Limits to local foodsheds:

The roles of social and biophysical resources for mobilizing local food production capacity

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Abstract

Local food systems have received growing attention among policymakers, practitioners, and researchers. With this attention, several scholarly studies have addressed the benefits and drawbacks of localizing food systems. More recently, a branch of research has emerged that focuses on the capacity of regions—including urban areas—to supply their population, evolving from questions of "are local food systems better?" to "are local food systems feasible?". 'Foodshed' analysis responds to this by conceptualizing the potential of regions to become more food self-sufficient as well as juxtaposing food supply and food demand by mapping food flows between the place of production and consumption. In this thesis, I build on the conceptual foundations of local food systems research from a rural and peri-urban food production vantage point, using an integrated approach that accounts for social and biophysical capacity and its dynamics within local foodsheds. My first study (Chapter 3 of this thesis) systematically reviews the scientific literature on foodshed analysis, synthesizes varying methodological approaches into a conceptual framework, and identifies gaps, limitations, and future research priorities. Based on these findings, I pursue three additional directions that address specific gaps in foodshed research (Chapters 4 to 6). Chapter 4 reviews how large cities (>300,000 people) in Canada and the United States plan to support local foodsheds and production capacity based on a thematic analysis of local food strategy and municipal action plan documents. Chapter 5 examines the diverse challenges of farmers selling to local markets in Québec and the role of social support systems and relationships in addressing those challenges. In the final analysis chapter (Chapter 6), I explore the impacts of the Covid-19 pandemic on farmers selling to local markets in the Province of Québec, including how they adapted their food production and distribution in response to the public health crisis. With this work, I contribute to our understanding of local food systems from the rural

vantage point, focusing on the producing stages of the supply chain rather than the market organization or consumer benefits. My research, therefore, collectively examines the intertwined relationship between biophysical resources (e.g., yields) and social resources (e.g., adaptation capacity) that can mobilize, shape, and limit the feasibility of local foodsheds. I argue that, without paying attention to the challenges facing farmers and the role of social support systems in local food production capacity, municipal and provincial goals toward building local food systems may be undermined.

Resumé

Les systèmes alimentaires locaux font l'objet d'une attention croissante de la part des décideurs politiques, des praticiens et des chercheurs. Dans le cadre de cette attention, plusieurs études savantes se sont penchées sur les avantages et les inconvénients de la localisation des systèmes alimentaires. Plus récemment, une branche de la recherche a vu le jour, qui se concentre sur la capacité des régions - y compris les zones urbaines - à approvisionner leur population, passant de la question " les systèmes alimentaires locaux sont-ils meilleurs ? " à " les systèmes alimentaires locaux sont-ils faisables ? ". L'analyse des " bassins alimentaires " répond à cette question en conceptualisant le potentiel des régions à devenir plus autosuffisantes en matière d'alimentation et en juxtaposant l'offre et la demande alimentaires en cartographiant les flux alimentaires entre les lieux de production et de consommation. Dans cette thèse, je m'appuie sur les fondements conceptuels de la recherche sur les systèmes alimentaires locaux du point de vue de la production alimentaire rurale et périurbaine, en utilisant une approche intégrée qui tient compte de la capacité sociale et biophysique et de sa dynamique au sein des bassins alimentaires locaux. Ma première étude (chapitre 3 de cette thèse) passe systématiquement en revue la littérature scientifique sur l'analyse des bassins alimentaires, synthétise les différentes approches méthodologiques dans un cadre conceptuel, et identifie les lacunes, les limites et les priorités de recherche futures. Sur la base de ces résultats, je poursuis trois orientations supplémentaires qui répondent à des lacunes spécifiques dans la recherche sur les bassins alimentaires (chapitres 4 à 6). Le chapitre 4 examine comment les grandes villes (>300 000 habitants) du Canada et des États-Unis prévoient de soutenir les bassins alimentaires locaux et la capacité de production en se fondant sur une analyse thématique des documents relatifs aux stratégies alimentaires locales et aux plans d'action municipaux. Le chapitre 5 examine les divers défis auxquels sont confrontés les agriculteurs qui

vendent leurs produits sur les marchés locaux au Québec, ainsi que le rôle des systèmes de soutien et des relations sociales pour relever ces défis. Dans le dernier chapitre d'analyse (chapitre 6), j'explore les impacts de la pandémie de Covid-19 sur les agriculteurs vendant aux marchés locaux dans la province de Québec, y compris la façon dont ils ont adapté leur production et leur distribution alimentaire en réponse à la crise de santé publique. Avec ce travail, je contribue à notre compréhension des systèmes alimentaires locaux du point de vue rural, en me concentrant sur les étapes de production de la chaîne d'approvisionnement plutôt que sur l'organisation du marché ou les avantages pour les consommateurs. Mes recherches examinent donc collectivement la relation entre les ressources biophysiques (par exemple, les rendements) et les ressources sociales (par exemple, la capacité d'adaptation) qui peuvent mobiliser, façonner et limiter la faisabilité des bassins alimentaires locaux. Je soutiens que, si l'on ne prête pas attention aux défis auxquels sont confrontés les agriculteurs et au rôle des systèmes de soutien social dans la capacité de production alimentaire locale, les objectifs municipaux et provinciaux visant à mettre en place des systèmes alimentaires locaux pourraient être compromis.

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Contribution of authors

This thesis is manuscript-based, meaning Chapters 3-6 were written as stand-alone manuscripts for publication in peer-reviewed scientific journals[1]. I served as the first author of each manuscript, leading the conceptualization of the study, methodological design, data collection and analysis, and writing. My supervisor and co-author Dr. Graham MacDonald on all manuscripts supported and guided the research, writing, and revision process of each manuscript. In addition, other co-authors contributed to the manuscripts as outlined in the following sections. I received approval for the survey and interviews in Chapters 5 and 6 by the McGill Research Ethics Board (REB File # 20-12-022).

Chapter 3 systematically reviews the status quo of foodshed analysis, a methodology to map local food self-sufficiency capacity and food supply chains, and identifies different methodological approaches and conceptual and methodological gaps. This chapter was co-authored by Gordon M. Hickey, Geneviève S. Metson and Brian E. Robinson who gave feedback on the results and helped writing sections of the manuscript. This chapter has been published: Schreiber, K., Hickey, G.M., Metson, G.S., Robinson, B.E., MacDonald, G.K. (2021). Quantifying the foodshed: A systematic review of urban food flow and local food self-sufficiency research. *Environmental Research Letters* 16 023003. DOI: 10.1088/1748-9326/abad59

Chapter 4 reviews how large cities in Canada and the United States plan to support local foodsheds and production capacity based on a thematic analysis of local food strategy and action plan documents. This chapter was co-authored by Killian Abellon, who undertook data collection for

[1] The reference style may vary across the manuscripts due to different journal guidelines.

the thematic analysis, and Klara J. Winkler, who contributed during the writing phase. This chapter has been submitted to the journal '*Urban Agriculture and Regional Food Systems*' and is currently under review.

Chapter 5 analyses the challenges of farmers selling to local markets in Québec and the role of social support systems and relationships in addressing those challenges. The manuscript was co-authored by Bernard Soubry, who contributed to the conceptualization of the study and the writing of the manuscript. The second co-author Carley Dove-McFalls supported the transcription of interviews and manuscript writing. The chapter has been published: Schreiber, K., Soubry, B., Dove-McFalls, C., MacDonald, G.K. (2022). Untangling the role of social relationships and challenges for local food systems: A case study of local farmers in Québec, Canada. *Agriculture and Human Values*. https://doi.org/10.1007/s10460-022-10343-0

Chapter 6 explores the impacts of the Covid-19 pandemic on farmers selling to local markets in Québec and their adaptation capacity and crisis response. The manuscript was co-authored by Bernard Soubry, who contributed to the conceptualization of the study and the writing of the manuscript. The second co-author Carley Dove-McFalls supported the transcription of interviews and writing of the manuscript. The chapter has been published: Schreiber, K., Soubry, B., Dove-McFalls, C., MacDonald, G.K. (2022). The impacts of the Covid-19 pandemic on local food production and marketing in Québec, Canada. *Journal of Rural Studies* 90 (124-133). https://doi.org/10.1016/j.jrurstud.2022.02.002

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List of Abbreviations

APMQ	Producteurs Maraîchers du Québec
CAD	Canadian Dollars
CAPÉ	Coopérative pour l'Agriculture de Proximité Écologique
CERB	Canadian Emergency Response Benefit
CSA	Community-Supported Agriculture
FFN	Family Farmers Network (Le Réseau des Fermiers|éres de famille)
ICT	Information and Communication Technology
IRCC	Immigration, Refugees and Citizenship Canada
LFS	Local Food Self-sufficiency
FAO	Food and Agricultural Organization of the United Nations
MAPAQ	Ministry of Agriculture and Fisheries Québec
RE	Resource use or Emissions
SAU	Subnational Administrative Unit
TFW	Temporary Foreign Workers
UPA	Union des Producteurs Agricoles

1 Introduction

1.1 Setting the table

Food is fundamental to human nourishment, livelihoods, and culture. The Food and Agricultural Organization of the United Nations (FAO) states that food security "*exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*" (FAO, 1996). Ensuring food security at an individual and household level and fulfilling global nutritional needs requires well-functioning, reliable, and resilient food systems (Schipanski et al., 2016). The term food systems[2] describes a "*network of activities connecting people to their food [that] operate at multiple spatial scales and include production, distribution, and consumption components*" (Schipanski et al., 2016, p. 601). At each stage of the supply chain, several actors manage processes, resources, and products, and various demographical, socio-cultural, and technological factors and drivers influence the performance and outcomes of this system (FAO, 2018). A functioning food system equitably and sustainably meets the global demand for food and sustains the livelihoods of farmers, processors, and other food systems actors while protecting the environment and natural resources (Simpson & Jewitt, 2019; von Braun et al., 2021).

[2] I refer to market-integrated and industrialized food systems. However, I acknowledge the wealth of food supply chains and foodways that are not or not entirely part of the system. For instance, indigenous communities worldwide aim to preserve or reclaim food sovereignty (e.g., traditional foodways, "country foods") (Ford et al. 2016, Newell and Doubleday 2020, Martinez-Levasseur et al. 2020). While such food systems are important, the diverse perspectives and plurality of actors in indigenous food systems are not the focus of my research.

Currently, agricultural management and technology allow us to produce enough calories to theoretically meet the dietary needs of the global population (Cassidy et al., 2013; Porkka et al., 2013; Ray et al., 2022). Nevertheless, financial crises, land use pressures, geopolitical conflicts, environmental disasters, and other disruptions have threatened food security and eroded the trust of many consumers in corporate globalized and centralized food systems and supply chains (Brinkman et al., 2010; Clapp, 2017; C. Müller & Robertson, 2014; Zhang & Broadstock, 2020; Zhou et al., 2020). In response, (urban) social movements establishing initiatives and programs to support farmers, increase food production near consumers, and foster local food systems have received growing attention (Derkatch & Spoel, 2017; Hinrichs & Allen, 2008; O'Hara & Coleman, 2017; Sonnino, 2009; Thilmany et al., 2021).

Local food systems refer to all activities involved in food production, distribution, and consumption within a "defined geographic area" (Kneafsey et al., 2013). This geographic area, also defined as foodshed (C. J. Peters et al., 2009)[3], can span across a circumference of a few dozen to several hundred kilometers or be delimited by subnational jurisdictions (Feldmann & Hamm, 2015; Schreiber et al., 2021). Local food system initiatives like farmers' markets, community-supported agriculture, and institutional procurement of food products from local sources are driven by diverse aims, such as strengthening local economies, gaining control over food supply chains, distributing profits and power more equitably, and reducing greenhouse gas emissions (Albrecht & Smithers, 2018; Bimbo et al., 2021; Megicks et al., 2012; Pícha et al., 2018) as well as building

[3] In my research, I employ varying definitions of local food systems appropriate to the scale of each study. In Chapters 3 and 4, I review the definitions that researchers (Chapter 3) and cities (Chapter 4) have used without limiting what comprises a local food system myself. In Chapters 5 and 6, the boundaries of local food systems align with the provincial boundaries of Québec.

food systems based on social and ecological values rather than profit-orientation (Albrecht & Smithers, 2018; Beingessner & Fletcher, 2020; Charatsari et al., 2018). Proponents of those social movements accentuate the geography of food supply chains and advocate for a disconnection from globalized food supply networks that are often dominated by multi-national corporations (Buchan et al., 2021; Jacques, 2021; Selfa & Qazi, 2005).

1.2 Are local food systems feasible?

Much research has been conducted on the opportunities, drawbacks, and misconceptions of shortening food supply chains and promoting 'local food systems' (Enthoven & Van den Broeck, 2021; Schmitt et al., 2017; Stein & Santini, 2021). Such research has debated to what degree claims by local food system advocates are substantiated and which targets should be given priority (i.e., resource efficiency vs. community creation). With the increasing enthusiasm for 'eating local' in the population and political support at different governance levels, questions around the capacity of a region to produce and supply enough food from local sources also surface: Can local agricultural resources meet the (urban) demand for diverse foods?

I argue that the scientific community probing and examining local food systems has tended to treat the food producer-facing side of local food supply, local food production capacity, and rural-urban relationships in less detail despite being a vital prerequisite to understanding and planning local food systems. Using the concept of foodsheds, which describes the geographical area from which food is sourced, previous studies have mapped, quantified, and analyzed local food supply chains, local food production capacity, and local food self-sufficiency at various geographical scales (e.g., Joseph et al., 2019; Kinnunen et al., 2020; Kriewald et al., 2019). As of the start of my doctoral research (circa 2018-2019), I had not encountered a consolidated analytical framework to map and assess foodsheds. Furthermore, food systems literature increasingly acknowledges the role of governance in the configuration of food supply chains (Boström et al., 2015; Carbone, 2017; Jia et al., 2020). Yet, within the context of local food systems research, an understanding of how cities govern their local foodshed and capacity and the strategies required to mobilize this food production capacity is largely missing. Finally, relevant studies that I encountered primarily focused on biophysical food production capacity but did not sufficiently integrate social capacity that can mobilize or limit production capacity within a local foodshed and help build resiliency to impacts.

It is crucial that regions critically examine the food production capacity of their current or potential local food system, assess windows of opportunity to build and sustain social and biophysical local food production capacity, and, just as important, identify limitations to localizing food systems. Without an integrated knowledge of social and biophysical capacity to build local foodsheds, cities and regions miss out on the opportunity to make informed decisions based on food systems data from their region. A lack of contextual information may also lead to overestimating food production capacity while underestimating the need to consider other land management options and provide necessary resources to food producers. Without grappling with these questions, I argue in this thesis that municipalities and regions risk setting the wrong policy incentives and steering the food system towards unintended outcomes. Given the major global and local challenges concerning food security, farmers' livelihoods, and ecological degradation humans are facing and will be facing in the coming decades, informed decisions pertaining to the food supply are in high demand.

1.3 Research Objectives and Thesis Structure

My Ph.D. research aims to expand the conceptual foundations of local food systems research using the local foodshed concept. Within this broader aim, my focus lies primarily on the food-producing stages of the supply chain rather than the market organization or food consumer. More specifically, I seek to understand better how foodsheds are quantified, planned, and sustained and how social and biophysical resources mobilize local food production capacity at the farmers' and urban governance levels. With this research, I seek to improve our understanding of the feasibility of local food systems and contribute to debates about and a body of literature on local food systems, rural-urban linkages, foodsheds, and the food production capacity of regions that allows them to become less dependent on global markets. Four specific objectives at three geographic scales guide my research, which corresponds to the four chapters of this thesis:

- **Objective 1:** conducting a global systematic literature review on urban foodshed analysis and proposing a novel calculation and conceptualization framework (Global)
- **Objective 2:** studying if and to what degree action plans and strategies towards food system localization of large cities in the US and Canada formulate objectives and tools to sustain or increase local food production and support the sustainable development of local agricultural production capacity (North America)
- **Objective 3:** identifying challenges and social support systems of farmers in the province of Québec selling to local markets that help to overcome challenges and build resilience to sudden and long-term impacts (Québec, Canada)
- **Objective 4:** investigating coping strategies of farmers in Québec selling to local markets in response to the Covid-19 pandemic (Québec, Canada).

In the next chapter (Chapter 2), I review relevant literature to provide a theoretical background for this work. The review covers the role and meaning of geography in food systems research, including global and local food systems and their promises and limitations, as well as research on foodshed analysis and local food production capacity. Following this review, the four original manuscripts are presented, connected by statements that explain their meanings for and contributions to the overall objectives of my Ph.D. research and their linkages with other work in this dissertation. The manuscripts fall into two methodological categories and three geographic scopes: Chapter 3 and Chapter 4 are based on document analysis and cover the global (Chapter 3) and North American scales (Chapter 4). In contrast, Chapters 5 and 6 are case studies at the provincial scale.

Subsequently, I comprehensively discuss the studies' findings, their contributions to the objectives of this dissertation, and the original contributions to knowledge and scholarship (Chapter 7). In Chapter 7, I elaborate and reflect on the methodological and conceptual contributions arising from my thesis, as well as three additional overarching contributions across the four empirical chapters which are discussed further in this synthesis chapter: the advantages of understanding food systems feasibility through food production capacity, the use of an integrated approach (social, biophysical) to studying local food systems, and the importance of analyzing dynamics in and beyond foodsheds (e.g., rural-urban linkages and international networks). I also weigh in on limitations as well as on implications for future research. Finally, in my conclusion (Chapter 8), I reflect on how the research objectives of this thesis were met through my research approach and summarize the implications of the dissertation's findings.

2 Literature Review

In this chapter, I provide a brief overview of the relevant literature for my dissertation. I organize this literature review by starting with an overview of the challenges in modern food systems from a global perspective. I move on to positioning food systems in a geographical context and briefly introduce global food trade, and its benefits and challenges, for juxtaposition with potential benefits, constraints, and limitations of local food systems, foodsheds, and food self-sufficiency capacity. Along with the meanings, claims, and challenges surrounding the local food systems concepts, I explain how foodshed analysis has been used to investigate local food systems and rural-urban relationships in the context of food supply by assessing local food production capacity and food self-sufficiency. My focus here lies on visualizing the status quo of the research field as well as identifying gaps.

2.1 Challenges facing food systems

The food systems concept is a starting point for analyzing the entire suite of factors responsible for bringing food from the producers to the consumers' table. These factors can determine whether food is produced, processed, consumed, and disposed of in a sustainable, fair, and equitable fashion. Central questions in food systems research are "How much food is required to meet food demands?", "How can we produce most sustainably?" and "How can we distribute food equitably?" (Foley et al., 2011). A growing and increasingly affluent global population, income-related food preference changes, such as the shift from starch-based to animal-based diets

(Kearney, 2010; Keyzer et al., 2005; Tilman et al., 2011) and rising demand for biofuel (Müller et al., 2008) call for growth and productivity improvements in the food and agricultural sector.

Pressures to increase agricultural productivity have led to undesirable outcomes. Modern food systems are dominated by destructive practices that exploit and pollute natural resources and require comparatively more land resources, leading to potentially irreversible impacts on people and the planet (Kastner et al., 2012, Aiking & de Boer, 2020). Those practices are often implemented to satisfy the growing demand for more perishable foods and animal protein among consumers with higher socio-economic status and means (Pingali, 2007). Agriculture is one of the largest emitters of greenhouse gases, consumes vast amounts of water, fertilizer, and substances, and occupies about 38%, or five billion hectares of the global land surface, of which about one-third is used for crop production and two-thirds for livestock (FAO, 2021). Impacts directly linked to agriculture are vast and comprise eutrophication, deforestation, water shortages, and water quality reduction (Pendrill et al., 2019; Scanlon et al., 2007; Tilman et al., 2011).

Other anthropogenic activities also challenge sustainability. For instance, land-use transformations threaten food production capacity and livelihoods, and foster land-use competition with potentially adverse effects on food production, agricultural systems, farmer livelihoods, and ecosystems (Bou Dib et al., 2018; Bren d'Amour et al., 2017; Haberl, 2015). Specifically, urban expansion and sprawl, one symptom of urbanization, are linked to food systems directly and indirectly (Seto & Ramankutty, 2016). Urban areas are generally closer to fertile land (Avellan et al., 2012; Bren d'Amour et al., 2017; van Vliet et al., 2017), which makes arable land more vulnerable to displacement, conversion, or pollution as a result of expansion and sprawl of physical urban space (Barthel et al., 2019).

Agriculture is increasingly affected by global climate change (Burke & Emerick, 2016; Challinor et al., 2014; Nelson et al., 2014). Among the most common threats to agricultural production are extreme weather events, such as floods, droughts, and storms, as well as soil erosion or water shortage (Rickards et al., 2012; Schilling et al., 2020). Those adverse events and processes are expected to compromise global land and water resources needed in agricultural, with adverse effects on yields, habitats, and livelihoods (Müller & Robertson, 2014; Nelson et al., 2014).

Geopolitical conflicts can further disrupt food supply chains, accelerate, and aggregate existing tensions, and contribute to food crises (Bar-Nahum et al., 2020; Clapp, 2017; Kemmerling et al., 2022). At the same time, food loss and waste along the entire supply chain is considered a global concern (Gustavsson, 2011). It is estimated that around 1.3 billion tons of food annually, or about 30% (UNEP, 2021), are never eaten by consumers, of which half (54%) is lost during the harvest and post-harvest stages (FAO, 2013). Besides the nutritional value, food loss and waste account for a loss equivalent to 25% of global resources necessary for its production and distribution, such as land, freshwater, energy, and fertilizer (Kummu et al., 2012; Lundqvist et al., 2008).

These and other compounding challenges threaten global food security and farmers' capacity to sustain their livelihoods and produce food for markets (Abate, 2008; Ashkenazy et al., 2018; Kangogo et al., 2020; Kohn & Anderson, 2021). Climate change impacts, such as droughts, floods, pest infestations, and other disruptions, threaten the livelihoods of farmers worldwide (Harvey et al., 2018; Kohn & Anderson, 2021; Thornton et al., 2017). In addition, farmers are vulnerable to uncertain funding and financial support (Fisher, 2013; Tregear & Cooper, 2016), challenges in adopting and adapting farming technologies (Castillo et al., 2021), and finding and accessing available agricultural land (Horst & Gwin, 2018).

On the consumer-facing side of food systems, obesity and non-communicable diseases are rising, especially in industrialized nations, due to the increasing availability and accessibility of hyper-processed, energy-dense yet nutrient-poor foods (Barnhill et al., 2018). At the same time, the FAO voices that, in 2020, between 720 and 811 million people globally experienced hunger due to temporary food shortages or chronic food insecurity (FAO, 2022). Although the technological infrastructure allows us to produce vast amounts of food, food security is still prevalent and exists not only in developing countries (Pollard & Booth, 2019). For instance, between 2017 and 2018, 12.7% of Canadian households (4.4 million people) were food insecure (Tarasuk & Mitchell, 2020). Stuckler and Nestle (2012) suggest that multinational food and beverage manufacturers and their market power are the sources of what they call 'nutritional failures' in global food systems.

2.2 Geographic perspectives on food systems: Global and local

Science, governance, and businesses are tasked with sustaining and creating environmentally and socially sustainable food systems and responding appropriately to food demands. Various solutions have been proposed to counteract the multi-dimensional pressures, such as closing yield and diet gaps, halting agricultural land expansion, and enhancing the efficiency of agricultural inputs (Foley et al., 2011). Besides technological advances, some scholars and advocates argue that the geographical distance, centralization, spatial networks, and length of food supply chains are responsible for many adverse outcomes of our current food systems (Kloppenburg et al., 1996; Ericksen, 2008; Raj et al., 2022). Therefore, re-organizing those supply chains could solve some of the problems that threaten current and future food production and distribution.

One approach to conceptualizing food systems and corresponding challenges is through a spatial lens, looking at food systems actors, processes, and outcomes at various scales. Within this research domain, food systems researchers dissect and juxtapose the vast networks of food flows across transnational borders through global food trade (Kastner et al., 2021; MacDonald et al., 2015) as well as food supply chains that operate at sub-national and 'local' levels and reduce the overall physical and social distance between food production, distribution, and consumption (G. Feenstra, 1997; Kneafsey et al., 2013; Renting et al., 2003).

2.2.1 Global food trade

Due to developments in food production, transportation infrastructure, mass retail, and globalization, our food supply chains are primarily international and trade-oriented (Goodman & DuPuis, 2002). Industrial processes such as refrigeration can extend the freshness and shelf-life of perishable foods and enable the transportation of those commodities over lengthier times and distances (Goodman & DuPuis, 2002; Schwarz et al., 2016). Most populations are no longer constrained by resource capacity limitations of their hinterland that can impede the growth prospects of a region. Instead, they can – or must – fill food supply gaps through imports from faraway regions (Kinnunen et al., 2020; Porkka et al., 2013).

Benefits of global food trade

Global food trade is an essential mechanism for securing the food supply of nations. For example, MacDonald et al. (2015) estimate that the volume of global food trade in the 2000s was enough to theoretically meet the basic caloric needs of almost 2 billion people. When considering land and water resources, approximately every sixth person in the world depends on international food networks to access certain agricultural products (Fader et al., 2013). Aside from macro-nutrients like carbohydrates and protein, Wood et al.'s (2018) models show that 146 to 934 million people get essential micro-nutrients from global food supply chains. Global food trade has undergone an overall augmentation in recent decades (D'Odorico et al., 2018). Fader and colleagues (2013) estimate that the dependency of people on food from global sources may further rise.

By importing food, countries can externalize social and environmental costs of food production, take advantage of more favourable conditions (e.g., resource endowments) in trading partner nations, and reduce dependency on domestic land and water resources (Clapp, 2014; Fader et al., 2013). Food imports can be prompted by stricter environmental protection regulations to avoid necessary and potentially costly, and politically unpopular regulations for the domestic agriculture sector (such as fertilizer application restrictions) (Nesme et al., 2016) or resource shortages (Yang et al., 2007). Food trade can also balance relative differences in resource efficiency and take advantage of resource-saving technologies (Dalin & Conway, 2016). Global food trade is also an option when technical advancements in the agricultural sector can only attain marginal yield improvements as resource efficiency ceilings are reached (Seekell et al., 2017).

Satisfying consumer demands for foreign or resource-intensive foods is another main benefit of global food supply chains. Long food supply chains grant most consumers in the Global North access to diverse foods from all over the world at almost any time of the year (Clapp, 2014). Many crops cannot be cultivated in the climates of the places of consumption, and seasonal restrictions apply to most domestic crops outside the tropics. For most consumers in North America and Europe, tropical fruits, coffee, specific types of seafood, and other crops would be inaccessible.

Critiques of global food trade

A growing body of literature finds multiple problems associated with global food trade (Dalin & Rodriguez-Iturbe, 2016). For instance, a country, aiming to reduce adverse effects or expenses linked to the production of a crop by importing this crop and growing a different crop instead, can negatively affect the local agricultural landscapes when the food production of the new crop requires different or higher resource use (Hansen et al., 2013; Sun et al., 2017). Additionally, the increasing number and magnitude of extreme climate change-related weather events, political tensions, and economic failures can compromise centralized international food networks, yielding power changes between exporting countries (or even monopolizing global food markets) and importing countries (Bren d'Amour et al., 2017; Gephart et al., 2016). Secondary shocks like export bans or tariffs to protect domestic stocks can place additional pressure on food trade networks (Gephart et al., 2016).

Furthermore, global food trade can lead to price increases of domestic staples, which may limit access to essential foods for people with low economic means (Meyfroidt, 2018; Wood et al., 2018). Although export markets can become an economic opportunity for small-scale farmers in exporting countries (Meyfroidt, 2018; Minten et al., 2009; Schwarz et al., 2016), evidence suggests that many farmers do not benefit or even experience negative repercussions with trade liberalization (Cheshire & Woods, 2013; Kanyamurwa et al., 2013; Nugroho & Lakner, 2022), including the loss of cultural identity and traditional knowledge (Sayok & Teucher, 2018).

Across the literature, some debate that unsustainable food systems are primarily driven by consumers' lack of awareness about the origins of their food and the impacts associated with its production, as consumers do not experience the detrimental effects of food production themselves (Kloppenburg et al., 1996; Ericksen, 2008; Raj et al., 2022; Sun et al., 2017). Hence, the physical and social distance between producers and consumers is considered a barrier to awareness creation about consumer impacts and required actions in food systems (Clapp, 2014; Dalin & Conway, 2016; Nesme et al., 2016). The accountability and transparency needed to identify, track, and persecute damaging behavior and detrimental actions, with some exceptions, are often missing in global food systems (Curtis et al., 2018; Ercsey-Ravasz et al., 2012; Morton et al., 2006).

2.2.2 Local food systems

In response to the augmentation of global food trade in recent decades, investing in local food economies and consuming locally grown food has received increasing attention in North America and has even been encouraged by various governmental institutions (Derkatch & Spoel, 2017; Hinrichs & Allen, 2008; O'Hara & Coleman, 2017; Thilmany et al., 2021). Growing awareness about agriculture's negative social and environmental impacts and distrust toward the 'conventional' food industry has inspired practitioner-led re-localization and food self-sufficiency movements with the goal to establish and promote initiatives such as farmers' markets and local food procurement groups. The recent global pandemic has, once again, reignited interest in local food systems driven by the fear of food shortages due to perceived or actual global supply chain disruptions (Aday & Aday, 2020; Zollet et al., 2021).

Defining local food systems

Despite a rich, multi-disciplinary literature on local food systems, no universally agreed-upon definition of 'local' has been established (Eriksen, 2013; Granvik et al., 2017) but instead consists of "*a diverse landscape of meaning*" (Eriksen 2013, p. 49). Various scholars have engaged in thoroughly analysing, synthesizing, and juxtaposing different definitions of 'local' (Eriksen, 2013; Feagan, 2007; Hedberg II, 2020). For instance, Eriksen proposes a taxonomy of proximity with three dimensions: "*geographical proximity, relational proximity, and values of proximity*," of which geographical proximity seemed to be the most frequently utilized (Eriksen 2013, p. 49-50). According to Eriksen, the dimension of geographical proximity in food systems describes a *"specific physical (territorial) locality, distance and/or radius within which food is produced (originates), retailed, consumed, and/or distributed*" (2013, p. 52)[4].

The delimitation of where 'local' ends and 'non-local' begins often depends on the geographical context, the actors managing a project or program, and its purpose. The definitions of 'local' even vary between different food systems stakeholders, such as consumers, producers, and food retailers

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[4] For my work, I used Kneafsey et al.'s definition of a local food system, which describes all activities involved in food production, distribution, and consumption within a "defined geographic area" (Kneafsey et al., 2013). In line with the watershed concept, this geographic area can be defined as a foodshed (Peters et al., 2009; Brinkley, 2013).

(Carroll & Fahy, 2015; Granvik et al., 2017; Cappelli et al., 2022). Generally speaking, local food systems can span across a circumference of a few dozen to several hundred kilometers or be delimited by subnational jurisdictions (DEFRA, 2003; Feldmann & Hamm, 2015; Schreiber et al., 2021). For instance, the U.S. Congress defined in their 2008 Farm Act that, to qualify as "*locally or regionally produced agricultural food product,*" the item must not travel further than 400 miles from the place of production or must remain in the state of production (Martinez et al., 2010).

Adjacent to the local food systems concept is the notion of ‘short food supply chains’ which has been promoted and studied extensively in recent years (Lankauskienė et al., 2022). What differentiates short food supply chains from local food systems is their focus on the operational character of food supply: short food supply chains primarily describe the organization of the supply chain, pertaining to direct or close-to-direct marketing of food from producers to consumers. Common modifications and values include the establishment of direct social linkages between food producers and consumers, the redundancy of large-scale intermediaries (e.g., supermarket chains), and a desire to build trust via reciprocal relationships and shared values that shape interactions and transactions (Bauermeister, 2016; Trivette, 2017; Blay-Palmer et al., 2018; Vittersø et al., 2019). While short food supply chains are often embedded in local food systems, due to the physical proximity needed to sell the food, not all food distribution in local food systems is direct between producers and consumers (Enthoven & Van den Broeck, 2021).

Although local food is often distributed directly to the consumer via farmers’ markets, farm stores, U-pick, or community-supported agriculture, efforts toward strengthening and scaling local food systems frequently and increasingly involve participation of intermediaries (Grigsby & Hellwinckel, 2016; Mount, 2012). Different demographic and socio-economic consumer categories may only be reachable via multi-modal distribution, including supermarkets (Zwart & Wertheim-Heck, 2021), small food businesses (Hernández et al., 2021), food hubs (Perrett & Jackson, 2015; Furman & Papavasiliou, 2018), and other food retailers (Blake et al., 2010; Bloom & Hinrichs, 2011; Trivette, 2019), as well as programs with institutional partners such as universities, schools, and other institutions (Buckley et al., 2013; Kretschmer & Dehm, 2021).

Local food systems, along with organic food production, short food supply chains, and supply chain certification (i.e., 'Fair Trade'), have been declared part of 'Alternative Food Networks.' These networks provide space for food production and distribution practices that differ from 'conventional' food systems by working toward more just and sustainable outcomes (Forssell & Lankoski, 2015). Alternative Food Networks are suggested to increase the heterogeneity of food supply chains, aiming to facilitate food systems that enable economically viable, ecologically sound, and socially equitable food provisioning (Feenstra, 1997). Although the concept is highly contested as the proclaimed sustainability benefits and positive impacts may not sufficiently materialize (Forssell & Lankoski, 2015), and the boundaries between 'alternative' and 'conventional' are not always apparent, Alternative Food Networks receives great interest from practitioners and scholars alike.

An outcome that some supporters of food systems localization often advocate for is food self-sufficiency, which has been used as a metric to describe the theoretical capacity of a region to feed its population with food produced from within the region (see Chapter 3). There is no agreed-upon definition of food self-sufficiency and self-reliance, and, according to Clapp (2017, p. 89), "*some aspects are still fuzzy.*" Most commonly, definitions take an aspirational tone, describing food self-sufficiency as a state in which a region relies exclusively on food production from its landscapes and refrains from any food trade while still meeting the food demands of the population (Clapp, 2017; Pradhan et al., 2014). Similarly, some scholars have used the term 'self-reliance' (see Conrad et al., 2017; Grewal & Grewal, 2012; Griffin et al., 2015; Orlando et al., 2019; Peters et al., 2016). This conceptualization often aligns methodologically with the metric food self-sufficiency in that it describes food production and consumption within a region. However, its theoretical assumptions can differ depending on how scholars employ this metric. For instance, Kloppenburg et al. (1996) suggest that, while self-sufficient regions aspire toward disconnecting from global food trade, self-reliant regions retain the ability and aim to participate in food trade.

Local food self-sufficiency is considered a strategy to secure food supplies, while a lack of capacity to ensure the necessary food supplies is suggested to present a potential security issue for households or even entire nations (Clapp, 2017; Nyikahadzoi et al., 2012). Local food self-sufficiency and self-reliance have been discussed and studied at the household scale (see Dunlap et al., 2020; Nyikahadzoi et al., 2012), city-scale (see Grewal & Grewal, 2012), regional/local scale (see Buschbeck et al., 2020; Gupta, 2014; Peters et al., 2016), country scale (see Clapp, 2017; Herdt, 1998) and across various scales (see Pradhan et al., 2014).

Local food activism and policymaking

Many urban food systems activists and politicians support the local food movement to manifest and show their commitment to local farmers, stimulate local food economies, and encourage spendings primarily within the community (Jacques, 2021). For over two decades, cities have been perceived as "*food system innovators*" within local food systems scholarship (Sonnino, 2009, p.

428). This shift in narrative has re-oriented the view on power distribution, responsibility, and accountability from food policies being a primarily rural concern to cities taking up the task of identifying, negotiating, defining, and shaping food systems goals and tools (Sonnino, 2009). For instance, some municipalities that implemented urban food policies intending to promote local food systems have seen an increase in food consumption from local sources (Wegener et al., 2012).

Formal networks created for municipalities demonstrate that an increasing number of cities set food sustainability on their municipal agendas or implement food policies, stakeholder groups, or councils (Candel, 2019). Such agendas most frequently target urban issues related to food systems, such as food insecurity, by tasking diverse urban actors (e.g., schools, NGOs) to increase the number of healthy foods supplied to food insecure communities and households. Growing food on urban land (commonly referred to as urban agriculture) and the organization and facilitation of farmers' markets are also commonly addressed themes.

Many initiatives have moved out of the niche and into the mainstream (DeLind, 2011). Although they take many shapes and forms, their commonality is the basic assumption that localization addresses shortcomings of global food systems and can contribute to a more sustainable and fair food procurement (Morgan, 2015).

Objectives and motivations of local food systems movements

The local food movement, according to Feenstra (2002, p. 100), is "*a collaborative effort to build more locally based, self-reliant food economies - one in which sustainable food production, processing, distribution, and consumption [are] integrated to enhance the economic,* *environmental, and local health of a particular place.*" This social movement tries to re-build local food supply chains and encourages consumers to buy local and support farmers in the region rather than rely on food from global trade networks (Buchan et al., 2021; Jacques, 2021; Selfa & Qazi, 2005). Local food systems research often emphasizes how the reliance on local resources and relationships may lead to a higher resilience to systemic shocks (Darnhofer et al., 2016; Vieira et al., 2018; Yacamán Ochoa et al., 2019; Chiffoleau & Dourian, 2020). Local food systems advocates further propose that those relationships and dynamic consumer co-creation enable governance processes and outcomes that allow for more bottom-up actions than food systems organized by often centralized multi-national corporations (Mars, 2015). Behind this agenda is the aim to take or build more control over production and marketing processes, redistribute benefits, and determine and realize outcomes that enhance social and environmental welfare. Within this philosophy, local food systems proponents may aim to shift and reorganize power relationships towards communities and reduce the influence of large multi-national corporations engaged in food production and global trade (Clapp, 2014; Hammon & Currie, 2021; Hitchman, 2016). By doing so, the movements aim to initiate and drive change at the community or city-scale and overcome power deficiencies (Porter et al., 2014). Local food systems may also provide the potential to close metabolic cycles between cities and local agricultural landscapes by recycling urban biowaste for agricultural purposes (Akram et al., 2019; van der Wiel et al., 2019).

Some of these attributes are reflected in consumers' motivations to buy more local food. The literature on the drivers to buy local is vast and finds that motivations tend to vary across geographical contexts. Studies have found that environmental concerns (Aprile et al., 2016; Hiroki et al., 2016; Bianchi, 2017; Albrecht & Smithers, 2018; Bimbo et al., 2021), local patriotism and pro-social behavior towards local food producers (Aprile et al., 2016; Bianchi, 2017; Hiroki et al., 2016; Megicks et al., 2012; Skallerud & Wien, 2019), high standards in terms of food quality (Megicks et al., 2012; Penney & Prior, 2014; Hiroki et al., 2016; Pícha et al., 2018), and perceived health concerns (Albrecht, 2018) are common drivers. As with consumers, the motivations of food producers participating in local food systems varies by context. This group of actors is not necessarily driven to local markets because of profits or financial returns but by their value systems and interest in contributing to community food systems, maximizing social benefits, and reducing the environmental impact of food systems (Izumi et al., 2010; Matts et al., 2016; Charatsari et al., 2018).

Critiques of local food systems movements

While enthusiasm over local food systems has reached the mainstream, critique of the goals and methods arises from various vantage points. Scholars and practitioners have challenged the claims on the benefits of local food systems for several years (Winter, 2003; Jarosz, 2008; Morgan et al., 2008; Coley et al., 2009). For instance, they criticized the concept of 'Alternative Food Networks' for its faint lines between 'alternative' and 'conventional,' which may lead to a dilution of the concept and co-opting by food producers, processors, and retail interested in marketing rather than actual change. Likewise, Morgan et al. (2008) argued that many local and 'alternative' food initiatives replicate elements of the conventional food systems, and that systemic change requires more disruptive action and transitions toward equitability and inclusivity.

Recent meta-studies have not found sufficient evidence to support most claims made by local food advocates and concluded that local food is not inherently more sustainable, healthier, socially inclusive, and fairer than food from non-local sources (Enthoven & Van den Broeck, 2021; Schmitt et al., 2017; Stein & Santini, 2021). Farmers participating in direct and short food supply chains do not necessarily benefit economically, increase access to healthy foods, or produce in a more environmentally friendly way (Enthoven & Van den Broeck, 2021). Somewhat paradoxically, local food systems could even interfere with food justice goals. The local food movement tends to be oriented towards and dominated by mostly white and affluent socioeconomic groups, such as in the case of niche urban food markets (Selfa & Qazi, 2005; Blake et al., 2010; Alkon & McCullen, 2011). Finally, O'Hara and Low (2016) found that income fluctuations can affect the consumers' willingness to pay for local food, which is often sold at premium prices, with potentially adverse effects on farmers' revenues. The sustainability of local food systems may also hinge on the degree to which nutrients essential for agricultural production (e.g., phosphorus) can circulate within the foodshed rather than be directly or indirectly imported through centralized global supply chains and trade networks (Hedberg II, 2020).

Likewise, local food self-sufficiency may not be a realistic or even desirable goal given local and domestic constraints, risks, and opportunity costs. Satisfying the demand for foods within a specific geographical boundary may not be feasible due to bio-physical and climatic constraints (Chapter 3), such as urban sprawl taking over fertile cropland (Barthel et al., 2019). Globally, food production may be vulnerable to disruptions, such as natural disasters and other fluctuations, and could undermine export potentials for farmers, which may translate into food insecurity and lead to food price rises and production declines due to market inefficiencies and distortions (Clapp, 2017). Although referring to the country-scale and not local scale, Clapp (2017) advocates for adopting a more nuanced perspective on food self-sufficiency and recognizing a continuum between closed borders and fully open trade.

Nevertheless, much discussion and need for research remain to understand to what degree conscious management can eliminate some limitations. For instance, a dominant argument about the concept of ‘food miles’ has gathered controversy and attention. Some argue that fewer ‘food miles’ (the distance that food travels from the place of production to the place of consumption) do not necessarily translate into lower environmental impacts due to the high complexity of food production and distribution systems (Coley et al., 2009; Michalský & Hooda, 2015; Christensen et al., 2018) and can be more energy-intensive than importing food (Avetisyan et al., 2014; Goldstein et al., 2016). Others propose that logistical optimization can make energy-efficient local food systems possible (Mundler & Rumpus, 2012), for example, by scaling food production (Grigsby & Hellwinckel, 2016). Further, Schnell (2013) argues that limiting the discussion over whether local food is ‘better’ on food miles and associated emissions distracts from other, primarily social, benefits and meanings of local foods.

In summary, local food systems can encompass direct and indirect social and environmental trade-offs (Ericksen, 2008) that vary by context and need specific attention. Neglecting those trade-offs and proposing local food systems as the most sustainable and desirable form of food sourcing can lead to maneuvering into a so-called ‘local trap’ (Born & Purcell, 2006). It is crucial to understand the limits of local food systems - not only for consumers. Born and Purcell (2006) argue that rural and urban planners sit at powerful levers and can weigh in on decisions that determine access to resources. We must, therefore, understand the role of scale in food systems planning and avoid managing or planning according to scalar differences based on assumptions without thorough reflection on empirical evidence.

2.2.3 Analysing local food systems and rural-urban relationships

Aspirations to change food systems by physically 're-connecting' consumers with producers have led to a paradigm shift: from food as a mere business and supply chain concern to a territorial conceptualization (Feenstra, 1997; Renting et al., 2003; Kneafsey et al., 2013). Employing diverse epistemologies, scholars have contributed to the territorial conceptualization of local food systems (Dubbeling et al., 2017) through frameworks such as 'foodsheds' (Hedden, 1929; Kloppenburg et al., 1996), 'city-region food systems' (Blay-Palmer et al., 2018), 'metropolitan agri-food systems,' (Sali et al., 2014), and 'food supply chain embeddedness' (Penker, 2006).

In this context, researchers have started to account for and study the social and physical relationships between (often) urban consumers and rural food producers (Dubbeling et al., 2017). Studies in this field focus on the linkages between cities and nearby or remote agricultural landscapes and the food producers' and consumers' shared interest in local food systems and food systems sustainability. Understanding and quantifying those relationships by studying food systems with foodshed maps can help us to determine local food production capacity and self-sufficiency capacity, the dependency on other regions, the vulnerability to food supply chain disruptions, and the role of local and global food supply in buffering those risks and dependencies (Dalin et al., 2012; Cumming et al., 2014; Dubbeling et al., 2017).

Foodshed analysis

To examine local food supply and self-sufficiency, foodshed analysis has been used to quantify the geographies of local food supply and specified relationships between food-producing and food-consuming regions. For instance, researchers have identified the origins of food, traced food supply chains at subnational and national levels, and studied the limitations of local food systems and relative resource endowments by conducting food flow analysis (Moschitz & Frick, 2021). Common approaches to quantifying local food systems and food self-sufficiency also include calculating and juxtaposing urban food demand with potential or actual local food supply and investigating the potential impact of behavioral and land-use changes on local food self-sufficiency capacity.

The foodshed, an analogy to the watershed, was conceptualized by Walter Hedden and Benton MacKaye in the 1920s. Foodshed analysis was only sparsely used throughout the 20th century but had a revival in the early 1990s when permaculturist Arthur Getz utilized the concept to convey normative and aspirational perspectives on local food systems and food self-sufficiency from a spatial angle (Getz, 1991). The concept was further developed by rural sociologists and geographers and was re-discovered and developed in the past decade. Most foodshed analyses have been conducted in high-income countries in the Global North (Chapter 3), leaving knowledge gaps in the African, South American, and Asian contexts. So far, relatively few studies have contributed to our understanding of foodsheds in those areas (e.g., Karg et al., 2022).

Several studies have mapped, quantified, and analyzed local food systems, foodsheds, and food self-sufficiency potentials (Carey et al., 2019; Doernberg et al., 2019; Zasada et al., 2019; Vicente-Vicente et al., 2021) as well as food distribution networks (Karg et al., 2016; Wegerif & Wiskerke, 2017; Moschitz & Frick, 2021). Measuring the feasibility of local food systems from a quantitative angle is considered necessary to assess the biophysical limits of local food systems and to estimate the degree to which those systems are realistic (Joseph et al., 2019; Kriewald et al., 2019; Kinnunen et al., 2020). Besides estimating food self-sufficiency potential, foodshed analysts have included additional objectives and goals such as improving local diets (Desjardins et al., 2011) and scrutinizing the environmental impact of localizing a food system and maximizing self-sufficiency given governmental environmental regulations (Buschbeck et al., 2020), among others (see Chapter 3).

The food production capacity of certain regions to feed their populations can be considerably lower than anticipated. For instance, with current food production and consumption patterns, only one-third or less of the world's food demand can be supplied by local sources (Kriewald et al., 2019; Kinnunen et al., 2020). Kinnunen et al. (2020) estimate that 11–28% of the global population could fulfill their crop-specific energy demand within 100 km. Likewise, foodshed analysts warn that augmenting local food self-sufficiency may compete with other goals and interests. For instance, local food self-sufficiency may inhibit meeting local environmental targets (e.g., impact reduction) (Buschbeck et al., 2020) or come at the cost of food diversity (Vicente-Vicente et al., 2021; Bingham et al., 2022). Some studies also found that organic production methods, because of yield differences compared to conventional intensive agriculture, may reduce local food production hence limiting food self-sufficiency potential (Zasada et al., 2019; Rüschhoff et al., 2022). Furthermore, limitations can also be found in terms of adequate storage, processing, and transportation infrastructure that is necessary to mobilize local food production capacity (Kurita et al., 2009; Peters et al., 2009). Satisfying the demand for local foods with specific growing or storage requirements (e.g., tropical and seasonal fruits and vegetables, bread, dairy, oils, fish, or meat) requires local technical or logistical infrastructure that may not be readily available (Godette et al., 2015, Chapter 3).

Radical changes in food consumption and production within the food systems could overcome some limitations presented above. For instance, recent studies have found that dietary shifts toward more plant-based products and reducing food loss and waste are influential factors in facilitating food systems localization and reaching local food self-sufficiency (Kurtz et al., 2020; Rüschhoff et al., 2022; Vicente-Vicente et al., 2021). The loss of food diversity through international trade could, to some degree, be compensated by increasing crop diversification within the region (Vicente-Vicente et al., 2021).

Despite considerable progress in the field of foodshed analysis, there are still gaps that must be addressed. For instance, foodshed analysts have been struggling with a lack of available or accessible data to study food systems from a territorial vantage point. Those gaps can limit the quality of analysis and the conclusions that can be drawn. Specifically, the spatial and temporal resolution of data is often inadequate and does not allow for analysis taking the socioeconomic and biophysical circumstances into account (Porter et al., 2014; Wegerif & Wiskerke, 2017; Akoto-Danso et al., 2019). Work also suggests that debates about the scope of local food systems should be expanded. For instance, current foodshed analyses do not include input factors of agricultural production (e.g., fertilizers). However, studying the flows of factors relevant to production, such as phosphorus, can offer insights into the dependency of food producers on global nutrient supply chains and their vulnerability to shocks in the world market (Hedberg II, 2020).

Expanding foodshed analysis: Social capacity for local food production

Although biophysical capacity is a crucial component in mapping local foodsheds and determining local food production and self-sufficiency capacity, it is only one factor among many. Food systems are complex networks of social, ecological, and technological factors, relationships, and interactions. Hence, social and infrastructural factors can further determine to what degree the biophysical capacity can be exploited and mobilized. However, scientific literature and crucial knowledge about the various ways local food production capacity is built and sustained is largely missing.

It has been shown that food producers must respond to various challenges that complicate or even threaten their businesses and livelihoods (Ashkenazy et al., 2018; Kangogo et al., 2020; Kohn & Anderson, 2021). For instance, farmers often struggle to find an affordable, stable, and dependable workforce (Bruce & Som Castellano, 2016; Bampasidou & Salassi, 2019; Rutledge & Taylor, 2019, Chapters 5 and 6). Especially for food producers participating in local food systems, workforce is a considerable cost factor and sometimes accounts for most expenses (Biermacher et al., 2007; Jablonski et al., 2019). Likewise, the ‘digital divide’, describing limitations in using information technology, can constrain farmers’ access to information, markets, and resources necessary to make informed decisions for their farming operations (Raison & Jones, 2020).

Very often, social infrastructure, such as social networks and relationships, offers crucial physical, economic, and emotional support to local food systems and farming communities (Iles et al., 2021; Scott & Richardson, 2021). Particularly grassroots organizations and other local food systems-oriented organizations are an essential factor in sustaining local food capacity by supporting farmers with various concerns and tasks (Allaby et al., 2021). Social support systems, such as entrepreneurial networks can drive or hinder the development of local food networks (Eriksen & Sundbo, 2016). This demonstrates the potential and importance of coordinated and joint strategies for building local food networks and the conflicts that can arise due to diverging interests. Godette et al. (2015) identify several factors that limit the development of local food markets and rural-urban linkages, including the farmers' perspective, such as costs, uncertainty, access to capital, attitudes toward change, risk adversity, and a lack of connectivity between producers and institutional buyers.

Limitations to local food systems lie in both biophysical capacity and the social dimension. Social factors require additional attention to understand their meaning for and the limitations of mobilizing local bio-physical food production capacity.

2.3 Summary and conclusion

This chapter has provided a brief review of scientific literature related to or adjacent to my research in this thesis. Discussing a selection of literature in this chapter helps to situate subsequent chapters within a broader body of research on food systems and local food systems in specific. I set the stage for my empirical chapters by introducing food systems, followed by a review of literature that acknowledges geography as an important vantage point through which we can understand the spatial processes and outcomes of food systems and potential leverage for change. The globalization of food trade has resulted in many benefits for the food system. However, the trade-offs have inspired and initiated action across various governance scales and dimensions aiming to balance or overcome what is deemed to be an unsustainable and unjust system. Although my dissertation does not explicitly and extensively examine global food trade, I am convinced that engaging critically with this body of research helps to better comprehend the diverse rationales of local food system advocacy and movements towards more local self-sufficiency.

As outlined in the previous sections, a vast body of literature exists on the sustainability dimensions of local food systems. To date, there seems to be a lack of consensus among scholars on the benefits and limitations of local food systems, most likely because of the high contextual variability. Beyond sustainability questions, an increasing body of literature has been questioning to what degree local food systems are feasible and challenge the food self-sufficiency capacity. To set the stage for my following empirical chapters, I shed light on recent local food systems and foodshed research, its theories, controversies, and research gaps. Local food systems and foodshed research has attracted much attention in the past 20 years and continues to play a role beyond the scholarly community.

Findings from my review of the literature demonstrate the need to study local food systems from a normative and a pragmatic angle and incorporate feasibility in future research methodology, analysis, and interpretation. Furthermore, based on my review of relevant scientific research, I propose that foodshed research, which focuses predominantly on biophysical resources, takes on questions covering social capacity needed to mobilize biophysical capacity.

Connecting Statement

In Chapter 2, I reviewed the literature on food systems research and how this research stream has conceptualized food systems through a geographical lens. I defined and juxtaposed global and local food systems and reflected on the latest findings and research gaps.

Next, I turn to my first analytical manuscript chapter, Chapter 3. In collaboration with co-authors, I conducted a systematic global literature review of peer-reviewed publications that quantify and analyze local food self-sufficiency and multi-scalar food flows between 1979 to 2019. This chapter provides an overview of how urban and local foodsheds have been studied and the gaps future foodshed analyses should address.

The classification of three overarching analysis types (agricultural capacity, food flow, and hybrid) and the development of a synthetic framework contributes to the consolidation of urban and local foodshed research. Besides pointing to future research avenues, I emphasize the value and potential of foodshed analysis to inform food systems policy and planning concerning the benefits and tradeoffs, as well as opportunities and limitations of food supply from local, regional, and global sources.

Findings from my analysis in Chapter 3 are then used to inform the analytical framework of the manuscript presented in Chapter 4. Likewise, the findings of the systematic review also underpin the studies on social relationships and adaptation strategies of local farmers in Québec, shown in Chapters 5 and 6. Most importantly, the foodshed research has predominantly focused on biophysical resources that limit or enable local food self-sufficiency without adequately acknowledging the role of social capacity to mobilize biophysical resources.

3 Quantifying the foodshed: A systematic review of urban food flow and local food self-sufficiency research

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Abstract

Cities are net consumers of food from local and global hinterlands. Urban foodshed analysis is a quantitative approach for examining links between urban consumers and rural agricultural production by mapping food flow networks or estimating the potential for local food self-sufficiency (LFS). However, at present, the lack of a coherent methodological framework and research agenda limits the potential to compare different cities and regions as well as to cumulate knowledge. We conduct a review of 42 peer-reviewed publications on foodsheds (identified from a subset of 829 publications) from 1979 to 2019 that quantify LFS, food supply, or food flows on the urban or regional scale. We define and characterize these studies into three main foodshed types: (1) agricultural capacity, which estimate LFS potential or local foodshed size required to meet food demands; (2) food flow, which trace food movements and embodied resources or emissions; and (3) hybrid, which combine both approaches and study dynamics between imports, exports, and LFS. LFS capacity studies are the most common type but the majority of cases we found in the literature were from cities or regions in the Global North with underrepresentation of rapidly urbanizing regions of the Global South. We use a synthetic framework with ten criteria to further classify foodshed studies, which illustrates the challenges of quantitatively comparing results across studies with different methodologies. Core research priorities from our review include the need to explore the interplay between LFS capacity and interregional food trade (both imports and exports) for foodsheds. Hybrid methodologies are particularly relevant to examining such dependency relationships in food systems by incorporating food flows into LFS capacity assessment. Foodshed analysis can inform policy related to multiple components of sustainable food systems, including navigating the social and environmental benefits and tradeoffs of sourcing food locally, regionally, and globally.

3.1 Introduction

Cities are economic and cultural centers yet rely on flows of resources and other materials from local and global sources (Haberman and Bennett 2019). This applies especially to food given both biophysical and practical constraints on food self-sufficiency in and around urban areas (e.g. Zumkehr and Campbell 2015, Clinton *et al* 2018). Urban food systems are thus 'telecoupled,' with cities and their hinterlands connected over vast distances through flows of food, money, knowledge, and information (Seto *et al* 2012, Liu *et al* 2013). Because of their linkages with peripheral areas, city-scale actions can lead to complex tradeoffs for land and water resources, as well as greenhouse gas emissions (Boyer and Ramaswami 2017). For example, transitions towards more animal-protein based diets, which may be related to urbanization, can result in agricultural land-use change in exporting countries (Defries *et al* 2010, Seto *et al* 2012, Seto and Ramankutty 2016, Silva *et al* 2017). Accordingly, cities are fundamental to understanding food systems sustainability (Seto and Ramankutty 2016) and city-regions are recognized as a key governance scale for food systems transformation (Blay-Palmer *et al* 2018). As urban areas now comprise the majority of population growth globally (UNDESA 2014), the reciprocal relationships between cities and their food supplying hinterlands is increasingly important but arguably understudied.

Globalized food systems with long and complex supply chains provide consumers in many countries year-round access to diverse foods, but also increases the physical and social distance between producers and consumers (Clapp 2014). Cities sourcing from international markets might, for example, lack the governance power to configure food supply chains towards greater sustainability (Porter *et al* 2014). At the same time, with current patterns of food production and consumption, just one-third or less of the world population's food demand can be supplied by local sources (Kriewald *et al* 2019, Kinnunen *et al* 2020). Food system mapping can therefore increase our understanding of a city's or country's import dependence and vulnerabilities related to food, including whether or not local or global sourcing is likely to improve or compound this (Dalin *et al* 2012, Cumming *et al* 2014, Dubbeling *et al* 2017).

The 'foodshed' concept is increasingly used to discuss the geography of urban food supply and particularly to describe the linkages between food-producing and food-consuming regions at different scales. The concept initially emerged in the early 20th century, drawing on the analogy of a watershed. To our knowledge, the planner and conservationist Benton MacKaye provided the first empirical study of the linkages between cities and agricultural hinterlands through supply chains. In 1920, he studied Washington D.C.'s food supply to identify logistics efficiencies and proposed a local and national food production and distribution network (Mackaye 1920). In the same decade, a potential strike of the train transit union that could have impacted food shipments to New York City initiated Walter Hedden's book 'How Great Cities are Fed' (Hedden 1929). Hedden mapped food flows from various agricultural sources in the United States, studied the impact of seasonality on food origins, and examined the logistical infrastructure involved (train lines, cooling and storage facilities, distribution centers, and food stores).

Foodshed discussions re-emerged in the early 1990s with permaculturist Arthur Getz, incorporating a more normative stance toward the perceived benefits of local food systems and local food self-sufficiency (LFS) (Getz 1991). Shortly after, some rural sociologists embraced foodsheds as a normative concept, proposing local food systems as more sustainable, and hence more desirable (Kloppenburg *et al* 1996, Kloppenburg and Lezberg 1996). In Kloppenburg *et al*'s (1996) predominantly aspirational notion, a foodshed encompasses a food system that is driven by a ‘moral economy,’ ‘commensal community,’ ‘self-protection, secession and succession,’ local and regional proximity, and the availability of natural resources. They suggest that foodsheds are inherently local and without ‘fixed or determinate boundaries.’ Lastly, their foodshed concept acknowledges the desired or required embeddedness of a region in global trade relationships, suggesting a self-reliant rather than self-sufficient food system (Kloppenburg *et al* 1996). A further review of Kloppenburg *et al*’s discussion of an aspirational local foodshed in contrast to characteristics of globalized food systems is provided in the Supplementary Material (text S1, available online at stacks.iop.org/ERL/16/023003/mmedia, and table S2).

Going beyond the aspirational narrative of a foodshed, a growing number of empirical studies at various scales highlight the concept’s utility as a quantitative framework to analyze urban food supply and rural-urban linkages. This includes innovative methodologies to assess foodsheds for individual cities (e.g. Joseph *et al* 2019) and collectively at the global scale (Kriewald *et al* 2019, Kinnunen *et al* 2020). A review by Horst and Gaolach (2015) examined the feasibility of LFS in North America based on peer-reviewed and community-led foodshed studies published between 2000 and 2013. However, they focused on local agricultural capacity (i.e. the quantity of different food groups that can be produced or the available land to grow food on) and omitted analyses of food flows. To our knowledge, there is no other comprehensive review of urban foodshed research to date.

Current foodshed analyses use disparate methodologies and definitions and are often multi-scalar and geographically context dependent in nature. While these characteristics have fostered the emergence of innovative and complementary approaches, they also limit the ability to compare findings across studies and to inform policy at different scales. To address this gap and to assess ‘the state of the art’ in urban foodshed research, we conducted a systematic review of empirical studies broadly considering urban food flows or LFS across the peer-reviewed literature. Our main objective was to examine the definition, aims, and potential applications of foodshed analysis in different geographical contexts, and to characterize the methodological approaches and data used. Given the aspirational framing of key writings on the foodshed concept (Getz 1991, Kloppenburg *et al* 1996, Kloppenburg and Lezberg 1996), we also assessed the degree to which Kloppenburg *et al*’s normative interpretation of foodsheds is reflected in quantitative foodshed studies. To do so, we drew on a broad search strategy that returned 829 candidate articles, which we screened to 42 final articles for our in-depth review. Based on this review, we developed a synthetic framework to classify foodshed studies and help move towards a more discrete research agenda. To this end, we identified several policy areas relevant to foodshed analysis across the 42 reviewed studies and draw on examples from different studies to outline a series of key research priorities and data challenges for an interdisciplinary research agenda on urban foodsheds.

3.2 Methodology

In our initial literature scoping, we noticed a lack of a concise definition, unifying framework or protocol for analysis across studies using the term ‘foodshed’. However, two broad definitions of foodsheds were common: the actual geographic areas from which a population sources its food [*sensu* Hedden] and the region surrounding a city with a certain potential to satisfy the population’s food demands [*sensu* Getz and Kloppenburg]. Accordingly, we developed search strings with Boolean operators using term combinations related to these definitions and further informed by a review of key studies (Horst and Gaolach 2015, Tedesco *et al* 2017). We used the preferred reporting items for systematic reviews and meta-analyses (PRISMA), a standard protocol for systematic reviews (Moher *et al* 2009), and applied various search strings (Supplementary Material Table S3) in the ISI Web of Knowledge and Scopus databases. To avoid the exclusion of potentially relevant studies that may not use the 'foodshed' term explicitly but that apply similar approaches, we also searched for the closely related terms 'carrying capacity,' 'flow,' and 'local food supply.' As our review focuses on the urban and finer sub-national scales, we accompanied our search with 'city,' 'urban,' and 'metropolitan.' We also included the terms 'urban material flow' and 'urban metabolism'. Urban metabolism is a well-defined area of research (Kennedy *et al* 2007) that we deemed to be synergistic with urban foodsheds despite often using different terminology. 'Food' was added to all strings to omit unrelated material or non-material flows (e.g. energy, water). Wildcards were used to account for divergent spellings or plural forms.

We identified 1271 documents through our initial search in ISI Web of Knowledge and Scopus databases (September 17, 2019). We then removed 442 duplicates and screened titles, abstracts, and keywords of the remaining 829 articles in order to retain those that met the pre-defined criteria of being published in peer-reviewed journals and related to urban foodsheds. Studies lacking consideration of rural or peri-urban food production (e.g. urban agriculture) or food flows were omitted. We retained large-scale studies that included finer subnational analysis, such as those approximating cities or towns and their surrounding region[5] and omitted studies that

[5] We identified 19 studies that focus on individual cities and 23 studies that account for multiple cities in a region or state. Larger-scale studies often emphasized the role of key population centers inside of geographic or administrative boundaries, and their inclusion helped to account for additional methodological approaches.

were conducted exclusively at the national scale with the exception of a study in Iceland (Halldórsdóttir and Nicholas 2016) that otherwise closely adhered to our inclusion criteria. The remaining papers were then further reviewed for eligibility by reading the articles' introduction and methods sections, and articles that met additional criteria were retained (e.g. empirical analysis, not just conceptual frameworks). We identified two foodshed studies through other means (Zumkehr and Campbell 2015, Kriewald *et al* 2019) and three through snowball sampling (Peters *et al* 2007, Desjardins *et al* 2010, Conrad *et al* 2017), for a total of 42 studies included in our review (Figure 3.1). Each paper was read in full by the first author and then summarized into a database by two authors by identifying study type, location, spatial systems boundaries, calculation method, data sources, foods studied, and the use of scenarios or analysis of temporal changes. The results of the classification and associated meta-data are provided in the Supplementary Material (spreadsheet 'S4_Schreiber *et al*._Quantifying the foodshed'). More information on data sources and the types of foods analyzed across reviewed studies can be found in the Supplementary Material text sections S5 and S7.

Our search strategy is not exhaustive and may therefore not have identified all relevant empirical studies. Since our aim was to capture the emergence of the scientific research field pertaining to foodsheds, we focused on peer-reviewed and English-language studies only, which excluded reports published by community organizations, municipalities, or non-academic stakeholder groups (e.g. Fradkin 2015, Thompson *et al* 2008). Our search strings focused primarily on technical aspects of foodshed analysis (e.g. data and methods to assess food flows and LFS capacity), which we coded and used to compare studies. Our search only encompasses the topic (title, abstract, keywords) and therefore may have missed papers where terms appeared only in the main text. Lastly, even though various papers use urban foodsheds as a conceptual, normative, or aspirational framework in the context of food systems sustainability (Kloppenburg *et al* 1996, Kloppenburg and Lezberg 1996, Lengnick *et al* 2015), we only reviewed empirical studies that mapped and quantified foodsheds. Nevertheless, our search strategy identified a number of non-self-described foodshed studies, providing useful approaches that would have otherwise been omitted (e.g., urban metabolism approaches).

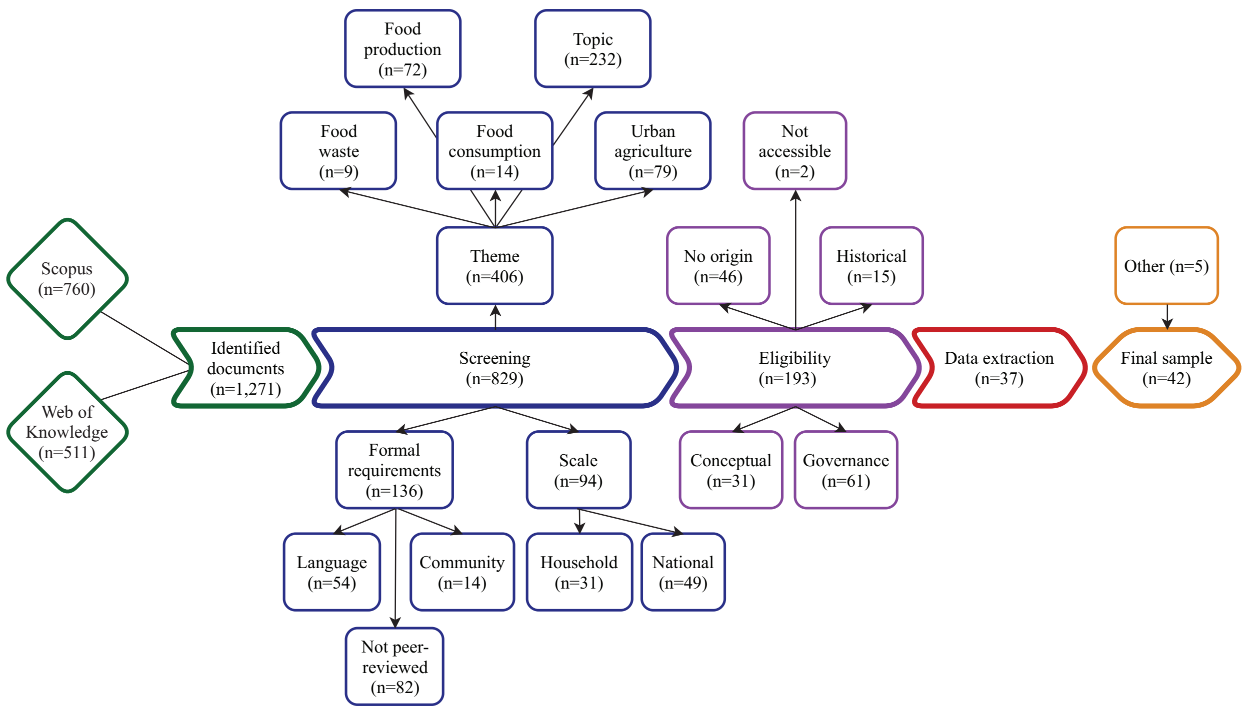


Figure 3.1 PRISMA process to identify the 42 reviewed papers. We searched two databases for scientific literature, eliminated duplicates and screened 829 documents according to whether they met the pre-defined criteria. We excluded 406 studies that did not match t thematically, 136 studies that did not meet our formal review criteria requirements, and 94 that did not meet our scale of analysis criteria. The remaining 193 studies were reviewed for eligibility by reading the introduction and methods sections. Our final sample includes 37 studies identified through the PRISMA process and an additional five studies that were identified through snowball sampling.

3.3 Results

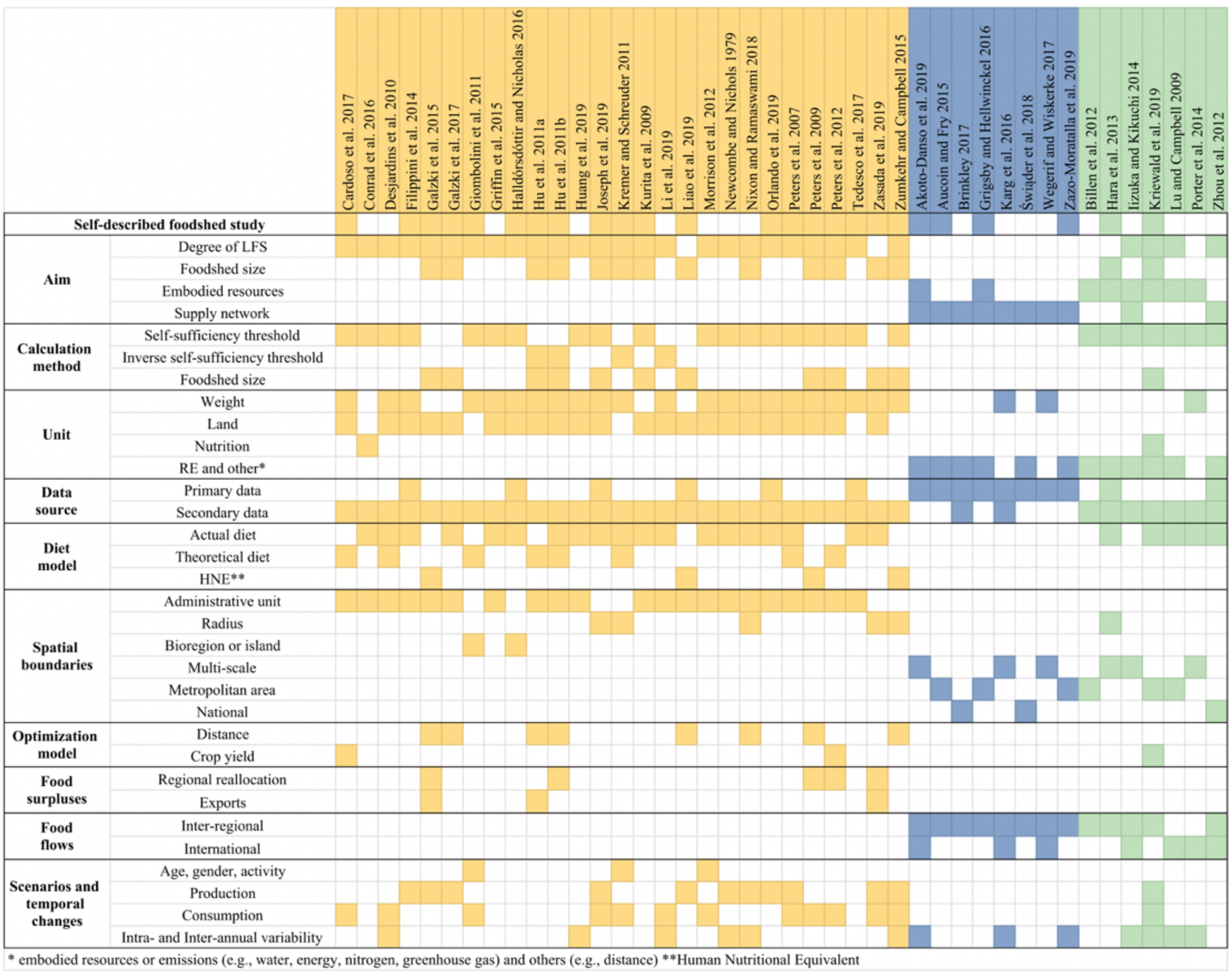
3.3.1 Foodshed study types

Drawing from across the 42 retained studies, we defined three main types of foodshed analysis: LFS capacity studies (*Capacity*), food flow studies (*Flow*), and those that combine both (*Hybrid)* (Figure 3.2). We systematically compared each of the three types of studies according to a set of ten criteria describing their aims and methodological approaches (Table 3.1) and provide a representative example of each study type highlighting key inferences and results (Tables 3.2–3.4). Our definition of *Capacity* studies included those that estimate LFS by comparing the food consumption of one city or multiple cities within a defined spatial boundary (e.g., a state or bioregion/watershed) with the theoretically or actually available quantity of food produced on peri-urban or surrounding rural agricultural landscapes. *Capacity* studies therefore estimate and test LFS potential, which could have implications if city-regions seek to increase reliance on local resources to meet local demands. *Flow* studies trace food shipments on multiple scales to map the various regions and supply networks that sustain cities. They often estimate resources or emissions embodied in food flows and analyze supply vulnerabilities and efficiencies as well as relationships between consumers and producers. *Hybrid* studies are all those that account for the impacts of food flows (e.g., imports and exports) on LFS, or that assess potential resource savings under food systems localization by combining methods from *Capacity* and *Flow* studies.

A brief overview of how the reviewed empirical studies reflected Kloppenburg *et al*'s (1996) aspirational notion of foodsheds can be found in the Supplementary Material (Text S1). Most reviewed studies embrace the 'Nature as measure' principle but do not or only partially adopt the other four principles. *Hybrid* studies align primarily with the idea of 'Proximity,' while several

Flow studies incorporate 'Moral economy' and 'Commensal community' dimensions. This illustrates the broad theoretical basis and evolving aims of foodshed research.

Table 3.1 Detailed overview and comparison of the 42 reviewed studies. We assessed all studies according to ten specific criteria that emerged in our review: (1) the aim, (2) calculation method, (3) functional unit of analysis, (4) predominant data source, (5) diet model used to estimate food consumption, (6) spatial boundary of the analysis, (7) optimization method used in the model (if applicable) to allocate food, (8) how surplus food in the region was allocated, (9) whether or not the study traces flows from regional or international sources, and (10) whether or not studies included scenarios or temporal changes. Color-coding refers to that of the foodshed study type in Figure 3.1 (yellow is Capacity, blue is Flow, and green is Hybrid).



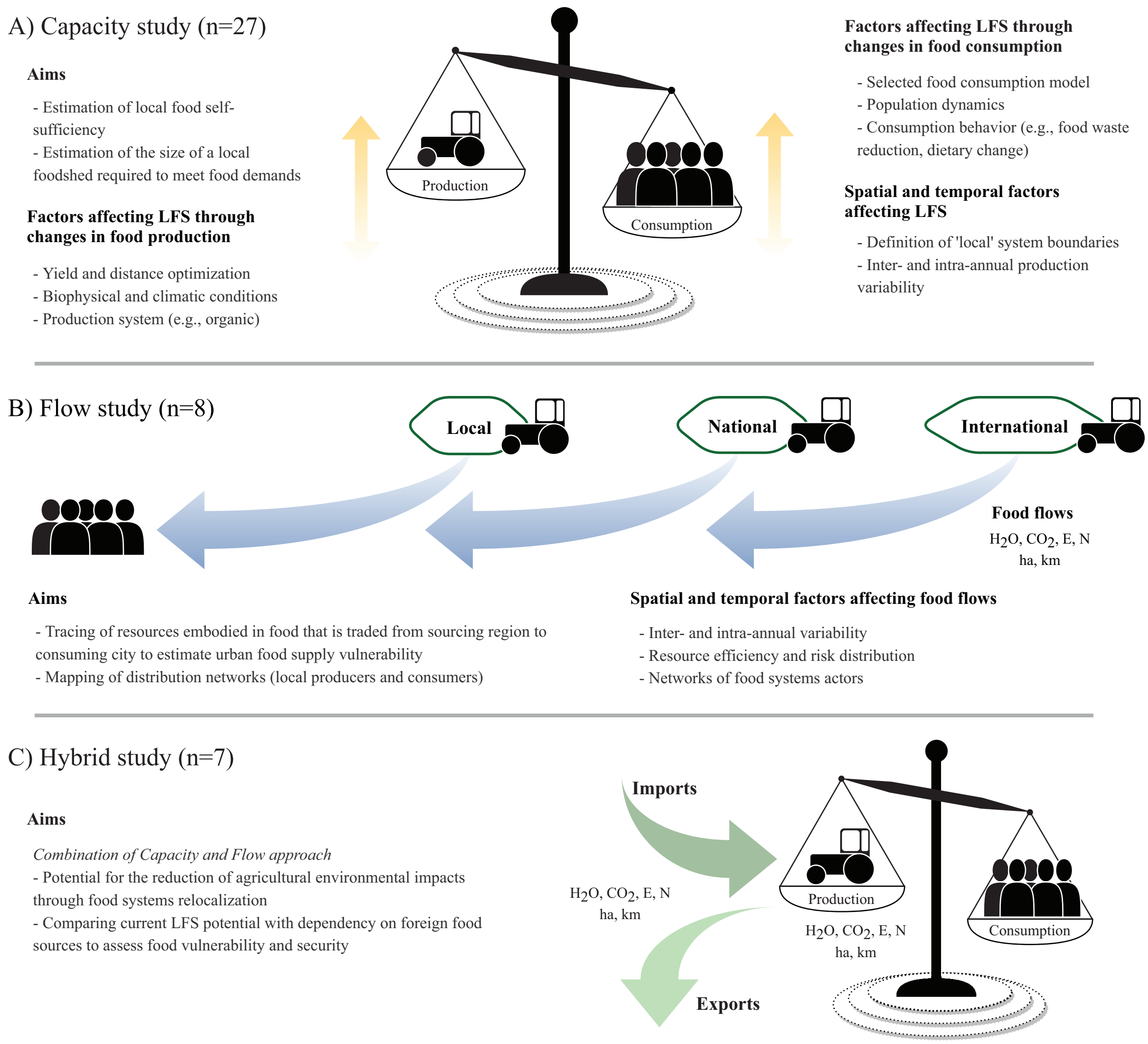


Figure 3.2 Classification of the three foodshed study types and their scopes. We assigned each of the 42 foodshed studies to a category: Capacity, Flow, or Hybrid study. Capacity studies (A) juxtapose local food production and consumption to estimate LFS potential and the size of a foodshed to meet local food demands. Different factors can help to model the dynamics of LFS (yellow gradient arrows depict increases/decreases in food production and consumption). Flow studies (B) trace food movements on local, national, and international scales to estimate spatially explicit embodied resource use and emissions (water, carbon dioxide, energy, nitrogen) or spatial characteristics (land size, distance), and/or analyze local food flow networks. Hybrid studies (C) calculate food production and consumption ratio while accounting for food flows (imports and exports) on different spatial scales, enabling analysis of interdependencies or comparative advantages between regions.

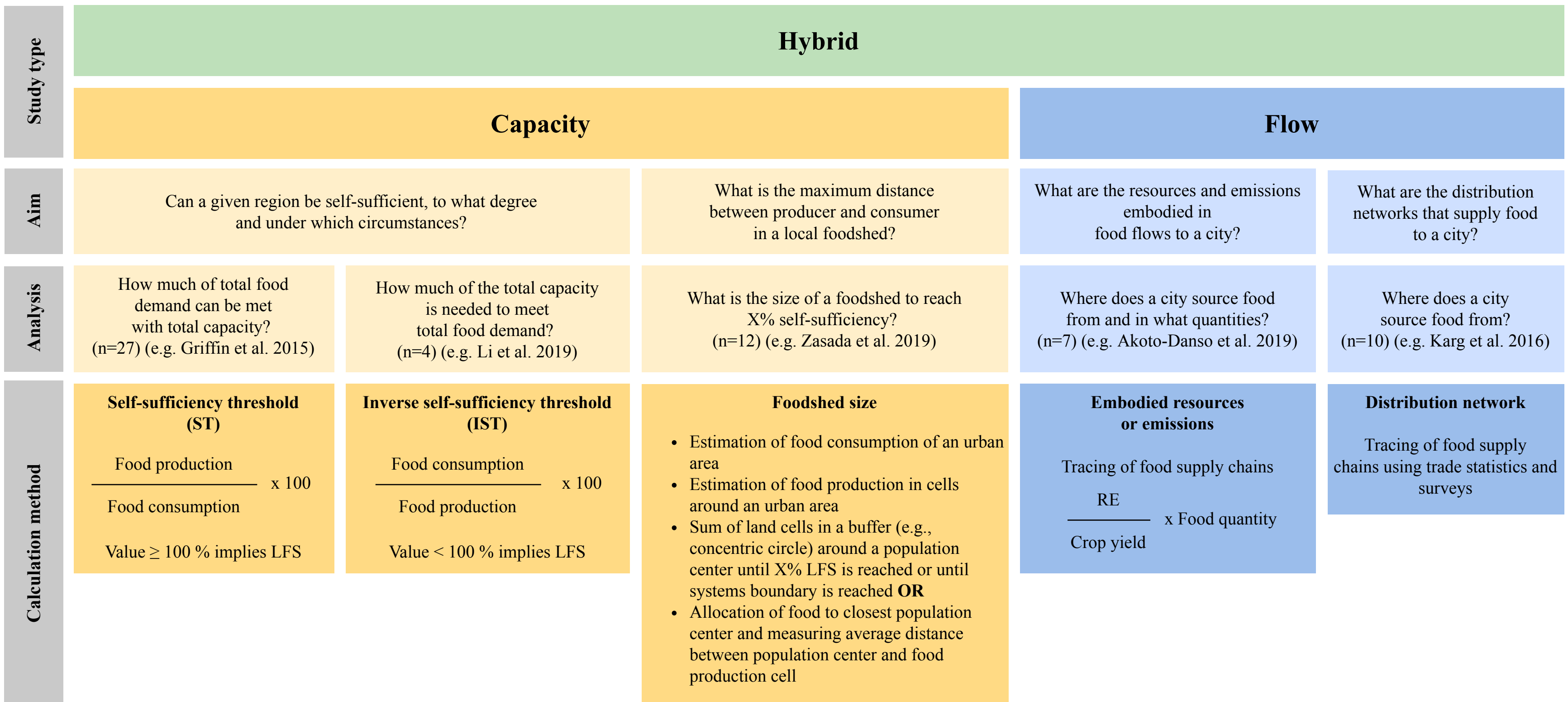


Figure 3.3 Synthetic framework for foodshed analysis. We devised the decision tree based on a synthesis of LFS calculation methodologies across the Capacity, Flow, and Hybrid studies. Our framework differentiates between local food self-sufficiency (LFS) capacity analysis (as utilized in Capacity and Hybrid type studies) and food flow analysis (Flow and Hybrid type studies). This hierarchy of steps (defining broad study type and aim; choosing the target analysis and calculation method) provides a heuristic that can help guide more systematic foodshed research with consistent calculation approaches.

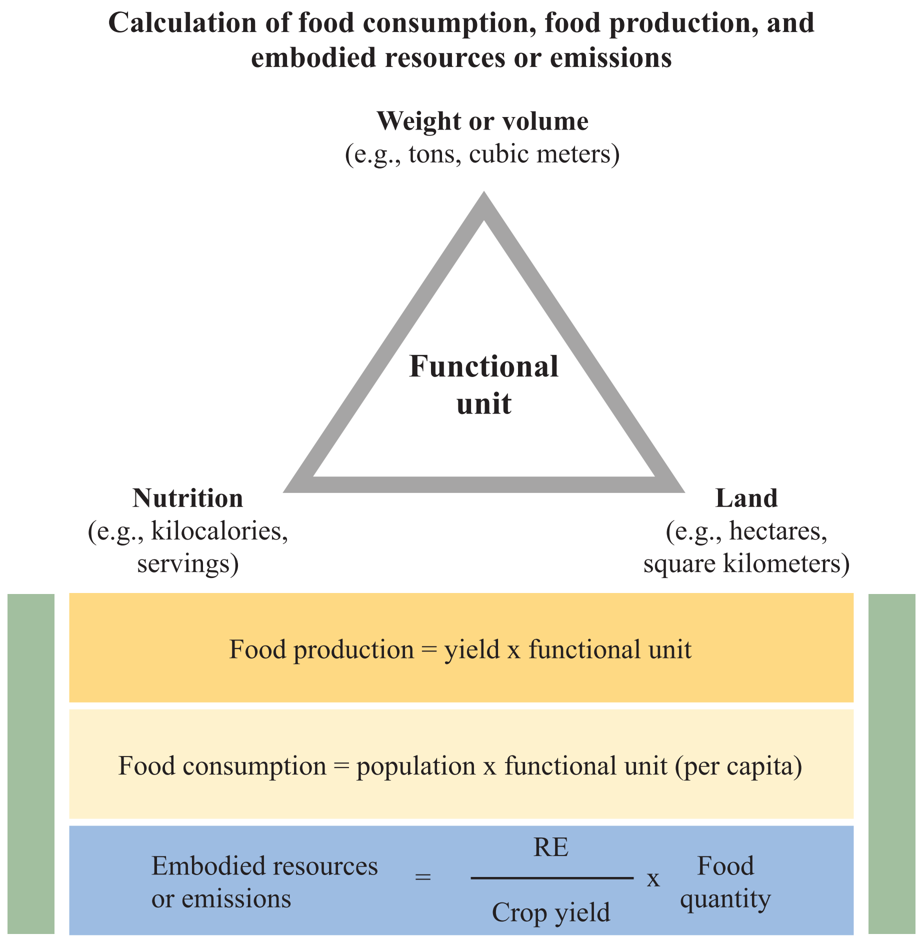


Figure 3.4 Capacity, Flow and Hybrid studies used three main functional unit categories to estimate food consumption and production, and embodied resource use or emissions (RE). Food production is the product of crop yields and a functional unit, while food consumption is the product of population and a functional unit per capita. Embodied resources (land, water, nutrients) or emissions (greenhouse gases) are calculated by multiplying the food flow quantity with the ratio of food-specific RE intensity values and crop yield. Colors indicate study types: Capacity (yellow), Flow (blue), Hybrid (green).

Capacity studies

Capacity studies used different calculation approaches, which we grouped into three categories: self-sufficiency threshold (ST), inverse self-sufficiency threshold (IST), and foodshed size (Figure 3.3 and Table 3.1). ST and IST compared production and consumption to calculate a ratio representing the share of food demand that could be satisfied through local production—an indicator of LFS potential (Kurita *et al* 2009, Hu *et al* 2011b, Morrison *et al* 2012, Hara *et al* 2013). ST calculations estimated to what degree agricultural production in a given area can meet the food demands of a given population. Values ⩾100% indicated that an area has a high LFS potential or produces surplus food. IST calculations examined what share of available agricultural capacity would need to be utilized if the population were to rely fully on local agriculture. Values <100% indicated that an area has a high LFS potential and produces surpluses. Food surpluses could be allocated to deficient population centers within the studied region or exported (Table 3.1). Foodshed size calculations determined how much local land is needed to meet the food demands of the given area as well as the radius that defines the maximum distance a population has to travel to meet those food needs. These approaches are not mutually exclusive and have been combined in some studies (Table 3.1, Figure 3.3).

Foodshed studies used three main functional units for food consumption and production values: weight, nutrition, and land (Figure 3.4 and Table 3.1). Food consumption was generally a function of the population of a given city and one functional unit (e.g., servings) on a per capita basis, whereas multiplying crop yield by the functional unit (e.g., hectares) was typically used to determine food production (Figure 3.4). *Capacity* studies often used secondary data to calculate production and consumption (Table 3.1, Figure S6). Due to a lack of spatially-explicit household consumption data, *Capacity* studies used 'actual diet' or 'theoretical diet' models, which follow dietary guidelines or scenarios, respectively (Table 3.1) (see Supplementary Material text S7 for details on data sources, and their advantages and limitations). Gridded spatial representations of a region with resolutions of 1 × 1 km (Kurita *et al* 2009, Hara *et al* 2013), 2×2km (Galzki *et al* 2017) to 5×5km (Galzki *et al* 2014) often helped to calculate food production and consumption in each cell. This is particularly useful for *Capacity* studies that estimate local foodshed size, and those applying distance and crop yield optimization.

Multiple studies used optimization models and scenarios to estimate the impact of local food system changes on LFS (e.g., reducing distance between farms and population centers, effects of dietary changes, or crop allocation to increase yields and other ecosystem services). Many *Capacity* studies analyzed the variability of LFS in terms of production, consumption, or spatial extent of a foodshed (Figure 3.2 and Table 3.1). Factors included food losses and waste, inedible parts of food, land management (e.g., irrigation), and locally relevant biogeophysical conditions such as fertilizer requirements, precipitation, soil erosion, or heavy metal concentrations (Table 3.1). For instance, Joseph *et al* (2019) estimated LFS under different diet and production system scenarios (Table 3.2). Several studies used spatial optimization models in order to determine LFS based on the minimum distance between consumer and producer (distance optimization) or to maximize production output (crop yield optimization). Optimization approaches complemented the basic calculation schemes through linear programming models, land and climate suitability, and crop yield models (Cardoso *et al* 2017). Others accounted for differences in age, gender, and activity levels of urban residents in their respective context and the impact of commuters and vacationers on urban food consumption (Tedesco *et al* 2017).

Table 3.2 Representative example of a Capacity study. Joseph et al (2019) estimated potential LFS under different dietary and production system scenarios, particularly for low-input agriculture (organic), changes in livestock systems, and reduced meat consumption, using primary and secondary data.

Study	*Joseph et al 2019* *Can Regional Organic Agriculture Feed the Regional Community? A Case Study for Hamburg and North Germany*
Context	Hamburg, Germany (and counties in 50 and 100 km radius)
Aims	• Estimation of LFS potential for Hamburg • Impact of diets on LFS potential (foods with high/low land requirements) • Production system impacts on LFS potential (conventional, organic)
Data sources	• Previous studies, governmental and FAO statistics • Primary crop yield data collection from farms in study area
Calculation methods	• Self-sufficiency threshold • Foodshed size
Scenarios used	• Impact of different diets and production system combinations on LFS (status quo, conventional, organic, 30% meat/legumes substitute) • Sensitivity analysis, measuring impact of change from three-tier cow system (dairy cows, meat cows, dual-use cows) to dual-use cows
Key findings	• High potential for LFS within 50 km (34–57%) and 100 km (74–100%) radius • Available agricultural land and per capita meat consumption have large impacts on LFS

Flow studies

Flow studies mapped food flow networks between cities and peri-urban, regional, national or international sources (Figure 3.2). Generally, these encompassed directional flows (countryside to city), but two studies also mapped bi-directional flows between urban, suburban, and rural areas (Zhou et al 2012, Karg et al 2016). Flow studies analyzed food distribution networks between cities and local food producers, and also estimated resource use or emissions (RE) embodied in producing foods as a product of food flow quantities and the ratio of a RE indicator and crop yields (Figure 3.4). Tracing of food flows and mapping networks often used primary data or a mixture of primary and secondary data (Figure S6, see text S7 for more details on the data sources and their advantages and limitations). *Flow* studies were often limited to the tracing of the origin of processed and unprocessed foods but did not typically identify actual processing and distribution stages along the way (but see Wegerif and Wiskerke 2017).

Flow analysis can provide knowledge on embodied emissions or resource use (Table 3.1), such as virtual water embodied in a city's food supply (Table 3.3). This can inform sustainable food systems strategies as resource efficiency is geographically context dependent. For instance, while low-input food production systems or resource recycling in combination with short supply chains can result in resource savings and emission reductions (Yang and Campbell 2017, Pérez-Neira and Grollmus-Venegas 2018), other studies have shown that local food is not always more resource efficient (Weber and Matthews 2008) or can even increase negative environmental impacts (Edwards-Jones 2010, Avetisyan *et al* 2014, Huang *et al* 2014). Specialization arising from agricultural globalization may therefore enhance resource-use efficiency but carry other social and environmental costs (Clapp 2014, Schipanski *et al* 2016).

Flow analysis can also help outline the limitations of 'localized' food systems. For instance, Akoto-Danso *et al*'s study (2019) concluded that the decentralization of food supply can spread the risk of food insecurity due to environmental shocks and resource shortages in the city's surrounding hinterland. Vulnerabilities (e.g., susceptibility to water shortages) can arise due to extreme weather or geo-political crises (Bren d'Amour *et al* 2016). Diversifying the sourcing regions of a city for risk distribution can be a way to avoid this vulnerability and ensure food supply (Karg *et al* 2016, Akoto-Danso *et al* 2019). Cities can also function as hubs for processing and re-export (Karg *et al* 2016, Akoto-Danso *et al* 2019). Specifically in locations with networks of strong reciprocal rural-urban and urban-urban interdependencies, tracing food flows is crucial for identifying potential supply bottlenecks and vulnerabilities.

Spatial mapping of food production networks can also reveal social connectivity between diverse local actors. Wegerif and Wiskerke (2017) showed that the nature of relations among supply chain actors and regional differences in crop yields were more relevant for food systems sustainability than physical distance between producers and consumers. Some *Flow* studies drew from alternative food networks (AFNs) and identified flows between farmers, markets, and consumers (Aucoin and Fry 2015, Grigsby and Hellwinckel 20162016, Brinkley 2017, Zazo-Moratalla *et al* 2019). For example, Brinkley (2017) traced the linkages between farms and various local food distribution entities (e.g., food hubs, farmers' markets, restaurants, food banks). Aucoin and Fry (2015) mapped flows of specific foods from farm to market (foodshed) as well as flows of people buying at those markets, illustrating the 'consumer draw' around a market called 'marketshed.'

Table 3.3 Representative example of a Flow study. Akoto-Danso et al (2019) calculated virtual water content of food flows to two West African cities and analyzes source diversity to estimate resilience to water-related shocks in producing regions.

Study	*Akoto-Danso et al 2019* *Virtual water flow in food trade systems of two West African cities*
Context	Tamale, Ghana, and Ouagadougou, Burkina Faso
Aims	• Mapping food flows to examine resilience of urban food supply to water-related shocks
Data sources	• Road and market surveys over six days at the end of two production seasons (peak and lean), one year in Ouagadougou and two years in Tamale (Karg et al 2016) • Monthly market foodshed survey (interviews with 33% of market food traders) • Extrapolation of six day road survey with market survey, secondary data from literature • and interviews with officers from government ministries and market leaders • Crop yields (FAOSTAT, West Africa averages), location-specific water use (previous research) • Inflows and outflows (re-distribution)
Calculation methods	• Embodied resources or emissions
Temporal changes	• Intra- and inter-annual sourcing changes
Key findings	• Highest contribution by cereals (most common food in diet) • 68% (peak season) and 40% (lean season) of imported foods were re-exported out of the cities • Tamale: Southern Ghana is major net virtual water importer (cereals, legumes, vegetables, livestock), Northern Region of Ghana is net exporter (all food groups except fruits) • Ouagodougou: rice imports from Asia via Ivory Coast • Seasonal variation in flows: 514 (peak season) and 2105 (lean season) million m3 yr−1 • Ouagodougou is more resilient to shocks (food supply and water) than Tamale

Hybrid studies

Hybrid studies combined *Capacity* and *Flow* approaches to study a city-region's LFS with regard to their embeddedness in national and global food supply chains (Table 3.1). The calculation approaches (Figure 3.3) and data sources for *Hybrid* studies are similar to *Capacity* and *Flow* studies (figure S6 and text section S7 for details on the data sources, and their advantages and limitations). *Hybrid* studies combine the benefits of both *Capacity* and *Flow* analyses and can therefore help investigate how exports and imports affect LFS potential in globalized food systems. Understanding the implications of trade on LFS is important since, as Zhou *et al* (2012) claimed, a region can have a high theoretical LFS potential but low actual LFS. This can occur in export-oriented regions with a comparative advantage in the production of a specific food commodity (e.g., corn). Moreover, a holistic analysis of ecological, economic, and infrastructural circumstances provides more realistic insights into LFS potentials beyond physical land capacity. Emergy synthesis, a concept merging the analysis of biophysical material, energy, and financial flows has been used to assess opportunities and constraints to growing food for local and global markets (see Lu and Campell's (2009) work for Shunde, China).

As with *Flow* studies, the *Hybrid* approach can be used to compare embodied RE in food production between current distant and potential local producing regions (Hara *et al* 2013, Porter *et al* 2014, Kriewald *et al* 2019). An analysis considering such factors can aid decisions about the environmental sustainability and food security of a city's food supply. Hara *et al* (2013) provide an illustrative case for this kind of analysis (Table 3.4).

Table 3.4 Representative example of a Hybrid study. Hara et al (2013) estimated potential for energy savings and transformation of abandoned land through food systems localization, in a context with fragmented rural land use due to urbanization, using intra-national food flow data. Governmental and non-governmental organizations supported local food as more sustainable despite little evidence and expected increase in food imports due to trade agreements.

Study	*Hara et al 2013* *Quantitative assessment of the Japanese 'local production for local consumption' movement: a case study of growth of vegetables in the Osaka city region*
Context	Osaka city region, Japan
Aims	• Flows: Tracing quantity and origin of vegetables, and calculation of energy consumption due to production (inorganic fertilizer and pesticide production, onsite electricity consumption and heating) and transportation • Capacity: Calculation of consumption/production quotient for 1 km2 cells in grid and for 20, 40, 60, and 80 km buffer zones around Osaka Castle • Mapping of land use, transportation networks, farmers' markets, and supermarkets • 500 m buffer zones to determine consumer access (distance of 500 m is used in other Japanese food access studies, accounting for aging population) • Outline of opportunities, motivations, incentives and limitations with regard to farmers' markets and governmental support
Data sources	• Governmental statistics • Interviews with producers at farmers' markets about motivations and with representatives from municipality about governmental support of local food
Calculation methods	• Self-sufficiency threshold • Foodshed size
Scenarios used	• Energy savings: elimination of exports and imports, transformation of abandoned farmland into vegetable production, organic agriculture and food distribution through farmers' markets
Key findings	• High embodied energy in vegetables from remote prefectures due to transportation and heating, 80% of embodied energy in nearby prefectures is due to the application of inorganic fertilizers and pesticides • Self-sufficiency: 20 km—5.7% of population fed, 40 km—21.7%, 60 km—50.0%, 80 km— 68.5% • Energy savings scenario: 20 km—6.2% of population fed, 40 km—24.5%, 60 km—55.0%, 80 km—75.5% • High local food systems potential with reuse of farmland abandoned due to urbanization and land speculation • Scenario with embodied energy reduction (transportation): Fewer exports—25% energy reduction; reuse of abandoned farmland—19%; Organic farming—33%

3.3.2 Descriptive statistics

Out of the 42 reviewed papers, we identified 24 self-described foodshed studies (those using the term ‘foodshed’ in the title, abstract, or keywords). Another 18 foodshed studies did not prominently use the term ‘foodshed’ but were otherwise deemed relevant (see Supplementary Material spreadsheet S4 for studies falling into each category). Seven studies, primarily in the *Capacity* category, provided an original foodshed definition (listed in Supplementary Material Table S8).

Capacity studies were the most frequent type of foodshed study (Supplementary Material Figure S6 and S9). We find a gap in any scholarship between 1979 and 2007 (Newcombe and Nichols 1979, Peters *et al* 2007), which could indicate a lack of empirical advancements in the field despite important conceptual and theoretical contributions (Kloppenburg *et al* 1996, Kloppenburg and Lezberg 1996). The higher number of foodshed publications in 2019 (only partially covered due to our search date cutoff) seems to indicate increased interest in the foodshed framework coinciding with current research trends on food systems.

Foodshed research has been concentrated in a few regions (Figure 3.5), mainly North America (n = 19), Europe (n = 13), and Asia (n = 6) (Supplementary Material S4 spreadsheet). *Capacity* studies have primarily covered North American (n = 14) and European (n = 10) regions. Most *Flow* studies were conducted in the USA (n = 3) and Africa (n = 3). We found most *Hybrid* studies in Asia (n = 5), when compared to Europe (n = 2) and Australia (n = 1). One *Hybrid* analysis was conducted at a global scale (Kriewald *et al* 2019).

Spatial system boundaries varied greatly among the studies, with contrasts among *Capacity, Flow*, and *Hybrid* studies. We identified three main spatial system boundaries for *Capacity* studies: radius (e.g., '100-mile diet'); subnational administrative unit (SAU), such as state, district, county, or province, encompassing multiple cities; and bioregions (Table 3.1). Kriewald *et al*'s global study (2019) is an exception that focused on peri-urban areas as food supplying territories (defined from remote sensing, agricultural model estimates, and population density statistics). *Flow* studies generally traced food flows within one metropolitan area, between a city and the surrounding hinterland, from national or international sources or a combination for multi-scalar analysis (Table 3.1). *Capacity* studies primarily used SAU and radius. The choice of systems boundary is often linked to the study objective and data availability in the given region (Supplementary Material text S10).

3.3.3 Quantitative comparison across foodshed studies

Our classification and framework for foodshed analysis (Figure 3.3, Table 3.1) illustrates difficulties in comparing results across the 42 reviewed studies given differences in methodologies, aims, and assumptions. Following patterns in Table 3.1, we selected a subset of more comparable *Capacity* studies that used the 'foodshed size' calculation method in the United States to examine average distance to meet all or a share of food demands. We then compared mean values from the main analysis presented in each, excluding ranges or scenarios (Figure 3.6). For example, Hu *et al* (2011b) showed that more than half of the population in eight states in the Mid-Western US could be supported within an 8 km range due to the high quantities of arable land and small towns (population <1000 people). For cities, foodshed sizes ranged from 16 km (De Moines) to 122 km

(Chicago area). This illustrates the utility of quantitative comparison, for example, in assessing the influence of city characteristics (e.g., population density) and geographic context (e.g., relative availability of arable land and crop yields) on foodshed outcomes. However, it is generally difficult to quantitatively compare past *Capacity* and *Hybrid* studies because of their divergent approaches (compare across rows in Table 3.1). For example, Peters *et al* (2009) found that 34% of New York State's total food demands can be met within 49 km while Peters *et al* (2012) found that 69% of the State's food needs can be met within 238 km. Discrepancies between the two estimates reflect methodological variations pertaining to optimization and allocation models used (i.e., to minimize food distance travelled and to maximize economic land use values, respectively).

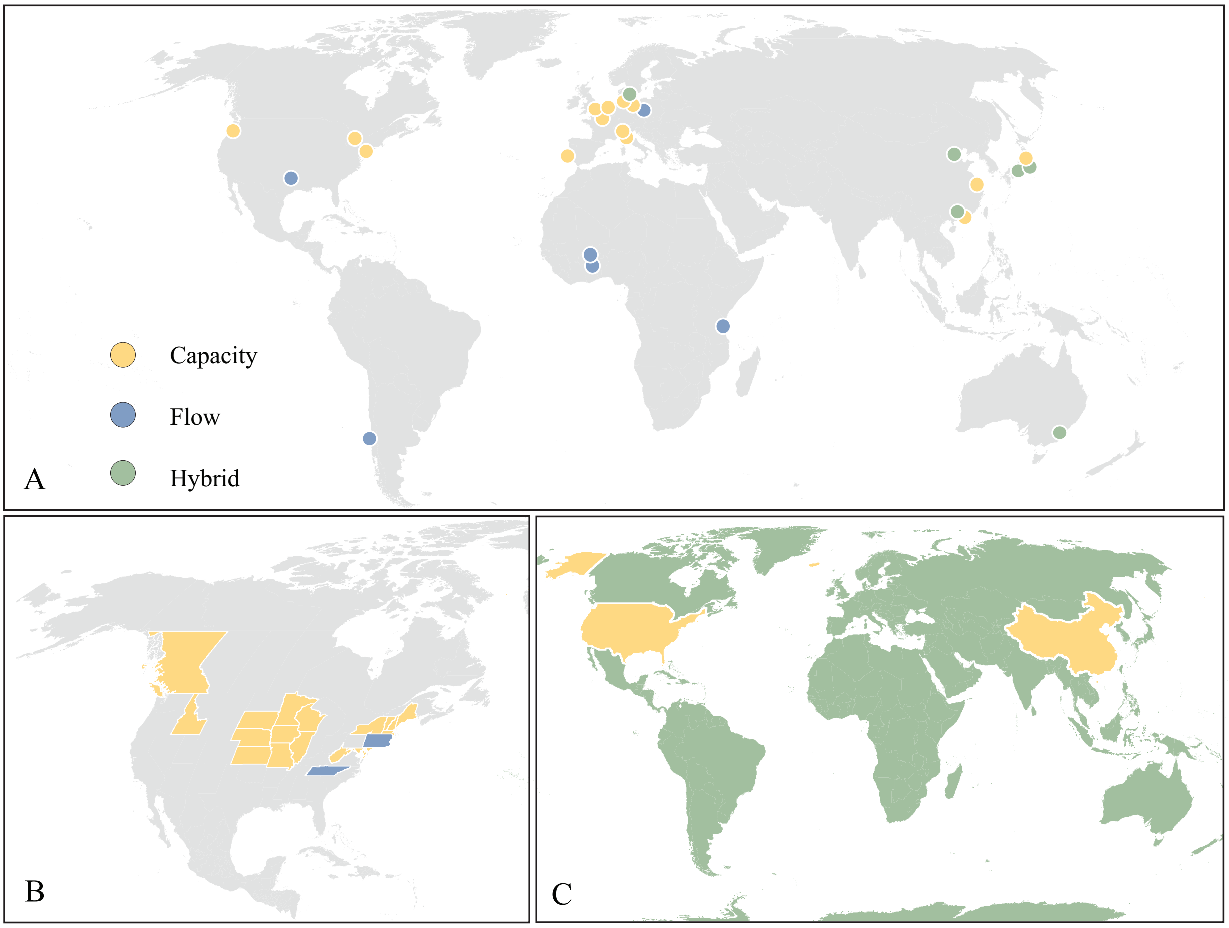


Figure 3.5 Geographic coverage of foodshed studies globally highlighting inter-regional disparities. Map A shows specific cities analyzed by foodshed studies in our review (note that some points represent clusters of multiple cities or bioregions). Map B shows all subnational administrative units (SAUs) in North America in which multiple cities or city-/town-regions were studied. Map C includes a study by Kriewald et al (2019), covering more than 4000 cities around the globe (represented by green shading), as well as studies by Halldórsdóttir and Nicholas (2016), Huang et al (2019), Nixon and Ramaswami (2018), and Zumkehr and Campbell (2015), who assess LFS of dozens of cities in China or the USA, respectively. Colors indicate study types: Capacity (yellow), Flow (blue), Hybrid (green).

3.4 Reflections on the value of foodshed analysis for holistic food systems research

3.4.1 Sustainability and dependency issues in food systems from a city perspective

The foodshed concept provides an interdisciplinary approach to investigate food systems by linking culture (*food*) with nature (*shed*) and therefore aspects of both people and place (Kloppenburg *et al* 1996). Foodshed analyses can highlight links between multiple production and consumption factors and the feasibility of LFS (Figure 3.7A). For example, understanding the impacts of changes in local diets towards less (Joseph *et al* 2019) or more animal-based proteins (Zumkehr and Campbell 2015) is crucial to estimating LFS potential. This applies particularly to regions facing pressures on local resources or high emissions, where agricultural intensification or extensification may be unfeasible. Foodshed studies have also investigated city-specific scenarios linking multiple social and ecological sustainability issues, such as the contribution of dietary changes and organic agriculture to human health and environmental quality (Joseph *et al* 2019), enhancing local nutritional sufficiency and the support of local farms and food enterprises (Desjardins *et al* 2010, Kremer and Schreuder 2012), as well as maximizing energy savings and reutilization of abandoned land (Hara *et al* 2013). Tools from business development, such as *strengths, weaknesses, opportunities, and threats* (SWOT) analysis, have also been used to systematically record the findings and juxtapose competing goals and outcomes (Orlando *et al* 2019).

Foodshed analysis can also help in weighing the benefits and limitations of local versus global food sourcing through comparative studies of agricultural capacity and food flows (Figure 3.7B). Localization strategies aim towards LFS by decreasing exports and imports. However, in contexts with high food trade, foodshed assessments must not only consider LFS potentials in the region of interest but all other regions that are connected through trade relationships. Foodshed studies can identify and map existing interdependencies with regard to resources and food security (Figure 3.7B). *Hybrid* approaches are particularly useful for assessing a region's embeddedness in those physical, economic, and cultural systems on multiple scales. Our review shows that *Capacity* studies, the most common foodshed study type, are limited in this regard. Without food flow analysis, high LFS potentials could result in misleading conclusions and policy recommendations. Several *Capacity* studies have emphasized potential impacts of food exports on LFS, such as the erosion of LFS or the dependency on food imports to fill local food supply gaps (i.e., Galzki *et al* 2014, Hu *et al* 2011a Giombolini *et al* 2011, Billen *et al* 2012, Porter *et al* 2014, Nixon and Ramaswami 2018). To date, two studies have included exports in their calculations (Lu and Campbell 2009, Zhou *et al* 2012). Nevertheless, the relationship is not well understood. *Hybrid* studies are therefore a promising tool with potential for further exploration.

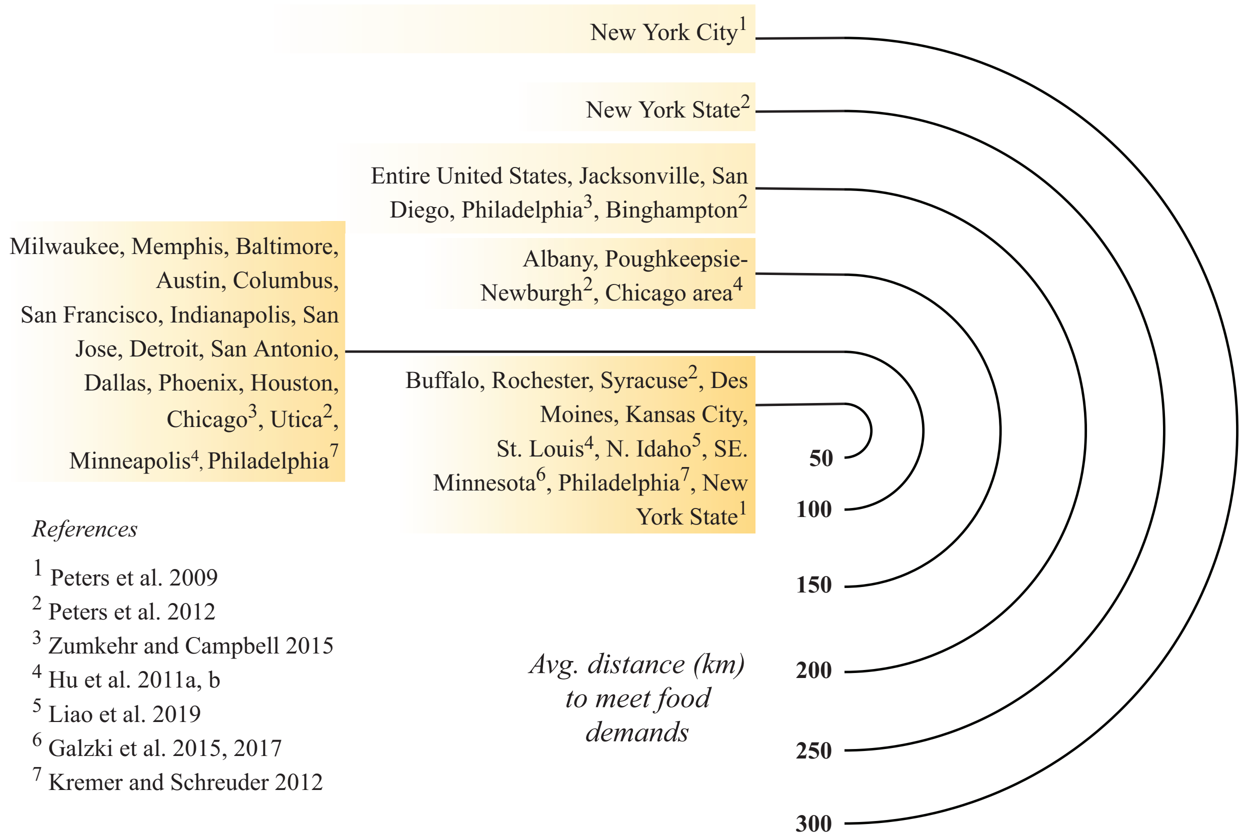


Figure 3.6 Quantitative comparison between nine Capacity studies using the 'foodshed size' calculation approach. The comparison demonstrates the role of population density and local/regional geographic context on results. All studies are located in the United States. We omitted one study that did not report numerical results (Kriewald et al 2019) and one that only reported foodshed sizes for select food types (Nixon and Ramaswami 2018). Note that not all cities included in this figure reach 100% LFS.

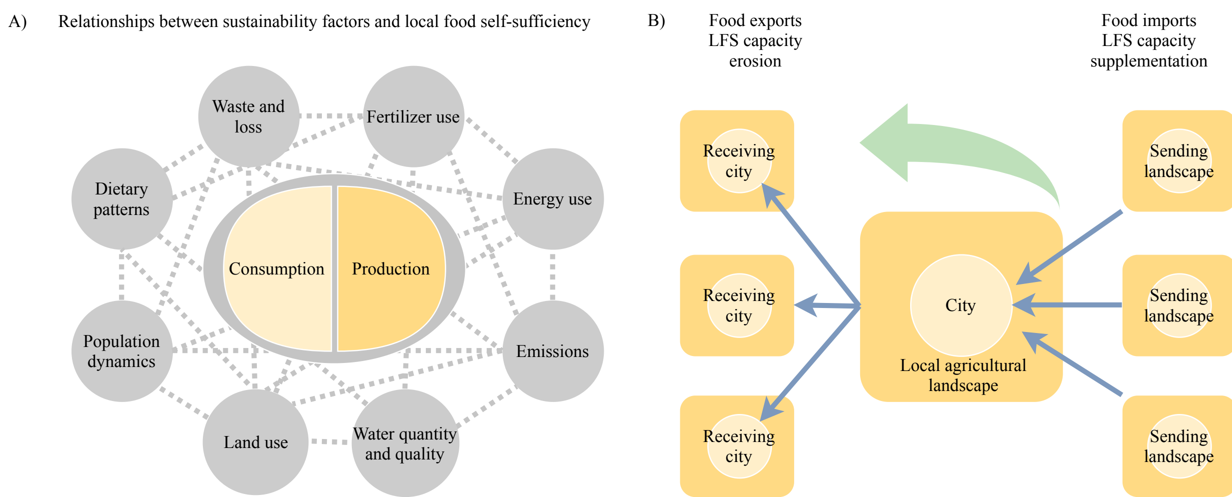


Figure 3.7 Value of foodshed studies for food systems sustainability research. Foodshed research can provide a tool (A) to assess, test, and understand relationships between local food self-sufficiency and various factors (e.g. energy, fertilizer use, and land use) contributing to food systems sustainability, and (B) to identify and map food flows and embodied resources or emissions that result in interregional interdependencies and can influence the vulnerability to potential supply chain disruptions. Such flows can entail, for instance, food imports to enhance food security or food exports that may erode LFS capacity but feed other region's populations. Colors indicate study types: Capacity (yellow), Flow (blue), Hybrid (green).

3.4.2 Research priorities and data challenges in the quantitative assessment of urban foodsheds

Our review highlights the diverse ways that urban foodshed analysis can be used to create new, and synthesize existing, knowledge on food systems sustainability (Peters *et al* 2009). To provide useful information for planners and decision-makers, foodshed researchers need to overcome several methodological and analytical challenges, particularly regarding subnational food flow data. Governments and private sector actors can aid this development by compiling and making necessary data accessible.

Research priorities and policy areas

Based on our review of the 42 publications, we have identified several broad policy areas, and associated examples, that require further attention in the context of foodshed analysis. These policy areas span the food system, from production to consumption (see Table 3.5), and, taken together, suggest two priority research areas for applied foodshed scholarship.

Priority #1: *How do physical and social barriers interact in local food systems?*

Almost all studies critically discuss, to some degree, the infrastructural, behavioral, and logistical barriers and limitations in the pursuit of LFS. A major point of critique of *Capacity* studies is that a high LFS potential cannot be exploited if neither adequate processing, storage, and transportation infrastructure nor the economic incentive to source locally prevail in a region (Kurita *et al* 2009, Peters *et al* 2009, Hu *et al* 2011a, Galzki *et al* 2014). Only a few studies suggest measures such as the establishment of food processing facilities to decrease the loss of local physical resources and increase the local job market (Lu and Campbell 2009) or transforming nearby vacant land to revive the areas' economic productivity (Hara *et al* 2013).

Most *Capacity* studies neglected social preferences, assuming that farmers will supply to the closest population center (Galzki *et al* 2017) and that citizens will refrain from buying imported foods and replace them through local options (Galzki *et al* 2014, Joseph *et al* 2019, Zasada *et al* 2019) or will eat seasonally (Conrad *et al* 2017). Only two studies in our sample conducted consumer surveys on preferences concerning local food sourcing (Halldórsdóttir and Nicholas 2016, Liao *et al* 2019). Further, few *Capacity* studies differentiated between production and distribution systems (e.g. community supported agriculture, greenhouse horticulture) (Aucoin and Fry 2015, Grigsby and Hellwinckel 2016, Brinkley 2017) or seasonal variability (Peters *et al* 2007, Karg *et al* 2016, Akoto-Danso *et al* 2019) despite the potential impact on food systems sustainability, resilience, and LFS.

Some foodshed study authors claimed that small and medium-sized cities might be better equipped for food systems localization due to the smaller physical distance to peri-urban agriculture and greater governance capacity (Kurita *et al* 2009, Filippini *et al* 2014, Liao *et al* 2019). Yet, empirical evidence on the relationship between city size and the physical and social capacity for local food systems remains scarce. Examples of studies on subnational (Galzki *et al* 2014, 2017), national (Zumkehr and Campbell 2015, Nixon and Ramaswami 2018) and global scale (Kriewald *et al* 2019) have already assessed potential LFS of cities of multiple sizes and their respective local hinterland. Accordingly, more studies should incorporate various city sizes and assess physical and social capacity in parallel.

Priority #2: *How are food flows linked with other urban material flows and embodied resources?*

Most *Capacity* and *Hybrid* studies assess the feasibility of LFS if regions were to move towards circular and integrated production systems or if consumers were to consume less animal-based proteins (Table 3.1). Accordingly, regions could reduce the dependency on external inputs, such as fertilizers, pesticides, or livestock feed. Future foodshed research could extend its analysis beyond the farm by identifying the origins of food production input materials. For example, Hedberg (2020) studied phosphorus flows to farms to identify sustainability of fertilizer supply chains that are necessary for local food production in the Northeastern US.

Combining foodshed analysis with urban metabolism and circular economy scholarship can also reveal the (potential) environmental sustainability of a city's food supply as a territorial ecology and territorial metabolism framework (Tedesco *et al* 2017). This can encompass streams of urban liquid and solid wastes to be reused in local agriculture ('wastesheds'), such as nutrients (Metson *et al* 2018) as well as potentials to reduce environmental degradation through integrated production systems (Liang *et al* 2019, Zeller *et al* 2019). Billen *et al*'s (2012) analysis provides an interesting example for a metabolism-based foodshed analysis, linking LFS, fertilizer use, and water quality.

Table 3.5 Areas of potential policy relevance for foodshed analysis identified from the 42 reviewed studies. The table lists the topics that have already been addressed or that were identified as critical but not further considered in the study.

Food system component	Policy area	Examples from the reviewed literature
Production	Farmer livelihoods and rural development	• Consider livelihood implications of changes in crop mix (Desjardins *et al* 2010; Giombolini *et al* 2011) • Understand effects of LFS for counteracting rural population decline (Desjardins *et al* 2010) • Benefits of establishing long-term agreements between rural producers and the city (Orlando *et al* 2019) • Account for economic relevance of agricultural sector in the region (Nixon and Ramaswami 2018)
	Infrastructure	• Plan for slaughterhouses and other processing facilities (Conrad *et al* 2017; Filippini *et al* 2014; Peters *et al* 2009) • Assess storage requirements for staple crops (Akoto-Danso *et al* 2019; Desjardins *et al* 2010; Peters *et al* 2007, Peters *et al* 2009, Peters *et al* 2012)
	Land competition and management	• Consider overlapping foodsheds and shared agricultural landscapes in metro-clusters (Joseph *et al* 2019; Kremer and Schreuder 2012; Nixon and Ramaswami 2018) • Understand effects of urban expansion on food production (Cardoso *et al* 2017; Huang *et al* 2019; Kriewald *et al* 2019) • Highlight potential conflicts related to meat industry in close proximity to the city (Giombolini *et al* 2011) • Account for conflicts between food vs. non-food use of croplands and competition between adjacent croplands in terms of crop mix or plant diversity (e.g., brassica family) (Giombolini *et al* 2011) • Plan for the restoration or protection of ecosystem services on landscape scale (e.g., abandonment of marginal land) (Conrad *et al* 2017; Griffin *et al* 2014; Liao *et al* 2019)
	On-farm management and decision making	• Contextualizes advantages and limitations of organic agriculture (Joseph *et al* 2019) • Understand impacts of conversion from commodity crops to specialty crops (Griffin *et al* 2014) • Explore ‘circular economy’ scenarios (Tedesco *et al* 2017; Zhou *et al* 2012) • Quantify impacts of climate change on crop yields (Kriewald *et al* 2019) • Consider the conversion of livestock systems (Joseph *et al* 2019; Zhou *et al* 2012)

Distribution	Supply chains and marketing	• Account for export-orientation for crops like wheat and blueberries (Giombolini *et al* 2011; Nixon and Ramaswami 2018; Zhou *et al* 2012) or dependence on imports (Akoto-Danso *et al* 2019; Halldórsdóttir and Nicholas 2016; Karg *et al* 2016) • Account for seasonal variability (Akoto-Danso *et al* 2019; Karg *et al* 2016; Zhou *et al* 2012) • Plan for alternative market schemes (e.g., community supported agriculture, farmers markets) (Brinkley 2017; Grigsby and Hellwinckel 2016; Świąder *et al* 2018) • Examine the impacts of locally-produced versus imported feed (Porter *et al* 2014)
Consumption	Diets, food preferences, and access	• Highlight the effects of a potential decrease in food supply diversity (Halldórsdóttir and Nicholas 2016) • Consider willingness to pay for local foods (Orlando *et al* 2019) • Illustrate potential effects of local dietary change scenarios (Joseph *et al* 2019; Kriewald *et al* 2019)

Data challenges and uncertainties

Models are generalizations of the real world that can inhibit a number of uncertainties that need to be considered when interpreting results, including related to data limitations and quality. Authors of *Capacity* studies, for instance, mentioned scarce, unreliable, and fragmented data on crop yields and soil properties (Desjardins *et al* 2010, Giombolini *et al* 2011, Kremer and Schreuder 2012, Filippini *et al* 2014, Galzki *et al* 2014, Cardoso *et al* 2017). Further, aggregation of various types of data across administrative units can introduce uncertainty in *Capacity* models. Sensitivity analysis is a mathematical approach to estimate the uncertainty of models and their results (Saltelli *et al* 2004) yet few reviewed foodshed studies used this tool. Nixon and Ramaswami (2018) estimate the impact of foodshed radius and Peters *et al* (2012) the impact of crop yields on LFS. Joseph *et al* (2019) assess how land use and livestock production systems affect LFS. The most comprehensive sensitivity analysis we found, by Zumkehr and Campbell (2015), encompassed six factors, including diets, crop yields, and cropland allocation.

Challenge #1: *Accounting for local socio-economic and cultural differences in food consumption*

The availability of high-quality data has a major impact on the spatial and temporal resolution of foodshed analysis. Our review shows that socioeconomic and biophysical context, as well as urbanization and development histories, can impact LFS potential and the nature of food flows (Porter *et al* 2014, Wegerif and Wiskerke 2017, Akoto-Danso *et al* 2019, Li *et al* 2019). Low resolution data can make it harder to distinguish whether results are city-specific or reflect national averages rescaled to population and land area. For instance, dietary preferences in large cities may vary from average national figures as well as between cities in the same country (Vanham *et al* 2016, 2017, González-García and Dias 2019). Further, household food expenditure data is often aggregated geographically or by food group (Nixon and Ramaswami 2018). Several studies raised concerns that production, consumption, and food flow data on subnational scales is often fragmented and/or unreliable (Desjardins *et al* 2010, Giombolini *et al* 2011, Kremer and Schreuder 2012, Filippini *et al* 2014, Galzki *et al* 2014, Cardoso *et al* 2017). Such data gaps can lead to an over- or underestimation of regional cultural or socio-economic food demands (see text S7 'Capacity studies' for examples) or the relevance of certain supplying regions.

Challenge #2: *Need for temporal data on inter- and intra-annual food supply dynamics*

Many foodshed studies (particularly *Capacity* studies) treat food supply and agricultural capacity as being static. In most regions, agricultural seasons are crucial determinants of type, quantity, and availability of foods, but seasonality is rarely addressed in foodshed studies. Peters *et al* (2007) account in their *Capacity* study for this limitation by defining summer and winter diets (e.g., processed or storable fruits and vegetables). However, the willingness of consumers to shift to seasonal diets is most likely low. Seasonality analysis is more prevalent among *Flow* studies than other study types, for example, through the use of local vegetable harvest and flow calendar (Table 3.1). Unless diets are adjusted to seasonal availability of foods, consumer demands for perishable food off-season can only be satisfied through food imports or greenhouse horticulture. Foodshed studies should therefore take this seasonal variability as well as the intra-annual flows (e.g., imports) that compensate for the lack of local agricultural capacity into account.

Increasing the temporal scope and resolution of foodshed studies could also make significant contributions to increasing their usefulness for planning, but sub-annual data are rarely readily available. We found that multiple studies model intra- or inter-annually variability of food flows or model the LFS capacity under different scenarios; what Porter *et al* (2014) call a 'bio-historical' approach (Table 3.2). For example, Kriewald *et al*'s (2019) global study used various scenarios (e.g., urban growth, climate change, diet change) and time-series modeling to estimate each scenario's influence on LFS from 2010 to 2050 across different world regions. Some studies also use time-series data to model intra-annual changes (Table 3.1).

Challenge #3: *The need for primary data collection to compensate gaps in data-poor regions*

A lack of standardized data on household food consumption and food availability, the various food types consumed, and their origin on a monthly basis poses a challenge to foodshed quantification. Studies have addressed this issue by either using national average data or via extensive primary data collection via market and street surveys. Karg *et al* (2016) and Akoto-Danso *et al* (2019) combined street and market surveys, literature, and interviews to build a more comprehensive data base for their analysis. Quantitative surveys among smaller samples of selected food systems actors, such as farmers participating in local or short food supply chains, can help to assess the agricultural capacity of a particular producer group to feed local consumers (Kurita *et al* 2009, Filippini *et al* 2014, Liao *et al* 2019). Similarly, interviews and surveys can help to trace supply and value chains (production, processing, and distribution) or bi-directional flows of food between different scales (Zhou *et al* 2012, Karg *et al* 2016). Wegerif and Wiskerke (2017) used ethnographic methods in their study of Dar es Salaam (Tanzania) to illustrate the value of understanding the relationships between material flows (food) and social relationships. The mapping of social networks underpinning urban food supply and consumption in order to measure structural and relational factors (e.g., trust, reciprocity, proximity, density, formality) is a helpful tool. However, in both examples, primary data collection requires considerable resources, with a resulting focus on smaller spatial extents and/or sample sizes.[6]

Especially in Global South countries, where urban growth is expected to have considerable impacts on agricultural land (Avellan *et al* 2012, Bren d'Amour *et al* 2016), planning for sustainable food systems means finding ways to decouple food supply from resource shortages, extreme weather, as well as geo-political conflict. However, such regions are understudied in terms of LFS capacity in particular. Data on food availability, the roles of intermediaries, food types, safety, and quality, as well as nutritional content, spoilage, and food origin on a monthly basis are important to identify gaps and vulnerabilities in food supply chains. These data can further be linked to questions of equity (e.g., youth and female participation), production (e.g., water usage, pest management), and infrastructure. Foodshed researchers working in this context must consider both formal and informal markets but note that food supply chain consolidation could limit transparency and access to proprietary data.

To summarize, we encourage researchers, policymakers, and food supply chain actors to collaboratively develop strategies to harness technological advancements to provide missing data.

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[6] Case studies such as Penker's work on the ecological embeddedness of the bread supply chain in Austria (2006) or Saguin's study (2014) on the bighead carp in the Philippines (not reviewed) offer more detailed insights into such pathways. However, their approach is very resource intensive and requires the focus on a type of food and its supply chain. Hence, it only allows conclusions about the ecological and social implications of a small fraction of the urban food supply.

Promising examples relevant to foodshed analysis include machine learning approaches to predict subnational food flows (Lin *et al* 2019), spatially-explicit predictive modeling of food consumption and production (Morrison *et al* 2011, 2012), and blockchain or other 'big data' approaches that draw on different data streams (Holden *et al* 2018, Saberi *et al* 2019). Such advancements could help to fill gaps in understudied regions and to take greater advantage of *Hybrid* approaches that combine multiple food systems issues. To achieve this, co-development of foodshed research with key stakeholders (e.g., food corporations and governments) may help to address multiple research priorities and data challenges (Smith *et al* 2017). Large-scale projects focused on a specific region could provide the necessary data and knowledge to produce scientific evidence for the social, economic, and ecological opportunities and limitations with regard to food systems localization (see Griffin *et al* (2014) and Conrad *et al* (2017) for studies embedded in the 'Enhancing Food Security in the Northeast through Regional Food Systems (EFSNE)' project, targeting local food security and rural development). Furthermore, large-scale projects can combine multiple complementing analyses, using the same data, which can justify an extensive primary data collection (see Karg *et al* (2016) and Akoto-Danso *et al* (2019)).

3.5 Conclusions

Foodshed research is an increasingly popular interdisciplinary approach to urban food systems research. However, our review shows a wide range of methods that have been used to assess urban foodsheds world-wide that presently limit comparison across studies. Due to the high complexity of food systems, integrated studies along more than just a few dimensions are also rare. Data limitations, specifically on local food consumption patterns and intra-annual food flows, are major hurdles that constrain foodshed analyses from moving away from the hypothetical toward explicit quantification of urban food supply chains. Particularly for *Flow* studies, reliable and up-to-date data on a sub-national level are often unavailable or are inaccessible, requiring extensive primary data collection. Finally, drawing from examples across the foodshed literature, we discussed the value of foodshed analysis and how it could progress towards a more consolidated and interdisciplinary research agenda. By drawing on a common framework and coherent set of methodological criteria, future urban foodshed research can more readily contribute to informing policies to address food systems sustainability and resilience.

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Connecting Statement

In the previous chapter, I conducted a systematic literature review of peer-reviewed publications that quantify and analyze local food self-sufficiency and multi-scalar food flows. This chapter synthesized different foodshed analysis methodologies and illuminated a suite of factors that can affect local food self-sufficiency and food production capacity based on biophysical resources. Urban governments and consumers are often important driving agents of local food systems. Hence, my findings raise the question whether and to what extent municipalities consider capacity limitations in their strategies and action plans towards more local food systems.

Chapter 4 seeks to answer this question by thematically analyzing local food systems strategy and action plan documents from major cities across the US and Canada. I use an analytical framework, combining relevant policy areas that were identified in Chapter 3 as important for building and sustaining local foodsheds and local food production capacity with the social-ecological-technological systems (SETs) framework used primarily in urban ecology research.

Chapter 4 contributes to the overall aim of my thesis by illustrating gaps and weaknesses in urban planning and governance toward local food systems and local food production, highlighting diverse social, environmental, and technological needs. Doing so, I argue that the relationships between cities (as major net food consumers) and rural areas (as major net food producers) not only exist to facilitate market opportunities. Instead, cities' interests and the resulting direct and indirect influence on nearby rural areas may be in conflict. Local food systems action plans should, therefore, highlight the cities' roles in planning their food supply with rural interests in mind.

4 Planning the foodshed: Rural and peri-urban factors in local food strategies of major Canadian and US-American cities

Under review at *Urban Agriculture and Regional Food Systems*

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Abstract

Many North American cities seek to increase the amount of locally sourced foods for their residents. But to what degree are cities planning for and supporting this peri-urban and rural food production? We examined this question by analyzing 25 documents from 22 cities across major US and Canadian cities (>300,000 residents) with specific strategies or action plans around local food. Our analytical framework combines social, ecological, and technological factors pertinent to local food production. The findings suggest that most cities have not articulated plans around issues affecting food production, such as farmland access and quality, agricultural training and workforce, processing infrastructure, climate change adaptation, and social justice aspects regarding Black, Indigenous and People of Color communities. Just under half of the cities defined how success or progress towards reaching their goal would be monitored and measured. Many municipalities considered collaboration as an important governance tool for realizing their strategies towards local food systems, including with actors from within the city and beyond, as cities' governance scope, resources, and power are often limited. Besides illustrating ongoing municipal efforts to enhance local food systems, our study identifies focus areas in food policy and planning to avoid overlooking social and environmental trade-offs in local foodsheds, including potentially overestimating local food systems feasibility.

4.1 Introduction

Food systems connect people and food through social and ecological linkages that span across diverse geographies (e.g., urban and rural) and scales (local, national, and global). Working toward functioning, sustainable, and resilient food systems requires understanding of various social and ecological dimensions and their interactions (Schipanski et al., 2016). Urban food action plans, strategies, and policies often seek to address these cross-cutting dimensions of food sustainability, such as justice, health, and ecology (Cohen, 2022; Moragues-Faus & Morgan, 2015). These policies summarize a city's food systems goals and objectives, as well as pathways toward those goals, and are considered a tool to address shortcomings of food systems through a more systemic perspective on sustainability at the city-region scale (Morgan, 2015). For instance, municipalities task diverse urban actors (e.g., schools, NGOs) to increase the number of healthy foods supplied to food insecure communities and households and put regulations in place that allow the cultivation of food on urban land (commonly referred to as urban agriculture) or organize and facilitate farmers markets.

The strategic advantage of cities lies in their governance scale. In comparison to regulations within the agri-food sector at national and international scales, which often fail to account for local needs and capacities (Moragues-Faus & Morgan, 2015), local food strategies and policies can focus on context-specific circumstances. According to Sonnino and colleagues (2019, p. 110) cities function as "transition nodes that can exploit the policy vacuum created by the absence of comprehensive, coherent, and integrated national and supra-national food policies to develop more sustainable food systems." At the global scale, networks of cities implementing action plans towards food systems sustainability also allow for aggregating local knowledge and action across several dimensions of the food system (such as governance, diets and nutrition, equity, food production, supply and distribution, food waste). For instance, the Milan Pact on Urban Food Policies was established in 2015 and signed by more than 250 cities (Barilla Center for Food and Nutrition (BCFN), 2019) in response to an increasing interest in and need for local-scale action.

Many cities now aim to increase access to food from local sources for their urban residents and initiate change toward a more local food system through food systems planning and governance (Buchan et al., 2021; Candel, 2019). There is no universally agreed-upon definition for local food. Instead, "local" serves as a proxy for a geographical area where food is produced, processed, and sold (Kneafsey et al., 2013). The geographical area is conceptualized as 'foodshed,' which can encompass other jurisdictions (e.g., states) within a few hundred kilometres (see Joseph et al., 2019; Kriewald et al., 2019; Kinnunen et al., 2020). The foodshed framework has been commonly applied for assessing the local food production capacity of cities in North America (Conrad et al., 2017; Griffin et al., 2015). The lines between local and non-local food are often drawn based on the geographical and social context, cultural understanding, and practicability (Allaby et al., 2021; Kneafsey et al., 2013).

Cities and their hinterland are not disconnected entities but have reciprocal relationships (Cohen, 2010; Blay-Palmer et al., 2018). Cities, particularly those with the aim to increase local food procurement, must consider the potential consequences of their actions on food-producing regions in their vicinity (e.g., urban sprawl and agricultural land displacement), and identify limitations or support and harness potentials towards sustainable food production (e.g., water management, labor conditions). When overlooking such limitations and potentials, cities may risk overestimating their local production potential and the capacity of a sustainable local food system (Schreiber et al., 2021). Accordingly, strategies and action plans that consider rural-urban linkages and incorporate concerns from surrounding peri-urban and rural agricultural areas may need to be put in place. Yet, despite growing interest in local food sourcing, knowledge about cities' engagement with their local foodsheds has often been limited.

To date, case studies or comparative research on urban food policies has examined how cities verbalize their actions pertinent to food consumption, such as food security, equity, and sovereignty (Wegener et al., 2012; Cohen & Ilieva, 2021; Smaal et al., 2021; Zerbian & de Luis Romero, 2021) as well as healthy diets (Sibbing et al., 2021). Urban food policies can also target a suite of diverse goals that address food systems challenges across multiple dimensions and interest groups (Candel, 2019; Doernberg et al., 2019; Sibbing et al., 2021) and can contribute to the fulfillment of the Sustainable Development Goals set by the United Nations (Ilieva, 2017). Past studies looking at urban food policies around support for local foodsheds found that cities aimed to enhance food production (Sibbing et al., 2021), foster mutual support of rural farmers, communities, and local economies through rural-urban relationships (Jablonski et al., 2019; Reina-Usuga et al., 2022), promote organic local food production, and preserve agricultural land (Doernberg et al., 2019). Many cities that signed the Milan Urban Food Policy Pact further committed to strengthening and supporting rural agriculture to create a robust, sustainable, and innovative farming sector (Candel, 2019).

To outline and define urban food policies, and mobilize resources to operationalize these policies, cities have relied on a suite of policy tools (Candel, 2019). Cities often use a mix of material, discursive, and organizational tools and instruments to influence food systems trajectories and narratives (Candel, 2019; Doernberg et al., 2019; Mattioni et al., 2022). Identifying driving actors and key stakeholders (Doernberg et al., 2019) as well as the cooperation and partnership between them (Reina-Usuga et al. 2021) may have an important role in pushing urban food policies and strategies toward realization. As case studies have illustrated, partnerships and resource mobilization and distribution can also harbor challenges. Tensions can arise between urban and rural actors involved in the policy and mobilization process that may limit the potential or achievements of urban food policies (Jablonski et al., 2019). Despite collaboration, the realization of urban food policies can also fail due to contextual barriers (Zerbian & de Luis Romero, 2021) and a lack of balance between inclusivity and efficiency in defining goals and desirable outcomes (Brons et al., 2022). Furthermore, Sibbing et al.'s (2021) study suggests that the tools cities use to meet their objectives are rather coercive and utilize primarily information and organization, lacking material support.

To our knowledge, prior research has not interrogated the specific goals, strategies, and tools major cities in North America put in place to support local food systems in terms of production capacity. Such considerations are a fundamental component in the facilitation of local food systems (Schreiber et al., 2021). In this study, we sought to identify if and how major cities in the US and Canada with explicit aims to support local food supply chains embed local food production in their urban food strategies or action plans. We conducted a review of urban food strategies and action plans from across 83 medium and large (>300,000 population) cities in the US and Canada containing municipal visions, aims, and goals toward local food production capacity, including the tools used to realize them. Based on our inclusion criteria, we identified 25 documents from 22 cities that are explicitly committing to fostering local food systems. Our thematic analysis of these documents examined how cities incorporate rural and peri-urban food production in their planning across different dimensions based on a framework that merges "social-ecological-technological" systems (SETs) (Bixler et al., 2019; McPhearson et al., 2016) with policy-relevant themes from existing local 'foodshed' research (Schreiber et al., 2021). We conclude that, despite a clear interest in local food systems, few of the analyzed cities have comprehensive plans supporting their local food production capacity, including tools to operationalize those plans and monitoring mechanisms to measure success towards their goals. Our findings suggest that cities particularly lack clear plans around land access, social justice in the farming sector, climate change adaptation as well as processing and logistics infrastructure. Given such cross-cutting gaps in food systems planning and governance, ongoing municipal efforts to enhance local food systems may overlook social and environmental trade-offs occurring within urban foodsheds and ultimately overestimate the feasibility of local food systems.

4.2 Methodology

We used a multi-tiered approach for data collection and analysis (Figure 4.1). Below, we outline the various steps related to the development of our urban food strategy dataset (section 2.1) and our analytical framework based on the SETs framework and local food systems policy themes (section 2.2) used in thematic coding. We also examined the use of target setting and monitoring around food strategies, and key governance dimensions (such as tools used to implement strategies and the role of collaboration; section 3.2.2). To provide context on the strategy documents, we further analysed how cities defined the boundaries of their 'local food system' and the rationales municipalities used to justify their pursuit of local foods. We focus only on medium and large cities because this allows for better comparison across cities in terms of food demands, governance power, reach, and challenges.

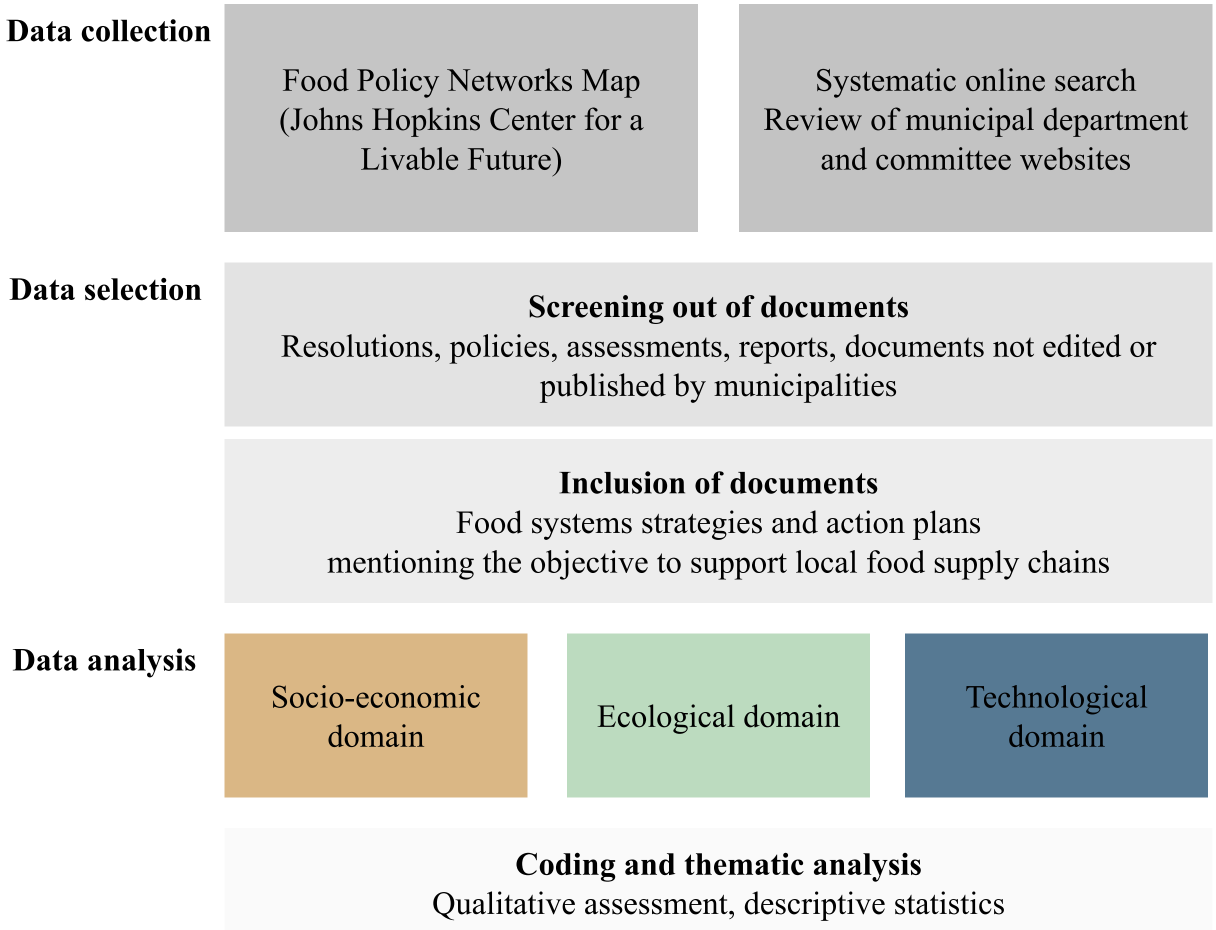

Figure 4.1 Multi-tiered approach to data collection, document selection, and thematic analysis.

4.2.1 Data collection

Document collection

We developed our urban food strategy dataset based on searching two primary sources. First, we accessed the Food Policy Networks Map curated by the Johns Hopkins Center for a Livable Future in June 2021. We filtered the documents for policy priorities directly or indirectly linked to food production (i.e., *Economic development, Food labor, Food procurement, Land use planning, Local food processing, Natural resources and environment*). We then selected only those documents from cities meeting our >300,000 population criteria (Supplementary information Table S1).

Since the Food Policy Network map does not provide an exhaustive list of urban food strategies across the US and Canada, we complemented the data through a systematic online search at the onset of our study between June and August 2021, using the Google search engine, to locate websites for each jurisdiction in our city list (66 cities in the US and 17 cities in Canada; Supplementary Information Table S1). Our search for documents across the 83 candidate cities included the following search strings: [name of the city] + "food strategy" OR "food policy" OR "local food" OR “food action plan.” We adapted our search to the province of Québec in Canada by searching for the French equivalents since the official language is French. We further reviewed the websites of related city departments or committees (Planning, Sustainability, Environment, Economic Development, and Public Health). If this search did not yield relevant documents, we repeated the search to include the name of the corresponding county or local/regional authority. As a final check to locate information on urban food strategies, we reviewed master plans created by the city, county, and relevant authorities, which mainly involved 'Resilience' and 'Sustainability' plans. Given the lack of a concrete definition of 'local food,' we also included documents referring to ‘regional food systems’.

Document selection

Our final dataset for analysis included 25 documents from 22 cities, including 13 US-American and nine Canadian cities, published between 2010 to 2021 (Supplementary Information Table S2). This dataset contained multiple versions of local food systems strategies for Columbus, OH, Vancouver, BC, and New York City, NY. We analyzed all versions, allowing for consideration of the temporal progression of themes in those three cities.

Our purposive sampling strategy sought to identify documents explicitly describing a city’s local food systems strategies and action plans around local food production, especially regarding peri-urban and rural farming and farmlands. We therefore included documents in our formal thematic analysis based on their relevance to the aim of our study (Figure 4.1). We screened out official resolutions or legislative documents related to policy development and documents exclusively dealing with food procurement, food security, and urban agriculture. These consumer-facing processes and themes take place directly within urban boundaries and municipal jurisdictions and have received extensive research attention and review (Baker et al., 2022; Baker & de Zeeuw, 2015; Mansfield & Mendes, 2013; Moragues-Faus & Morgan, 2015) as important aspects of local food systems. Instead, our study centers around local food production capacity in peri-urban and rural areas, as already highlighted in some European food policies and agendas (see

Doernberg et al. 2019, Sibbing et al. 2021), including context-dependent factors important to understanding the feasibility of more localized food systems (Schreiber et al. 2021).

4.2.2 Data analysis

Analytical framework: SETs aspects of local food systems and policy dimensions

To account for the multi-dimensional needs to plan for and govern local food systems, we developed an integrated analytical framework drawing on two literature branches: 1) 'socioeconomic-ecological-technological' systems (SETs), a framework that has been used in the urban sustainability and resilience literature (e.g., McPhearson et al. 2016, McPhearson et al. 2022, Bixler et al. 2019) and 2) a systematic review on foodshed analysis that identified various policy domains pertinent to local food systems planning and governance (Schreiber et al. 2021) (Figure 4.2). We adapted the three main domains of the SETs framework to the context of the local food systems of cities (which encompass peri-urban and nearby rural agriculture) and intersected these with Schreiber et al.'s (2021) list of seven policy-relevant themes[7] for local foodshed analysis. Combining these categories from the SETs domains and foodshed research resulted in 18 categories across the three SETs domains (Figure 2; Supplementary information Table S3).

The SETs framework has been increasingly used in urban sustainability research to conceptualize the connections between human and natural systems (Balogh et al., 2017). Governance towards urban sustainability must consider conditions, interactions, and processes in the socioeconomic,

[7] The policy-relevant dimensions of foodsheds assessment identified from Schreiber et al.'s (2021) systematic review include: farmer livelihoods and rural development, infrastructure, land competition and management, on-farm management and decision making, trade dynamics, and seasonal food production limitations.

ecological, technological domains of urban systems and how different actors at various spatial and organizational scales govern those domains (McPhearson et al. 2016, McPhearson et al. 2022, Bixler et al. 2019). The framework acknowledges that urban systems are embedded in the complex systems beyond the city's geographical and institutional boundaries, including diverse actors and processes (McPhearson et al. 2016, Grabowski et al. 2017). Its capacity to conceptualize human-nature interdependencies across spatial boundaries makes it, with some adaptation, transferrable and appropriate for studying local food systems. Additional information about the SETs framework can be found in Supplementary Information S4.

Thematic analysis

Using the software MAXQDA, we coded each document according to the 18 categories in our analytical framework and the governance tools described in the previous section. We followed thematic and content analysis principles to ensure a level of abstraction (Erlingsson and Brysiewicz 2017) and trustworthiness (Elo et al. 2014). In some instances, individual strategies overlapped within one domain (e.g., a strategy within the ecological domain could be either 'Land quality (soil)' or 'Nutrient cycle') or between two or more domains (e.g., a strategy could be either 'Production methods' (technological domain) or 'Water' (ecological domain)). In such cases, we assigned the strategy to both domains and categories to be as inclusive as possible in our analysis. We also assessed governance methods to mobilize strategies and action plans, and indicators to measure success and progress. Specifically, we noted to what degree collaboration among different actors played a role in defining and mobilizing the strategies.

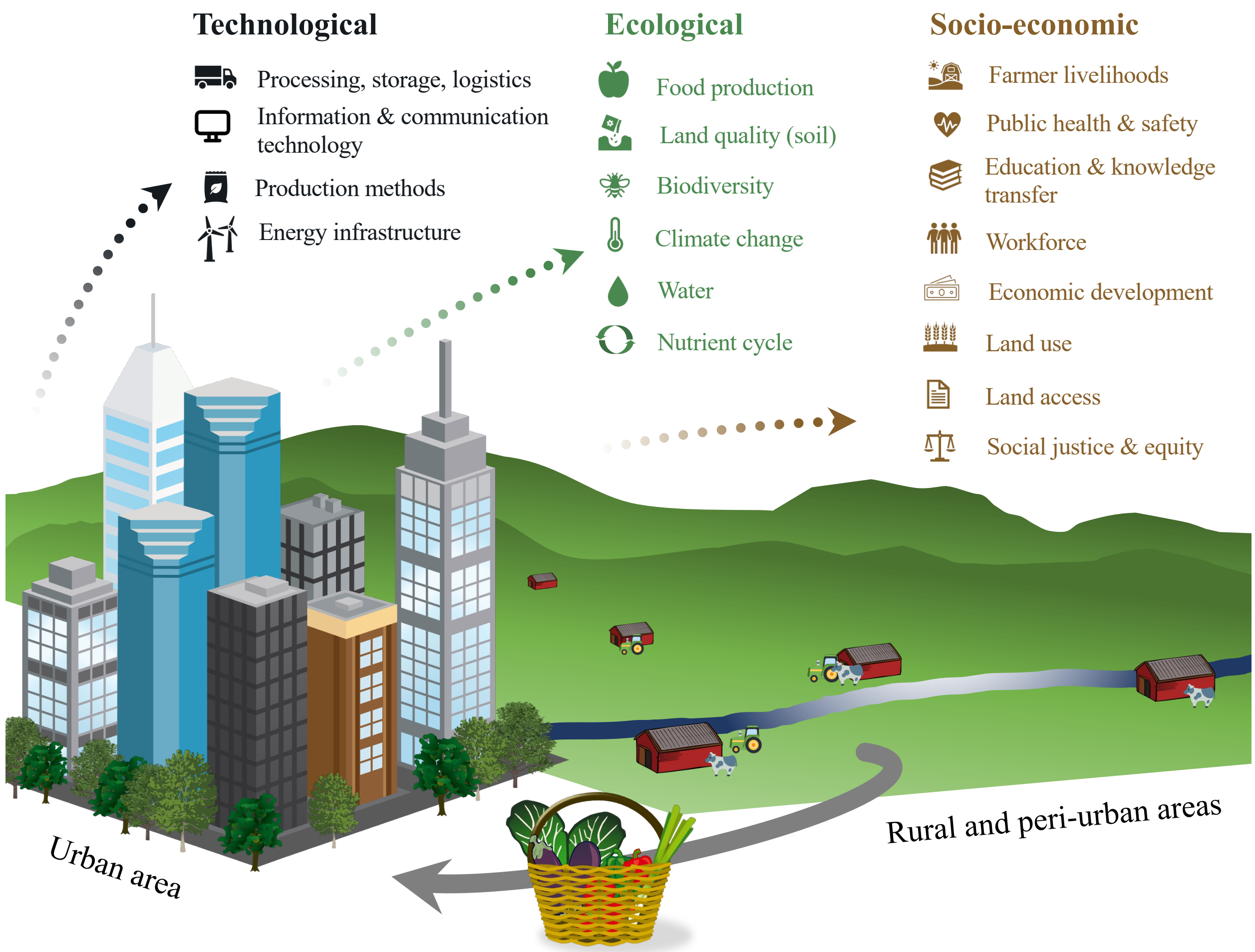

Figure 4.2 Synthetic analytical framework depicting a combined urban SETs-Foodshed approach (McPhearson et al. 2016, Bixler et al. 2019, Schreiber et al. 2021). We apply this framework to categorize the extent to which the urban local food strategies and action plans govern their rural and peri-urban foodshed across three SETs domains and 18 nested categories towards local food systems.

4.3 Results

Only 27% of the 83 Canadian and US cities in our search had local food strategies and action plans as of August 2021. Collectively, the 25 food strategy documents in our dataset addressed most SETs domains and categories in our analytical framework, but a few cities contributed disproportionately to this. Plans and strategies covering climate change were particularly underrepresented. Several of the cities in our dataset lacked a definition of tangible targets for local food production and progress or success indicators. Overall, our findings suggest that major North American cities aiming to foster local food systems have not yet sufficiently accounted for the diversity of factors involved in growing the production capacity of local food in an ecologically and socially sound manner. Such gaps may indicate that cities are likely to overlook trade-offs and overestimate the feasibility of local food systems.

4.3.1 Local food system definitions and rationales

Only five cities in our dataset defined the boundaries of their local food system. Calgary, AB (2012) and Vancouver, BC (2011) considered food coming from their respective provinces as local, despite the large geographic size of those provinces. Stockton, CA (2017) defined local food as from within the county (San Joaquin County, CA). The City of Philadelphia, PA (2011) define the local foodshed by drawing a 100-mile (160 km) radius around the city, including 70 counties in five states. Conversely, Pittsburgh, PA (2020) restricted the boundaries of its local food system to Southwestern Pennsylvania.

Varying rationales were given about why cities wanted to support local food systems. We identified three overarching reasons (Table 4.1): (1) Environment and well-being for people and animals, (2) supporting the local economy, and (3) reducing vulnerability to threats to food security. In some instances, cities stated multiple rationales. For instance, Philadelphia, PA, aimed to foster "food security and economic, social, and environmental benefits of the regional food system that feeds Greater Philadelphia" (Philadelphia 2011, p. 7). The strategy of Riverside, CA, states that the city wanted to

"…[e]stablish and grow a resilient and productive local food and agricultural system that provides a year round supply, supports community involvement and enables profitable enterprises for farmers and allied businesses while providing the needs of the community and the sustainable use of natural resources" (Riverside 2015 p. 24).

Table 4.1 Summary of city rationales toward enhancing local food systems, with representative examples from the document analysis.

Rationale	**Targets and goals**	**Representative documents**	**Representative quote**
Environment and wellbeing for people and animals	- Restore and sustain human and environmental health - Control the use of pesticides, fertilizers, and hormones - Protect animal wellbeing, habitat, and biodiversity - Increase resource efficiency and reduce waste and emissions	Seattle, WA 2012 Vancouver, BC 2013 Peel, ON 2019 Riverside, CA 2015	"Growing food locally can reduce a whole array of emissions. Buying local will reduce the energy consumption in transport, storage, and food preservation, which will reduce climate impacts. Local buying can also involve less food packaging, further reducing greenhouse gas emissions." (Riverside 2015, p. 12)
Supporting the local economy	- Create jobs and improve working conditions - Create profitable enterprises - Circulate money in the local economy - Generate local capacity to balance food imports	Calgary, AB 2012 Vancouver, BC 2013 Stockton, CA 2017 Seattle, WA 2012	"…the more locally produced and locally managed the food supply is, the stronger the local economy will be, and the more benefits in the form of jobs and economic activity will be realized" (Riverside 2015, p. 9)
Reducing vulnerability to food insecurity	- Address potential food shortages and reduce dependency on other regions	Vancouver, BC 2011 Riverside, CA 2015	"…the vulnerability of Metro Vancouver residents to uncertainties in the global food system" (Vancouver 2011, p. 24)

4.3.2 Degrees of engagement in planning local food production across the cities

The 25 documents in our dataset described various actions from across the three domains and categories. Eight documents addressed at least half the categories, while three addressed none. Vancouver, BC (assessed 94% in 2011 and 78% in the 2016 plan, respectively) and Riverside, CA (89%) proposed actions in the most categories. Similarly, Riverside, CA (2015), Philadelphia, PA (2011), Sacramento, CA (2015), and Pittsburgh, PA (2020) had comprehensive and diverse strategies. A few cities focussed only on one or two domains, such as Seattle, WA (2012), which proposed actions in the social and ecological domain, or Laval, QC (2019), which defined only social and technological strategies. Three municipalities (Peel, ON; New York City, NY; Toronto, ON) covered none of the categories in our analytical framework despite their aim to bring more local food to the city.

Compared to other cities, Vancouver, BC, had the most detailed description of strategies, with all domains and categories covered in the social and ecological domain and the majority in the technological domain (Figure 4.3). Vancouver updated its action plan from 2011 to 2013 and again in 2016, with roughly the same foci, and stated in its document from 2013 that their action plans were based on previous plans from 2004 and 2007. The document from 2011 further highlighted that the city aimed to revisit and update the plans every five years (although our data shows that the updates were more frequent than stated). Vancouver, therefore, seems to have a comparatively long-term local food systems strategy.

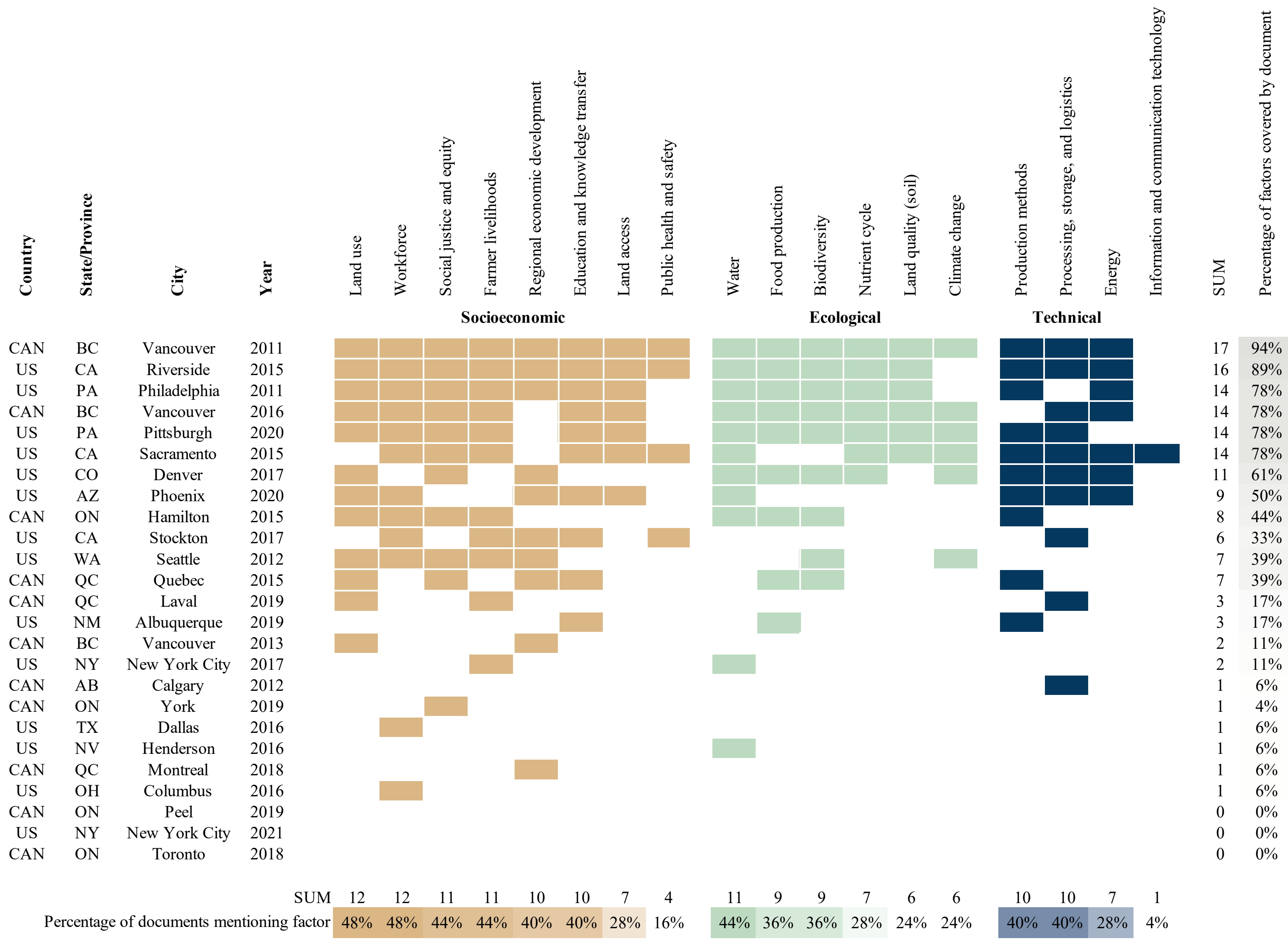

Figure 4.3 Overview of domains and factor frequency for each city.

4.3.3 Coverage of each SETs domains relevant to local food production planning

The most frequently mentioned categories in the documents were in the social domain, particularly "Land use" and "Workforce" (48% each), and "Social justice and equity" and "Farmer livelihoods" (44% each). Ecological categories in the focus of cities were primarily around "Water" (44%), and "Food production" and "Biodiversity" (36% each). In the technological domain, cities most frequently wanted to support better "Production methods" and improve local "Processing, storage and logistics" (40% each). Least frequently mentioned categories were "Land access (28%) and "Public health and safety" (16%) in the social domain, "Climate change" and "Land quality (soil)" (24%) in the ecological domain, and "Information and communication technology" (4%) in the technological domain (Figure 4.3). Further detail on the specific domains is described in the following sections.

Social domain

Nearly half the reviewed documents (48%) made statements about protecting agricultural land from development for other urban and non-food land uses. However, relatively fewer (28%) noted the importance of ensuring access to affordable farmland. Vancouver, BC (2011) raised the concern of conflicts at the urban-rural interface between urban residents and farming and pledged to mediate.

Plans for building a well-educated population of farmers and agricultural workers and making agricultural jobs more attractive and accessible to a diversity of people appeared in 40% of documents. Eleven documents (44%) presented strategies for social justice and equity, aiming at improving access to farming resources for historically marginalized communities such as women, new farmers, and, to a lesser extent, Black, Indigenous, and People of Color (BIPOC). Twelve documents (48%) mentioned the interest in improving the labor conditions by ensuring fair wages for growers and workers (Sacramento, CA 2015), decent and fair working conditions and accommodations, worker services, healthcare, and a living wage (Philadelphia, PA 2011), as well as legal worker protection (e.g., labor unions, overtime pay or minimum wage) (Pittsburgh, PA 2020). However, if farm labor was considered in the strategies, they focused more on the working conditions and less on the amount of (seasonal) labor needed to produce food, especially labor-intensive crops like fruit and vegetable. Only Vancouver, BC (2011) mentioned the need to have reliable access to labor and considered workforce demand changes over a year.

Ten strategies (40%) aimed to strengthen the overall regional economic development of the farming sector as well as farmer livelihoods (44%), including plans toward profitable and competitive farming businesses. Only two cities made dependencies with other areas (imports and exports) in their strategy documents explicit. For instance, Denver, CO (2017, p. 23) aimed to "increase production and export of Denver food and beverage products, brands, and innovations." Sacramento, CA (2015) and Calgary, AB (2012) uniquely acknowledged the potential for erosion of local food capacity through exports, working towards balancing food imports and local food sourcing.

Less frequently mentioned goals in the social domain included preserving agricultural heritage and history (Vancouver, BC 2011), protecting residents from potential contaminants from agricultural activity (chemicals, water contamination, dust, noise, odor) (Vancouver, BC 2011), and food safety education for farmers (Sacramento, CA 2015). Pittsburgh (2020) was unique in its aim to loosen food safety requirements to reduce barriers for small food businesses.

Ecological domain

Environmental stewardship played a role several of the strategies in our analysis, such as Hamilton, ON (2015), Denver, CO (2017), Philadelphia, PA (2011), and Seattle, WA (2012). To sustain food production capacity, some food strategies planned to protect or improve land quality and preserve ecological health by sustaining ecosystem services such as soil quality preservation (24% each), water quantity and quality (44%), and nutrient cycles (28%), as well as biodiversity (36%). Water management was the most commonly mentioned in the ecological category, being addressed in eleven documents (44%). For instance, two cities aimed to support technology to increase water use efficiency and water quality (Vancouver, BC 2011 & 2016, Riverside, CA 2015). Vancouver, BC (2011) stood out with the most detailed water-related plans, possibly owing to being one of the few coastal cities in our analysis where harbors and bays feature prominently.

Nine documents (36%) mentioned goals toward ecological dimensions of food production capacity. This could be by either sustaining (preventing capacity deterioration) or expanding on (increasing capacity) food production, as well as by increasing the quality and diversity of crops, foods. In terms of the social implications of crop diversification, only Hamilton, ON (2015) highlighted the role of meeting both nutritional needs and cultural preferences of residents. Although most strategy documents focused on agriculture, Vancouver's also covered aquatic food systems; the municipality aimed to conserve and restore fish habitat and promote sustainable ways sources of seafood by reducing "contaminant loadings through sewage treatment upgrades and better stormwater management improves fish habitat" and "protecting and restoring spawning and rearing habitat in the network of urban streams in the region" (2011, p. 25). Vancouver's strategy further included reintroducing several fish species while ensuring drinking water quality and safety.

Technological domain

In total, ten of the reviewed documents laid out plans to change fam management by supporting sustainable production methods (e.g., regenerative practices) to reduce resource use and greenhouse gas emissions or to help adapt to changing environmental conditions. A total of 28% of documents worked towards renewable energy and energy efficiency. Stockton, CA (2017) also highlighted its interest in growing the agricultural technology sector of the region.

To harness local food capacity, some cities also called for the expansion and support of the processing and logistics sector (40%). Philadelphia, PA stated the need to "apply efficiencies of the global food system to the regional food system" (Philadelphia, PA 2011). Calgary, AB (2012) had the only strategy that thoroughly discussed the need for small-scale processors to account for the unique needs of small-scale producers. The interest in storage and processing facilities was relatively low among the cities in our dataset despite the need for some crops and foods to benefit from processing and temperature-controlled storage and transportation.

Automation and information technologies were also largely absent. Only Sacramento, CA (2015, p. 36) mentioned communication technology and infrastructure in its plans, stating that:

"…broadband (high speed internet) is needed to utilize many of these technologies, which would help farmers become more resource efficient and reach markets more effectively. This would help get needed broadband infrastructure into rural, underserved, and unserved communities. The development and adoption of these technologies can make the region a global center of innovation for sustainable agriculture; food storage, processing, and distribution; and nutrition and community health."

4.3.4 Governance dimensions of local food strategies

Tools to realize local food strategies

The cities in our dataset defined various tools and approaches to realize their local food strategies (Table 4.2). We classified these as: (1) Legislation, policies, and regulations, (2) Programs, investments, and financial support, and (3) Management and development of strategies and plans. Approaches mentioned across multiple documents included arrangements for the exchange of equipment and knowledge (e.g., Riverside, CA 2015) and platforms and programs to foster the exchange of land between landowners and farmers (e.g., Philadelphia, PA 2011, Vancouver, BC 2011, Quebec, QC 2015, Pittsburgh, PA 2020). Technical assistance (e.g., Philadelphia, PA 2011) and payments for ecosystem services and other market-based solutions (Philadelphia, PA 2011, Riverside, CA 2015, Vancouver, BC 2011) were also targeted toward preserving, protecting, and restoring the ecological health of agricultural land.

Rarer tools included inventories for agricultural land and soil (Vancouver, BC 2011, Riverside, CA 2015), incubator farms (Vancouver, BC 2011 and 2013), management plans to ensure resource protection and restoration (Vancouver, BC 2011, 2016), quantification protocols, and certification standards for carbon sequestration on agricultural land (Vancouver, BC 2011), changing zoning regulations to allow for accommodations for seasonal workers (Philadelphia, PA 2011), protecting prime agricultural land by transferring land development rights to cities (Seattle, WA 2012) and Dallas, TX (2016) planned on setting up a website providing an overview for farming opportunities and labor needs (Dallas, TX 2016).

Some cities used less clearly defined tools, such as encouragement, recognition, acknowledgment, and support, that are difficult to measure. Examples include “Strengthen the role and responsibility of the Agricultural Land Commission and provide adequate resources for this work” (Vancouver, BC 2011, p. 31).

Table 4.2 Summary of governance tools used to mobilize local food strategies and action plans.

Tool	Cities using these tools	Contextual examples of tools
Legislation, policies, regulations	- Phoenix, AZ 2020 - Vancouver, BC 2011, 2013, 2016 - Sacramento, CA 2015 - Riverside, CA 2015 - Philadelphia, PA 2011 - Seattle, WA 2012	"Supports policies to enhance the capacity of regional and provincial governments to adapt to climate change impacts, protecting productive BC farmlands, or supporting BC farmers" (Vancouver 2013, p. 51) "Adopt a new land use policy to encourage agricultural use of these lands, and incorporate it into the City of Riverside General Plan. Include provisions that will allow flexibility to permit compatible land uses that will preserve agricultural options for the future" (Riverside 2015, p. 30) "Continue to support Seattle's role in conserving regional agricultural land through transferring development rights from farmland to urban areas." (Seattle 2012, p. 31)
Programs, investments, and financial support	- Phoenix, AZ 2020 - Vancouver, BC 2011, 2016 - Sacramento, CA 2015 - Riverside, BC 2015 - Philadelphia, PA 2011	"Fund research that introduces new hardy crop varieties and innovative and efficient production methods." (Vancouver 2011 p. 49) "Maintain affordable land for farmers through a range of potential innovations and new business models. These include addressing the retirement needs of farmers, identifying opportunities to transition preserved land into food production, and creating investment vehicles for long-term agricultural production on preserved land." (Philadelphia 2011, p. 11)
Management and development strategies and plans	- Phoenix, AZ 2020 - Vancouver, BC 2011, 2016 - Riverside, CA 2015 - Philadelphia, PA 2011	Drinking water management plan, air quality management plan, parks and greenways plan, integrated stormwater management plan (Vancouver 2011).

Collaboration

Collaboration with different stakeholders and partners was mentioned in 21 of the 25 documents (Figure 4.4). These references included describing how municipal governments collaborate with different entities to develop food strategies (n=15) as well as collaboration to mobilize food strategies (n=17). In a few cases, the city clarified the types of stakeholders they consulted and aimed at including a range of expertise, such as Riverside, CA (2015, p. 33):

> *"Energy utilities, financial experts, and renewable energy promoters to identify the most cost-effective way to deploy renewable resources in food production. Work with farmers and their representatives to determine how to make cost effective investments in renewables and engage the financial and utility communities in designing investment vehicles and financing strategies based around valuing conservation and renewables as resource."*

Fourteen documents also stated that collaboration within the city administration is crucial to meeting local food production goals. Such collaboration with research institutions and organizations was noted in several documents (n=11). For example, Riverside, CA (2015, p. 3-4) mentioned the role of university extension programs:

> *"Diversify agricultural production. Create a comprehensive speciality food and crop variety program with UC Cooperative Extension and the Riverside County Farm Bureau. Focus on innovations for citrus and on crops suitable for the local climate that will meet local demand."*

Seven documents emphasized that collaboration with neighboring jurisdictions was essential to account for the effects of actions on other municipalities and counties. For example, Denver, CO (2017) aimed to coordinate with other counties to preserve high-quality agricultural land and water resources for fresh fruits, vegetables, and other healthy foods (Denver, CO 2017).

Eleven documents expanded the action plans and strategies to governance levels beyond the municipality. For instance, Vancouver, BC (2011) suggested actions at different scales (Metro Vancouver, municipalities, other governments, and organizations), calling on the federal government to create a “migrant worker commission, to investigate and address the challenges of Canada’s labor migration programs and protect Canada’s legacy as a fair and just society” (Vancouver, BC 2011 p. 27).

Monitoring

A total of eleven documents mentioned the need to monitor success and progress. However, detail about indicators and metrics varied, ranging from very detailed to very vague. Such metrics included concrete goals with numerical targets the cities aimed to reach within a specific time frame (e.g., Calgary, AB 2012) and clear goals or progress metrics without numerical targets (e.g., Phoenix, AZ 2020, Vancouver, BC 2011, Denver, CO 2017, Sacramento, CA 2015). Sacramento, CA (2015), for example, defined both tangible outputs and vague goals. The city worked toward building “a coordinated regional farmer training program model approved for accreditation and apprenticeship certification” (Sacramento, CA 2015, p. 48) but also planned to put “organizational capacity in place to connect farmers with financing resources and farmland” (Sacramento, CA 2015, p. 47) without explaining what this organizational capacity entails.

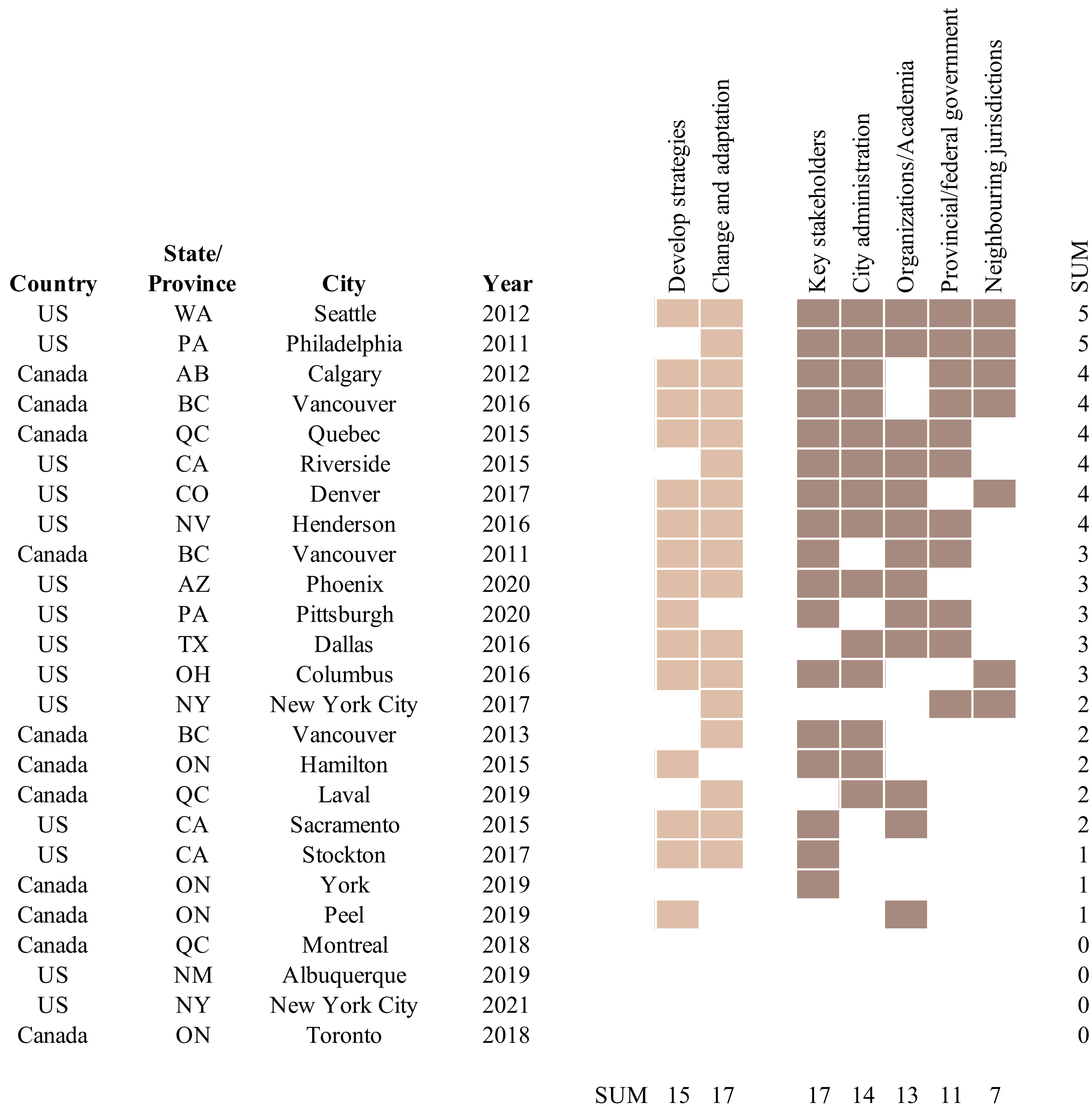

Figure 4.4 Collaboration purpose (first two columns) and types of stakeholders/partners described by cities in our dataset.

4.4 Discussion

This study aimed to identify local food systems strategies and action plans of major North American cities, as well as the degree to which these define strategies towards enhancing local food production capacity. Our synthetic analytical SETs-foodshed framework was useful for examining this by providing a cross-cutting template to compare the planning and governance of local food systems by cities across social, ecological, and technological domains, including through consideration of peri-urban and rural farmers and farmlands.

Our results have important implications for research around local food systems and for planners and policy makers involved in developing local food strategies. Cities are often inward-looking, focusing on procurement issues in the city (Cohen 2010). However, cities and their hinterland are not disconnected entities but impact each other. Rural and urban areas are intricately connected through flows of ecosystem services and market opportunities, benefitting both (Gebre & Gebremedhin, 2019). As demand for local food is growing (Martinez, 2021), cities need to consider the consequences their actions can have on food-producing regions in their vicinity (e.g., urban sprawl, rural livelihoods), harness potentials to support sustainable production (e.g., water management, labor), and understand the limitations of their local foodshed. Although local food systems may not be objectively preferable to non-local food sourcing in a social or ecological sense (Enthoven & Van den Broeck, 2021; Schmitt et al., 2017; Stein & Santini, 2021), food systems planning could help overcome some constraints and trade-offs, such as land-use conflicts between urban and rural areas. Considering multiple dimensions of sustainability, which is facilitated by the SETs framework, can not only serve to determine what cities can do to support local food systems but also – perhaps more importantly – determine the limitations, drawbacks, and thorny issues involved in developing local food capacity.

The cities represented in our dataset show diverse approaches to enhancing local food production capacity, with both strengths and potential blind spots. Our analysis sought to capture how cities framed food production from local sources, including peri-urban and rural farms. We found that a few specific cities had strong focus on multiple domains (e.g., Vancouver, BC), considering systemic components needed to build and sustain local food supply. Yet, our results across cities suggests that despite articulating a local food strategy, several cities nonetheless overlook various aspects of their local and regional food system. In some instances, those gaps may be surprising. For example, the City of Toronto, which received global attention for developing the Toronto Food Policy Council working towards sustainable food systems (Schiff 2008, Blay-Palmer 2009), described none of the categories in our analytical framework in its food strategy and action planning documents. Aside from a few specific cities (e.g., Riverside, CA, Philadelphia, PA and Vancouver, BC) that covered almost all categories in the three SETs domains, most cities overlook systemic factors to local food production in their local food systems strategies. This mirrors findings from Sibbing et al. (2021), who showed that urban food strategies and policies in the Netherlands were primarily focused on increasing public health and local food production with less attention given to landscape preservation or biodiversity.

Below, we elaborate on a selection of policy-relevant gaps that future local food systems strategies and action plans should consider. While this list is not exhaustive, it offers some insights into pressing policy issues that cities, in collaboration with governance partners, should address when planning local food systems.

4.4.1 Policy implications: Governance blind spots around local food and ways to improve strategies and action plans for mobilizing local food production potential

Power distribution and social justice

Gaps in the social domain are crucial to address since sustainable food systems should promote fair and socially responsible food production (see Feenstra, 2002). Overall, the focus on land quantity to grow food and prevent land-use changes seemed to concern many cities. In contrast, land access issues were only mentioned by a few, with most cities neglecting land tenure regimes that determine access to and power over land (Wästfelt & Zhang, 2018). We found some planning on social justice and equity issues in the local food strategies in our dataset. However, action plans rarely discussed BIPOC perspectives and interests, farm worker wellbeing, and generational transitions. None of the studied documents considers land use rights, knowledge transfer, food sovereignty, and financing pertinent to Indigenous communities or revitalization of Indigenous foodways despite their involvement in agricultural land holdings and practices (Arcand et al., 2020; Vaarst et al., 2018). Likewise, even though a stable farm workforce is a crucial factor for local food production (Schreiber et al., 2022) and among the most substantial cost factors for farmers with local-market-orientation (Biermacher et al., 2007; Jablonski et al., 2019) none of the reviewed food systems strategies explicitly clarified how this workforce could be paid fairly and equitably, leaving this crucial factor at the responsibility of food producers.

Climate change adaptation and environmental conservation

We propose that more attention should be paid to ecological factors, particularly climate change adaptation, since it presents a considerable challenge for food production and farmer livelihoods (Kohn & Anderson, 2021; Thornton et al., 2017). In our study, conservation and restoration of natural resources and ecological cycles received little consideration, particularly regarding water resources, despite their relevance in the mutual relationships between urban and rural areas (Cohen, 2010). Likewise, water shortages due to climate change are expected to intensify rural-urban conflicts around access to surface-water (Flörke et al., 2018). At a time when cities seek to reduce their environmental impact (Bergesen et al., 2017; Newman, 2006), a lack of attention towards critical levers of sustainability may throw a negative light on urban initiatives (such as initiatives towards local food systems). Agriculture, natural resources, and ecological networks and cycles are intricately linked, and detrimental cascading effects (Moss 2008) as well as restorative actions (Lefcheck et al., 2018) warrant consideration in urban action plans.

Access to adequate resources and infrastructure

Support of farmer livelihoods was a common theme across the cities. Yet, we found little differentiation and consideration of the specific and often varying needs of farmers. Besides diverse ethical, socio-demographic, and socio-economic backgrounds, food producers with different volumes, food types, or ownership structures (e.g., family farm, corporate farm, etc.) require respective assistance concerning infrastructure, transportation, and processing (Cohen, 2010). Previous research suggests that the lack of this intermediary infrastructure at a suitable scale for different producer types and sizes may affect decision-making and the overestimation of food self-sufficiency capacity (Godette et al., 2015). Likewise, while information and communication technology has been used by farmers for knowledge exchange and marketing purposes (Schreiber et al. 2022), many farmers in rural areas still struggle with a lack of access to or knowledge to use this infrastructure (Raison & Jones, 2020).

Need for realistic targets and on-going monitoring

Numerous scholars have highlighted the importance of defining goals and targets for measuring success in urban food strategies and action plans (Conner et al., 2020; Freudenberg et al., 2018; Ilieva, 2017) and the lack thereof in many urban food policies across the globe (Candel, 2019). In this regard, the documents in our dataset showed little effort towards a thorough definition of goals, targets, and monitoring tools, with few exceptions. At the same time, cities may not be able to access all kinds of data they need to track and make evidence-based and data-driven decisions. Conner et al. (2020) point out that tracking food consumption data is particularly difficult because big retailers often do not want to disclose their data. Furthermore, some local food systems interactions occur through informal channels and exchanges that are difficult to track (Hendrickson et al., 2020). Those gaps may represent a barrier to assessing progress or obstacles within local food systems development, potentially resulting in low political accountability (Candel, 2019).

The role of collaboration for meeting goals and objectives

We acknowledge that cities may be limited in their power to influence processes beyond their jurisdictions, including around rural farmlands. However, partnerships with surrounding jurisdictions could help to overcome such administrative and political boundaries (see Vancouver, BC). Collaboration can support more democratic and inclusive strategies and action plan development along with goals and targets (Jablonski et al., 2019). Desjardin et al. (2011) highlighted in their study on the Waterloo region (Canada) the importance of accounting for various stakeholder interests, needs, and capacities in urban and rural land use planning for local food supply chains. Given the fluidity between rural and urban areas in terms of resource streams, the inclusion of system-wide needs and interactions is necessary. The case of Vancouver, BC demonstrates how cities can be proactive in incorporating production factors crossing jurisdictional boundaries, for example, managing water quantity and quality in cities to identify resource conflicts and reduce the reciprocal negative impacts while enhancing benefits. However, collaboration does not guarantee success and is vulnerable to biases regarding participation, political changes, power conflicts, and other factors (Ilieva, 2017; Olsson, 2018). Urban food strategies are not inherently inclusive and democratic, and their operationalization can fail despite high stakeholder involvement (Zerbian & de Luis Romero, 2021), for instance, due to conflicting priorities and needs (Jablonski et al., 2019). Hence, cities should critically reflect on inclusion processes (Brons et al., 2022) and collaboration goals across temporal and spatial scales to plan just and sustainable foodsheds.

4.5 Limitations

Vagueness around 'local' food terminology had several implications for our results but also points to gaps in strategic planning that municipalities developing such documents should consider in the future. Firstly, municipal interpretations of 'local agriculture' or 'local food' was not always clear. In most instances, local agriculture and food production, in the broader sense, encompassed farming close to the consumer with a focus on food production in rural areas. In other cases, many strategy documents referred to 'local food production' exclusively as urban agriculture or used the term for both rural and urban agriculture. This echoes studies in the literature, such as Colasanti and Hamm (2010), who use local food and urban agriculture synonymously. Such ambiguity may have affected our document selection and thematic analysis but also signals a lack of clear definition of the term 'local,' a circumstance that is well known and recognized among researchers and practitioners alike (Eriksen, 2013; Granvik et al., 2017). With unclear terminology, it is hard to identify where the goals apply, how resources will be allocated, and who will benefit.

Since our purposive document sampling included only a limited type of documents—namely self-defined food strategies and action plans of cities—we did not consider municipal climate change action plans or sustainability/resilience planning documents that may have been published by municipalities and included relevant data about food strategies (e.g., The City of Hamilton, 2015). Furthermore, we limited our search within the documents to strategies and action plans to food production. Hence, we excluded strategies on food procurement and marketing. While this component of food supply chains plays a crucial role in bridging urban consumers and rural producers, our goal was to focus our attention on the food-producing stages.

Conceptual frameworks are a valuable tool to guide analysis but can sometimes impede the analysis as some aspects do not fit. We addressed this challenge to determine the best categorization for water and energy since both could be considered ecological and technological concerns. We decided to assign water to the ecological and energy to the technological domain. This decision may have resulted in some distortion about a city's contribution to a diversity of sustainability domains but speaks to the fact that we need to understand food systems spanning urban and rural areas as intertwined rather than neatly separate systems.

Finally, although we cover collaboration, tools, and monitoring in our review, we did not analyze processes of decision making, including the process and relationships involved in developing them. Non-democratic processes in strategy development may affect which topics are brought to the forefront and which are omitted. Future comparative studies of urban food strategies toward local food systems should incorporate an analysis of power dynamics and the diversity of voices, as well as their implications on the objectives and outcomes of urban food strategies.

4.6 Conclusions

Many North American cities are working towards increasing the amount of locally sourced foods available to their residents. However, our review highlights the limited attention typically given by these cities to the feasibility of local food sourcing, including through mechanisms to support peri-urban and rural food production as part of their goals. We argue that local food strategies need to reach beyond urban focus to consider their foodsheds and connections to rural farmers and farmlands. Our thematic analysis identifies gaps and opportunities where municipalities can work to better integrate social, ecological, and technological dimensions of rural and peri-urban farmers and farmlands in their planning around local food systems. For instance, timely and critical issues such as climate change adaptation and social justice aspects are also frequently missing from local food strategies and action plans. Despite being illustrative of ongoing municipal efforts to enhance local food systems, our study shows that cross-cutting measures and rural-urban linkages need to be considered to avoid overlooking potential social and ecological trade-offs. Failing to do this, cities risk overestimating the feasibility or even desirability of greater reliance on their local food systems.

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Connecting Statement

In Chapter 4, I explored how local food systems planning and governance needed to mobilize local food production capacity is being addressed by large US and Canadian cities. Overall, I find that few cities verbalized and defined concrete goals across three sustainability dimensions towards local food production, as well as tools and tangible success indicators. My findings also suggest how little concrete and formal support may be being assigned to farmers to sustain or increase local food production. Farmers are managing different kinds of challenges and must find ways to address them, including through relationships with other actors. Similarly, in foodshed analyses, as demonstrated in Chapter 3, this social capacity has been largely disregarded in foodshed analyses to date.

In order to address this gap, the following chapter, Chapter 5, expands the foodshed concept by centering around the social factors of local food production. From this angle, I examine the meanings of social capacity for the mobilization of physical food production capacity towards local food systems and food self-sufficiency. Using a case study design, I investigate which challenges farmers selling to local markets in Québec, Canada encounter and how their social support system helps them navigate those challenges.

This empirical chapter contributes to the overall aims of my dissertation by demonstrating the relevance of building and sustaining social capacity in local food systems and emphasizing the need for an integrated view on local food systems and foodsheds. More specifically, the findings illustrate how social networks spanning across different temporal and spatial scales help farmers to mobilize local biophysical resources in order to grow and distribute food in local food systems.

5 Untangling the role of social relationships for overcoming challenges in local food systems: A case study of farmers in Québec, Canada

Agriculture and Human Values (2022)

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Abstract

Advocates for re-localizing food systems often encourage consumers to support local farmers and strengthen local food economies. Yet, local food systems hinge not only on consumers' willingness to buy local food but also on whether farmers have the social support networks to address diverse challenges during food production and distribution. This study characterizes the challenges and support systems of farmers selling to local markets in Québec, Canada, across multiple growing seasons using a mixed-methods research design. We sent an online questionnaire to 1,046 farmers and conducted follow-up interviews with 15 of the 133 respondents. Our findings show that farmers relied on an average of four support actor groups, particularly employees, customers, and other farmers. Actors played distinct roles in terms of the importance, frequency, and formality of interactions, providing immediate and long-term support through formal and informal relationships across multiple spatial scales (farm, local community, and regional/international). Our thematic analysis showed that support actors helped farmers in four key domains: (1) Knowledge sharing and emotional support; (2) Labour and workforce; (3) Material and financial aid; and (4) Consumer education and business promotion. Farmer associations provided resources to tackle various challenges, acting as bridges across multiple support actor groups. Yet, our results suggest that political desires to encourage local food systems are in some cases poorly matched with resources to address specific types of challenges farmers face. Specifically, overlooking the role of diverse social support actors in helping farmers build food production and distribution capacity could undermine efforts to foster localization.

5.1 Introduction

Programs by grassroots organisations, agricultural associations, and governmental actors in the Global North aim to (re-)build and support local food supply chains with the goal to increase the demand for food from local sources and the capacity of a region to produce and sell more food within its boundaries rather than depend on distant markets (Selfa and Qazi 2005; Buchan et al. 2021). Within this context, and partly in response to the pandemic, the Government of the province of Québec, Canada, announced plans in late 2020 to bolster local food self-sufficiency (Radio-Canada 2020). While some regions in Québec can, theoretically, be fully supplied from local farms (Des Roberts 2018), the agricultural sector faces multiple, often compounding challenges that can limit the amount and quality of food local farmers can produce and market (Abate 2008). For instance, farmers' livelihoods and operations in many regions are increasingly vulnerable to impacts resulting from climate change (Thornton et al. 2017; Kohn and Anderson 2021). Consequently, this may compromise the feasibility of local food systems and further constrain the feasibility of local food self-sufficiency in some regions (Kinnunen et al. 2020).

Farmers must respond to a myriad of challenges to sustain their livelihoods (Ashkenazy et al. 2018; Kangogo et al. 2020; Kohn and Anderson 2021) and supply food to markets. Social relationships and social capital can build farmers' capacity to address obstacles and innovate, grow, and adapt their operation to changes and prepare them for future impacts (van Duinen et al. 2012; Paul et al. 2016; Jones et al. 2022). The local food systems movement in particular considers mutual aid, cooperation, and direct consumer-producer relationships as factors that distinguish territorial food supply chains from globalised, "disconnected" trade networks (Bauermeister 2016; Blay-Palmer et al. 2018).

Local food systems activists and policymakers often encourage consumers to "support local farmers" to strengthen local food economies (Jacques 2021). Yet, the ability to respond to these calls, including in the province of Québec, can be constrained by a lack of understanding of the specific types of challenges that food producers supplying local markets in the Global North face, as well as which types of resources are needed to help address them.

Studies often focus on a single challenge type such as climate change (Harvey et al. 2018), access to funding (Fisher 2013; Tregear and Cooper 2016) and land (Horst and Gwin 2018), or the adoption of new technologies (Castillo et al. 2021). Comparatively, fewer studies investigate a suite of challenges (Bruce and Som Castellano 2016; Iles et al. 2021). Furthermore, previous research has primarily explored how local food systems can build social capital and relationships. Still, few assessed how farmers in local food systems benefit from and rely on those relationships (Glowacki-Dudka et al. 2013; Elton et al. 2021). While McIntyre and Rondeau (2011) analysed consumer-facing limitations to buying local food, producer-facing perspectives on supplying local food are still sparce. Few studies have analysed the needs, challenges, and motivations of farmers involved in direct food marketing. Although social values and community-orientation seemed to drive participation, the authors did not assess whether and how social infrastructure in turn helped farmers to overcome challenges and barriers (see Charatsari et al. 2018; Beingessner and Fletcher 2020). Furthermore, some studies largely focused on specific distribution schemes, such as farm-to-institution programs (see Izumi et al. 2010; Matts et al. 2016; von Germeten and Hartmann 2017).

We address this knowledge gap by using a mixed-methods approach to interrogate the meaning of support actors in overcoming diverse challenges for farmers selling to local markets in the province of Québec across diverse distribution channels. Acknowledging the role of social relationships for local farmers, we identify how different actor groups support local food production and distribution. Below, we briefly introduce the local food systems concept and describe the study's methodology. We then present the results, starting with an overview of our respondent demographics, followed by the results from our quantitative analysis on the actor groups farmers in Québec rely on. We close the results section by elaborating on the meanings of social support for overcoming challenges, combining both qualitative and quantitative data from our survey and interviews. Finally, we discuss our findings around implications for local food research and practice more broadly and propose future research directions.

5.2 Local food systems, short food supply chains, and social proximity

Interest in local food systems evolved in response to an erosion of trust in global food supply chains and agro-industrial systems (Ekici 2004) caused by an overall increasing awareness about negative social and environmental impacts of agriculture (Foley et al. 2011) and international food crises (Clapp 2017). Despite the lack of scientific evidence that food from local sources is inherently more sustainable, healthier, and fairer than non-local food (Enthoven and Van den Broeck 2021; Stein and Santini 2021), local food self-sufficiency and local food supply movements have experienced growing enthusiasm, especially among consumers and policymakers.

Local food movements aim towards building a just and sustainable food system through localising social and physical food distribution networks (Morgan 2015). The reduction of social and physical distance is expected to help shift power from centralised multi-national corporations to the community scale (Clapp 2014; Hitchman 2016; Hammon and Currie 2021) and (re)build trust via reciprocal relationships and shared values between all actors involved along the entire food supply chain (Trivette 2017), among other goals.

To date, there is no universally agreed-upon definition of the local food. Generally speaking, local food is sourced from within a certain geographical boundary or a "local foodshed" which can encompass a sub-national area (e.g., state, county) or span across a certain radius around a place of interest (e.g., a city) (Feldmann and Hamm 2015; Schreiber et al. 2021). Food systems scholars and practitioners often draw the geographical boundaries of local food systems based on the context and purpose of action, program, project, or study.

5.3 Methodology

Our sequential mixed-methods approach involved a semi-standardized online questionnaire sent to farmers selling to local markets in Québec ('local farmers') and semi-structured follow-up interviews with respondents (Supplementary Information SI 1). Data collection and analysis were guided by three main questions: (1) Which challenges do local farmers encounter, and how do they affect their operations? (2) Which actor groups do local farmers consider important to address those challenges, what is their relationship with them? (3) How do these actor groups contribute to overcoming challenges? This study is part of a larger research project on local farmers' challenges and coping strategies in Québec (Schreiber et al. 2022). The data collection took place from February to April 2021 after the study was approved by the Research Ethics Board of our University.

The semi-standardized survey included fixed-response questions, open-ended questions, as well as open-ended response boxes for most fixed-response questions to allow for elaboration. The respondents selected the relevant challenges from a list of seven challenge types that they had encountered before the onset of the pandemic (2017–2019) and at the onset of the pandemic. For this analysis, we focused on the pre-pandemic challenges. The challenge types were collaboratively defined by the authors during the design of the questionnaire and covered four production-related and three distribution-related challenges (SI Table 5.1). We then asked farmers to indicate the actors and actor groups that they drew on for support (Table 5.1) as well as to rate each actor group in terms of their importance (reliance on the actor), frequency of interaction (relevance in their daily operation), and degree of formality (commitment and trust) (Table 5.2). We sent the questionnaire in French and English via e-mail to 1,046 business e-mail addresses that we collected using the platforms of four local initiatives and organizations that connect consumers with local farmers: Coopérative pour l'Agriculture de Proximité Écologique (CAPÉ), Le Réseau des Fermiers|ères de famille, Mangez Québec, and Mangeons Local. We received 133 full questionnaire submissions (12% response rate), which included a total of 343 clarifying comments as a source of qualitative data for the pre-pandemic period.

The purpose of the follow-up interviews was to provide additional depth to the quantitative and qualitative data from the survey, and to better understand the meanings of support actor groups for farmers selling to local markets in Québec. The sampling strategy for our interviews was based on purposive criterion sampling of a voluntary roster to which 49 survey respondents signed-up by entering their e-mail address. We purposively sampled interviewees according to different characteristics (i.e., food diversity, food types, gender, age, marketing, farm location, support actor groups, challenges) to ensure that the interview sample represented our survey population and to find common themes in terms of perspectives on support actors and challenges. We contacted 31 of the volunteer respondents, starting with the most information-rich cases based on their survey responses. A total of 16 respondents subsequently withdrew from the interview process after follow-up e-mails. We therefore conducted 15 interviews with local farmers in English and French after which, in combination with qualitative data from the survey, we reached thematic saturation and little or no new aspects arose and existing ones began to repeat.

The interviews lasted between 25 and 75 min and were recorded with the interviewees' consent. The interview recordings were fully transcribed by the first and third author and coded with the data management software MAXQDA. The first author conducted thematic analysis on the coded interview transcriptions and the open-ended responses from the questionnaire. Our coding strategy was deductive and inductive, following the principles for qualitative data analysis (Kuckartz 2014) and hybrid thematic analysis (Fereday & Muir-Cochrane 2006). This hybrid approach allowed for theory-driven and data-driven codes and more flexibility while maintaining scientific rigour.

Table 5.1 Categories of actor groups in our study

Support actor group	**Examples of specific types of actors within each category**
Employees & Volunteers	Temporary and permanent workers (full-time and part-time); volunteers
Customers	Private customers; business/institutional customers (i.e., restaurant chefs, hotels, schools, and hospitals; supermarkets; independent grocery stores)
Associations	Coopérative pour l'Agriculture de Proximité Écologique; Equiterre; Les Bio Locaux; L'Union des producteurs agricoles; Québec Farmers Association; Associations des producteurs maraîchers du Québec; Union Paysanne; Family Farmers Network
Other farmers	Farmer acquaintances; neighbours
Family & Friends	Relatives; acquaintances; friends
Government	Provincial Ministry of Agriculture and Fisheries (MAPAQ); Agriculture and Agri-Food Canada

Table 5.2 Characterization of relationships with support actor groups in terms of their importance (reliance on the actor), frequency of interaction (relevance in their daily operation), and degree of formality (commitment and trust)

Indicator	**Rationale**	**Questions in our questionnaire**	**Response options**
Importance	Degree of reliance on support actor group; relevance for farmer	"How crucial are these contacts for you to address challenges?"	Less important Important Very important
Frequency (Sharp & Smith, 2003)	Frequency of interactions between farmer and support actor group; relevance for daily operations and long-term development	"With regard to the [relationships with the selected actors], approximately how often do you interact with these contacts?"	At least once per week Once per month Not more than once per season
Formality (Fletcher et al., 2020)	Trust; accountability; commitment	"Are these relationships more informal (e.g., conversations, sharing information with customers), more formal (e.g., contracts, grants), or both."	Informal Formal Both formal and informal

5.4 Results

We begin with a brief overview of the respondent demographics. We then summarize our primarily quantitative findings on the meanings of support actors for local farmers in Québec and their various roles. Following this, we give more in-depth insights into these meanings and associated challenges, drawing from both the qualitative and quantitative data from our survey and interviews. Our thematic analysis resulted in four main categories of support networks: (1) Knowledge sharing and emotional support; (2) Labour and workforce; (3) Material and financial aid; and (4) Consumer education and business promotion. Finally, we elaborate on the specific role associations play for local farmers in Québec.

5.4.1 Respondent demographics

Most survey respondents (48%) were between the age of 45 and 64. Among the survey respondents, 42% identified as female and 57% as male. Farm operations in our sample were heterogeneous in terms of diversity of produced food, production methods, and distribution models. More than half of the survey respondents (57%) produced five or more types of food while the rest (42%) specialised in four or less, such as squash, meat, eggs, and fruit (cranberries, blueberries, strawberries, raspberries, haskap berries, ground cherries). While all survey respondents sold food in Québec, 16% also marketed their products in other Canadian provinces. A total of 8% of our survey respondents sent food to the US and 2% internationally. Most survey respondents used farm stores (62%) to sell their food, followed by independent grocery stores (44%), restaurants (42%), and public and farmers markets (41%) (Schreiber et al. 2022). Overall, close to 60% sold their products directly to consumers and through intermediaries, whereas a quarter of respondents sold only to end consumers, and 9% only to intermediaries (SI Fig. 1). Subscription systems (e.g., vegetable baskets) and restaurants were used more by farms with higher food diversity than those with fewer food types. In contrast, supermarkets and U-pick were more frequently chosen as outlets for farms that produced more food types (SI Fig. 2).

Similar to the survey, 43% of interview participants were between the age of 45 and 64. The gender-distribution among our interviewees was considerably less balanced than among the survey respondents. Only four of the 15 interviewees identified as female and eleven as male. In terms of food diversity, nine interviewees produced more than five types of food and six interviewees focused on five crops or less. All interviewees sold food in Québec. Additionally, one interviewee marketed their products in other Canadian provinces, but none sold food in the US or internationally. Most interview participants sold their food directly to consumers and intermediaries (60%), 33% only directly to consumers, and 7% only to intermediaries.

5.4.2 Actor groups local farmers in Québec rely on to address challenges

Eight out of ten respondents considered the group ‘Employees & Volunteers’ as an essential source of support (77%), followed by customers (75%) and other farmers (68%). Close to 2/3 of our respondents relied on governmental support (65%) and associations (60%). Half of the farmers (48%) selected ‘Family and Friends’ as important (Fig. 5.1, Table 5.3). Most respondents used e-mail and social media, whereas less communicated via phone calls and in-person and virtual meetings (SI Fig. 3). Overall, most farmers relied on multiple support actor groups. On average, respondents selected four (3.9) out of six support actor groups (Fig. 5.2).

Our detailed quantitative analysis of the meanings of support actors showed apparent differences in terms of importance, frequency of interaction, and formality of interaction among support actor groups. We found that employees and volunteers (72%), as well as family and friends (67%), were considered very important to the surveyed farmers (Fig. 5.3a). Hence, family and friends were selected by the fewest respondents as support actors (48%) but were of high importance for those who relied on them for help and contacted the most frequently. Farmers interacted least frequently with associations and the government (Fig. 5.3b). In terms of the formality of the relationships, farmers had the most informal support relationships with family and friends, as well as with other farmers. The most formal interactions took place with governmental actors, most likely due to grants farmers applied to and programs they participated in (Fig. 5.3c).

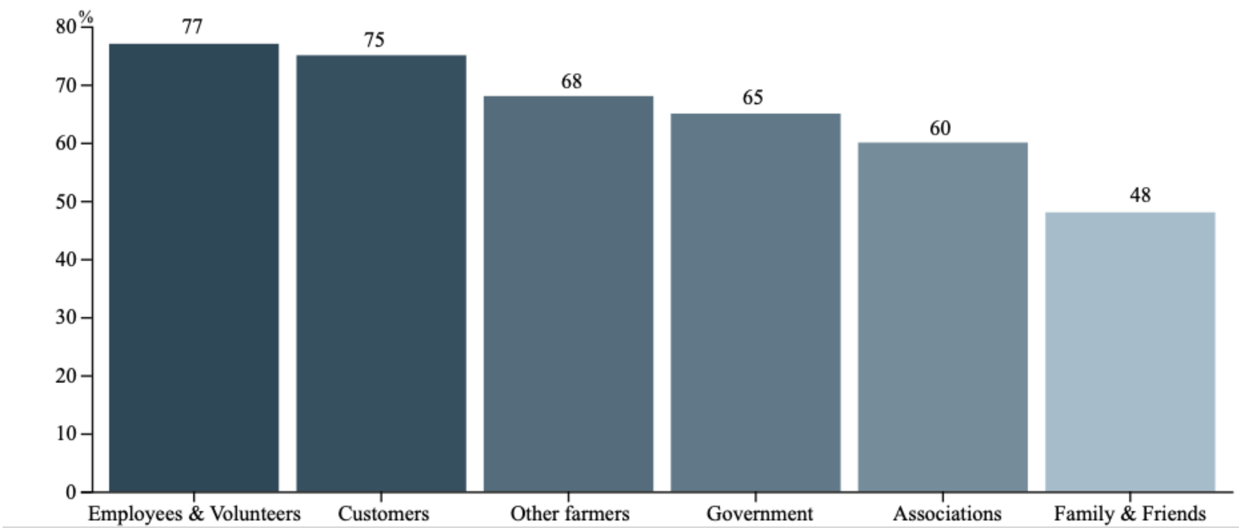

Figure 5.1 Overview of support actor groups that local farmers rely on for resources. The y-axis shows the results standardised as % of respondents in the questionnaire and the numbers on the bars show the absolute number of respondents. Local farmers found employees and volunteers to be the most important support actors, followed by customers and other farmers

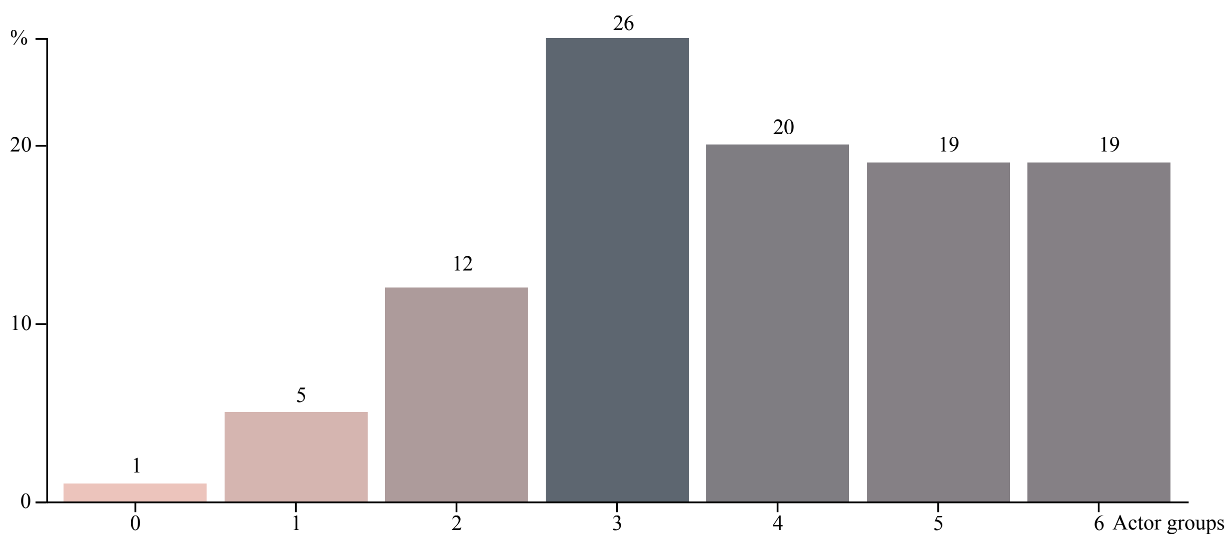

Figure 5.2 Histogram showing the distribution of support actor groups selected by local farmers as being important. The x-axis shows the number of support actor groups selected by respondents as either 'important' or 'very important' in the questionnaire (see Table 5.2). The y-axis shows the results standardised as % of respondents in the questionnaire and the numbers on the bars show the corresponding absolute number of respondents. On average, the farmers we surveyed were supported by four support actor groups.

Table 5.3 Summary of actor groups

Actor group	Examples of specific actors	Share	Sample types of support provided	Interaction	Barriers
Employees & Volunteers	Paid employees Volunteers Temporary foreign workers	77%	Volunteers can reduce financial pressure Harvest & care Services & marketing	Harvest & fieldwork Customer interaction	Hiring and retention of workers Locals often underqualified or unmotivated
Customers	Restaurants Individuals Institutions Market organizers	75%	Cash flow Customer recommendations Spreading awareness	Direct contact Storytelling Social media Labels	Lack of understanding Internet access Expectations
Other farmers	Neighbors Mentors	68%	Sharing of resources Mentoring	Social media Neighbourhood Meetings	Competition
Government	MAPAQ Agriculture & Agri-Food Canada	65%	Financial aid Help with recruitment of TFW Mentorship	Grants Programs Mentors	Lack of representation Access to grants
Associations	CAPÉ Family farmers network UPA Québec Farmers Association	60%	Representation of interests Collective action Knowledge sharing Workforce	Marketing & promotion Meetings Workshops	Membership fees Some sectors lack formal organization
Family & Friends	Close and extended family Friends	48%	Emergency help Free services Sharing equipment	Everyday interactions	Work-life balance

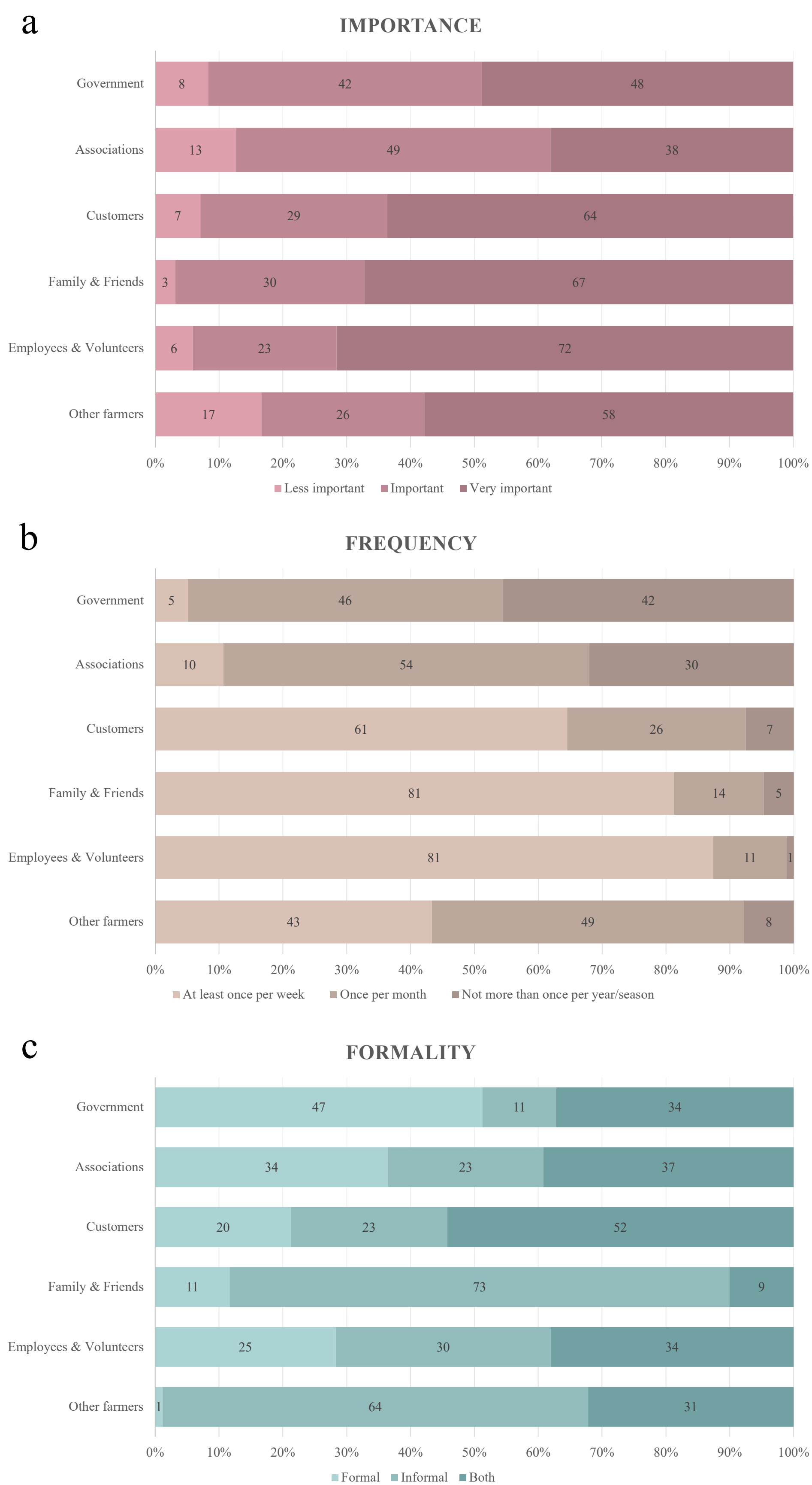
a
IMPORTANCE
Government 8 42 48
Associations 13 49 38
Customers 7 29 64
Family & Friends 3 30 67
Employees & Volunteers 6 23 72
Other farmers 17 26 58
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Less important
Important
Very important
b
FREQUENCY
Government 5 46 42
Associations 10 54 30
Customers 61 26 7
Family & Friends 81 14 5
Employees & Volunteers 81 11 1
Other farmers 43 49 8
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
At least once per week
Once per month
Not more than once per year/season
c
FORMALITY
Government 47 11 34
Associations 34 23 37
Customers 20 23 52
Family & Friends 11 73 9
Employees & Volunteers 25 30 34
Other farmers 1 64 31
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Formal
Informal
Both

Figure 5.3 Variations in importance, frequency, and formality of different support actors a) Importance of interactions with support actor groups. The actor groups of the highest importance ("Important" and "Very important") were family and friends, employees and volunteers, customers, and the government. Associations and other farmers were more often rated as 'less important' (13% and 17% of respondents selecting these actors, respectively). b) Frequency of interactions with support actor groups. Farmers interacted most frequently with employees and volunteers, family and friends, and customers. In relative terms, respondents interacted least frequently with government and associations – generally once per month, year or season. c) Formality of interactions with support actor groups. The most informal interactions occurred with family and friends, and other farmers. Half of the farmers relying on customers interacted with this group both formally and informally. Overall, interactions with the government were far more likely to be formal as compared to other support actors.

5.4.3 Meaning of support actors for local farmers

In this section, we present the meaning of support actors for local farmers drawing from the qualitative data and thematic analysis. Our thematic analysis showed that support actors helped farmers in four key domains: (1) Knowledge sharing and emotional support; (2) Labour and workforce; (3) Material and financial aid; and (4) Consumer education and business promotion. Farmer associations provided resources to tackle various challenges and acted as a bridge across multiple support actor groups. Under "Roles of Associations," we elaborate on the unique position of associations as a bridging actor between several support actor groups. Further results concerning the specific types of challenges and their repercussions are summarised in Table 5.4.

Knowledge sharing and emotional support

Trustful exchanges with other farmers, selected by 68% as an important support group, were crucial for new and small-scale farmers as they benefited from information and knowledge sharing. Specifically, several beginning farmers were mentored by more experienced peers but also within their group. For example, one interviewee explained knowledge sharing in response to the Covid-19 pandemic:

> *"People had to build online stores really quickly and we already had one because of the sales we're doing. Just getting on the phone with a friend who is also a farmer to ask those technical questions was, for sure, happening a lot. It's just, in general, a big part of our farming life to be able to just find out from other's experiences [I-14].*

Interaction between farmers with shared values, as well as family and friends (48% of the farmers chose this group), provided mutual emotional support and encouragement. One interviewee, for example, shared their experiences as a beginning farmer and the value of family support:

"For me, it's free labor to have a supportive family. Especially, because it's a career change for me, so I experienced a bit of imposter syndrome at the beginning. Knowing that my family is behind me and that I am capable" [I-2].

However, family responsibilities sometimes also conflicted with the farming business. Several farmers, predominantly female, pointed out the difficulty of maintaining a work-life balance and finding childcare.

Although most farmers depended on the "arm's-length" support and knowledge exchange, many respondents could not or did not want to rely solely on resources from the province. Many farmers valued relationships abroad or in other provinces to learn about novel methods and tools from farmers with similar values and goals. Social media helped to overcome logistical barriers to enable this exchange. Likewise, one farmer also emphasized that engaging in exchange with other farmers in Québec, especially with farmers that focus on similar products, was perceived as a risk factor due to local competition. Instead, the farmer primarily interacted with farmers abroad about technical concerns and innovation, which allowed them to access knowledge about novel production methods:

"We talk to each other, we're friends [farmers in Québec], but we keep the language superficial. The big advantage I have is my relationship with a group of producers in France. We openly tell each other everything because we are not competitors, we are just colleagues. This group also has contacts in Peru, Mexico, Italy, Belgium, and Spain. Often, we advance, and our new findings sometimes start from mistakes. […] Sometimes one person's mistake has

resulted in a new technology. By having a wider network, we can manage to advance [and innovate] much faster. Everything—machinery, classification, harvesting, […] all this experience comes from France and Europe. Here in Québec, in Canada, we are too few to have companies interested in producing and developing things for us. We are not a big enough market for them, so it's good to have eyes on the other side, in Europe, to allow us to move forward faster" [I-3].

Labor and workforce

We found that 77%[8] of farmers perceived support by their employees and volunteers as crucial, yet 43% encountered challenges, for instance, to find and retain the right quantity and quality of workers. Predominantly, this applied to the seasonal workforce, although personnel with special skills and knowledge for greenhouses were difficult to recruit, too.

High costs and slim margins were perceived as one of the most crucial factors that limited workforce stability. Multiple farmers mentioned in the survey that low wages, long work hours during the peak season, and the seasonal character of the work were often discouraging local people from jobs in agriculture. Farmers interested in hiring locals said that few were willing to work under such conditions. For instance, one farmer explained that people in Québec, due to shorter summers and extreme weather, prefer to go on vacation rather than work on farms. To overcome this concern, two interviewees mentioned that they paid higher wages and fostered a sense of belonging among their employees and volunteers, resulting in a more stable workforce. However, paying higher wages seemed to depend on the farmer's values, financial support

[8] There was also a small share of farmers without employees. Those producers often ran the farm as a hobby or retirement project or did not have the financial means to hire employees.

systems, and whether the farm was considered a hobby or primary source of income. One respondent shared their frustration in terms of compensation for a physically-taxing job while working in a low-profit-margin sector:

> *"It's hard to provide a competitive wage to our employees because we function with tight margins. Once folks come and see how hard the work actually is, they wonder why they do it for so little money" [Q-95].*

To compensate for local workforce shortages, some local farmers in our survey hired temporary foreign workers (TFW), acknowledging the help of the provincial Ministry of Agriculture and Fisheries (MAPAQ) in the recruitment process. Several interviewed farmers pointed out that family and friends offered free labour, especially during peak harvest time. Friends and other helpers were often compensated for their time with products from the farm through which farmers could save money and time that they invested into other projects. In emergency situations, family members also recruited volunteers in their own social networks. Individual farmers mentioned that employees and volunteers helped to promote the farm among their social contacts. Two small-scale farmers pointed out in the interviews that their employees told family and friends about the farm and helped to get new customers and volunteers.

Material and financial aid

Almost half of farmers (46%) faced financial challenges whereas 30% of the survey respondents reported technical problems and one-fifth of local farmers (18%) encountered logistical barriers (Table 5.4). Most technical, financial, and logistical challenges arose due to the lack of machinery and vehicles, especially among farmers with non-mainstream farming methods and smaller production volumes. For instance, two livestock producers we interviewed shared that processing and transportation infrastructure was often not adapted or adaptable to small enterprises and production volumes. Furthermore, some farmers were concerned about the lack of access to suitable delivery vehicles. Those obstacles limited the farmers' access to markets or increased their operation costs.

Farmers often found ways to address specific challenges within their community thanks to social ties. For instance, family and friends helped to overcome financial barriers to investments. This support was particularly crucial for farmers during the start-up phase of their enterprise when working capital was limited. Farmers with relatives in the farming business also shared equipment or experiences with novel techniques to reduce expenses. Likewise, some farmers saved money by lending machinery from neighbours or having neighbours work on the farmers' land for a little compensation, products, or services. One interviewed farmer explained the benefits of collaborating with a neighbouring farm:

> *"We're a small farm, we got a smaller tractor, we've got small equipment. He's a good neighbour, so he doesn't charge us a lot to do all that work. He's already got the equipment. His fields are kind of surrounding us. So, for him, it doesn't make [a difference]. All he does is to do our field like the other one. The difference is that we're organic. So, he has to do us first or last, depending on what he's doing. The first thing that comes to my mind is cost. We don't have a bailer and the machinery to seed the ground. We only own the tractor with a bucket for small stuff. He helps us with hay and hay bales, straw bales. All those things that are really expensive to buy when they're all done. We pay for the seeds and the labour cost is so cheap compared to us owning all those big machinery for the amount of field we have" [I-12].*

A total of 75% of farmers relied on their customers for support. Customers primarily contributed to the cash flow of the farm, which was necessary to cover expenses (e.g., salaries, feed, seeds) and make investments. For example, one mid-size livestock farmer explained that they needed a constant cash flow as they couldn't afford to buy feed in bulk. Hence, building stable relationships with private customers and retailers was perceived as essential. Nevertheless, some farmers struggled with low margins, rentability, and low liquidity..

A considerable share of surveyed farmers (68%) indicated that they were impaired by environmental challenges that required material and financial aid (Table 5.4). Extreme precipitation patterns (e.g., droughts, extensive rainfall, and humidity), extreme temperatures (e.g., heatwaves, late frost), strong wind, diseases, and pests forced farmers to invest in irrigation systems, crop protection, and other equipment. In the interviews and survey, farmers explained that the unstable and extreme weather was limiting their food production capacity, destroying crops, and becoming a burden or even health threat for farmworkers. In fact, environmental challenges exceeded the new challenges posed to farmers by the disruptions of the first year of the Covid-19 pandemic (Schreiber et al. 2022).

The majority of farmers had relationships with the MAPAQ (65%) and benefited from subsidy programs, for instance, for capital-intensive investments such as greenhouses and nets, as well as risky investments in new technologies to foster mechanisation and development, among others. MAPAQ also supported farmers by providing agronomists and pest experts that visited farms to prevent, address, and mitigate the spread of pests. Although programs were in place that could support farmers financially, one farmer criticized that documentation and application formalities made aid inaccessible to some farmers that were new to agriculture, "functionally illiterate," or could not pay professional assistance with grant proposal writing:

> *"It is not easy to apply for assistance even if the project presents practically no risk. The government is cautious, and it is very laborious to make additional requests to improve the business" [Q-12].*

Furthermore, the Ministry's requirements seemed to limit some farmers' access to resources. For example, one farmer whose production methods differed from standard practises could not find suitable equipment in Québec. Buying the equipment abroad was not feasible as provincial subsidies only applied to purchases with suppliers in Québec. The farmer bought the pieces individually and built the equipment according to the instructions of farmer acquaintances. Some small-scale operations reported that bulk purchases were sometimes not feasible due to limited storage space and disposable monetary resources, leading to higher per-unit costs.

Multiple farmers reported that insurance costs skyrocketed after several insurance companies stopped their operations in 2020. Access to insurance was limited, as farmers explained, due to the declining number of companies and competition between companies, resulting in higher insurance prices. This limitation led one farmer to pause an important construction project on the farm and others to adapt their cropping plans.

Consumer education and business promotion

A total of 38% of respondents mentioned marketing challenges and 25% of farmers pointed out that they encountered challenges with customer relationships (Table 5.4). Among those, many farmers had issues with publicity and making themselves known to potential customers. This particularly applied to farmers with niche products that were not widely known, farms with non-mainstream production methods, or young enterprises without a stable customer base. Some farmers supported each other formally by collaborating with other local enterprises, creating an ecosystem of food and food products to attract local consumers and tourists. Farmers also supported each other informally. For instance, a farmer we interviewed explained that other farmers in his network lost crops due to drought, and in response, they referred their customers to his farm.

Furthermore, challenges arose in response to diverging expectations and requirements when interacting with private and business customers. Farmers often struggled to convey the difference in price and quality between local and imported products as well as products of higher quality. Since labels were often costly and difficult to obtain, farmers mitigated this challenge by increasing customers' knowledge through direct interaction as highlighted by a farmer participating in Community Supported Agriculture (CSA):

> *"We still had to do a fair bit of education around the CSA model and justify the slightly higher cost of our produce compared to non-organic produce or produce that comes from far away. […] also quite a bit of education about eating in season and the fact that we cannot grow things like watermelons all summer in our climate" [I-14].*

Some farmers without direct consumer interaction highlighted relationships with business customers, such as butchers and chefs, since they could convey the special characteristics of the product which was not possible in a supermarket. Those direct relationships were also preferred since strict packaging and labelling standards, enlisting expenses, and competing with other producers and brands for restricted (visible) space on store shelves limited the integration of local food products into the retail sector and supermarkets. Restaurants also played an important role in creating awareness for niche and local products in Québec. One farmer explained how they supported their business:

> *"I've been making [crop] for about seven years and initially I had just a small area to try. I sold a little bit of it at the kiosk on my farm, but the Québecers who bought it said that it was not so good. I concentrated on the production. I did not know the kitchen at all. While doing my little tests in the Association of Market Gardeners, I had entered in my client file that I was producing [crop]. A great restaurant in Montréal was looking for [the crop] and called me. This is where I set foot in the restaurants. All chefs know each other. It wasn't long before my friend, who knew a chef, took them to the farm. When he came to visit, we were in production. We gave a tour and he was really excited. He had big eyes and wanted to have this [crop]. The next day at noon, he called me and told me he loved it. He put 2-3 photos on his Facebook and lots of chef friends asked him for my number to buy [crop] too. He told me he didn't have a problem to share but asked me to be served first before these friends if he ran out" [I-3].*

According to our respondents, customers also contributed indirectly to a farm's business by increasing the farm's visibility on social media and among their friends and family. Storytelling on social media, as another farmer highlighted, helped to communicate crop or product qualities, and share information about the farm's processes and philosophies to attract potential new customers, build trust relationships, justify relatively higher prices, and create an understanding of food production and processing. However, the requirement for using social media was also considered a challenge in itself as farmers wanted to share the farm life but not their personal life, which was sometimes difficult to separate. Furthermore, while many farmers valued social media as an overall affordable and easy way to stay connected with customers, and promote and manage sales, others emphasised the difficulty of learning to use online tools. The time and monetary investment as well as poor and expensive internet connection in the countryside seemed to be particularly challenging (Schreiber et al. 2022). Finally, private and business customers were also crucial sources of non-monetary benefits including recognition, trust, dialogue, fun, encouragement, and understanding which helped farmers to adapt or overcome challenges.

Roles of associations

Associations enabled farmers to get together, exchange ideas and experiences, and build capacity to strengthen their marketing and public relations. Associations also built linkages beyond the farming community by connecting farmers with other industries and customers as well as representing their interests and needs in front of the government.

As the largest farmers organisation in Québec, the Union of Agricultural Producers (UPA, "L'Union des producteurs agricoles") was described by some interviewees as an entity that invests heavily in advertisement to increase demand for local food and go up against the domestic and foreign competition. The UPA supported farmers with tax refunds, temporary foreign worker recruitment, and applications for wage subsidies, and advised farmers at any stage of development, with a particular focus on beginning farmers. Politically, the association was perceived as an intermediary between farmers and the government that provided the space for negotiation and represented collective interests with regard to taxes, pesticide use, land access, and other topics of concern. Finally, the UPA assisted farmers in implementing new laws and regulations. Several smaller farmers, however, complained about the high membership fees and the perceived low relative benefit they drew from their membership while being poorly represented.

While major farmer associations, such as the UPA, played an important role for most farmers, they failed to sufficiently account for alternative types of farming covered by some participants in our study. Smaller organisations such as the CAPÉ and the Family Farmers Network (FFN) appeared to fill this gap by representing interests that farmers in our study felt were left out in UPA debates and by engaging in political work. As FFN members pointed out, the association helped in building networks of shared identity, exchange, and mutual aid among small-scale organic farmers. More concretely, the FFN offered training opportunities (programs, workshops, and conferences), information distribution (listserv), mentoring between more established and new farmers, and help with constructing of equipment. The FFN further organised collective buying to take advantage of discounts for bulk purchases and supported farmers with marketing. Organisations like the CAPÉ therefore worked across the province and helped farmers to identify product demand and potential drop-off points for food baskets.

Sector-specific groups and organisations helped farmers to merge forces for marketing and political representation. For instance, an association mobilised resources for social media campaigns and video material to promote asparagus from Québec. Producers also organised clubs to build and expand formal and informal networks within and beyond their community to exchange knowledge and share issues or support each other's marketing (e.g., selling products from other members). Clubs served as substitutes for formal organisations or as bridging institutions between actors from different sectors. Those clubs included farmers, craftspeople, food processors, and shops from a subregion to foster agritourism. However, one respondent highlighted that not all sectors were sufficiently formally organised. Due to a lack of formality, it was difficult to bring problems to the attention of the government, especially with regards to foreign and domestic competition.

Table 5.4 Summary of local farmers' challenges and their implications for the farming operation

Challenge Type	**Share**	**Examples of specific challenges**	**Implications of challenges**
Environmental	68%	Precipitation patterns (e.g., droughts, extensive rainfall, and humidity) Extreme temperatures (e.g., heatwaves, late frost), strong wind, crop diseases, and pests	Limiting food production capacity Crop loss Burden or even health threat for farm workers
Financial	46%	Labour costs Low margins and liquidity High insurance costs	Starting, running, and expanding business Investments (building and equipment, insurance) Limited bulk purchases
Workforce	43%	Finding workforce (quantity and quality) Retaining workforce	Workforce shortages and fluctuations Limiting productivity
Sales & Marketing	38%	Domestic and international competition Building and maintaining a customer base	Limited growth potential Limited market access
Technical	30%	Lack of storage Access to specialized equipment Processors not adaptable to small producers	Higher production cost Limited market access
Customer relationships	25%	Mismatch in expectations and requirements Costly labelling	Responsibility to educate consumer and retailers Limited market access
Logistics	18%	Logistics firms not adapted to small producers Limited access to vehicles and rental trailers	Additional costs Limited market access

5.5 Discussion

Our study examined local food systems through a social relationships lens from the food producer's perspective. Social infrastructure is an important factor in farming communities, particularly among those participating in local food systems and among small-scale farmers (Iles et al. 2021; Scott and Richardson 2021), offering both emotional and physical benefits (Scott and Richardson 2021). In analysing the challenges local farmers encounter, the actors that can support them in overcoming challenges, and the meaning of those relationships, we demonstrated that social bonds between local farmers and a diverse set of support actors can contribute to local food systems in realising and mobilising local food production potentials. These bonds range from formal to informal, frequent to infrequent, and span across geographic scales from the farm to international level. Stepping away from an idealised notion of consumer-producer relationship that hinges solely on the willingness of customers to purchase local foods, our results indicate that the capacity to localise food systems requires a broad network of support actors with different relationships and meanings across various temporal and spatial scales.

We showed that local farmers overall relied on a diverse network of support actors, with each farmer being supported by an average of four out of six actor groups that helped farmers across various challenge domains. This suggests that, although consumers may play an important role in promoting local food systems, farmers need a range of support and draw on a variety of networks. While we do not know whether farmers with more connections "perform" better, support actor diversity could have implications on resilience. Resilience theory suggests that redundancy, diversity, and modularity in a social-ecological system can enhance its capacity to bounce back after impacts (Kharrazi et al. 2020). Future research could investigate possible relationships between resilience characteristics and identify whether certain relationships help farmers more than others.

Our results indicate that actor groups often supported farmers across different challenge domains by providing specific types of resources and assistance (i.e., “Knowledge sharing and emotional support,” “Labour and workforce,” “Material and financial aid,” and “Consumer education and business promotion”). Akin to previous studies, we found that our respondents benefited heavily from the immediate, frequent, informal, and direct support from peers, family members and technical advisors when dealing with these challenges (Gielen et al. 2003; Oreszczyn et al. 2010; Glowacki-Dudka et al. 2013). Although informal relationships built on trust and frequent interactions helped to deal primarily with urgent issues and short-term challenges, we find that many high-stakes challenges such as environmental issues or workforce gaps should be tackled with long-term solutions in mind. In concert with our previous study on the same farmer population, which indicated that farmers perceived environmental challenges as more severe than those arising from the Covid-19 pandemic-related impacts (Schreiber et al. 2022), we suggest that farmers would benefit from more systemic and formal support at various levels, especially moderated and facilitated by associations. Associations played a particularly important role for the local farming community as they served many needs and helped to access different types of resources to address farmers’ challenges. Local associations further functioned as intermediaries, connecting homogenous and heterogenous food producer groups with each other, with other stakeholders, and representing their interests on the political stage. In their study of 25 small-scale farmers in Québec, Allaby et al. (2021) found that the CAPÉ and other grassroots organisations supported small farmers in overcoming financial, knowledge, and time barriers related to the direct marketing of their produce online. This capacity that associations exhibit in Québec could prove valuable for tackling large-scale, long-term issues that need more formal and collective action such as climate change adaptation, thereby facilitating social innovation and grass-roots actions (Cattivelli and Rusciano 2020; Vercher et al. 2022).

Our results also indicate spatial and temporal variability among the support networks. Although access to local resources was deemed crucial (e.g., sharing of machinery and locally specific knowledge), the support relationships often go beyond the provincial boundaries to acquire new knowledge, fill technological gaps, introduce novel methods, and retain market advantages. Although, in the latter case, the trust relationships with locals may be lower, the province's food supply might, overall, still benefit from more open innovation networks in the long run by overcoming inertia (Cofre-Bravo et al. 2019). From a temporal point of view, social networks served as a source of support for immediate and on-going concerns. As mentioned previously, we found that some support actors helped with responding to short-term or suddenly arising challenges (e.g., harvest, field preparation, childcare), while others were needed for long-term support and transitional change (i.e., climate change adaptation, infrastructure). Future research could explore in more detail to what degree this spatial and temporal variability affects farmers and local food systems quantitatively.

This study has shown that formal and informal social relationships between farmers and support actors can help farmers access various resources to address their challenges. Yet, we did not account for the network processes and social norms that could affect the entire community's success. Social interactions within and beyond a community, regardless of their formality, require agreed-upon norms and rules that govern those relationships, which is the foundation for building and sustaining social capital (Putnam 2000). Social capital among farmers has been shown to facilitate a range of processes that benefit farmers and farming communities, such as knowledge sharing and acquisition (Pratiwi and Suzuki 2017; Thomas et al. 2020), diffusion of innovation (Oreszczyn et al. 2010; Cofre-Bravo et al. 2019, Cofré-Bravo et al. 2019), increasing access to funding (Fisher 2013; Tregear and Cooper 2016), fostering the adoption of new technologies (Lanza Castillo et al. 2021) and adaptation to new agricultural policies (Arnott et al. 2021). Furthermore, social capital can improve an entire community's capacity to deal with challenges by facilitating formal and informal collective action and community building (Glowacki-Dudka et al. 2013; Hulke and Diez 2020). Despite its benefits, social capital can also function as a barrier. For instance, strong bonding capital in tight-knit communities limits exposure to innovation, prevents actors from seeking new opportunities or challenging their own perceptions, goals, and tools (Cofre-Bravo et al. 2019; Arnott et al. 2021). Overreliance on social capital may cause inertia and reduce the members' willingness to engage in change and compromise (Gargiulo and Benassi 1999). In the context of local food systems, our understanding of social capital could help us determine to what degree the benefits and drawbacks of social norms, trust, and reciprocity can reduce or increase local food production and distribution capacity. Future research could investigate the social support systems of local farmers in Québec from the vantage point of social capital, trust, and reciprocity within and beyond the farming community, and how those factors affect the access to resources (Putnam 2000).

Farmers are experts at their craft and evolve in multivariate systems every day. But the problems that they face are equally complex, and the institutional support they receive should acknowledge their diversity. For example, most of our respondents struggled with environmental impacts, a threat to farmer livelihoods, worker health, and food crops alike. Similarly, a considerable share of farmers faced challenges recruiting a suitable and reliable workforce and paying fair wages.

Especially small-scale farmers and producers in niche markets often found it difficult to access the right transportation, processing, and storage infrastructure. Policymakers should put more emphasis on addressing or mitigating those and related challenges by sustaining farmer representation across different sectors, production systems, and distribution channels, embracing international knowledge exchange, and building new or improving existing infrastructure and technology. Furthermore, governments should acknowledge the role of informal and often unpaid, yet crucial labour in farming provided by families and friends, and cater their needs in an appropriate, equity-oriented, and inclusive fashion.

5.6 Limitations

We used a mixed-methods approach to collect quantitative and qualitative data and assess the challenges and support actors through the lens of food producers. Our case study's scope was limited to farmers in Québec who already distribute food through local food supply chains (e.g., farmers and public markets, CSA, farm stores) and identify themselves as such to potential customers through online platforms. Hence, we may not have reached all possible respondents and our sample could be biased towards farms that are using online platforms for marketing purposes. Future research should employ methods to reach farmers without access to or interest in such marketing tools. Furthermore, our interview participant sample was predominantly male and, unlike other characteristics, did not match the gender distribution of the survey. This imbalance may have introduced gender bias to our interview data and our findings and conclusions.

Instead of focusing on farmers of a specific size, food type, or sales venue, we allowed for a diversity of producers, making our results less generalizable. However, according to the values of the local food system movement, food systems ought to move away from large-scale standardised operations towards a more diverse agricultural landscape with more complexity. Hence, our study aimed to represent the various challenges and support actor groups and meanings that will result from the localization of food supply chains in Québec. Furthermore, investigating a broad variety of challenges and support actor types enabled us to identify overlaps across and between different challenge domains and actor groups. While a reductionist approach that focuses on individual challenges or actors is helpful in providing more detailed insights, it doesn't lend itself to understanding the broader context in which local food systems take place (see McIntyre and Rondeau 2011).

Even though our study covered a broad variety of challenges, we did not identify some widely known challenges such as land access (Horst and Gwin 2018), farm succession (Bruce and Som Castellano 2016), and language constraints (Scott and Richardson 2021). The latter challenge may play an important role among farmers with limited ability to communicate in French in Québec. Thus, suggesting various predefined challenge types to our respondents may have affected our results and conclusions. Although farmers could add open-ended responses to the questionnaire, some farmers may not have taken advantage of this option due to time constraints or privacy concerns.

5.7 Conclusions

Strengthening and (re-)building local food systems by supporting local farmers is a common objective among food systems advocates, planners, and policymakers. As Québec and other regions are trying to augment local food self-sufficiency, knowledge of support systems is crucial in understanding and planning for realistic targets of local food system provisioning. In the long run, if such aspirations are not backed up by the necessary social support system that helps in accessing physical and mental resources may be barriers to the development of fair and just local food systems. Our findings suggest that local governments must allow for diverse support systems to thrive while making sure that large-scale issues are matched with the necessary resources that cannot be retrieved from existing community ties. This may be particularly true with the new challenges created by the Covid-19 pandemic and other disturbances that compounded pre-existing issues, such as workforce shortages and extreme weather. Efforts to encourage local food self-sufficiency need to be matched with resources that address the broad types of challenges farmers face at different times. Without better acknowledgement of the role of social networks and relationships for local food production across temporal and spatial scales, physical local food production capacity may not be harnessed, undermining efforts to foster localization.

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Connecting Statement

In Chapter 5, I explored the challenges that farmers in Québec who sell to local markets encountered and the meanings of different support actor groups in addressing those challenges across multiple growing seasons. My findings indicate that diverse social relationships play a crucial role in enabling local food production and distribution in Québec and to use local biophysical capacity as well as develop resiliency to various challenges and stressors.

In the second year of my Ph.D. program, the Covid-19 pandemic started and caused disruptions within and beyond the food sector, which inspired the next and final empirical chapter. Chapter 6 examines the sudden, tangible, and real-world impacts of the Covid-19 pandemic that tested the resiliency of local food systems. I investigate the implications of the Covid-19 pandemic on farmers selling to local markets in Québec, Canada, identify various challenges and opportunities, and examine the adaptation strategies that helped farmers manage disruptions and harness new demands and interest in local food at the onset of the pandemic.

My case study demonstrates that research on foodsheds and local food systems can benefit from assessing food production-facing challenges and adaptation strategies and taking an integrated approach. Building further on the data described in Chapter 5, this study shows that social capacity helped sustain local food systems despite considerable adverse impacts brought about by a global public health crisis. To a great part, flexibility and redundancy among local farmers seemed to play a major role in adapting to new or existing challenges. This study also demonstrates gaps in current foodshed analysis in that it provided an opportunity to examine disturbances on local farmers that are pertinent to local food self-sufficiency but have largely been absent from foodshed modelling.

6 Diverse adaptation strategies helped local food producers cope with initial challenges of the Covid-19 pandemic: Lessons from Québec, Canada

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Abstract

The Covid-19 pandemic has demonstrated the vulnerability of food systems to disturbances. Advocates have promoted short food supply chains as more resilient and adaptable thanks to their embeddedness in local economic and ecological networks. As part of a broader case study on challenges facing farmers in local food supply chains in Québec, Canada, we asked farmers about the pandemic's impacts on food production and marketing in the province, including how food producers coped with these challenges. We sent an online questionnaire to 1,046 farmers who distribute food through direct marketing in Québec, identified through consumer-facing online platforms. We conducted follow-up interviews with 15 of the 133 farmers that completed the questionnaire to gain a better understanding of their pandemic-related challenges and opportunities, as well as their adaptation needs and strategies. We identified four main types of challenges among farmers: workforce shortages, balancing food demand and supply, changes in sales outlets and marketing channels, and other operational and development issues. In turn, six key adaptation strategies helped farmers reorganize their marketing and sales, which we categorize as: redistribution, streamlining, replacement, collaboration, farm adjustment, and outlet adjustment. Most surveyed local farmers felt well-prepared to adapt to the four major challenges that the Covid-19 pandemic forged or escalated, and our findings suggest that they demonstrated remarkable resilience to additional challenges posed by the pandemic. Our study therefore contributes important insights about how flexibility and redundancy among local farmers stabilized the local food system during the onset of a global pandemic.

6.1 Introduction

The onset of the Covid-19 pandemic and associated public health measures unveiled weaknesses and strengths in our food supply chains. Globally, nearly all food production sectors and operation sizes felt the impacts of public safety measures, including the milk and dairy industry (Wang et al., 2020), small-scale fisheries (Bennett et al., 2020), fruit and vegetable growers (Campbell and McAvoy, 2020), and family farms (Cavalli et al., 2020; de la Peña García et al., 2020). In between food security and livelihood concerns, paradoxical situations emerged, especially in agricultural sectors that relied heavily on high-volume foodservice markets like tourism and institutions (Campbell and McAvoy, 2020; Wang et al., 2020). For instance, 70–80% of fruits and vegetables from the largest producers in Florida are sold to the foodservice sector, so farmers responded to closures and lack of demand by terminating fields or dumping produce during the peak season (Campbell and McAvoy, 2020).

Initial studies and reports on how the pandemic impacted food systems suggest that numerous coping strategies at the local scale helped to address some of the most pressing issues. For example, online markets were used in Ohio, United States and in the Canadian North to ensure the continuation of local food sales (Radcliffe et al., 2021; Raison and Jones, 2020). Community Supported Agriculture (CSA), a popular management system in local food systems built on direct marketing relationships between food consumers and producers, has seen a surge in demand over the pandemic (Westervelt, 2020). In response to the breakdown of the tourism industry in Florida, many producers used social media to distribute food through alternative, local food networks, while new partnerships between packing houses and farmers helped to facilitate direct sales opportunities (Campbell and McAvoy, 2020). Organizations and farmers in the US and Europe built new connections between food insecure urban consumers and local producers and processors, donating surpluses to food banks, healthcare centers, and churches instead of dumping the food (Campbell and McAvoy, 2020; Cattivelli and Rusciano, 2020; Wang et al., 2020). The Covid-19 pandemic has bolstered the interest in and awareness for "eating local" (Zollet et al., 2021), picking up a trend that has grown in North America over the past decades (Thilmany et al., 2021). The literature around local food and direct marketing has emphasized their capacity to build resilience to shocks, largely due to their dependence on relationships rather than on physical infrastructure (Clapp, 2017; Darnhofer et al., 2016; Vieira et al., 2018). Food systems that create and foster more direct interactions between food producers and consumers are often described as more sustainable and resilient to shocks due to their ability to draw on nearby social support actors and local resources (Chiffoleau and Dourian, 2020; Yacamán Ochoa et al., 2019). Blättel-Mink et al. (2017) argue that the resilience of CSA springs from the intentional distancing from competitive and volatile global commodity markets. Going further, resilience within food systems is relational and dynamic, rather than a stable state (Darnhofer, 2021; Darnhofer et al., 2016). A resilient food system must balance the ability to be efficient in the current context with the ability to re-organize, and to adapt in response to unforeseen (or unforeseeable) change (Schipanski et al., 2016; Tendall et al., 2015). While food systems literature has begun to engage with how to build adaptive capacity to climate change (Soubry et al., 2020; Soubry and Sherren, 2022), there remains a gap in understanding how local food systems respond to more sudden crises.

In the Canadian province of Québec, local food initiatives have steadily expanded over the last few decades, manifesting in food origin labels, markets, agritourism, and sales initiatives. But how have local farmers coped and adapted with the challenges brought on by the Covid-19 pandemic? In this study, which is part of a broader case study of challenges that farmers face and their capacity to cope, we surveyed farmers who sell through short and direct food supply chains ("local farmers") in the province of Québec to understand their coping and adaptation strategies at the onset of the pandemic. Using a mixed-methods approach, we found that local farmers encountered new challenges related to farm production and marketing due to public safety measures or faced the compounding of previous pre-pandemic problems regarding workforce. Respondents indicated the use of various adaptation mechanisms and strategies to cope with new challenges arising during the early part of the pandemic. Our findings suggest that flexibility and redundancy among local farmers stabilized the local food system during the onset of a global pandemic, and that government measures to address recovery had unintended impacts on farmers' capacity to adapt. These results largely corroborate existing theory around food systems and resilience, but also contribute to a new avenue of inquiry regarding how certain high-level responses can compound challenges for local producers.

6.2 Methods

We employed a mixed-methods approach, combining an online questionnaire with semi-structured follow-up interviews with local farmers conducted via video or phone calls. Responses were collected from mid-February to mid-April 2021. We intended to capture the perspectives of farmers in Québec that already participated in direct marketing. We sent the questionnaire in French and English via e-mail to 1,046 business addresses collected from online marketing databases intended to help consumers connect with local farmers from key producer organizations: two smaller organizations and grassroots farmer cooperative networks representing organic family farmers (*Coopérative pour l'Agriculture de Proximité Écologique* which manages the *Le Réseau* *des Fermiers|éres de famille)*, as well as *Mangez Local,* which is managed by the *Union des Producteurs Agricoles (UPA)* and *Mangeons Québec*, initiated by the *Association des Producteurs Maraîchers du Québec (APMQ)*. In addition, the *UPA* communications team posted a link to the questionnaire on their social media platforms. We received 133 full questionnaire submissions as of April 2021 (12% response rate). The survey was hosted on 'Lime Survey', and we used spreadsheets to clean and organize the results. The semi-standardized questionnaire combined short open-ended questions, multiple choice questions, and Likert-style responses. Those questions were part of a larger questionnaire about farmer challenges, resources, and support systems which can be found in the Supplementary Information (SI), Appendix A. Initial questions asked about farmer demographics and farm characteristics (e.g., municipality in which the farm is located, farmer age, farmer gender, year of farm establishment, production methods, distribution outlets and geography). The main emphasis of questions related to challenges faced by farmers in terms of food production and distribution, which were asked separately for two time periods 'pre-pandemic' (2017–2019) and 'during the pandemic' (from March 2020). We also asked whether the local farmers changed their distribution strategy due to the pandemic and how well they felt prepared for the challenges they encountered in the pre-pandemic and pandemic season. Each standardized response option provided a comment box where respondents could explain or elaborate on their responses.

At the end of the questionnaire, respondents were invited to participate in a follow-up interview in French or English, conducted by the first author. 15 respondents were interviewed. The interviews' objective was to understand how local farmers responded to the challenges they encountered and how they perceive the future of their farm and local food supply chains. Farmers were asked about each challenge they selected in the questionnaire (and, where applicable, elaborated on), the impact it had on their operation, and the strategies they applied to overcome this challenge (SI, Appendix B). This set of questions was repeated for each challenge from the questionnaire. The interviews lasted between 25 and 75 minutes and were recorded after interviewees consented. The interview recordings were fully transcribed and coded with the data management software MAXQDA. We applied inductive coding to capture the challenges and adaptation strategies in the interviews and conducted thematic analysis on the coded interview transcriptions and the responses to the open-ended questions in the questionnaire. Codes that emerged from the analysis revolved around workforce challenges, changes in food demand, sales outlets, and sales procedures, as well as other challenges.

6.3 Results

6.3.1 Respondent demographics

The majority of farms were located in municipalities in Southern Québec along the Saint-Lawrence River (Figure 6.1) and had, on average, 112 ha of cultivated area (SI, Appendix C). 82% of our survey respondents and 80% of the interviewees were between 30 and 64 years old, which is below the average age of farmers in Québec (SI, Appendix D). In the survey, 42% of the respondents identified as female (57% as male), which differs from the gender balance among farmers in Québec (29% female, 71% male; Statistics Canada, 2021). Of our 15 interviewees, four identified as female and eleven as male (SI, Appendix E). Half of the survey respondents (57%) grew or produced more than five types of food, while 42% specialized in five or fewer crops. Among the 15 interviewees, nine produced more than five types of food and the rest grew less than five. Farms with lower crop diversity mainly focused on cranberries, blueberries and other kinds of berries, or meat, eggs, ground cherries and squash (SI, Appendices F-G).

Farmers in our study mainly marketed their produce in the province. Besides the local market, 16% of survey respondents and one interviewee sold their products and produce to other Canadian provinces, while 8% of survey respondents marketed food to the US and 2% internationally (one of the interviewed farmers sold to either destination). Before Covid-19, the most commonly used sale outlets among survey respondents were farm stores (62%), independent grocery stores (44%), restaurants (42%), and public and farmers markets (41%). We interviewed farmers who run the farm as their main business, those that undertake the farm as a side-business, and others who view the farm as a hobby.

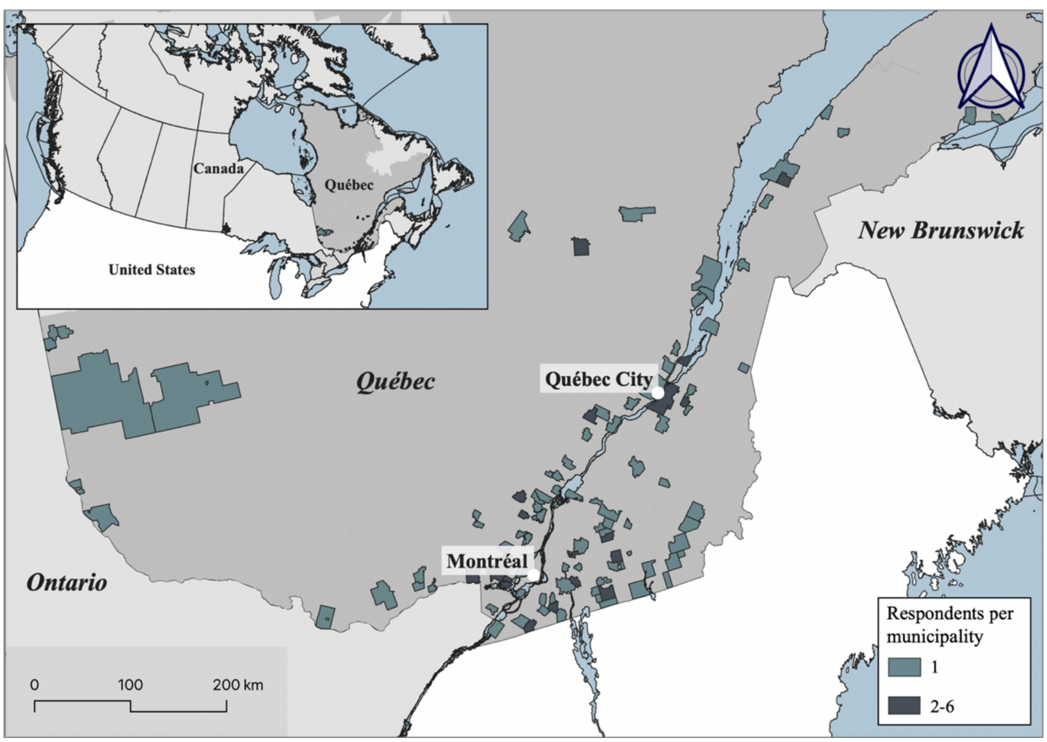

Figure 6.1 Spatial distribution of respondents and their farms (aggregated to the Québec municipality in which the farm resides). The inset shows the Province of Québec in relation to the rest of Canada and the US

6.3.2 Overview of impacts of the Covid-19 pandemic on local farmers

Our survey showed that the number of farmers dealing with workforce, marketing, and logistics related challenges increased during the pandemic while financial concerns decreased (Table 6.1). Although the restrictions posed new and reinforced existing challenges for farmers, environmental conditions (e.g., variable precipitation, hot weather, and pest infestations) remained overall the most common concern.

From our interviews and the numerical as well as open answer boxes in the questionnaire, we identified four major impact areas: (1) workforce challenges, (2) food supply and demand variability, (3) challenges concerning the distribution strategy and marketing channels, and (4) other operational and development issues (see Table 6.2). Farmers also reported various coping and adaptation measures in response to these main impact fields. In the following sections, we outline in more detail each of these four main impact fields, including specific challenges and adaptation strategies of local farmers in Québec during the first year of the Covid-19 pandemic. We then provide an overview of how farmers perceived their preparedness to address challenges, both before and after the onset of the pandemic.

Table 6.1 Percentage of survey respondents (n=133) indicating different types of challenges for the pre-Covid-19 (2017-2019) period relative to the Covid-19 period (from March 2020)

Challenge	Examples	Pre Covid-19	Covid-19	Change
Workforce	Farm labor, health and safety	43%	56%	+13
Sales & marketing	Unpredictable demand, facilities	38%	50%	+12
Logistics	Vehicles, transportation	17%	26%	+9
Customer relationships	Interactions, trust, help	25%	33%	+8
Technical	Equipment, supplies	30%	31%	+1
Environmental	Weather/climate, soils, pests	68%	65%	-3
Financial	Costs, insurance, investments	45%	38%	-7

Table 6.2 Summary of impact fields identified from the analysis of the questionnaire and interviews

Impact field	***Challenges***	***Adaptation strategies***
Workforce	Acquisition and retention of farm labour	Help by volunteers, family members, and friends
Food supply and demand	Changes in demand for specific commodities (including increase, decrease or variability)	Increase of production capacity; change of distribution strategy
Distribution strategy and marketing channels	Temporary and permanent closure of sales outlets; safety concerns for customers, farmers, and farm workers	Focus on, add or pause sales at marketing outlets; implementation of safety measures
Other operational and development issues	Developmental barriers of business or sector; resource shortages; new expenses	Virtual meetings; pausing projects; better planning; higher prices

Workforce

Most participants said that the pandemic impacted their capacity to find farm workers, both due to entrenched systemic difficulties and government responses to the health crisis. This challenge was often addressed through temporary help from family members and friends. In contrast, few farmers, primarily those participating in CSAs, reported that they received more offer of support than needed due to more time that volunteers could dedicate to farm work.

A total of 56% of survey respondents and 13 interviewees indicated that they had problems with getting farm workers. Although a lack of workforce is not uncommon and existed prior to the pandemic, many local farmers explained in the questionnaire and interviews that the reasons for a shortage in farm workers were more varied as a result of the pandemic. Travel restrictions were put in place in March 2020 to limit the risk of virus transmission, which coincided with the start of the growing season for vegetables and fruits in Québec. Local farmers therefore dealt with uncertainty around whether, when, and how temporary foreign workers (TFW) could enter Canada at a key time. The Ministry of Agriculture and Fisheries Québec (MAPAQ) and Immigration, Refugees and Citizenship Canada (IRCC) announced that TFW were considered essential workers and allowed to enter and work in Canada after a 2-week quarantine (CBC, 2020 Mar 18). Even once TFW were in Canada, one farmer explained, rapid turnover led to a workforce shortage during the peak season and a surplus during the lean season. Three farmers compensated temporary workforce gaps by hiring locals, which, as they explained, was often not an adequate replacement due to the lack of training. A local farmer who did not manage to fill the gap sufficiently reported the loss of several ten thousand pounds of high-value vegetables that could not be harvested. Some farmers also had to replace their usual international volunteers, so called “Wwoofers” (from “World Wide Opportunities on Organic Farms”), due to international travel restrictions.

Counterintuitively, an unemployment benefit had unintended negative side-effects for some local farmers. The Canadian Emergency Response Benefit (CERB) was implemented by the Canadian federal government in April 2020 and paid $2000 CAD for four weeks to every Canadian that lost their employment due to Covid-19, and particularly intended to support employees in the hard-hit entertainment and hospitality sectors. A relatively small share of our respondents (three survey respondents and three interviewees) reported that the CERB made temporary farm jobs unappealing or unnecessary for people who, besides their farm job, were employed as part-time workers in other sectors. As people were laid off from their part-time jobs and received the CERB, the motivation to continue working in the often less well-paid and physically strenuous jobs on the farm declined. One farmer explained:

> *“I made job offers, but several wanted to stay on CERB. They would tell me, ‘I want to work, but not longer than 3pm because I don’t want to give up my CERB.’ It is impossible in an orchard. In the high season I needed people” [I-02].*

In one case, a worker had to quit their farm job when schools and daycare centers closed temporarily to take over childcare responsibilities. One farmer who relied on the help of students during spring and fall could not fill the positions due to schedule mismatches. Some farmers also addressed the lack of workforce by changing their distribution approach. For instance, one farmer explained that they reduced their sales at farmers markets and focused on their U-Pick operation in order to balance the lack of farm workers during the season.

However, not all farmers reported negative consequences with regard to their workforce. According to one farmer, there was newfound interest in participating in farm labour:

> *"Because a lot of people weren't working during Covid, there was a booming interest in working on farms. People who may be otherwise be in the city, working in restaurants or something. We felt like we had a really good quality of employees and people who were interested in working with us. And that was a big boon for us in our first year on the farm. There was a lot of support. Having these positively engaged employees was great. It was interesting because there were a lot of stories in the news about the temporary farm workers and challenges for people finding and getting their labour force. But because we hired local people, it wasn't the same challenge for us. It was also a nice opportunity for us to be able to explain that sort of thing to customers and talk a little bit about how things work on small farms" [I-14].*

Food supply and demand

The impacts on food quantity and demand varied considerably. While many farmers reported massive increases in demand, others, especially those producing niche products, experienced a drop in sales due to the lack of direct connection with customers at markets and other in-person events that were cancelled. Half of our survey respondents (50%) mentioned that the pandemic had no negative impact on food sales. Some local farmers experienced a spike in demand early in the season, although one farmer explained that the heightened demand was short-lived and only lasted until mid-summer, when many customers were able to harvest fruits and vegetables from their home gardens. In this case, the demand surpassed the supply in the beginning of the vegetable and fruit season and ebbed off towards the end of the season. One way to cater to high demands was to increase the production capacity, lower or fluctuating demands were often addressed by changing the distribution and marketing strategy (i.e., switch to different sales outlets).

Some farmers experienced a demand above that of previous years throughout the entire season. For instance, one CSA farmer explained that the number of subscriptions at each of the delivery points more than doubled. Although the 2021 growing season was not part of our study, several local farmers emphasized that the high demand in 2020 appeared to be carried over to the next growing season. A CSA farmer mentioned that, at the time of the interview in early March 2021, most of the capacity at several drop-off locations was already reached for the season. Another farmer highlighted that the retention rate of customers buying vegetable baskets from his farm was at around 75%, which they considered high. Several respondents linked the spike in demand with the consumers' concern about a potential lack of access to fresh vegetables due to import restrictions, since countries that export fresh food to Canada may have terminated shipments to ensure food security in their own countries. Farmers considered an increase in food demand as both an opportunity and a challenge, which often required some adaptation (see 3.2.3 *Changes in distribution strategy and marketing channels)*. For instance, sudden spikes in demand posed logistical and planning challenges (e.g., temporal disaggregation of pick-ups). Some respondents also mentioned an insufficient capacity to meet the customers' demands for local food and the pressure to take advantage of this demand. One farmer highlighted the fear of negative effects on their well-being:

> *"We have seen an enormous demand for local food since Covid hit last spring. We are in a good place to be able to ramp up production so we will this year. But I fear growing too much and too fast and burning out" [Q- 95].*

A few farmers also dealt with lower demands due to a lack of consumer interest or the inability to interact directly with consumers which many niche products require. Finally, temporary restrictions that disrupted inter-regional travel within Québec were responsible for sudden sales losses among farms participating in agritourism or with roadside stands. For example, an apple producer with customers from Montréal explained that, when the city became a 'red zone' (with travel restrictions to and from the designated region), residents from this zone were not allowed to leave or enter the zone for non-essential purposes.

Changes in sales outlets and marketing channels

The temporary or permanent closure of outlets as well as strict public safety measures forced many producers to adapt. A total of 40% of the survey respondents changed their distribution strategy due to the pandemic (Figure 6.2). The adaptation measures ranged from streamlining and adjusting existing outlets to adding or setting up new sales outlets, including online shops. In parts of the US, sudden closures of entire sectors and the lack of adaptation capacity forced farmers to plow under entire fields of produce, leading to food loss (Yaffe-Bellany and Corkery, 2020). None of the surveyed and interviewed farmers reported food losses due to outlet closures (although one farmer experienced produce losses due to the lack of workforce to harvest). This outcome may have been avoided due to flexible and adaptable food distribution systems in which each producer adapted according to their capacity and consumer demands. Based on the themes emerging from interviews and the questionnaire, we grouped farmer adaptations related to distribution into 6 strategies: redistribution, streamlining, replacement, collaboration, farm adjustment, and outlet adjustment (Figure 6.3).

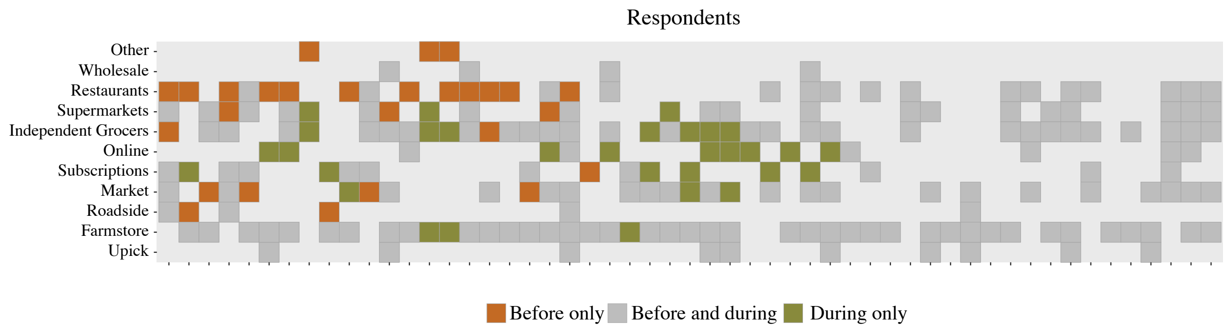

Figure 6.2 Summary of sales outlets and changes due to the pandemic indicated by individual questionnaire respondents (n=53) who changed their distribution strategy. Orange squares indicate that a sales outlet was served before the pandemic but abandoned during Covid-19. Green squares show the adoption of new sales outlets. Gray squares indicate that the respective sales outlet was supplied before and during the pandemic; some farmers reported a change in distribution strategy (e.g., adding new social distancing measures) but maintained the same outlets during the pandemic.

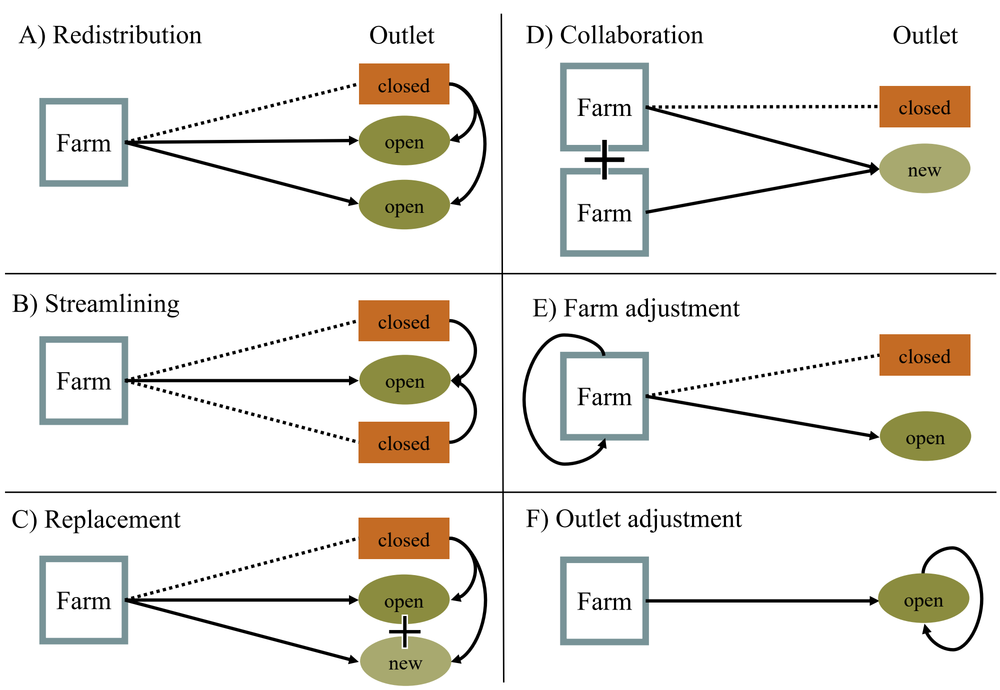

Figure 6.3 Stylized depiction of the main distribution pathways of farmers to adapt to the Covid-19 pandemic. A) farmer redistributes food from one closed outlet to remaining outlets; B) farmer focuses on one outlet to streamline operations, all food goes to one outlet; C) farmer replaces closed outlet with a new one; D) farmer collaborates with another producer and allocates food from closed outlet to new outlet; E) farmer adjusts food production to closure of outlet; F) farmer undertakes adjustment of sales procedures or outlet location. The surveyed farmers responded to

planning uncertainties in different ways, for instance, by redistributing food dedicated to restaurants to other outlets. Others decided to abandon outlets that they previously sold to in order to focus on the distribution of subscription vegetable baskets. One farmer explained that they set up a collaboration with other producers:

> *"At the start of the pandemic the shops took very few cheeses from us, and we did not know if the farmers' markets were going to open, so we created a home basket delivery service with other producers" [Q-152].*

In one case, the increased demand combined with changes in sales outlets posed a challenge for a farmer due to diverging expectations in terms of supply and capacity between producers, retailers, and end customers:

> *"Merchants don't understand the business model "small sustainable farming". We can't adapt as quickly as multinationals. We had to adjust within 2 weeks, which is difficult. [...] Everyone made orders at the same time, and now I had to be like a Walmart with stock for when they deign to want products" [Q-40].*

The closure of important institutional buyers led one farmer to change their crop plan to respond to new customers:

> *"It also meant that we had to change our crop plan part way through because, you know, there are things that we had planned. For example, for the workplace kitchen that weren't necessarily the same things that we would grow for a CSA. There was just a need to adapt our production" [I- 14].*

Agritourism is a vital part of many local food businesses. While some farmers completely shut down this branch of their business, others adjusted to the safety restrictions. One farmer responded to restaurant closures by offering picnic baskets that attracted tourists to the farm.

In cases when respondents reported not changing their distribution strategy due to the pandemic (60%; n = 78), farmers mostly only adjusted their existing ways of marketing (e.g., implementation of pick-up schedules and social distancing measures). One farmer explained that they built an additional kiosk to avoid crowding of people on his farm. Farmers that did not change their strategy often mentioned that they benefited from an increase in demand for their food and focused on meeting this demand by streamlining their operations to benefit from more efficient processes. Some farmers, especially those using a CSA model, could continue their operation similarly to pre-pandemic conditions or augment production to serve more customers. Some farmers described that they did not have to change their distribution strategy since their outlets were not affected by the public safety measures or that they were considered essential business and did not experience a disruption.

In total, 14% of respondents (which accounts for about one-third of those that changed their marketing strategy in 2020), used an online store to adapt to Covid-19 related challenges, a doubling compared to the pre-Covid time. Information and Communications Technology (ICT) solutions enabled contactless deliveries and were a widespread tool to facilitate communication (Garcia et al., 2020; Mittal and Grimm, 2020; Thilmany et al., 2021). Some local farmers complemented their online sales with a delivery service or a self-service station. One farmer participated in a 'virtual farmers market' that allowed consumers to order from several local producers online and to pick up products or get them delivered. For many farmers that were new to online marketing, the transition from offline to online sales required additional effort, time, and costs. An unstable and expensive internet connection in rural areas and home schooling limited the opportunity to build online shops quickly in some cases. Especially the urgency and pace at which this distribution system had to be implemented was challenging for farmers.

For local farmers that produce and sell specialty products in our study, moving sales online was often not an appropriate alternative for in-person marketing. While some local farmers responded to this challenge by focusing on their existing customers, finding new customers is an essential step for young farming enterprises, especially with high-value products or farmers operating in niche markets that require a lot of explanation and communication. For those farms, the physical disconnection from their (potential) customers exasperated the struggles that are common to new farms:

> *"It is not easy to be an emergent farm in an emergent field. We must simultaneously advance a sector, educate the public, develop the land ... Before COVID, we had already adjusted our business plan in order to develop our field of action. As COVID arrived, it destroyed the work that was already done ... back to square one, we [had to] revise the business plan" [Q-40].*

In cases where direct interaction was possible, local farmers protected themselves and their customers from potential infections by investing time and money into safety strategies and equipment (e.g., sinks, sanitizers, masks, additional scales). Other adaptation strategies, such as the implementation of a U-pick system with reserved timeslots, setting up additional kiosks, and providing longer opening hours, helped to decrease the amount of people present at the farm at any time while continuing the farming business. Finally, complying to public safety measures was not only crucial in terms of reducing the risk for farmers and customers to transmit Covid-19 but also, as one farmer explained, to show responsibility to authorities that distribute farmer and public market licenses, such as the municipal/town government:

"We wanted to be the safest possible for [the customers] and also for the city. Because we have a special authorization to put the kiosk up in this beautiful spot in town. Not all people are allowed to do that there. To be allowed to do that, we really wanted to be on top" [I-12].

Other operational and development issues

Finally, minor issues also arose with regard to a lack of access to resources, such as seeds and feed, and the ability to develop the farming operation or advance sectoral associations. Operational adjustments helped farmers to cope with the often uncertain and quickly changing circumstances. Local farmers in our sample found it difficult to adapt to the sanitary rules, especially quarantine requirements that reduced the workforce and added challenges to planning. High cost of personal protective equipment and other infrastructure, and poor support from the government, were criticized as well as the restrictions on farms that were like those in supermarkets. One farmer reported high investments that had to be made for toilets to ensure safety for the farmer, their family, and the farm workers. Other farmers minimized the amount of farm workers present at the farm to protect themselves and each other at the cost of productivity.

Although the survey and interviews indicated that producers could adapt to Covid-19 related challenges, some respondents pointed out that provincial regulations followed a "watering can" approach (e.g., posing the same measures for sales at outdoor farms as for supermarkets). This somewhat mirrors initial findings, such as by Zollet et al. (2021), who identify concerns about preferential treatment of big players in Italy. Not only does this show insufficient agricultural emergency and insurance programs that were not designed for pandemics (Ker, 2020) but also the lack of nuanced regulations for different types of operations. Although the government provided some financial aid, one local farmer criticized the lack of support:

> *"The inconsistency of some subsidy programs, such as the one to compensate for investments necessary for security due to Covid-19, excluded any expenses made before July 1. Yet health and safety requirements were made long before, from the start of the pandemic, in March" [Q-37].*

Another farmer explained that, due to the size of their enterprise, governmental aid did not apply:

> *"[There was] no way to set up installations for Covid-19; we couldn't afford it and our farm was too small for the governmental budget" [Q- 100].*

Some participants reported resource access and developmental problems. Two interviewed farmers explained their struggles with access to resources like seeds or feed for small livestock, for example, due to demand and supply shifts and variabilities:

> *"People decided to do more gardening at their own place. Last year, and even this year in the beginning, everybody has thrown themselves onto the seed market and seeds are disappearing like crazy. We ordered our seeds before Christmas. So, we're good. But if you were to get your seeds now you would be too late" [I-08].*

> *"The grain price is really high right now, compared to the past year. Whenever there is a higher demand, everything in agriculture goes kind of crazy. This year, it's because of Covid. All the local stuff went crazy. We know that the grain this year [2021] is going to sell for a lot higher price than it sold the past year. I guess it's going to affect the price of the feed. So, it's not only going to be hard for us to find [organic feed], but it's going to be more expensive. We're having trouble getting organic feed because we're far from*

big cities. Our region doesn't really grow a lot of organic, compared to, let's say, Québec City or Montréal" [I-12].

Several farmers also reported limitations regarding the physical and organizational development of their business since many projects had to be put on hold or took longer to realize. For instance, the construction of a farm store was delayed due to the pandemic. Another farmer explained that an export project was cancelled. Furthermore, essential work in associations and organizations that represent the interests of different agricultural sectors was delayed due to social distancing measures. In a few cases, farmers report that those measures also inhibited the communication with intermediaries, including suppliers and sellers.

6.3.3 Perceived preparedness to address challenges

Overall, many local farmers assessed their operations as being well-prepared for the challenges that they encountered in 2020, compared to their recall of the 2017–2019 seasons. On a scale from 1 to 5, with 1 representing a low degree of preparedness ('not prepared') and 5 a high degree of preparedness ('very well prepared'), 58% of the local farmers rated their perceived preparedness as 4 ('well prepared'). A total of 75% rated their preparedness as 4 or 5. Only 10% of the respondents indicated that their perceived preparedness dropped from a 4 or 5 (pre-Covid) to a 3 ('prepared') in 2020, meaning that 90% of the respondents rated their perceived preparedness as similar or better (Fig. 4).

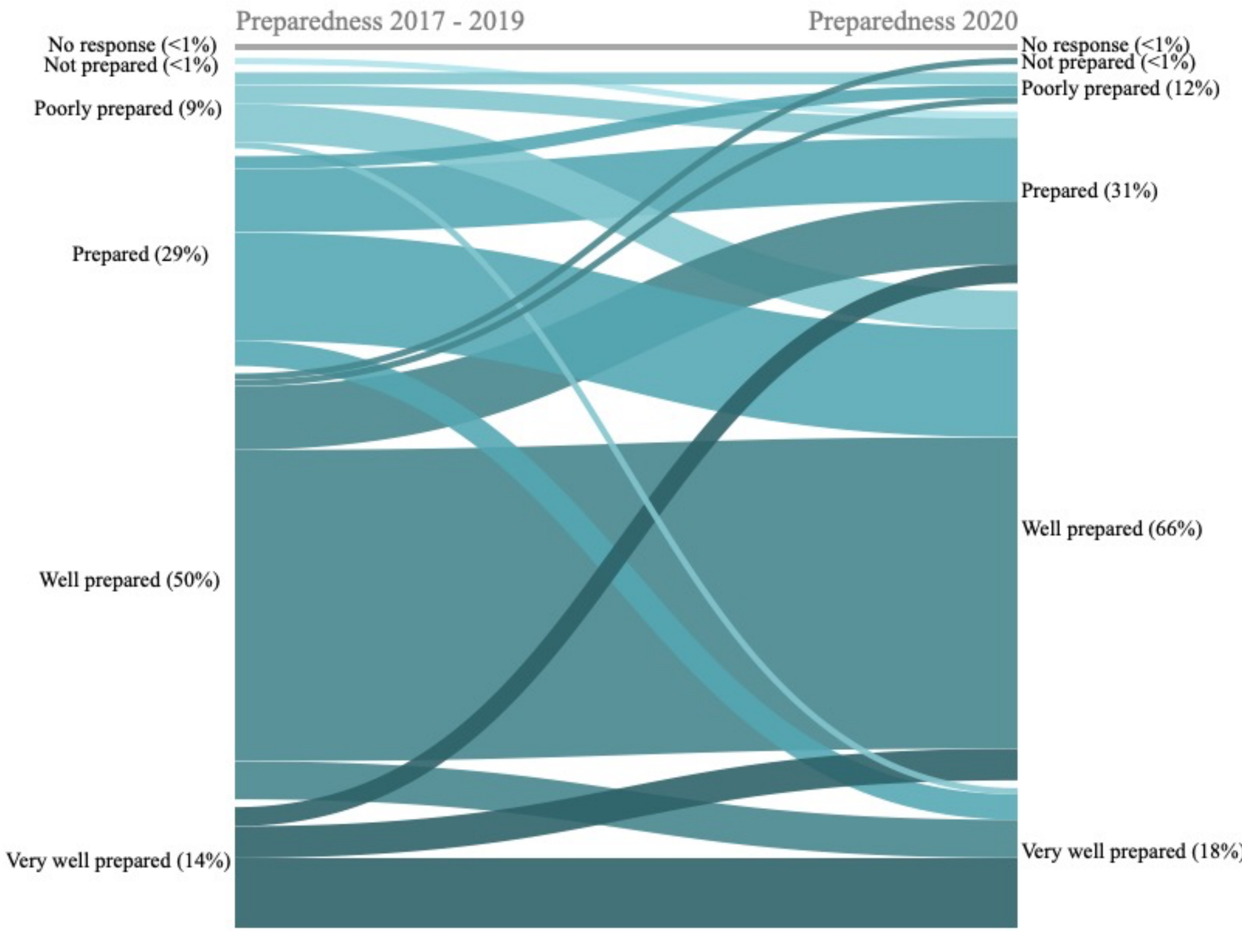

Figure 6.4 Local farmer's perception of preparedness to address challenges from 1 (poorly prepared) to 5 (very well prepared). Most farmers felt well and very well prepared for challenges, both before and during the pandemic.

6.4 Discussion

Our study sought to understand the implications of the Covid-19 pandemic on food producers engaged in or focused on local food distribution and short food supply chains in Québec. The Covid-19 pandemic has led to disruptions in food systems around the world and magnified systemic issues and shortcomings. Overall, we find that local food producers with a range of different contexts (i.e., modes of production and distribution) in Québec relied on a diverse portfolio of adaptation strategies to effectively adjust their operations. Below, we highlight three key points that arose from our results, provide an outlook to remaining questions for future work, and discuss the limitations of our study.

6.4.1 Short-term adaptation capacity of local farmers

From the beginning of the pandemic, researchers have tried to estimate the potential short- and long-term implications on the Canadian food system (Gray, 2020). Around the world, the closure of businesses deemed non-essential, rising unemployment, social distancing measures, and border closures intensified existing or even created new perceived and real food security concerns. In Canada, fears of consumers about potential food shortages early in the pandemic (i.e., around March–May 2020) led to panic buying and food hoarding. Yet, growing evidence suggests that the Canadian and, broadly speaking, the North American food supply chains have shown a high resiliency and adaptation capacity in terms of food availability at large. Especially the bilateral trade between Canada and the US enabled the food systems in both countries to benefit from each other's redundancies (Chenarides et al., 2021; Deaton and Deaton, 2020; Hobbs, 2020).

Some researchers have questioned whether food hoarding would impair the growth potentials of direct marketing and local food during the pandemic. For instance, Richards and Rickard (2020) observed that people in North America stockpiled frozen fruits and vegetables when the pandemic began, which may have decreased the amount of food bought later (Thilmany et al., 2021). Although mainly qualitative in nature, our findings show that the sales losses were not as severe as anticipated for local farmers in Québec. In fact, our results indicate that a concern around food supply shortages may have encouraged more people to buy food from local farmers, especially CSAs. We found that, in case of disruptions, producers often expressed being able to adapt due to an increased demand for local food, flexibility that allowed farmers to switch sales outlets, and online tools (social media, online stores, and virtual markets) served this adaptation process.

6.4.2 Uncertainty around longevity of high demand for local food

Whether consumers' enthusiasm about local food in Québec will stay intact over a longer period and will translate into tangible outcomes (e. g., sales, revenue, support) for farmers is uncertain. Several farmers pointed out that the longevity of this demand hinges on farmer-producer relationships and the nurturing of newly developed and intensifying existing relationships post-pandemic. Further, the government of Québec has explicitly taken measures to encourage the purchase of local products, including but not limited to food, and put into place initiatives such as '*La Panier Bleu*,' a website listing local businesses. It is not clear, however, whether consumer demand alone will or can drive local food systems and where Québec will hit physical, social, economic, and political boundaries. According to O'Hara and Low (2016), local food sales are more tied to income fluctuations compared to non-local products, raising questions about willingness or ability to spend money on local food if economic concerns arise in the wake of Covid-19 (Zollet et al., 2021). Hence, to what degree financial commitments, as found in CSA, or household income will determine continued support of local farmers has yet to be seen. Over the course of the pandemic, many communities and jurisdictions in industrialized countries have implemented new infrastructure and started programs to support local farmers which have the potential to turn a short-term solution into an institutionalized practice. In Florida, such initiatives have led grocery stores to commit to buying more local produce and advertising local produce using labelling (Campbell and McAvoy, 2020). Moreover, technology to connect local producers with consumers may have been an important vehicle for raising people's awareness of the importance of supporting local food producers (Campbell and McAvoy, 2020). Future research should investigate the longevity and equitability of different local food network support strategies that were built during the pandemic and how they can foster or block equitable and accessible local food systems for all actors along the supply chain.

6.4.3 System redundancies, adaptation, and digital divide

Building redundancy appeared to be a critical factor in the adaptation process of many local farmers in our study (see Figure 6.3). Systems with a degree of redundancy can often withstand impacts better since their components are replaceable and independent from distinctive features (Worstell, 2020). Switching from one sales outlet to another or temporarily replacing a farm worker indicates a degree of redundancy that enabled farmers to compensate potential revenue losses. However, this redundancy may have led to a shift in terms of the number of consumers that have access to local food. For example, the switch from market sales to CSA may have limited access to local food for households with lower disposable incomes. CSA can involve seasonal upfront payments which may not have been feasible for those households due to financial uncertainty in the early stages of the Covid-19 pandemic. Likewise, the transition to online stores may have discriminated against people without internet literacy or the appropriate hardware and payment method.

Responses to our survey were pertinent to the idea of a ‘digital divide’, which describes the lack of physical hardware for or proficiency in using web technology to access information or undertake financial transactions (Raison and Jones, 2020). As Torry (2020) explains, Covid-19 deepened “a national digital divide, amplifying gains for business that cater to customers online, while business reliant on more traditional models fight for survival”. As useful as online tools were for the management of contact-less sales and customer relationships, not all farmers - and perhaps many consumers - could use those tools or access the necessary resources at the right time, leaving questions about equality. Although the percentage of local farmers using the internet doubled during the onset of the pandemic 2020, web illiteracy, expensive services to run online shops, or the lack of a stable internet connection may have limited which producers and consumers benefit from online sales. Although not the focus of our investigation, local farmers lacking access to the resources necessary to set up and run an online store or engage in social media and online communication may have been at a disadvantage.

6.4.4 Limitations and future research

Our choice of scope and methods enabled us to shed light on this sector of the food system in Québec but presented some limitations. We focused on self-identified local farmers that were listed in consumer-facing databases and platforms accessible to the public, which may not have captured experiences from all farmers in Québec engaged in less direct producer-consumer supply chains. Hence, our sample of farmers and findings should be considered relatively small in scope and may be biased towards farmers who are more inclined to respond to inquiries via e-mail and have the capacity and infrastructure to participate in video or phone interviews. Additionally, our focus on the farmer's perspective overlooks other food systems actors like processors, other intermediaries, and consumers although Thilmany et al. (2021) and Béné (2020) call attention to the need for the adaptation of regulations and policies that foster the resilience of the entire food system and supply chains to shocks.

Second, we did not assess the repercussions on farmer and farm worker well-being although this issue existed even before the pandemic (Daghagh Yazd et al., 2019; Hagen et al., 2020). At least one interviewed farmer stated fear of burn-out due to pressure to take advantage of the rising demand for local food. Some farmers also reported that momentary constraints for employing temporary foreign workers (TFW) led to stress. Despite the dependence of some of our respondents on TFW, the experiences and concerns of TFW working for local farmers in Québec has yet to be studied. Advocacy groups and the media have called out unsafe lodging and work conditions that put TFW at risk at the beginning and even one year into the pandemic (Mehler Paperny, 2021). TFW may be at greater risk of potential exposure to Covid-19 (Parks et al., 2020), compounding farm labour shortages and meaning that these workers must work harder to compensate for lost income. Future research should assess how pandemic-related concerns and stress factors have compounded existing or added new pressure on farmers and farm workers.

Finally, our study did not assess farmer support systems in-depth, although social capital, or the relationships between multiple people or groups (Woolcock and Narayan, 2000), can contribute to the adaptation process of farmers through knowledge exchange, information sharing, as well as mental and financial support (Paul et al., 2016; Saptutyningsih et al., 2020). Canada's federal, provincial, and territorial government support programs have helped to prevent overall food shortages. However, such programs were developed without a global pandemic in mind and may not have reduced farm stress related to income, labour, transportation, and border closures, leaving it to farmers to compensate for losses (Ker, 2020). Federal programs like the CERB which intended to support Canadians that lost their jobs due to Covid-19 affected local farmers employing local workforce in unintentionally negative ways, leading to new challenges for those farmers. In many instances, the farmers' family and friends helped to cope with workforce shortages, infrastructural adaptation, and other concerns. Future studies could delve into whether and how social capital helped in navigating transition processes during the pandemic because of, or despite, governmental and provincial programs.

6.5 Conclusions

Our study contributes important insights that show how flexibility and redundancy among local farmers stabilized the local food system during the onset of a global pandemic. Using a mixed-method approach, our findings demonstrate that local farmers in Québec generally managed to address the diverse challenges (e.g., safety protocols, travel restrictions, and other public health measures) that they encountered in the first year of the pandemic (March 2020–March 2021). While many local farmers struggled due to the pandemic, others reported overall positive impacts on their sales and operations. For instance, many farmers benefited from the increased awareness of and demand for local food. Furthermore, we investigated how those farmers navigated new and compounded challenges (e.g., losses of sales outlets, workforce shortages), and how they adapted their businesses, if necessary, to rapidly changing regulations and demands. According to most of our respondents, various adaptation mechanisms helped them to adjust their operations, including the implementation of online shops and infrastructure to ensure safe work and sales environments for consumers, farmers, and workers. At this stage, predictions about long-term impacts of the Covid-19 pandemic on local food systems are not possible. Yet, our results demonstrate that many local farmers were able to withstand most disruptions of a global pandemic in the short-term.

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7 Synthesis and discussion

Local food systems have gained interest among researchers, politicians, and consumers in the past decade, but many conceptual and methodological gaps and questions still exist. My literature review in Chapter 2 demonstrates that, while much research has been conducted on sustainability aspects of local food systems, the feasibility of local food systems has been underexplored, particularly biophysical and social capacity that is needed to build and sustain local food systems. Therefore, the aim of my doctoral thesis was to expand the conceptual foundations of local food systems research through a foodshed lens by

- Systematically comparing and synthesizing urban foodshed analysis methodologies,
- Analysing gaps in action plans and strategies towards food system localization of large cities in North America
- Examining the challenges of local farmers in the Province of Québec and their social support systems, and
- Investigating coping strategies of local farmers in Québec to the Covid-19 pandemic.

Investigating local food systems through a foodshed lens allowed me to examine the feasibility of local food systems in terms of food production capacity, accounting for biophysical and social factors. My work contributes to debates in literature about local food systems, foodsheds, and the food production capacity of regions by shedding light on the temporal and spatial dynamics and interconnections within and beyond the foodshed that may affect how well food production can adapt to multiple pressures, such as the role of social support systems. Across the four manuscript chapters, I examined how foodsheds are quantified, planned, and sustained and, in specific, how social and biophysical resources mobilize local food production capacity at the level of farmers and urban governance. Overall, my focus were the food-producing stages of the supply chain rather than the market organization or consumer benefits. In doing so, my research makes important contributions to understanding both biophysical and social factors that shape local foodsheds and their role in mobilizing local food systems and food self-sufficiency.

This final thesis chapter provides an overarching discussion of my work in the context of local food systems scholarship. First, I recap and summarize the findings of the individual manuscripts (Chapters 3-6). I then move on to discuss the contributions of the collective body of research presented in this thesis. This chapter closes with a discussion of the limitations of my work and future research avenues.

7.1 Chapter overviews

Chapter 3 is the first systematic global literature review of peer-reviewed publications that quantify and analyze local food self-sufficiency and multi-scalar food flows. This manuscript characterizes how foodsheds have been conceptualized, compares peer-reviewed publications based on different criteria in a synthetic framework, and identifies core research priorities and gaps. Besides pointing to future research avenues, this work emphasizes the value of foodshed analysis to inform food systems policy and planning concerning the benefits and tradeoffs, as well as opportunities and limitations of food supply from local, regional, and global sources.

Chapter 4 uses a purposive sampling approach and thematic analysis to assess local food systems strategies and action plans published by major cities across the US and Canada. Combining the

SETs framework and policy-relevant areas in local foodshed analysis (identified in Chapter 3), this manuscript identifies considerable gaps in the local food systems action plans and strategies across various social, ecological, and technical themes relevant to local food production. I also highlight the lack of progress monitoring tools and examine the ways collaboration within and beyond the city government is used to meet local food systems goals.

Chapter 5 is based on a mixed-methods case study with online questionnaires and semi-structured follow-up interviews with farmers in Québec who sell to local markets. This manuscript explores the farmers' challenges and the meaning of different support actor groups in addressing diverse challenges across multiple growing seasons (and not related to the onset of the Covid-19 pandemic, which is the focus of chapter 6). Chapter 5 examines how farmers rely on a diverse network of support actor groups across various spatial and temporal scales. Based on those findings, I argue for more acknowledgement of existing support networks and tailored aid to deal with the diverse challenges farmers selling to local markets encounter.

Finally, Chapter 6 draws on the same data collected for Chapter 5 but focuses on pandemic-related stressors, opportunities, and adaptation strategies. In this study, I identify main challenges among farmer at the onset of the Covid-19 pandemic as well as key adaptation strategies that helped farmers reorganize their marketing and sales. This study contributes critical insights into the role of flexibility and redundancy among local farmers to stabilize local food systems during the onset of a global pandemic.

7.2 Contributions to original knowledge

7.2.1 Methodological and conceptual contributions

The idea of a "local foodshed" has been used as methodological and theoretical tool to frame, map, analyze, and discuss the linkages between geography, food, and agriculture. Its foundations are rooted in the early 20th century. Yet, the field has only recently reignited interest due to increasing public and scholarly interest in local food systems and local food provisioning. As an interdisciplinary concept, a diverse group of researchers has translated it into a methodology to study local food systems and local food self-sufficiency. However, a systematic overview has been missing to date, rendering foodshed studies challenging to compare.

My dissertation contributes, through Chapter 3, to the aggregation and systematization of the research field. Chapter 3 is the first of its kind systematic global review of quantitative foodshed analysis. In this paper, my co-authors and I identify several methodological approaches (study types and calculation methods) which helps the research community to choose the most appropriate approach for answering their research questions in a specific geographical context from the various foodshed analysis modules. Based on the studies in the review set, I further show critical data gaps and policy-relevant themes for future research and policymaking that can inform action and practice as well as methodological development. As of the date of submission, the published manuscript (Chapter 3) has been cited 15 times (according to Web of Knowledge, December 1, 2022), including as a source for foodshed definition and methodologies. For instance, it was referenced in a recently published book on food systems modelling, illustrating different foodshed analysis and carrying capacity calculation methods (Peters, 2022).

Chapter 4 uses a novel analytical framework drawing from the established social-ecological-technological (SETs) approach from urban ecology and my own review of the policy relevance of foodshed analysis (Chapter 3) to study how cities in the US and Canada plan for their local foodsheds. This multi-dimensional framework provides a tool to assess the diversity of factors influencing local foodsheds (social, ecological, technical) along with the governance mechanisms necessary to define goals, track success, and identify limitations. In addition to summarizing the current degree that North American municipalities are planning around peri-urban and rural farming, my approach in this study can help inspire and inform food systems researchers to conduct rigorous comparative studies in other world regions and build upon the three-dimensional framework.

7.2.2 Understanding food systems feasibility through food production capacity

Organizations, governments, and other advocates for re-localizing food systems at various levels call on consumers to support local farmers and strengthen local food economies. Furthermore, local food systems scholarship has, overall, focused on the benefits or trade-offs of sourcing food locally and their contribution to sustainability. Although recent meta-analyses have concluded that, the lack of evidence does not allow us to generalize about presumed benefits of local food systems (Enthoven & Van den Broeck, 2021; Schmitt et al., 2017; Stein & Santini, 2021), in practice, local food systems are still associated with sustainability, a widely agreed-upon goal among advocates and planners.

My work argues that local food systems hinge on more than consumers' willingness to buy local food or their assigned benefits. In fact, I suggest that this consumer-orientation may distract from other questions concerning upstream food supply chain processes such as food production and distribution. Instead, I propose to pay more attention to those supply chain stages within local food systems that sit at the source and are crucial for food supply in the first place. This reorientation of perspective enables us to grapple with how feasible local food systems are at its root. My thesis expands our knowledge in this regard by examining local food systems, using the concept of foodsheds, with a focus on food production capacity. At its core, this work does not aim to engage in the debate around "are local food systems better?" but proposes to add another dimension to the debate, namely "are local food systems feasible?".

Within this argument, Chapters 3, 5, and 6 demonstrate in different ways how our understanding of the production-side of the supply chain can help in determining the feasibility of local food supply chains. Each of these focus on the availability and mobilization of local resources, how farmers manage their resources, and the limitations and opportunities to build and expand this production capacity. While Chapter 3 reviews and synthesizes foodshed analyses based on food consumption and production data, their analysis remains largely superficial with regard to factors that affect food production. To fill this gap, Chapters 5 and 6 delve deeper into the rural experience and explore how farmers ensure productivity, which can complement quantitative foodshed analyses and provide a more contextual understanding of the feasibility of local food systems.

Chapter 4, in turn, portrays the urban perspective on planning local food production and shows that large cities in North America have not yet and not thoroughly integrated food production in their local food systems strategies and action plans. Hence, this analysis demonstrates that research and advocacy should expand and grow their efforts to understanding the opportunities and limitations within their local foodshed and estimate the feasibility of food production towards local food systems.

7.2.3 Integrated approach to studying local food systems

This perspective change, which is an important outcome of my research, focusses on the production and distribution of local food and further raises questions on the types of capacities needed to mobilize local food production. Previous foodshed studies have heavily focused on actual or potential biophysical food production capacity within a foodshed. However, questions surrounding the underlying social factors needed to mobilize the biophysical production capacity (or how they may limit food production) have been missing. For instance, land tenure regimes, driven by political incentives, can affect how much peri-urban land can be sustained for agricultural production and who has access to it (Wästfelt & Zhang, 2018). When comparing existing quantitative local foodshed analyses (Chapter 3), the social side of food production has been largely missing. The question of who grows the food or raises the animals for local consumption remains unknown.

Investigating food systems through a production perspective, this work further aims to elucidate the social (tangible and intangible) and biophysical capacity that must be in place and mobilized to sustain or expand local food production capacity and the mobilization of both. Based on this assumption, I argue that foodshed researchers should apply an integrated approach to study and plan social resources (such as workforce, adaptation capacity, support systems) and biophysical resources (such as land, yields, water). Including both angles allows us to understand how to better plan for local food systems and understand its capacity limitations.

To complement foodshed research that is predominantly focused on biophysical resources, my thesis puts farmers selling to local markets and their challenges, coping strategies, and support systems at the center of attention (Chapter 5 and Chapter 6). The mobilization of social and biophysical capacity was best understood through those two empirical chapters where farmers explained how they use different strategies and access social support networks to sustain their farming operations and produce food for local consumers. My case studies demonstrate that farmers can adapt to challenges that may inhibit their capacity to produce food for local markets. At the same time, further support mechanisms could help to overcome challenges and built additional capacity.

However, Chapter 4 demonstrates that cities in the US and Canada with a self-proclaimed interest in expanding their sourcing from local landscapes plan for rural concerns have not yet sufficiently internalized the various needs and concerns of rural food producers, which may limit how biophysical resources can be mobilized. With local food becoming more and more part of urban planning, I find that very few cities define strategies and action plans for their local foodshed at all. Those that do, often overlook diverse social, ecological, and technical factors. This chapter showcases how limited the current efforts of larger cities in Canada and the US are in: a) publishing local food systems strategies, b) defining actions and strategies across a multitude of food systems dimensions, and c) identifying concrete goals and success indicators. It further ties the social, ecological, and technical domains through an integrated framework, incorporating some lessons from Chapter 3. The findings show the need to better address the social and biophysical factors that allow farmers to produce food for local urban markets.

7.2.4 Dynamics in and beyond foodsheds: Rural-urban relationships and international networks

Factors affecting social and physical capacity are not static, which the ‘Capacity’ approach to foodshed analysis (Chapter 3) may suggest. In this approach, food production and consumption are juxtaposed comparable to a balance sheet. Although simplification can help understand (and map) actual or potential local food self-sufficiency more broadly, this snapshot approach ignores important changes and dynamics within the foodshed that may affect who produces which kind of food and how much.

Previous studies analyzing local foodsheds observed strong relationships concerning local food self-sufficiency as a result of modelling changes of food consumption in cities and those applied at the food production stage in rural areas. Those studies integrated systemic changes in their consumption or production models or sensitivity analysis (i.e., transition to organic food production, plant-based diets, reduction of food waste (see Chapter 3 and Kurtz et al., 2020; Rüschhoff et al., 2022) but did not consider other impacts that may be out of food producers’ control, such as climate change or global public health incidents and that need immediate or long-term support. Little consideration was given to the connectedness of food producers with other regions that pose crucial exchange relationships for the transfer of tangible and intangible goods, values, and support, including but not limited to food. Building the capacity of local foodsheds towards local food self-sufficiency implies growing independence from external sources and markets. Nevertheless, many underlying embodied flows of people, goods, services, and decisions across borders and political boundaries may be necessary to sustain economic competitiveness and food security (Clapp, 2014, 2021). Understanding those flows that are often hard to trace is important to understand dependencies and secondary impacts, as in the case of fertilizers, an essential input to agriculture (Hedberg II, 2020).

This argument also applies to the rural-urban relationships built in local food systems. As outlined in Chapter 2, the urban perspective of benefits drawn from local food systems has dominated scholarship and activism, born out of a concern for food security and is only slowly shifting towards integrating rural concerns (Blay-Palmer, 2009; Blay-Palmer et al., 2018). The gravity that draws particular attention to cities may be justified as cities are often net consumers of food and other resources from local and global sources (Haberman and Bennett 2019). Hence, cities seem to have a certain degree of agency that they could use to reduce their impact on other regions (Seto et al., 2012; Liu et al., 2013). Concepts such as local food systems and foodsheds lend themselves for integrating food consumer behavior and needs and food producer capacity through a spatially inclusive lens.

My findings demonstrate the importance of connectedness of a city and food producing region with other regions through international flows of the workforce (Chapter 5 and Chapter 6), knowledge (Chapter 5), and food (Chapter 3), as well as the relationship with other neighboring jurisdictions and governance scales. Chapter 3 shows that, despite the linkages identified in previous research and this thesis, only a few large cities interested in local food systems plan for those social, bio-physical, and climatic dynamics. Food import/export dependencies is also needed in local food systems strategies and action plans.

An overarching result of my research is a need to expand the 'snapshot' perspective of local food systems, as applied in foodshed analysis, with a 'dynamic' approach to capture the temporal, spatial, and multi-dimensional dynamics of food supply. In doing so, researchers investigating the feasibility of local food systems through a foodshed lens should account for the on-going temporal and spatial changes and challenges within and beyond the foodshed.

My research identifies and examines such temporal and spatial dynamics, various impacts, and phenomena that render local food systems dynamic, such as climate change and workforce issues, as outlined in Chapter 5 and Chapter 6. Those two chapters demonstrated the role of resourcefulness, adaptation capacity, and social support systems in building and sustaining local food production. Both empirical papers showed how farmers addressed immediate and long-term challenges using their support systems and were, overall, capable of providing the province with food from local sources. While the empirical papers demonstrate that adaptation, change, redundancy, and flexibility, supported by a support network, can render farmers resilient to impacts and secure food production, the lack of consideration for municipal action in addressing these challenges at a larger scale suggests that farmers are on their own navigating these challenges.

7.3 Limitations and implications for future research

Although my work has contributed to scholarship in the field of local food systems, the limited scope of this research did not allow to examine other relevant and timely aspects. In this section, I will highlight how future research could engage with the questions and hypothesis that remain to be investigated.

Within local and global value chains scholarship, there is a need to capture intermediate steps involving the storage, processing, and transportation of food (Conrad et al., 2017). My two case studies on Québec presented in this thesis show that some producers struggled with the appropriate transportation infrastructure, but more research should study the limitations and opportunities of adaptable transportation solutions. Regarding storage and processing, future work should engage in investigating suitable options to re-built, establish, and enhance this type of infrastructure and determine their relative advantage over more centralized and scalable organization. Perishable products like fresh fruits and vegetables and other raw foods are an essential component of diets and require appropriate climate controlled storage. Furthermore, a majority of our daily intake is met through food that has been processed to some degree, such as grain-based foods and dairy. I did not explicitly account for storage or processing facilities in this work although they can considerably influence (and their absence could reduce) availability of specific products within a local foodshed. Future research could pay more attention to the diverse needs of local producers to store and process food for local consumers, taking into account differences in terms of production volume and capital access.

Furthermore, current research focusses primarily on land-based food production. Water-based food production only came up in Chapter 6, where the City of Vancouver defined concrete action plans on how to protect and revive aquaculture. Likewise, studies in the field of local food systems do not account for seasonal variations in terms of food availability. Along those lines, there is also knowledge missing on growing season-extending technologies (i.e., greenhouses, controlled environment agriculture, vertical farming) and how their use can affect local food self-sufficiency. Greenhouses can play an important role in countries dealing with colder climates or other weather extremes. However, to date, neither seasonal variability nor season extending technologies have received much attention by food systems researchers.

My case studies also did not center around a specific sector (e.g., dairy) or food type (e.g., tomatoes, strawberries), although it is likely that a focus on individual sectors might elicit different results. For example, Conrad and colleagues (2017) analysed regional self-reliance in the meat, dairy, and egg sector in the Northeast USA. Other scholars studied the supply chains of bread in Austria (Penker, 2006) or fish species in the Philippines (Saguin, 2014). This approach would have allowed for more in-depth analysis of food flows and local food production capacity of foods and food products with complex supply chains or high local relevance for cultural and nutritional reasons. Instead, I chose to take a more comprehensive and higher-level perspective on the local foodshed in Québec. It enabled me to include many farmers producing a broad variety of foods and analyse the foodshed at a scale large enough to identify flows and impacts on a larger population but small enough to allow for contextual nuances.

The choice of scale poses another limitation worth reflecting on. Food systems operate across various scales and dimensions (FAO, 2018; von Braun et al., 2021). To tackle the growing challenges triggered by food systems and affecting food systems, an understanding of the multi-scalar nature of those challenges and suitable solutions is needed for food systems governance (Delaney et al., 2018). Several scholars have debated (and questioned) whether local food systems as a valuable scale through which food systems issues can be addressed. For instance, Born and Purcell's (2006) warning of the local trap have received much attention. The dominant scale of my

Ph.D. research was the local, although findings in all four empirical chapters show interactions across different scales (e.g., Chapter 6: farm – local food system – temporary foreign workers). Nevertheless, my research could have been enriched by a more in-depth cross-scalar or multi-scalar assessment. Hedberg's multi-scalar analysis of phosphorus use and supply chains in New York state (2020) has demonstrated the benefits of gathering and comparing insights at and across different scales. He argues that "*[p]robing these scalar interactions exposes unreflexive notions of localness but also dislodges current notions of the local trap to reveal new opportunities for scaling sustainability*" (p. 700). The author emphasizes the importance of "*[reframing food] as the embodied flow of natural resources, farm labor, capital, social relations, and cultural meaning."* (Hedberg II, 2020, p. 700). Integrating foodshed analysis in multi-scalar assessments and vice versa could, in future projects, help to better identify and understand cross-scalar processes and linkages that may alter or affect the interpretation of study findings.

8 Conclusions

This dissertation sought to investigate local food systems using the local foodshed lens focused on food production rather than the market organization or consumer benefits. My main objectives were to understand how foodsheds are quantified, planned, and sustained and how social and biophysical resources are mobilized to create local food production capacity at the scale of individual farmers' and urban governance levels. My research encompassed in this thesis aimed to improve our understanding of the biophysical and social feasibility of local food systems.

To contribute to the growing body of literature on local food systems and local foodshed analysis, I conducted a systematic review to study existing analytical approaches for and limitations of foodshed analysis and develop a conceptual framework, examined how cities plan for local foodshed capacity and overcome barriers to local foodsheds and analyses gaps, identified and studied challenges of farmers participating in local markets and the role of social support systems for addressing challenges and sustaining local food production capacity and distribution, and investigate farmers' adaptation capacity to crisis and their strategies for sustaining local food production capacity and distribution.

Food systems governance has relied mainly on policies relevant to either the food producing (rural) or the food consuming (predominantly urban) communities and areas. As demonstrated in this dissertation, food systems researchers and policymakers need to pay more attention to the rural-urban linkages that bridge both spheres and processes to make better and more sustainable decisions that allow transitions towards social justice, environmental protection, and economic feasibility in the food system. Understanding the interrelationships between food consumption and production, as well as other social and environmental factors affecting those processes, is crucial, as foodshed analysts warn, because augmenting local food self-sufficiency may compete with other urban and rural goals and interests.

My work contributes to scholarly and political debates about local food systems, foodsheds, and the food production capacity of regions that allows them to become more autonomous from global food markets and food trade. Given the rising interest in food from local sources, researchers and policymakers must better understand the synergies and trade-offs of food systems across various scales to make informed decisions. In doing so, they must shed light on the benefits and limitations of local food systems from multiple complementary and sometimes competing angles (normative vs. pragmatic). Informed decision-making requires contextually-grounded and scientifically sound evidence to avoid overestimating local food self-sufficiency capacity and downplaying behavioral, technical, and ecological challenges and barriers – presently and in the future.

9 References

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11 Appendices for the individual chapters

11.1 Appendices for Chapter 3

S1 Normative stance in quantitative foodshed studies

Few analyses in our sample explicitly embrace Kloppenburg et al.'s notion in its entirety. Our review shows that a majority of samples are primarily natural resource oriented, aligning with Kloppenburg et al.'s "Nature as measure" (table 5). Only a few examples, primarily *Flow* studies, include the community or moral economy aspect of Kloppenburg et al. (1996) (Aucoin & Fry, 2015; Brinkley, 2017; Desjardins et al., 2010; Wegerif & Wiskerke, 2017; Zazo-Moratalla et al., 2019). Some authors take a rather critical stance and use foodshed analysis to challenge unsubstantiated claims that local food supply is more sustainable (Hara et al., 2013). *Hybrid* studies, which map local and non-local food supply seem the closest to Kloppenburg et al.'s principle of "Proximity".

S2 Kloppenburg et al.'s (1996) aspirational interpretation

Summary of Kloppenburg et al.'s (1996) aspirational interpretation of a local foodshed in contrast to a global food system. Most reviewed studies embrace the "Nature as measure" principle but do not or only partially adopt the other four principles. *Hybrid* studies align primarily with "Proximity," while several *Flow* studies incorporate "Moral economy" and "Commensal community".

	Global food system	**Local foodshed**
Moral economy	Efficiency, competitiveness, utility maximization	Focus on human needs (e.g., community supported agriculture)
Commensal community	"Atomistic market relationships"	Recovery of social networks (beyond and within producer and consumer groups), access to disempowered and marginalized groups, environmental stewardship
Self-protection, secession, and succession	Dependency on dictating food industries	Disconnection from global system, gaining independence, conscious knowledge and resources transfer
Proximity	Disconnection of people and place	No fixed boundaries, embeddedness in external trade relationships (self-reliance), awareness about local natural resources
Nature as measure	Overcoming limitations of natural resources (deficiency)	Embracing opportunities of natural resources (capacity)

S3 Search strings for the identification of relevant studies

Search string	**Results**	
	Web of Knowledge	Scopus
"foodshed*" OR "food-shed*" OR "food shed*"	52	50
("food flow*" OR "flow* of food" OR "food import*") AND ("city" OR "cities" OR "urban" OR "municipal*" OR "metro*")	66	100
"food" AND ("carrying capacity" OR “production capacity” OR "self-relian*" OR “self relian*” OR "self-sufficien*" OR “self sufficien*”) AND ("city" OR "cities" OR "urban" OR "municipal*" OR "metro*")	227	390
"urban food supply" OR "city region food" OR “local food supply”	99	155
“food” AND (“urban metabolism” OR “urban material flow*” OR “urban material flux*”)	67	65

S4 Excel spreadsheet with meta data and search results of foodshed study review

Legend and abbreviations

Categories and definitions of meta data for Capacity, Flow, and Hybrid foodshed studies

Quantifying the foodshed: A systematic review of urban food flows and local food self-sufficiency research

Schreiber, K., Hickey, G.M., Metson, G.S., Robinson B.E., MacDonald, G.K.

Basic Info	Authors	*Authors of study*
	Year	*Publishing year*
Geography	Continent Country Region Cities	*Geographical context in which study or studies take place*
Background	Self-described	*Study identifies as "foodshed" study. Must mention the term as underlying conceptual framework*
	Spatial boundaries	*Systems boundaries of study*
	Purpose	*Focus and objective of study*
Methodology and data	Calculation method	*Describes the calculation method of Capacity studies (ST, IST, Foodshed size)*
	Unit	*General unit in analysis*
	Data source	*Primary data, secondary data or mix of both data types*
	Optimization	*Usage and type of optimization model (distance or yield)*
	Food production	*Methodological approach to estimate food production within defined systems boundaries*
	Food consumption	*Methodological approach to estimate food consumption within defined systems boundaries*
	Food flow	*Data and data collection approach used to trace food flows*
Additional information	Food type	*Foods, food types or groups included in foodshed study, including raw and processed foods, feed for livestock*
	Scenario / temporal changes	*Scenarios used to assess the sensitivity of results or assess future potentials and limitations with regard to LFS, trends over several years or decades, inter- and intra-annual variability, seasonality*
	Other	*Additional information about approaches or purpose of study*

Abbreviations

EPA	Environmental Protection Agency
ERS	Economic Research Service
FAO	Food and Agricultural Organization
FCID	Food Commodity Intake Database
IST	Inverse self-sufficieny threshold
ISTAT	National Statistics Institute[Istituto Nazionale di Statistica]
LPIS	European Land Parcel Identification
MAFF	Ministry of Agriculture, Forestry and Fisheries
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MSL	Master Soils List
NASS	National Agricultural Statistics Service
NDSR	Nutrient Database for Standard Reference
NHANES	Center for Disease Control's National Health and Nutrition Examination and Survey
NLCD	National Land Cover Base
OSUES	Oregon State University Extension Service
ST	Self-sufficiency threshold
STATSGO	State Soil Geographic database
USDA	United States Department of Agriculture

Capacity studies

Authors	Year	Continent	Country	Region	Cities	Self-described	Spatial boundaries	Calculation method	Unit	Data source	Optimization	Food production	Food consumption	Food type	Scenario / Temporal changes	Other
Cardoso et al.	2017	Europe	Portugal	Ribatejo e Oeste and Grande Lisboa		Yes	SAU	ST	land, weight	2nd	Yield	- Regional average crop yields - Animal land footprint values from Life Cycle Analysis	[Theoretical diet] - Portugese Food Balance (BAP)	All food groups	Meat-based, plant-based, strict-vegetarian (USDA dietary guidelines)	
Conrad et al.	2016	North America	USA	Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Delaware, West Virginia, and DC		No	SAU	ST	nutrition	2nd	na	- NASS - Department of Agriculture annual reports	[Actual diet] '- Food Availability Data System by ERS (USDA) - Livestock feed crops	Meat, dairy, eggs		
Desjardins et al.	2010	North America	Canada	Waterloo Region		No	SAU	ST	land, weight	2nd	na	- Official Waterloo website and publication by first author (not accessible)	[Theoretical diet] - Canada's Food Guide [Actual diet] - Food disappearance data (Statistics Canada) - Serving sizes rather than weight units	- Grain products, vegetables, fruit, meat and alternatives, milk and alternatives - Food selected according to criteria: 1) agricultural suitability, 2) data availability, 3) consumption frequency, 4) potentials for diet improvement	Degree of LFS under optimal consumption scenario with projected population in 2026	Merging of regional agricultural development and support of healthy diet
Filippini et al.	2014	Europe	Italy		Pisa	Yes	SAU	ST	land, weight	X	na	- ISTAT - On-farm surveys with 14 farms	[Actual diet] - ISTAT	Meat (beef and lamb)	Potential, current, and actual supply	
Galzki et al.	2014	North America	USA	SE Minnesota, 11 counties: Dodge, Fillmore, Freeborn, Goodhue, Houston, Mower, Olmstead, Rice, Steele, Wabasha, Winona		Yes	SAU	ST, Foodshed size	land	2nd	Distance	- NASS - EPA - Adjustments for inedible portions and processing losses	[HNE] - Annual and high-value crops (HNEa) and perennial forage (HNEp) = total quantity of food (HNEt); - adjusted to Southern Minnesota - Feed crops and grazing	All food groups	Removing marginal cropland from cultivation in vulnerable landscapes with high ecological value to increase the environmental benefits of locally grown foods	- Relatively small population centers (<76,000 inhabitants) - Environmental benefits index (EBI) and crop productivity index (CPI) - Surpluses considered as export capacity
Galzki et al.	2017	North America	USA	SE Minnesota		Yes	SAU	ST, Foodshed size	land	2nd	Distance	- NASS - Adaptation to Minnesota	[Actual diet] - US Bureau of Labor Statistics - ERS (USDA) - Feed crops	All food groups (incl. preserved and processed foods; excl. food consumed away from home and miscellaneous food categories (frozen meals, spices, condiments))	Removing marginal cropland from cultivation in vulnerable landscapes with high ecological value to increase the environmental benefits of locally grown foods	Relatively small population centers (<115,000 inhabitants)
Giombolini et al.	2011	North America	USA	Willamette Valley		Yes	Bioregion	ST	weight	2nd	na	- OSUES - Oregon Agricultural Information Network	[Theoretical diet] - Federal Dietary Guidelines for Americans (DGA) (USDA and USHHS) - Account for moderate activity levels, age cohorts, and gender - Serving sizes and caloric intake	Grains, vegetables, fruits, dairy, meat and beans, and oils	Five year average data to account for changes in population and yields	Simplified method for community research
Griffin et al.	2015	North America	USA	Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Delaware, West Virginia, and DC		No	SAU	ST	land, weight	2nd	na	- NASS Surveys and Census - State Departments of Agriculture annual reports and specialty crop reports	[Actual diet] - Food Availability Data System by ERS (USDA)	89 foods, animal-based foods, fruits, vegetables, food grains, pulses, oils and sweeteners		Classifies farm land uses
Halldórsdóttir and Nicholas	2016	Europe	Iceland			Yes	Island	ST	land, weight	X	na	- Previous research - Agricultural University of Iceland	[Actual diet] - FAO food balance database - Feed crops and grazing	The most important crops (over 10% of kcal supply per capita per day): Dairy, cereals, meat		- Comparison of fertilizer and water use with cereal importer countries - Survey of Island's residents and tourists regarding the motives of and satisfaction with buying local food
Hu et al.	2011a	North America	USA	Iowa		Yes	SAU	IST, Foodshed size	land, weight	2nd	Distance	- Food Availability (Per Capita) Data System (ERS, USDA)	[Theoretical diet] - MyPyramid (USDA)	40 key crops, primarily fruits and vegetables	- Aggregated food distribution (allocation to one central distribution point in each county) - Disaggregated food distribution (allocation to population centers)	Surpluses considered as export capacity
Hu et al.	2011b	North America	USA	Iowa, Illinois, Missouri, Kansas, Nebraska, South Dakota, Minnesota, and Wisconsin		Yes	SAU	IST, Foodshed size	land, weight	2nd	Distance	- Agricultural Cencus (USDA) - Yearbook Summaries for Vegetables and Fruits and Nuts (USDA)	[Theoretical diet] - MyPyramid (USDA) [Actual diet] - ERS (USDA)	40 key crops, primarily fruits and vegetables		
Huang et al.	2019	Asia	China		70 metropolitan areas	No	SAU	ST	land, weight	2nd	na	- Resource and Environment Data Cloud Platform of the Institute of Geographic Sciences and Natural Resources Research of the Chinese Academy of Sciences - Statistical yearbooks of China	[Actual diet] - State Food and Nutrition Consultant Committee of China	Grains (rice, wheat, sorghum, millet, other cereals, soybeans and potatoes)	Trends from 1990-2015 in terms of self-sufficiency	Relationship between yield increases, population growth, and land availability
Joseph et al.	2019	Europe	Germany	N Germany	Hamburg	Yes	Radius	ST, Foodshed size	land, weight	X	na	- Data collection on local organic farm - FAOSTAT - Destatis - Previous research - USDA Nutrient Database for Standard Reference - Food loss and waste, non-edible parts	[Actual diet] - Destatis by BMEL Statistik - Feed	All food groups (only local varieties)	- City of Hamburg and counties in 50-km and 100-km radius - Substitution (meat, legumes), - Production methods (conventional, organic) - Sensitivity analysis: replacing three-tier cow system (dairy cows, meat cows, dual-use cows) through dual-use cows system	Sensitivity analysis with regard to replacing three-tier cow system (dairy cows, meat cows, dual-use cows) through dual-use cows system
Kremer and Schreuder	2012	North America	USA		Philadelphia	Yes	Radius	IST, Foodshed size	weight	2nd	na	- NASS - Census of Agriculture (USDA) - Vegetables and Melons Yearbook and the Fruit and Tree Nut Yearbook (USDA-ERS)	[Theretical diet] - Federal Dietary Guidelines for Americans (DGA) [Actual diet] - ERS (USDA) - Feed crops	Major food groups: produce (fruits & vegetables), grains, meat, poultry, dairy, oil not included	Current local foodshed, 50-mile foodshed, 100-mile foodshed	Account for moderate activity levels, age cohorts, and gender in diet models
Kurita et al.	2009	Asia	Japan	Kanto plain	Multiple large cities and mega urban agglomeration (Tokyo)	Yes	SAU	ST, Foodshed size	land	2nd	na	- MLIT - MAFF	[Actual diet] - MAFF	Rice and most commonly consumed leafy greens, fruit vegetables, and root vegetables		
Li et al.	2019	Asia	China	Xinbei District, three sub-districts and seven towns	Suzhou, Wuxi, Zhenjiang, Shanghai, Nanjing, Hangzhou	No	SAU	IST	land, weight	2nd	na	- Changzhou Municipal Bureau of Land and Resources - Statistical Yearbook of Changzhou City	- Substraction method: Difference of seed food and industrial food consumption (brewing and seasoning products, feed production) estimation	n/a	Future population peak in 2025 and 2050	- Maximum population that can be supported by local food based on future regional food supply - Accounts for land resource use status, farmland quality grade, heavy metal concentration in soil
Liao et al.	2019	North America	USA	Northern Idaho, Mountain West		Yes	SAU	Foodshed size	land	X	Distance	- NASS - Yield data from Washington State - NLCD - Commercial websites on food producer locations - Idaho State Department of Agriculture - Expert input on feasibility of production in Idaho - Food losses and inedible portions	- Web-based survey among retail grocery stores and restaurant buyer - [HNE] Annual and high-value crops (HNEa) and perennial forage (HNEp) = total quantity of food (HNEt) - Local food programs through Idaho State Department of Agriculture (Idaho Preferred program)	Vegetables, fruits, meat, dairy, eggs, grains, field crops and others	Removal of marginal land (less productive, highly erodible land)	- Links soil erosion and LFS, potential gains from transformation of annual into perennial agriculture - Incorporates location of existing farms (for distance optimization model) - Study of preferred local foods among retailers and restaurants - Production allocation: water capacity, precipitation, slope, soil depth, soil fragments, soil pH, temperature, and distance to nearest city and highway
Morrison et al.	2012	North America	Canada	British Columbia		No	SAU	ST	land, weight	2nd	na	- Statistics Canada - Data from previous research project	[Actual diet] - Data from previous research project - Age cohorts and gender	All food groups		- Use of Bayesian modelling - No region more than 100% self-sufficient in a certain food group, reallocation
Newcombe and Nichols	1979	Asia	China		Hongkong	No	SAU	ST	land, weight	2nd	na	- Hong Kong Department of Agriculture and Fisheries - Hong Kong Human Ecology Programme	[Actual diet] - Hong Kong Department of Agriculture and Fisheries and Hong Kong Human Ecology Programme	Vegetables, fruit, rice, chickens, ducks, geese, quail, pigeons, eggs, pigs, cattle, milk, fish	Conversion of fallow land and paddy land to market gardening, 1958 - 1976	- Typology of Hong Kong farmers (type of crop produced, size of farm, number of livestock, number of people employed or working in the sector - Linking local food capacity with water pollution (fertilizer source and application)
Nixon and Ramaswami	2018	North America	USA			Yes	SAU, Radius	ST, Foodshed size	weight	2nd	Distance	- Census of Agriculture and surveys (USDA) - Food loss (Food Availability Database)	[Actual diet] - NHANES with modifications - EPA and FCID for conversion into commodity weights - Accounts for different sociodemographic groups	Fresh and unprocessed food, highly processed food or food from complex supply chains	- Non-competitive (food allocation from surrounding land to demanding center) and competitive scenario (surplus production allocated to deficit counties) - Varying definitions of 'local' (MSA, radius: 25, 50, 75, 100 miles)	No region more than 100% self-sufficient in a certain food group, reallocation
Orlando et al.	2019	Europe	Italy	Lombardy region (Milan, Monza and Brianza Provinces)	Milano metropolitan region	Yes	SAU	ST	land, weight	X	na	- ISTAT	[Actual diet] - Regional database about social services; surveys to institutions in charge of school food services; questionnaires (developed meal through roundtables with researchers and representatives of Lombardy region and catering companies)	Fruits, vegetables, grains, dried legumes, meat, milk, eggs	Removing less productive, highly erodible lands	- SWOT analysis - Focus on public mass catering
Peters et al.	2007	North America	USA	New York State		No	SAU	ST	land, weight	2nd	na	- NASS - Animal science faculty at Cornell University - NDSR - USDA publications for processing yields and post-harvest losses	[Actual diet] - Food Commodity Intake Database [Theoretical Diet] - Food Guide Pyramid (USDA)	All food groups	42 different dietary patterns varying in terms of total fat and total servings of meat, low-fat, lacto-vegetarian to high-fat, meat-rich omnivorous	Seasonality of produce availability: summer and winter diets (winter: only processed or storable fruits and vegetables)
Peters et al.	2009	North America	USA	New York State	132 population centers	Yes	SAU	ST, Foodshed size	land, weight	2nd	Distance	- STATSGO - Master Soils List, maintained by Department of Crop and Soil Sciences at Cornell University and published annually by NYS Department of Agriculture and Markets - Food spoilage and waste	[HNE] - Annual and high-value crops (HNEa) and perennial forage (HNEp) = total quantity of food (HNEt)	All food groups	42 different dietary patterns varying in terms of total fat and total servings of meat, low-fat, lacto-vegetarian to high-fat, meat-rich omnivorous	No cell more than 100% self-sufficient in a certain food group, reallocation
Peters et al.	2012	North America	USA	New York State		Yes	SAU	ST, Foodshed size	land, weight	2nd	Yield	- MSL maintained by Department of Crop and Soil Sciences at Cornell University and published annually by NYS Department of Agriculture and Markets	[Theoretical diet] - Food Guide Pyramid (USDA)	All food groups	11 scenarios: different degrees of willingness among local population to eat local in %	No cell more than 100% self-sufficient in a certain food group, reallocation
Tedesco et al.	2017	Europe	France	Saclay plateau		Yes	SAU	ST	weight	X	na	- Face-to-face or phone interviews and publications on Saclay plateau - LPIS - Agreste database	[Actual diet] - INCA 2 study (AFSSA) - Accounts for workers and inhabitants, work fluxes, and vacation impacts on food demand - Feed crops	All food groups		
Zasada et al.	2019	Europe	UK, Germany, Italy, Netherlands		London, Berlin, Milan, Rotterdam	Yes	Radius	Foodshed size	land, weight	2nd	na	- Regional and national databases - FAO statistics	[Actual diet] - FAO food balance database	All food groups	Organic vs. conventional agricultural systems, diet, food waste, population, and combined effects	
Zumkehr and Campbell	2015	North America	USA			Yes	Radius	ST, Foodshed size	weight	2nd	Distance	- NASS - ERS	[HNE] - Annual and high-value crops (HNEa) and perennial forage (HNEp) = total quantity of food (HNEt)	Grains, vegetables, fruit, dairy, eggs, and meat	- Food losses, - Foodshed radius (30 miles - 300 miles) - Different diet types - Sensitivity analysis: uncertainty in driver data (population sizes, crop yields, food losses), long-term developments (1850 - 1900)	

Flow studies

Authors	Year	Continent	Country	Region	Cities	Systems boundaries	Self-described	Purpose	Unit	Data source	Food flows	Food	Scenario / Temporal changes	Other
Akoto-Danso et al.	2019	Africa	Ghana, Burkina Faso	N Ghana and central Burkina Faso	Tamale, Ouagadougou	Multi-scale	Yes	Resource use, networks	other	1st	- Quantitative street and market surveys - Crop yields (FAO) and water us (previous research) - Literature and monthly market survey - Interviews with stakeholders (Ministry of Food and Agriculture, market leaders) - Inflows and outflows	Cereals, fruits, vegetables, legumes, root, tuber and other staples, livestock	- Account for seasonal variability - Account for multiple years	- Geo-spatially explicity virtual water calculation - Tracing of major outgoing flows (re-exports) - Based on data from Karg et al. (2016)
Aucoin and Fry	2015	North America	USA	Dallas Fort Worth Metroplex	Dallas, Fort Worth	Metropolitan area	Yes, sense of place and community	Networks	other	1st	Interviews with producers, market managers, consumers, website	Meat, dairy and produce		Use of foodshed (where food comes from) and marketshed (where food goes to)
Brinkley	2017	North America	USA	Chester County, Pennsylvania		National	No	Networks	other	X	- Farm and market data from civic documents, market promotion material, media, farm website listings, county farm listings, Local Harvest affiliates, buyer associations - Farm manager surveys with e-questionnaires (idenfitication of geographic coordinates, raw products and direct sale/donation markets. - Surveys sent to 700 farms and 2000 markets/users, 117 farms and 637 unique users responded - Semi-open ended interviews with program directors			- Farm network mapping (marketsheds) - CSA farmers and market farmers
Grigsby and Hellwinckel	2016	North America	USA	Knox County, Tennessee		Metropolitan area	Yes	Resource use, networks	other	1st	Interview/survey with farmers selling fruits and vegetables in direct-to-consumer local markets	Fresh produce	- Farm size - Vehicle type	- Use of Life Cycle Analsysi and transportation economics to account for fuel use efficiency - Focus on farmers markets
Karg et al.	2016	Africa	Ghana, Burkina Faso	N Ghana and central Burkina Faso	Tamale and Ouagadougou	Multi-scale	No	Networks	weight	X	- Road surveys - Secondary data from customs data - Market surveys	- >50 crops and animal products, lightly processed items (smoked fish), processed rice and groundnuts - No Eggs and dairy products	- Account for seasonal variability - Data collection over 2 (Tamale) and 1 year(s) (Ouagadougou)	- Tracing of goods imported via railway - Tracing of major outgoing flows (re-exports) - Data foundation for Akoto-Danso et al. (2019) study
Świader et al.	2018	Europe	Poland		Wrocław	National	No	Networks	other	1st	Market survey	Food groups (food baskets, healthy food pyramid)		Statistical correlation between travelled distance of food and food type
Wegerif and Wiskerke	2017	Africa	Tanzania		Dar es Salaam	Multi-scale	No	Networks	weight	1st	Qualitative multi-sited ethnographic approach	Most important food and sources of food for majority of people	Multiple years, but not comparatively	Tracing sources of food from urban eaters to primary producers (including retailers,
Zazo-Moratalla et al.	2019	South America	Chile	"Biobio" region	Concepción Metropolitan Area (11 townships)	Metropolitan area	Yes	Networks	other	1st	- Snowball sampling method to identify food outlets (based on percentage of foodstuffs that reach urban points and nodes as a destination of the LFS) - Standardized survey (Local foods that each point receives, origin of each food) twice per year (summer and winter), no volumes	Fresh and processed food	Summer and winter, one year	Two local food systems organizations

Hybrid studies

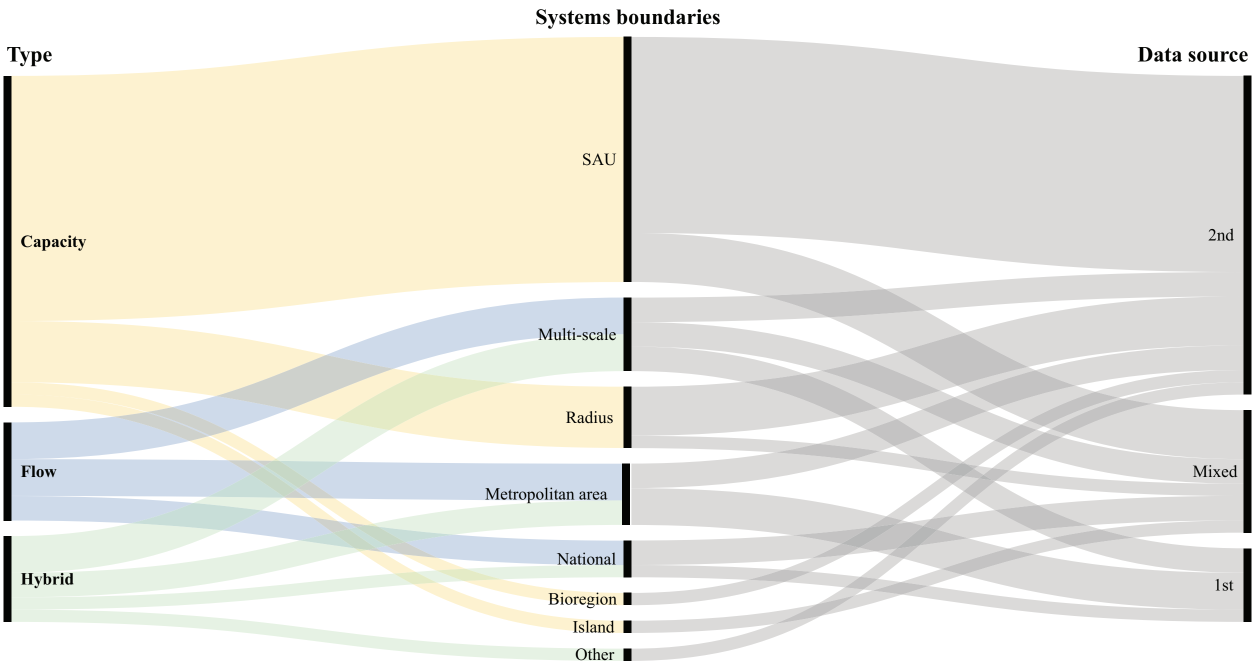
Authors	Year	Continent	Country	Region	Cities	Systems boundaries	Self-described	Purpose	Calculation method	Unit	Data source	Optimization	Food production	Food consumption	Food flows	Food	Scenario / Temporal changes	Other
Billen et al.	2012	Europe	France	Ile de France	Paris	Metropolitan area	No	Resource use		other	2nd	na	- Agreste, Ministry of Agriculture	- Food transport to Paris = food consumption	- FAO (trade statistics) - SitraM database on commodity transport between French departements (French Ministry of Environment)	Food groups	- Organic farming to restore nitrogen contamination - Animal feed from local sources - Dietary change (meat reduction)	- Uses "territorial ecology" concept - Analyses environmental effect of Paris' food consumption on biogeochemical processes in rural hinterland, understand relations between urban food demand, nitrogen cycling in agricultural systems, and nitrate contamination of water resources. - Includes feed imports
Hara et al.	2013	Asia	Japan	Osaka city region (six prefectures: Osaka, Hyogo, Kyoto, Shiga, Nara, Wakayama		Multi-scale	Yes	Resource use	ST, Foodshed size	other	X	na	- Ministry of Agriculture, Forestry and Fisheries' (MAFF)	[Actual diet] - MHLW (vegetable consumption per prefecture)	- Ministry of Agriculture, Forestry and Fisheries' (MAFF)	14 major vegetables in two categories (leafy and root vegetables)	Reduction of energy consumption through local production, transformation of abandoned farmland, organic agriculture and farmers markets	- More consumption of vegetables from region while eliminating exports to other prefectures - Utilization of all abandoned farmland for vegetable production so as to reduce the current transport of vegetables from remote prefectures - Estimation of embodied energy consumption
Iizuka and Kikuchi	2014	Asia	Japan		Tokio	Multi-scale	No	Networks	ST	other	2nd	na	- Japan Census and Ministry of Agriculture, Forestry and Fisheries - Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheries - Previous research	Not mentioned	- Monthly report or Tokyo Metropolitan Central Wholesale Market - Trade statistics of Japan - Interviews	Grains, milk, eggs, meat, vegetables, onions and pumpkins	1970 - 2010	Monthly flows of vegetables to Tokyo Metropolitan Central Wholesale Market with origins to estimate geographical and temporal variability
Kriewald et al.	2019	Global				Peri-urban area (based on sattelite land cover and population density)	Yes	Resource use	ST, Foodshed size	nutrition, other	2nd	Yield	- Yield model 'GAEZ' by IIASA/FAO	[Actual diet] - FAOSTAT - National diets	Shortest distance between peri-urban production and urban cluster	All food groups	- Urban growth - Dietary pattern changes - Accelerated climate change - 2010 - 2050	- Use of sophisticated models incorporating large data sets, remote sensing, and population density - Calculate urbanization and climate change as well as emissons savings (ground transportation) - Global analysis
Lu and Campbell	2009	Asia	China		Shunde city	Metropolitan area	No	Resource use	ST	other	2nd	na	- Statistical Yearbooks of Shunde city - Imports and exports of food products = difference between local consumption and local production	[Actual diet] - Statistical Yearbooks of Shunde city - Annual Report of the Agriculture Bureau of Shunde (ABSD)	- Statistical Yearbooks of Shunde - Agriculture Bureau of Shunde (ABSD) - Annual Report of the Agriculture Bureau of Shunde (ABSD)	Grains, vegetables, pork, poultry, fish, fruit	22 years	- Accounts for imports and exports of agricultural products - Use of the "emergy" concept, and energy systems models - Measures effect of industrialization on LFS
Porter et al.	2014	Australia, Europe, Asia	Australia, Denmark, Japan		Canberra, Copenhagen, Tokyo	Multi-scale	No	Resource use	ST	weight	2nd	na	- Statbank Denmark, Landbrugsstatistik Danmark - Australian Bureau of Statistics, Australian Bureau of Agricultural and Resource Economics, Australian Meat and Livestock Association - Ministry of Agriculture, Forestry and Fisheries, Japan, Ministry of International Affairs and Communicationis Statistics, Japan	[Actual diet] - Division method: Production - exports + imports	- FAOSTAT, UN Comtrade	Common local foods, beef, wheat, rice, dairy products and pork, processed foods	1965 - 2005	- Food secure cities with respective agricultural area, varying size, different global, climatic, and physical locations and socio-economic contexts - Different trading systems: old world (Australia), European Union (Denmark), food traditions and culture (Japan) - Estimation of embodied land areas - Extent to which food security is due to productive capacity of landscapes on which receiving city has not governance power
Zhou et al.	2012	Asia	China		Tianjin	National	No	Networks	ST	other	X	na	- Tianjin Statistics Bureau - National Bureau of Statistics - Previous research	[Actual diet] - Previous research - Tianjin Statistics Bureau	- Qualitative interviews with researchers from Tianjin Academy of Agricultural Sciences, government officers, food sellers in open markets, and managers of wholesale markets, government officials from Commercial Committee, the Bureau of Cereals, the Bureau of Agriculture, and the Agriculture Committee - Semi-structured survey with farm families Xiqing District and Ninghe County - Tianjin Statistics Bureau	Flows: Vegetables, rice, wheat, corn Cap: Cereal, vegetables, pork, beef & mutton, poultry, eggs, fish, milk		- No meat data because difficuly to obtain data from slaughterhouses - Links policy (price deregulation of pork) with land use change and change of food flows (pork production) - Traces direction of different food items between urban, suburban and rural areas, but no total quantities - Identifies inter-regional dependency - Provides a local vegetable harvest and flow calendar

S5 Food types considered in foodshed studies

Due to computational power allowing for the processing of large amounts of data, most *Capacity* studies analyze a food basket, i.e., several dozen foods from all or selected food groups (fruit, vegetables, grains, meat, fish, dairy and dairy products, eggs, legumes, roots and tubers, oils). The selection process of food items varies depending on the study's purpose and data availability. For example, Halldórsdóttir et al. (2016) selected the most important food crops with high macronutrient content (calories) and a high share of imports. Desjardins et al.'s (2010) selection approach was the most thorough of all the studies we reviewed. They only included crops that fulfill a set of criteria in an iteratively developed selection protocol (spreadsheet S4).

Some studies focused on crops with high regional relevance, like rice and leafy greens (Kurita et al., 2009) or grains (Huang et al., 2019), used legumes and pulses as a meat alternative (Desjardins et al., 2010) or included canned vegetables to account for seasonal supply gaps (Galzki et al., 2017; Peters et al., 2007). Conrad et al. (2017) estimated LFS for livestock, dairy, and eggs to identify potential for agricultural diversification and the reduction of nutrient overload. Several studies substituted foods like sugar, tropical fruits, cocoa or coffee, which cannot be grown in the region through local alternatives (Cardoso et al., 2017; Joseph et al., 2019; Zasada et al., 2019). Others neglected food items that are eaten less frequently according to household expenditure statistics, such as soybeans or fish (Cardoso et al., 2017; Desjardins et al., 2010), or foods with insufficient data (Giombolini et al., 2011). With one exception (Newcombe & Nichols, 1979), fish was only part of the foodshed analysis in *Hybrid* (Lu & Campbell, 2009; Zhou et al., 2012) and *Flow* studies (Karg et al., 2016; Zazo-Moratalla et al., 2019).

S6 *Relationships between study type, spatial systems boundaries, and data sources*



Most Capacity studies use subnational administrative units (SAU) or a specified radii around a city as a spatial boundary. Flow studies trace food movements between cities on different scales, including metropolitan areas or national scales. Data from secondary sources (2nd) like national statistics are the most commonly used, while primary (1st) sources and mixed (both primary and secondary) represent similar shares.

S7 Data sources

Capacity studies

None of the reviewed studies used city-specific secondary statistical data on urban food consumption. To compensate for data gaps in food consumption at sub-national scales, many studies turned to national food availability or expenditure data from national (e.g. USDA for the

United States) or international (e.g., FAO) organizations (spreadsheet S4). In the US, surveys by the National Health and Nutrition Examination Survey (NHANES) can provide finer data on food consumption (Nixon & Ramaswami, 2018). Both dataset types are relatively well accessible and applicable yet may be imprecise since they only list averages and neglect regional variation in diets (Galzki et al., 2014). Furthermore, such a dataset can contain recall errors as respondents are less likely to report 'unhealthy' foods (Nixon & Ramaswami, 2018). A foodshed study on New York State used the 'Human Nutritional Equivalent' (HNE), a diet model developed by the United States Department of Agriculture (USDA) Economic Research Service (ERS) that captures both, dietary recommendations and actual food preferences (Peters et al., 2009). Galzki et al. (2017) adapted the HNE for diverging diets in Southern Minnesota through consumer expenditure survey data. Liao et al. (2019) adjusted their food demand model with data from retailer and restaurant buyer surveys as well as expert advice on the biophysical agricultural capacity in Northern Idaho for the production of certain crops. Porter et al. (2014) used an alternative approach, estimating crude food consumption based on: production - exports + imports.

Besides national-scale and other proxy data on food consumption, some studies used 'theoretical diet'-models adapted from food intake recommendations or food guidelines. These datasets are publicly accessible and often suggest specific quantities of food groups and types in weights, volumes, or serving sizes. Similar to the previous data sources, they often neglect actual consumer choices, which can prioritize low-cost and processed foods (Galzki et al., 2014).

To estimate food production, studies either utilized readily available data on the regional production capacity from crop and livestock harvest statistics or calculate land capacity with yield factors and arable land size. Liao et al. (2019) pointed out that limiting the analysis to land assigned for agricultural purposes can bias the analysis since forests and grasslands can be equally relevant for foraging and grazing. Several studies incorporated land for grazing in their models (Galzki et al., 2014; Halldórsdóttir & Nicholas, 2016) and distinguished between annual and perennial crops (Galzki et al., 2014; Liao et al., 2019; Peters et al., 2009; Zumkehr & Campbell, 2015). To what degree studies considered forests quantitatively as a food source is unclear as none of the reviewed studies mentioned foraging in their methodology. Data for food production estimations generally stemmed from secondary sources such as agricultural censuses and land use surveys conducted by national or sub-national state departments and agencies or research centers. In few cases, primary data from interviews with farms and other agri-food supply chain actors complemented secondary data if specific information was required (Iizuka & Kikuchi, 2014; Tedesco et al., 2017; Zhou et al., 2012). If available, regional level data can complement national level data (Hara et al., 2013).

Flow studies

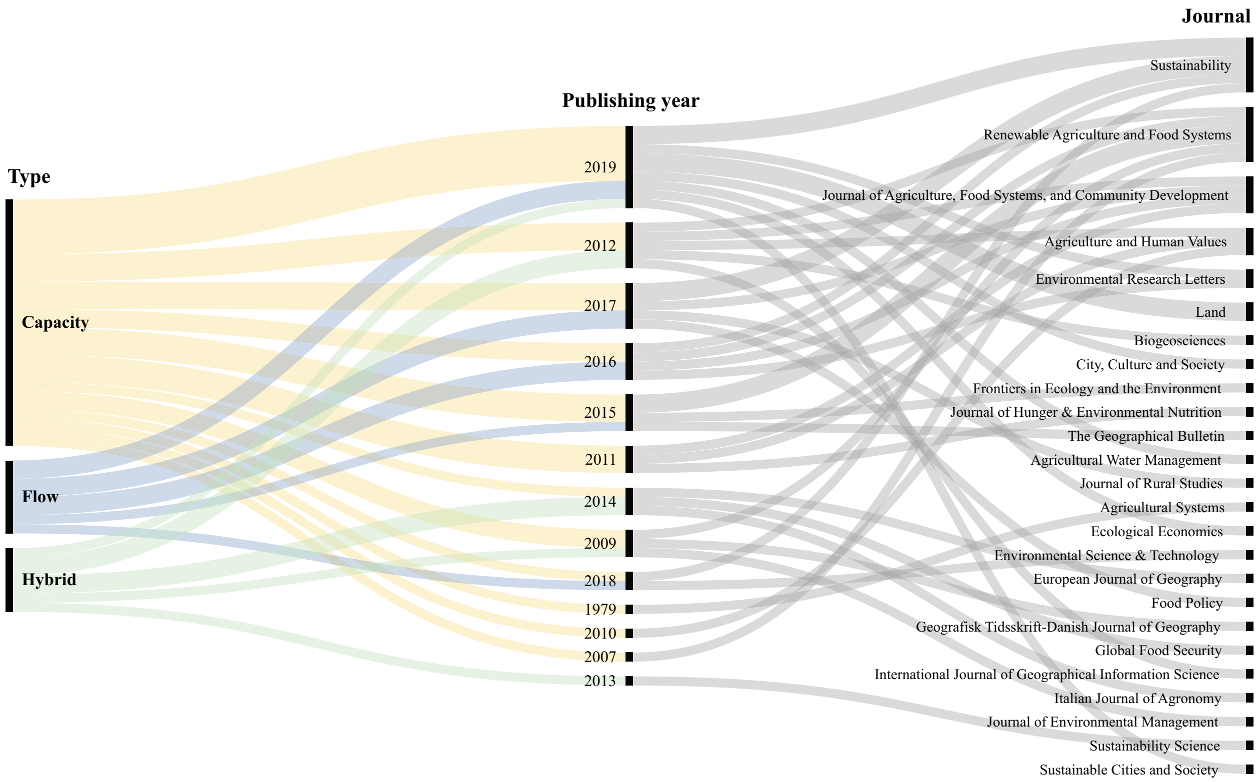
Thorough and precise datasets on sub-national food flows are rare. In China, annual statistical yearbooks record inter-provincial and inter-municipal trade flows, yet, reliability and quality of reported values is questionable (Zhou et al., 2012). France and Japan provide similar and more reliable documentation of sub-national food trade. Datasets from the Food and Agricultural Organization of the United Nations (e.g. Food Balance Sheets) can help to trace international trade. To what degree this captures subnational flows to cities remains unclear.

Due to this lack of data, *Flow* studies often relied on primary data collection through surveys or semi-structured interviews with market vendors, farmers, supermarkets, researchers, civil servants, and other key actors. Karg et al.'s (2016) analysis accounted for different modes of transportation (e.g., truck and railway) that bring food to the two West-African cities Tamale and Ouagadougou as well as seasonal variability of food origins. An in-depth approach like this requires considerable resources for data collection and is vulnerable to power relationships between municipal authorities and researchers with regard to research permissions and approvals. This may explain the smaller number of cities captured by *Flow* studies, while *Capacity* studies can cover dozens of cities at once.

S8 Original definitions found in key foodshed studies in chronological order and sorted by foodshed study type

Authors	Type	Foodshed definition
Peters et al. 2009 and 2012	Capacity	*"… a potential local foodshed is the land that could provide some portion of a population center's food needs within the bounds of a relatively circumscribed geographic area. This concept provides a framework for analyzing the capacity to produce food locally at the scale of an individual city."*
Hu et al. 2011a	Capacity	*"… a foodshed is the geographic area from which the population acquires its food supply."*
Kremer and Schreuder 2012	Capacity	*"… counties that were documented as currently supplying food to the local food system in the city."*
Zumkehr and Campbell 2015	Capacity	*"Local food systems are characterized by "foodsheds" – geographic areas in which food is both produced and consumed."*
Karg et al. 2016	Flow	*"… geographical sources supplying food to the urban population…"*
Joseph et al. 2019	Capacity	*"[…] refers to the surface of land required to produce food for a specific population."*

S9 Relationships among foodshed study type, year of publication, and journal in which article has been published.



An increase in foodshed studies in 2019 (impartially covered in our review) could indicate a rising interest in this methodology among food systems researchers. We did not identify any published empirical foodshed studies between 1979 and 2007 in our review.

S10 Spatial systems boundaries

Spatial systems boundaries often reflect disparities in data availability in the study region. Many *Capacity* studies focus on subnational scales (state, province, department, prefecture, municipality) in which agricultural census data are collected by governments (fig. S9). In the US, detailed agricultural statistics are available at the county-level (Kremer & Schreuder, 2012), but availability and consistency can vary between administrative units (Galzki et al., 2014). Analyses can also focus on a single state or municipality due to the perceived governance potential for planning and supporting local food systems, assuming that direct producer-consumer exchanges and decision-making are more likely to succeed at this scale (Filippini et al., 2014; Kurita et al., 2009; Liao et al., 2019). The organization of supply chains at the local and regional scale can provide better control and management of production and consumption and adapt to local potentials and demands (Robert & Mullinix, 2018).

Multiple studies delimit foodsheds based on a radius from the city center (i.e., ‘100-mile diet’) (Figure S9). However, as stated by some authors (Hara et al., 2013; Kremer & Schreuder, 2012), this approach neglects that a city’s potential foodshed can overlap with other cities’ foodsheds or non-arable lands (e.g., ocean, mountains), resulting in potential resource competition or scarcity. Furthermore, the use of radius or SAU ignores that cities or farmers on the fringe of those theoretical boundaries may also trade with neighboring domestic or foreign partners.

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11.2 Appendices for Chapter 4

Table S1 List of the 83 cities in the US and Canada above 300,000 residents, which we used as the starting point for our document search. Population values were derived from the most recently available U.S. Census Bureau, Population Division (2020) and Statistics Canada (2021).

Canada

Municipality	**Estimated population in 2020**
Toronto, Ontario	2,988,408
Montréal, Quebec	1,821,070
Calgary, Alberta	1,361,852
Edmonton, Alberta	1,047,003
Ottawa, Ontario	1,043,130
Mississauga, Ontario	774,116
Winnipeg, Manitoba	766,894
Brampton, Ontario	713,463
Vancouver, British Columbia	697,266
Surrey, British Columbia	598,530
Hamilton, Ontario	581,722
Québec, Quebec	550,326
Halifax, Nova Scotia	448,231
Laval, Quebec	442,648
London, Ontario	430,828
Markham, Ontario	351,163
Vaughan, Ontario	331,572

United States

Municipality	**Estimated population in 2019**
New York, New York	8,336,817
Los Angeles, California	3,979,576
Chicago, Illinois	2,693,976
Houston, Texas	2,320,268
Phoenix, Arizona	1,680,992
Philadelphia, Pennsylvania	1,584,064
San Antonio, Texas	1,547,253
San Diego, California	1,423,851
Dallas, Texas	1,343,573
San Jose, California	1,021,795
Austin, Texas	978,908
Jacksonville, Florida	911,507
Fort Worth, Texas	909,585

Columbus, Ohio	898,553
Charlotte, North Carolina	885,708
San Francisco, California	881,549
Indianapolis, Indiana	876,384
Seattle, Washington	753,675
Denver, Colorado	727,211
Washington, District of Columbia	705,749
Boston, Massachusetts	692,600
El Paso, Texas	681,728
Nashville-Davidson, Tennessee	670,820
Detroit, Michigan	670,031
Oklahoma City, Oklahoma	655,057
Portland, Oregon	654,741
Las Vegas, Nevada	651,319
Memphis, Tennessee	651,073
Louisville/Jefferson County, Kentucky	617,638
Baltimore, Maryland	593,490
Milwaukee, Wisconsin	590,157
Albuquerque, New Mexico	560,513
Tucson, Arizona	548,073
Fresno, California	531,576
Mesa, Arizona	518,012
Sacramento, California	513,624
Atlanta, Georgia	506,811
Kansas City, Missouri	495,327
Colorado Springs, Colorado	478,221
Omaha, Nebraska	478,192
Raleigh, North Carolina	474,069
Miami, Florida	467,963
Long Beach, California	462,628
Virginia Beach, Virginia	449,974
Oakland, California	433,031
Minneapolis, Minnesota	429,606
Tulsa, Oklahoma	401,190
Tampa, Florida	399,700
Arlington, Texas	398,854
New Orleans, Louisiana	390,144
Wichita, Kansas	389,938
Bakersfield, California	384,145
Cleveland, Ohio	381,009
Aurora, Colorado	379,289
Anaheim, California	350,365
Honolulu, Hawaii	345,064

Santa Ana, California	332,318
Riverside, California	331,360
Corpus Christi, Texas	326,586
Lexington-Fayette, Kentucky	323,152
Henderson, Nevada	320,189
Stockton, California	312,697
St. Paul, Minnesota	308,096
Cincinnati, Ohio	303,940
St. Louis, Missouri	300,576
Pittsburgh, Pennsylvania	300,286

Table S2 Food strategies and action plans analysed in our study

City	Year	Title
Calgary, AB, Canada	2012	Calgary Eats! A Food System Assessment and Action Plan for Calgary
Vancouver, BC, Canada	2011	Regional Food System Strategy
Vancouver, BC, Canada	2013	What feeds us: Vancouver Food Strategy
Vancouver, BC, Canada	2016	Regional Food System Action Plan
Sacramento, CA, USA	2015	Sacramento Region Food System Action Plan
Riverside, CA, USA	2015	Food and Agriculture Policy Action Plan
Stockton, CA, USA	2017	City of Stockton Food and Ag Action Plan
Denver, CO, USA	2017	Denver Food Vision
Albuquerque, NM, USA	2019	Albuquerque Food & Agriculture Action Plan
Henderson, Nevada	2016	Local Foods, Local Places. A Community-Driven Action Plan for Henderson, Nevada
New York City, NY, USA	2017	Food Metrics Report 2017
New York City, NY, USA	2021	Food Forward NYC: A 10-Year Food Policy Plan
York, ON, Canada	2019	York Region Food Network Strategic Plan 2019-2022
Hamilton, ON, Canada	2015	Hamilton Food Strategy: Healthy, Sustainable, and Just Food for All
Peel, ON, Canada	2019	2021 to 2023 Strategic Plan, Peel Food Action Council
Philadelphia, PA, USA	2011	Eating Here: Greater Philadelphia’s Food System Plan
Phoenix, AZ, USA	2020	2025 Food Action Plan: Healthy Food for All
Pittsburgh, PA, USA	2020	Greater Pittsburgh Food Action Plan
Montréal, QC, Canada	2018	Conseils du Système alimentaire montréalais: Plan d’action intégré – document integral
Québec, QC, Canada	2015	Vision du Développement des activités agricoles et agroalimentaires dans l’agglomération de Québec
Laval, QC, Canada	2019	Politique alimentaire de la ville de Laval

Dallas, TX, USA	2016	Local Foods, Local Places: A Community-Driven Action Plan for Dallas, TX
Seattle, WA, USA	2012	City of Seattle Food Action Plan
Henderson, NV, US	2016	Local Foods, Local Places: A Community-Driven Action Plan for Henderson, Nevada
Columbus, OH, US	2016	Local Food Action Plan
Toronto	2018	Toronto Food Strategy 2018 Report

Table S3 Examples for SETs-foodshed categories

	Category	Example
Socioeconomic	Land use	Protection of land from non-food land use
	Workforce	Ensuring stable workforce and strengthen labour rights (migrant workers)
	Social justice and equity	Supporting farmers from marginalized communities and beginning farmers
	Farmer livelihoods	Supporting farm profitability and ensuring access to capital for investments
	Regional economic development	Strengthening farming sector and trade
	Education and knowledge transfer	Providing training programs and designing career pathways
	Land access	Ensuring access to land and capital to acquire land
	Public health and safety	Protection of residents and farmers from pollution and contamination
Ecological	Water	Management of water quantity and quality
	Food production	Sustain or increase food production
	Biodiversity	Expanding crop diversity and protecting pollinators and wildlife
	Nutrient cycle	Efficient and safe use and reuse of agricultural fertilizers
	Land quality	Soil quality preservation
	Climate change	Adaptation and mitigation
Technological	Production methods	Promoting and implementing sustainable and regenerative methods (incl. season-expanding production)
	Processing, storage, and logistics	Protecting and establishing processing, transportation, and storage infrastructure
	Energy	Promoting the use of renewable energies and resource efficiency
	Information and communication technology	Expanding and strengthening networks for data transfer

Text S4. SETs framework: additional information

The SETs framework proposes three domains in which issues occur and change can happen: socio-economic-demographic, ecological, infrastructure-technical-technological. In cities, population and economic trends, public health and safety, social justice and equity, education, and land use and mobility shape the socio-economic-demographic domain. Within the ecological domain, sustainable cities should plan for biophysical factors and processes, such as biodiversity and vegetation, land and water-based food production, soil, and geology, as well as hydrology and biogeochemistry. From an infrastructure-technical-technological perspective, cities aiming for sustainability should manage their energy infrastructure, construction, water management and infrastructure[9], Information and Communication Technology (ICT), and transportation. Bixler et al. (2019) further suggest that governance networks propel the knowledge-to-action processes across the SETs domains. Those networks include all formal and informal relationships between stakeholders and actors across various jurisdiction and sectors, including negotiation and planning processes among and between individuals and organizations that influence the trajectory of processes and structures in the city.

[9] For this study, “water” was categorized as natural resource and affiliated with the ecological domain.

11.3 Appendices for Chapter 5

SI 1 Questionnaire and interview guide (simplified)

Section 1: Farm

Q1. Which of these roles applies to you (Select all that apply)? You can add additional options if necessary. *Farm owner, farm manager, Other*

Q2. When was your operation established? Please enter the year below. *[Number]*

Q3. Please indicate your age-group. *18-30, 31-44, 45-64, 65+*

Q4. Please indicate your gender. *Female, male, other, prefer not to say*

Q5. Please enter the name of the municipality in which your farm is situated (e.g. "Napierville"). *[Text]*

Q6. How much land is cultivated on your farm? Please enter the approximate number and specify whether it is acres or hectares. *[Number and Text]*

Q7. On average, how many people work on your farm permanently and temporarily?

[Number] Permanently full time, Permanently part time, Temporarily full time, Temporarily part time. *1-4, 5-9, 10-49, 50+*

Q13. How many different crops and other food products were produced on your farm in the past few years (2017 - 2020)? *1-4, 5-9, 10-49, 50+*

Q9. What kind of foods do you produce (Check all that apply)? You can add additional options if necessary. *Vegetables (e.g., zucchini, eggplant, tomatoes, cucumber, bell peppers, green beans), leafy vegetables (e.g., spinach, cabbage, lettuce, celery), root vegetables (e.g. potatoes, carrots, radishes), flower vegetables (e.g., cauliflower, broccoli), bulb vegetables (e.g. onions, shallots), grains (e.g. wheat, oats, corn), legumes (e.g. soybeans, other beans), pumpkin and squash, herbs and micro greens, meat (e.g., chicken, beef, pork, fish), dairy (e.g. milk, cheese, yoghurt), eggs, honey, edible mushrooms*

Q10. Did you produce non-food products (e.g. hemp)? If yes, please specify what kinds of products. *Yes/No*

Q11. Which of the following best describes your farm? You can add additional options if necessary. *Certified organic, awaiting certification, organic in practice but not certified (i.e., no synthetic fertilizers or pesticides), agroecological farming/conservation agriculture, conventional agriculture (no conservation), Other (please specify)*

Section 2: Food marketing and sales

In this section, I will ask about your food marketing and sales system for different growing seasons - first for 2017 - 2019, then for 2020. I refer to a growing season as spanning from March of the given year to February of the next year. For example, the growing season 2019 includes March 2019 to February 2020.

Q12. Between 2017 and 2019, where did you sell your farm products? (Check all that apply). *Québec (province), other Canadian provinces, USA, International (other non-USA countries)*

Q13. Between 2017 and 2019, how did you market your food? You can add additional options if necessary. (Check all that apply)? *Restaurants, supermarket, independent grocery store, farmers' market, vegetable basket subscription, roadside stand, U-pick, farm store*

Q14. In 2020, where did you sell your farm products? (Check all that apply). *Québec (province), other Canadian provinces, USA, International (other non-USA countries)*

Q15. In 2020, how did you market your food? You can add additional options if necessary. (Check all that apply)? *Restaurants, supermarket, independent grocery store, farmers' market, vegetable basket subscription, roadside stand, U-pick, farm store*

Q16. Did you change your distribution strategy between the growing seasons 2019 and 2020 due to COVID-19? Please explain why or why not. *Yes/No*

Section 3: Challenges

In this section, I will ask about your major challenges concerning your operation - first for 2017 - 2019, then for 2020.

Q17. Thinking about the growing seasons 2017 - 2019, what were the major challenges encountered in your operation with regard to food production? Please select all that apply. If possible, list or describe briefly what these challenges were. *Environmental (e.g. weather, soils), Technical (e.g. equipment and supplies), Social (e.g. farm labor, health and safety), Financial (e.g. costs, insurance)*

Q18. Thinking about the growing seasons 2017 - 2019, what were the major challenges encountered in your operation with regard to food marketing? Please select all that apply. If possible, list or describe briefly what these challenges were. *Sales and marketing (e.g. unpredictable demand, facilities), Logistics (e.g. vehicles), Social (e.g. labor, health and safety, relationships with customers)*

Q19. Thinking about the growing season 2020, what were the major challenges encountered in your operation with regard to food production? Please select all that apply. If possible, list or describe briefly what these challenges were. *Environmental (e.g. weather, soils), Technical (e.g.*

equipment and supplies), Social (e.g. farm labor, health and safety), Financial (e.g. costs, insurance)

Q20. Thinking about the growing season 2020, what were the major challenges encountered in your operation with regard to food marketing? Please select all that apply. If possible, list or describe briefly what these challenges were. *Sales and marketing (e.g. unpredictable demand, facilities), Logistics (e.g. vehicles), Social (e.g. labor, health and safety, relationships with customers)*

Q21. On a scale from 1 (not prepared) to 5 (well prepared) how would you rate your farm's general ability to respond to the challenges during the growing seasons 2017 - 2019?

Q22. On a scale from 1 (not prepared) to 5 (well prepared) how would you rate your farm's general ability to respond to the challenges during the growing season 2020?

Q23. Reflecting on how your farm has addressed the challenges you selected, please rate the following in terms of their importance:

	Not important	Less important	Somewhat important	Very important	No answer
Social and business relationships (e.g. information sharing with other farmers or customers)					
Equipment and infrastructure (e.g. irrigation, tunnels/hoop houses, harvesters)					
Farm management (e.g. which crops to grow, planting and harvesting dates)					
Financial aid (e.g. grants, loans)					
Marketing decisions (e.g. use of subscription schemes)					

Section 4: Relationships that help with adaptation to challenges

Q24. Which actor groups and organizations do you perceive as important for addressing the challenges you indicated on the last page by providing resources (e.g., time, money, equipment, information)? You can add additional options if necessary. *Other farmers in your network, Other farmers in your network, Permanent workers on your farm, Family, Volunteers, Individual customers (direct marketing), Chefs (Restaurants), Hotels and Institutions, Supermarkets, Independent grocery store, Farmers' market organizers, Coopérative pour l'agriculture de proximité écologique (CAPÉ), Équiterre, Les bio locaux, L'Union des producteurs agricoles (UPA), Ministère de l'agriculture, des pêcheries et de l'alimentation du Québec (MAPAQ), Agriculture and Agri- Food Canada, Québec Farmers' Association, Association des producteurs maraîchers du Québec, Union Paysanne, Other*

Q25. Which communication tools do you perceive as important to address your challenges? You can add additional options if necessary. *E-mail, Mailing lists, Social media (e.g. Facebook, Twitter), Forums, Telephone, In-person meeting/conversation, Virtual meeting tool (e.g. Zoom, Skype), Other*

Q26. How crucial are these contacts to you to address challenges? *[Selected actors and organizations from Q24] Somewhat important, Important, Very important, No answer*

Q27. Are these relationships more informal (e.g., conversations, sharing information with customers), more formal (e.g., contracts, grants), or both. If you do not feel comfortable sharing this information, please click on "No answer". *[Selected actors and organizations from Q24] Somewhat important, Important, Very important, No answer*

Q28. With regard to the above relationships, approximately how often do you interact with these contacts? *[Selected actors and organizations from Q24] Somewhat important, Important, Very important, No answer*

Section 5: Final question

Q.29 Is there anything else important you'd like to share with us?

Q.30 If possible, I would like to follow up on your responses in a 30-minute interview. The interview would be conducted through video or audio-call (e.g., Skype, Zoom) or on the phone in English or French. If you are interested, please leave your e-mail address in the box below and I will contact you within the next couple of days.

Getting to know / Warm-up

FQ1. Can you tell me a bit about your farm? When did you start? Where is your farm?

Seasons 2017 - 2019 and 2020

FQ2. In the survey, you listed challenges for the growing seasons 2017 to 2019 and 2020, before and during the Covid-19 pandemic. Can you describe how these challenges impacted your farm? [If necessary, remind respondent of challenges]

FQ3. What role did relationships to the actors and organizations you selected in the survey play to solve your challenges? [If necessary, remind respondent of relationships]

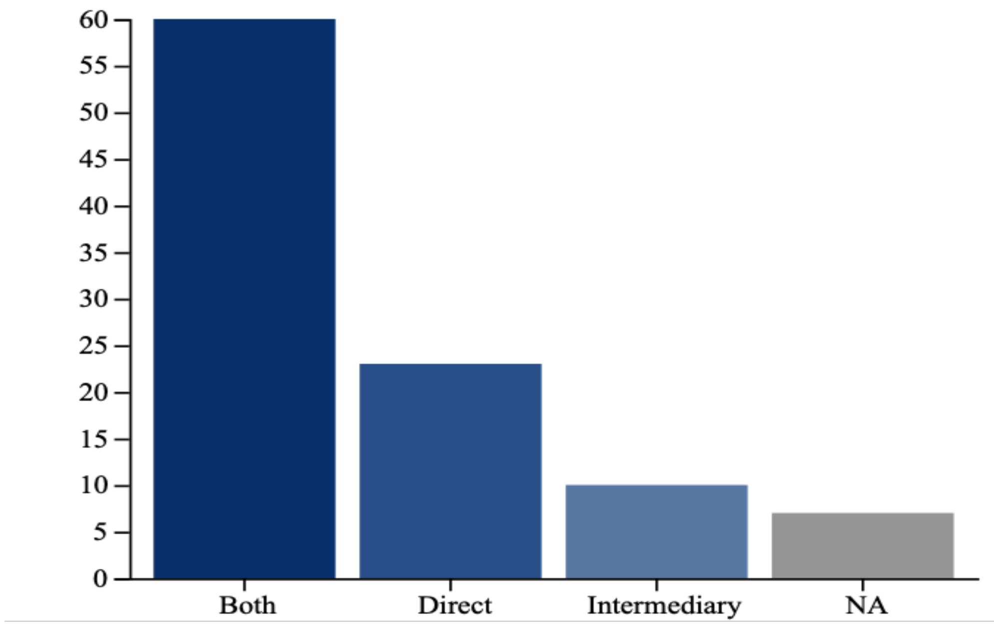
FQ4. What role did those tools and resources you selected in the survey play to solve your challenges? [If necessary, remind respondent of tools and resources]

Season 2021

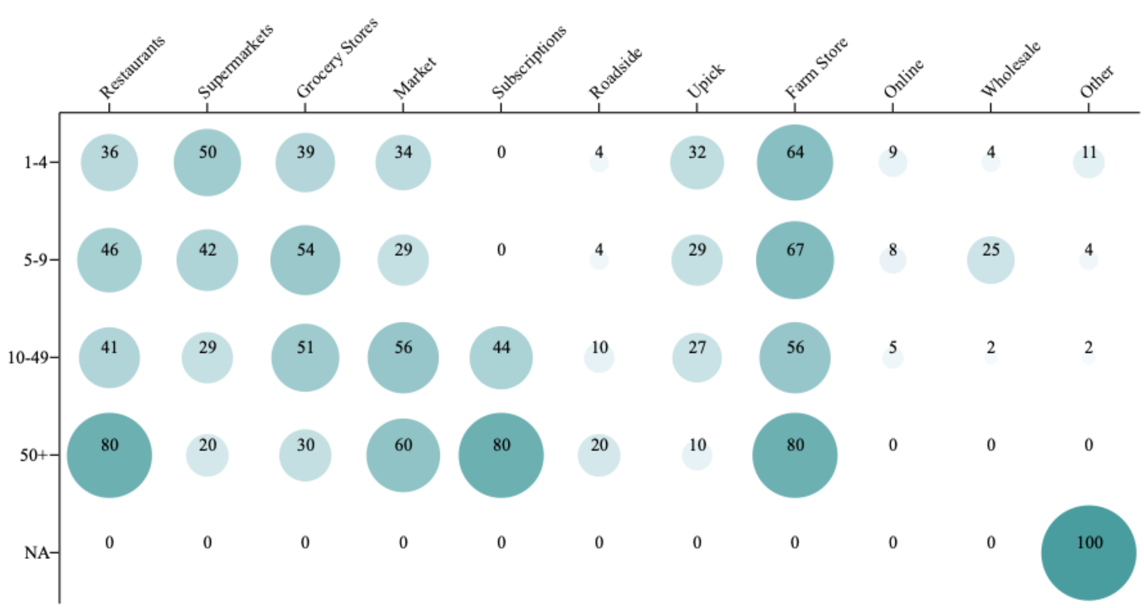
FQ5. What does it feel like to look into the future?

SI Table 1 Production and distribution challenge categories

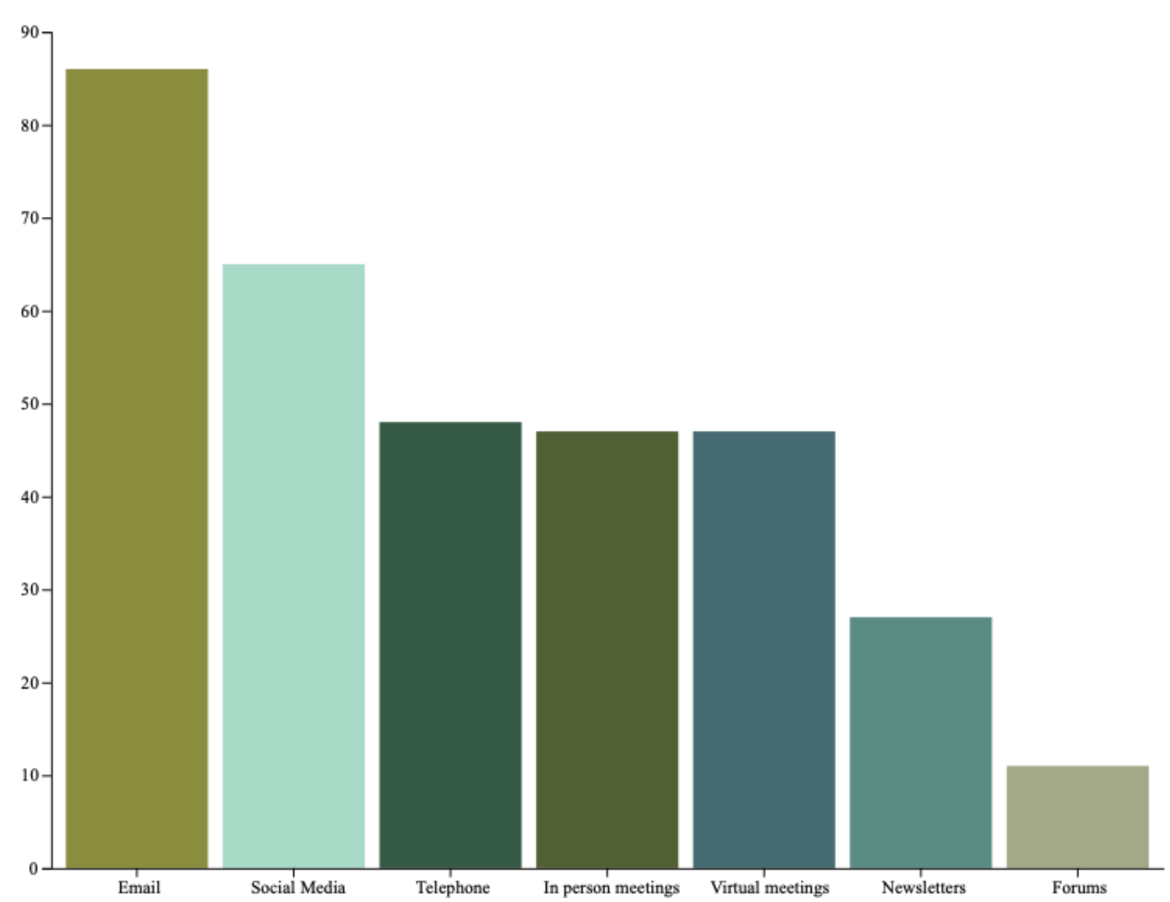
Challenge type	**Examples**
Environmental	*Weather, soils*
Technical	*Equipment and supplies*
Social (workforce)	*Farm labour, health and safety*
Financial	*Costs, insurance*
Sales and marketing	*Unpredictable demand, facilities*
Logistics	*Vehicles*
Social (customer relationships)	*Health and safety sales, relationship with customers*



SI Figure 1 Distribution of local farmers in percentage. The majority of farmers (60%) delivered directly to consumers (e.g., Upick, farm store, subscription) as well as to intermediaries (e.g., restaurants, supermarkets, stores). Close to a quarter of respondents sold to consumers only and every tenth exclusively to intermediaries.



SI Figure 2 Farms with lower crop diversity often sold their food through their farm store, supermarkets, independent grocery stores, restaurants, farmers and public markets, and by offering U-pick. Those with a bigger variety of crops tended to sell their food primarily to restaurants, or distribute their food through subscriptions, farm stores, and markets.



SI Figure 3 Communication Tools. Most farmers used e-mail to communicate with their support network, followed by social media, in-person meetings, phone, and virtual meetings. Few received help through newsletters and forums.

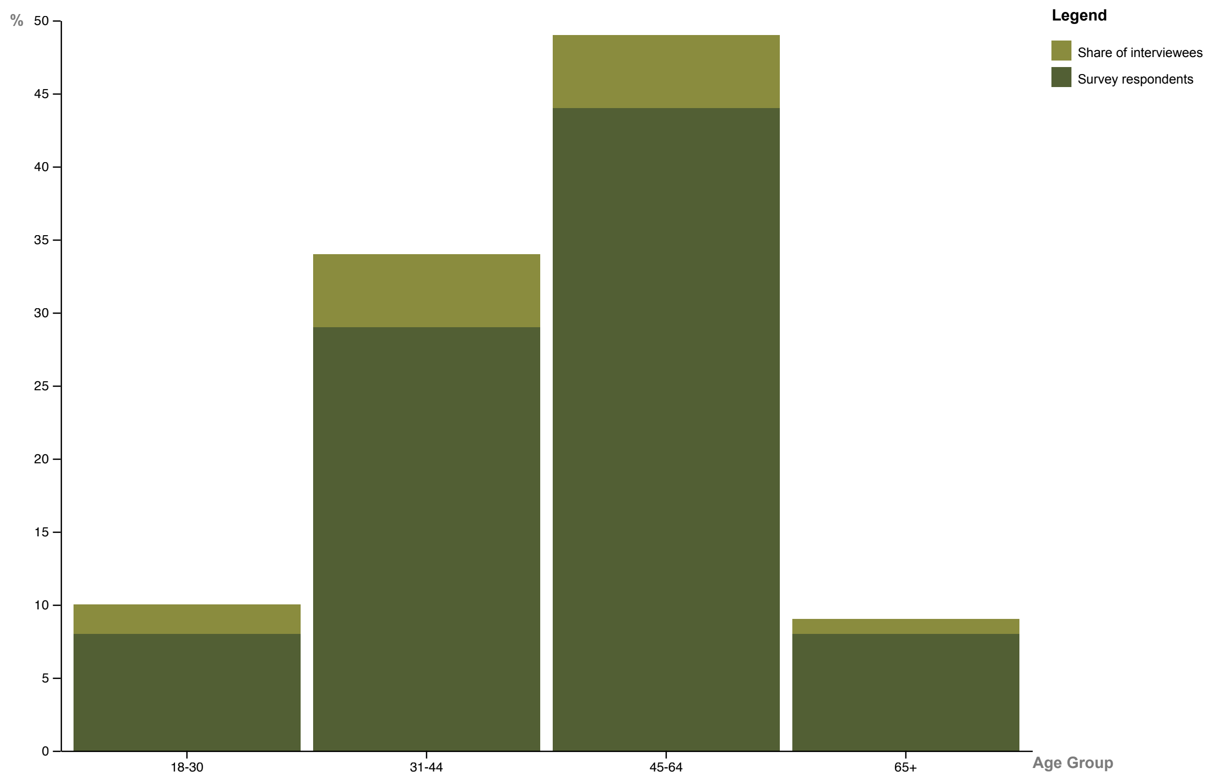
11.4 Appendices for Chapter 6

Appendix A. and B. is the same as "SI 1 Questionnaire and interview guide (simplified)"

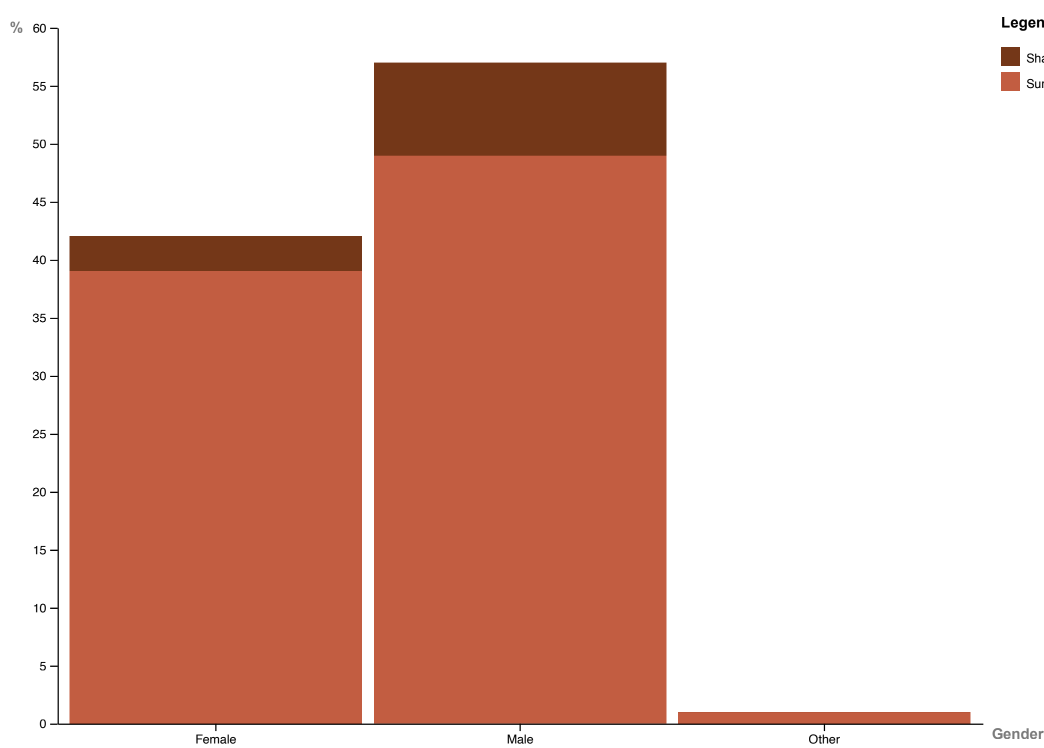
Appendix C: Farm demographics for survey (n=133) and the interviews (n=15)

		Surveys	**Interviews**
Status	*Farm Owner*	84%	86%
	Farm Manager	12%	0%
	Both	13%	13%
Cultivated area	*Average*	112 hectares	15 hectares
	Min	<1 hectares	<1 hectares
	Max	3,642 hectares	80 hectares
Farm age	*Average*	23 years	12 years
	Min	1 year	2 years
	Max	113 years	49 years

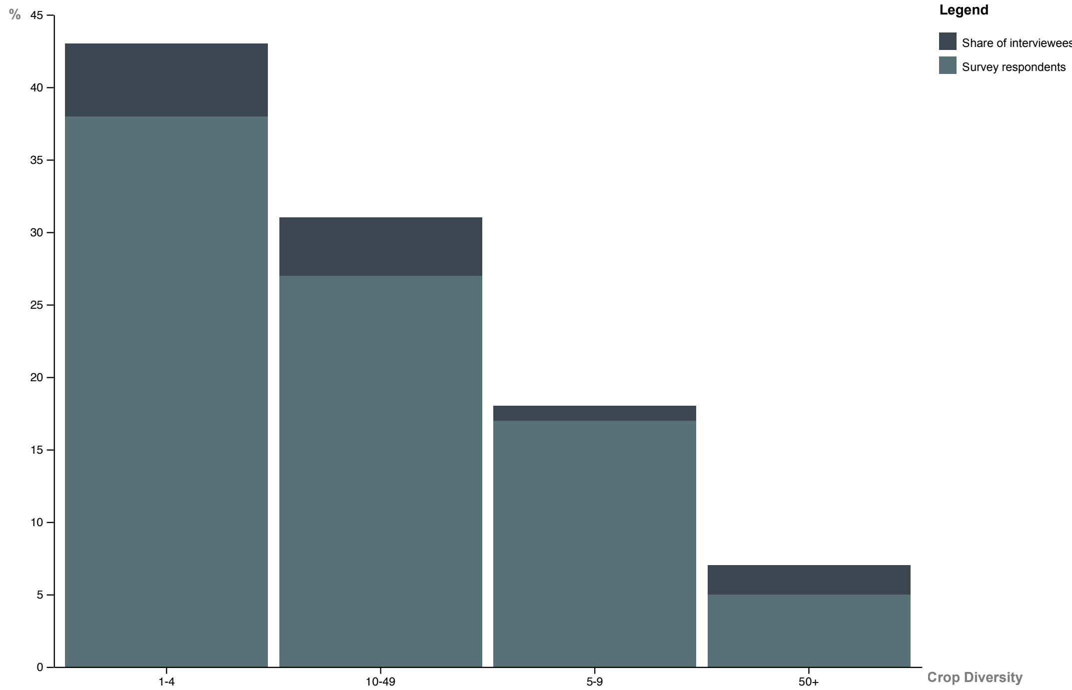
Appendix D. Farmer age distribution survey (n=133) and the interviews (n=15)



Appendix E. Farmer gender distribution survey (n=133) and the interviews (n=15)



Appendix F. Number of cultivated crops for survey (n=133) and the interviews (n=15)



Appendix F. Types of cultivated crops for survey (n=133)