The Environmental Impacts of Urban Sprawl: Integrating New Evidence and Emergent Issues

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Abstract:

In this article, we review articles published in planning journals since 2001 that focus on the environmental impacts of sprawl and assess the extent to which this research addresses what we see as two of the most important meta-challenges for environmental planning and management in the coming decade—resilience and justice. Our review organizes the sprawl’s impacts by four elements – earth, air, water and fire – and by developed and developing country contexts. Our assessment looks for reference to meta-challenges and consideration of multiple issues, elements or contexts. We find evidence that the sprawl-related research from last decade often engages the meta-challenges of resilience and justice, the array of environmental outcomes being considered within individual sprawl studies is expanding, and distinctions between studies from developed and developing countries are increasingly difficult to detect.

Keywords: sprawl, environmental planning, resilience, justice
1. Introduction

In this article, we review articles published in planning journals since 2001 that focus on the environmental impacts of sprawl and assess the extent to which this research addresses what we see as two of the most important meta-challenges for environmental planning and management in the coming decade—resilience and justice. For our purposes, *resilience* is understood as the overall ability of a system “…to absorb change and disturbance and still maintain the same relationships between populations or state variables” (Holling, 1973, p. 14) and *justice* refers to conditions where responsibility and opportunity is fairly distributed across groups and individuals. Several considerations prompted and informed this review and synthesis. In the past, sprawl research been characterized by a relatively narrow and fragmented approach, both in terms of the outcomes considered as well as in the geographic areas studied. This approach is reflected in prior review articles summarizing the empirical work on one of the many dimensions of urban sprawl, like Ewing and Dumbaugh’s 2009 review linking the built environment characteristics with traffic safety. While useful, these highly focused empirical studies and the specialized literature reviews they engendered, provide a limited understanding of issues that transcend disciplinary and geographical foci such as the challenges of climate change or the equity impacts of globalization.

Deepening inequality and climate change impacts are two specific issues that have gained increasing attention from both policymakers and the public, and the way that development takes place in and around urban areas figures prominently in these debates. Therefore, it is useful to understand whether and how the broader meta-challenges of
resilience and justice are reflected in the way sprawl research is designed, conducted, and presented over the last decade. Further, a variety of policy measures are being tested that call upon planners to identify and implement solutions for these and other emerging issues. For example, one of the key policy priorities of U.S. Housing and Urban Development Authority’s recent Sustainable Communities Initiative is to foster regional coordination and enable programs that are resilient in difficult economic times and promote policies that overcome discrimination and exclusion (Been et al., 2010). In order to successfully respond to the twin meta-challenges of resilience and justice, it is important to recognize the connections between research findings, encourage work that bridges disciplinary silos, and moves beyond the familiar developing-developed country dichotomy. We focus on sprawl because it is a critical and widely studied aspect of urban development and also because the recent sprawl literature demonstrates progress towards this goal.

The remainder of this article proceeds as follows. We begin by situating this review within the context of the broader sprawl literature. We then organize the recent literature according to four elements or areas of environmental impact, and for each element we provide a summary of important themes that emerged during the review process. Given the variation in study areas, we separate studies that focus on developed and developing countries within each element and contrast findings both within and between contexts. Next, we analyze these studies to determine the extent to which the meta-challenges of resilience and justice are reflected in the evolving sprawl discourse. We conclude by identifying the lessons learned, critical gaps, and key questions for future research.

2. Moving Past the Conventional Sprawl Debate
The Winter 1997 issue of the *Journal of the American Planning Association* highlighted a pair of articles (Ewing, 1997; Gordon and Richardson, 1997) that distilled prior discussion of urban sprawl and helped to frame subsequent debate surrounding the issue. In addition to the fundamental question of whether sprawling development was harmful or largely benign, three additional questions dominated much of the sprawl debate during the 1990s: (1) how to best define and measure sprawl, (2) what are the fundamental causes of sprawl, and (3) which policies are most effective for combating sprawl. In a frequently-cited article, Johnson (2001) provided an overview of the most salient environmental impacts of sprawl at the time but in the intervening decade, much has changed. For example, climate change and inequality have emerged as some of the most critical and commonly discussed challenges for both environmental planning and management. In order to facilitate a systematic and balanced review of the literature published over the past decade, we adopt a simple typology consisting of the four basic elements. These elements—earth, air, water, and fire—serve as an organizing principle for the substantive focus of the literature reviewed. This typology is complemented by the two meta-challenges of *resilience* and *justice* that are used as lenses for further evaluating shifts in the way that sprawl research is designed, conducted, and presented.

For the earth element, we focus on empirical studies that primarily examine the impacts of sprawl on farmland, sensitive areas, and open space (Kline and Austin, 2004; Lichtenberg and Ding, 2008), but also connect with broader questions of vulnerability, food security, and rural character. In the air element, we consider research linking development patterns to local air quality outcomes (Atash, 2007; Stone Jr., 2008; Wilby,
2008; Schweitzer and Zhou, 2010) as well as greenhouse gas emissions (Andrews, 2008a) as a related, but farther-reaching issue. Articles highlighted under the water element are primarily concerned with drinking water supplies (Page, 2001; Khatri and Vairavamoorthy, 2008; Lee and Schwab, 2005) both as a critical resource for sustaining human settlements and as a strategic concern in planning for resilience in an altered-climate future, but more familiar issues like runoff and flooding are also addressed. Finally, in the fire element, we focus largely on the research linking urban form and energy consumption. This strand of literature generally proceeds from the compact city debate (Neuman, 2005; Ewing and Rong, 2008; Randolph, 2008), and in most cases has been localized in scope from the broader discussions of energy security and climate change impacts (Andrews, 2008b; Brown and Southworth, 2008; Dhakal 2009; Permana et al., 2008; Zahran et al., 2008). Figure 1 provides a frequency distribution of the articles reviewed across the environmental elements and geographical contexts.

3. An Elemental Look at the Recent Sprawl Literature

3.1 The Earth Element

The conventional sprawl debate focused heavily on the consumption and fragmentation of farmland, open space, and land resources in general. Our review of the recent sprawl literature identified 14 articles from the developed countries versus 5 from developing countries that align with the earth element of the typology. The research from the former focuses heavily on the European Union (van der Valk, 2002; Garcia and Riera, 2003; Paül and Tonts, 2005; Dumas et al., 2009; Zasada et al., 2010; Vimal et al., 2012)
and relies primarily on remote sensing and statistical analysis to document and analyze the impact of sprawling development on farmland, open space, and habitat (Robinson et al., 2005; Dumas et al., 2009). Although most articles conclude with a call for more proactive growth management policies, Pauleit et al. (2005) question the assumption that the negative environmental consequences of sprawl are worse than the impacts of compact development. The authors use remotely sensed imagery coupled with quantitative models to test this assertion in England and conclude that urban infill results in a decline in environmental performance measures such as increased surface temperatures and run-off, and decreased biodiversity.

van der Valk (2002) focuses on the use of dwindling and increasingly fragmented land resources in The Netherlands. He suggests that solving the land use challenges will involve thinking more broadly and implementing a new planning paradigm that simultaneously increases bio-diversity and preserves open space, while allowing for water retention and energy production. The question of how to use scarce land more efficiently is echoed in Frenkel’s (2004) study of growth management policies in Israel. Using a combination of scenario planning and quantitative models Frenkel demonstrates that focused growth management policies can be more effective than current policies in preserving open space and farmlands. Maruani and Amit-Cohen (2010) focus specifically on Tel Aviv and also argue that large amount of public land ownership in Israel (93 percent) is ideally suited for strong environmental protection policies through land management regulations.
We were able to identify relatively fewer articles relevant to the earth element from developing country contexts. Two articles (Xu, 2004; Xi et al., 2012) focus on outward growth from established cities as a threat to farmland along the fringe and both pinpoint a lack of planning in the rural areas of China as a key contributor to this issue and obstacle to overcoming the problem. Fazal (2001) argues that a lack of planning has contributed to similar patterns of prime farmland loss around Saharanpur City in northern India. But rather than simply calling for tighter growth controls, the author argues that inventories and maps of land productivity should be made and used to strategically channel outward expansion of cities onto less fertile parcels. Sarvestani et al. (2011) use remotely sensed imagery and GIS to quantify and map the spatial dispersion of Shiraz, Iran from 1976 to 2005. Overall, the earth element literature from both developed and developing countries are comparable in their methodologies with remote sensing and GIS tending to play a prominent role (Paül and Tonts, 2005; Robinson et al., 2005; Pauleit et al., 2005; Huang et al., 2009; Dumas et al., 2008; Vimal et al., 2012; Fazal, 2001; Sarvestani et al., 2011; Xi et al., 2012).

3.2 The Air Element

Many of the studies from developed countries that address the air element focus on the relationship between transportation and greenhouse gas emissions within the broader context of global climate change. In addition, these studies are typically conducted in either the United States (Stone Jr. et al. 2007; Lee and French, 2009; Barbour and Deakin, 2012) or the European Union (De Ridder et al., 2008; Bart, 2010; Lehmann, 2012). These articles focus heavily on the role of public policy as both a contributor and possible
solution to air quality and greenhouse gas emissions issues. For example, Barbour and Deakin (2012) evaluate the effectiveness of California’s Senate Bill 375, which takes a demand-side approach to reducing vehicle miles traveled. The authors find that the legislation has no teeth, the reduction targets do not account for anticipated population growth, and are widely viewed as politically, economically, and socially costly at the local level. Power (2001) concludes that in order to truly curb sprawl in England and Wales its true costs must be recognized and felt by everyone and public investment must be shifted to recovery in urban areas. Similarly, Bart (2010) holds that the EU can best curb sprawl and control emissions from transport by focusing on land use rather than transport policy. Their findings support requiring access to transit, higher density developments, urban growth boundaries, and supporting climate change action plans and emissions trading.

Tiwari et al. (2011) examine the relationship between land use, transportation, and greenhouse gas emissions in Perth, Australia and like Stone Jr. et al. (2007), rely on scenario analysis. Specifically, the authors develop three scenarios—business as usual, bus-based, and light-rail based—to argue for a “carrots and sticks” implementation approach for achieving a more sustainable outcome not only in Bentley Technology Precinct, where the study was focused, but also in Perth and beyond. De Ridder et al. (2008) considers these issues in a predominantly industrial context by investigating urban sprawl’s effect on air quality in the Ruhr area of Germany, which is an urban agglomeration composed of several interconnected cities. The authors conclude that while urban sprawl has a relatively minor impact on the overall exposure of residents in a region like the Ruhr to air pollution, those living in more suburban areas are far less impacted than those living in denser, central city
locations. This supports the view that sprawl is an environmental justice issue in some instances where those who have the ability to move out of the city are exposed to less health hazards.

Several articles use the urban heat island effect as a critical link between transport, emissions, density, air quality and climate change. Song (2005) examines the urban heat island effect in Bundang, South Korea which is one of several new towns in the greater Seoul region. The study specifically focuses on comparing relative changes in surface temperature over Bundang’s development (1989–1996) as well as understanding temperature distribution throughout the surrounding region. By analyzing a time series of satellite imagery and modeling surface temperatures with regression techniques, the author concludes that the area is indeed experiencing a heat island effect that exacerbates air pollution and climate change concerns. Lee and French (2009) estimate growth rates for the Atlanta region from 2000 to 2030 and discuss the implications of these calculations for air quality (ground ozone) and energy consumption (demand for interior cooling) in the context of the urban heat island effect. Stone et al. (2010) find a positive correlation between sprawl and extreme heat events between 1956 and 2005, which suggests yet another important connection linking urban form and environmental outcomes.

In the developing country context China is particularly well-represented (Pucher et al., 2007; Zhao et al., 2010; Zhao and Lu, 2011; Lehmann, 2012) with climate change dominating as a motivating factor and framing principle for many of the studies addressing the air element. Pucher et al. (2007) focus on trends in transportation policies and their implications of greenhouse gas emissions in China and India as two of the most populous
developing countries. Sprawling areas in China are generally characterized by higher densities than typical North American suburbs and the planning of these areas is closely coordinated with the provision of basic public infrastructure. In India, sprawl is attributed in large part to government policies aimed at decongesting city centers, yet the overall result is unplanned, poorly connected residential areas. Household travel surveys reveal a higher non-motorized trip share in China than in India, greater public transport shares in cities with rapid population growth, and a significant increases in private motorized vehicle travel in both countries. Transport-related air pollution is a major concern the larger cities such as Beijing and Delhi and sprawl contributes to the problem by increasing average travel time and traffic congestion. The urban poor are disproportionately affected by the social and environmental impacts of the transport system’s weaknesses because they are forced to live on the urban periphery where rising motor vehicle use triggers greater traffic dangers, noise, and air pollution and is clearly relevant to the justice meta-challenge. The authors recommend that both China and India implement policies that remove current incentives encouraging automobile dependence in order to mitigate its social and environmental consequences. Roy (2009) argues that national climate change policies tend to focus on adaptation, but neglecting mitigation is a potentially costly oversight. While Roy (2009) considers several rapidly growing regions in East Asia, the primary focus is Dhaka, Bangladesh where a built-out urban core and increasing population has forced new development into adjacent floodplains. The author argues that developing cities are clearly among the most vulnerable to climate change, and therefore must consider land
conservation and hazard prone areas when planning for future development, which is another example of how the recent sprawl research is engaging the *justice* meta-challenge.

The African continent is also represented in this set of articles with Barredo and Demicheli (2003) simulating the growth of Lagos, Nigeria from 2000 to 2020 using a dynamic spatial model and Sietchiping et al. (2012) comparing trends in transportation across Sub-Saharan African cities. Both articles identify important factors that differentiate planning practice in developing and developed countries. In the former article, the authors note that planning for sustainability in a developing country differs from the environmentally-centered efforts most commonly seen in developed countries with the survival of the urban poor often taking precedence. This observation perhaps suggests that the *justice* meta-challenge is more central to planning efforts in cities of the developing world. The authors also argue that since cities are complex, complicated places where unforeseeable events often occur, simulations such as those performed for Lagos should be treated as hypotheses and tools that can guide planners to urban and regional strategies to mitigate the effects of rapid population growth.

Sietchiping et al. (2012) contend that unlike planners in most developed cities, planning authorities in sub-Saharan cities do not recognize cycling as a legitimate activity in transportation discussions. They draw upon prior studies that show the role of cycling and pedestrian transport in reducing urban emissions and carbon footprints, and suggest that sub-Saharan cities should adopt policies that integrate multiple modes through upgrading infrastructure and advocating for and enforcing progressive legislation. They
also stress the need to provide adequate transport for the urban poor and vulnerable groups such as women, another example of a clear connection to the justice meta-challenge.

Although the context for the sprawl research conducted in developing countries for the air element is heavily influenced by climate change concerns, the recommendations offered draw heavily upon the Smart Growth canon of encouraging more compact development (Lehmann; 2012), investing in transit (Zhao and Lu, 2011; Sietchiping et al., 2012), balancing jobs with housing (Zhao et al., 2010), and ensuring that the true costs of development are passed on to the direct consumers (Pucher et al., 2007). This pattern of similarity in responses to sprawl is evidence of convergence across geographic contexts that transcends the familiar developed-developing country dichotomy.

3.3 The Water Element

Articles from developed countries that address the water element are overwhelmingly drawn from the United States (Berke et al., 2003; Tang et al., 2005; Davis et al., 2010; House-Peters and Chang, 2011; Rayne and Bradbury, 2011; Brody et al., 2011) and European Union (Domene and Saurí, 2006; Hasse and Nuis, 2007; Poelmans et al., 2010), but exhibit greater diversity of substance than the air or earth elements. Several studies are more general and consider watershed health (Berke et al., 2003) or the urban water balance (Hasse and Nuis, 2007; Poelmans et al., 2010), while others focus specifically on stormwater runoff (Pauleit et al., 2005; Tang et al., 2005; Davis et al., 2010), potable water supply (Rayne and Bradbury, 2011), flooding (Brody et al., 2011), or household consumption patterns (House-Peters and Chang, 2011). The hydrologic impacts of sprawl are well-documented with impervious surface coverage as the critical link
between this development pattern and the familiar consequences of increased volume, rate, and pollutant content of storm water leaving a site. Beyond these established relationships, several insights from the recent sprawl literature warrant mention here.

Rayne and Bradbury (2011) examine the effects of residential subdivision development on groundwater resources in southeastern Wisconsin where suburban developments often rely on domestic wells. The study provides ways to estimate impacts and identify mitigation strategies using groundwater flow modeling. It found that development lot size, spread of subdivisions and soil type, all play significant roles. For example, when larger lots (commonly, 1.2 hectares) are built over an entire township with clayey soils, recharge rates tend to be lower causing greater impact of withdrawing water.

In another study, using linear extrapolation of changes in satellite imagery in the Flanders-Brussels region of Belgium, Poelmans et al. (2010) forecast future development patterns and then apply a hydrologic model. The authors found that the spatial extent of urban expansion has a much higher negative hydrological impact that the type of urban expansion, and impacts are much greater on surface runoff than on evapotranspiration and groundwater recharge.

In the developing country context, the research most relevant to the water element frames the issues in a slightly different way. The loss of wetlands and the ecological services they provide is a prominent theme in three of the six publications reviewed (Kamini et al., 2006; Taylor, 2008; Zhou et al., 2011), while water quality (Bosselmann et al., 2010), water supply (Küçükmehmetoğlu and Geymen, 2009), and general watershed health (Wang et al., 2011) are also represented. China and India again dominate, with five
of the six articles focusing on study areas from these countries. The lone exception focuses on Istanbul, Turkey which ranks among the most dense cities in the world and whose geography and size make water accessibility particularly challenging.

Küçükmehmetoğlu and Geymen (2009) document the water resource basins available to meet the Istanbul’s demand, noting that with an average population growth rate of 4.5 percent and intense growth pressure to expand outward from the crowded core, water resources are severely constrained. Using satellite imagery and GIS to document and monitor land use changes, the authors found that leap-frog, low-density development has increased in recent decades due in large part to capital improvement projects designed to improve accessibility to the city core. In order to prevent further encroachment and loss of the city’s water resources, the authors advocate more focused zoning, public education and awareness campaigns, more diligent enforcement of existing regulations, building the technical capacity of government and public officials to monitor growth changes, and enacting further preventative measures through the legal system.

The impact of urban development on the physical characteristics of river networks is a recurring theme among the developing country articles. Wang et al. (2011) use GIS to examine the relationship between urbanization and watershed health near the city of Lijiang in southwest China. The density and length of the river system decreased significantly between 1995 and 2009 due to branch reduction and alterations that accompanied rapid development. The authors anticipate that the rate of urbanization in the watershed will lessen in the coming years, but also expect some degree of urban expansion to continue and offer specific recommendations like constructing natural rainwater
collection fields and embankments to maintain a basic level of ecosystem functions and ecological services. Similarly, Zhou et al. (2011) focus on Shenzhen in China’s Guangdong Province, which is located near the coast and has experienced rapid urbanization since the mid-1980s due to market reforms and globalization. The authors explore the temporal and spatial urban land change through remote sensing and GIS and detect river network alterations using hydrologic modeling, topographic maps, field surveys, and aeromagnetic and aerial photography. In order to restore river ecological services, the authors suggest that local and provincial governments pay close attention to both technical (e.g., stream restoration, floodplain mapping) and institutional innovations (e.g., land use controls) in river system restoration. Kamini et al. (2006) use GIS and remotely sensed imagery to study the relationship between land use/land cover change, wetlands loss, and flooding in the Mithi River catchment near Mumbai, India. Although the authors never use the term “sprawl” their focus on impervious surface coverage has clear relevance for this section. They find that rapid urbanization has decreased the overall length of the river, constricted the river course, and combined drainage and sewerage systems while increasing impervious surface cover, which contributes directly to flooding in Mumbai.

3.4 The Fire Element

The air and fire elements are closely linked in many of the articles considered as a result of the emergence of climate change as a key challenge for cities, and by extension environmental planners. The relevant sprawl literature from developed countries approaches energy consumption, whether for transport or residential purposes, as a
phenomenon to be better understood through surveys and analysis or as a nuisance to be
curbed in order to mitigate climate change. A few of the studies highlight the conflicts in
meeting adaptation and mitigation goals. For example, Hamin and Gurran (2009) use case
studies to examine the relationship between energy consumption, public policy, and
climate change mitigation and adaptation, and determine whether the two classes of
climate change responses could complement one another. Byron Shire and Port Stephens
in Australia’s New South Wales are offered as two examples where the implementation of
adaptation and mitigation strategies can potentially conflict. They argue that this is because
mitigation strategies typically advocate heightened densities and adaptation strategies often
recommend open spaces for better stormwater management. To avoid such conflicts
planners are urged to think more critically about such conflicts using, for example, a ‘green
infrastructure corridor’ approach to open space planning integrated into compact urban
form as opposed to creating large, disconnected parks. Saavedra and Budd (2009) come to
a different conclusion using King County, Washington as a case study and argue that
climate adaptation and mitigation strategies do not conflict, but rather are complementary.
The plan mandates county departments to show progress in a variety of areas including the
reduction of greenhouse gas emissions, and leverages growth management tactics to rein in
sprawling development. We, however, find King County unique in that its primary source
of electricity is hydropower (eliminating the need for rethinking electricity generation) and
because the majority of its greenhouse gas emissions are from transportation and methane
gas released by landfills and wastewater treatment plants.
While a full accounting\(^2\) is beyond the scope of this article, several studies (Mindali et al. 2004; Shim et al., 2006; van de Coevering and Schwanen, 2006) have provided additional evidence to support Newman and Kenworthy’s (1989) findings that more compact urban form is also more energy efficient from a transportation perspective. Holden and Norland (2005) conduct a household survey of eight regions of Oslo, Norway and model residential energy use for heating and travel. The authors find significant relationships whereby larger and older residences consume more energy. There was also evidence of a density effect with lower consumption observed in more densely developed areas. Based on these findings, the authors then argue for more compact urban form as a means of improving energy efficiency and moving toward more sustainable patterns of development. Behan et al. (2008) use an integrated land use and transportation model to simulate the effect of increased density and other Smart Growth techniques on reducing energy consumption and vehicle-generated emissions in Hamilton, Ontario, Canada.

Many of these studies also reflect a new trend that considers not just transportation-related but also residential energy consumption. According to Ewing and Rong (2008) there are three primary mechanisms through which urban form influence residential energy consumption. The first centers on distribution losses that occur as a result of transmitting energy from generation sites to residences. These losses should be higher when the development pattern is more decentralized, but the magnitude of this effect is “likely to be small, because electric transmission and distribution losses account for less than 7 percent of the total electricity generated in the United States” (p. 7). The remaining two mechanisms represent indirect relationships and center on: (1) the urban heat island effect
contributing to higher temperatures and stimulating greater energy demand and (2) the size (i.e., increased area to heat and cool) and type of housing stock (i.e., compact urban form implies smaller housing units). The authors conclude that facilitating compact urban form and encouraging smaller, attached housing types will reduce energy consumption in both the transportation and residential sectors. This reasoning has drawn criticism and Randolph (2008) argues that land use is not an appropriate lever to influence energy consumption and the focus should instead be on improving the energy efficiency of residences. Brown and Southworth (2008) offer a more centrist perspective and recommend a variety of strategies to be used in tandem that emphasize compact urban form, energy efficient building practices, financial incentives for energy producers and consumers, and public outreach.

Perhaps more than any of the other elements, the fire element articles from the developed and developing countries are similar in terms of both substantive focus and methods. Zhao and Lu (2011) examine development patterns and implications of demographic and energy consumption trends for greenhouse gas emissions in Beijing, China. The city itself is largely built-out, so its growing population has little choice but to move further out. The authors see increased vehicle miles traveled and rising petroleum usage in China’s transport sector as key challenges facing the city in the coming decades. Household interviews used to collect information on commuting practices and preferences echo patterns from the west—namely that households with the financial means or opportunity to drive are much more likely to do so than to take transit. While investing in high-quality public transportation systems benefits the low-income and female populations
who are more likely to take transit, the market forces, decentralization of government, and globalization factors that have led to sprawling development continue to dominate.

Using data collected from four central municipalities as well as 26 provincial capitals, Liu et al. (2012) measured indicators of urban form (form ratio, compactness ratio, elongation ratio, and urban population density) and indicators of urban eco-efficiency (total water consumption, total electricity consumption, total food consumption, and total cultivated land) in the different locations. Their statistical analysis suggests that city compactness may contribute to eco and resource efficiency while outward urbanized expansion undermines eco-efficiency. However, the authors also note that pollution concentrations also tend to increase with density and therefore caution urban planners to balance city compactness with limits to population density.

In summary, the research reviewed here focuses more heavily on study areas within developed country contexts. Of the 56 studies reviewed, 24 (43 percent) were conducted at the local level, 24 (43 percent) at the regional level, and the remaining 8 at the state, national, or global levels. The distribution across elements is relatively balanced with approximately 20 articles reviewed for each, with the exception of the fire element where a total of 13 articles were identified. This discrepancy could be due to the recent resurgence of interest in energy consumption by urban planning researchers, while the relative parity of fire element articles from developed and developing countries attests to the intensity of that interest.

4. Meta-Challenges and the Recent Sprawl Literature
In this section, we analyze the literature presented above to determine whether and how the evolution of sprawl research is transcending barriers and addressing the meta-challenges of *resilience* and *justice*. We first characterize each of these meta-challenges to establish its connection with the impacts of sprawl, then explore trends in the articles discussed above within that context. For evidence of convergence across geographies or a wider approach to studying environmental outcomes, we discuss articles that compare across developed and developing contexts or address multiple elements. We also consider whether the authors explicitly situate their research within the broader framework of one the meta-challenges as further evidence of new directions in the sprawl literature. Table 1 provides a summary of our findings.

4.1 Resilience

Resilience, as commonly used today, has its origins in ecology and was defined nearly four decades ago as “the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships among populations or state variables” (Holling, 1973, p. 14). Within an urban planning context, the term resilience was closely associated with natural hazards mitigation for many years (Olshansky and Kartez, 1998; Mileti, 1999) and a community’s ability to function and recover following a disaster. This focus has now expanded to include responses to climate change impacts and the broader shifts in conditions (economic, energy prices, etc.) that are critical to the functioning of urban systems. The application of the notion of resilience can also be seen

[Insert Table 1 About Here]
more generally in scenario planning or other techniques that explicitly acknowledge the uncertainty inherent in planning for the future (robust decision making).

Pickett et al. (2004) argue that resilient cities is an “integrative metaphor” that helps to galvanize thinking much in the same way City Beautiful or Garden City visions shaped and guided planning practice in the past. Resilient physical, social, economic, and environmental systems are characterized by redundancy, diversity, efficiency, autonomy, strength, interdependence, adaptability, and collaboration (Godschalk, 2003). We take this idea of resilience as an “integrative metaphor” for understanding how environmental outcomes are treated in the recent sprawl literature.

Eleven of the 56 papers we reviewed address resilience directly or indirectly and to varying degrees. Seven of those articles are from the developed country context, while the other four are from the developing country context. We also find some of them referring to the traditional meaning of the term resilience, while others are using it as more broadly. In the developed country context, Saavedra and Budd (2009) is firmly situated within the climate change conversation and specifically mentions “building resilient communities” (p. 250) as well as equity issues surrounding global climate change (p. 251). This article is a good example of the emerging narrative of addressing meta-challenges in relation to sprawl impacts. Stone Jr. et al (2010) also talk about vulnerability to climate change impacts and the focus on extreme heat events provides a connection to health outcomes. This article is one of a relative few that use the term “resilience” (p. 1427) and is also broader than their previous work (Stone Jr. et al., 2007) which focuses only on the air element and is not situated within the context of climate change. This is most likely
because the pollutants modeled are indirect greenhouse gases (VOCs, NOx, carbon monoxide). House-Peters and Chang (2011) is another example of how recent sprawl research uses connections with global climate change to approach the resilience meta-challenge. Their article considers two of the four elements with respect to sprawling development patterns, linking land use change to water and energy consumption outcomes under different climate change scenarios for the city of Hillsboro, Oregon.

For the other developed country articles, connections to the resilience meta-challenge tend to be less direct. For example, Poelmans et al. (2010) is potentially relevant to resilience if maintaining adequate water supply falls under its umbrella, but the authors are vague as to how their work is connected to shortages and planning for sustainable water supply. Similarly, Domene and Saurí (2006) is relevant if we expand the understanding of the resilience meta-challenge to include water availability more generally and the same is true for Zasada et al. (2010) and Küçükmehmetoğlu and Geymen (2009).

In the case of developing country studies, these connections are less common. Fazal (2001) focuses on the loss of farmland in India and talks about the long-term implications for maintaining agricultural productivity and by extension food supply, but never uses the terms “sustainability” or “resilience”. Xu (2004) focuses on food security in China in the wake of development of the countryside and the general lack of rural planning. However, this article fits well with an expanded understanding of resilience that includes food security in much the same way that the water supply studies mentioned above could be interpreted.

4.2 Justice
The *justice* meta-challenge is rooted in the movements of the past that sought to demonstrate the negative and inequitable distribution of resources, opportunities and power, and higher vulnerability to future uncertainties (Bullard, 2007). These articulations are consistent with the postmodernist, post-colonial and feminist critiques of planning that seek to undo past harms (Lindblom, 1959; Jacobs, 1961; Friedman, 1987), as well as the principles embodied in the advocacy planning framework (Davidoff, 1965). More recently, Fainstein (2010) identifies democracy (participatory governance), diversity (physical and social heterogeneity), and equity (appropriately redistributive public policy) as the three fundamental dimensions of *justice* and argues that a key challenge for planners is to navigate the inherent tensions between these imperatives. We view *justice* as an equally relevant and compelling lens with which to view the recent sprawl literature and as a way to identify patterns and new directions in this strand of the literature.

Ten of the articles we reviewed address *justice* directly or indirectly and unlike the *resilience* meta-challenge, a greater share of these articles focus on developing countries. For example, Xi et al. (2012) is related to *justice* in that it assesses the potential conflicts between China’s Building a New Countryside initiative with farmland protection and the impacts on the ability of poor farmers to support themselves. Similarly, Küçükmehmetoğlu and Geymen (2009) focus on water resources for Istanbul and present an ongoing issue with illegal squatting on land near the city’s surface water reservoirs. They argue that the government has failed to enforce existing regulations to protect water supply basins and also to “direct the transition from an agrarian rural society to an industrialized one” which has driven the growth of illegal settlements within the city. Sietchiping et al. (2012) is also
relevant to the *justice* meta-challenge because it explicitly talks about income and gender as important factors in understanding travel behavior and as a legitimate compass for transportation investment and policy. Bosselmann et al. (2010) could be useful as an example of a more participatory process in that the local village committee had some voice in the planning process that was going to impact their community. This case study is also interesting because intergovernmental relationships figure prominently with the city of Foshan essentially annexing the village of Dadun.

In addition to these direct references, a number of other developing country studies warrant mention for their less obvious ties to the *justice* meta-challenge. For example, Xu (2004), referred to earlier in the *resilience* section, notes the hypocrisy of “protectionist regulations and policies” designed to protect prime farmland and the reality that these resources are “often sacrificed to capital accumulation by the state” (p. 1613), which speaks to the participatory governance aspect of Fainstein’s notion of justice. Similarly, Pucher et al. (2007) briefly considers the implications for the poor and segues from that discussion into policy recommendations (p. 396). Taylor (2008) is a master’s thesis that focuses on wetlands that are important from a climate change impacts perspective (e.g., flood control,) but at the same time could be linked to the *justice* meta-challenge because they “support tens of thousands of local poor populations.” Finally, Zerah (2007) is not an empirical study, but is clearly relevant to the *justice* meta-challenge. It discusses that the efforts in Mumbai to protect greenspaces within the city have been linked to sprawl along the periphery. For example, the city is attempting to preserve Sanjay Gandhi National Park, but illegal settlements have led to the relocation of squatters to the periphery that
reduces the access the poor have to city amenities and services. While not an argument to develop a national park, the article can be taken as a lack of consideration of the needs of the poor in the planning process.

As for developed country studies, Pauleit et al. (2005) calculate an index of multiple deprivation and consider how the loss of open space varies across more and less affluent areas, concluding that the environmental costs of development are not uniformly distributed. This work clearly fits with the justice meta-challenge. Vallianatos et al. (2004) is related to the justice meta-challenge in that it speaks to Fainstein’s third dimension of justice (“appropriately redistributive public policy”). Namely, the article focuses on local food production as a sprawl mitigation strategy but also as a way of “improving the health and nutrition of school-age children, particularly low-income youth (p. 415)”. Power (2001) is more descriptive than explanatory in its approach, but nevertheless makes the connection between sprawl and social exclusion in England and Wales. Lastly, De Ridder et al. (2008) is a clear example of how sprawl can be understood as an equity issue and the central finding is that more affluent suburban residents have lower exposure to potentially harmful air pollution than those who reside in central cities (p. 7077).

5. Discussion

While 21 of the 56 (37.5 percent) articles we reviewed refer to the meta-challenges of resilience and justice, limiting our discussion to these articles may underestimate the degree of silo-busting or convergence in the recent literature. In order to capture other important trends, we also identified articles that draw contrasts across the developing-
developed country divide, that consider multiple elements, or that situate themselves within larger, but related conversations.

Surprisingly few studies were found that are comparative in nature and work across national boundaries. Lehmann (2012) compares Berlin with Shanghai and demonstrates that many of the consequences of sprawl and conversations around the meta-challenges transcend the familiar developed-developing dichotomy. Hamin and Gurran (2009) also provide a comparative case study, albeit between developed country contexts (U.S. and Australia) and like Lehmann (2012), clearly focuses on the climate change issue. We also found a few studies that, though not comparative, draw references or implications for other contexts. For example, Zhao and Liu (2011) mention the developed-developing world dichotomy in the first sentence of their article and focuses specifically on transportation policies to limit carbon emissions in Beijing. Similarly, Paül and Tonts (2005) mention the developed-developing world dichotomy and discuss at length the loss of rural character and agrarian lifestyle in the wake of sprawling development (p. 11; p. 21) in the Barcelona region. These studies offer some evidence that the developed-developing world dichotomy is becoming less relevant for sprawl research.

As shown in Table 1, ten of the studies reviewed discuss more than one element and several others make clear connections with broader scholarly discourses. Among those that fit the latter criterion, McEldowney et al. (2005) specifically mention the convergence of land use and transportation policy initiatives in Belfast, Northern Ireland “as a means of delivering more sustainable patterns of development in terms of reducing car dependency and urban sprawl (p. 508)”. Hasse and Nuissl (2007) focus primarily on the water element,
but also conclude that “the environmental dimension of urban sprawl is connected to the societal sphere” (p. 11) and that opposition to sprawl in Leipzig is driven by a variety of concerns (e.g., NIMBY, social exclusion) that extend beyond its environmental consequences. Huang et al. (2009) mention both globalization and “global environmental change” as key drivers of the sprawling development that has threatened agricultural land and ecological functions in the northern region of Taiwan. Finally, Garcia and Riera (2003), Bart (2010), Barbour and Deakin (2012), Tiwari et al. (2011) and Greca et al. (2011) are all examples of articles that situate themselves firmly within the climate change conversation.

In summary, we find evidence that the sprawl-related research from last decade often attempts to connect with the emerging meta-challenges of resilience and justice. We also conclude that the array of environmental outcomes being considered within individual sprawl studies is expanding and distinctions between studies from developed and developing countries are increasingly difficult to detect.

6. Conclusions: A Research Agenda for the Next Decade

This article documented and synthesized sprawl literature from the past decade across four environmental elements, developed and developing country contexts, and through the lens of resilience and justice as key meta-challenges for environmental planning and management. Our findings suggest that sprawl research has evolved and the key questions that defined the sprawl debate in previous decades have largely been resolved. Emerging issues like climate change and the inequality associated with globalization are increasingly used to frame and inform urban planning research in general.
and evaluate sprawl’s impacts. We believe that this trend is motivated by several key factors. First, while past work on developing specific measures of sprawl enabled this new research, the inability of past work in addressing the emerging challenges from climate change and globalization have also necessitated researchers to adopt less narrow and more interdisciplinary approaches. Second, the interconnectedness of human and natural systems demands greater consideration in planning decisions. For example, the dependence of sprawling development patterns on cheap and abundant energy is threatened by fluctuations in prices. Finally, government and large funding agencies are increasingly emphasizing the need for interdisciplinary and comprehensive proposals. It is therefore not surprising to see researchers responding to these signals.

We should also note a number of limitations with our review and synthesis. First, while we find that a large subset of our reviewed studies situate themselves in the literature on meta-challenges, some continue to be narrowly focused. This could be attributed to our approach of looking at journal articles only, given that this publication format may require researchers to present their work in certain ways. Next, we only reviewed English language planning journals that are overwhelmingly published in developed countries. These kinds of institutional factors may help to explain why we find more examples of articles from developed contexts and, to some extent, the convergence of research topics published in these journals.

Our review indicates several encouraging trends in the recent sprawl-related research, but it is too soon to characterize this as a complete paradigm shift. In fact, we see several areas where more research is needed. For example, we would like to see more
comparative studies across developed and developing countries. While at first glance this may seem to perpetuate the dichotomy between these contexts, these types of studies have the potential to be particularly instructive as we seek to provide useful guidance for planning practitioners. Next, while we find evidence of convergence in studies from developed and developing countries, this does not imply that context no longer matters, but rather that similar issues are gaining visibility around the globe. This trend could signal that conditions are ripe for more ambitious research and planning efforts that cross boundaries and address meta-challenges. Future research that is more nuanced in its treatment of scale would fill key gaps in the literature as perhaps help to coordinate work at the local, regional, national, and global levels. Finally, we find that justice has received less attention than resilience in the sprawl literature in the developed country context and vice versa. We hope to see more research that engages with and balances the two meta-challenges identified here across all geographic contexts in order to better guide policy and planning practice.
References


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Table 1: Characteristics of journal articles.

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Figure 1: Frequency distribution of articles reviewed.

Note: Articles that address multiple elements are included, which explains why these numbers do not sum to 56.

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1 The total number of first and second-order streams is a common measure of the complexity of a hydrologic network.

2 See Rickwood et al. (2008) for a more thorough treatment of this strand of literature.

3 It may seem strange that justice is not a component of resilience, but perhaps the emphasis on maintaining current conditions helps to explain why they are treated as distinct here.