Digital Commons @ LMU and LLS

Cities and the Environment (CATE)

Volume 5 | Issue 1 Article 3

8-21-2012

Integrating Grey and Green Infrastructure to Improve the Health and Well-being of Urban Populations

Erika Svendsen
USDA Forest Service, esvendsen@fs.fed.us

Mary E. Northridge
New York University, men6@nyu.edu

Sara S. Metcalf
University of Buffalo, smetcalf@buffalo.edu

Integrating Grey and Green Infrastructure to Improve the Health and Well-being of Urban Populations

One of the enduring lessons of cities is the essential relationship between grey infrastructure (e.g., streets and buildings) and green infrastructure (e.g., parks and open spaces). The design and management of natural resources to enhance human health and well-being may be traced back thousands of years to the earliest urban civilizations. From the irrigation projects of the Indus Valley and the aqueducts of the Roman Empire to integrated systems of landscaped urban parks and street trees in contemporary times, humans have sought to harness the capacity of nature to advance city life. This article presents a systems science framework that delineates critical relationships between grey and green elements of cities and human health and well-being by modeling the complex, dynamic problem of asthma in socioeconomically disadvantaged city neighborhoods. By understanding the underlying structure of urban spaces and the importance of social interactions, urban planners, public health officials, and community members may capitalize on opportunities to leverage resources to improve the health and well-being of urban populations and promote social justice and health equity.

Keywords
community gardens, asthma, systems science, ecosystems, green infrastructure, urban health, health equity

Acknowledgements
The authors would like to thank the membership of American Community Gardening Association (ACGA) and the Vibrant Cities & Urban Forests Task Force for their inspiration in developing this work.

Note: This paper was initially presented in August 2011 as the keynote address at the American Community Garden Association National Conference in New York, NY. It maps a conversation among the authors that is intended to introduce core system dynamics concepts. The causal map is presented for illustrative purposes only. It will be refined over the course of the next several years through a project recently funded by the USDA Forest Service titled, "Integrating the Grey and the Green to Improve Health and Well-Being for Urban Populations" (Research Joint Venture Agreement, #12-JV-11242309-095).

Throughout the history of cities, a wide range of social actors has competed over urban land as a scarce resource (Svendsen 2009). Regrettably, grey infrastructure (e.g., streets and sewers) has too often been positioned as being at odds with green infrastructure (e.g., parks and open spaces), instead of the two being conceived of as mutually beneficial (Svendsen 2011). While there is increasing recognition that cities are ecosystems with interacting human, structural, and ecological components (McDonnell and Pickett 1993; Machlis et al. 1997; Vibrant Cities & Urban Forests Task Force 2011), to date it has been difficult to communicate regarding how the involved elements relate to one another, much less decide how best to intervene to obtain desired outcomes. The purpose of this paper is to use system dynamics to visualize and explore the complex and dynamic relationships between grey and green infrastructure, and the benefits of their integration on the health and well-being of urban populations.

As a vital component of green infrastructure in cities, community gardens are exceptional in their ability to address an array of public health and livability issues across the lifespan (Twiss et al. 2003). While they began more than a hundred years ago at the turn of the twentieth century (Lawson 2005), they are especially important during times of war, economic crisis, and food shortages (Helphand 2006). For example, during the Great Depression, city lands were made available to the unemployed and impoverished by the Work Projects Administration (WPA), with nearly 5000 gardens on 700 acres cultivated in New York City alone (Hynes 1996 as cited in Armstrong 2000). Today, community gardens are viewed as beneficial to participants by providing them with opportunities to be actively involved in decision-making about the development and use of urban space (Stone 2009).

SYSTEMS SCIENCE

A systems science approach may inform healthy cities and sustainable urban agriculture initiatives by providing mechanisms for modeling complex, dynamic problems (Northridge and Freeman 2011; Metcalf and Widener 2011). In particular, system dynamics is concerned with the identification and modeling of feedback relationships that characterize a particular problem, including inherent delays (Forrester 1961; Sterman 2000). By linking the structure of complex systems to their behavior over time, system dynamics modeling helps interested parties and decision makers assess the impact of different interventions in both the short-term and the long-term (Metcalf et al. 2011).

Moreover, because it is a methodology that is conducive to interdisciplinary work and an inherently iterative process, the construction of a system dynamics model provides an opportunity for input from a variety of stakeholders, which may be especially important in understanding the relationships between community gardens and human health and well-being. After jointly articulating the problem, a causal map is drawn to visualize feedback relationships among the relevant factors that shape system behavior over time (Metcalf et al. 2011). Such a representation constitutes a dynamic hypothesis of plausible relationships that may be tested with a formal computer model, often after undergoing significant revision through either a participatory or group modeling process (Metcalf et al. 2010; van den Belt, 2004). For community groups and practitioners who lack the resources needed to quantify and calibrate a simulation model, or who aim primarily to reflect group knowledge using visual iconography, the construction of a causal map may be a worthwhile goal in and of itself (Ford 2009). The derived causal map then becomes a boundary object that facilitates team communication about project scope and underlying assumptions (Star and Griesemer 1989), and may be utilized in community visioning and strategic planning processes (Twiss et al. 2003).

An orientation to the causal mapping process is called systems thinking (Senge 1990; Meadows 2008) or feedback thought (Richardson 1991), a necessary skill in system dynamics modeling. In order to introduce key concepts, a systems perspective is employed in this article to frame the problem of community concern around the high prevalence of asthma symptoms in underserved urban neighborhoods.

CAUSAL DYNAMICS

The etiology of asthma is complex and multi-factorial, including both genetic and environmental influences (Brisbon et al. 2005). It is currently the most common chronic disease of childhood in the United States and the primary reason for school absenteeism, and disproportionately burdens many socioeconomically disadvantaged urban communities (Gold and Wright 2005). Explanations for this health inequity include poverty, variations in environmental exposures, and differential access to medical care; reducing the burden of asthma requires efforts to address the underlying social justice conditions that produce this health inequity (Greenwood et al. 2011).

The hypothesized causal dynamics involved in the prevalence of asthma symptoms in socioeconomically disadvantaged urban neighborhoods are mapped in Figure 1, with a focus on community concern for asthma as a motivating factor for both grey and green infrastructure interventions.

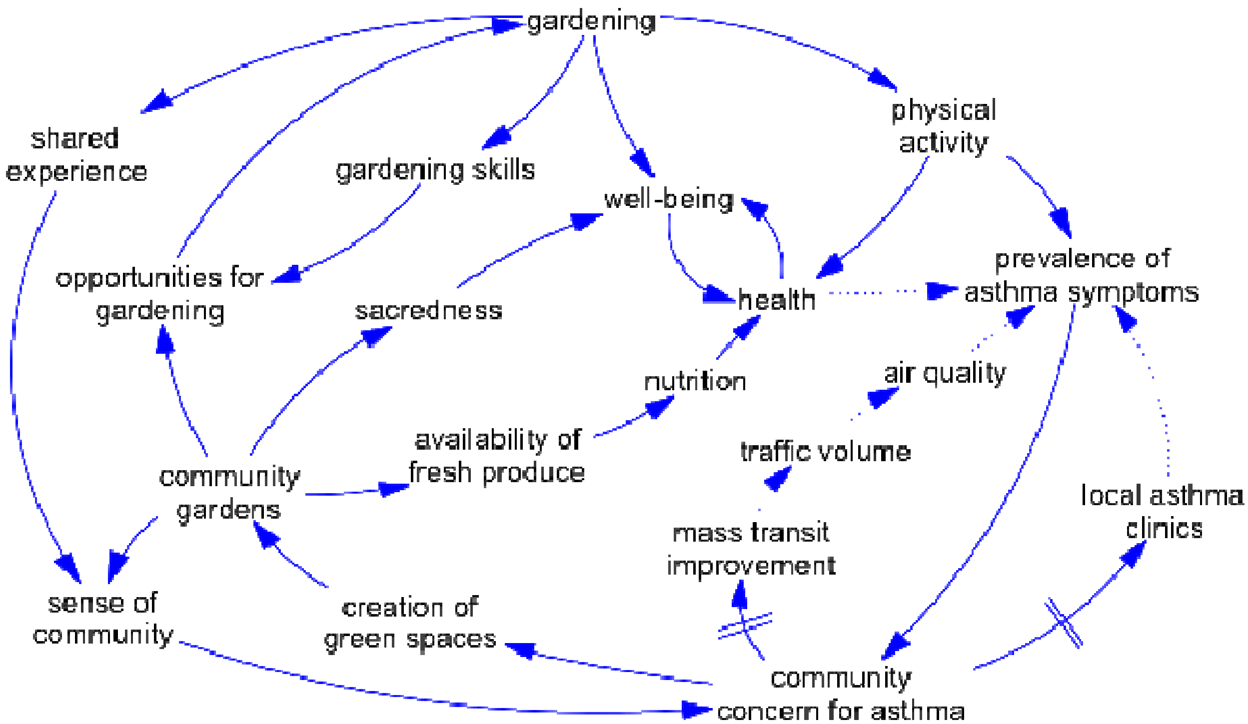

Figure 1. Causal dynamics of asthma in socioeconomically disadvantaged urban neighborhoods. Solid arrows indicate positive polarity. Dotted arrows indicate negative polarity, or inverse relationships. Hatched arrows indicate a delay, or time lag, to allow for resulting shifts in behavior and activity.

The causal map in Figure 1 makes explicit features of conversations among the authors regarding the complex and dynamic relationships involved in the case of asthma. This causal map was constructed by co-author Sara S. Metcalf and revised with feedback from the other authors. Note that the causal map uses solid arrows to indicate positive polarity, and dotted arrows to indicate negative polarity, or inverse relationships. Positive polarity signifies that an increase in the cause results in an increase in the effect, whereas negative polarity indicates that an increase in the cause results in a decrease in the effect. These links combine to create a set of reinforcing and counteracting feedback loops, as discussed in the sections that follow. While many of the transitions outlined in Figure 1 involve implicit delays, the hatched arrows from “community concern for asthma” to “mass transit improvement” and “local asthma clinics” signify delays that are substantially longer than other delays in the system. Explicit recognition of these time lags is necessary to allow for resulting shifts in behaviors and activities. This causal map is a representation of the authors' shared understanding about the influence of grey and green infrastructure on urban health issues such as asthma. As this modeling effort continues, certain unintended consequences of proposed interventions may challenge these initial hypotheses and thus require further analysis.

GREY INFRASTRUCTURE DYNAMICS

Grey infrastructure has been defined as conventional storage structures (reservoirs, detention ponds) and conveyances (pipes, canals) used to manage drinking, sewer, or storm water, usually constructed of concrete or metal (Foster et al. 2011). It also includes streets, roads, bridges, and buildings that do not incorporate technologies intended to achieve environmental goals (Foster et al. 2011). At the bottom of Figure 1 are two balancing or counteracting loops. For the sake of illustration, assume that mass transit improvements and local asthma clinics are part of the grey infrastructure of a community, even as it may be possible to incorporate natural vegetation and innovative grey materials such as permeable pavements and white roofs into these interventions (Foster et al. 2011).

In the outermost counteracting loop at the bottom right of the causal map, community concern for asthma leads to the construction of local asthma clinics, but this takes time, as indicated by the hatched arrow. Once the local asthma clinics are operating, however, the prevalence of asthma symptoms is decreased, as depicted by the dotted arrow. In the absence of education and outreach on the importance of its mitigation, a lower prevalence of asthma symptoms could lead to less community concern for asthma, as depicted in the causal map. In other words, prevalence increases concern, and lower prevalence ultimately lowers concern. This would tend toward cycles of increasing prevalence and concern, followed by mitigated prevalence, diminished concern, disinvestment, and a potential resurgence of asthma prevalence. A useful comparison would be a campaign against secondhand smoke, a trigger for asthma symptoms: although the prevalence of smoking has declined, the campaign against secondhand smoke remains quite strong. Without a secondhand smoke campaign, concern about smoking might diminish, and smoking prevalence may again increase.

A second counteracting loop is triggered by community concern for asthma leading to mass transit improvement, although again it may take time for funds to be allocated and construction to be completed, as per the hatched arrow designation. To the extent that mass transit is then more efficient to use than automobiles, traffic volume will decrease, as indicated by the dotted arrow. Lower traffic volume means improved air quality due to lower levels of respiratory irritant pollutants such as ground level ozone and respirable particulate matter (Brisbon et al. 2005), as signified by a dotted (inverse) arrow in the causal map. In turn, improved air quality leads to a lower prevalence of asthma symptoms, once again denoted by a dotted arrow. Over time, the counteracting loop is completed when a lower prevalence of asthma symptoms eventually leads to less community concern for asthma, as before. In recognition of this potential feedback mechanism, alternative interventions may be represented that would mitigate the diminishing of community concern for asthma as its prevalence declines. By diagramming the underlying structure of these relationships, consequent behaviors and activities flowing from grey infrastructure investments may be explicitly articulated and constructively debated.

GREEN INFRASTRUCTURE DYNAMICS

Green infrastructure encompasses the naturally occurring and human-built features that manage storm water, remove pollutants, conserve energy, reduce erosion, and provide other ecological, cost-effective, and environmentally sustainable services (Vibrant Cities & Urban Forests Task Force 2011). Community concern for asthma may motivate individual volunteers, civic groups, and philanthropic donors to create green spaces centered on plants and waterways, leading to the cultivation of community gardens (Svendsen 2011). The bottom left of Figure 1 depicts a reinforcing feedback loop whereby community concern for asthma leads to the creation of green spaces, which in turn leads to the cultivation of community gardens, resulting in a stronger sense of community, which leads to renewed community concern for asthma. Note that green infrastructure interventions may be deployed more rapidly than mass transit improvements or the construction of asthma clinics (i.e., there are no hatched arrows leading into or out of the community gardens element in the causal map).

In addition, the cultivation of community gardens leads to more opportunities for gardening, and eventually to more members of the community being involved in gardening (Figure 1). On the right-hand side of the causal map, there are two additional reinforcing feedback loops. In the outermost loop, gardening leads to shared experience among community members and a stronger sense of community, which again results in renewed community concern for asthma. In the adjacent interior loop, gardening leads to enhanced gardening skills, then in turn to more opportunities for gardening. According to Twiss et al. (2003), gardening workshops provide opportunities for community members of all ages to develop skills in leadership, community organizing, cultural competency, and program planning, implementation, and evaluation; gardening skills are enhanced through experiential learning, which includes intergenerational and peer-to-peer mentoring and train-the-trainer models. Ongoing, interactive learning opportunities help to sustain momentum for gardening, which is effectively communicated via the reinforcing feedback loop in the causal map.

HEALTH AND WELL-BEING DYNAMICS

According to the World Health Organization (WHO), “Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.” (see https://apps.who.int/aboutwho/en/definition.html) While social well-being is included in the WHO definition of health, well-being includes multiple dimensions and is measured in a variety of ways in the scientific literature. For individuals, well-being may be understood as positive affect, life satisfaction, or simply happiness. For communities, well-being may be thought of as livability, or shared experiences.

A central reinforcing loop in Figure 1 is formed by the positive and reflexive relationship between health and well-being. For instance, enhanced well-being may lead to lower blood pressure and less hypertension, resulting in fewer cardiovascular events (Shirai et al. 2009). On the other hand, good health may foster engagement in social activities, including community gardening, thereby improving individual and community well-being (Armstrong 2000). For illustrative purposes, two pathways leading from community gardens are depicted in the causal map, which are consonant with the research interests of the involved authors. The first pathway leads to well-being through sacredness, an interpretive act of ‘setting aside’ space for community or personal use that intertwines the sacred and the profane, and may include rituals, ceremony, and pilgrimage (Svendsen and Campbell 2010). The second pathway leads to improved nutrition and better health through the availability of fresh local produce (Metcalf and Widener 2011). Note also at the top of the causal map that gardening leads to increased physical activity, which in turn leads to better health, in concert with both the existing literature and the lived experiences of gardeners (Armstrong 2000; Wakefield et al. 2007).

Systems dynamics modeling is also useful for understanding unanticipated effects. For instance, while physical activity leads to enhanced health, it may also induce asthma symptoms (Parsons et al. 2011), as depicted in Figure 1. In general, though, better health leads to a lower prevalence of asthma symptoms, as denoted by the dotted arrow in the causal map.

Teig et al. (2009) reported that the social organizational underpinnings of gardens give rise to a range of social processes, including social connectedness, reciprocity, mutual trust, collective decision-making, civic engagement, and community building—all of which are part of pathways leading to improved human health and well-being. Systems science modeling may be used to simulate social networks as well (Valente 2010), even as it will not be dealt with at length in this article.

WHOLE SYSTEMS

As exemplified by Figure 1, ongoing efforts to improve asthma in disadvantaged city neighborhoods may be meaningfully abetted by modeling that explicitly links grey and green infrastructure. An integrative, complex systems perspective helps to identify interventions as leverage points that impact interconnected components and domains. Through the process of articulating causal relationships between elements, community members and social scientists engage in a participatory process of knowledge sharing to develop a joint sense of how resources ought to be allocated to improve the health and well-being of urban populations and promote social justice and health equity. As illustrated in the causal map, two counteracting loops are induced with grey infrastructure interventions (mass transit improvements and establishment of local asthma clinics), which also incur meaningful investment and inherent delays.

On the other hand, the causal map is valuable in identifying a series of reinforcing loops that is induced with green infrastructure interventions. In other words, planting a community garden may not be the most direct response to addressing the prevalence of asthma symptoms in disadvantaged neighborhoods, even as it leads to the availability of fresh produce and improved nutrition and engenders a sense of community and sacredness, which are linked in turn to health and well-being.

While virtuous cycles were emphasized earlier in this article related to the preservation of green spaces and the creation of community gardens, they might become vicious cycles if environmentally sustainable city planning is not enforced, economic policies fail to consider the short-term and long-term benefits of urban forests, and incentives that curtailBris sprawl and encourage biodiversity are not enacted (Brown and Jameton 2000). The reinforcing nature of the feedback loops indicates their capacity to destabilize the ecosystem. To counter this tendency, a systems perspective underscores the value of coordinated interventions that integrate grey and green infrastructure, to guide decisions that provide urban populations with environmental, economic, social, and health benefits, and build resilience in social-ecological systems (Olsson et al. 2004).

LITERATURE CITED

Armstrong, D. (2000). A survey of community gardens in upstate New York: Implications for health promotion and community development. Health & Place. 6:319-327.

Brisbon, N., J. Plumb, R. Brawer, and D. Paxman. (2005). The asthma and obesity epidemics: the role played by the built environment--a public health perspective. The Journal of Allergy and Clinical Immunology. 115:1024-1028.

Brown, K. H., and A. L. Jameton. (2000). Public health implications of urban agriculture. Journal of Public Health Policy. 21:20-39.

Ford, A. (2009). Modeling the Environment. Washington, DC: Island Press.

Forrester, J. W. (1961). Industrial Dynamics. Waltham, MA: Pegasus.

Foster, J., A. Lowe, and S. Winkelman. (2011). The Value of Green Infrastructure for Urban Climate Adaptation. Washington, DC: Center for Clean Air Policy. Available at: http://mi.mi.gov/documents/dnr/TheValue_347538_7.pdf. Accessed February 21, 2012.

Gold, R., and R. Wright. (2005). Population disparities in asthma. Annual Review of Public Health. 26:89–113.

Greenwood, H. L., N. Edwards, A. Hoogbruin, E. K. Kahwa, O. N. Odhiambo, and J. A. Buong. (2011). A review of equity issues in quantitative studies on health inequalities: the case of asthma in adults. BMC Medical Research Methodology. 11:104.

Helphand, K. I. (2006). Defiant Gardens - Making Gardens in Wartime. San Antonio: Trinity University Press.

Hynes, H. P. (1996). A Patch of Eden: America's Inner-City Gardeners. River White Junction, Vermont: Chelsea Green.

Lawson, L. J. (2005). City Bountiful: A Century of Community Gardening in America. Berkeley: University of California Press.

Machlis, G. E., J. E. Force, and W. R. Burch (1997). The human ecosystem part I: The human ecosystem as an organizing concept in ecosystem management. Society and Natural Resources. 10:347-367.

McDonnell, M., and S. T. A. Pickett. (1993). Humans as Components of Ecosystems: The Ecology of Subtle Human Effects and Populated Areas. New York: Springer-Verlag.

Meadows, D. (2008). Thinking in Systems: A Primer. White River Junction, VT: Chelsea Green Publishing Co.

Metcalf, S. S., E. Wheeler, T. K. BenDor, K. S. Lubinski, B. M. Hannon. (2010). Sharing the floodplain: mediated modeling for environmental management. Environmental Modelling & Software. 25:1282-1290.

Metcalf, S. S., and M. J. Widener. (2011). Growing Buffalo's capacity for local food: A systems framework for sustainable agriculture. Applied Geography. 31:1242-1251.

Metcalf, S. S., M. E. Northridge, and I. B. Lamster. (2011). A systems perspective for dental health in older adults. American Journal of Public Health. 101:1820-1823.

Northridge, M. E., and L. Freeman. (2011). Urban planning and health equity. Journal of Urban Health. 88:582-597.

Olsson, P., C. Folke, and F. Berkes. (2004). Adaptive co-management for building resilience in social-ecological systems. Environmental Management. 34:75-90.

Parsons, J. P., T. J. Craig, S. W. Stoloff, M. L. Hayden, N. K. Ostrom, N. S. Eid, and G. L. Colice. (2011). Impact of exercise-related respiratory symptoms in adults with asthma: Exercise-Induced Bronchospasm Landmark National Survey. Allergy and Asthma Proceedings. 32:431-437.

Richardson, G. P. (1991). Feedback Thought in Social Science and Systems Theory. Waltham, MA: Pegasus.

Senge, P. M. (1990). The Fifth Discipline: The Art and Practice of the Learning Organization. New York, NY: Random House.

Shirai, K., H. Iso, T. Ohira, A. Ikeda, H. Noda, K. Honjo, M. Inoue, S. Tsugane, for the Japan Public Health Center-Based Study Group. (2009). Perceived level of life enjoyment and risks of cardiovascular disease incidence and mortality: The Japan public health center-based study. Circulation. 120:956-963.

Star, S. L., and J. R. Griesemer (1989). Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. Social Studies of Science. 19:387-420.

Sterman, J. D. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston, McGraw-Hill.

Stone, E. (2009). The Benefits of community-managed open space: Community gardening in New York City. In: Restorative Commons: Creating Health and Well-being through Urban Landscapes. L. Campbell and A. Wiesen. Newtown Square, PA: USDA Forest Service.

Svendsen, E. S. (2009). Cultivating resilience: Urban stewardship as a means to improving health and well-being. In: Restorative Commons: Creating Health and Well-being through Urban Landscapes. L. Campbell and A. Wiesen. Newtown Square, PA: USDA Forest Service.

Svendsen, E. S., L.K. Campbell. (2010). Living memorials: Understanding the social meaning of community-based memorials to September 11, 2001. Environment and Behavior. 42:318-334.

Svendsen, E. S. (2011). Cultivating health and well-being through environmental stewardship. American Journal of Public Health. 101:2008.

Teig, E., J. Amulya, L. Bardwell, M. Buchenau, J. A. Marshall, and J. S. Litt. (2009). Collective efficacy in Denver, Colorado: Strengthening neighborhoods and health through community gardens. Health & Place. 15:1115-1122.

Twiss, J., J. Dickinson, S. Duma, T. Kleinman, H. Paulsen, and L. Riveria. (2003). American Journal of Public Health. 93:1435-1438.

Valente, T. W. (2010). Social Networks and Health: Models, Methods, and Applications. New York: Oxford University Press.

van den Belt, M. (2004). Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building. Washington, DC: Island Press.

Vibrant Cities & Urban Forests Task Force. (2011). Vibrant Cities and Urban Forests: A National Call to Action. New York: New York Restoration Project.

Wakefield, S., F. Yeudall, C. Taron, J. Reynolds, and A. Skinner. (2007). Growing urban health: Community gardening in South-East Toronto. Health Promotion International. 22:92-101.