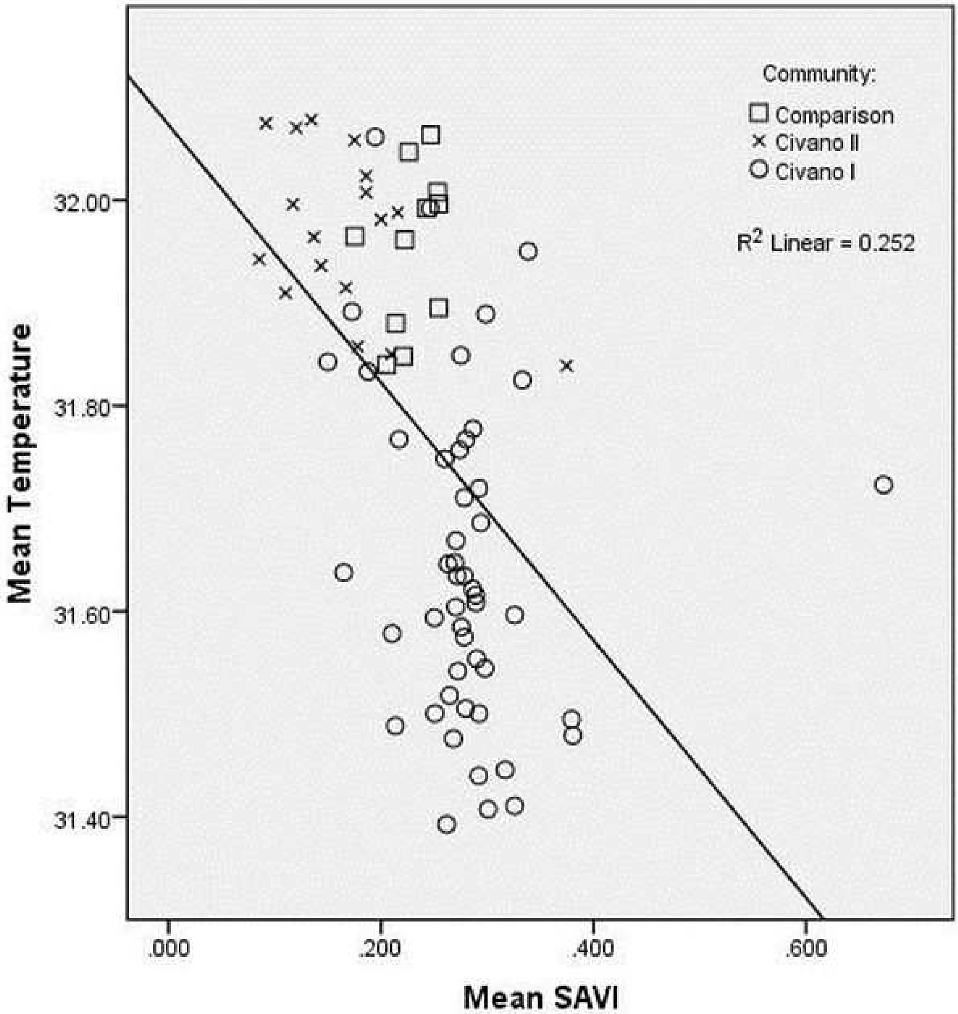

Figure 6: Scatterplot Temperature and SAVI

The multinomial regression of temperature and SAVI in the three communities reveals that lower temperature blocks were more likely to be located in Civano I as opposed to Civano II or the comparison community (Table 7). Highly vegetated blocks were more likely to be located in Civano I as opposed to Civano II, but vegetation was not significantly different between Civano I and the comparison community. Civano I has both the highest albedo and most densely vegetated city blocks but albedo, as opposed to vegetation, is a more significant predictor of temperature.

Table 7: Multinomial Regression of Environmental Variables

		Beta	Significance
Comparison	Intercept	-812.251	0.003
	SAVI	-2.038	0.812
	Temperature	25.485	0.003
Civano II	Intercept	-828.735	0.005
	SAVI	-22.638	0.038
	Temperature	26.141	0.005

*Civano I is the reference category.

3.2 Social Variables: potable and non-potable water consumption and FCV

The mean normalized potable water consumption for city blocks in both Civano II and Civano I was lower than comparison community (Figure 7, Table 8). The large difference in average annual potable water consumption between the two Civano communities and the comparison is due in part to the fact that Civano I and Civano II derive some of their water supply from non-potable water resources (Figure 8) for outdoor irrigation while the comparison community must use potable water resources for landscaping and common areas. Mean normalized non-potable water consumption in Civano II was greater than in Civano I, however, the standard deviation was very high in Civano II and city blocks using high amounts of non-potable water were only slightly more likely to be located in Civano II as opposed to Civano I (Table 9). Since the standard deviation from the mean non-potable water consumption was so large, we also calculated the median. The mean and median were similar for Civano I, however, the median for Civano II was much lower highlighting the fact that a few very high values skewed the mean. The fact that Civano II directs such large quantities of non-potable water resources to a handful of city blocks suggests that non-potable water resources are utilized to water common areas and open spaces. The comparison community did not consume any non-potable water.

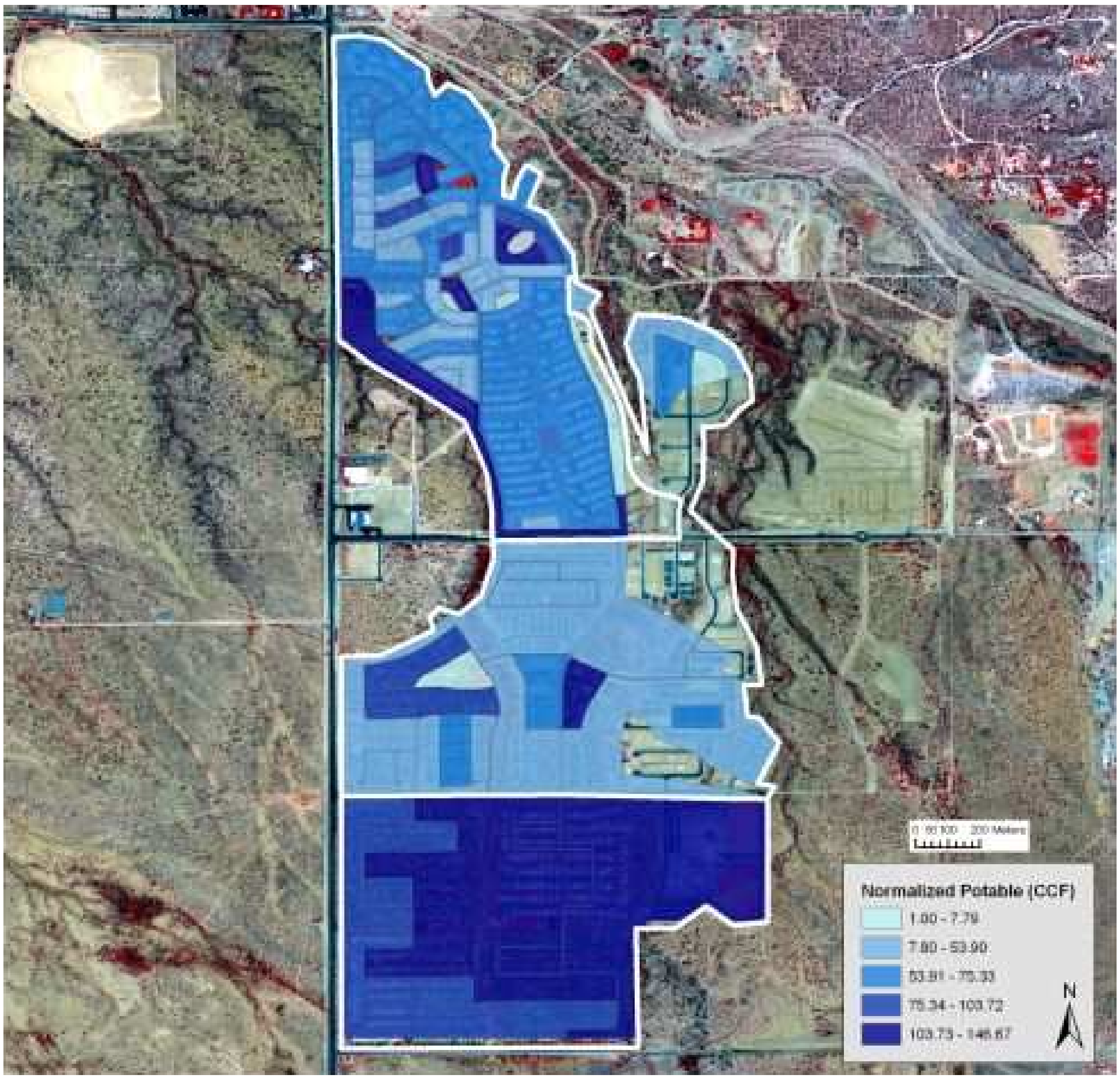

Figure 7: Potable Water Consumption

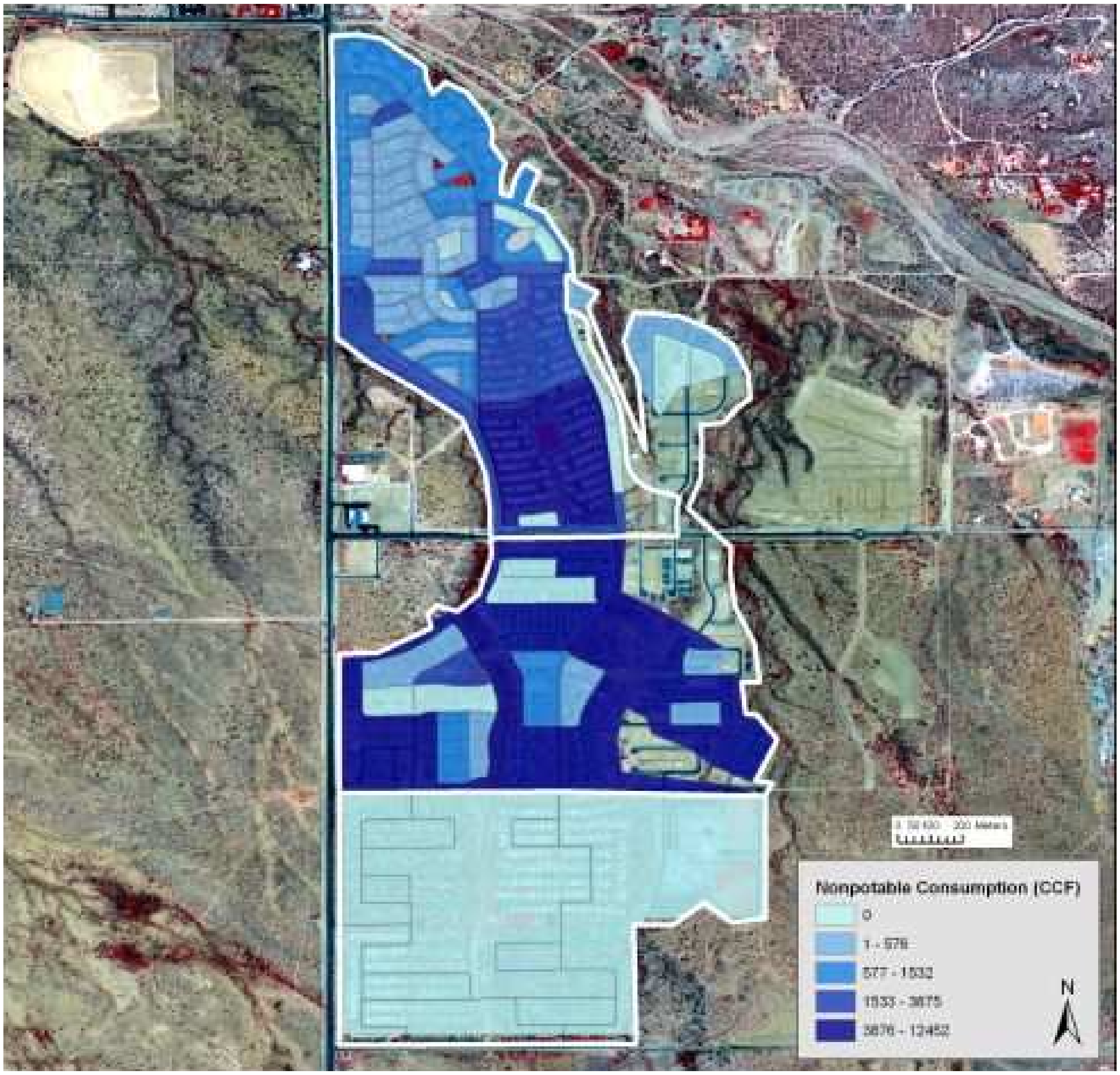

Figure 8: Non Potable Water Consumption

Table 8: Mean Potable Water Consumption

Mean Potable Water Consumption		
	Mean	SD
Civano I	65.25	22.15
Civano II	63.94	26.99
Comparison	103.56	23.48

Table 9: Mean and Median Non-Potable Water Consumption

Mean and Median Non- Potable Water Consumption			
	Mean	SD	Median
Civano I	68.52	78.82	48.99
Civano II	428.53	402.72	171.13
Comparison	NA	NA	NA

Property values in Civano I were slightly higher than in Civano II and the comparison community. Mean FCV of single family homes was highest in Civano I and lowest in Civano II. The standard deviation was highest in Civano II and Civano I and lowest in the comparison community suggesting greater diversity in housing price points in the two Civano communities.

Table 10: Mean Full Cash Value

Mean FCV Dollars		
	Mean	SD
Civano I	198964	39135
Civano II	155980	49318
Comparison	157537	26992

In the MLR model of potable and non potable water consumption and FCV (Table 11), city blocks with less potable water consumption were more likely to be located in Civano I as opposed to the comparison community, however, blocks with fewer potable water consumption were not significantly more likely to be located in Civano I than Civano II. Blocks with high non potable water use were slightly more likely to be located in Civano II than in Civano I. The comparison lacked non potable water connections. Higher full cash value blocks were slightly more likely to be located in Civano I than Civano II. Differences in full cash value were not significant between Civano I and the comparison community. The slight differences in FCV across communities lend credence to the argument that the differences in urban design, as opposed to affluence, are driving differences in environmental outcomes beyond that of socio-economic status.

Table 11: Multinomial Regression of Social Variables

		Beta	**Significance**
Comparison	Potable Norm	0.045	0.026
	NonPotable Norm	-10.444	NA
	Full Cash Value	-0.227	0.061
Civano II	Potable Norm	0.019	0.135
	NonPotable Norm	0.003	0.041
	Full Cash Value	-0.177	0.003

*Civano I is the reference category.

DISCUSSION

Our findings reveal differences in the provisioning of three key ecosystem services between the two communities tied to urban design. Civano I more successfully regulated micro-climate and increased primary productivity by incorporating higher albedo building materials and more vegetative cover into the community design than Civano II and the comparison community. Interestingly, the design guidelines for Civano II roofing material restrict, “White, off-white, aluminum or other highly reflective coatings or colors,” (Sierra Morado CCR 2005, pg. 7). In contrast, Civano I requires the development to minimize “the amount of heat absorbed—in buildings and in streets, resulting in minimizing the energy needed to reduce the impact of that heat…” although reflective finishes “are discouraged, by [sic] may be approved on a design specific basis”

(Civano CCR 1998). The comparison community also restricts white roofing material, but the presence of some high albedo roofs suggests that this rule changed, was not enforced, or that high albedo roofs were achieved through some other mechanism. Civano I was also more densely vegetated than both Civano II and the comparison community. One potential explanation for differences in vegetation is that Civano II was built later and that the vegetation has yet to mature; the comparison community, however, had denser vegetation than Civano II as well and it was completed last. A more likely explanation is that Civano I salvaged 80 percent of the native vegetation during construction, while Civano II used new plantings that have yet to mature. Furthermore, the urban design of Civano I clusters buildings in order to maximize open space available for contiguous desert vegetation and turf-grass common areas.

The results also show that albedo was more closely correlated to temperature than vegetation across all of the communities. Given limited water resources in Tucson, the use of high albedo roofing material may be a good option for micro-climate regulation in the context of the arid region. High albedo roofs are a particularly attractive option when arranged in a clustered urban design like that of Civano because the contiguous high albedo area amplifies the cooling effect while minimize trade-offs associated with increasing building area (i.e., loss of open space). Our results also call into question the efficiency of using vegetative cover to regulate local micro-climates in the desert, especially in instances where vegetation requires water resource inputs, however, both Civano I and Civano II primarily watered outdoor vegetation using non-potable water resources, somewhat offsetting these concerns. The comparison community did not use any non-potable water for irrigation purposes and the data does not reveal how much potable water might be allocated for outdoor uses. It does show that overall mean potable water consumption was much higher in the comparison community than both Civano I and Civano II. City blocks with higher non-potable water consumption were slightly more likely to be located in Civano II than Civano I yet, given similar non-potable water portfolios, Civano I generated higher primary productivity.

Civano I and Civano II lowered the provisioning of potable water resources by supplementing that supply with non-potable water resources, which may reflect the fact that reductions in water consumption were enforced through memorandum of understanding with the City of Tucson. Mean potable water consumption in the Civano communities was almost 40 ccfs lower than in the comparison community annually, however, mean non-potable water consumption in both Civano I and Civano II was highly variable. Both communities contained city blocks with one or few non-potable service lines and very high non-potable water consumption as well as city blocks with several non-potable services lines with no or very little non-potable water consumption. One explanation for the differences lies in the implementation of building and design aimed at lowering water provisioning in the two phases of development. Civano I mandated that all homes have non-potable water hook-ups installed, however, due to the high cost of maintenance and delivery, many residents eventually opted to stop using them (Nichols and Laros 2009). The developers of Civano II chose to funnel non-potable resources into the watering of common areas.

Our results point to tradeoffs in the use of urban design and albedo to regulate microclimate. The modest differences in temperature across the three communities raise questions about the efficacy of urban design as a mechanism for micro-climate regulation at the neighborhood scale. For instance, increasing home insulation or installing low flow appliances might be more cost-effective approaches to managing energy and water consumption than decreasing local temperatures through urban design. These technological substitutes do not reduce outdoor temperature, which is a key driver of high energy and water consumption. The lack of night-time temperature data may suppress differences in temperature due to urban design, however, because the dense vegetation and high albedo roofs in Civano I are more likely to cool in the evening while the high impervious surface coverage in Civano II is more likely to retain heat. The very hottest blocks were located in Civano II and the comparison community while the very coolest blocks were concentrated in Civano I along with some hotter blocks. This internal variation in temperature in Civano I suggests that some portions of the urban design may generate significant cooling, especially if replicable at larger scales. Our results show that high albedo roofs may substitute as a more effective mechanism for microclimate regulation than vegetation, however, it cannot replace the full range of services that vegetative cover provides including: habitat, flood regulation, and soil retention.

PROJECT SCOPE AND DATA LIMITATIONS

We explored the potential to utilize fine scale spatial data to link neighborhood design to environmental outcomes and we recognize the presence of data and analytical constraints. We were unable to capture daily or seasonal variations in our variables because we were limited to a single-time snap shot of the Quickbird image. The urban heat island effect is generally more pronounced in cities during the evening when the thermal holding capacity of low albedo impervious surfaces stay warmer well into the evening hours. Conversely, the desert is hotter during the late morning and throughout the day (Brazel et al. 2007) but then cools off as the sun sets. Due to data limitations – NASA ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), the only satellite platform capable of capturing night time temperature data at relevant resolutions, currently has no night time summer temperature data for the study area from 2007 onwards – night time temperature could not be evaluated for all three communities so we restricted our study and discussion to day time temperature effects. The differences in temperature during the late morning between the communities gave an indication of sustainable outcomes that are related to energy usage and micro-climate regulation. Future studies should consider night time surface temperatures in addition to daytime surface temperatures for a comprehensive understanding of the relationship between urban form and micro-climate regulation. Additionally, the City of Tucson water data does not disaggregate indoor and outdoor uses, which obscures the impact of urban design versus home design on water consumption. Previous studies found that outdoor water consumption accounts for approximately 70% of residential water consumption in an arid environment (Wentz and Gober 2007). Water conserving landscape designs and indoor technologies would likely alter the indoor-outdoor water demand balance at Civano I and II.

CONCLUSION

Our results show that differences in urban form and urban design contribute to moderate differences in the provisioning of ecosystem services at the neighborhood scale. Urban design that incorporates high albedo materials and dense vegetation regulates local climate by reducing temperatures. The configuration of the built environment matters because dense clustering of houses with high albedo rooftops generates greater reductions in temperature than more dispersed designs. Albedo may be a more effective and water efficient design feature for reducing temperature but it presents a trade-off with increasing NPP through vegetative cover. This trade-off may be somewhat offset by introducing non-potable water resources for watering outdoor landscapes which has a significant impact on reducing overall potable water consumption.

The ecosystem services framework shows that individual goals may be conflicting when they present trade-offs between services. In this instance, there is a trade-off between more effective and water efficient cooling and increasing NPP through vegetation because albedo was more strongly linked to regulating temperature than vegetation. There was also a trade-off between NPP and the provisioning of non-potable water resources in Civano I compared to Civano II. Civano I used less non-potable water to achieve more lush vegetation than Civano II, but at a higher cost to residents due to the maintenance and delivery of non-potable water to individual homes.

Future research should continue to expand upon these findings through additional case studies unified by the ecosystem services framework. This study analyzed three ecosystem services but due to data limitations and project scope did not investigate many other environmental outcomes of interest to urban sustainability. Other ecosystem services—for instance, those tied to biodiversity—merit further investigation as well. For example, dense vegetation in Civano I most likely also has an influence on native biodiversity as habitat. NPP relates to many other ecosystem services including biodiversity, nutrient retention, and soil retention among others. A fuller investigation of these services was beyond the scope of this project but nevertheless seems warranted in future deliberations.

Finally, our results suggest that incorporating an ecosystem services perspective into urban planning and design builds upon current efforts to urbanize sustainably by providing quantifiable metrics for measuring and monitoring a broad suite of environmental outcomes. Sustainability can be interpreted many ways and the ecosystem services framework provides guidance in identifying environmental goals beyond those associated with the built environment alone. Ultimately, it is the individual actors and institutions that make the decisions that influence urban design and an ecosystem services approach can supplement current urban planning strategies.

Chapter 4

AN INSTITUTIONAL ANALYSIS OF THE CAPACITY OF SUSTAINABLE URBANISM TO ACHIEVE ENVIRONMENTAL GOALS THROUGH CONVENTIONAL MASTER PLANNED DEVELOPMENT

INTRODUCTION

Urbanization has always produced environmental challenges and in the 21st century those challenges will be amplified by the number of people living in mega-urban complexes (Marshall 2005). Addressing these challenges requires innovations in how we plan, build, and manage cities: urbanization processes. One of the most profound changes to the urbanization process has been the rise in master planned development globally, a process that decentralizes and privatizes the urban planning process and relegates a large amount of control over the creation of new urban landscapes to national and international development firms (Seto et al. 2010). With conventional developers at the helm, master planned communities have contributed to environmentally unsustainable urbanization trajectories. A growing number of developers, however, seek to reverse these trajectories through a suite urban planning and design interventions collectively known as sustainable urbanism (Farr 2008). These design alternatives are often implemented within the conventional development framework of master planning, potentially undermining their capacity to achieve desirable environmental outcomes.

Evidence from environmental social science fields like political ecology and environmental commons research suggest that undesirable environmental outcomes are ultimately the result of institutional frameworks that undermine the capacity to sustainably manage urban and other human-dominated environments (Ostrom 2005, Turner 2005, Beddoe et al. 2008, Robbins 2012). Institutions include the broad-scale political economy that structures decision-making at local to global scales as well as the informal and formal rules in use in society (Ostrom 1990, Pete and Watts 1996). The role of institution in environmental management has been particularly well demonstrated in common pool resource theory, which reveals the failure of panaceas, one-size-fits-all management approaches, to prevent resource depletion due to institutional mismatch with the social context of the resources users and the environmental context of the resource system (Ostrom 2007, Ostrom 2009). In urban systems, institutional mismatch can be driven by legal- and policy-centric institutional frameworks that emphasize one-off decision-making and uncertainty reduction that are poorly equipped to handle environmental management contexts shrouded in variability, ambiguity, complexity, and uncertainty (Quay 2010). Sustainable urbanism is likely to face similar challenges operating within existing institutional frameworks for master planned development.

This research asks how conventional development processes facilitate or constrain the capacity of sustainable urbanism to achieve environmental goals through master planning. This central question is addressed through an institutional analysis of planning and development processes in three case-studies in sustainable urbanism in the United States—Civano (Tucson, Arizona), Mueller (Austin, Texas), and Prairie Crossing (Grayslake, Illinois, United States)—to reveal the barriers and opportunities for implanting alternative planning approaches through conventional master planned development. The case-studies represent a range of socio-environmental and urban planning contexts, and all claim to increase environmental sustainability through planning and design.

CONVENTIONAL DEVELOPMENT AND THE SUSTAINABLE URBANISM ALTERNATIVE IN THE UNITED STATES

The institutional mechanisms that facilitate conventional development in the United States are the culmination of a dramatic shift in the way urban and suburban lands are planned and streamlined by land-use regulations that give a large degree of control to developers. These changes have been characterized by Weiss (1987) as the rise of master planning and development in the 20th century which increased the scale of development and economic integration across all phases of the development process. Many cities attempt to regulate development by adopting master plans that divide the city into land-use zones for future development; but these plans codify a preferred spatial arrangement for the city at a particular point in time that sometimes conflict with changing conditions and priorities in the city. To get around such conflicts, developers can apply for zoning overrides to legally change the planned use for a piece of land. The bureaucratic process, however, is cumbersome for a development industry that benefits from rapid land improvements and sales to ensure maximum profit. The Planned Unit Development (PUD) has emerged as a more efficient device to legally resolve conflicts between development and zoning plans. The PUD allows an area of land to be rezoned before project implementation giving the developer ultimate control over the spatial arrangement of the development and eliminating the burdensome process of obtaining ad-hoc zoning overrides (Tarlock 2013). Developers maintain control through the development stage and beyond by establishing legally binding Covenants, Codes, and Restrictions (CCRs) that detail lot improvement and architectural standards to ensure that homes are congruent with the overarching vision for development once improved land is sold to homebuilders for construction. One manifestation of the increasing economic integration across all phases of development observed by Weiss (1987) is the folding of homebuilding and development activities under one firm, however, CCRs remain the industry standard for detailing lot improvement and architectural standards. They provide legally binding property restrictions that run in perpetuity with the land and, once development is complete, the developer's vision is sustained by transferring enforcement authority to a Homeowners Association (HOA). The HOA is comprised of an elected board of property owners and management staff that maintains common areas and enforces CCR guidelines financed through property owner dues and fines for non-compliance (McKenzie 1994). The PUD, CCR, and HOA constitute the institutional framework that facilitates conventional master planning and development.

Conventional development processes in the United States have resulted in urban sprawl: large-scale, low-density, fragmented landscapes associated with a suite of undesirable environmental outcomes including loss of open space, increased resource consumption and waste generation, and water and air quality degradation (Johnson 2001). The sustainable urbanism movement is an alternative to conventional development that attempts to reverse these undesirable environmental outcomes through best practices in planning and design. Sustainable urbanism includes a suite of urban planning movements including New Urbanism, Transit Oriented Development (TOD), Conservation Subdivisions, and Agricultural Urbanism among others (Duaney et al. 2000, Cervero et al. 2002, Arendt 1996, Duaney et al. 2011). The common message in these planning and design movements is that dense, mixed-use neighborhoods connected by a network of multi-modal transportation options and buffered by a variety of open space land uses will improve environmental and public health by reducing land consumption, auto dependency, and the overall impact of development on the natural system (Farr 2005). While innovations in urban design and green technologies have been the primary focus, sustainable urbanism also utilizes planning process aids, including rating system assessments and forums for community involvement (Duaney et al. 2000). Those design principles and process aids are commonly applied to the master planning process and the institutional framework designed to facilitate conventional development, implicitly suggesting that the existing framework is compatible with sustainable urbanism. Yet perceptions of financial risk, insufficient regulatory controls, and narrow definitions of environmental sustainability within the development industry have been identified as barriers to achieving environmentally oriented goals such as climate adaptation and conservation (Taylor et al. 2012, Bueshel and Rudel 2009). These findings suggest institutional mismatch between conventional development and sustainable urban alternatives.

Nevertheless, developments touting versions of sustainable urbanism are proliferating globally including hundreds of Leadership in Energy Efficiency and Design for Neighborhood Development (LEED-ND) pilot projects[1] in the United States, Canada, and China and Eco-Cities[2] with locations on every continent as of 2009 (USGBC 2013, Joss 2010).This phenomenon has caught the attention of scholars concerned with the lack of empirical evidence linking design alternatives to espoused environmental outcomes, despite awards and accolades bestowed upon sustainable urban developments within planning practice (Garde 2009, Mapes and Wolch 2011) The earliest studies were highly critical, dismissing sustainable urbanism as conventional suburbia capitalizing on sustainability as a marketing tool, however, more recent research reveals that such wholesale dismissals disguise a great deal of variance in environmental performance across sustainable urban projects (Zimmerman 2001, Trudeau and Malloy 2011). Current research efforts attempt to explain this variation based on resident's environmental attitudes, knowledge, and behaviors, municipal regulations, and developer implementation practices (Youngentob and Hostetler 2005, Hostetler and Noiseux 2010, Grant 2009, Göçmen 2013, Hostetler and Drake 2009). This research builds on recent efforts to explain variation in environmental outcomes in sustainable urban development by drawing on insights on the role of institutions in shaping those outcomes.

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[1] LEED-ND is a rating system developed by the US Green Build Council (USGBC), Congress for New Urbanism (CNU), and the National Resource Defense Council (NRDC) to guide sustainable urban design of buildings and neighborhoods. Developments receive points for addressing the following environmental priorities: site location, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation in operations. (Source: USGBC)

[2] The Eco-city concept first emerged out of the 1970s environmental movement and gained in popularity during the United Nations Earth Summit in Rio de Janeiro (1992) and the Agenda 21 sustainable development program. The eco-city approach to sustainable urbanism is city-scale and holistic with the goal of creating cities that are entirely self-sufficient and self-sustaining. (Source: Joss 2010).

METHODS

Case study selection

The three case-study developments were identified from a list LEED-ND pilot projects (2010), limited to all mixed-use developments located in the United States for which at least one phase of the development had been completed[3]. The three cases were selected to maximize difference across three gradients of variation: biophysical context, type of development, and approach to sustainable urbanism (Table 1, Figure 1). The variations in biophysical context highlight implementation similarities and differences across environmental conditions. The presence or absence of public-private partnerships addresses the role of collaborative processes in achieving environmental goals. Varying the approach to sustainable urbanism gleans insight into the specific challenges and opportunities that stem from different versions of environmental sustainability versus processes held in common across all developments.

[3] LEED-ND pilot projects incorporate the rating system standards throughout the development or limit participation to a sub-section of the development.

Table 1: Case Study Attributes

	Civano	**Mueller**	**Prairie Crossing**
Location	Tucson, AZ	Austin, TX	Grayslake, IL
Approach to sustainable urbanism	Solar Energy, New Urbanism	Brownfield Infill, Airport Redevelopment	Conservation Subdivision, Agrarian Urbanism
Biophysical context	Arid	Semi-Arid	Temperate
Development type	Public-private	Public-private	Private
Size (Acres)	1145	700	678
Number of Households at Build Out	2600	5700	362
Development Start	1981	1984	1980

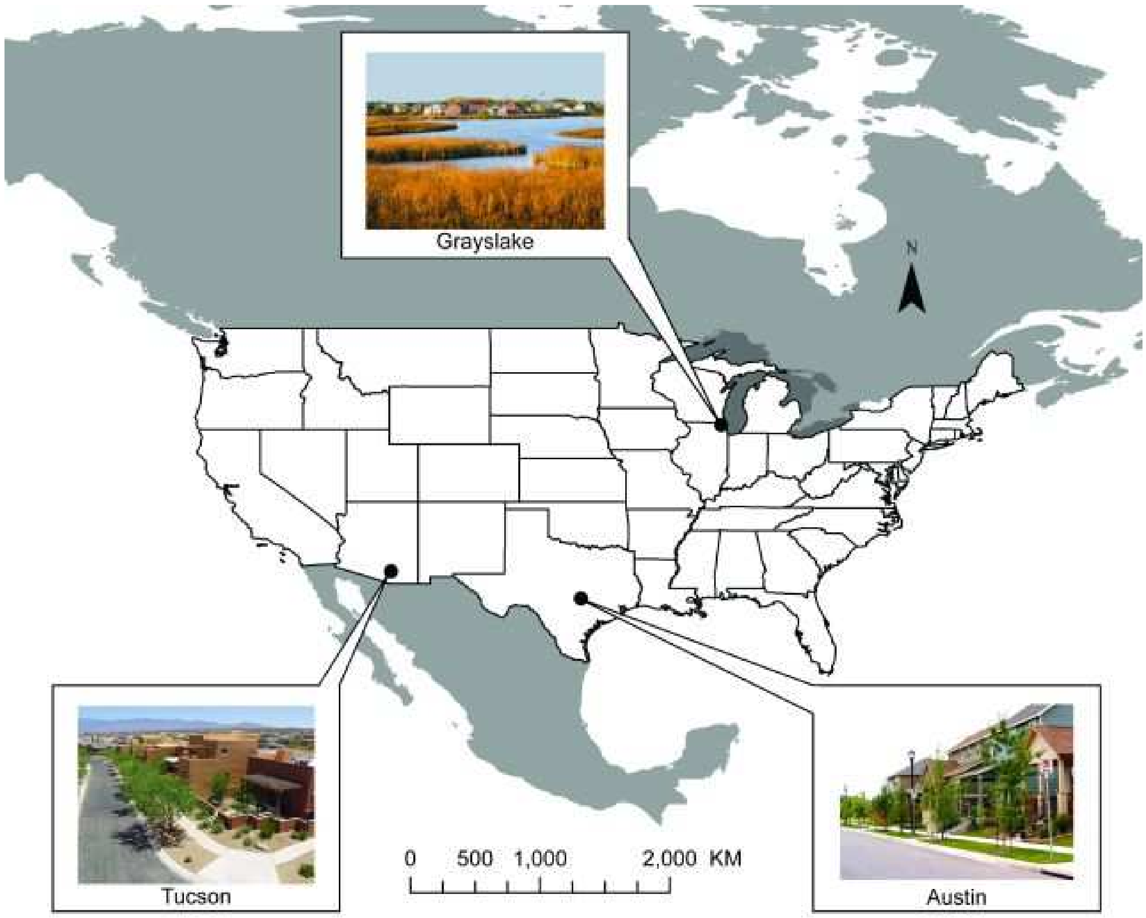

Figure 1: Case study locations

Data Collection and Analysis

In depth, semi-structured interviews (38-125 minutes) were conducted in person or over the phone in the Fall 2012 with stakeholders (n=22) involved in the planning and implementation of each development. Stakeholders were purposefully selected as leaders in one of three key stakeholder groups: the planning and development team, municipal employees, and community leaders living in the development and the surrounding neighborhoods. Incidentally, many stakeholders from each group were also homeowners.

Stakeholders were asked to describe each phase of the development process for which they were involved—inception, planning, and implementation—and to comment on the biggest challenges and successes that emerged during those processes. Interviews were transcribed and coded using QSR NVivo 10 qualitative analysis software (QSR International, 2010). Transcripts were coded (Table 2) inductively for emergent themes categorized as constraints or facilitation and these sub-nodes were aggregated into parent nodes expressing broader themes.

Table 2: Coding Parent and Sub-nodes Used in Analysis

Parent Node	**Sub-Node**
Land & Home Development Costs	Constraints: Land holding costs, land improvement costs, home building cost Facilitation: Incentives, shifting costs, scaling down, phased development
Market Risk & Uncertainty	Constraints: Lack of precedents, industry standards, mass marketing, misinformation Facilitation: Research, education, control of message, anticipatory design
Regulations & Liability	Constraints: Zoning and land-use regulations, environmental regulations, liability Facilitation: Flexible master plan, scoping, environmental regulations, training programs
Partnerships & Public Participation	Constraints: conflicting agendas, politics, elected official turnover, loss of political capital, power asymmetry Facilitation: material resources, subsidies, coalitions, advocacy and negotiation
Guiding Principles	Constraints: inflexible, difficult to measure, conflict with municipal rules Facilitation: institutionalized, revisited, revised
Institutions versus Individuals	Facilitation: leadership skills, interpersonal network, neutrality Constraints: fatigue, interpersonal conflicts, institutional momentum

CASE STUDY BACKGROUND

Civano, Mueller, and Prairie Crossing represent three approaches to sustainable urbanism as reflected in each development's guiding principles (Table 3). Civano had relatively narrowly defined goals, mostly related to resource consumption, that were designed to be adapted into quantifiable metrics of success (Civano 2013). Sustainability at Mueller was defined as development that is, "planned in a way that promotes energy and water efficiency, resource protection, reduced auto dependency, watershed protection and green space preservation" (Mueller 2013). This goal of environmental sustainability complements a list of socio-economic goals. Prairie Crossing has several goals directly relating to environmental sustainability—environmental protection and enhancement, convenient and efficient transportation, and energy conservation—as well as several holistic goals relating environment to well being through healthy lifestyle, sense of place, and lifelong learning and education (Prairie Crossing 2013). Each development claims that planning according to their particular guiding principles will generate more environmentally sustainable development.

Table 3: Guiding Principles for Case-study Developments (Civano 2013, Mueller 2013, Prairie Crossing 2013)

Civano	**Mueller**	**Prairie Crossing**
• Reduce building energy demand	• Fiscal Responsibility	• Environmental protection and enhancement
• Increase building energy supply	• Economic Development	• Healthy lifestyle
• Reduce potable water consumption	• East Austin Revitalization	• Sense of place
• Solid waste recycling	• Compatibility with Surrounding Neighborhoods	• Sense of community
• Transit and air quality	• Diversity and Affordability	• Economic and racial diversity
• Land use balance (density and connectivity)	• Sustainability	• Convenient and efficient transportation
• Housing affordability		• Energy conservation
		• Lifelong learning and education

Civano: From Solar Village to Sustainable Community and Back

Civano is a mixed-use development built on State Trust land[4] located at the Southeast periphery of Tucson, Arizona. The development features energy and water efficient homes, many of which are outfitted with photovoltaic panels and hot water heaters as well as non-potable water hook-ups for outdoor irrigation. An onsite nursery facilitated tree salvaging during the early phases of development, native desert landscaping in residential yards, and building a community garden. The first phase of

[4] State Trust Land was given to the state by the federal government at the time of statehood to be used to support education. Over time these lands were leased to ranchers and mining companies and today they are sold to developers for market prices.

development incorporated New Urbanism design principles such as compact development, densely networked streets layout, and architectural and landscaping features that are congruent with the Sonoran desert and local culture (CNU Charter). There is a palpable divide between the first phase of development, Civano I, and the second phase, Sierra Morado, due to the devolution of the original guiding principles that stripped away many of the landscape and architectural design ideals while retaining the core water and energy consumption reduction metrics. Civano I and Sierra Morado both achieve high energy efficiency and low potable water consumption, but Sierra Morado looks like a typical residential subdivision with wide streets and cul-de-sacs, front-loading garages, and minimal, immature landscaping. Critics claim that Civano's location far from the city center undermines environmental outcomes such as reduced water and energy consumption. Supporters point to Civano's pioneering efforts in sustainable development and influential role in directing the development of City wide energy standards as major successes.

The development was originally conceived of as the Tucson Solar Village in the 1980s garnering the support of local and state governments eager to attract federal funding for alternative energy production following the energy crises of the 1970s. The governor at the time, Bruce Babbitt, was impressed by a solar homes showing in Tucson and agreed to dedicate a portion of State Trust Land to develop a solar-oriented, mixed-use development. The City of Tucson then established the Metropolitan Energy Commission to develop measurable energy standards and the Arizona Solar Village Corporation to create a master plan. The scope of the development increased during the

1990s after sixty public workshops revealed that Tucson residents preferred a more holistic approach to environmental sustainability. The expanded goals included water conservation, recycling, air quality improvement as well as social goals such a job creation and affordable housing construction. These expanded goals closely aligned with the growing New Urbanism planning movement and several experts were invited to hold a design Charette that yielded a master plan. The name of the development was then changed to the Civano, after the Late Classical Period of the Hohokam Civilization that once inhabited the region because it was "an era that balanced natural resources with human needs" (Buntin 2013). Ironically, the Civano period also marked the beginning of the decline of the civilization.

The implementation phase was mired by financial problems that stymied community input and city support, and undermined the version of sustainable urbanism outlined in the original guiding principles. Civano's development model was a public-private partnership in which the City provided financial resources and infrastructure improvements in exchange for development according to the master plan. Finding a developer to implement the plan proved difficult. Mainstream developers found the project too risky and eventually a team of smaller developers bought the state auctioned land. The developers experienced delays and increased development costs, and expended political capital to garner municipal support for land-use regulation overrides. Eventually, facing bankruptcy, the developers entered into a partnership with the Federal National Mortgage Association (Fannie Mae). Fannie Mae financed the completion of phase one and sold the second phase of the development to Pulte Homes, a large national developer, who negotiated weakened environmental standards with the beleaguered City of Tucson.

Mueller: Leaning Toward the Best Intentions

Mueller is located in East-central Austin, Texas on the site of the Robert Mueller Municipal Airport (RMMA) and adjacent to historically low-income East Austin neighborhoods. The City was cognizant that re-development could displace residents of those neighborhoods or alternatively it could enhance and support those communities. The guiding principles reflect the City's desire to support the latter through economic development, east Austin revitalization, affordability, and compatibility with the surrounding neighborhoods. The guiding principles also emphasize fiscal responsibility. The development had to self-finance because it utilized municipal land which meant it needed to provide a public benefit for the City without requiring public (tax payer) funds. In addition to these socio-economic goals, Mueller promotes environmental sustainability through green building and infrastructure and New Urbanist design features such as dense, mixed-use, and multi-modal transit design. The community features a restored native prairie habitat designed by the Ladybird Johnson Wildflower Center and maintained in partnership with Friends of the Prairie—a group of resident volunteers (Mueller2 2013). Mueller hosts the Pecan Street Project, a University of Texas, Austin smart grid research project that allows residents to manage household energy consumption while collecting data for research. Homes must conform to Austin Green Building or LEED energy standards, and solar energy production is encouraged in homes and featured in a solar flower art installation. Critics claim that Mueller falls short of its ideals since it lacks some basic amenities such as walkable retail and public transit and some of the residential areas were developed at lower densities than originally intended. Supporters point to the long-term potential of the community to attract more retail and public transit through design that can easily be retrofit for those features and trends toward more dense development in later phases of development.

Mueller is the product of a lengthy public-private-community partnership that began in the 1980s. The original concept for a mixed-use community to replace the RMMA after closing emerged through a public engagement forum called Citizens for Airport Relocation (CARE). Many CARE participants remained actively involved in the planning processes when the City created the RMMA Task Force which was comprised of environment, planning, and legal experts from across the municipality. The City hired a private firm, ROMA Design Group, to assist the City and the RMMA Task Force with developing a master plan and eventually hired California developers, Catellus, in favor of local developers for their experience and willingness to implement the master plan that had emerged after nearly 20 years of public engagement.

Initially, the State of Texas intended to participate in the planning process and create State office space on site. When this plan fell through, some state legislators attempted to keep the RMMA open for private air traffic which alienated both the City of Austin who had a vested interest in seeing the development proceed and East Austin residents, who did not want an environmental dis-amenity in their neighborhood. The State of Texas inadvertently created a partnership between the City and East Austin residents fighting to keep the airport closed. This informal partnership would continue throughout the planning process when East Austin residents formed the Mueller Neighborhood Coalition to give voice to their concerns about the development.

Mueller's implementation phase addressed several of the problems that undermined Civano and other early adopters of sustainable urbanism. The City granted Mueller planned unit development (PUD) status and used an existing Traditional Neighborhood Development (TND) ordinance to guide zoning changes before development began to avoid the delays for zoning overrides during development. Even with foresight and the TND ordinance as a guide, this process took two years to complete. The City also created an innovative financing system that reduced development costs through phased development and onsite tax revenues but allowed a type of development, "big box retail," that many community members believed was not in the spirit of sustainable development. As development continues, the developer, City, RMMA Implementation Group (an augmented version of the RMMA Task Force), and Mueller Neighborhood Coalition remain partners in the development with the addition of the Mueller Neighborhood Association representing the interests of the residents that populate the first phases of development.

Prairie Crossing: A Culture that Values Conservation

Prairie Crossing is a private development in The Village of Grayslake, Illinois, a suburb 40 miles northwest of Chicago. The site was subject to a lengthy legal battle during the 1970s and 80s in which a group of “gentleman farmers”—businessmen from Chicago who owned farm land in the area—legally contested a proposed 1600 unit conventional residential subdivision. The land owners won their lawsuit and formed a non-profit entity, the Prairie Holdings Corporation, led by George and Victoria Raney, to plan and develop a “conservation community” with restored prairie, wetland habitat, and an organic farm. The development features restored prairie habitat that is managed by residents through controlled burns and a man-made wetland habitat. The latter was selected by the Illinois Department of Natural Resources to introduce endangered fish species due to its very high water quality. There is also an organic farm, an educational “learning farm”, and several smaller organic farm lots for lease. The farms contribute to a community supported agriculture (CSA) program, farmers market, summer camps, and the Farm Business Development Center (FBDC) that supports individuals interested in becoming organic farmers. The homes were part of the U.S. Department of Energy’s Building America Program (DOE) and the “main street” district complies with LEED-ND standards.

The Prairie Holdings Corporation employed a team of experts including consultants to assist with team-building, environmental design, and to set up the infrastructure to sustain the conservation goals once building was complete and residents were responsible for community management. Co-developing the guiding principles was part of the team-building process, creating an agreed upon standard for implementation decisions. The team revisited the guiding principles twice annually throughout the process to ensure that the project continued to meet those ideas and when the developer relinquished control over the community to the residents, the community chose to adopt the guiding principles in perpetuity. The developers created non-profit institutional mechanisms to manage the farm and market the farm lifestyle.

RESULTS: INSTITUTIONAL CONSTRAINTS AND CREATIVE SOLUTIONS

Each case-study development confronted challenges implementing its planning and design model because the institutional mechanisms that facilitate conventional master planned development sometimes contradicted that model. Major impediments included (1) existing financing mechanisms that impose large holding costs, (2) market conservatism that favors risk reduction and mass marketing, (3) and a one-shot, one-way, regulatory landscape that inhibits learning and adaptation. Operating within this institutional framework contributed to failures to achieve planning and design goals but also inspired creative solutions that capitalized on context-specific conditions or windows of opportunity to temporarily tilt favor toward sustainable urban development.

Financing and Implementing Development

Interview participants in all three communities emphasized that the developments were entrepreneurial ventures—they needed to generate profits to be viable—yet they incurred costs above and beyond conventional development. For Civano, this additional financial burden stemmed from the need to hold land longer than conventional developments and to reduce the impact of development through augmented land improvements. A member of the development team explained the challenge of containing land holding costs at Civano: “Here are these two small companies, not insanely capitalized, having to bear the interest cost of 800-1100 acres of land…Things were taking longer—tick, tick, tick—we used to call it the interest clock because everybody that worked there was always looking over their shoulders, ‘How much interest have we spent this month and have we really gotten that far along?’ So this just led to enormous financial pressure.” The developers financed the purchase of the land to develop Civano through investors which meant they had to pay interest on those loans. That interest cost was especially high because of the size of the land purchase and the length of time it took to improve the land. Furthermore, low impact development practices like salvaging trees increased improvement costs. A member of the development team summarizes, “Everything just added to the price of the land.” In the case of Civano, the existing mechanism for financing development through investors was insufficient to address the high cost of land improvement over long time horizons with low impact development standards. The developers faced bankruptcy and were forced to sell Civano to Fannie Mae, an entity that did not “buy-in” to the version of sustainable urbanism articulated in the guiding principles. Land holding and improvement costs in the first phase of development undermined the capacity to achieve environmental goals in the second phase of development.

With the financial catastrophes of developments like Civano in mind, Mueller respondents described how the City of Austin developed a creative financing mechanism to reduce land holding costs. The City held the land while Catellus and the homebuilder improved it in pieces, then, when properties were ready for sale, the City transferred the piece of land to Catellus who transferred it to the homebuilder for sale to potential homeowners. The money from the sale of the land, supplemented by property and sales taxes from retail on site, contributed to a reserve of funds that the City used to reimburse Catellus for the cost of land improvements. As one municipal official explained, "because of the way things are structured, we're basically paying them for the use of their money. So we are incentivized and they are incentivized for them not to spend very much money…They're not having holding cost for the land. That saves them money so it saves us money." This financing scheme was only possible, however, because the City owned the land and had a vested interest in the development which provides amenities like parks for all of Austin. It was also possible with the addition of "big box" national retailers like Home Depot and Best Buy to occupy the "cash register use" portion of the development to provide a steady flow of property and sales tax revenues to finance the rest of the development. This decision angered many stakeholders as a member of the development team explains, "folks did not envision big box retail as being consistent with everthing we talked about in terms of this plan: mixed use, pedestrian oriented, kind of local." He goes on to explain the solution:

> *So what we did was we designed it in a way that will allow it to be redeveloped over the life of this project. Instead of just building big expanses of parking lots and just plunking down boxes, we created this grid of driveways that can become streets with sidewalks along them, trees along them, utilities under them. A lot of the time utilities just get put anywhere and it makes it hard to redevelop parking lots, to intensify that use, because you've got utilities going all over the place. So we purposely designed it so that in 20 years, and I really do believe this will happen, in 20 years those sites will start to get redeveloped to higher density use.*

This anticipatory design does allow Mueller to adapt as markets change over time but the decision to use big box retail to help finance the development created trade-offs with other design goals in the near term.

Unlike Mueller, Prairie Crossing was privately owned land, and the developers compensated for the cost of conserving open space through prairie and wetland restoration by capitalizing on the relatively low cost of home construction. The developer was able to add square footage to homes at a nominal cost to increase profit from home sales. However, this approach created a trade-off with the goal of conserving resources. A member of the development team explains: “I think of conservation as conserving energy, conserving resources, and when I think that way I'd say the houses are way too big. However, I know very well that smaller houses couldn't have been built at much less expense because the house had to, the property cost had to include the open land. Somehow, it all has to be paid for.” Operating within the conventional development framework, the developers of Prairie Crossing could finance one goal, conservation of open space, through property sales but this financial model produced a trade-off with another, conservation of resources.

Participants in all three communities conceded that homebuilding costs were relatively low compared to land development costs. The challenge to implementing environmental improvements in homebuilding at Mueller stemmed from the conventional new build sales approach. In conventional new build subdivisions, homebuilders offer basic model homes that can be outfitted with upgraded features at an additional cost to the buyer. Homebuilders at Mueller offered environmental upgrades but some homeowners were reluctant or unable to incur additional costs. One community leader and resident at Mueller wanted solar panels and a flash hot water heater, “but that was expensive so I didn’t. I would have loved to but…no.” The standard upgrade-to-basic-model approach to homebuilding constrained some homeowners from improving homes beyond the energy efficient construction standards required at Mueller. The upgrade problem extended beyond new construction to retrofits; as building standards improved over time the cost burden for updating homes to meet those standards shifted to the homeowner. In the case of Prairie Crossing, the Green Build Home program had progressive energy standards at the time homes were being built in the 1990s but now the standards are commonplace. At Civano, one community leader and homeowner financed “net negative” upgrades—he produces more energy than he consumes—but, he admits, “I didn’t do it because it’s going to save me money in the long run because it’s not. I did it because I had the money and felt that I was obligated.” The cost of upgrades for the homeowner were sometimes cost prohibitive, creating a barrier to both building peak performing homes in new construction and retrofitting existing homes to keep pace with improvements in building performance standards.

Market Conservatism

Another major challenge identified by respondents in all case studies was the conservative mind-set of the development industry. It favored risk reduction through market analysis and appeals to mass markets which created a problem for the relatively risky, niche venture of sustainable urbanism developments. In the case of Civano, planners from the City of Tucson, and the community at large developed an ambitious plan to create a "sustainable community," but attracting a developer and investors proved difficult because the project was considered too risky. A member of the development team described the reaction of potential investors after receiving a pitch about the project, "they'd say, 'that's a fantastic idea, when you're doing number three come talk to us.'" A municipal employee explains the importance of precedents for reducing risk (i.e.: financial loss) by conducting market analysis: "How do we find a developer for something that's basically never been developed? The normal way you do real-estate market analysis is you look at what's happened for the last five years and then you make some inferences based on what's going on now and how your product is different. There was no last five years for this." In the case of Civano, conservative industry standards intended to reduce financial risk in conventional development was an obstacle to securing the financial backing for a project attempting a more innovative, but riskier, approach to development.

Civano and Prairie Crossing circumvented the conventional market analysis process by commissioning market studies of hypothetical developments. The development team at Civano conducted phone surveys with residents of Tucson and asked them if they would like particular environmental features in their community and how much more they would be willing to pay for those features. Survey results indicated that residents of Tucson valued those environmental features enough to pay slightly more for a home in a development that had them. Similarly, the development team at Prairie Crossing conducted a survey to determine if people would like an organic farm in their community and, according to a member of the development team, “people were not at all interested in coming to a community with a farm unless they knew for sure that farm would never, ever, ever become a bunch of more houses.” In both instances these studies became internal barometers that guided development and informed marketing for home sales. They compensated for the fact that there were no existing models of these types of developments that could be used to gauge demand.

Another mechanism for reducing financial risk in conventional development was to appeal to mass markets. Respondents in each case study described a tension in the process between promoting unique features that would appeal to niche markets and mass marketing to a broad base of consumers to generate sales. In Civano, this tension played out as a “control of message” struggle. Civano centralized home sales in a welcome center with a staff trained to speak about the environmental features of the development in order to retain control of message. This process was distinct from conventional development in which the developer relegates control of sales and branding to the homebuilder. Fannie Mae ended centralized sales when they took over the project and several participants pointed out the detrimental effect this had on environmental awareness among residents. As one municipal employee explained, “there were people buying houses in Civano that didn’t even know it was an innovative environmental community with all these features.”

At Mueller, the tension between niche and mass markets played out as a division between “pioneers”—residents that bought into the sustainable urbanism theme before the development was fully established—and residents who simply like the development aesthetics. A municipal official describes this division: “Some people don't understand the big picture. Some people do. Especially our first people that moved in, they totally went there for the vision. They bought houses before there was anything on the ground which was a lot of faith. As it started developing, people start coming in and they aren't there for the vision, they just saw a house they liked.” Despite several educational opportunities such as Homeowners 101 events, informational brochures, and an abundance of signs explaining environmental features and future plans, some residents were ignorant of the guiding principles and plans. One community leader explains how this lack of knowledge led to opposition to design features like urban transit, “A couple residents spoke out against rail which was surprising because that's always been in the plan and if you buy a house here, you would think that your realtor would share with you the vision.”

The tension between niche and mass marketing at Prairie Crossing played out as the tension between a productive farm model and agritourism. Prairie Crossing was developed around a productive farm model in which the organic farm on site would be self sufficient and not subsidized by the rest of the development. In the agritourism model the entertainment value of the farm may supersede productivity and reduce the need for the farm to be profitable on its own. The developers of Prairie Crossing developed a marketing plan in which they funneled the majority of their marketing budget into events that would garner interest in the local news as opposed to paying for advertising. For instance, the developers would sponsor events with wagon rides and a petting zoo to attract potential homebuyers and media coverage. According to a member of the development team these marketing tools veered toward agritourism: “I kept saying this is really agriculture and we're going to set up expectations that this is all cute as opposed to productive. We can be cute and maybe break even. We can be productive and neat and attractive, but probably not cute.” Another marketing device the participant identified as counter to the productive farm model was the inclusion of Community Supported Agriculture (CSA) shares worth $300 to new homebuyers. He explained, “From just a farmer's perspective, you think, ‘I can't give away a CSA share.’ From a developer's perspective it's like, ‘that's the cheapest advertizing I can do. I can't buy four lines in the Chicago Tribune real estate section for $300 for one day.’ While the productive farm model might have appealed to a niche market, agritourism provided a mass marketing mechanisms to attract homeowners in the short run that was not economically viable over the long run. The temporary appeal to mass markets via agritourism was abandoned after the homes were sold and the farm at Prairie Crossing returned to a productive farm model.

Regulatory Landscape

Respondents described a regulatory landscape in which municipal land use regulations, state and federal environmental regulations, and liability laws favored one-time, one-way approaches to planning and environmental management often based on single-issue risk assessment. It is well established among urban planning practitioners that municipal zoning ordinances calling for minimum street widths, building densities, and building setbacks from the street often conflict with the designs standards of sustainable urbanism that call for narrow roads, high building densities, and minimal building setbacks from the street (Duaney et al. 2000). During the course of development at Civano, such conflicts between the master plan and municipal zoning ordinances abounded and development was frequently delayed as the development team fought for zoning overrides. A member of the development team for Civano recalled finally winning a long battle for a zoning override to allow the narrow streets stipulated in the master plan, “He was out going to look at some zoning violation in a trailer park, and as he went in the trailers were getting closer and closer together and he said, ‘as the streets are getting narrower, I'm slowing down. I get it.’ So that was a big battle and we've got trailer parks to thank for that.” Good fortune played a role in the narrow streets battle, but several participants noted that not all design features materialize because of zoning conflicts, despite the development teams’ well-reasoned arguments.

In order to avoid the delays and missed opportunities to implement alternative designs that arose due to zoning conflicts in developments like Civano, Mueller was granted a PUD with limited restrictions on design. In the planning stage, city officials and the development team visited other airport redevelopments. A municipal official describes an important insight they gleaned from Stapleton, an airport redevelopment in Denver, Colorado:

> *Here’s the big thing they told us. They hardwired their zoning. They had to go back almost weekly—a ridiculous number of times—to change their zoning because they hardwired it. So we did just the opposite. The zoning looks crazy if you look at it. There's set backs of zero. The zoning is the kind of very gross level of regulation where it looks like everything is allowed and there are no setbacks. And then you come down and the design guidelines will say for this type of building here's all the regs. And*

then the smallest unit of regulation is we have a lot of restrictive covonents on the individual lots.

While it is well established that zoning is problematic for many conventional and sustainable urban developments, the lesson the development team learned from Stapleton was that re-zoning a PUD according to a master plan was an insufficient strategy to avoid the need to obtain zoning overrides during the implementation phase because zoning is inherently static. Sustainable urban developments like Stapleton and Mueller had long time horizons and new approaches to design and over time required adjustments to the master plan due to unanticipated changes such as an emerging consumer preference for density over the course of development. Shifting design regulation away from municipal zoning regulation to development design guidelines imbedded greater flexibility in the master plan and allowed the design to change over time without depending on cumbersome bureaucratic override process. Obtaining such a flexible PUD required City approval, which was relatively easy in this instance because the City was a partner in the development and had already approved a Traditional Neighborhood (TND) ordinance with many of the same sustainable urbanism goals and approaches to urban design as Mueller. Even with the benefit of a flexible PUD and TND, reconciling the Mueller PUD with existing land use regulations before construction began delayed development two years.

Without the benefit of municipal support, as was the case at Mueller, the development team at Prairie Crossing engaged in issue scoping to overcome a conflict between municipal maximum density regulations and high densities in the master plan. A commuter rail line that lacked a station happened to cut though The Village of Grayslake and Prairie Crossing. The municipality agreed to allow a limited area of high density development at Prairie Crossing in exchange for the construction of two rail stations on site. Although transit was not part of the original master plan, the developer was able to achieve some of the desired density by extending the scope of the development to include transit oriented development (TOD)—mixed use, high density development along rail to encourage the use of alternative transportation. Adopting TOD was a context specific solution and, as one member of the development team conceded, sometimes development outpaced regulatory change, "which was really unfortunate because as a result of the developer agitating, and agitating, and agitating they were allowed but it was too late in many cases for this development."

Intuitively, environmental regulations would work in concert with the goals of sustainable urbanism, however, that was not always the case. At Mueller, State land use regulations required the construction of detention basins to manage stormwater runoff from the site. Developers wanted to turn the largest detention basin into a lake amenity and to use reclaimed water to conserve water. A member of the development team lamented, "Oh, that's a bad story. We're using reclaimed water for all of our irrigation. But our State Commission on Environmental Quality won't let us put that water in this pond. Even though we want to." Texas water quality regulations acted as a barrier to that goal because "not one drop" of non-potable water is allowed to mix with potable water and nearby drinking fountains at the park utilize potable water. State regulations that focus on a single issue—environmental quality—created a trade-off with water conservation goals at Mueller.

State regulations also required detention basins to manage stormwater runoff at Prairie Crossing and, as was the case at Mueller, the development team decided to create a pond amenity. Unlike Mueller, Prairie Crossing is located in a temperate region with high rainfall. The pond is fed by rainfall and water quality is maintained through a "stormwater treatment train" in which swales route stormwater through prairie and wetland grasses to slow runoff and allow it to be absorbed into the soils and filtered before entering the pond. One challenge to maintaining high water quality was winter road snow salting which caused seasonal spikes in salinity. Armed with data from water quality monitoring activities, the development team negotiated a deal with the municipality to reduce the salt content of the mix used on roads in the development and eventually the entire Village of Grayslake. In this instance, environmental regulations extended the goals of the development team and eventual drove management changes to improve water quality in the development and the Village of Grayslake.

All developments must contend with legal liability concerns by assessing risks in order to avoid being sued. Participants from Civano and Mueller indicated that liability concerns conflicted with environmental management. At Civano, individuals that bought homes in Civano after Fannie Mae took control of sales were not informed of the environmental features of the development because, as one municipal official explained, "the lawyers got so nervous. They felt that if you don't tell people they're going to save 50% on their energy bill and they don't see any savings then they're not going to sue us."

At Mueller, the community group, Friends of the Prairie, would manage the restored prairie lands on site by pulling and cutting weeds, however, due to the cost of liability insurance, they were no longer permitted to actively manage the prairie. A community leader explains:

> *This is an obscure area of property law. You'll see like city parks, like friends of city parks and they have clean up day and plant a tree day and stuff like that. Well they're doing that on city property and if someone should cut their foot off with a shovel, the city's not liable. But this property is owned by the POA or Catellus, depending on at what point the transfer is. But it's not public. We allow the public to use it but it's privately owned. So if someone from the FOTP is out there chopping weeds and chops off a foot, then the POA is liable to be sued.*

The Friends of the Prairie revised their management activities by indicating weed location to a management crew by marking them with spray paint, but even that activity, required costly liability insurance.

Partnerships and Public Participation

Establishing public-private partnerships allowed Civano and Mueller to leverage resources of multiple stakeholder groups but also generated tension when their agendas clashed. For the development team of Civano, partnering with the public sector reduced some bureaucratic barriers to development, but introduced political agendas that sometimes clashed with the project. As one developer observed, “One thing that I've learned is, anytime you get a politicized entity as a development partner, problems will happen. They're not entrepreneurial. They have a different mindset. And they have a broader agenda that has nothing to do with the project.” Indeed, Civano received key resources from all scales of government but in each instance, those resources came with trade-offs. In the planning phase, the City offered "inducements" in the form of infrastructure investments, however, some of these never materialized because they got embedded in local political debates. For example, the municipality failed to provide a public park, as a member of the development team remarked, "because there were a lot of people on the bond advisory committee that hated Civano...Why spend money on that when we could build parks on the West side?" Political turnover also contributed to problems implementing environmental design at Civano. General municipal support for the project diminished as "political fatigue" set in and turnover occurred within City Council. A municipal official explains, "You had some core supporters with strong environmental values all through the 90s and the people who took their place didn't share those values." As a result, the new City Council allowed Pulte to develop the second phase with diminished environmental standards.

State support provided land and financial resources to Civano because the development overlapped with political agendas. A member of the development team remembers the state supported creating a solar village to represent Arizona as a leader in alternative energy and to attract federal funds available for state initiatives to reduce energy consumption. But, as one member of the development team recalls, the State was not loyal to the project in Tucson, per se, "An interesting sideline is during our use of the money the state confiscated some of it and we had to fight for it back. They put it in transporation in Phoenix, which of course saves energy, but we already had the money in our budget." The State Land Department also provided land below market rate for the development, which limited the locations available for development. The site selected was located on the periphery of Tucson but within its municipal boundary in an area where the City anticipated future growth. The development site drew criticism from those who argued that the development contributed to urban sprawl and the very auto dominant lifestyle it attempted to circumvent through New Urbanist design.

Finally, the partnership with the federal entity, Fannie Mae, provided the financial resources to save the project from bankruptcy but also led to the eventual corrosion of environmental goals. A municipal official contextualized the rationale behind Fannie Mae's involvement, "At this point, 1996, Clinton is in the White House, looks like Gore is going to run. Gore is the administrations environmental guy. To them it's a way they can capture Gore's attention when he wins: bad bet." Fannie Mae was more interested in the political support than the environmental goals as another municipal official pointed out, "they were paradoxically really scared about New Urbanism and sustainability." Civano was no longer a political asset; it was liability with risky sustainability objectives and Fannie Mae was not a developer so they, "simply wanted to get out of Dodge for many reasons so they looked for a large developer who would purchase the rest of the stuff and they could get out." They eventually sold the project to national developer, Pulte, and negotiated a deal with the City that eliminated many of the original environmental objectives.

Mueller also utilized a public-private partnership model, but the scope of public sector involvement was limited to the municipality. In the early planning stages, the State intended to provide financial resources for the project to build state offices but eventually backed out of the project, to the relief of one municipal official, “they don't have to follow any municipal rules. They said that they would but you just don't know what would have happened.” The uncertain nature of the State’s investment in redeveloping the airport was brought to light when they attempted to keep it open for private air traffic. A community leader commented, “You keep it open and the demographics of who has a private pilots licence is probably in the state legislature quite high but in the neighborhoods very low.” Keeping the airport open served the interests of State legislatures travelling to capital city from all over Texas but the City and the neighborhoods surrounding the airport had a vested interest in Mueller for the social and environmental benefits it would bring to a historically disadvantaged community.

The collaborative effort to keep the airport closed created social networks between City and neighborhood representatives who were able to negotiate when interests conflicted. As a community leader explained, “The project as it exists today is a manifestation of the compromises that were arrived at. Some of which I'm sure are good and some of which are bad. I think any time you have a planning process like that, the interests of the broad view of the city, sometimes do not match up with the interests of the local parties.” For example, the City had an interest in connecting the development through existing roads to promote public access to Mueller as an asset for the entire city, but this strategy conflicted with the local interest in minimizing neighborhood vehicular traffic. The compromise included medians to prevent vehicular traffic from exiting Mueller and entering adjacent neighborhoods and connecting greenbelts with existing neighborhood parks. After the buffers and medians were constructed some neighborhood members lamented the lack of road connectivity, underscoring the difficulties in adjudicating the interests of neighborhood residents, adjacent neighborhoods, and the city's overall goal of promoting access to Mueller. Despite some sub-optimal outcomes, one community leader emphasized the importance of community involvement as a check on the interests of the City to generate revenue and the developer to generate profit, "It's a flagship model and Catellus get's that. If you cannibalize it for the sake of a short term buck, then that's what you're known for…As you face changes, if you're still in communication, then the evolution of the master plan will lean towards the best intentions."

Figure 2: Mueller Site Plan (Prepared for Catellus Development Corporation by McCann Adams Studio, July 2011)

Although Prairie Crossing had no formal partnerships with the City of Grayslake, the development team did negotiate with the City to obtain zoning overrides to increase allowable density, reduce salt content in winter road salting mix, and find a compromise for the alignment of a state road through the community's farm land. Many residents have run for political office at all scales of government including the Grayslake Village board, the House of Representatives, and Federal Courts. As one community leader reflected, "we have a lot of folks here that are interested in community but also in local government." Perhaps these political ties have facilitated some of the local spill-over effects that Prairie Crossing has had on the municipality as he goes on to describe, "We're a little unconventional but [the city] has adopted some progressive ordinance changes because some of the things we're doing, they want to do in other parts of the Village as well: traditional neighborhood design, transit oriented development, a little bit more recycling...so you see a little bit more acceptance in the landscaping."

Institutionalizing Guiding Principles

Each of the three communities institutionalized a set of guiding principles to guide development and ensure consistency over time. The guiding principles of Civano were designed to be converted into quantitative metrics of success. The resulting document, the IMPACT Assessment was adopted as a memorandum of understanding with the City of Tucson. Some principles were not easy to quantify as one community leader explains, "It was a constant conversation, okay; we have these very lofty goals but how do we measure it? And, thinking about something like New Urbanism, well, how do you measure that?" The metrics that eventually were institutionalized through the IMPACT system were the ones that were relatively straight forward to quantify like energy and water use. The City already had an energy code in place which was used as a template for the Civano energy code. The existing energy code was simple to upgrade and attractive to homebuilders because it tied energy reduction to home construction. New Urbanism added a design and orientation component, placing a premium on the spatial arrangement of buildings. Unsurprisingly, Pulte, a developer and production home builder housed in one company, implemented the energy and water reduction goals but abandoned New Urbanism in the second phase of development.

Mueller and Prairie Crossing, in contrast, established broader guiding principles that evolved over the course of development and have been adopted by residents. According to a municipal official the principle of "sustainability" at Mueller originally meant "environmental sustainability." According to a member of the development team, that meaning expanded to "creating neighborhoods and communities that people want to invest in; people want to stay in." He goes on:

> *That's something I'm really proud of in terms of Mueller because it has now gone beyond the developer and beyond the planners. It is really the residents and the property owners that are stewards of this place. And I think part of that is just creating the kind of place where people want to take on that responsibility. And I think that's a big factor of sustainability because you can't sustain something unless you have people who are willing to invest in it and to protect it.*

This vested interest in place and environmental stewardship was manifest in the formation of groups like the Friends of the Prairie whose volunteer efforts contribute to environmental education and landscape management. Similarly, many residents of Prairie Crossing became environmental stewards contributing efforts in activities such as wetland maintenance and prairie burns which a community leader describes as "a communal event…it's sort of a fun, neighborhood community thing to do."

Beyond informal diffusion of the guiding principles, a member of the development team and homeowner at Prairie Crossing also formally monitored the guiding principles through an annual review. She has found that, “most people see all of the guiding principles as important but not equally important” and that finding had been consistent over time. This exercise had the dual purpose of gauging resident sentiment about the guiding principles but also to give them a public presence in meetings and print in order to sustain community awareness and dialogue about those principles over time. She explains, “What I want is for the principles to be in front of people. Especially those who haven't looked at them because they're brand new or because it's just not of interest to them.”

Leadership

Participants highlighted the key role of leadership in the successes of each development, but leaders themselves expressed fatigue from constantly fighting against institutional momentum. This comment from a Mueller community leader exemplifies the importance of leadership, “The takeaway for me is the power of personality. In some ways it comes down to, we were really lucky to have people of that talent and intellect and passion and energy to be involved in it. I don't think you can talk about success if you don't talk about the individuals…It wasn't just generic leaders. It was those people, with those skill sets.” The importance of particular skills in leaders was echoed by a member of the development team at Prairie Crossing who described the lead developer, “I’d say [he is] a practical visionary. He really understands what is to be achieved and accomplished.” Leadership, a member of the development team of Civano warns, is not a silver bullet:

> *One of the problematic things that happened at Civano was that everyone was looking for the enlightened developer, which I was convinced meant, does not care what it costs to do. And the enlightened developer will be the answer for why we don't have kid's playground still, the enlightened developer will do this, oh if we only had the enlightened developer..it's not that easy.*

His comments underscored an important point: developers, like all leaders, operated within the confines of institutional structures and expended a large amount of social capital and physical energy trying to institute change. Many stakeholders in leadership roles expressed a sense of fatigue from advocating, arbitrating, and tapping in to social networks. As a community leader reflected about his time working on Civano, “it really used people up.”

DISCUSSION AND CONCLUSION

> *We're so enamored with growth. We're tempted, we're seduced by lots of money or lots of impact and we want to go a lot faster than perhaps we're capable of and then we set ourselves up for crash because we can't sustain it...we don't have a lot of institutions that reinforce growing in a way that's still human scale but allows us to increasingly deal with complexity and finances and organizational change in a way that is manageable. (Community Leader, Civano)*

This research revealed the challenges in implementing sustainable urbanism while operating within institutional framework that facilitates conventional development. These challenges extend from institutional mismatch between conventional approaches to urban planning and design and those favored by those informed by New Urbanism. Despite these mismatches, innovative designs were implemented through strong leadership, capitalizing on context-specific conditions and windows of opportunity. Other strategies for overcoming challenges included innovative partnerships to leverage the financial, material, political, or social capital of multiple stakeholders; developing internal barometers of success; and exploiting the capabilities of dynamic leaders to overcome institutional hurdles.

Discord between sustainable urbanism and conventional development is likely to persist because the current institutional framework supports large-scale urbanization and lacks mechanisms to account for the undesirable consequences of such development. Specifically, large-scale development is low-cost with broad appeal and requires minimal effort to meet regulatory standards. Contrastingly, sustainable urbanism imposes normative development standards that account for undesirable consequences but at a higher cost for a limited niche market and require greater flexibility than regulatory landscapes typically permit. In this context, the process of implementing sustainable urbanism in developments within the conventions of master planning led to failures. Such failures prompt some scholars to dismiss sustainable urbanism as a viable approach to reversing the undesirable environmental outcomes associated with urbanization.

Dismissing sustainable urbanism entirely, however, overlooks the successes and opportunities for broader change in urban development. This research reveals that, although institutional constraints limit the capacity of developers to implement innovative design alternatives, they also prompt creative, participatory, problem-solving strategies that reflect the complex, dynamic, and uncertain environments into which sustainable urbanism has come to be practiced. Mueller's model of flexible planning and anticipatory design enabled adequate densities, urban rail access, and local retail development. Prairie Crossings' political activism led to changes in winter road management in the community and improved water quality. Civano proved a critical learning experience that would inform future development and the creation of the LEED-ND rating system. Some context dependent solutions have limited potential for replicability in future developments, while others constitute pioneering efforts that change conventions through local and distal spillover effects on policy and development practice.

Planned developments implementing different versions of sustainable urbanism are proliferating globally and future research should continue to frame them as experiments to learn from the successes and understand the failures rather than dismissing them as middle-class enclaves using sustainability as a marketing tool. This research explains these successes and failures, traces them to particular institutional constraints, and reveals strategies for overcoming challenges in practice. Learning from case-studies in sustainable urbanism helps anticipate challenges in future development and contributes valuable information to those who want to innovate in *planning practice*. Bridging planning practice with institutional analysis provides a more complete picture of the barriers that impede sustainable urban development and the mechanisms that local communities have used to reduce the deleterious social and environmental consequences of large-scale urbanization.

Chapter 5

CONCLUSION

Master planned developments implementing versions of sustainable urbanism to address urban environmental challenges proliferated globally as a dominant mechanism of urbanization in the late 20th and early 21st century. These developments captured the attention of supporters and critics alike despite little empirical evidence supporting or repudiating environmental claims. This dissertation drew from multiple knowledge domains bridging the natural and social sciences as well as planning practice to address this paucity of evidence supporting environmental claims. It reveals deep challenges in conceptualizing and measuring the impacts of sustainable urbanism and developing innovative planning practice within the constraints of existing institutions. These challenges are not insurmountable, however, and the findings in this dissertation suggest potential future avenues of research and practice to overcome them.

Understanding the capacity of sustainable urbanism to reverse the negative environmental impacts of large-scale urbanization will require the insights of multiple domains of knowledge, yet conflicts between disciplinary perspectives impede the synthetic process. Within the field of geography, epistemic differences between representative and reductionist approaches sustain a rift between urban and nature-society geographies, relegate systems-based human-environment approaches (i.e. land change science) to the interdisciplinary borderlands, and stymie robust nature-city interactions research capable of measuring the environmental outcomes of sustainable urbanism and the social processes that mediate those outcomes. These observations echo the reflections of the discipline's leadership over the past quarter century in presidential plenary addresses and in the *Annals of the Association of American Geographers*. Scholars from urban and nature-society traditions have pondered geography's disciplinary identity, lamented entrenched rifts between sub-disciplines, attributed those rifts to antagonistic positivist-post positivist divisions, and prescribed pedagogical, structural, and affective changes to the academy (Gober 2000, Hanson 2004, Turner 2004, Baerwald 2010). Fields that conceptualize the city as a complex-adaptive system such as ecosystem services, institutional analysis, and decision-making under uncertainty have bridging potential because they resonate across intellectual domains and reduce epistemological barriers to synthesis.

This research also highlights the tremendously difficult task of measuring the environmental outcomes of urban form. Such measurement is challenging due to the sheer complexity of urban environments in which outcomes are the product of urban design, technologies, and human behavior and the difficulty of disentangling the relative impact of each. For instance, water consumption was much lower in both phases of Civano than in the comparison community due to the addition of non-potable water resources but it is difficult to isolate the effects of urban and landscape design from trends in the use of water efficient home appliances and changing lifestyle choices of residents. Furthermore, there are trade-offs between different environmental outcomes, for example, white roofs provide a cooling effect but cannot replace the habitat role of vegetative cover. Measuring the link between urban design and environmental outcomes is further complicated by access to scale appropriate data. For the quantitative analysis of

Civano, water consumption data was only available at the neighborhood block scale and data on energy consumption was not publicly available at all.

Beyond the measurement issues, creating “good” urban form is a normative venture that can be at odds with hypo-deductive approaches to quantifying urban design and environmental outcomes. Stakeholders from Civano constantly referenced the palpable aesthetic and experiential difference between the first and second phase of development which they attributed to the difference between the New Urbanist approach to design in phase one and the conventional production development in phase two. These less tangible outcomes are difficult or impossible to measure but translate into real differences in environmental awareness, values, and initiative between residents of the two communities.

This study is limited in its capacity to generalize from the findings of three case studies; however, insights about the process of creating sustainable urban communities can be gleaned by linking the findings to existing theory in environmental social sciences literature. Stakeholders from three distinct planning and development contexts identified similar institutional constraints to implementing sustainable urbanism through the master planning process because it tilts momentum toward conventional development and currently lacks mechanisms to account for the undesirable consequences of such development. By looking at sustainable urbanism through the lens of complex adaptive systems, this research reveals that the specific challenges experienced by stakeholders in each of the case study communities coalesce as the broader challenge of institutional mismatch. . Inflexible institutions that offer one-way solutions to environmental problems constrained the capacity to achieve environmental design goals in the case-study communities. For example, the case studies revealed that rigid municipal zoning regulations and a hard-wired master plans limited implementation of environmental design plans and caused cost accruing delays. State regulations—even environmental regulations that intuitively would work in concert with the goals of sustainable urbanism—proved challenging because they emphasized single policy issues and neglected the interconnectivity of the urban systems.

Environmental social scientists have, for example, posited that flexible institutional arrangements, capable of adapting to changing conditions, that have reflexive mechanisms for analytic and social learning can improve environmental management outcomes. Instances of success in overcoming challenges in the case-study communities appear to confirm these hypotheses. Imbedding flexibility in the master plan at Mueller allowed the developers to adapt the plan when an unanticipated change in the market occurred. Some adaptations like increasing residential density were more congruent with sustainable urbanism goals than others like replacing offices with "big box" retail; however, flexible urban design will allow improvements as the market shifts in the future. Mechanisms for learning addressed gaps in understanding about system dynamics and enhanced future decision-making processes, respectively. For example, water quality monitoring activities at Prairie Crossing revealed seasonal fluctuations in salinity from winter road salting that allowed the community, and eventually the municipality, to improve environmental management activities.

In the years since these case-studies were developed, the 2008 downturn led to a decline in development of all kinds in North America, including sustainable urban communities. This economic climate has been both liberating and limiting for the sustainable urbanism agenda in the United States. The recent turnaround has favored tactical urbanism—small-scale, incremental, and sometimes temporary interventions intended to proliferate through idea sharing via social media—that has emerged as citizens, municipal planning departments, and developers accept limited financial resources and work outside the constraints of conventional development to make investments in local communities (Lydon 2012). The master planning process prematurely generates "climax condition" urban infrastructure while skipping the evolution of place that occurs over years of planning, development, and re-development in urban areas (CNU 2013). Tactical urbanism and other, more incremental approaches may more closely match this evolution of urban form over time that occurred in the examples of good urban form in the older cities that inspired sustainable urbanism. This lot-by-lot approach may also be limiting because the long-term benefits of incremental investments in urban infrastructure may be slow to materialize. Furthermore, some social goals (e.g.: multi-modal transportation connectivity) and environmental benefits (e.g.: those with scale-dependent ecological thresholds) depend on the functioning of the entire urban complex and may require system-wide investments. Finally, chronically over-budget master-planned developments built prior to the recession have provoked innovation and reflection in the sustainable urbanism community. Movements like tactical urbanism are partly a by-product of a regulatory landscape in which rigid land development codes—including overly dogmatic deployment of those promoted by sustainable urbanism—created bureaucratic hurdles and drove the cost of development upward. New Urbanist leader, Andres Duany, explains “We made codes glamorous. But we forgot to say the original codes were simple, were lean. They got fatter. Nobody can afford to (redevelop spaces) anymore. You can’t get a permit. The public-private partnership is a patch. We need to go back to the simplicity” (Lefkowitz 2013). He advocates “lean urbanism” that scales back the pace and size of development while also softening the regulatory landscape.

Despite the changing landscape of sustainable urbanism implementation approaches, there are ample opportunities to continue to learn from existing experiments in sustainable urbanism, master planned and otherwise. Future research can continue to link sustainable urbanism planning processes to social scientist’s insights on institutions, especially emerging research on social innovation in the private sector. This line of inquiry contends that the private sector has a high capacity to innovate but lacks incentives to innovate sustainably and seeks to understand the conditions and processes that could shift incentive structures (Westley et al. 2011). Several of Duaney’s observations about sustainable urbanism are congruent with findings in the innovations research stream. Duaney argues that strict codes have failed and advocates for so called ‘pink codes’ that have greater flexibility, which is congruent with the argument that “setting the conditions works better than setting down rules” in top-down approaches to fostering innovation (Westley et al. 2011; 769). Bottom-up approaches like tactical urbanism complement top-down mechanisms for fostering innovation because they reside in contexts that encourage experimentation that can be given broader impact and durability through connections with more resource rich institutions like the Congress for New Urbanism (Westley et al. 2011, CNU 2013). Top-down and bottom-up approaches are connected by clusters of "institutional entrepreneurs"—individuals that broker relationships between unlikely partners—that create "shadow networks" working to develop alternative, "niche regimes" capable of replacing dominant institutional regimes under the right conditions. Sustainable urbanism approaches to urbanization may be coalescing as one such niche regime alternative to the conventional planning and development process.

Sustainable urban master planned developments are maturing and are ripe case-studies for inquiry in empirical fields interested urban systems. Geography and cognate disciplines have the theoretical and methodological tools to mine these case-studies. The lines of inquiry introduced in this study—chronicling environmental performance and development processes through the lens of complex adaptive systems thinking—can aid urban planners that are keen to, as one stakeholder articulated, "transform the industry."

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