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Original Research Article

Mapping the growing capacity of climate smart food in urban environments

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Abstract

The practice of urban agriculture (UA) is a unique food system model that localizes the production of sustainable, geographically appropriate food. The environmental benefits inherent in UA align with the emerging field of climate smart agriculture (CSA). However, the agro-industry focus of CSA is beyond the scope of most UA initiatives. Instead, we put forward the term *climate smart food* as a more appropriate framework to examine the environmental impact of food production in an urban context. The purpose of this study, rooted in the recognition of underutilized private urban land resources for UA, is to assess the potential of urban land to grow climate smart food. The Bowness neighbourhood in Calgary, Alberta is used as a case study. A geospatial process of constraint mapping was applied to analyze suitable private land space that could be converted from lawns to cultivated gardens. Using data from a local food cooperative as a benchmark for local urban production capacity, it was determined that six urban farms in Calgary produced roughly 8,200 pounds of food from private gardens in 2016. In the Bowness neighbourhood, 42 percent of the land was held as private turf grass, and produced only about 800 pounds of food. This type of analysis serves to quantify the magnitude of underutilized land within an urban boundary that could produce significant amounts of climate smart food.

Keywords: climate smart food, urban agriculture, climate smart agriculture, GIS, spatial analysis, constraint mapping

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Introduction

The practice of urban agriculture (UA) offers a unique model for a food system that localizes the production and consumption of predominantly plant-based food within an urban boundary. UA is mainly practiced through the conversion of both public and private land into plots of intensive cultivation of vegetable and fruit crops (Eigenbrod & Grude, 2015; Huang & Drescher, 2015). Multiple studies have explored the range of initiatives and the effectiveness of UA in order to address rapid urbanization and the concomitant need to feed growth in cities across the globe (Galhena, Freed, & Maredia, 2013). To meet the world's future food supply, food production needs to increase while reducing the environmental footprint (Foley et al., 2011). In addition to the perspective that urban food spaces offer therapeutic places and activities for people to "de-alienate" themselves from their food (McClintock, 2010) and create an urban food community (Scharf, Levkoe, & Saul, 2010), there is growing evidence that locally grown urban food can contribute, albeit marginally and variably, to urban food security; notably infusing fresh seasonal produce to diets (Kortright & Wakefield, 2011).

Opportunities exist for municipalities to incorporate UA into improved policies that enhance a local food system (Huang & Drescher, 2015). These policies can be built on the premise that plentiful food that is geographically appropriate can be grown in limited space (Mok et al., 2014). Food produced in vacant and underutilized urban spaces can be critical to reaching food security targets and reducing the emissions intensity of agriculture (Eigenbrod & Gruda, 2015). A key incentive of UA promotion should be based in the idea that the way we produce and consume food has an impact on climate change related emissions. The UA framework is an aspect of *climate smart agriculture* (CSA) that is worth pursuing because it challenges assumptions about where and how food is grown and distributed.

CSA aims to be a transformative structure for agriculture to develop, adapt, and thrive within the uncertainty posed by climate change (Lipper, et al., 2014). A CSA lens points out that the climate crisis will have huge consequences on the global food system, and is designed as an appropriate framework to support climate resilient pathways to sustainable agro-industrial food systems (Gliessman, 2014). According to Dubbeling, Hoekstra, Renting, Carey, and Wiskerke (2015), integrating the ideas of CSA and UA requires that urban food systems shift away from production methods or technology, and refocus on the food being produced and consumed within the city. The introduction of the term *climate smart food* (CSF) is useful to address the environmental impacts of food beyond agro-production to include food choice, alternative land use, transportation, and consumption. We define CSF here as "appropriate and adaptable food that is deliberately produced and consumed locally because of its associated low-carbon intensity".

This paper presents a case study of Calgary's urban food system, addressing the role UA has in developing CSF locally. Specifically, this project uses vegetable production data in the Bowness neighbourhood to extrapolate growing potential in a limited city zone. The main premise is that there are underutilized private urban land resources that can be managed through sustainable intensification to produce CSF. The geospatial output shows the amount of suitable private land available for UA in Bowness, as well as 2016 yield data for known gardens in the neighbourhood. This research serves as a foundation for analyzing and tracking the impact of UA in city boundaries, while refocusing the conversation on the climatic impact of food production and consumption.

The emergence of climate smart food

Urban agriculture

While urban agriculture (UA) is not a new trend, it is attracting increased interest as a solution to both food insecurity and reducing greenhouse gas emissions in the agricultural sector (Kortright & Wakefield, 2011; Mok et al., 2014). The overarching characteristics of UA are: dispersed and heterogeneous plots within a metropolitan boundary, predominant focus on vegetable crops, intensive cultivation in small-spaces (less than one acre), and a food system that links local growers to local consumers. Characteristics of UA can be parsed into specific actors, scale and location, market orientation, growing technology, and down to the horticultural products themselves (Eigenbrod & Gruda, 2015). In North America, cities from Detroit to Dartmouth, Chicago to Calgary all have instances where traditional concepts of farm and city have merged.

The connection between backyard food spaces and increased food security has roots in the Victory Gardens of World War II. These gardens were patriotically promoted as crucial to the war effort in the United States, and at the peak of production, these gardens accounted for 40 percent of the nation’s vegetable supply (Mok et al., 2014). Victory Gardens were grown coast to coast, providing food, employment, and purpose for people affected by the war. High intensity UA has a tendency to arise from crisis, such as in Cuba, when economic sanctions essentially forced residents to convert all available land to agriculture for basic food security in the early 1990s (Altieri, 1999).

The intensive production of vegetables and food crops within a peri-urban boundary has been a response to the rapid population growth in cities, and the concomitant need to feed that growth. Global food production will need to increase by 60 to 70 percent by 2050 (FAO, 2017), while the suitable land resources are decreasing**.** With an estimated 600 million people globally engaged in UA (Kortright & Wakefield, 2010), UA is in a strategic position to help meet that demand. Although the research base is growing, the potential for urban landscape changes through UA to meaningfully address that growth in food demand is unknown.

Urban agriculture can be distinguished from conventional rural agriculture beyond the criterion of farm location only. The Food and Agriculture Organization (FAO) recognized the distinctiveness of UA (Mougeot, 2000), where urban food production is embedded in a diversified economy rather than agrarian culture. This difference is important because rather than a high percentage of the population engaging in subsistence growing, UA addresses a market shortage of appropriate food. Within these heavily managed spaces, the potential to advance urban food security and reduce environmental impact is substantial.

In developing nations, urban food cultivation is an extension of rural farmers bringing traditional practices with them as they urbanize. This differs from cities in developed nations, where urban agriculture has risen as a market response, and a push toward local economies that is promoted by varying levels of government. A common definition of local food was popularized by the "100 Mile Diet" (Smith & MacKinnon, 2007). UA can be described as *hyper-local*, which refers to the production and consumption of food within an urban boundary; shifting the focus from food miles to food feet. The global South has dominated research outlining effective UA policies and practices, with information in the Canadian context especially limited (Huang & Drescher, 2015). Taylor and Lovell (2014) have outlined the future research directions of North American UA, with an explicit focus on the understudied home-food gardens because of their durability and the ease of conversion from lawn to garden.

There is no definitive literature on the economic impact of UA. Home gardens are integral to supporting food production worldwide; and through targeted proliferation, they can play an important role to increase food security from global price shocks and natural disasters (Galhena et al., 2013). A useful exercise for policy makers would be to determine the economic linkages of a well-developed system of UA food, from employment of farmers to the success of restaurants serving hyper-local produce. A thorough analysis would show the monetary benefits that a local food economy brings to a community. Data is provided later in this article on the total output of six urban farms in Calgary, and the associated value of their products. It is evident that UA in underutilized backyard spaces has created economic opportunities; and, as this research shows, the land resources are available to fully develop such opportunities.

In Toronto, the contribution of edible gardens has been shown to increase food security at various income levels (Kortright & Wakefield, 2010). It has been estimated that potential yields of up to 50 kg/m^2 of vegetables in global urban horticulture are sufficient to meaningfully contribute to food security (Eigenbrod & Gruda, 2014). Mok et al. (2014) have identified five areas that need further attention in the connection between UA and food security. The most pertinent factors they identified were the loss of peri-urban agricultural production from urban sprawl, the carbon footprint of food miles, and reasonable definitions of urban self-sufficiency. However, the connection between UA and food security is not straightforward, with detractors stating that overall, UA contributes very little to food security, and potentially, even food sustainability (Edwards-Jones et al., 2008).

Climate smart agriculture

CSA has emerged as an umbrella term to describe food systems that increase productivity, encourage adaptive technologies, reduce greenhouse gas emissions, and help meet food security targets (FAO, 2017; Lipper et al., 2014). CSA is the simultaneous improvement of food security and efforts to mitigate climate change (Scherr, Shames, & Friedman, 2012). The concept of CSA unites the communities of international development, agriculture, and climate change. Because of its broad appeal, however, it can be criticized for vague connections (Neufeldt et al., 2013).

There are a series of suitable tools available to support CSA, notably the FAO *Climate Smart Agriculture Sourcebook* (FAO, 2017), and the *Climate Smart Agriculture Rapid Appraisal (CSA-RA) Prioritization Tool* developed by Mwongera et al. (2014). The rapid appraisal method is designed to establish baseline understanding of CSA in a region. This includes an agricultural snapshot, an assessment of impacts, recognizing the most suitable CSA practices, and appraising the policy and financial aspects (Mwongera et al., 2014). Both the *Sourcebook* and the *CSA-RA* compile a global list of CSA projects, which is a useful model for agricultural organizations and researchers to implement CSA projects. However, the majority of cases come from developing nations, and none specifically address the Canadian context—further emphasizing why the present study is important. A possible reason why there are few CSA projects and data in developed nations could be the inherent differences in agriculture production. Farmers in developed countries have more access to technology and financing to make changes in production, and as a result have a lower risk to a changing climate.

The three overarching objectives of CSA (FAO, 2017; Lipper et al., 2014) are: (1) sustainably increasing agricultural productivity to support equitable increases in incomes, food security and development; (2) adapting and building resilience to climate change from the farm to national levels; and (3) developing opportunities to reduce greenhouse gas (GHG) emissions from agriculture compared with past trends.

To be considered “climate smart”, UA should seek to integrate each of these objectives. The first objective, increasing productivity, is a necessity due to the limited land available in an urban environment. Examples of increasing productivity can be seen in indoor growing through aquaponics and *small-plot-intensive farming* (SPIN) often found in UA. SPIN is a set of horticultural techniques designed for private yard spaces smaller than one acre, and many urban farmers in Canada follow this model (Newman, 2008). UA has a clear focus on extracting the highest yield in the smallest space possible. SPIN farming requires little land by utilizing borrowed or rented backyard space. The capital inputs are considerably lower than in a conventional rural vegetable or grain farm.

Next, *resilience* can be defined as “the capacity of a food system to absorb and manage the adverse effects of external stress and shocks” (FAO, 2017). Likewise, *food security* can be defined as follows:

> …the ability of a community to meet the dietary needs of its people year-round with food that is nutritionally varied, seasonally appropriate, and not susceptible to global price shocks. It is the ability to prevent, mitigate, and recover from agricultural shocks in weather or markets. Changes in trade policy, severe drought or weather in a regional supplier, or any event that can limit the flow of food to a city can impact the resilience of that food system (Barthel & Isendahl, 2013).

In Canada, a significant amount of our total food comes from imported sources. Resilience in a food system means that agro-climatic impacts beyond the consumer's borders, including where that food is imported from, are considered. A major drought in California or Mexico, for example, could seriously impact food availability in Canada. By building the food growing capacity in a city, the reliance on imported food decreases, and so do the risks associated with importing vegetables over thousands of kilometers. Effective UA is well poised to increase urban resilience (Barthel & Isendahl, 2013).

The third objective of CSA is reducing GHG emissions from agriculture. The environmental benefits, including GHG reduction capacity, of a local food system have not gone unquestioned. From a scientific perspective, it is nearly impossible to formally test whether local food is more sustainable than non-local food. The arguments made in favour of promoting local food often centre on reduced food miles and a smaller carbon footprint, and increasingly, the carbon sequestration potential of agricultural soils, which is addressed below (Edwards-Jones et al., 2008; Weber & Matthews, 2008). To make the argument that UA can be climate smart, accurate estimates of carbon accounting are increasingly necessary. A common way to address the environmental benefits of a local food system is through a spatially explicit life cycle assessment (LCA) (Edwards-Jones et al., 2008; Koerber, et al., 2009). A LCA gathers the relevant knowledge to determine the environmental impact of a product, from its initial resource extraction (cradle), to its disposal (grave). The food chain produces GHG at all levels of the life cycle, but it is the agricultural stage that emits the most greenhouse gases (Edwards-Jones et al., 2008).

Finding the best opportunities to reduce GHG emissions in the food chain is important. Advancing technology is promising, but the single most important factor is shifting diets from GHG intensive food like meat and dairy products, and specialty food such as surf n' turf (Garnett, 2011; Kauffman, et al., 2017), emphasizing that food choices matter. Aside from providing diet alternatives, there is a huge opportunity for reduction and removal of GHG in the context of UA by shortening food transportation distances, eliminating heavy machinery use, and land-use conversion from high GHG uses such as urban turf, which requires GHG intensive maintenance such as mowing (Selhorst & Lal, 2013; Townsend-Small & Czimczik, 2010).

There is an increased awareness of the potential for agricultural soils to store carbon through soil carbon sequestration. It is estimated that global agricultural soils can offset one-quarter to one-third of anthropogenic increases in carbon emissions through intensive management (Lal, 2004). However, this is an unlikely priority of UA given its very small footprint. Calgary, with one of the largest land areas of any city in North America at over 200,000 acres, has a meager amount of cultivated land compared with the broader agriculture sector in Alberta. Even with the best practices of building long-term soil carbon through biomass accumulation and conservation tillage, the capacity of UA is insignificant when compared to larger scale agro-ecosystems and broad acre commodity farming. Research to reduce GHG in the atmosphere through agricultural soil sequestration should focus on a scale larger than UA, and research to reduce GHG in the urban environment should focus on transportation, heating, and lighting the city.

Climate smart food

Projects promoting CSA have not traditionally targeted UA; the risks from a changing climate are weighted against rural smallholder farmers in developing nations, or large-scale agro-industry. However, it is necessary to build the resilience against climate impacts at all scales of the food system—from hyper-local to agro-industrial, and from urban to rural. Given a global trend toward increasing urbanization and the growing evidence that food choice matters (Wallén, Brandt, & Wennersten, 2004), a CSA framework is an important lens through which to view and inform UA. However, there is inadequate information to support decision making for urban CSA. The potential of urban agriculture to provide food security while reducing the environmental impact of food production is not well understood (Taylor & Lovell, 2012).

A promising intersection for the two fields is outlined in the move from CSA to climate-smart-landscapes, defined by Scherr, Shames, and Friedman (2012). The key features of a climate smart landscape are diversity of land use and effective management. A landscape approach seeks to manage the synergies between the ecological, social, and economic aspects of agriculture and to recognize the key role of individual households as environmental stewards. To achieve a climate smart landscape, technical capacity must be built, political support actualized, and the spatial and planning component strengthened. However, a landscape framework does not consider the conceptual value of food in the goal of reducing emissions.

Due to the many forms and scales that UA can take (from community gardens to edible skyscrapers), the relevance of UA to CSA and climate smart landscapes, and the unique focus on food, we propose that a "climate smart food" perspective would be more appropriate to understand the intersection between climate smart and urban food. As mentioned earlier, we have defined climate smart food as "geographically appropriate and adaptable food that is deliberately produced and consumed because of its associated low-carbon intensity". The geographic component of CSF generalizes that food is seasonally and climatically appropriate and is consumed as close to the source of production as possible. A broad understanding of the environmental impact and GHG emissions released from the production and distribution of agricultural products should become an important factor when making food choices. Through these deliberate choices, consumers can impact where and how food is grown. Wallén et al., (2004) and Weber and Mathews (2008) both address other environmental considerations that influence food choices. CSF, a blending of CSA and UA concepts, differs from CSA because it enunciates the decisions from production to consumption at a local level, rather than at the agro-farm food manufacturing level. CSF differs from UA because it extends beyond location, that is, "urban", to consider and reduce the environmental impact of the food produced. A study conducted in Sweden found that "dietary choices, as they relate to the reduction of greenhouse gas emissions, will not produce any changes in the level of emissions without necessary changes in the existing production methods in farming, processing, and distribution" (Wallén et al., 2004, p. 7). However, it is in an urban environment that we are able to balance food production and food choice; shifting the conversation from CSA in an agricultural setting to CSF in an urban setting actively involves consumers from production practices that are climate friendly to food choices that are locally-appropriate. Indeed, a CSF approach can strategically facilitate the maximized strengths of both CSA and UA.

Methodology

Mapping food environments

Utilizing the power of geographic information systems (GIS) to understand food economies and agricultural patterns gives researchers, government, and farmers the ability to make informed food production and distribution decisions. Food mapping is useful to understand the interlay of social, environmental, and economic systems that make a food system. Mapping the food environment, increasingly in the form of web-maps, is important at various scales. Sweeney et al. (2016) present a thorough review of methodologies used in food mapping, summarizing the methods of 70 recent food web-mapping projects. The purpose of this mapping project was to determine available private land that could be converted from lawn to cultivated gardens in a neighbourhood. The use of mapping supplements the CSF framework presented because it shows the simplicity and potential abundance of a climate-smart-urban food system.

Ecological studies of urban biodiversity have largely ignored the urban backyard as a habitat space, despite the fact that it makes up the largest proportion of green space in many urban areas (Gaston et al., 2005). To determine the total area of specific backyard space available within an urban boundary, various methods have been used with different accuracy levels and time commitments. In the city of Dunedin, New Zealand, high resolution IKONOS satellite image with an automated object orientated approach was used to classify urban gardens with an overall accuracy level of 77.5 percent (Mathieu, Freeman, & Aryal, 2007). The research revealed that 46.4 percent of the residential land area was held as private gardens. However, it was noted that it could take more than one year to map an entire city using their approach. Using a similar method with IKONOS 3.2 m multispectral resolution, urban vegetation categories were segmented with 87.7 percent accuracy in Nanjing China (Zhang, Feng, & Jiang, 2010).

Taylor & Lovell (2012) used high-resolution aerial images in Google Earth to map the extent of UA in Chicago. While tedious, their approach of manual interpretation and polygon extraction of identifiable urban gardens across the entire city resulted in an accuracy of 85-96 percent depending on the extent of ground-truthing. For their assessment, their indicators of a garden space were: an orthogonal garden layout, definitive rows of vegetation, and indications of bare soil or mulch between rows. These polygons were classified by size into three categories, and when totalled, they found that 208,225 m^2 of the city were dedicated to urban food production. On a sobering note, it took 400 hours of analysis to map the entire city with this method.

Despite this limitation of the Chicago method, manual interpretation "may be the only suitable strategy for identifying such a diverse and fine-scale urban land use as urban agriculture, particularly at the scale of the home garden" (Taylor & Lovell, 2012, p. 59). It is worth exploring unsupervised image classification of a high-resolution satellite image. In their discussion, Taylor and Lovell (2012, p. 68) also state that "future advances in remote sensing, such as computer-assisted photo interpretation and geographic object based image analysis, may allow for faster and accurate automated or semi-automated classification of sites at scales as fine as the residential garden." In Philadelphia, researchers combined remotely sensed and traditional vector based imaging to map the urban food network (Kremer, 2011). Using both methods gives a more complete understanding on the potential of urban areas to support food production.

Using geospatial technologies to illustrate the various components of a food system is useful for farmers, planners, and other stakeholders. Specific to urban agriculture, food mapping should move beyond the creation of a land inventory and a categorization of suitable spaces. Mapping methods offer many possibilities to explore an urban food system, such as: neighbourhood-level crop rotation, disparities in food access between neighbourhoods, or transportation and supply chain optimization.

Study site: Urban agriculture in Calgary

In 2012, a collaborative effort resulted in *Calgary Eats: A Food System Assessment and Action Plan for Calgary* (City of Calgary, 2012). This document outlines the City's vision for a sustainable food system. This conclusive effort outlines the steps needed for a land inventory analysis, but only went as far as plotting the location of individual community gardens. While important, the potential of private spaces spread over a community poses less bureaucratic obstacles than using city land to grow food. The report noted that in 2012 there were 390,629 low-density residential properties in the city. Based on the sample neighbourhoods of Rundle and Evergreen in Calgary, it was estimated that an average yard size across Calgary is 453 m^2. This translates into approximately 17,700 ha of land available for food production. However, this does not extract features that impede food production, such as trees, slope, and orientation. Calgary has a broad geography of soil types and microclimates, and not all neighbourhoods are suitable for food production.

In Calgary, there is a strong movement of consumers choosing locally grown produce, which has driven the supply side of UA to convert backyard spaces into SPIN farms. Farmers are able to grow a broad range of vegetables, with some of the highest returning products being leafy greens. *YYC Growers* is a cooperative that brings together 20 local farmers, six of which grow exclusively within Calgary. They link local produce with consumers through restaurant sales and a 500-person weekly food box program. In a traditional community shared agriculture program, the risk is taken by one farm supplying vegetables for shareholders. The cooperative model with many suppliers decreases risk of crop failure at a single farm, and allows the program to benefit more people through an economy of scale. While not the only group promoting UA in Calgary, *YYC Growers* are the most visible and active group in the city.

Through summer working arrangements with the organization, data was collected on how much of each vegetable product was harvested and sold for each of *YYC*'s six urban farmers. This data was compiled through their online sales tracking platform, Local Orbit, which records sales weight and price for each transaction that took place for the 6 farms. Specific to the analysis, Leaf & Lyre Urban Farms is the largest urban farming operation in Calgary, and grows out of 30 private backyards, 11 in the community of Bowness.

Calgary data

Due to the large spatial extent of Calgary's footprint, a whole-city analysis was not feasible for this study. Instead, we estimated growing capacity by exploring a case study of urban agriculture in the Bowness neighbourhood using parcel data created by the City of Calgary. Bowness is an established neighbourhood in NW Calgary, with a standard low-density suburban model that has been built up since the 1950s. Originally a separate community from Calgary, the neighbourhood has a low-rise mixed commercial zone, its northern boundary is the Bow River, and a railway crosses through the community.

Bowness was chosen because of available data on the number of urban gardens in the neighbourhood, obtained from Leaf & Lyre Urban Farms. Data was collected through the growing season by the author and other farm employees, between May 1st and September 30th, 2016. Leaf & Lyre manages over 30 backyard plots throughout the city, with 11 in Bowness. The cultivated area of each plot was measured, and the addresses recorded. Post-harvest weight from the specific yard was recorded with a scale after each picking. Manual records were corroborated with the digital sales data. The different products span kale, potatoes, chives, carrots, and other vegetables. A full list of the vegetables grown by the urban farm is available in section 4.2. Weights of vegetables were treated equally; that is, dense roots vegetables and squash varieties were treated the same as leafy greens and boutique herbs. Where harvested masses were missing, sales receipts were used to fill in the gaps. Because most gardens employ a diverse planting regime through the season, it was not possible to attribute specific products to the exact garden. It is important to note that these measurements represent harvested weight, and not total biomass grown, which is certainly more.

The geospatial data for the cartographic output was collected in the winter of 2017. City parcel data was obtained through the Spatial and Numeric Data Services at the University of Calgary. The files were created by the City of Calgary between 2012 and 2014. Parcel data includes vector shape files for buildings, the tree canopy layer, the Bowness outline, and green space for each privately-owned land parcel. Additional shape files were obtained from the City of Calgary Open Data resource. This included publicly owned park space, such as riparian boundaries and managed sports field and park space, as well as a railroad vector line file. These files were projected in the three degree Transverse Mercator (3TM WGS 1984 W114) projection, with a central meridian set at 114 degrees longitude. All maps must be set in a specific projection, with 3TM being the standard for accuracy in Calgary.

Methods

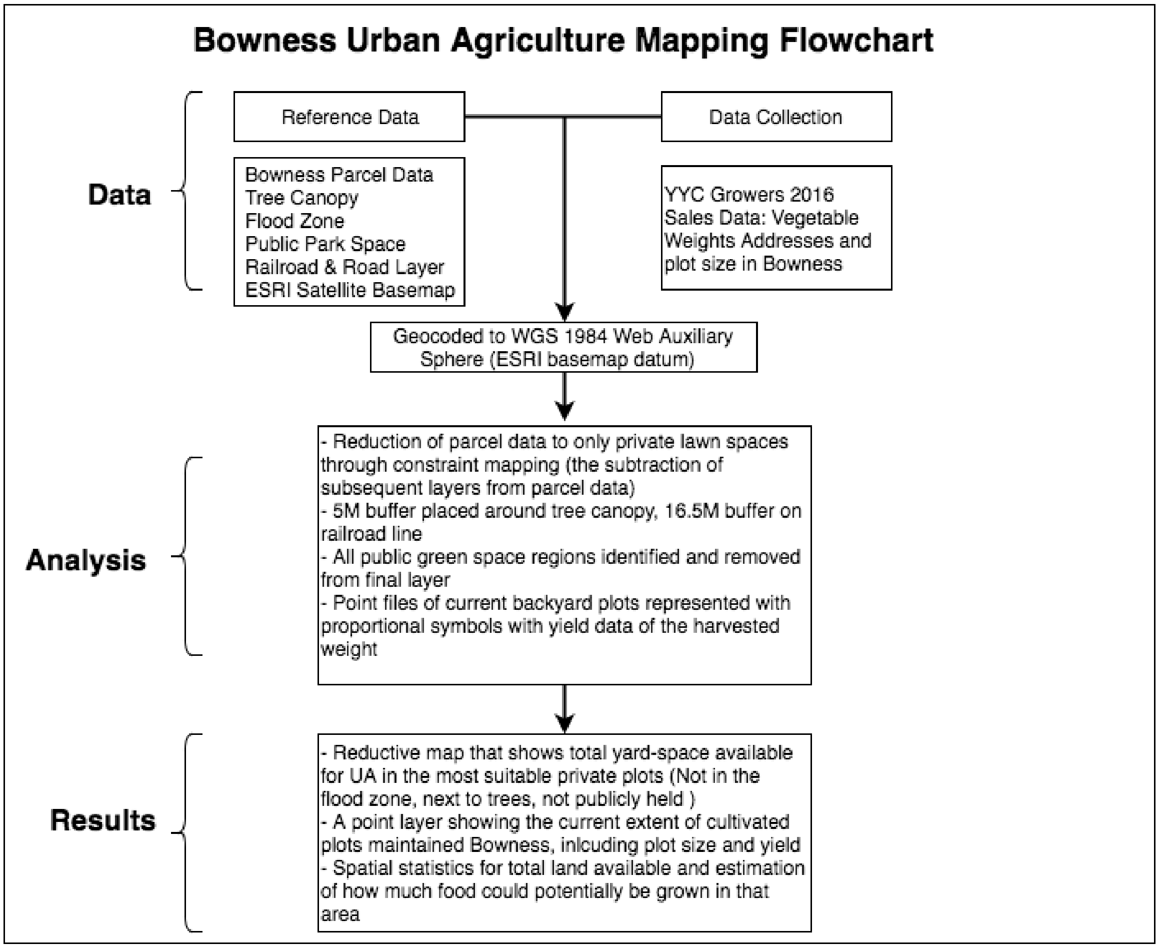
The purpose of this mapping project was to determine available private land that could be converted from lawn to cultivated gardens. The area of available land put forth in Calgary Eats was calculated simply by subtracting building parcels, ignoring the many nuances of a suitable site. While others have applied object-orientated approaches to satellite images to map urban backyard space (Mathieu, et al., 2007; Zhang et al., 2010) the process is beyond the scope of this project. In this study, an estimate of the available private green space, currently expressed predominantly as backyard turf lawns, was used to estimate possible vegetable production in the neighbourhood. Through *constraint mapping* (the process of subtracting the area of undesirable data from the underlying and desirable base map), the amount of suitable yard space for UA in Bowness was identified. This was reflected in the space of individual parcels without the constraints of buildings, tree canopy, or other built up features and public land.

The City of Calgary green space parcel shape-file was used as the defining base. The assumption was made that most of this land, where not built up, is managed turf grass. The buildings, public green space, railroads, roads, and tree canopy were applied as constraints, each reduced from the base layer using the Erase tool in ArcGIS version 10.0. This sequence of steps creates a base layer that is reduced in variables to the one that is most desirable. This process created over 3,000 individual polygons that are predominantly composed of underutilized turf grass.

A five metre buffer was placed around the tree canopy layer because of a common gardening heuristic; the well-established trees in Bowness provide too much shade and outcompete a garden for water and nutrients. A 16.5 metre buffer was also placed on the both sides of the railroad line to accommodate the width that this linear feature takes up.

From an aerial view, the available public park layer, representing sports fields and other lawns managed by the City of Calgary, is not easily distinguishable from the green space of private parcels. Subtracting this layer is an imperfect measurement of the total land that is publicly managed. Because this map is largely conceptual, it was deemed sufficient for the accuracy needed for this map.

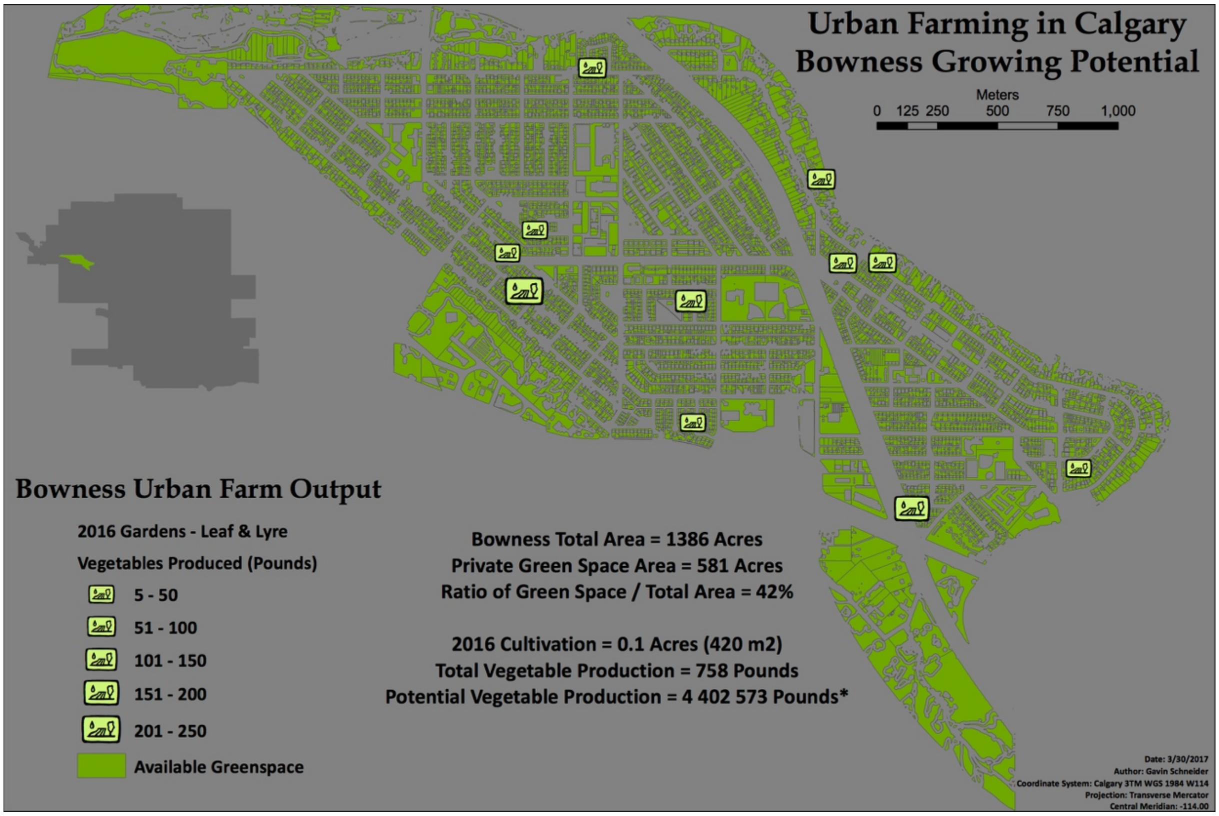
Figure 1: Workflow of the data collection and analysis to produce a potential urban food map.



To assess accuracy, the resulting polygon was placed over top of the high-resolution ArcGIS satellite image base map with a high transparency. Polygons that remained that were clearly not representative of a managed lawn were removed. In the absence of time available to ground truth the data, these site-specific judgment decisions improved the accuracy, but not in any measurable way. The flowchart in Figure 1 summarizes the methodology through data, analysis, and results.

Specific yards in Bowness that were farmed by Leaf & Lyre in 2016 were plotted on the map as single point files. The 11 addresses were converted to a geospatial coordinate (geocoded) to fit the 3TM projection, which is the standard projection in Calgary. The harvested yields that were weighed and recorded for each order that went out, as described in section 3.2, were correlated with the 11 plots. These points were then represented through how much harvestable product they generated. The differences were displayed using a proportional symbol correlated to the yield.

Figure 2: The amount of private land available for urban agriculture in Bowness, as well as 2016 production data. The map was produced through the constraint mapping of city parcel data.
*Based on maximum yields from all private green space



Results

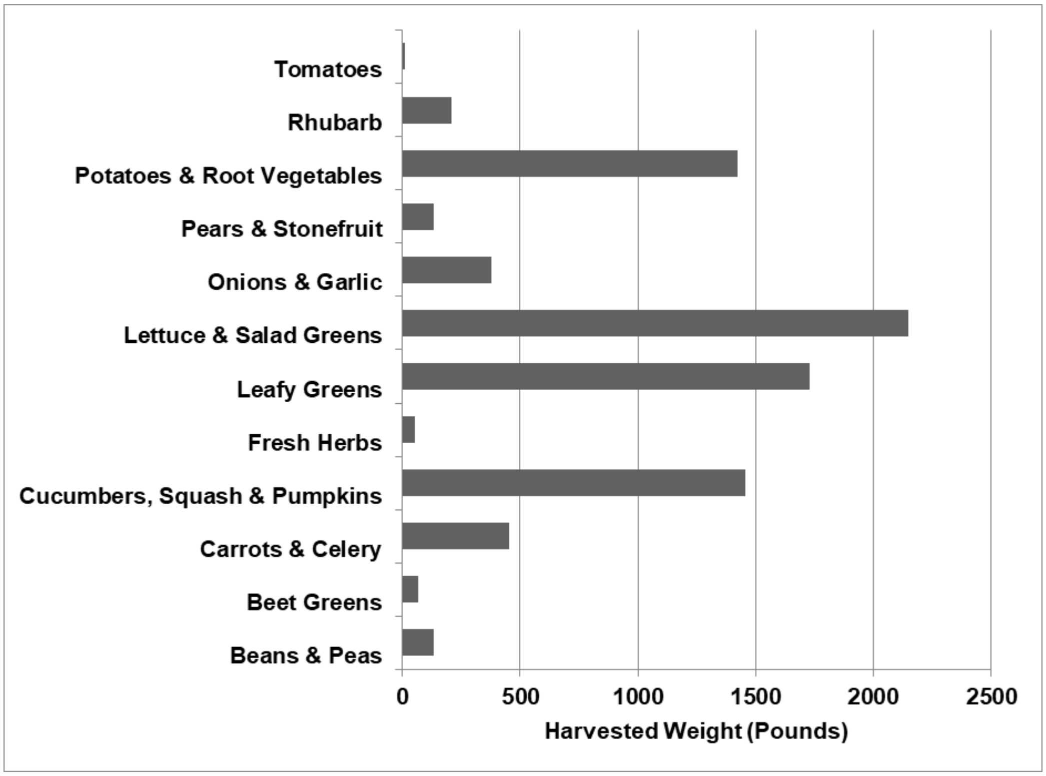
Bowness urban food map

Figure 2 shows the final map that was created through the constraint methodology to show underutilized green space in Bowness. In summary, the map shows the “available” private area currently managed as turf grass in Bowness, represented by the green shapefile. The map also shows the placement and harvested yields from the 11 gardens managed by Leaf & Lyre, represented as the yellow proportional symbols.

Production analysis

This section summarizes the production data from all six urban farms associated with *YYC Growers*. This data was collected from the cooperatives online sales system, which records what farm sold what vegetables, the amount, and the price it sold for. Figure 3 summarize the data from the six outdoor farmers operating across Calgary. This differs from the Bowness exclusive results in section 4.1. The 8,189 pounds of food was grown exclusively within the Calgary urban boundary from six urban farms.

Figure 3: Total amount of vegetables produced and sold by six Calgary urban farms working with YYC Growers from January-December 2016



Spatial statistics

Table 1 below summarizes the results from the geospatial analysis of the map in section 4.1. The Bowness total area represents the polygon outline of Bowness. The amount of private green space is the final outline of over 3,000 reduced parcel polygons, which are assumed as having a turf grass cover. This resulted in 42 percent of the total area of Bowness. The amount of cultivation area, 0.1 acres or 420 m^2, is the sum of the 11 gardens managed by Leaf & Lyre in Bowness. The harvested weight is the harvested mass recorded through the 2016 season. The potential production is an estimate based on the maximum 2016 harvested weight per m^2 on every square metre of available private green space. The 11 gardens produced an average of 1.81 pounds per m^2 of food, or 7,304 pounds per acre. Assuming enough resources and translated across the entire area, over four million pounds of food could theoretically be grown in the Bowness green space.

Table 1: Spatial summary of the amount of land available for urban agriculture in Bowess

Bowness Total Area	Private Green Space Area	Green Space / Total Area	Bowness Cultivation Area 2016	Harvested Weight	Potential Production
1,386 Acres ($5,608,943\ m^2$)	581 Acres ($2,351,224\ m^2$)	42 percent	0.1 Acres ($420\ m^2$)	758 Pounds	4,255,715 Pounds

Discussion

This research has brought together two different themes in food systems research: urban agriculture and climate smart agriculture. The *climate smart food* approach to growing food in urban spaces refocuses the emphasis that both food choices and growing locations matter. Geospatial analysis offers one research lens through which to explore the impact of UA; however, it is not the only frame available to understand and promote the practice further. The results from the mapping exercise were intended to connect the two concepts, and to visually show the potential sustainable intensification in an urban setting.

The analysis highlights that there is underutilized urban space—in fact, 42 percent of the land in the Bowness neighbourhood of Calgary is private lawns—that can be used to grow sizable quantities of food. This finding can challenge how space in an urban setting is valued. Proponents of new urbanism emphasize cities as dense, livable, and efficient infrastructure and services that minimize sprawling lawns and private land while maximizing walkability (Nordahl, 2009). And while the notion of new urbanism is appealing, the reality is that many North American cities are comprised of low-density, single-family suburban neighbourhoods. Merging the concept of farm and city to produce climate smart food works with the agrarian ideals of early American regional planning.

From a quantitative perspective, it was estimated that over four million pounds of vegetables could be produced in Bowness. This potential assumes maximum intensification of every square metre of the 581 acres of green space. Of course, this is an unachievable ideal. Even the most successful agro-ecological market farms have dedicated staff working intensively, and often full time, to achieve a maximum harvest potential. However, there is clearly a production gap between the extraction of almost 800 pounds of food from one-tenth of an acre and what could be produced through more deliberate lawn to garden conversion.

While the map shows “available” and potential green space—that is, private land free from buildings and trees—the next step would be to map suitable space. This would include consideration for aspect (sun exposure), soil type, organic matter accumulation, and historical management. Not every acre of the 581 acres estimated is suitable for growing high quality market vegetables. Urban farmers can use aerial photography, satellite images, and suitability mapping to find potential sites, but these geospatial methods still require in-situ boots-on-the-ground observation. Rather, it is more accurate to view geospatial methods as a first step to assessing UA site potential, saving time for the more intensive work of land-owner consultation and site setup.

This process is most useful as a visual tool to re-imagine urban agro-environments. What the map shows is a neighbourhood not dissimilar in size and population to the many small communities across Alberta. This model of sustainable intensification in backyard spaces could be spread across many communities of various sizes to increase food resiliency and decrease emissions related to diet. If consumers demand it, farmers will supply it. In many cases, landowners are eager to donate their lawn to food production. As evident through the existence (and success) of *YYC Growers*, farmers in Calgary and other cities have demonstrated urban growing is a viable business model. Multiplied across Canada, intensified backyard growing could be highly successful.

The results from section 4.2 summarized the 2016 harvested yield of six urban farms in Calgary. Unfortunately, more detailed spatial data was only available for one of the farms. While 500 people (aka: shares) benefited from the year-round *YYC Growers* weekly farm share, it is unclear exactly how many people received all or part of their diet from within the city. Despite plans for the YYC Growers program to double to 1,000 shares in 2017, it is unlikely that even a highly-developed system of UA will ever exclusively feed a city of over a million people. However, it is still clear that market forces are making UA viable and their products desirable.

Further, the six urban farms produce significantly less than their rural counterparts; the other 14 rural farms in the cooperative provided the majority of the food, especially in the winter months dominated by stored root vegetables. Even with a venture seeking to promote UA, it is inevitable that large rural farms will always be required to feed an urban population. With this urban and rural mix, an important goal of a sustainable food system for a city should focus on the broader food-shed for the supply of climate smart food.

Using the definition of CSF as appropriate and adaptable food that is deliberately produced and purchased because of its associated low-carbon intensity, is food produced through UA climate smart? Exploring the aspects of what climate smart agriculture is, from sustainable intensification to reduced food miles, then certainly, food grown in an urban environment can be climate smart. There is ample evidence to support that UA decreases the carbon emissions from transport and machine operation, and reduces the land requirement for growing food. The potential of soil carbon storage through biomass accumulation from UA, even if multiplied across many cities, would be inconsequential in the global agricultural context. Managing carbon in a small-acre farm is insignificant compared to efforts of a ten-thousand-acre commodity farm. Any research and effort towards its implementation would detract resources from pursuing soil carbon sequestration on a meaningful scale.

Of greater importance in the connection of UA to CSF is the land optimization potential. UA is practiced on already disturbed land. Suburbia came before the garden. With the rise of indoor growing systems, there is even more potential to grow meaningful quantities of food from smaller amounts of land. The conversion of natural ecosystems to agricultural production poses significant global threats to biodiversity and climate change. Large mono-cropping systems contribute to land fragmentation and the release of soil carbon through cultivation. These commodity products, from palm oil, canola, wheat, barley, soy, and rice are driving the rapid expansion of agriculture into marginal land. This is driven by the diet choices of urban dwellers. UA decreases the stress put on remaining natural systems.

Ultimately, a change of diet is a pre-requisite for a more sustainable food system. While substantial changes in consumers' food choices is a wicked global challenge, simply increasing the availability of more appropriate food choices is a good first step. This geospatial analysis has shown that a significant quantity of food is being grown hyper-locally, and that the potential is far greater. While UA is unlikely to ever produce enough food for all of Calgary, it should nonetheless be encouraged. Consumers, farmers, and government should encourage the promotion of UA as a source of climate smart food.

Conclusion

Finding solutions to feed a burgeoning world population, while at the same time reducing carbon emissions and protecting habitat is undoubtedly one of the greatest challenges faced by the global community. Increasing the efficiency and awareness of urban agriculture can be part of the solution to reducing agriculture's environmental impact and providing localized food security. UA should be promoted as a system that produces climate smart food, that is, horticultural products that are produced and consumed because of their associated low carbon emissions from production and transportation. This research demonstrates the magnitude of underutilized land within an urban boundary that can produce significant quantities of food, all while shifting food miles to food feet, farm tractors to garden shovels, and industrial irrigation to rain water catchment.

It is worthwhile to estimate the potential land area that can be used to grow food within a city boundary. The underlying premise of mapping UA potential is the recognition of underutilized private urban land resources that can be managed through sustainable intensification. Using city parcel data through the process of constraint mapping can show potential growing space. In a city as large as Calgary, there are thousands of acres of underutilized land that can be sustainably managed to provide high quality food for its citizens. Based on yields from local gardens, it was estimated that over four million pounds of food could be grown in the available private green space in Bowness. While this assumption of maximum yields extracted from every square metre of green space is wildly improbable, it does indicate a huge gap between current production and potential yields.

While urban food growing spaces represent only a fraction of total food produced and consumed, the argument put forth here is that underutilized urban lands can be cultivated to add fresh produce to diets, improve food sovereignty and security, and reduce the climatic impact of our food system. Much attention has been devoted to low fat, low carb, and low sugar diets; it is time to put more meaningful attention toward climate smart diets. This study signifies only the start of the conversation on climate smart food.

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References

Altieri, M. A., Companioni, N., Cañizares, K., Murphy, C., Rosset, P., Bourque, M., & Nicholls, C. I. (1999). The greening of the “barrios”: Urban agriculture for food security in Cuba. *Agriculture and Human Values*, *16*(2), 131–140.

Barthel, S. & Isendahl, C. (2013). Urban gardens, Agriculture, and water management: Sources of resilience for long-term food security in cities. *Ecological Economics*, *86*.

City of Calgary. (2012). *Calgary eats! A food system assessment and action plan for Calgary.* Calgary. Retrieved from http://www.calgary.ca/PDA/pd/Documents/Calgary-Eats/CalgaryEATS-Full-Food-System-Assessment-Action-Plan-for-Calgary.pdf

Dubbeling, M., Hoekstra, F., Renting, H., Carey, J., & Wiskerke, H. (2015). City Region Food Systems. *RUAF Foundation: Resource Centres on Urban Agriculture and Food Security*, 29, 1–72.

Edwards-Jones, G., Milà i Canals, L., Hounsome, N., Truninger, M., Koerber, G., Hounsome, B., Jones, D. L. (2008). Testing the assertion that “local food is best”: the challenges of an evidence-based approach. *Trends in Food Science and Technology*, *19*(5), 265–274.

Eigenbrod, C. & Gruda, N. (2015). Urban vegetable for food security in cities. A review. *Agronomy for Sustainable Development*, *35*(2), 483–498.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., & Balzer, C. (2011). Solutions for a cultivated planet. *Nature*, *478*(7369), 337-342.

Food and Agriculture Organization of the United Nations, FAO (2017). *Climate Smart Agriculture Sourcebook*. Second edition. http://www.fao.org/climate-smart-agriculture-sourcebook/en/

Galhena, D., Freed, R., & Maredia, K. (2013). Home gardens: a promising approach to enhance household food security and wellbeing. *Agriculture & Food Security*, *2*(1).

Garnett, T. (2011). Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy, 36*, 523–532.

Gaston, K. J., Warren, P. H., Thompson, K., & Smith, R. M. (2005). Urban domestic gardens (IV): the extent of the resource and its associated features. *Biodiversity and Conservation*, *14*(14), 3327-3349.

Gliessman, S. (2014). A Wakeup Call for a Climate-Smart Food System. *Agroecology and Sustainable Food Systems*, 38(7), 745–747.

Huang, D. & Drescher, M. (2015). Urban crops and livestock: The experiences, challenges, and opportunities of planning for urban agriculture in two Canadian provinces. *Land Use Policy*, *43*, 1–14.

Koerber, G. R., Edwards-Jones, G., Hill, P. W., Milà, L., Nyeko, P., York, E. H., and Jones, D. L. (2009). Geographical variation in carbon dioxide fluxes from soils in agro-ecosystems and its implications for life-cycle assessment. *Journal of Applied Ecology*, 46, 306–314.

Kauffman, J. B., Arifanti, V. B., Hernández Trejo, H., del Carmen Jesús García, M., Norfolk, J., Cifuentes, M., Murdiyarso, D. (2017). The jumbo carbon footprint of a shrimp: Carbon losses from mangrove deforestation. *Frontiers in Ecology and the Environment*, 183–188.

Kortright, R. & Wakefield, S. (2011). Edible backyards: A qualitative study of household food growing and its contributions to food security. *Agriculture and Human Values*, *28*(1), 39–53.

Kremer, P. & DeLiberty, T. L. (2011). Local food practices and growing potential: Mapping the case of Philadelphia. *Applied Geography*, *31*(4), 1252–1261.

Lal, R. (2004). Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science*, *304*(5677), 1623-1627.

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12), 1068–1072.

Mathieu, R., Freeman, C., & Aryal, J. (2007). Mapping private gardens in urban areas using object-oriented techniques and very high-resolution satellite imagery. *Landscape and Urban Planning*, *81*(3), 179–192.

McClintock, N. (2010). Why farm the city? Theorizing urban agriculture through a lens of metabolic rift. *Cambridge Journal of Regions, Economy and Society*, *3*(2), 191–207.

Mok, H.-F., Williamson, V., Grove, J., Burry, K., Barker, S., & Hamilton, A. (2014). Strawberry fields forever? Urban agriculture in developed countries: a review. *Agronomy for Sustainable Development*, *34*(1), 21–43.

Mougeot, L. (2000). *Urban agriculture: definition, presence, potentials and risks, and policy challenges*. International Development Research Centre (IDRC), Cities Feeding People Series Report 31.

Mwongera, C., Shikuku, K.M., Winowiecki, L., Twyman, J., Läderach, P., Ampaire, E., van Asten, P., Twomlow, S. (2014). *Climate-Smart Agriculture Rapid Appraisal (CSA-RA) Tool: A Prioritization Tool for Outscaling CSA*. Cali, Colombia: International Center for Tropical Agriculture (CIAT). http://hdl.handle.net/10568/68633

Neufeldt, H., Jahn, M., Campbell, B. M., Beddington, J. R., DeClerck, F., De Pinto, A., Zougmoré, R. (2013). Beyond climate-smart agriculture: toward safe operating spaces for global food systems. *Agriculture & Food Security*, 2(12), 1–6.

Newman, L. (2008). Extreme local food: Two case studies in assisted urban small plot intensive agriculture. *Environments*, 36(1), 33–43.

Nordahl, D. (2009). *Public produce: The new urban agriculture*. Island Press.

Scharf, K., Levkoe, C., & Saul, N. (2010). *In every community a place for food: the role of the Community Food Centre in building a local, sustainable, and just food system*. Toronto: George Cedric Metcalf Charitable Foundation.

Scherr, S. J., Shames, S., & Friedman, R. (2012). From climate-smart agriculture to climate-smart landscapes. *Agriculture and Food Security*, 1(1), 12-12.

Selhorst, A. & Lal, R. (2013). Net carbon sequestration potential and emissions in home lawn turfgrasses of the United States. *Environmental Management*, *51*(1), 198–208.

Smith, A. & MacKinnon, J. B. (2007). *The 100-mile diet: A year of local eating*. Vintage Canada.

Sweeney, G., Hand, M., Kaiser, M., Clark, J. K., Rogers, C., & Spees, C. (2016). The State of Food Mapping: Academic Literature Since 2008 and Review of Online GIS-based Food Mapping Resources. *Journal of Planning Literature*, *31*(2), 123–219.

Taylor, J. R. & Lovell, S. T. (2014). Urban home food gardens in the Global North: Research traditions and future directions. *Agriculture and Human Values*, *31*(2), 285-305.

Taylor, J. R. & Lovell, S. T. (2012). Mapping public and private spaces of urban agriculture in Chicago through the analysis of high-resolution aerial images in Google Earth. *Landscape and Urban Planning*, *108*(1), 57–70.

Townsend-Small, A. & Czimczik, C. I. (2010). Carbon sequestration and greenhouse gas emissions in urban turf. *Geophysical Research Letters*, 37(2).

Wallén, A., Brandt, N., & Wennersten, R. (2004). Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science and Policy*, *7*(6), 525–535.

Weber, C. L. & Matthews, S. H. (2008). Food-miles and the relative climate impacts of food choices in the United States. *Environmental Science & Technology*, *42*(10), 3508–3513.

Zhang, X., Feng, X., and Jiang, H. (2010). Object-oriented method for urban vegetation mapping using IKONOS imagery. *International Journal of Remote Sensing*, 31(1), 177–196.