2017

Growing Climate Smart Food in Urban Environments

URBAN FOOD MAPPING IN CALGARY, ALBERTA

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Abstract

The practice of urban agriculture (UA) offers a unique food system's model that localizes the production and consumption of horticultural products. The main premise is that there are underutilized private urban land resources that can be managed through sustainable intensification to produce food that is geographically appropriate and contributes to food security. The framework for what constitutes the emerging field of climate smart agriculture (CSA) has not been applied to UA. The definition of the term climate smart food is put forward as a more appropriate framework to examine UA. Through a case study in the Bowness neighborhood of Calgary, Alberta, the potential of the Calgary environment to grow climate smart food was assessed. The methods of urban food mapping were explored, and a geospatial process of constraint mapping was used to determine available private land space that could be converted from lawn to cultivated gardens. In the neighborhood, 42% (581 acres) of the land was held as private turf grass, with only 0.1 acres under cultivation producing about 800 pounds of food. Using data from a local food cooperative, it was determined that six urban farms in Calgary produced roughly 8200 pounds of food from private gardens in 2016. A shift of focus from production methods to the food itself is a pre-requisite for a more sustainable food system. While UA is unlikely to produce enough food for all of Calgary, its role should be encouraged as a source of climate smart food.

1. 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 yard spaces to plots of intensive cultivation of vegetable and fruit crops (Eigenbrod & Grude, 2011; Huang & Drescher, 2014). Multiple studies have explored the range of initiatives and effectiveness of UA in order to address rapid urbanization and the concomitant need to feed growth in cities across the globe. To meet the world's future food supply, production must increase substantially while the environmental footprint must decrease (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), there is growing evidence that locally grown urban food can contribute, albeit marginally and variably, to urban food security; notably infusing fresh seasonal horticultural goods to diets (Kortright & Wakefield, 2011). Vegetables 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).

Overall, the frame of UA is an aspect of sustainable agriculture worth pursuing because it challenges assumptions about food; plentiful food can be grown in limited space that is geographically appropriate (Mok et al., 2013).

Opportunities exist for municipalities to incorporate UA into improved policies that enhance a local food system (Huang & Drescher, 2014). A key incentive of UA promotion should be from a climate change perspective. For this research, a central focus is to examine UA within the emerging framework of Climate Smart Agriculture (CSA). CSA aims to be a transformative structure for agriculture to develop within the uncertainty posed by climate change. A CSA lens is appropriate to plan future urban food production systems in North America. However, the case is made that the focus of UA should be on the food itself rather than specific production methods or technology. The introduction of the term Climate Smart Food (CSF) is useful to address the total emission impacts of food beyond production to include transportation and consumption. CSF is defined here as appropriate and adaptable food that is deliberately produced and purchased 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 climate smart agriculture locally. Specifically, this project uses vegetable production data in the Bowness neighborhood 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 Climate Smart Food. This research will be exploratory in creating local food geospatial database that can be used to track changes in UA. 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 neighborhood.

2. Background and Literature

2.1 Urban Agriculture

While urban agriculture (UA) is not a new trend, it is receiving increasing interest as a solution to both food security and reducing greenhouse gas emissions in the agricultural sector. The overarching characteristics of UA are: dispersed and heterogeneous plots within a metropolitan boundary, predominantly a focus on vegetable crops, intensive cultivation in small-spaces (< 1 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% 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 1990's (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 60-70% by 2050 (FAO, 2013), 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 meet that demand. While the research base is growing, the potential for urban landscape changes through UA and a heterogeneous city are unknown.

Urban agriculture can be distinguished from conventional rural agriculture beyond farm location. The Food and Agriculture Organization (FAO) in the late 1990's introduced one of the first official definitions of UA (Mougeot, 2000). 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 practiced mainly because rural farmers move to the city and bring traditional practices with them. This differs from cites in developed nations, where urban agriculture has risen as a market response, as a push towards local economies, and promoted by varying levels of government. The global South has dominated research outlining effective UA policies and practices, with information in the Canadian context especially limited (Huang & Drescher 2015). In 2014, Taylor & Lovell outlined the future research directions of North American UA, with an explicit focus on the understudied home-food gardens because of their durability and ease of conversion.

2.2 Climate Smart Agriculture

Climate Smart Agriculture (CSA) has emerged as an umbrella term to describe enhanced food systems that increase productivity, encourages adaptive technologies, reduces greenhouse gas emissions, and meets food security targets (Lipper et al., 2014; FAO, 2013). CSA is the simultaneous improvement of food security and efforts to mitigate climate change (Scherr, Shames, & Friedman, 2012). Given a global trend towards increasing urbanization, UA is in a position to develop within a CSA framework. A broad framework is needed to build the evidence base to support its implementation. There is a notable inadequacy on suitable information to support decision making to guide CSA, and few articles connect UA and CSA.

The execution of CSA projects have been dominated by the Global South, and have not focused specifically on UA projects. This is because the risks from a changing climate are weighted against rural smallholder farmers in developing nations. However, building the resilience against climate impacts of all food systems- whether local or national- is context specific and is a worthy target for all systems. The concept of CSA brings unites the communities of international development, agriculture, and climate change. Because of its broad appeal, it can be criticized for sometimes vague connections (Neufeldt et al., 2013)

Identifying CSA practices and methods is an important future research direction. There are a series of suitable tools available from the website www.csa.guide.com. They have a rapid appraisal method to establish baseline understanding of CSA in a region. This includes an agricultural snapshot, an assessments of impacts, recognizing the most suitable CSA practices, and appraising the policy and financial aspects. This organization is compiling a global list of CSA projects, which is an incredibly useful learning tool. However, the majority of cases come from developing nations, and none specifically dealing in a Canadian context, which is why this study is an important exploration.

There are three overarching objectives of CSA (Lipper, 2014; FAO, 2013):

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.
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. Urban farmers in Canada often follow this model. 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.

There is no definitive literature on the economic impact of UA. A useful exercise 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. Data is available in section 4.2 on the total output of six urban farms in Calgary, and the associated value of their products. It is evident that UA has created economic opportunities from underutilized yards, but that effect has not been fully quantified.

In Toronto, the contribution of edible gardens has been shown to increase food security at various economic levels (Kortright & Wakefield, 2010). Mok et al. (2013) 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 foot print of food-miles, and reasonable definitions of urban self-sufficiency. However, the connection between UA and food security is not straight forward, with detractors stating that overall, UA contributes very little to food security, and potentially, even food sustainability (Edwards-Jones et al., 2008)

From the literature, there are estimates that the potential yields of up to 50 kg/m^2 of vegetables in global urban horticulture (Eigenbrod, Gruda, 2014) are sufficient to meaningfully contribute to food security. Home gardens are integral to supporting food production worldwide, and through targeted proliferation, can play an even more important role to increase food security from global price shocks and natural disasters (Galhena, Freed, & Maredia, 2013).

Resilience can be defined as the capacity of a food system to absorb and manage the adverse effects of external stress and shocks (FAO, 2013). It is the ability to prevent, mitigate, and recover from agricultural shocks in weather or markets. In Canada, a significant amount of our total food comes from imported sources. Resilience in a food system should consider agro-climatic impacts beyond the consumer's borders to include where that food is imported from. A major drought in California or Mexico could seriously impact food availability in Canada. By building the food growing capacity in a city, the reliance on imported food decreases, and so does the risks associated with importing vegetables over thousands of kilometers. 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. Effective UA is well poised to increase that resilience.

The environmental benefits of a local food system have not gone unquestioned. From a scientific perspective, it is nearly impossible to formally test whether local food is better than non-local food. The arguments made in favor of promoting local food often center on reduced food miles and a smaller carbon footprint, and increasingly, the carbon sequestration potential of agricultural soils (Edwards-Jones et al., 2008). The best way to address the environmental benefits of a local food system is through a spatially explicit life cycle assessment (LCA).

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 (Dorward, 2012). Decreasing the GHG emissions in agriculture can be achieved by decreasing machine and transportation costs, or through the process of soil carbon sequestration. Aside from providing diet alternatives, the goals of reduction and removal of GHG in the context of UA should focus exclusively on the reduction of GHG emissions through land use and transportation.

A life cycle assessment (LCA) gathers the relevant knowledge to determine the environmental impact of a product, from its initial resource extraction (cradle), to its disposal (grave). The third objective of CSA, reducing GHG emissions from agriculture (Lipper et al., 2014), necessitates an accurate LCA of local agricultural economies. To make the argument that UA can be climate-smart, accurate estimates of carbon accounting are necessary. The food chain produces GHG at all levels of the life cycle, but is the agricultural stage that emits the most greenhouse gases (Garnett, 2011).

There is an increased awareness of the potential for agricultural soils to store carbon; it is estimated that global agricultural soils can offset 1/4 to 1/3 of anthropogenic increases in carbon emissions through intensive management (Lal, 2004). However, this should not be a priority of UA given its very small footprint. Calgary, with one of the largest land area of any city in North America at over 200,000 acres, has a meager amount of cultivated land in relation to the broader agricultural sector. 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.

2.2.1 Climate Smart Landscapes

In both the context of UA and CSA in North America, mapping efforts are relatively limited. As a whole, the potential of urban agriculture to provide food security, while reducing the emission impact of food production, has gone unstudied (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, & Friedman (2012). The key features of a climate smart agricultural 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 recognizing 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. A landscape framework could be critical in the assessment of UA.

2.2.2 Sustainable Intensification

Global urbanization will appropriate an estimated 120Mha of land by 2030, reducing the fertile land available for agriculture (Canadell & Schulze, 2014). As this process happens, regional planning can integrate UA into urban development and protect spaces that can support food production. It will be crucial that space is reserved in rapid urban developed for food production. Maximizing the use of this space can be achieved through the broad frame of sustainable intensification (SI).

SI is the process of increasing food production on existing farmland, while reducing the overall environmental impact of the operation through adaptation and mitigation (Burney, Davis, & Lobell 2010). CSA and SI are closely linked and should be pursued in tandem. For each dollar invested in agricultural intensification since 1961, it is estimated 249 kg of CO2 equivalent are reduced (Burney, Davis, & Lobell 2010). There are three main opportunities to achieve this: 1) yield intensification per unit area 2) Temporal intensification through crop diversification 3) spatial intensification through land optimization (Canadell & Schulze, 2014). To achieve climate smart goals, UA should build on this approach.

The emissions contribution of global land-use change for agriculture has been estimated at 10-12% (Scherr, Shames, & Friendman, 202). In the context of developing climate smart UA, the effects of land-use change needs clarification on several fronts. Globally, natural ecosystems sequester a far greater amount of soil organic carbon than any type of agro-ecological system could ever impersonate. For this reason, it is critical that food production develops with goals of sustainable intensification to reduce the stress on natural ecosystems. This idea of “land-sparing” emphasizes that food production is management intense and spatially insignificant to maximize the land available for conservation (Garnett, 2011). Rather than clearing additional land to increase food production, UA in backyard spaces repurposes an already altered landscape.

However, the assumption that increased urban horticultural production decreases stress on rural land conversion is unfounded. Globally, the total land devoted to intensive horticultural production is growing (Foley et al., 2011); however, this form of agriculture is not a significant threat to unmanaged ecosystems. Rather, it is the broad-acre planting of commodity crops that poses the biggest threat. This expansion of agricultural land has been heavily documented on every continent. Broad solutions for a cultivated planet include: halting agricultural expansion, closing yield gaps, increasing crop efficiency, and changing diets (Foley et al., 2011). There is simply no reason that commodity crops like corn and wheat will ever be grown economically in a densely populated area. Despite this, it does not negate the connection between intensive agro-ecological farms and corporate farms.

Further clarification is needed on the opportunity cost of converting backyard turf-grass to backyard gardens. It could very well be that the net effect of converting a traditional manicured lawn to a garden has a more significant carbon footprint than the benefits of having local food. It is estimated across the bioclimatic zones in the United States, total turf grass area could sequester 4.96×10^{11} kg of carbon (Selhorst & Lal, 2012). Of critical note in that estimation is the hidden cost of carbon related to lawn management (mowing and fertilizers), which over a period of decades outweighs any potential soil carbon sequestration. To make the case that UA is a more sustainable use of lawn turf grass area, it is important to understand the opportunity costs that this could represent if implemented on a broad-scale.

2.3 Climate Smart Food

Due to the many forms that UA can take- from community gardens to edible skyscrapers- perhaps the more appropriate analysis of UA should be from a Climate Smart Food (CSF) perspective. In the end, commercial UA is producing food that people want to eat. It is dietary preference driving the growth of broad acre mono cropping, and a broad change in dietary values is needed to reduce the emissions intensity of agriculture. While different consumers may value production methods more highly, the ultimate concern lies with the quality of the food. Changing the approach to CSF pressures UA development based on demand rather than supply.

The labels attached to food impact a consumer's choice. Local, organic, ethically produced; the frame placed around food is critical. *CSF can be defined as appropriate and adaptable food that is deliberately produced and purchased 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 GHG emissions released from the production and distribution agricultural products is an important factor when making food choices.

CSF differs from CSA because it enunciates the decisions from farm to fork, rather than specifically the farm level. Transportation accounts for approximately 11% of GHG emissions, with the production phase dominating emissions from agriculture (Weber & Mathews, 2008). From a climate change perspective, the way food is grown matters more than how it got to a dinner plate. What needs to be proven is how consumers can influence production practices. Specific to UA, if consumers are exposed to food production in their backyard, this could influence their choices.

In contradiction to this idea, 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." (Wallen, Brandt, & Wennersten 2004, pg 7). Shifting the conversation from CSA to CSF in an urban setting requires that consumers actively pursue production practices that are climate friendly. Indeed, UA is in strategic position to facilitate this shift in food values because of the direct marketing employed.

Global agriculture, as a principal contributor of planetary warming carbon dioxide, accounts for 10-12% of anthropogenic emissions (IPCC, 2014). A carnivorous diet supplemented by refined grains fuels the expansion of commodity crops grown with high fertilizer and machine inputs that disproportionally affect agricultures GHG emissions. Ideally, UA should be driven by the market preferences of consumers instead of a concerted planning effort. All food is an opportunity cost, and if people value vegetables produced locally, they will decrease the demand for high input foodstuffs. A LCA of a typical hamburger from a global supply chain against a vegetarian meal from the neighbor's backyard would reveal what the climate-smart food is.

2.4 Urban Food Mapping

Utilizing the power of geographic information systems 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. For a thorough review of methodologies used in food mapping, refer to Sweeney et al. (2016). This resource summarizes the methods of 70 recent food web-mapping projects, and could prove incredibly useful for this project.

Ecological studies of urban biodiversity have largely ignored the urban backyard as a habitat space, despite having the largest proportion of green space in many urban areas (Gatson 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, previous research have used a high resolution IKONOS satellite image with an automated object orientated approach to classify urban gardens with an overall accuracy level of 77.5% (Mathieu, Freeman, & Aryal, 2007). The research revealed that 46.4% of the residential land area was held as private gardens. However, it was noted that their approach could take more than one year to map an entire city. Using a similar method with IKONOS 3.2m multispectral resolution, urban vegetation categories were segmented with 87.7% accuracy in Nanjing China (Zhang, Feng, & Jiang, 2009).

A conclusive approach to urban food mapping was illustrated by Taylor & Lovell (2011), who 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%. 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 totaled, they found that 208,225m^2 of the city was dedicated to urban food production. Of a particular and sobering note, is that to map the entire city in this method, it took 400 hours of analysis.

Despite the Chicago method stating that 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, 2011), it is worth exploring unsupervised image classification of a high-resolution satellite image. In their discussion, the authors 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. For a comprehensive summary on the current state of food mapping refer to Sweeney et al. (2016). 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; neighborhood level crop-rotation could be planned, disparities on food access between neighborhoods can be geographically displayed,

3. Methodology

3.1. Study Site: Urban Agriculture in Calgary

In Calgary, there is strong movement of consumers choosing locally grown produce, which has driven the supply side of UA to convert backyard spaces into "small-plot-intensive" (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, 6 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 (CSA) 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 *YYC Growers* is by no means the only group promoting UA in Calgary, they are the most visible and active group in the city.

Through summer working arrangements with the organization, data was collected that details how much of each vegetable product was harvested and sold for each of the 6 urban farmers. Specifically, *Leaf and Lyre Urban Farms* is the largest urban farming operation in Calgary, and grows primarily out of private backyards in Bowness. Data was available from *Leaf and Lyre* for each garden in Bowness, and how much food was grown in those specific plots through the 2016 growing season.

In 2012, a collaborative effort resulted in "Calgary Eats: A Food system Assessment and Action Plan for Calgary". This document outlined the cities vision for a sustainable food system. This conclusive effort outlined the steps needed for a land inventory analysis, but only went as far as plotting individual point of 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 notes that in 2012 there were 390,629 low-density residential properties in the city. Based on the sample neighborhoods of Rundle and Evergreen, they estimate that average yard size across Calgary is 453m^2. This translates into 17,700ha of land available for food production. However, this does not extract features that impede food production, such as trees and aspect. Calgary has a broad geography of soil types and microclimates, and not all neighborhoods are suitable for food production.

3.2 Calgary Data

A reasonable long-term objective for cities is to determine how much private yard space is available and suitable for UA. Due to the large spatial extent of the Calgary's footprint, a whole-city analysis was not feasible for this research. 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, Freeman, & Aryal, 2007; Zhang, Feng, & Jiang, 2009) the process is beyond the scope of this project. Instead, this question was explored within a case-study of urban agriculture in the Bowness neighborhood using parcel data created by the City of Calgary.

Bowness is an established neighborhood in NW Calgary, with a standard low-density suburban model that has been built up since the 1950's. Originally a separate community from Calgary, the neighborhood has a low-rise mixed commercial zone, its northern boundary is the Bow River, and a railway that crosses through the community.

Bowness was chosen because of available data on the number of urban gardens in the neighborhood, obtained from urban vegetable producers *Leaf & Lyre Urban Farms.* Data was collected through the growing season, between May and September 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. Harvested weight from the specific yard was recorded with a scale after each picking. . The different products span kale, potatoes, chives, carrots, and other vegetables. A full list of the various 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 winter 2017. City parcel data was obtained through the Spatial and Numeric Data Services at the University of Calgary. The files were created and updated by the City of Calgary between 2012 and 2014. Parcel data includes vector shapefiles for buildings, the tree canopy layer, the Bowness outline, and greenspace for each privately owned land parcel. Additional shapefiles were obtained from the City of Calgary Open Data resource. This included publically 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 Calgary standard 3 degree Transverse Mercator (3TM WGS 1984 W114) projection, with a central meridian set at 114 degrees longitude.

3.3 Methods

The purpose of this mapping project was to determine available private land space that could be converted from lawn to cultivated space. An estimate of the "available" private green space, currently expressed predominantly as backyard turf lawns, was then used to estimate possible vegetable production in the neighborhood. Through constraint mapping, 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. Constraint mapping is the process of subtracting the area of undesirable data from the underlying and desirable base map.

The greenspace parcel shapefile 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 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 3000 individual polygons that are predominantly composed of underutilized turf grass. This methodology has been used to estimate greenspace in New York City, and has many applications for a simple GIS analysis.

A 5 meter 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 33 meter buffer was also placed on the railroad line to accommodate the width that this linear feature takes up.

From an aerial view, the available public park layer- which represents sports fields and other lawns managed by the City of Calgary- is not easily distinguishable from the greenspace of private parcels. Subtracting this layer is an imperfect measurement of the total land that is publically managed, but it was deemed sufficient for the accuracy needed for this 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 judgement 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 *YYC Growers* in 2016 were plotted on the map as single point files. The eleven addresses were geocoded to fit the 3TM projection. Production data was collected throughout 2016 season, from May 1st to September 30th. The harvested yields were weighed

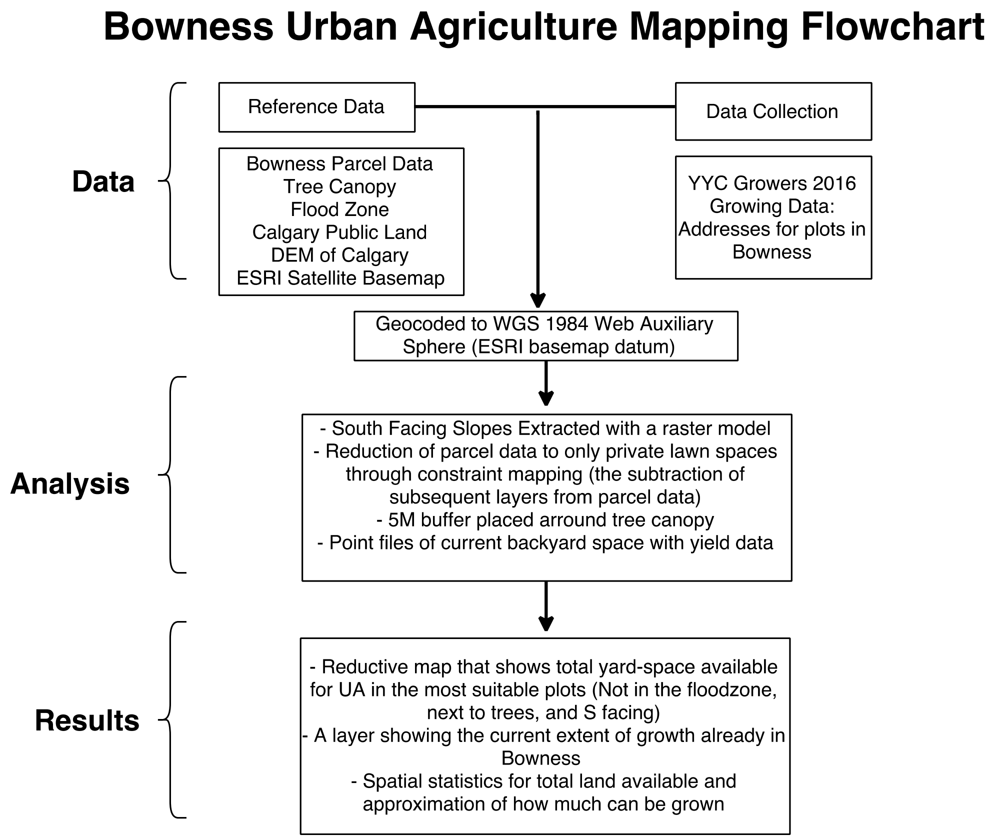

Figure 1 Workflow of the data collection and analysis to produce a potential urban food map.

and recorded for each order that went out, as described in section 3.2. These points were then represented through how much harvestable product they generated. The differences were displayed using a proportion symbol correlated to the yield.

4. Results

4.1 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 eleven gardens managed by *Leaf and Lyre*, represented as the yellow proportional symbols.

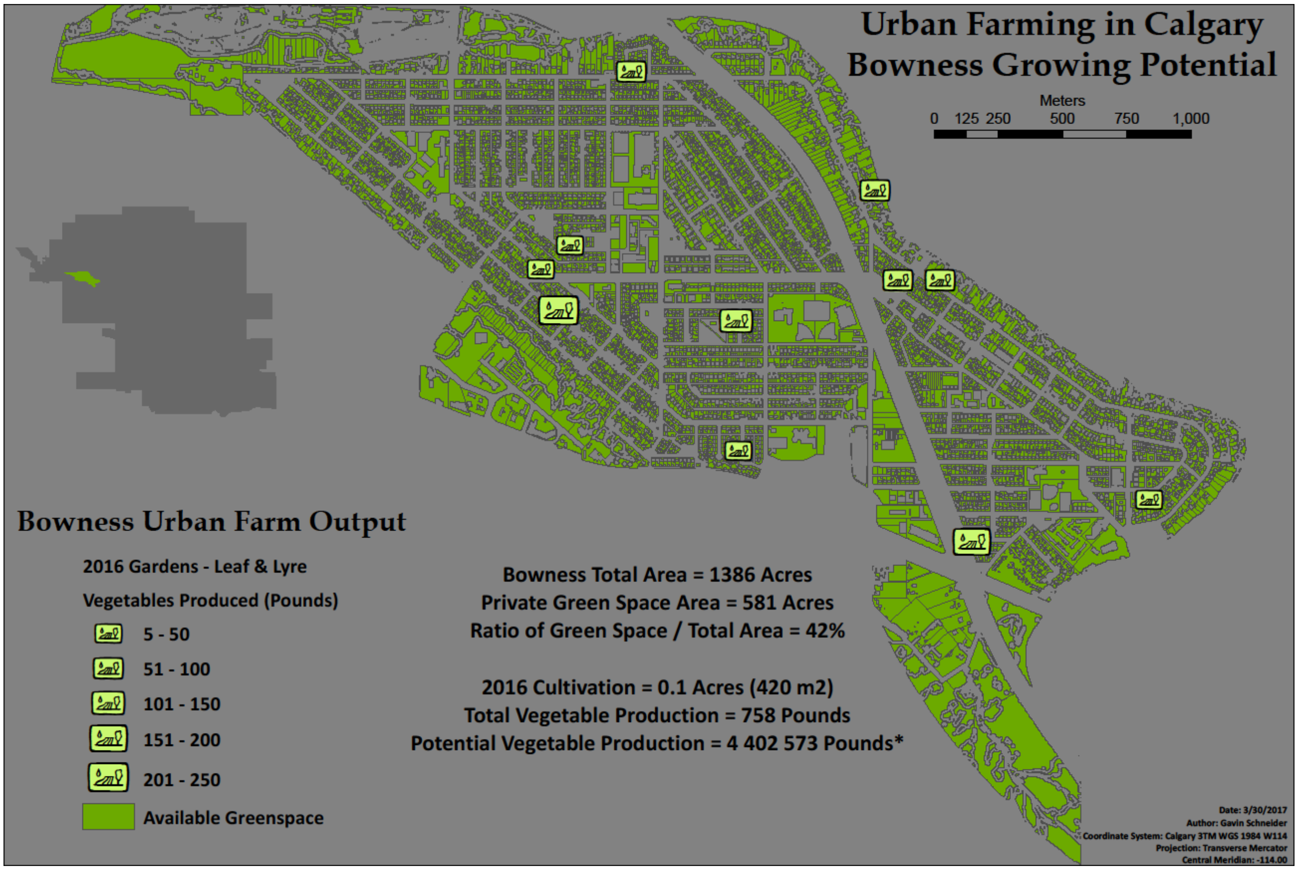

*Figure 2 The amount of land private land "available" for urban agriculture in Bowness, as well as 2016 production data. The map was produced through the constraint mapping of city parcel data. *Based on maximum yields from all private green space.*

4.2 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. Table 1 and 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 8189 pounds of food was grown exclusively within the Calgary urban boundary.

Table 1 Total amount of vegetables produced and sold by six Calgary urban farms working with YYC Growers from January-December 2016.

Vegetable & Fruit Category	**Harvested Weight (Pounds)**	**Vegetable & Fruit Category**	**Harvested Weight (Pounds)**
Beans & Peas	134	Lettuce & Salad	2150
Beet Greens	65	Onions & Garlic	377
Carrots & Celery	451	Pears & Stone Fruit	131
Cucumbers & Squash	1456	Potatoes & Root Veg.	1425
Fresh Herbs	52	Rhubarb	210
Leafy Greens	1730	Tomatoes	9
Total	8189		

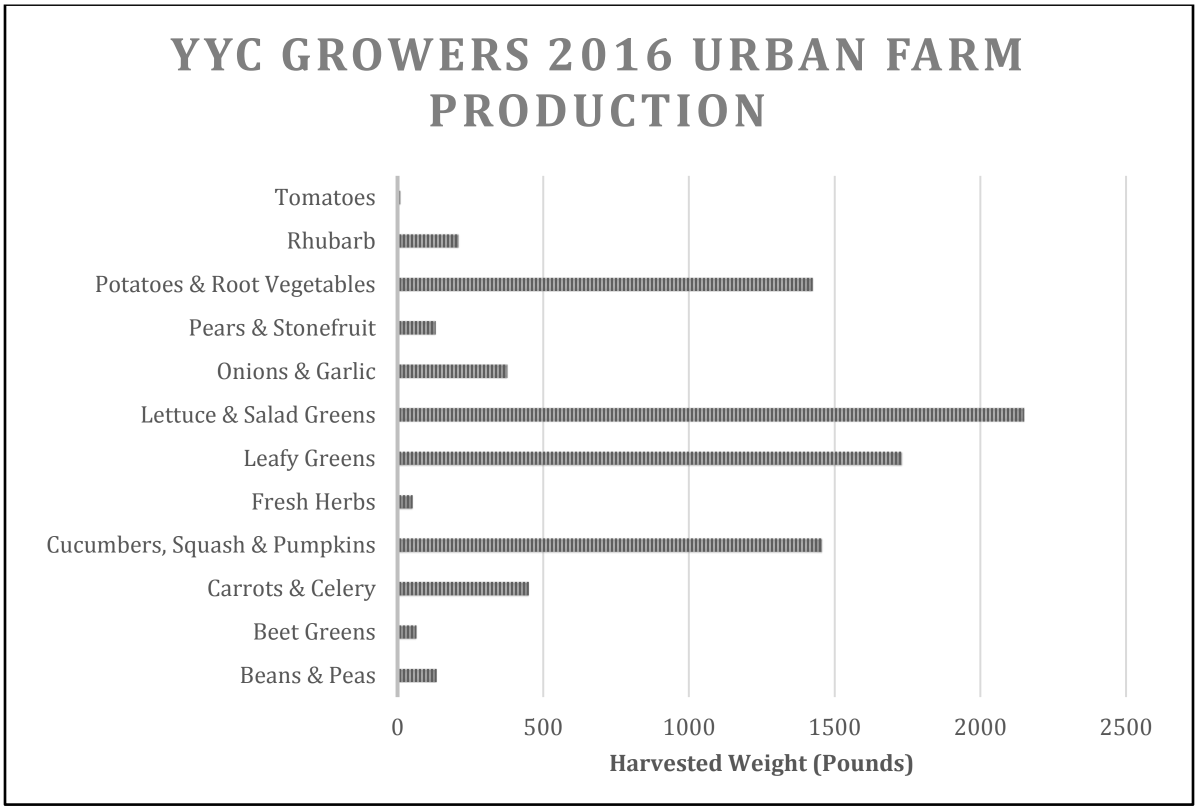

Figure 3 Total amount of vegetables produced and sold by six Calgary urban farms working with YYC Growers from January-December 2016.

4.3 Spatial Statistics

Table 2 Spatial summary of the amount of land available for urban agriculture in Bowness.

Bowness Total Area	Private Green Space Area	Ratio of Green Space / Total Area	Bowness Cultivation Area 2016	Harvested Weight	Potential Production
1386 Acres (5 608 943 m^2)	581 Acres (2 351 224 m^2)	42%	0.1 Acres (420 m^2)	758 Pounds	4 255 715 Pounds

Table 2 above 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 3000 reduced parcel polygons, which are assumed as having a turf grass cover. This resulted in 42% of the total area of Bowness. The amount of cultivation area, 0.1 acres or 420 m^2, is the sum of the eleven 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 meter of "available" private green space. The eleven gardens produced an average of 1.81 pounds per m^2 of food, or 7304 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 greenspace.

5. Discussion

This report brought together two different themes of urban agriculture: the substitution of the term climate smart food instead of climate smart agriculture, and urban food mapping. Geospatial analysis offers one research lens to explore the rise of UA; however, it is not the only frame available to understand and promote the practice further. The results from the mapping exercise had the intention of connecting the two concepts, and to visually show the potential sustainable intensification in an urban setting.

The effective qualitative result of the final map produced is a challenge to the way people visualize space in an urban setting. Rather than seeing the city as a dense collection of buildings, roads, and commercial ventures, the emphasis is on the available green space. The contention set at the beginning of the analysis, that there is underutilized urban space that can be used for growing large quantities of food, is proven by this map. The fact that 42% of the land in this Calgary neighborhood is essentially private lawns shows that cities are not only the civil engineering feats that they are thought to be. It is not unreasonable to suggest that the agrarian ideals of early American regional planning could actually be achieved in a low-density, single family suburban neighborhood. Merging the concept of farm and city to produce climate smart food will require that urbanites see potential in limited space, which was what this map shows.

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 meter of the 581 acres of greenspace. Of course, this is a flamboyant exaggeration. Even the most successful agro-ecological market farms get nowhere close to that harvest potential or land use. However, there is clearly a production gap between the extraction of almost 800 pounds of food from 1/10 of an acre and what could be produced through more deliberate lawn to garden conversion.

While the map shows "available" and potential greenspace – that is, private land free from buildings and trees- it would be more useful 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 and satellite images to find potential sites, but these geospatial methods would never replace a boots-on-the-ground observation. While there is potential time savings of assessing site potential in this way, if the ultimate goal of UA is to encourage more food production, then the ultimate usefulness of urban food mapping has been overestimated.

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

Despite plans for the program to double to 1000 shares in 2017, it is unlikely that even a highly developed system of UA will ever meaningfully feed a city of over a million people. Clearly, market forces are making UA viable and their products desirable. But, vegetable supply will always be dominated by a rural or peri-urban region. What the map shows is a neighborhood 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.

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 due to 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. 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 that UA encourages. 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 a smaller amount 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 natural systems to produce a rapidly growing and urbanizing population.

Ultimately, it is about the food, not the growing methods, to reduce agricultures impact on global emissions. A change of diet is a pre-requisite for a more sustainable food system. This geospatial analysis showed that there is significant quantities of food being grown hyper-locally, and that the potential is far greater. While UA is unlikely to ever produce enough food for all of Calgary, its role should be encouraged. The promotion of UA as a source of climate smart food should be encouraged by consumers, farmers, and government.

6. Conclusion

Finding solutions to feed a burgeoning world population, while at the same time reducing carbon emissions and protecting habitat, will undoubtedly be one of greatest challenges faced by the global community. Increasing the efficacy and awareness of urban agriculture (UA) can be part of the solution to reduce agricultures environmental impact and provide 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. While the goals of climate smart agriculture are suitable to frame the production side of UA, it is more appropriate to examine the whole food system through a climate smart food approach.

As more farmers, consumers, and government officials adopt UA, it is worthwhile to estimate the potential land area that can be used in grow food within a city boundary. The underlying premise of mapping UA potential is that there is underutilized private urban land resources that can be managed through sustainable intensification to grow horticultural products. It is possible to use remote sensing imagery to estimate potential yard space suitable for UA. Further, it is possible to show broader socioeconomic, distribution and transportation aspects of UA through geospatial methods.

The approach used here used city parcel data to extract the amount of land suitable for UA in the Bowness neighborhood of Calgary through constraint mapping. Based on 2016 yields from eleven gardens in the neighborhood, it was estimated that over four million pounds of food could be grown in the "available" private green space. While this assumption of maximum yields extracted from every square meter of greenspace is wildly improbable, it does indicate a huge gap between current production and potential yields. The final map produced through this process is most useful as a visual tool to reimagine urban environments. By eliminating the built up environment, it is possible to see that suburban spaces are largely turf grass dominated, representing an opportunity cost for land optimization.

In 2016, six outdoor urban farms in Calgary produced over eight thousand pounds of food, based off sales data provided by the local food cooperative, *YYC Growers.* It is unlikely that UA will ever feed the majority of Calgary's citizens. However, a concerted effort of UA promotion can play a role in reducing the environmental impact of the food consumed in a city. In a city as large as Calgary, there is thousands of acres of land that can be sustainably managed to provide high quality food for its citizens. In conclusion, this study demonstrates that small amounts of food grown in small spaces can improve food security and increase the supply of climate smart food.

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