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Can cities become self-reliant in food?

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ABSTRACT

Modern cities almost exclusively rely on the import of resources to meet their daily basic needs. Food and other essential materials and goods are transported from long-distances, often across continents, which results in the emission of harmful greenhouse gasses. As more people now live in cities than rural areas and all future population growth is expected to occur in cities, the potential for local self-reliance in food for a typical post-industrial North American city was determined. Given current policies and bylaws and available area, crop yields, and human intake, three distinct scenarios were developed to determine the potential level of food self-reliance for the City of Cleveland, which has been plagued with home foreclosures and resulting vacant land, lack of access to healthy food, hunger, and obesity particularly in disadvantaged neighborhoods. Scenario I, which utilizes 80% of every vacant lot, can generate between 22% and 48% of Cleveland's demand for fresh produce (vegetables and fruits) depending on the vegetable production practice used (conventional gardening, intensive gardening, or hydroponics), 25% of both poultry and shell eggs, and 100% of honey. Scenario II, which uses 80% of every vacant lot and 9% of every occupied residential lot, can generate between 31% and 68% of the needed fresh produce, 94% of both poultry and shell eggs, and 100% of honey. Finally, scenario III, which adds 62% of every industrial and commercial rooftop in addition to the land area used in scenario II, can meet between 46% and 100% of Cleveland's fresh produce need, and 94% of poultry and shell eggs and 100% of honey. The three scenarios can attain overall levels of self-reliance between 4.2% and 17.7% by weight and 1.8% and 7.3% by expenditure in total food and beverage consumption, compared to the current level of 0.1% self-reliance in total food and beverage by expenditure. The analysis also reveals that the enhanced food self-reliance would result in $29 M to $115 M being retained in Cleveland annually depending upon the scenario employed. This study provides support to the hypothesis that significant levels of local self-reliance in food, the most basic need, is possible in post-industrial North American cities. It is concluded that while high levels of local self-reliance would require an active role of city governments and planners, public commitment, financial investment, and labor, the benefits to human health, the local and global environment, and the local economy and community may outweigh the cost.

Introduction

Globalization has been one of the most enchanting experiences of human civilization. It has facilitated the exchange of information and ideas, advancing technology and progress to heights never even envisioned by generations past (Friedman, 2005). Globalization has also contributed to the spread of cultures and tolerance and led to the rise of international organizations committed to peace and justice (Appadurai, 1996; Pieterse, 2009; Tomlinson, 1999). Yet, globalization has inflicted externalities on both local communities and the global environment. First, globalization undermines local economic resilience, creating an unnecessary and unhealthy dependence on foreign goods which communities could produce at home (Shuman, 1998). Likewise, globalization undermines the autonomy of local communities (Shuman, 1998). As multinational corporations increase their economic and political influence, communities lose control over their most basic necessities, such as food and energy. This local power leakage allows the well-being of residents to be placed in the hands of corporate CEOs who may be thousands of miles away and who frequently have no understanding of or respect for the local economic, social, and cultural fabric of the community. Globalization also has a devastating effect on the environment (Morris, 1987; Roseland, 2005; Shuman, 1998). Corporations have no economic incentive to preserve the environment and the culture of global goods transportation results in tremendous greenhouse gas emissions. Another harm of globalization is the promotion of a culture of unsustainable consumerism and excessive consumption (Belk, 1996; Morris, 1987; Roseland, 2005; Shuman, 1998). As a result of globalization, the consumer

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has been separated from the producer and thereby no longer witnesses the detrimental effects of consumerism: depletion of finite resources, pollution of natural environments, and accumulation of waste. Without a firsthand reminder of these harms, this trend of excessive consumption will likely continue unabated, which can have dire consequences for sustainability and the environment. Therefore, globalization negatively affects local economic resilience, autonomy, the environment, and sustainability.

Given the serious detriments associated with globalization, a comprehensive paradigm shift is needed. Local self-reliance (Morris, 1987; Shuman, 1998) refers to the principle that localities should be able to obtain at least their basic necessities, if not more of their goods, from within their own physical footprints. Local self-reliance encourages communities to use their limited resources in the most efficient and sustainable manner, and grants localities both autonomy and economic resilience, counteracting the major negative externalities of globalization. Local self-reliance can be applied at different scales, including household, neighborhood, city, region, and even country. In a global age, it is unrealistic and even unadvisable for a locality to become completely isolated from the rest of the world. Therefore, local self-reliance fully encourages the global exchange of ideas and technology, the promotion of international organizations and justice, and the spread of tolerance and peace. However, local self-reliance entails that localities be as self-reliant as possible with regards to basic necessities like food, energy, water, and materials.

Self-reliance in terms of daily food needs requires the production of food within urbanized areas. Food production in the cities can take many forms, including home gardens, community gardens, market gardens, school gardens, rooftop gardens, windowsill gardens, aquaculture, and urban farms, among others. The choice of production method will vary due to the circumstances of each community and its preferences, but the benefits can be generalized: Urban agriculture has the potential to increase access to healthy and nutritious food (Blaine, Grewal, Dawes, & Snider, 2010; Duchemin, Wegmuller, & Legault, 2008; Minnich, 1983), reduce human impact on the environment (Doron, 2005; Flores, 2006; Halweil, 2005; Howard, 2006), strengthen local economies (Masi, 2008; Moustier, 2006), and promote a sense of community (Flores, 2006; Malakoff, 1995; Patel, 1991). Blaine et al. (2010) found that engagement in community gardening results in dietary changes leading to increased vegetable intake. Minnich (1983) discovered that under average growing conditions in a 130-days growing season, a 10 by 10 m plot can provide a household's yearly vegetable needs, including much of the household's nutritional requirements for vitamin's A, C, and B complex and iron. Given the escalating hunger and obesity in the USA, increasing accessibility and supply of nutritious food is extremely important. Gardening can also provide physical exercise, from cutting stems to turning compost piles (Brown & Jameton, 2000). Finally, gardening can be a way to relax and release stress, thus improving the psychological health of urban residents (Kaplan, 1973; Malakoff, 1995).

Producing food within the city also improves the environment. It is estimated that food in the United States travels an average of 1500 miles from the farm to our plates (Halweil, 2005). Doron (2005) calculates that if food in the United Kingdom was produced and consumed locally, the level of carbon dioxide emissions would be reduced by 22% – twice the amount the UK has committed to under the Kyoto Protocol. Increased gardening can also increase rates of carbon sequestration, further mitigating the human impact on climate change. Additionally, urban agriculture can reduce the problems associated with stormwater runoff, since rainwater can be redirected to gardens.

Local self-reliance also has many economic benefits. In addition to reducing local economic leakage, the increased green space can also reduce the urban heat island effect, resulting in lower air conditioning costs (United States Environmental Protection Agency, 2008). It can also create jobs throughout the food sector, including production, processing, and marketing. Additionally, kitchen waste can be reused as fertilizer, resulting in less waste collection costs for the city and reduced expenditures on synthetic fertilizers. Likewise, redirection of stormwater to food production would reduce the cost of stormwater management. Finally, property values would increase as vacant lots are put to attractive yet productive usage and there is an overall reduction in crime in the city (Malakoff, 1995).

Urban gardening, especially collective gardening, can also promote a sense of community. Patel (1991) found that "gardening cut across social, economic, and racial barriers and brought together people of all ages and backgrounds." Further, Malakoff (1995) notes that neighborhoods with garden projects in Philadelphia and San Francisco observed "marked reductions" in burglaries, thefts, and illicit drug dealing. Finally, local self-reliance promotes a feeling of community empowerment. "Those who control our food control our lives, and when we take that control back into our own hands, we empower ourselves toward autonomy, self-reliance, and true freedom" (Flores, 2006).

Despite the importance of urban agriculture in the ecology of the cities, food systems have remained excluded from the planning discipline until recently. Pothukuchi and Kaufman (1999) were among the first to recognize this omission and noted that the urban food system was less visible than other systems such as transportation, housing, employment, or even the environment. They argued that despite its low visibility, urban food system contributes significantly to community health and wellness and metropolitan economies, connects to other urban systems such as housing, transportation, land use, and economic development, and impacts the urban environment. Pothukuchi and Kaufman (2000) conducted a survey of 22 US city planning agencies that provided further evidence for the limited attention given to the food system. They discussed the practical and conceptual reasons why planners should devote more attention to the food system and described several specific ways planners can strengthen the urban food system. Their efforts provoked the American Planning Association to produce its seminal *Policy Guide on Community and Regional Food Planning* in 2007 (APA, 2007). While the omission remains a matter of historical interest, food planning has now emerged as a legitimate part of planning agenda in the developed and developing countries (Morgan, 2009; Morgan & Sonnino, 2010).

Data from urban areas around the world indicate that a significant portion of a locality's vegetable and animal intake can be met locally. In Sarajevo, 2 years after the blockade began in 1992, self-reliance in urban food production was estimated to have grown from 10% to over 40% for vegetables and small livestock (Sommers, 1994). Lee-Smith (2006) found that urban agriculture provided "as much as 90% of leafy vegetables and 60% of milk sold in Dar es Salaam, Tanzania" as well as 76% of vegetables in Shanghai and 85% of vegetables in Beijing. Even in the United States, households produced enough to meet 40% of the nation's fresh vegetable demand during the 'victory garden' movement of World War II (Brown & Jameton, 2000).

Can such high levels of self-reliance be achieved in contemporary North American cities? We conducted a case-study examining the potential of local self-reliance in a typical post-industrial US city, Cleveland, Ohio, in order to serve as a model for the application of the local self-reliance principle. Cleveland was once a major manufacturing center, but with the decline of heavy manufacturing, Cleveland's economy has become more diversified and the service sector has grown considerably. More recently, Cleveland has been facing home foreclosures and resulting vacant lots (Dewar, 2008) and has several 'food deserts,' where fast food restaurants are 4.5 times closer than grocery stores selling fresh produce to the average household (Masi, 2008). In the wake of these challenges, Cleveland has become a home to a growing urban agriculture movement as well as a city government which has embraced urban agriculture as a legitimate use of the vacant land (Masi, 2008).

Therefore, the objectives of this study were to determine the current and potential levels of self-reliance in food for the city of Cleveland and to calculate the potential economic benefits of the increased self-reliance. It is envisioned that the results will advance discourse on urban food production as well as serve as inspiration for city governments to move toward local self-reliance. It was hypothesized that Cleveland can indeed become 100% self-reliant in meeting fresh vegetable, fresh fruit, egg, poultry, and honey demand given current policies and bylaws and data on intake, yields, and available area.

Materials and methods

Estimation of current level of local self-reliance in food

Currently, there are nearly 200 community gardens engaged in vegetable and fruit (fresh produce) production in Cleveland. In addition, there is a 1-acre commercial farm and a few small market gardens. There are also some private home gardens. Current land area devoted to community gardens in Cleveland and the resulting dollar value of fresh produce was obtained from a report prepared by Masi (2008). As data on other sources are not available at this time, we used only the community garden production data to estimate Cleveland's current level of local self-reliance in fresh produce and total food and beverage. The average dollar value was taken as the annual Cleveland production of fresh produce. Given the expenditures for the average household in Northeast Ohio on fresh produce and on total food and beverage each year (Sporleder, 2007), Cleveland's expenditures on fresh produce and in food and beverage was calculated by multiplying the average household expenditure by the number of households in Cleveland. The Cleveland fresh produce production was then divided by the total fresh produce expenditure for Cleveland to obtain percent self-reliance in fresh produce, and the Cleveland fresh produce production was divided by total food and beverage expenditure in Cleveland to obtain percent self-reliance in total food and beverage.

Estimation of potential level of local self-reliance in various food groups

In 'MyPyramid', the United States Department of Agriculture (USDA) divides food into six categories: (1) grains, (2) vegetables, (3) fruits, (4) milk and dairy products, (5) meats, eggs, and nuts, and (6) fats and oils (USDA, 2010). In urban areas, grain production is less feasible due to low yields and consequent large land requirements. Grains are also hardy and capable of withstanding long journeys, extensive storage and minimal packaging, making them prime options for harvesting outside the city (Barrs, 2002). While we will therefore not include grains in this study, city planners could encourage farmers to grow grains as close as possible to their city to minimize long-distance transport. Vegetables are commonly grown in urban areas, and can be grown on any type of lot or even rooftop. Fruits are likewise feasible in urban areas. Cows are not yet permitted in Cleveland, so we chose not to measure dairy or beef production. However, meat can be obtained from chickens, roosters, rabbits, and other small livestock. Eggs can likewise be obtained from chickens, ducks, and turkeys. Finally, while not a dietary requirement, sugar in the form of honey can be attained through beekeeping. Bees will also provide pollination services thus boosting crop yields. We therefore measured potential self-reliance in vegetables, fruits, poultry, eggs, and honey.

In order to determine the potential for self-reliance in food for Cleveland, we applied the following general formula to each food group:

$$\%\ \text{self reliance} = \left\{\frac{\text{Area} \times \text{Yield}}{\text{Intake}}\right\} \times 100$$

The 2010 data on land and rooftop surface area were obtained from the Cleveland City Planning Commission (Kristofer Lucskay, personal communication). Yield (the amount of food produced per unit area) was obtained from multiple published sources, as it can vary based on a number of factors, including climate, gardening technique, and soil quality. One of the most commonly used measures of intake is the United States Department of Agriculture's per capita food availability data system (ERS/USDA, 2010a), which we multiplied by the population of Cleveland (US Census Bureau, 2009) to obtain Cleveland's annual intake of various food groups.

Vegetables

Data on availability and therefore intake for 37 types of vegetables by weight were obtained from the United States Department of Agriculture (ERS/USDA, 2010a). Of these, only one (artichoke) cannot be grown in Ohio, and so was removed from the calculations, resulting in a total of 36 vegetables. The data were separated for both fresh and processed vegetables (including canning, freezing, drying, etc.). Published vegetable yields were found for four different production practices: commercial rural farming (Cleveland, 1997; ERS/USDA, 2010b; Lane, 1992), conventional urban gardening (Cleveland, 1997; Duchemin et al., 2008), intensive urban gardening (Cleveland, 1997; Dervaes, 2009; Duchemin et al., 2008; Lane, 1992; McGoodwin, 2009), and hydroponic urban rooftop gardening (Anonymous, 2007). All yields were from the normal growing seasons at multiple locations and climates, including the US national average (ERS/USDA, 2010b), Seattle, Washington (McGoodwin, 2009), Montreal, Canada (Duchemin et al., 2008), the Sonoran Desert in Arizona (Cleveland, 1997), Ohio (Lane, 1992), Pasadena, California (Dervaes, 2009) and San Francisco, California (Anonymous, 2007). In addition, two sources had data on not only the average vegetable yield, but also specific types of vegetables. The USDA had data on total acreage and production (and thereby yields) in the US for 25 of the 36 vegetables mentioned above (ERS/USDA, 2010b). McGoodwin (2009) collected yield data from a community garden in Seattle, Washington for nearly 80 different species of vegetables. For more than one species of the same vegetable, we took the average yields. Yields were found for 28 of the 36 vegetables from this site. We used the USDA and McGoodwin data to confirm that the other sources were in fact average vegetable yields and not just one very productive vegetable.

Fruits

Data on fruit availability were found for 29 types of fruit (ERS/USDA, 2010a). Of these, 14 can be grown in Ohio. The data were separated for both fresh and processed fruits (including canning, freezing, juicing, drying, etc.). Published yield data were obtained from the USDA for all fruits (ERS/USDA, 2009), which represent commercial rural fruit yields under the average US growing season. No other yields were found.

Eggs

Data on availability of eggs were obtained from the USDA (ERS/USDA, 2010a). These data were separated by both egg consumption directly from the shell and indirectly through egg products. Published yields (eggs per hen per year) were found from a variety of sources. The USDA reported that the average layer in 2004 produced 260.4 eggs per year (ERS/USDA, 2006). The American Egg Board reports between 250 and 300 eggs a year (American Egg Board, 2010). Dual-purpose hens (for both meat and eggs) can produce between 200 and 250 eggs a year (The Small Farm Resource, 2007). According to the 'Chicken and Bees' legislation passed by the Cleveland legislature in February, 2009, residential lots are permitted one chicken for every 800 sq. ft. (about 74.3 square meters), and non-residential lots are permitted one chicken for every 400 sq. ft. (about 37.2 sq. m) (Anonymous, 2009).

Poultry

Data on availability of poultry by carcass weight were obtained from the USDA (ERS/USDA, 2010a). Published yields (carcass weight per chicken) were found from a variety of sources. Jacob, (1998) report weights for Cornish hens (1.29 kg in 4 weeks), fast food (1.86 kg in 6 weeks), grocery store (2.72 kg in 7.5 weeks), and deboned broilers (2.95 kg in 8.5 weeks). Yields were also found for dual-purpose hens. Barred Plymouth Rock hens weigh 3.40 kg and Rhode Island Red hens weigh 2.95 kg after 18 weeks (Poultry-One, 2009).

Honey

Data on availability of honey were obtained from the USDA (ERS/USDA, 2010a). Average yields per manmade beehive were obtained from the San Francisco Beekeepers' Association (2010). Yields for a modified manmade beehive (Stair, 2004) were also used. According to the 'Chicken and Bees' legislation in Cleveland, residential lots are permitted one beehive for every 2400 sq. ft. (about 223.0 sq. m), and non-residential lots are permitted one beehive for every 1000 sq. ft. (about 92.9 sq. m) (Anonymous, 2009).

Scenarios for local self-reliance in multiple food groups

We considered three distinct scenarios for Cleveland to increase its level of self-reliance in multiple food groups. Scenario I utilizes 80% of every vacant lot: 78.5% (equivalent to 80 ft. by 80 ft. of garden, on average) for vegetable and fruit production, and another 1.5% (equivalent, on average, to an 11 foot by 11 foot chicken coop and run) for housing chickens, leaving the other 20% for tool sheds, walkways between plots, and strips next to the road. Beehives are kept on 15% of the vacant lots using the average beehive yield. Scenario II utilizes the same 80% of every vacant lot and then 9% of every occupied residential lot: 7.2% (equivalent to a 20 foot by 20 foot garden, on average) for vegetable and fruit production, and the remaining 1.8% (equivalent, on average, to a 10 foot by 10 foot chicken coop and run) for housing chickens. Scenario III utilizes the same 80% of every vacant lot and 9% of every occupied residential lot and then 62% of every industrial and commercial rooftop for vegetable and non-tree fruit production. All three scenarios are then further sub-divided by vegetable production practice: conventional urban gardening, intensive urban gardening, or hydroponic rooftop gardening. All three scenarios use USDA availability as their measure of intake, the rural USDA yield for fruits, dual-purpose hens for both eggs and poultry and then grocery store broilers for additional poultry, and the average beehive yield. For each scenario the percent self-reliance in fresh vegetable, fresh fruit, shell eggs, poultry, and honey, were calculated by weight. Percent self-reliance in total food and beverage was calculated by expenditure by dividing the total amount of money retained in Cleveland (see below) by the total expenditure (Sporleder, 2007) to permit comparison with the current level of self-reliance.

Estimation of reduction in economic leakage for various scenarios

The amount of money retained in Cleveland for each of the three scenarios was calculated using the following formula for each food group:

$$\text{Amount of money retained} = \text{Total expenditure} \times \text{Percent self reliance}$$

The average Northeast Ohio household's annual expenditures for fresh vegetables, fresh fruits (not including bananas, oranges, and other citrus fruits), poultry, and eggs were obtained from Sporleder (2007). These data were then multiplied by the number of households in Cleveland to obtain the Cleveland's total expenditures on each food group. These expenditures were then multiplied by the percent self-reliance in each food group for each scenario to determine how much is produced locally in dollars. For honey, data was not available from Sporleder (2007), so the average retail price per pound (National Honey Board, 2010) was multiplied by Cleveland's intake (see above) to determine total Cleveland expenditure. This amount was then multiplied by the percent self-reliance in honey in each scenario to determine the amount of money retained in Cleveland. All of these data were then summed to obtain the total amount of money retained in Cleveland.

Results

Cleveland's current level of self-reliance in food

According to the Ohio State University Extension, the 50 acres devoted to community gardens in Cleveland generate between $1.2 and 1.8 million worth of fresh produce annually (Masi, 2008). Cleveland's expenditure on fresh produce was calculated at $89 million a year, and its expenditure on total food and beverage was calculated at $1.5 billion. By expenditure, therefore, Cleveland is about 1.7% self-reliant in fresh produce and 0.1% self-reliant in total food and beverage.

Cleveland's potential level of self-reliance in various food groups

According to the US Census Bureau (2009), the 2009 estimate of Cleveland's population is 431,363. Table 1 shows land lot and rooftop surface areas in Cleveland and it indicates that there are 18,345 vacant lots amounting to 3414 acres of vacant land. There are also 115,714 occupied residential lots, at an average size of 0.128 acres per lot. Finally, there are 2902 acres of industrial and commercial rooftop surface.

Vegetables

Table 2 shows the land requirements to achieve 100% self-reliance in fresh and total (fresh and processed) vegetables for Cleveland using four different production practices (conventional urban gardening, commercial rural farming, intensive urban gardening, and hydroponic rooftop gardening). The data indicate that conventional urban gardening has the lowest yields (1.20–1.35 kg/m^2/year) and thereby the largest land requirements, while hydroponic urban rooftop gardening has the highest yield (19.53 kg/m^2/year) and thus the smallest land requirements. Fig. 1 shows the land requirements to achieve 100% self-reliance in fresh and total vegetables for each practice using the averages of all the sources within each practice. Those averages were: conventional urban gardening (1.28 kg/m^2/year), commercial rural farming (2.42 kg/m^2/year), intensive urban gardening (6.20 kg/m^2/year), and hydroponic rooftop gardening (19.53 kg/m^2/year). Table 3 shows yield data and the resulting land requirement for 100% self-reliance for the 36 different vegetables that can be grown in Ohio using two separate production practices

Table 1
Number and area of residential, industrial, and commercial lots and rooftops in Cleveland[*].

Category		Number	Area (acres)	Average area (acres)
Lots	Total	166,471	42,096	0.252
	Residential	127,482	16,288	0.127
	Industrial	5323	6423	1.206
	Commercial	8261	2846	0.344
Occupied lots	Total	148,126	38,682	0.261
	Residential	115,714	14,844	0.128
	Industrial	2142	5163	2.410
	Commercial	4865	2136	0.439
Vacant lots	Total	18,345	3414	0.186
	Residential	11,768	1444	0.122
	Industrial	3181	1260	0.396
	Commercial	3396	710	0.209
Rooftops	Total	138,701	4463	0.032
	Residential	127,593	1561	0.012
	Industrial	4162	1900	0.457
	Commercial	6946	1002	0.144

[*] Cleveland City Planning Commission, August 10, 2010. The numbers in various categories may not add up to the total because of other land uses.

Table 2
Number of acres required for 100% self-reliance in fresh and total (fresh and processed) vegetables for Cleveland using four different production practices and one or more published sources of yield for each practice and one or more published sources of yield for each practice.

Production practice	Source	Yield (kg/m^2/year)	Cleveland land requirement (acres)	
			Fresh	Total
Conventional Urban Gardening	Cleveland (1997)	1.20	7498.2	15767.0
	Duchemin et al. (2008)	1.35	6665.1	14015.1
Commercial Rural Farming	Cleveland (1997)	1.70	5292.8	11129.6
	ERS/USDA (2010b)	2.62	3440.8	7235.3
	Lane (1992)	2.93	3070.9	6457.5
Intensive Urban Gardening	Duchemin et al. (2008)	5.40	1666.3	3503.8
	Lane (1992)	6.05	1487.2	3127.3
	McGoodwin (2009)	6.30	1428.9	3004.6
	Cleveland (1997)	6.50	1384.3	2910.8
	Dervaes (2009)	6.75	1333.0	2803.0
Hydroponic Rooftop Gardening	Bay Localize (2007)	19.53	460.7	968.8

(ERS/USDA, 2010b; McGoodwin, 2009). The average vegetable yield for commercial rural farming from the USDA (ERS/USDA, 2010b) was 2.62 kg/m^2/year and average vegetable yield for intensive urban gardening from McGoodwin (2009) was 6.30 kg/m^2/year.

Fruits

Table 4 shows that over 5000 acres are required to achieve 100% self-reliance in the 14 different fruits that can be grown in Ohio under commercial rural farming conditions and nearly 10,000 acres are required to meet total (fresh and processed) fruit demand for the 14 fruits. Fruit yields also varied considerably by fruit type, with blueberries yielding 0.17 kg/m^2/year and strawberries yielding 1.30 kg/m^2/year.

Eggs

Fig. 2a shows the number of chickens required to achieve 100% self-reliance in shell eggs and total eggs (shell and egg product) for Cleveland using layer or dual-purpose hens. The data indicate that 274,784 layers or 326,692 dual-purpose hens are required to meet 100% of Cleveland's shell egg demand while 392,793 layers or 466,992 dual-purpose hens are required to meet 100% of Cleveland's total egg demand.

Poultry

Fig. 2b shows the number of chickens required to achieve 100% self-reliance in poultry consumption for Cleveland using either broilers or dual-purpose hens. The data indicate that about 1,000,000 chickens are needed using broilers and about 2,000,000 are needed using dual-purpose hens to meet Cleveland's demand for poultry. Important to note is that 'number of chickens' in fact refers to the number of spots available on a lot for chickens; for instance, if a lot is allowed to have six chickens according to zoning codes and then one is slaughtered for poultry consumption and replaced, that lot still has six chicken spots as opposed to seven chickens.

Honey

The data indicate that about 17,027 beehives are needed using average manmade beehives and 2128 using Stair's modified manmade beehives to achieve 100% self-reliance in honey consumption for Cleveland.

Scenarios for increasing local self-reliance in multiple food groups

Table 5 shows the three scenarios and their resulting levels of food self-reliance. Scenario I, using only vacant land, can meet between 22% and 48% of Cleveland's fresh produce (vegetable and fruit) demand depending on the vegetable production practice used, 25% of both poultry and shell eggs, and 100% of honey. Scenario II, using both vacant land and occupied residential lots, can meet between 31% and 68% of the needed fresh produce depending on the vegetable production practice used, 94% of both poultry and

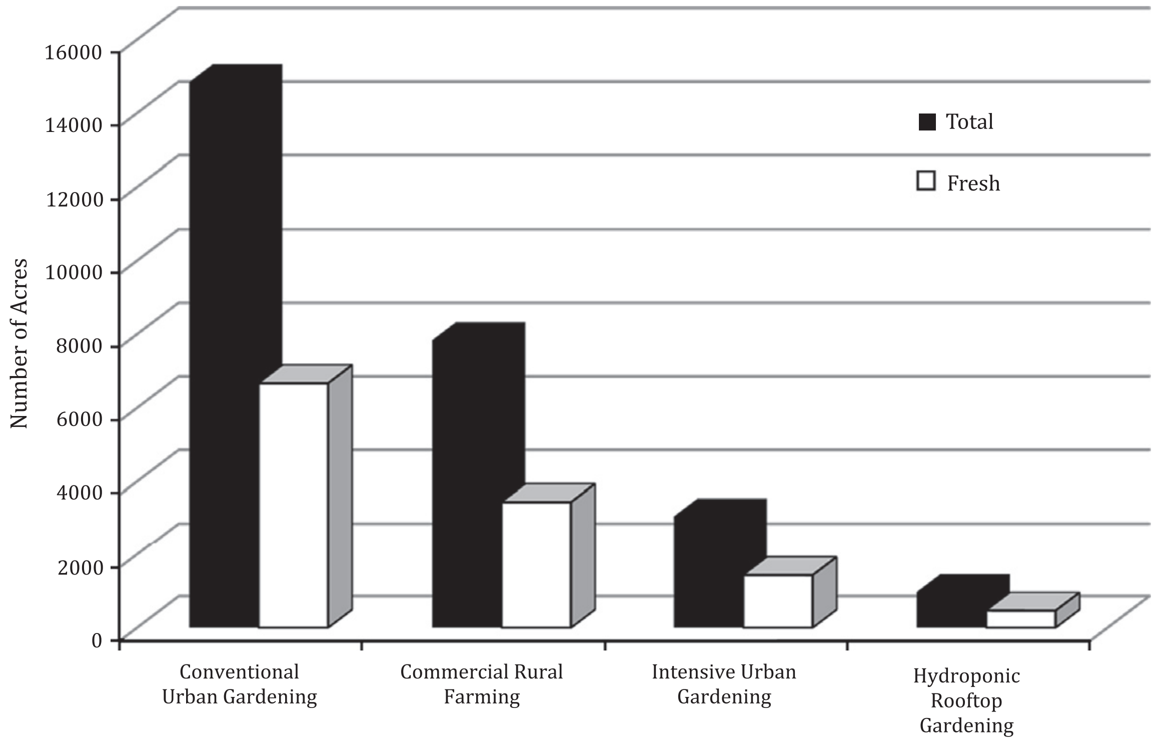

Fig. 1. Number of acres required to meet 100% of Cleveland's fresh and total (fresh and processed) vegetable demand using various production practices and average yield obtained from different published sources listed in Table 2.

shell eggs, and 100% of honey. Finally, scenario III, which adds industrial and commercial rooftops in addition to the land area, can meet between 46% and 100% of the fresh produce need depending on the vegetable production practice used, and 94% of poultry and shell eggs and 100% of honey.

As for self-reliance in terms of total food and beverage consumption, the three scenarios can attain self-reliance levels between 4.2% and 17.7% by weight and 1.8% and 7.3% by expenditure, compared to the current level of 0.1% by expenditure in total food and beverage (Table 5).

Estimation of reduction in economic leakage for various scenarios

Cleveland spends about $44.0 million annually on fresh vegetables, $25.7 million on fresh fruit (excluding bananas and citrus fruits), $36.4 million on poultry, $9.1 million on eggs, and $2.1 million on honey. This amounts to $115.3 million that Cleveland could produce at home given its natural and physical resources and climate. Given the levels of self-reliance per food group for each of the scenarios above, between $28.9 million and $114.7 million could theoretically be retained in Cleveland (Table 5), compared to the $1.5 million it currently retains.

Discussion

This study shows that Cleveland's current self-reliance in fresh produce and total food and beverage is 1.7% and 0.1%, respectively. Although production data were available only for community gardens in Cleveland, other current sources of production such as home gardens and greenhouses are likely small. Self-reliance calculations were also limited to fruits and vegetables, as data on local production of other food groups are not available. Even though the "Chicken and Bees" legislation was passed in February 2009 allowing specific livestock in Cleveland, no data are yet available on how much meat, eggs, or honey is produced within the city. Again the local production of these items is likely small. While levels of current self-reliance are fairly low, the 50 acres used for community gardens to produce vegetables and fruits and the resulting $1.5 million generated locally is not trivial (Masi, 2008).

This study demonstrates that it is indeed possible for the city of Cleveland to achieve considerable levels of self-reliance in fresh vegetable, fresh fruit, shell eggs, poultry, and honey given current policies and bylaws and data on area (land and rooftop), potential yield, and intake. It must be stressed that yields used in this study come from a variety of climatic regions, from Arizona to Montreal, and as a result the exact levels for Cleveland may differ somewhat from the averages used here. However, using even the lowest vegetable yield (conventional urban gardening) and only the available vacant lots, Cleveland would be able to attain 22% self-reliance in fresh produce (both vegetables and fruits), while using the highest vegetable yield (hydroponic production in controlled environmental conditions) and all available land and rooftop area, Cleveland could attain 100% self-reliance in fresh produce. As for chickens, giving every vacant lot a certain number of chickens (according to current legislation) can generate 25% self-reliance in both poultry and shell eggs, whereas by adding chickens on every occupied residential lot as well increases that level to 94%. Finally, 100% self-reliance in honey can be most easily met, with only 2–15% of vacant lots keeping beehives depending on the method used. Overall, the findings of this study correlate well with other studies. Ted Caplow, executive director of the New York Sun Works company, estimates that since New Yorkers eat 100 kg of fresh vegetables on average per year, the rooftops of New York City would provide roughly twice the needed space to supply the entire city using greenhouse vegetable yields (Vogel, 2008). Using intensive vegetable gardening yields, only 1/3 of Cleveland's total rooftops or 1/2 of the industrial and commercial rooftops would be sufficient to meet Cleveland's fresh vegetable requirement. Even less space would be required if hydroponic or indoor factory production is employed. For example, Despommier (2010) calculates that a vertical farm

Table 3
Per capita availability and the number of acres required to meet 100% of Cleveland's demand for individual fresh and total (fresh and processed) vegetables that can be grown in Ohio.

Vegetable	Per capita availability (kg/yr)		USDA yield (kg/m²/year)	Land required for Cleveland (acres)		McGoodwin yield (kg/m²/year)	Land required for Cleveland (acres)	
	Fresh	Total		Fresh	Total		Fresh	Total
Asparagus	0.5	0.7	0.33	172.4	212.9	0.31	187.2	231.2
Dry edible beans	NA	2.9	0.20	0.0	1543.5	4.07	0.0	75.2
Lima beans	0.0	0.2	0.29	0.4	66.1	6.30*	0.1	2.4
Snap beans	1.0	3.5	0.82	141.1	428.8	6.84	14.9	54.0
Beets	NA	0.2	2.62*	0.0	10.0	8.69	0.0	3.0
Broccoli	2.7	3.8	1.77	161.7	227.3	8.95	32.1	45.0
Brussel sprouts	0.1	0.1	2.62*	5.5	6.0	5.86	2.7	2.7
Cabbage	3.7	4.1	4.18	94.7	105.8	4.56	86.9	97.1
Carrots	3.7	4.8	4.69	104.5	126.0	10.50	37.2	48.7
Cauliflower	0.7	1.0	2.03	37.4	51.9	6.30*	9.4	13.0
Celery	2.8	2.8	7.93	38.0	38.0	6.30*	37.2	37.2
Collard greens	0.2	0.2	2.62*	7.0	7.7	6.30*	2.5	2.5
Sweet corn	4.2	11.1	1.57	320.6	737.1	6.30*	55.0	145.7
Cucumbers	3.1	4.5	1.72	154.2	284.5	15.62	20.9	30.9
Eggplant	0.4	0.4	2.62*	14.4	15.8	4.88	8.5	8.5
Escarole	0.1	0.1	2.62*	4.0	4.3	4.88	2.3	2.3
Garlic	1.3	1.3	1.89	71.0	71.0	0.98	137.1	137.1
Kale	0.1	0.1	2.62*	4.9	5.3	6.84	2.0	2.0
Lettuce (head)	7.7	7.7	3.99	204.3	204.3	7.69	106.1	106.1
Lettuce (romaine, leaf)	5.0	5.0	3.07	174.8	174.8	7.69	69.8	69.8
Mushrooms	1.1	1.7	2.62*	41.2	70.3	6.30*	14.6	22.7
Mustard Greens	0.2	0.2	2.62*	5.8	6.3	2.44	6.8	6.8
Okra	0.2	0.2	2.62*	7.7	8.4	6.30*	2.7	2.7
Onions	8.7	10.5	5.49	169.1	203.4	7.06	131.4	158.1
Peas (dry)	NA	0.3	0.16	0.0	211.5	3.25	0.0	10.5
Peas (green)	NA	1.3	0.44	0.0	315.4	3.25	0.0	42.7
Peppers (bell)	4.5	4.5	3.50	136.1	136.1	2.93	162.5	162.5
Peppers (chile)	NA	2.8	1.87	0.0	159.0	4.15	0.0	71.6
Potatoes	16.6	54.5	4.44	399.1	1307.2	7.32	242.1	793.1
Pumpkins	2.2	2.2	2.75	85.7	85.7	30.27	7.8	7.8
Radishes	0.2	0.2	2.62*	8.7	9.6	9.03	2.8	2.8
Spinach	0.7	1.1	2.04	43.5	61.6	2.44	32.0	48.9
Squash	1.9	1.9	1.77	114.1	114.1	11.52	17.5	17.5
Sweet potato	2.3	2.3	2.12	114.4	114.4	6.30*	30.0	30.0
Tomato	8.4	39.2	6.31	270.1	619.5	12.45	71.9	335.8
Turnip greens	0.2	0.2	2.62*	5.6	6.2	32.22	0.5	0.5
Total or average	**84.4**	**177.5**	**2.62**	**3111.9**	**7750.0**	**6.30**	**1534.5**	**2828.4**

NA = not applicable.
* Used the average.

Table 4
Per capita availability and the number of acres required to meet 100% of Cleveland's demand for individual fresh and total (fresh and processed) fruits that can be grown in Ohio.

Fruit	Per capita availability (kg/year)		Fruit yield (kg/m²/year)	Land required for Cleveland (acres)	
	Fresh	Total		Fresh	Total
Apples	7.3	22.1	0.78	999.5	3006.4
Apricot	0.1	0.4	0.37	17.4	121.2
Blackberries	NA	0.0	0.19	0.0	26.3
Blueberries	0.4	0.5	0.17	234.6	349.2
Cantaloupes	4.0	4.0	0.75	569.3	569.3
Cherries	0.5	0.9	0.17	285.3	533.9
Grapes	3.9	9.4	0.44	942.7	2290.6
Honeydew melons	0.8	0.8	0.60	133.0	133.0
Peaches and nectarines	2.3	4.1	0.51	476.5	850.4
Pears	1.4	2.4	0.83	181.0	311.3
Plums and prunes	0.4	1.0	0.31	142.0	349.9
Raspberries	0.1	0.3	0.48	26.9	63.4
Strawberries	2.9	3.7	1.30	239.6	305.0
Watermelon	7.0	7.0	0.89	836.5	836.5
Total or average	**31.0**	**56.7**	**0.56**	**5084.4**	**9746.5**

NA = not applicable.

of the size of a city block can feed 50,000 people with vegetables, fruits, eggs, and meet for the entire year. Therefore, it can be concluded that post-industrial North American cities has the capacity to substantially increase self-reliance in food.

While the measure of intake – per capita availability – is one of the most reliable estimates of consumption (ERS/USDA, 2010a), it has its limitations. Availability measures the total food supply available to a population, and thereby is not an exact measure

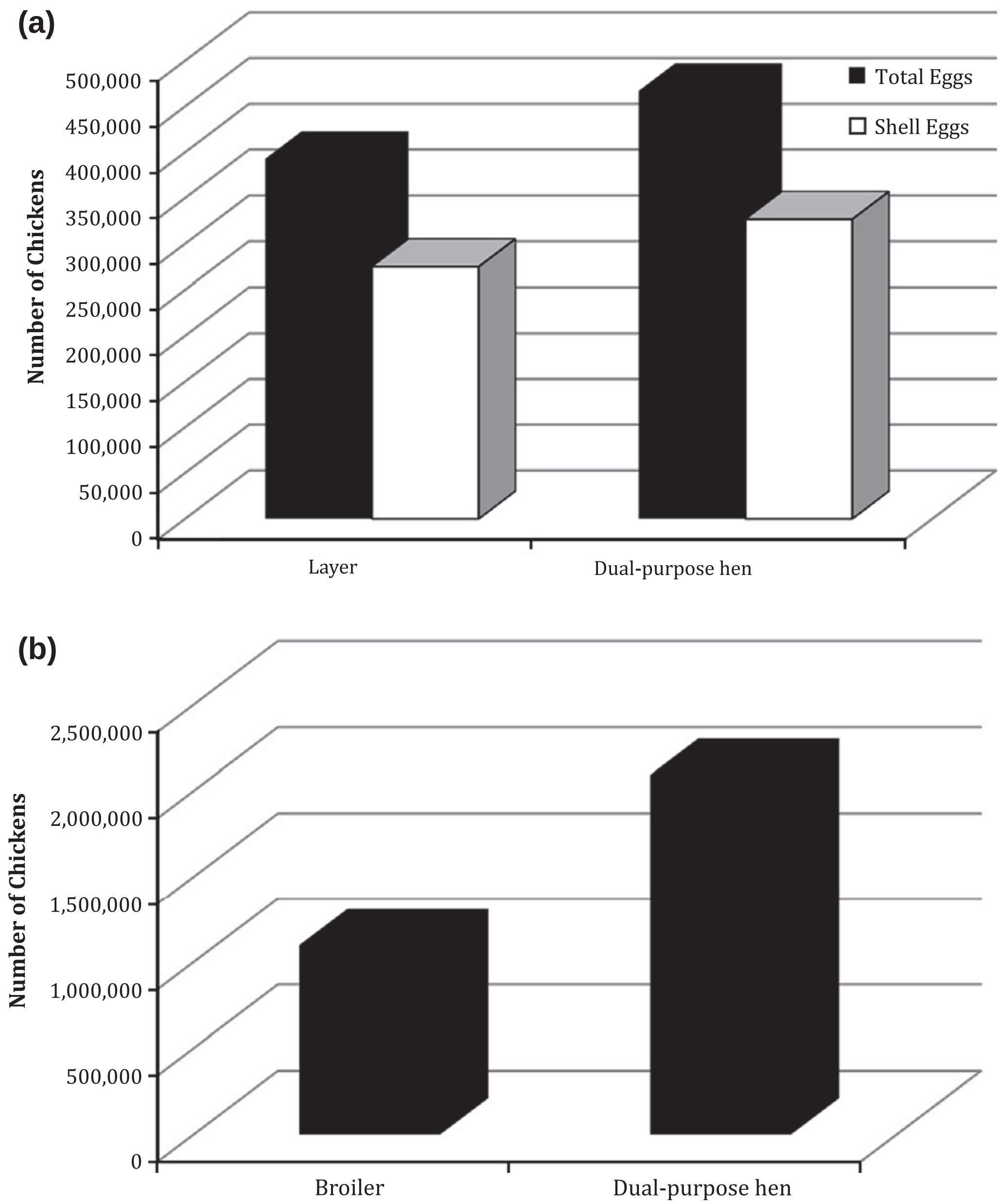

Fig. 2. Number of chickens required to meet 100% of Cleveland's shell egg, total egg (shell and egg product), and poultry demand using layers, broilers, and dual-purpose hens.

of consumption. It includes food that is wasted or spoiled (ERS/USDA, 2010a). It can be argued that with more food produced and consumed locally there will be less food wastage since there will be less loses due to spoilage in transportation of food. Thus, we may need to produce less food for local self-reliance, resulting in even less area needed than envisioned in our scenarios. One measure of intake that excludes spoilage and excessive consumption is the United Nations Food and Agriculture Organization's recommended intake (FAO, 1999). The FAO recommends a minimum of 73 kg/person/year each of vegetables and fruits, compared to the USDA's availability figure of 178 kg/person/year of vegetables and 114 kg/person/year of fruits (ERS/USDA, 2010a). Using these recommended intake data, Cleveland would need even less space to achieve 100% self-reliance in fresh produce. Future research could even calculate the amount of each vegetable or fruit needed to meet human vitamin and mineral requirements.

This study indicates that yield is the key factor in determining what level of self-reliance is possible. The vegetable yields used here appear to be realistic. The multiple published sources used in this study are relatively similar within each production practice even though the yields came from multiple locations and climates, including the US national average (ERS/USDA, 2010b), Seattle, Washington (McGoodwin, 2009), Montreal, Canada (Duchemin et al., 2008), the Sonoran Desert in Arizona (Cleveland, 1997), Ohio (Lane, 1992), Pasadena, California (Dervaes, 2009) and San Francisco, California (Anonymous, 2007). Given this diversity, the average of the sources within each category was used to determine the production potential for different scenarios. Two of these sources gave data on each individual type of vegetable, and the average vegetable yields from these two sources are relatively similar to the yield data from the other sources that were used. This appears to confirm that the other sources also use the average vegetable yield as opposed to one vegetable that has a very high yield. The

Table 5
Percent self-reliance in fresh vegetable, fresh fruit, shell eggs, poultry, honey, and total food and beverage and corresponding money retention in Cleveland for three hypothetical scenarios using three vegetable production practices: conventional (C), intensive (I), and hydroponic (H).

	Scenario 1*			Scenario 2*			Scenario 3*		
	C	I	H	C	I	H	C	I	H
Fresh vegetable**	22	41	48	31	58	68	46	85	100
Fresh fruit**	22	41	48	31	58	68	46	85	100
Shell egg***	25	25	25	94	94	94	94	94	94
Poultry***	25	25	25	94	94	94	94	94	94
Honey***	100	100	100	100	100	100	100	100	100
Total food and beverage	4.2[a]	6.5	7.4	9.3	12.6	13.8	11.1	15.9	17.7
	1.8[b]	2.7	3.0	4.3	5.5	5.9	4.9	6.6	7.3
Money retained (in millions)	$28.9	$42.1	$47.0	$66.6	$85.4	$92.4	$77.1	$104.3	$114.7

* *Scenario 1*: 78.5% of every vacant lot (80 foot by 80 foot garden) for vegetables and fruits, 1.5% of every vacant lot (11 foot by 11 foot chicken coop and run) for eggs and poultry, and 15% of vacant lots having beehives. *Scenario 2*: scenario 1 plus 7.2% of every occupied residential lot (20 foot by 20 foot garden) for vegetables and fruits and 1.8% of every occupied residential lot (10 foot by 10 foot chicken coop and run) for eggs and poultry. *Scenario 3*: scenario 2 plus 62% of every industrial and commercial rooftop for vegetables and fruits.
** Of the vegetables (36 out of 37) and fruits (14 out of 29) that can be produced in Ohio.
*** Given current zoning codes limiting the number of chickens and beehives. Total food and beverage % self-reliance was calculated based on total weight (a) and total expenditure (b). Money retained was calculated based on total expenditure.

high yielding production methods such as greenhouses, hydroponics and indoor plant factories would extend both the growing season and the production efficiency, thus reducing the need for space. For example, a model plant factory, Angel Farm in Fukui, Japan, claims a yield of 165 kg/m^2 through vertical farming and indoor lighting (Dr. Peter Ling, personal communication), compared to the hydroponic yield of 19.53 kg/m^2.

Localization of food will require considerable natural resources including land, buildings, nutrients, and water all of which may have other competing uses. In this regard, city planners, researchers and community leaders may collaborate to identify and realign available resources from within the city to support food production, processing and utilization in the city. Programs could be developed to collect urban food and yard waste to produce compost for use as a nutrient source for the plants, rain water could be collected from rooftops to irrigate the gardens rather than using city water, and waste energy sources from the city could be used to establish structures for extending the growing season. All three scenarios for Cleveland's food self-reliance developed in this study utilize every available vacant lot, which will confront other competing uses and the issues of urban soil quality. Recent research on soil quality in vacant lots and community gardens in Cleveland and other cities in Ohio suggests that soil quality, although variable, is acceptable for planting vegetables and fruits (Grewal, Cheng, Wolboldt, Masih, & Knight et al., 2011). Further improvements in soil quality can be accomplished through amendments derived from urban food and yard waste, thus closing the nutrient loop. Soil contamination particularly with heavy metals is a serious issue which must be addressed carefully. Again preliminary research indicates that less than 15% of the vacant lots in Cleveland had lead contamination levels that could pose a human health risk (Sharma, Basta, and Grewal, unpublished data). Also, there are several ways to manage the risk of lead contamination, including phytoremediation (Blaylock et al., 1997; Zhu, Chen, & Yang, 2004), microbial remediation (Leusch & Volesky, 1995) and chemical stabilization procedures (Basta & McGowen, 2004). In addition, healthy soil can be brought in from elsewhere, as is often done in urban landscaping, which can be used to create raised beds either on top of the contaminated soil or after its removal. Also one could selectively grow crops which have lower propensity to accumulate lead. Research has also shown that the risk of lead exposure is mainly via the inhalation of dust, not so much through the intake of food produced on contaminated soils. Therefore, ecologically sound methods of food production can be devised which keep the soil covered, thus minimizing dust pollution. Alternatively, the contaminated sites may be used to construct above-ground greenhouses, thus eliminating contact with the soil underneath.

Likewise, scenarios II and III require every household to have a 20 ft. by 20 ft. garden, which would mean a great deal of labor and maintenance. Some households already have vegetable gardens, while others could be motivated to plant them as was done in the Victory Garden movement during World War II (Brown & Jameton, 2000). Although it can be argued that households who do not have time may hire a garden care company as is currently done for lawn care throughout North America (Grewal, 2007), it remains to be seen, whether these homeowners will be willing to replace all or part of the their beloved lawn to plant a garden (Pollan, 2006; Robbins, 2007). In scenario III, it was estimated that 62% of every industrial and commercial rooftop would be used for vegetable and fruit production, which may require some rooftops to be refurnished to make them strong enough to hold the weight of the gardens. Finally, the scenarios may have underestimated the available area as some fruit trees could be placed along streets or even in public parks. As the edible landscaping movement grows, more area will be found in cities which could even include patios and windowsills. One must also recognize that the amount and type of food a community consumes can vary with culture and current trends. Advertising and education can shift consumption trends and may help to reduce excess consumption, promote vegetarian diets, and increase preference for local food over imported food, thus aiding in the promotion of local self-reliance. In short, the onus is not all on the producers – consumption habits can also change which can lead to greater self-reliance in food and promote healthy diets and life styles.

Finally, localization of food would also require considerable financial capital, government involvement, public commitment, and labor. In this context, the city governments, planners, and non-profit organizations can play a big role. Even if a city does not reach 100% self-reliance, there are significant economic benefits to increasing the level of local food production. This study shows that reduction in annual local economic leakage for Cleveland would be between $29 M and $115 M depending on the scenario considered. Such directly saved money can fuel local economies through its direct and indirect multiplier effects. Also, there are numerous other benefits to local self-reliance in food, including the improvement of human health, the reduction of the human impact on the environment, and the promotion of a sense of community. Therefore, city governments can mobilize local, state and federal resources to promote local self-reliance in food to stimulate local economic development, enhance overall food security and access to healthier food, and generate employment and entrepreneurial opportunities for residents in the food system. City governments can create grants and loan programs to facilitate the initial establishment of gardens and local food businesses covering the entire supply chain from production to consumption. The city governments and planners can work together to create policies to define urban agricultural overlay districts/zones with more conducive policies and land tenure (5–10 years leases) to facilitate the establishment of community and market gardens, greenhouses, vertical farms or plant factories, and conventional farms. City governments can also use federal stimulus money focused on "brown field" (old industrial/commercial sites) reclamation to create new land resources for the establishment of local food businesses or unrelated businesses just competing for land or space. In addition to the above benefits of food localization, the production of food using the newly discovered urban resources will increase resource use efficiency and contribute to global food security in the wake of burgeoning human population which would require additional farm land to feed.

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