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Growing Buffalo's capacity for local food: A systems framework for sustainable agriculture

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A B S T R A C T

This paper employs a systems framework to explore sustainable agriculture as a source of food in Buffalo, NY and other Rust Belt cities that exhibit an abundance of abandoned property and vacant lots in core urban areas. Considering land as a common stock proves helpful for determining whether or not a system is sustainable, such that stocks of natural resources are not depleted faster than they can be replenished. By identifying feedback relationships in the local food system, planners and activists in these cities are redesigning their food production and distribution systems to meet the needs of food-insecure residents.

A common stock

> "The earth is given as a common stock for man to labor and live on. If for the encouragement of industry we allow it to be appropriated, we must take care that employment be provided to those excluded from the appropriation. If we do not, *the fundamental right to labor the earth returns to the unemployed*." (emphasis added)
> – Thomas Jefferson[1]

In recognizing the necessity of land for livelihood, Jefferson reasoned that limits should be placed upon the appropriation of land if it resulted in the exclusion of the people who depend upon it. As with citizenship, when recognized, our implicit human right to labor the earth becomes a civic responsibility. The logic of returning the land to its inhabitants has anticipated the emergence of voluntary 'guerrilla gardening' of neglected spaces as a way to overcome property bounds, largely because the property is devalued in areas that are neglected. As implied by their moniker, guerrilla gardeners seek to wage 'war' against scarcity and neglect, and to reconsider land ownership in the quest to "reclaim land from perceived neglect or misuse and assign a new purpose to it".[2] Through interactions with the newly formed Buffalo Growing (http://buffalogrowing.org) coalition and practitioners such as Buffalo's Massachusetts Avenue Project (http://www.mass-ave.org), this study examines the potential for sustainable agriculture to shift urban focus from *planning* per se to *planting* seeds for change. Using a systems approach, we consider two issues involving human rights and responsibilities in shaping a sustainable urban ecosystem:

a) How to equitably satisfy the human right to healthy, local, fresh, and culturally appropriate food.
b) How to exercise the human right to labor the earth in such a way as to restore its ecosystem function.

Systems modeling is the art and science of linking system structure to behavior for the purpose of changing structure to improve behavior. With its normative emphasis, systems modeling is well-suited for studies involving sustainability. Sustainability science focuses on the complex dynamics that arise from interactions between human and environmental systems (Clark, 2007). One way to view sustainability of the urban ecosystem is to consider the intersections between these dimensions in the quest for an equitable (society & economy), healthy (society & ecology), and efficient (ecology & economy) city (Horner & Widener, 2010; Knigge, 2010). However, conventional wisdom that the economy be balanced with the environment excludes the hierarchical dependence of human life on the finite natural resources provided by the earth (Gore, 2006; Meadows, Meadows, Randers, & Behrens, 1972). Because humans are part of the earth's ecosystem, and the economy is of our own devise, a hierarchical conception of the three pillars of sustainability (ecology > society > economy) is warranted.

Sustainable agriculture, as management of a complex adaptive ecosystem, requires process-based tools for policy analysis and

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[1] In a letter to James Madison dated October 28, 1785, cited in Berry (1977, p. 220).

[2] From http://www.guerillagardening.org, accessed June 23, 2010. Eponymous texts have been authored by Adams (1983), Tracey (2007), and Reynolds (2008).

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evaluation amidst system uncertainty. The principle of adaptive ecosystem management holds that practitioners should locate themselves within the ecosystem they manage and thereby move toward sustainable scenarios (Norton, 1999). Effective stewards of the land must learn to pace expectations according to natural cycles, as adaptive management requires both an understanding of current conditions and foresight as to how biological rhythms may shift as growing seasons change (Karl et al 2009).

The food movement

Amidst economic crises, oil shocks, and apprehension of global climate change in an already resource-constrained, conflict-ridden world, food security has become one of humankind's most pressing problems (Brown, 2009; Magdoff & Tokar, 2009; Pollan, 2008). This study was motivated by media representations of urban agriculture and a growing public appreciation of and demand for locally grown, healthy foods. Like sustainability, the 'local' norm may prove more useful as a relative concept – *more* local than the current (global) food system, with its complex supply chain and intensive fossil fuel inputs (Selfa & Qazi, 2005). Whether the local 'foodshed' is defined by the extent of its bioregion, a fixed radial distance (e.g., 100 or 200 miles) or a set of counties surrounding a core metropolitan area, local foods provide fresh, accessible alternatives to industrially-produced, processed foods that are shipped hundreds or thousands of miles before being purchased.

In *Diet for a Small Planet*, Lappe (1971) critiques the economic construction of scarcity and underscores how shifts in our everyday food choices have a significant impact on the prospects for our shared future. Her daughter Lappe (2010) advocates a plant-based 'real' food diet with a potential to 'cool' the planet, via a lowered ecological 'foodprint' with fewer greenhouse emissions, many of which currently coming from large-scale animal factory farms. With an informed reckoning about the state of the planet, citizens can take action to grow and exchange local food, thereby reducing our ecological foodprint. When consumed fresh, local produce is more nutritional – and potentially more flavorful – than food that was grown to endure travel over long distances (Kingsolver, 2007; Pollan, 2006). 'Locavores' who participate in the emerging local food movement seek to relocalize food systems through farmers' markets, community supported agriculture, food cooperatives, and home and community gardens using ecologically sustainable practices (DeLind, 2002; Lyson, 2005; Pollan, 2010). Although terms like 'locavore' and 'foodprint' may be new to our lexicon, calls for a sustainable agriculture, or permaculture, have long been made by advocates for sustainably sharing our common stock of land (Berry, 1977; King, 1911; Lappe, 1971; Todd & Todd, 1984).

While the locavore impulse has taken hold among many conscious food consumers, different facets of food are emphasized by those participating in the broader movement to align food choices with the needs of the planet. In a Google search for "local food", the top hit is the Slow Food USA website (http://www.SlowFoodUSA.org), along with the question: "Love Locally Grown Food?" The site advocates for 'good, clean, fair food' from 'plate to planet'. This global, grassroots 'slow' food movement has rippled through the United States as a public fight against fast food, an industry whose excesses have been exposed by Schlosser (2001). Will Allen, a MacArthur fellow and leading proponent of sustainable agriculture, has officially marked the tipping point of the food movement by declaring the 'good' food revolution, under the premise that fresh, healthy food should also taste good (http://www.growingpower.org/blog). Not all local (slow, real, cool, just, good, etc.) food advocates are vegetarian or vegan. While normative, these descriptors are notably vague on the role of meat in a healthy diet (Pollan, 2006). However, food advocates are increasingly 'less-meat-arian', eating lower on the food chain out of concern for environment and health. A variation on the theme is the 'freegan', one who may not be a vegan but chooses to reduce waste in the food system through activities such as dumpster diving, sorting through food discarded by others. Though advocates may disagree as to the optimal norm for diet and lifestyle, many of us would agree with Will Allen that the food movement has become a revolution.

Empirical context

Over the course of its rich history, the city of Buffalo, NY has accrued a number of nicknames: Queen City, Nickel City, City of Light, City of Trees, City of No Illusions, and the City of Good Neighbors. Buffalo's particular Rust Belt image and associated narrative of decline come into focus with visits to once iconic sites now abandoned such as the Central Terminal and the Statler Towers. In addition to the images derived from visiting urban places, narratives of Buffalo's historical trajectory have manifested in a range of media sources. Aware of the persistence of negative public perception about long-term economic and population decline, Rust Belt community activists and politicians struggle to instill a positive image of their cities. Although an emergent rhetoric emphasizes the 'green economy', local leaders generally reinforce the normative urban-economic growth discourse, seeking quick fixes for economic ills without addressing needs of existing residents, exemplified by recent unsuccessful attempts to lure a Bass Pro Shop to Buffalo's waterfront.

Western New York's geographically dispersed and automobile-dependent population is fragmented politically (with 44 local governments in Erie County) along textbook lines of Republican Party dominance in the suburbs and Democratic Party dominance in the city. As a case in point, the Democratic incumbent Mayor Byron Brown, the city's first mayor of African–American heritage, was re-elected in 2009 without an opponent from the Republican Party; the first time since the Civil War that a Republican nominee was not on the ballot. With low Democratic turnout for the uncontested mayoral election, the GOP picked up three additional seats on the County Legislature, bolstering the power held by Erie County Executive Chris Collins, a Republican who was elected in 2007 on a platform of "running government like a business". True to his word, Collins' administration has targeted cuts in public services that benefit the city at the expense of the county, reflecting his own roots in the affluent suburb of Clarence, whose poverty rate is an order of magnitude less than Buffalo's nearly 30% of the population who live below the poverty threshold.[3] Buffalo's poverty rate is comparable to other Rust Belt cities (Detroit, Cleveland) and Western New York communities (Rochester, Syracuse).[4]

Disparities between the city and its suburbs are evidenced in part by the abundance of grocery stores in the latter, and a notable absence of such stores in the city. Fig. 1 maps the locations of full-service grocery stores in Buffalo, using a half-mile buffer for travel along the road network, to illustrate areas that lack access. Moreover, underserved areas are apt to house a larger fraction of the population (indicated by darker shades of green) who lack access to a private automobile. Buffalo's approximately 14,000 vacant lots (shown in blue in Fig. 1) are concentrated largely in the city's East

[3] The US Census estimates the 1999 household poverty rate at 2.2% for Clarence (population 28,084) versus 25.4% for Buffalo (population 292,648). Since 1999, Buffalo's population has dropped by 7.6%–270,240 (2009). Recent (2007) assessments of the poverty rate from the American Community Survey estimate Buffalo's population in poverty at 28%.

[4] A thorough positioning of Buffalo's poverty rate was performed by Wende Mix (2008) in "The Geography of Urban Poverty," available at http://www.buffalostate.edu/geography/documents/paper.pdf.

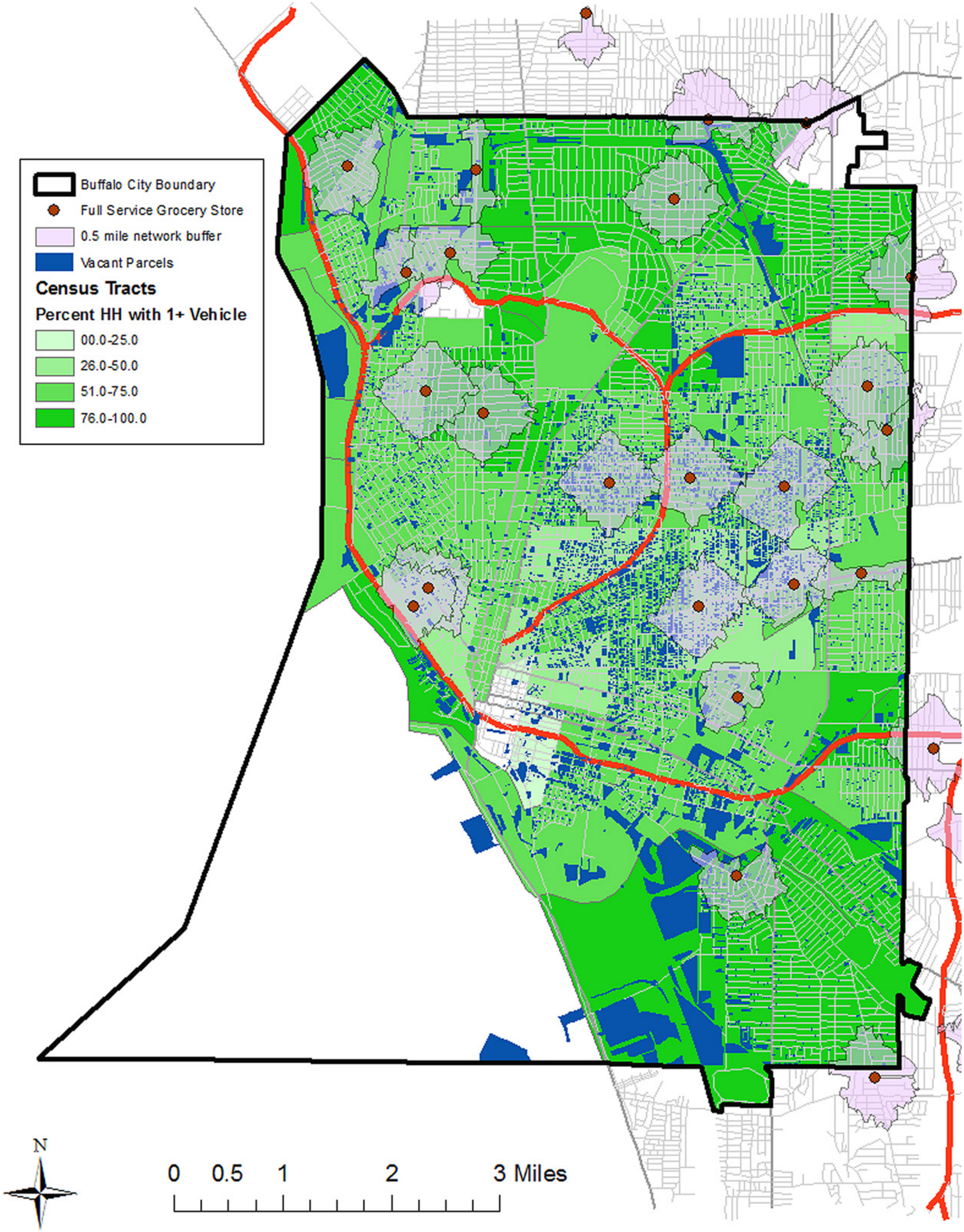

Fig. 1. Geographic Buffer Analysis of Buffalo Grocery Stores.

Side, whose residents are predominantly African–American, many of whom live below the poverty threshold.

Alongside abundant vacant and abandoned spaces, violent crime, homelessness and poverty have remained acute problems for Buffalo, whose long years of economic dysfunction have left many with inadequate access to healthy food. But increasingly, and alongside the national wave of awareness signified by the local food movement, Buffalo's media have called attention to a number of urban farms and community gardens in bloom. As signs of care and cultivation, urban farms have taken root in the shadows of derelict

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Fig. 2. MAP's Growing Green urban youth farm hosts greenhouses and raised beds.

skyscrapers that have come to signify the city, undermining the clarity of a division between urban and rural spaces (Wolch, 2007; Cronon, 1992).

As the 'City of No Illusions', Buffalo's lack of faith in the ability of industry and government institutions to provide for its citizens has given rise to a parallel movement of community organizers constructing landscapes of self-sufficiency and social support. With the emergence of urban farms and gardens in Buffalo, a corresponding discourse about the meanings of urban space has begun to take shape in local media, politics, and communities (Leccese, 2003; Schilling, Schamess, & Logan, 2006; Meyer, 2009). Just as local narratives of Buffalo's decline exhibit racial bias reproduced by increasing disparity between the city and the suburbs,[5] discourse around urban farming both reflects and masks contestation between land stewards and stakeholders (Barraclough, 2009; Cope & Latcham, 2009).

Recent media reports and online comments relevant to the case of urban farming in Buffalo were explored to gauge local reactions to *points of crisis* where expectations of urban spaces are defied by the transgression of agriculture. As Cresswell (1996) defines them, points of crisis are "moments in which dominant ideological belief systems are challenged and disrupted". While most revealed reactions to urban farming in Buffalo have been positive, online comments reveal that for some, urban farms are seriously transgressive. For example, in response to the question of whether chickens should be allowed in the city, one commenter cried 'fowl': "Come on people.. has anyone here ever smelled chicken crap? It is one of the worst odors known to man. If you want a chicken, move to the suburbs. NIMBY."[6]

In this context, we ask: How can cities like Buffalo – with its persistent stock of abandoned property, vacant lots, poverty, homelessness, and lack of living wage employment – internally restructure their food production and distribution systems to better serve the needs of their inhabitants? Toward the goal of spatial justice in terms of both social equity and ecosystem resilience, this study considers how urban agriculture contributes to local food production as a means of meeting the needs of underserved residents in Buffalo's food deserts.

Massachusetts Avenue Project

While issues of transgression and logistics remain, a number of organizations have been actively promoting local food and urban farming in Buffalo. A particularly successful and widely benchmarked organization is that of the Massachusetts Avenue Project (MAP), founded in 1992 in response to violent crime on the Lower West Side of Buffalo. MAP began with a focus on food entrepreneurship to expose youth in a distressed neighborhood to opportunities for both economic development and community engagement. MAP's increasing emphasis on sustainable urban agriculture was outlined in its award-winning "Food for Growth" report, which was produced collaboratively with the University at Buffalo's Department of Urban and Regional Planning (Leccese, 2003).

Since 2000, MAP has operated the Growing Green urban youth farm (Fig. 2), providing educational and employment opportunities for up to 50 local youth per year, and dramatically increasing production through innovative greenhouse aquaponics technology (Fig. 3). MAP operates two state-of-the-art greenhouses: one a sustainably designed strawbale structure, the other an enormous hoophouse with a capacity for about 35,000 fish to be cultivated in a closed-loop aquaponics (aquaculture/hydroponics) system.[7] The timing of this study coincides with what is undoubtedly a tipping (or inflection) point in terms of yield, from about 3000 pounds of annual produce to an order of magnitude more, with increasing emphasis on aquaculture to meet the nutritional needs of area residents.

Buffalo's experiments with urban agriculture reveal social issues of privilege (race, gender, class) and access (distance, daily time budgets, mobility limitations, affordability) to locally grown, healthy food (Raja, Ma, & Yadav, 2008). While MAP's primary

[5] Only 0.6% of households in the suburb of Clarence identified with the African–American racial category in the US Census of 2000, versus 37.2% in Buffalo that year.

[6] Response to article posted on Buffalo Rising, 31 March 2009. The chicken issue was resolved in favor of city chickens, as recently reported by Galaraneau (2010).

[7] MAP's mission and its sustainable urban agriculture practices are elaborated in a recent video: http://bit.ly/c5NqVb.

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Fig. 3. Interior view of MAP's aquaponics facility, a closed-loop system of fish and plant growth.

clientele are its neighbors in the Lower West Side, the organization relies in part upon funding and support from locavores in the larger community who can afford to volunteer time, attend fundraisings, and travel farther to visit their food stand. As such, MAP's Growing Green Garden emphasizes social justice and involvement of youth in discussion of systemic dysfunction and identification of agency through agriculture.

In 2008, MAP joined forces with organizations such as Grassroots Gardens (http://www.grassrootsgardens.org), Urban Roots (http://www.urbanroots.org), the Curtis Urban Farm Foundation (http://www.buffalocuff.org), and the Wilson Street Urban Farm (http://wilsonstreeturbanfarm.wordpress.com) to form a Community Garden Task Force, which eventually became known as the Buffalo Growing coalition. Shared concerns include lease agreements with the city for use of vacant lots (Meyer, 2010), composting, transplanting, and seedling swaps. The coalition meets monthly, distributes a calendar of events and encourages local leaders to make allowances for urban agriculture in its zoning codes. For example, Buffalo Growing members have been vocal participants in discussions about what to include in a new 'green code' as part of an overhaul of the city's zoning system. In this way, concerned citizens grapple with the question of how Buffalo can best restructure its food system and vacant spaces to meet basic needs and improve quality of life for all residents.

Although urban agriculture practitioners at Buffalo Growing coalition meetings cite community residents who hesitate to join in the task of community gardening, ever-observant neighbors and visitors are sometimes inspired to reinvest time and resources into their own gardens. This experience was affirmed by Detroit's urban farming adherents in a recent workshop. As appropriate for "The City of Good Neighbors", direct observation of gardening activity and increasing evidence of urban agriculture may stimulate an IMBY – In My Back Yard – sort of imitative response over time, a domino effect potentially reflecting the inverse of the contested 'broken window' contagion theory (Harcourt, 2001). Unlike the rapidity with which windows can be broken, diffusion delays in urban agriculture may be significant, as novice gardeners need experience (and therefore time) to develop expertise, and stand to learn a great deal from 'seasoned' gardeners via networks such as the Buffalo Growing coalition. Indeed, diffusion of innovative agricultural practices has provided some of the earliest evidence for the strength of local knowledge and social influence (Ryan & Gross, 1943). Furthermore, the IMBY attitude has been harnessed before, as with the "victory gardens" cultivated to support the U.S. engagement in World War II, in which citizens were encouraged to grow their own vegetables to relieve the strain on the food distribution network (Thone, 1943).

A systems framework

Rittel and Webber (1973) call into question the ability of planners to adequately formalize 'wicked' environmental problems that defy a singular solution. While conventional management techniques define system boundaries before embarking upon policy analysis, adaptive ecosystems defy clear delineation of system boundaries because their policy and management problems tend to spill over designated system boundaries. For example, a range of spatial boundaries may be revealed by asking: What is the current, potential, and 'natural' geographic extent of the Buffalo foodshed? Like a watershed whose extent is defined by the flow of water into sub-basins, a foodshed reflects the capacity for production and distribution of food within a bioregion.

Buffalo has ample vacant area to meet its residents' vegetable intake through locally grown produce, although significant city concessions, labor and natural resource inputs are needed to begin the transformation of vacant lots to agricultural area. Sustainable practices such as composting lower the cost of inputs required for gardening but also involve a significant investment in terms of real work – labor – that reflects commitment to place and civic engagement (DeLind, 2002). While technologies such as closed-loop aquaponics dramatically improve productivity, infrastructure constraints (e.g., limited access to water supplies) may impinge upon the potential urban area that can be cultivated. Ecosystem trade-offs corresponding to degrees of local food production should be considered alongside an equitable distribution system.

Ecological problems become wicked when they require agreement among stakeholders with widely varying perspectives on the problem. In practice, wicked problems are often formulated only after a solution has been presented, underscoring the importance of iteration in the modeling process, as recognized also by the method of grounded visualization (Knigge & Cope, 2006). Effective food policy support tools should therefore focus on improving decision-making processes through experimentation with heuristics under different settings. An advantage of systems modeling is the ability to simulate outcomes for alternative assumptions, generating enough data to make wicked problems more benign through apprehension (Metcalf, Wheeler, BenDor, Lubinski, & Hannon, 2010).

The principle of adaptive ecosystem management holds that practitioners should locate themselves within the ecosystem they manage and thereby move toward sustainable scenarios (Norton, 1999). Locating oneself within the problem is a necessary first step toward wise action and whole-systems thinking (Senge, Laur, Smith, Kruschwitz, & Schley, 2008). Although wicked environmental problems continue to defy singular solutions, exploratory systems modeling can be employed to simulate paths toward progress in the form of a more equitable and sustainable urban ecosystem.

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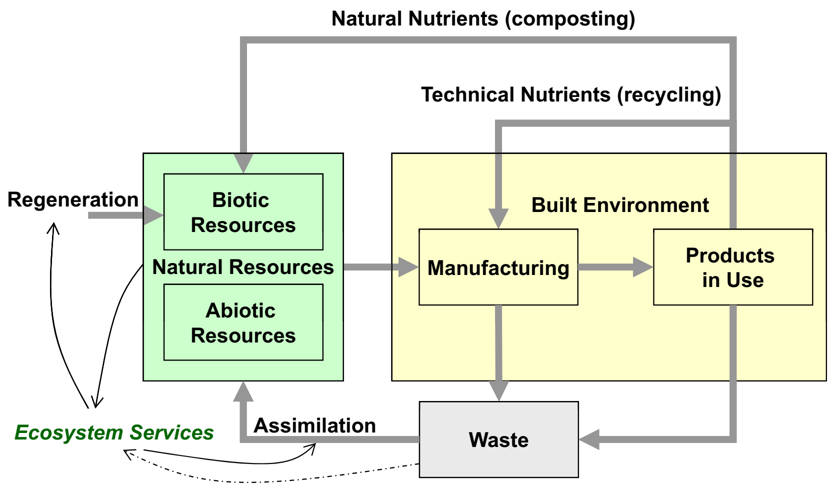

Fig. 4. Waste Assimilation and Re-use in the Urban Ecosystem.

Cultivating natural capital

The closed-loop system outlined in Fig. 4 is derived from the principles of a "natural capitalism" that returns nutrients to quickly regenerate biotic resources, rather than depleting abiotic (e.g., fossil fuel, mineral) resources that do not regenerate on a time scale relevant to human life (Hawken, Lovins, & Lovins, 1999; Senge, Seville, Lovins, & Lotspiech (2001)). Using a systems framework, Hawken and colleagues present four basic shifts essential for restoring balance to an ecosystem[8]:

1. *Radical Resource Productivity*: Increase yield using innovative technology to improve efficiency and save cost (getting more product out of each ton of natural material extracted), congruent with the profit motive. Because this principle is most consistent with existing economic imperatives, opportunities to improve productivity are often 'low-hanging fruit' in system redesign.
2. *Biomimicry*: Using biologically inspired models, where waste from one organism (e.g., fish) becomes food for another (e.g., cabbage), this principle involves a shift to "closed-loop" production systems that re-use and thereby eliminate waste streams in the system (Benyus, 1997). Because the water and nutrient flows are recirculated within the system, MAP's greenhouse aquaponics designs are consistent with the systems model outlined in Fig. 4. "Closed-loop" solutions such as aquaculture and use of renewable energy are more sustainable than linear systems that accumulate waste.
3. *Shift from Product to Service*: In a traditional product-based business model, the consumer has ultimate responsibility for disposition of goods, hence most are discarded after use. In a service-based model, the producer (in this case, the farmer) maintains ownership of goods produced, encouraging "take back" activities such as remanufacturing, recycling and/or composting when the product's useful life ends. Many community supported agriculture programs treat food as a service rather than a particular good, with standard baskets or boxes of fruits and vegetables distributed weekly throughout a particular season. City composting services are also consistent with this principle. Hyperlocal IMBY agriculture completely aligns producer with consumer, maintaining responsibility from food production through consumption.
4. *Investment in Natural Capital*: Humans acting at both the individual and institutional level must restore, sustain, and expand the planet's ecosystems to recreate an abundance of resources and services. If these actions are not pursued proactively, costs of reinvesting in natural capital will skyrocket with depleting stocks and rising ecological problems, leading to widespread reactionary pressure for social and governmental reform.

While Hawken et al. (1999) used the language of capitalism to address powerful business interests, these four basic shifts involving fundamental material flows provide a rich theoretical foundation for sustainable food systems. The constructed dichotomy, or dislocation, between body and earth fails to respect limits on the *pace* at which resources can be consumed sustainably, which must be slower than the pace at which they can be regenerated (Meadows et al., 1972). If we synchronize our daily rhythms with earth's capacity for nurturing life, we make room for equity through sustainable living.

By transferring knowledge among neighbors and across generations, humans can avoid moving from denial about environmental problems to a state of despair without *doing* something to improve our collective longevity (Gore, 2006). In an era that President Obama declared "the age of responsibility" during his 2009 inaugural address, we must critically examine the extent of individual and institutional denial that enables us to maintain the energy-intensive material consumption patterns that dominate our daily lives. The contemporary social upheaval over the crises caused by our neoliberal economic system, with a profit motive further corrupted by alignments between industry and government, suggests that individual citizens may be more apt than big business to reinvest in natural capital. Within a changing political and physical climate, this research constructs policy support tools to encourage sustainable local action toward food security and urban ecosystem resilience.

Scenario exploration

The discord generated by an awareness of excess should prompt humans to consider what scenarios may be in store for us. The way to avoid despair about climate change and other environmental threats is not through denial, but rather through doing – taking action that invokes the classic Earth Day message "think globally,

[8] These shifts and the diagram in Figure 4 were adapted from Senge et al. (2001).

act locally". Within a systems modeling framework, a first step is to articulate our most-feared scenario (the negative vision inducing denial of its plausibility). Such a scenario enables direct contrast with the business as usual trajectory, unless the status quo has become the most-feared scenario. Simulations of status quo and alternative scenarios of urban ecosystem resilience aid in the allocation of land, human, financial, and ecological resources. To counterbalance the worst-case scenario, a vision of the most hopeful scenario is also considered, to see what synergies and possibilities may exist for steering toward it. Scenarios of food security and ecosystem resilience are first envisioned in order to be cultivated (e.g., Todd & Todd, 1984; Wolch, 2007).

Global climate change scenarios spanning decades and human life spans inform local examinations of community resilience to the impact of extreme events, such as Buffalo's October "surprise" snowstorm of 2006 that damaged tens of thousands of trees in the bioregion. Because biological cycles are often temperature-dependent, effects of global climate change such as extended growing seasons can disrupt the relative balance of plant, animal and insect populations due to asynchronous and temperature-dependent species emergence. As non-indigenous species become increasingly common with global traffic of tourists and trade, local ecosystems become vulnerable in new ways. Feedback relationships among plant and animal species necessary for ecosystem function have been examined using systems modeling to represent relative delays in species life cycles (BenDor & Metcalf, 2006).

Restorative approaches to land cultivation show promise to be ecologically sustainable, but more intensive demands on human labor must also be justified by an economic evaluation that reflects long-term consequences of land stewardship. Trade-offs must be made between up-front costs (demolition or renovation of infrastructure, soil remediation, water treatment, labor) and anticipated community benefits (food, recreation, employment, ecological function). Alternative geographic distributions of forests, farms, gardens, farmers' markets, and other distribution outlets throughout the community situate equity of access to amenities alongside habitat contiguity for green spaces. From such a model, measures of biodiversity, soil composition, habitat contiguity and structural protection (e.g., the wind-breaking function of urban forests) inform which alternatives are most sustainable for Buffalo's four-season ecosystem.

Scenarios identified in the course of this study include:

- Scenario A: Status Quo – vegetation, where present, results from neglect and disinvestment rather than intent.[9]
- Scenario B: Gentrification – city encourages conversion of vacant lots to urban agriculture in the form of market farms and community gardens to beautify neighborhoods and attract capital investment.
- Scenario C: Sustainable Agriculture, IMBY (In My Backyard) - diffusion of best practices among engaged citizens and organizations.

While Scenario A is undesirable, it also represents the momentum scenario – what happens when nothing is done to put vacant land to productive use. In Scenario B, gardening stimulates circuits of capital, and while this scenario results in economic development, it does not address issues of equity. Moreover, land leased from the city for urban agriculture may be reclaimed to encourage capital development. Scenario C envisions a city whose inhabitants adopt an IMBY attitude and attempt to cultivate what land is available to them. The sustainable urban agriculture scenario (C) is motivated by citizens' desire to minimize their ecological *foodprint* via local production and consumption of fresh food (fossil fuel reduction from fewer miles traveled and less food processing) and via improved sequestration capacity from full integration of urban forests and farms designed to maximize human and environmental benefit.

Because human evaluation of environmental change is endogenous to the adaptive management process, systems models offer a means of understanding and communication that can be harnessed for an inclusive, participatory process of land stewardship. Models help us to transcend outmoded thinking and steer toward sustainable scenarios.

Constructing a causal map

A participatory modeling process was used to develop a causal map that expresses relationships between elements of the local food system. Causal maps are also known as dynamic hypotheses, and often undergo significant revision before being tested with a formal, equation-based model. Fig. 5 illustrates a causal map developed during this civic engagement with MAP and the Buffalo Growing coalition. Using iconography in which accumulations (stocks) are represented with boxes connected by pipes with valves that control the rates (flows) of change over time, Fig. 5 outlines major land-use categories and shifts toward sustainable agriculture alongside a functional built environment, so that a status quo of neglect and abandonment can be transformed into a scenario in which the city provides for the most basic of human needs while respecting cultural diversity of its residents.

Causal relationships in Fig. 5 that reinforce the signal are shown with a solid arrow, and inverse relationships are shown with a dotted arrow (e.g., the effects of *Vacant Lots* and *Abandoned Buildings* on *Property Value*). The boxes represent categories of land use that have distinct effects on the availability of land for urban agriculture. The flow from *Vacant Lots* to *Urban Agriculture* is thus constrained by vacant land area, and returns to vacant status if urban agriculture activities are neglected, prohibited, or otherwise discontinued. When well-maintained and aesthetically pleasing, *Urban Agriculture* has the potential to increase *property value*, which stimulates redevelopment of *Vacant Lots* and thereby induces gentrification (Scenario B). The presence of *Abandoned Buildings* and *Vacant Lots* contributes to public perception of urban decline, which is inversely linked to property value.

Buffalo's *performance-based city lease*, and its forthcoming *green code*, offer ways to increase *opportunities for urban agriculture*, and to slow the rate at which community gardens are reclaimed by the city for redevelopment purposes. As urban agriculture activities increase, local food becomes more available, increasing access for those who live in the food deserts identified by the grocery gap map earlier (see Fig. 1), and enabling residents to become more familiar with (and thereby cultivate a taste for) local food. At first locally grown vegetables may be unfamiliar, but as familiarity increases (so long as experiences are positive), preferences for local food increase, as does community support for urban agriculture. For residents in closest proximity to a convenience store, even ubiquity of fresh food might not be enough to overcome a preference for potato chips and soda. Although MAP offers cooking classes, many low-income and/or single-parent households face challenges budgeting adequate time for food preparation, especially when children's palates must also be pleased. Travel costs intensify the existing grocery gap, and limited time budgets make it difficult for those in proximity to farmers' markets to participate, even with money in the pocketbook.

[9] As per Emmanuel (1997) and Nystuen, Ryznar, and Wagner (1996), who demonstrated through remote sensing that areas with vegetative overgrowth corresponded with economic decline.

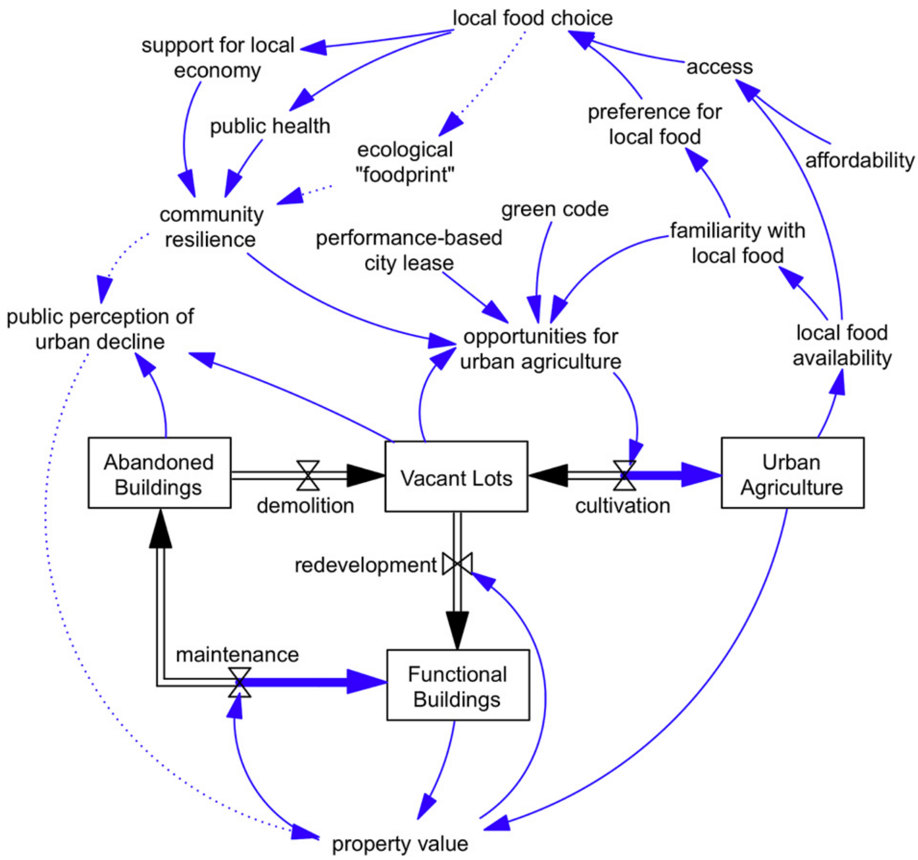

Fig. 5. Impacts of Land-Use Change and Local Food Choice.

Once preferences for fresh produce are aligned with access to local food, residents are equipped to make healthier food choices. Whether from urban or rural sources, a shift of preference toward locally grown food stimulates latent demand for fresh food as healthy choices become a more significant component of residents' daily food consumption (DeLind, 2002). An individual's local food choice strengthens *community resilience* via the three dimensions of sustainability – reducing the urban ecological 'foodprint', improving public health, and supporting the local economy. With fewer vacant lots and greater community resilience, public perception improves, enabling property values to rise. However, in the absence of mitigating effects, rising *property value* from the direct and indirect effects of urban agriculture leads to gentrification of the area. A sudden influx of capital shifts land use toward redevelopment of the built environment rather than cultivation of urban farms.

While it does not denote all of the legal, capital, and social barriers to urban agriculture, neither does the representation in Fig. 5 include enablers from IMBY activities, which extend opportunities for *Urban Agriculture* well beyond the space available in *Vacant Lots*. Activities such as guerrilla gardening further accelerate conversion of *Vacant Lots* to *Urban Agriculture*. In addition to the land-use dynamics shown in Fig. 5, causal maps have been developed over the course of this study to represent the closed-loop production systems operated by MAP, and to reflect states of awareness and levels of commitment held by locavores and neighbors in need of greater access to fresh produce. The dynamics by which awareness, experience, and expertise are relayed through community networks can generate an S-shaped pattern of diffusion over time, characteristic of the Bass diffusion model, in which a tipping point signifies the buildup of a critical mass to the point where the community becomes saturated with a new 'best' practice (Sterman, 2000).

As practices of urban agriculture gain in acceptance, and as youth engage in directly addressing persistent social injustices through better nutrition and sustainable skill development, the potential for relocalizing the foodshed increases. Techniques for managing such a progressive shift without inducing displacement of existing residents through the processes of gentrification (via upwardly mobile economic forces) warrant exploration. With systems models, citizen scientists tinker in virtual worlds with new ideas while living deliberately in a borrowed, shared, physical world. Locating ourselves in Nature, we must act responsibly to improve conditions that ripple beyond our generations, life spans, and species. Because the multiple scales of our spheres of influence are often embedded and overlapping, studies of environmental justice have implicated scale in the reproduction of urban political power structures (Heynen, 2003; Keil, 2003).

Thinking like a plan(e)t

> "The garden is the smallest parcel of the world and then it is the totality of the world." – Michel Foucault[10]

In the context of global climate change, and echoing Foucault's observation about the simultaneity of scales, the practice of gardening signifies 'thinking like a plan(e)t' – about both plant and planet, local and global, or 'glocal' behavior.[11] Software has advanced sufficiently to simulate alternative formulations of

[10] Cited by Pena (2006).

[11] The phrase 'thinking like a plan(e)t' is inspired both by Leopold's (1949) 'thinking like a mountain' and a forthcoming work by Hirsch and Norton (2011).

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ecosystem dynamics at multiple scales of interdependence. Integration of multiple modeling paradigms (e.g., GIS analysis, stock-flow dynamics, agent interactions) enables hybrid modeling of continuous and discrete aspects of human–environment interactions in Buffalo's urban ecosystem.

Modeling at the micro-scale of individual plants, Hunt and Colasanti (2007) simulate "roots and shoots" of plant growth over short periods of time. At the macro-scale, remote sensing informs large-scale efforts to simulate land-use change (Parker, Manson, Janssen, Hoffmann, & Deadman, 2003). These remote sensing images reveal Buffalo's land-use and land cover patterns, scales of local agricultural practices, relative abundance of tree species and canopy, the vertical dimension of built infrastructure, and population density in urban areas. While differing perspectives exist as to the most important benefits of urban agriculture – local food production, carbon sequestration, soil regeneration (e.g., Magdoff, 1992), phytoremediation (e.g., Chaney et al., 2007; Prasad & de Oliveira Freitas, 2003), stormwater management, groundwater filtration, micro-climate improvements (e.g., Day, Gober, Xiong, & Wentz, 2002), reconnecting with community (e.g., Mark, 2010), recreation or sheer beauty – the urgent need for sustainable practices *at all scales* within our sphere of influence has been recognized by many (Ellis, 2009; Flores, 2006; Pollan, 2008; Ostrom, 2010).

Over the course of this study, experienced gardeners and urban farming advocates noted the need for four-dimensional thinking, with time as the fourth dimension. On the scale of seasons, such thinking involves consideration of phenomena such as the timing of harvests and changes in vegetation. On the scale of centuries, it involves an economic and historical appreciation of agriculture in the city. On the scale of decades, it includes forward thinking about climate change. With sufficient resources for its development and calibration, a dynamic simulation model helps to examine the role of timing and environmental uncertainties in shaping strategies for plant selection, seed planting, transplanting, root and shoot development, harvesting, distributing, consuming, composting, and letting land lay fallow. Sustainable agricultural practices gleaned from MAP and the Buffalo Growing coalition inform modeling at the decision-making scale of the garden, contrasting types of land ownership, planting strategies, harvest sharing, and food distribution.

Conclusion

"We must cultivate our garden." – *Candide* (Voltaire, 1759)

In Voltaire's 18th century novella, the character Candide embarks upon a journey to ascertain whether he did live in the "best of all possible worlds," as asserted by the hegemony of his day. His search leads him to conclude that we can never know whether we live in an optimal world, and that it is counter-productive to believe so. Candide's closing imperative to tend our own gardens reflects the necessity of constructive action in the face of considerable uncertainty.

The quickening global consciousness of this information age compels us, out of responsibility, to domesticate not just plants and animals (already amply domesticated), but also technology. As Berry (1977) notes, the Amish practice of minimal technology use is one way to limit its dominance in farm operations. While minimizing technology is useful for reducing fossil energy use, another approach is to "domesticate" it, harnessing its power to serve the needs of the community. By rendering relationships visible, a systems model for sustainable urban agriculture functions in part as a knowledge repository of relevant strategies and interactions between people, animals and plants in a functional urban ecosystem. Systems modeling helps humans to tame technology via the practice of engaging with computers for the purpose of virtual experimentation, testing the boundaries of knowledge by rendering plausible alternatives to the status quo.

To *cultivate* is to care for, to tend to plants without controlling them. That this process holds the key to social change is evidenced in MAP's slogan, "the revolution will be cultivated," words that resonate with musician Gil Scott–Heron's admonition that "the revolution will not be televised; the revolution will be live." A modified mantra for systems modeling in the information age could be: "the revolution will not be simulated; the revolution will be *cultivated*." It is in translating insights from the simulated, virtual world to change at the ground level that the potential for a sustainable social movement can be realized. Models help aspiring urban farmers and gardeners to think through seasons and respond to climatic uncertainty, but will never substitute for the direct experience of reaping what we sow. With insight from systems models alongside civic engagement, we can slow the pace of our daily circuits to match that of the community and the planet on which we depend, and thereby learn how to re-root ourselves through sustainable agriculture.

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