

Doctoral Dissertation:

Fostering sustainable food systems: A case study of Comox Valley, British Columbia

By

Mohaddese Ghadiri

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of

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We acknowledge and respect the Ləkʷəŋən (Songhees and Esquimalt) Peoples on whose territory the university stands, and the Ləkʷəŋən and W̱ SÁNEĆ Peoples whose historical relationships with the land continue to this day.

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Abstract

Food systems are complex and interconnected with environmental sustainability, climate change, biodiversity, and human health challenges. Global food systems faces numerous challenges, including climate-induced disruptions, biodiversity loss, and growing public health concerns that threaten long-term food security and sustainability. This case study of the Comox Valley region of British Columbia, Canada, applies a climate-biodiversity-health (CBH) nexus framework to promote sustainable and resilient food systems. Integrated planning approaches and frameworks, such as the CBH nexus, are crucial to addressing these multidimensional challenges and creating holistic solutions for local and regional food systems. This is a paper-based dissertation that consists of three academic publications (two of which have been published and one that is under review).

This thesis is structured as three connected papers. The first paper adapts and applies the CBH nexus as a framework for integrated food systems planning, exploring the critical intersections between climate action, biodiversity conservation, and human health. It employs a qualitative, place-based approach to understand how food systems in the Comox Valley interact with these three domains. Through semi-structured interviews with regional stakeholders, the research identifies key challenges, strategies, and opportunities for aligning local food systems with broader sustainability goals. The study demonstrates the applicability of the CBH nexus to local planning efforts and highlights its potential for fostering resilient food systems in diverse community contexts.

The second paper uses participatory system mapping techniques to clarify the complexity of food systems, operationalising the CBH nexus. The study engages local stakeholders in the Comox Valley, including government, civil society, and agriculture representatives. The research demonstrates that participatory methods enhance stakeholder engagement and improve the relevance and practicality of the CBH nexus framework by grounding it in local knowledge and experiences. The findings of this paper reveal the multifaceted nature of food systems and underscore the importance of including diverse stakeholder perspectives in the planning process. The system mapping process helps visualize how different food systems strategies align or conflict with CBH objectives, offering a clear picture of the system and action-supporting tool for community planning.

The final paper applies the CBH nexus to a policy evaluation of local food systems strategies in the Comox Valley. It analyzes existing regional policies, programs, and plans, identifies gaps and opportunities for more integrated and sustainable approaches to food systems planning. The research highlights the importance of aligning food system policies with climate action, biodiversity conservation, and public health objectives. While several promising initiatives have been implemented, the findings suggest that more work is needed to integrate these three domains fully into local planning efforts. The CBH nexus offers a valuable framework for understanding the co-benefits and trade-offs of different food system strategies and identifying areas where policy improvements can be made.

Overall, this dissertation contributes to the growing knowledge on sustainable food systems by providing a comprehensive framework for integrated planning. The CBH nexus offers theoretical insights into the intersections of food systems, climate, biodiversity, and health and serves as a practical tool for guiding policy development and community-based planning. The research demonstrates the value of participatory approaches and provides actionable recommendations for fostering resilient, sustainable, and equitable food systems.

Keywords: Climate-Biodiversity-Health nexus, food systems, sustainability, resilience, participatory system mapping, integrated planning.

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Chapter 1: Introduction

1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) (2023) finds that there is a more than 50% chance that global temperature rise will reach or surpass 1.5 degrees Celsius (2.7 degrees F) between 2021 and 2040 across studied scenarios, and under a high-emissions pathway, the world may hit this threshold even sooner — between 2018 and 2037. This rise in temperature will result in increased frequency of extreme weather issues like extreme heat, heavy precipitation events, and strong storms (Collins et al. 2013 as cited in Rotz & Fraser, 2015). Climate change will also result in phenological effects like an increase in the growing season length (Právělie, 2018), catastrophic impacts on natural and ecological systems like increases in mean temperature in most land and ocean regions, and the probability of drought and changes in precipitation patterns (Masson-Delmotte et al., 2019).

The effects of climate change impact various aspects of society in different ways, including food systems (Masson-Delmotte et al., 2019). Food systems consist of the processes of food production, aggregation, processing, distribution, consumption, and disposal, as well as the interactions of all related actors and activities with these processes. They can be defined on different scales: global, national, regional, and local. Food systems have similar components at all scales and across the work, but they differ due to cultural, environmental, economic, and social differences among various scales and places (von Braun et al., 2021). Global food systems refer to the existing world food systems in which areas with favourable agricultural conditions engage in food production, and different areas produce specific kinds of products depending on their competitive advantages in global food markets. In contrast, local food systems are often developed with the goal of diversifying food production and supply to meet the food needs of local populations (Rotz & Fraser, 2015).

Food systems have impacts on environmental sustainability and human health (Ahmed et al., 2019; Willett et al., 2019). There is a bidirectional relationship between food systems and the environment. Food systems are influenced by environmental issues, pollution, climate change, and consequences like biodiversity loss, water shortage, and soil infertility (Ahmed et al., 2019). On the other hand, food systems can cause environmental issues “from topsoil loss and food packaging waste to unsustainable levels of greenhouse gas emissions and water pollution” (Horst, 2017, pg. 52). Agricultural yields depend on natural and ecological health (Rotz & Fraser, 2015). However, agricultural production is the greatest threat to freshwater habitat and resources due to its water usage (70% of global water consumption), the amount of land that it requires (about 34% of ice-free land surface) and the harmful inputs, like pesticides and fertilizers that can damage freshwater and coastal ecosystem (Dalin & Outhwaite, 2019; Liverman & Kapadia, 2012; Ramankutty et al., 2008). Food production can be affected by biophysical influences like the quality of soils and water (Liverman & Kapadia, 2012). Food waste contributes to methane emissions, an increase in fossil fuel usage (and thus CO₂ emissions), and freshwater consumption, which impacts the environment and contributes to climate change (Hall et al., 2009).

Food systems in many places are neither resilient nor sustainable. In North America, agricultural industrialization has led to the reduction of crop diversity, an increase in pesticide usage, and a loss of soil fertility (Rotz & Fraser, 2015). Agricultural industrialization has also led to farm

consolidation and a great reduction in smaller farms. In Canada, the number of small farms has been decreasing rapidly since 2011, while the remaining farms have grown in size (Statistic Canada, 2022). This farm consolidation and industrialization negatively influence food production and accessibility by causing long distances between the places where foods are produced and where they are consumed, increasing supply chain distance and thus its vulnerability to environmental, economic, and political shocks. Industrialized farming practices, economies of scale and competitiveness and the regulatory environment for farming and agricultural products have made it increasingly challenging for small farms to survive (Rotz & Fraser, 2015).

Food systems sustainability involves “food security and nutrition for all in such a way that the economic, social, cultural, and ecological bases that generate food security and nutrition for future generations are safeguarded” (von Braun et al., 2021, p. 748). Various actions and policies have been adopted to strengthen food systems. For example, 225 cities globally have signed the Milan Urban Food Policy Pact (MUFPP) to “develop sustainable food systems that are inclusive, resilient, safe, and diverse, that provide healthy and affordable food to all people in a human rights-based framework, that minimize waste and conserve biodiversity while adapting to and mitigating impacts of climate change” (Milan Urban Food Policy Pact, 2015, p. 2). Canada has developed the Food Policy for Canada to support sustainable food systems (Agriculture Canada, 2022) . Some Canadian cities like Vancouver have signed MUFPP and made various policies under this agreement to achieve these goals (Valley & Wittman, 2019).

Although valuable efforts toward food systems sustainability and resilience have been made, more work needs to be done (Valley & Wittman, 2019). Integrated and multi-scale food systems approaches to planning and policy need to be implemented to consider food issues in the same manner as other subjects of planning and to develop plans and policies with consideration of their interactions and links among different levels of government. These types of approaches to planning and policy can improve food system resilience and sustainability (Horst, 2017; Pothukuchi & Kaufman, 2000).

2 Literature review and background

The lack of accessibility and availability of quality foods, i.e., food insecurity, is an issue of global importance (Ford, 2009; Pollard et al., 2018). According to the World Health Organization (2024), 733 million people, or one in 11 people, globally faced chronic hunger in 2023. In Canada, the percentage households encountering food insecurity rose from 15.9% in 2021 to 17.8% in 2022 representing 6.9 million people, including almost 1.8 children (*PRCOF*, 2023).

The drivers of food insecurity include unsustainable food systems (Capone et al., 2014), climate change (Hasegawa et al., 2018), changes in dietary habits (Bin Zarah et al., 2020), socioeconomic issues like inequality and poverty (Elmes, 2016), and poor land use planning (Agidew & Singh, 2017; Kuusaana & Eledi, 2015; Oba, 1991). Climate change, industrial farming, a decrease in farmers’ authority, and prioritizing market interests over producer interests in policymaking are all factors that have led to unsustainable food systems (Rotz & Fraser, 2015).

Identifying and implementing strategies for ‘sustainable local food systems’ can address food systems’ challenges. Sustainable local food systems are developed through collaborative efforts to build more localized and self-reliant food systems and economies. Such efforts consider human health and the environment, and they aim to enhance the local economy, local food production and distribution, and local participation in community life (Peters, 1997). Decentralization, localization, and diversification of food systems can address some of the shortcomings of global food systems (Connelly, 2014; Toldo, 2015) (see Figure 1).

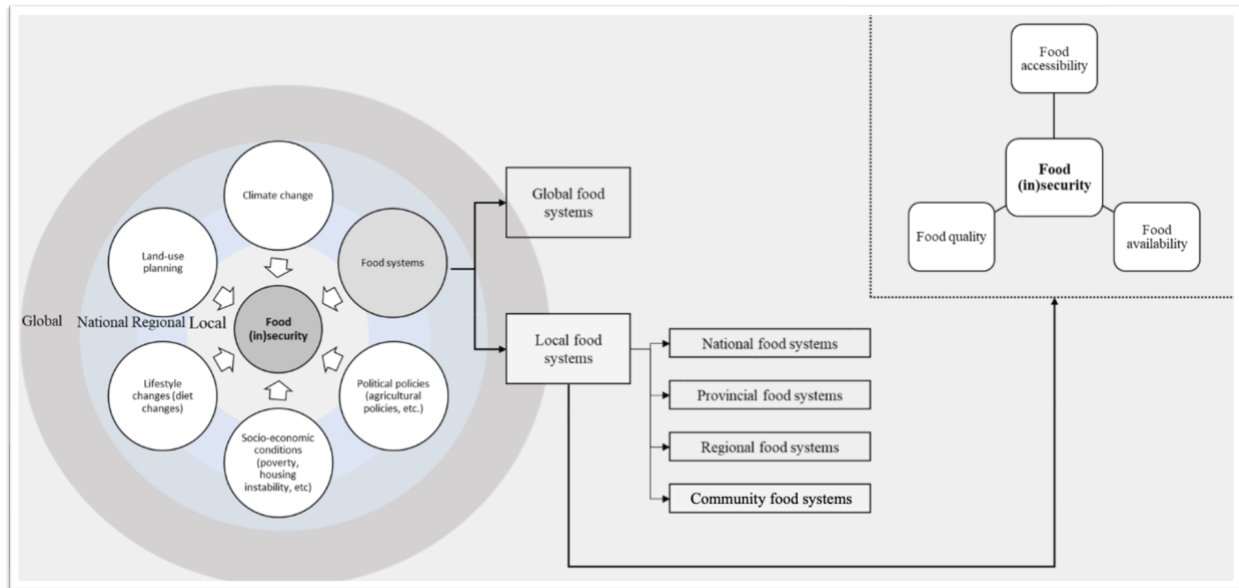


Figure 1. Theoretical framework

Sources: Agidew & Singh, 2017; Bin Zarah et al., 2020; Capone et al., 2014; Elmes, 2016; Ford, 2009; Hasegawa et al., 2018; Rotz & Fraser, 2015.

How are sustainable food systems developed and fostered? Do such systems involve high-yield indoor urban agriculture (e.g., Gnauer et al., 2019; Marchant & Tosunoglu, 2017), partnerships between urban, peri-urban, and rural areas (e.g., Knieling et al., 2017), a circular economy for food (e.g., Ellen MacArthur Foundation, 2019), etc.?

Research on community and regional food systems commonly identifies a lack of comprehensive and integrative perspectives in local planning and policy making (Hammelman et al., 2020; Issac et al., 2022). Food systems studies have produced significant insights into the benefits and challenges of different agricultural strategies and approaches. For example, the role of local strategies in improving access to food assets (Block et al., 2012; Toth et al., 2016), the role of ecosystem services in food systems (Nyanga et al., 2020), the importance of social interaction and local employment in improving local food production and economies (Seyfang, 2006; Valley & Wittman, 2019) and, the trade-offs between agricultural yield and ecosystem health (e.g., Egan & Mortensen, 2012; Phalan et al., 2011; Law & Wilson, 2015).

Integrated perspectives are essential for local and regional food systems planning (Blay-Palmer et al., 2016). They can help to comprehensively understand the benefits and trade-offs of different food strategies and approaches, thus enabling effective transitions toward local sustainability. Local food systems are complex, involving interactions among humans, the built environment, ecosystems, and the food system processes that occur from food production to access and consumption (Ericksen, 2008).

Frameworks have been developed to help scholars and researchers examine and develop approaches to integrated planning, such as the water-energy-food, water-food-energy-climate (Beck & Walker, 2013), and water-energy-food-environment (Hellegers et al., 2008) nexuses. Some argue such frameworks can be helpful in understanding how to implement sustainable community development (Galderisi, 2017; Hoff, 2011; Sperling & Berke, 2017). However, others have identified the shortcomings in these frameworks and their practical value, discussing them as ambiguous in terms of how they are applied to local planning and policy (Cairns & Krzywoszyńska, 2016). There is a need for clear and comprehensive practitioner methods to support day-to-day planning and policy implementation (see Figure 2).

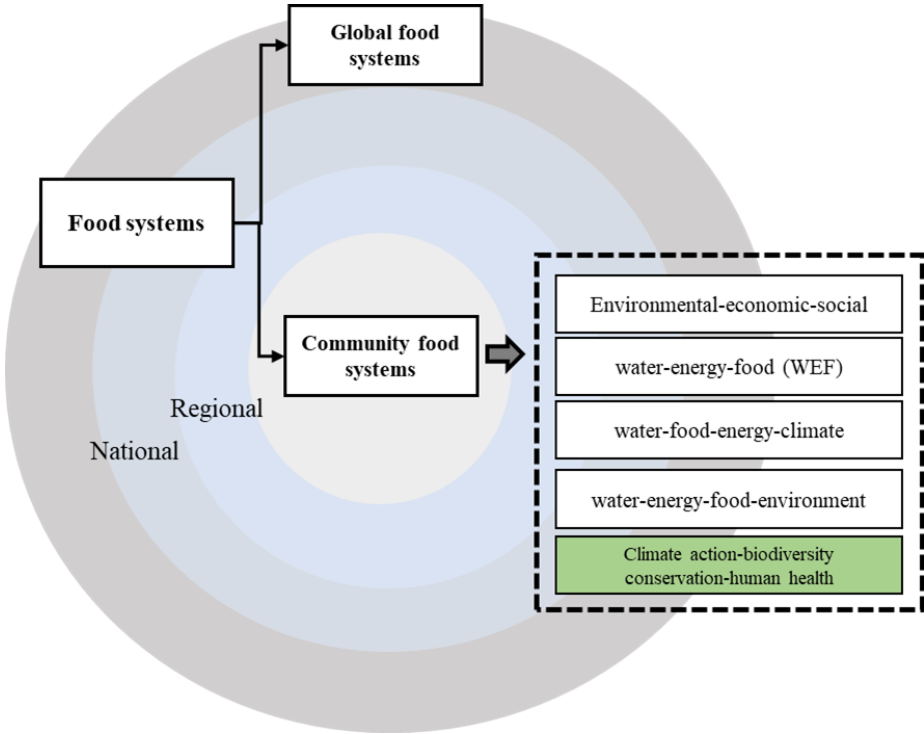


Figure 2. The conceptual framework

Sources: Beck & Walker, 2013; Hellegers et al., 2008; Galderisi, 2017; Hoff, 2011; Sperling & Berke, 2017; Newell et al., 2022.

A climate action, biodiversity conservation, and human health (CBH) nexus framework presents invaluable opportunities for identifying and implementing integrated strategies that mutually support one another (see Figure 3). For example, urban and pre-urban agriculture can preserve ecosystem services in urban areas (Wilhelm & Smith, 2018), and urban farms can serve climate

adaptation functions similar to green infrastructure in managing surface run-off and regulating local temperatures (Spencer et al., 2017). Eco-agricultural practices can be implemented in local farms to provide vegetation for supporting pollinators (Scheer & McNeely, 2008). Additionally, climate action strategies aimed at reductions in GHG emissions and pesticide usage benefit human health since they lead to healthier food production (Hanson, 2020). Local and urban agriculture can support climate action and biodiversity conservation/enhancement by reducing food imports (Newell et al., 2018) and contributing to pollinator relationships (Reynolds et al., 2019), while also contributing to mental and physical health by providing opportunities for social interaction (Seyfang, 2006) and a supply of local nutrition (Spencer et al., 2017). Healthy global diets and nutrition support human health objectives and also climate mitigation and biodiversity conservation (Willett et al., 2019).

Exploring the intersections of the CBH nexus provides opportunities for understanding which food systems strategies can produce co-benefits for broader sustainability objectives, as well as reveal systems interactions surrounding critical sustainability issues (see Figure 4). For example, land use from current large-scale industrial agriculture and food processing practices is linked to climate change, loss of habitat and biodiversity, and increased health problems like obesity (IPCC, 2019). It is essential to consider that although the CBH nexus provides a valuable lens for understanding effective integrated strategies, these strategies can have trade-offs and problems. This happens with strategies that have economic implications; for example, trade-offs can be seen with competing land uses, where agriculture competes with habitat conservation (Turner et al., 2014). Economic co-benefits of climate action, biodiversity conservation, and health strategies have been researched (IPBES, 2019; IPCC, 2018; MEA, 2005; Nemet et al., 2010; Stern, 2007), but trade-offs can also occur in CBH and food systems. For example, climate change mitigation policies aimed at pesticide and GHG emissions reductions can lead to lower food crop yields, an increase in food price, and impacts to food affordability (Nyanga et al., 2020). Focusing on improving food security at the expense of habitat and biodiversity can lead to overuse of land and expansion of agricultural lands (Hanspach et al., 2017). These examples highlight how trade-offs can occur with climate action, biodiversity conservation, and food systems strategies and goals.

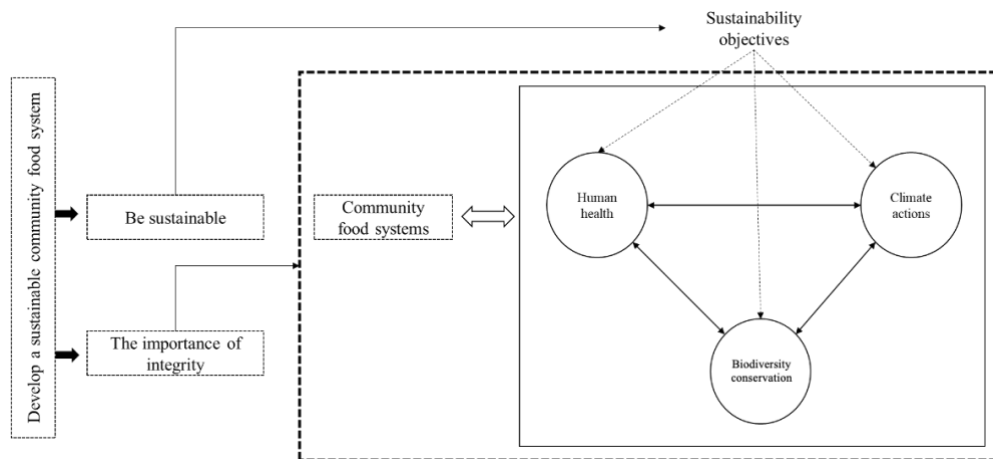


Figure 3. The analytical framework
Source: Author.

This research applies the CBH nexus to local and regional food systems, using the Comox Valley as case study. This region was selected as a case study for the following reasons:

- I. The presence of food and CBH-related organizations, plans, and strategies;
- II. The presence of local agricultural lands and;
- III. It is feasible to conduct in-person interviews and meetings with stakeholders and visits to the community.

The Comox Valley region is in the northern part of Vancouver Island encompassing an area of 1700 km² and having a total population of 70,039 in 2021 (see Figure 4)). This region is the traditional territory of the K'ómoks First Nation and includes Comox, Comox Valley, Courtenay, Cumberland, and Puntledge (*Comox Valley Regional District, Canada, 2022*). Agricultural land uses constitute about 14% of the Comox Valley region (23,429 hectares), including small and large farmlands (Ministry of Agriculture, 2014).

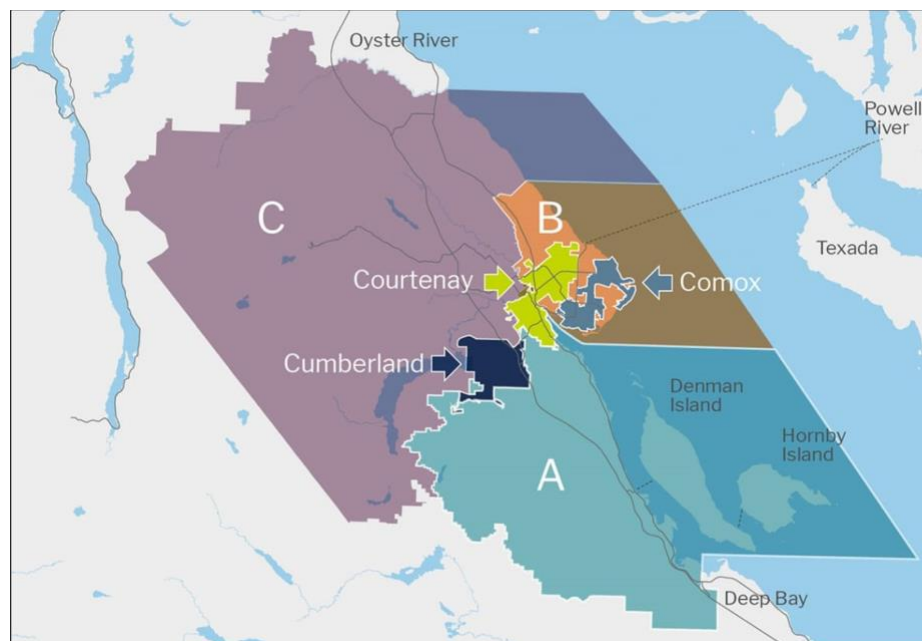


Figure 4. Comox Valley region, Vancouver Island

Sources: (*Electoral Areas, Member Municipalities & First Nations | Comox Valley Regional District, 2022; VCH - OASIS - Listing of Community Services Map - Vancouver Island, 2022*).

Comox Valley communities participate in the Partners for Climate Protection program run by the Federation of Canadian Municipalities (2008). In addition, climate action, biodiversity conservation, and local health are referenced in the region's sustainability plan, the Comox Valley Sustainability Strategy, which includes plans for the Comox Valley Regional District, Village of Cumberland, Town of Comox, and City of Courtenay (Comox Valley Regional District, 2010). For such reasons, the region serves as a good case study for the application of the CBH nexus.

3 Research objectives and questions

The proposed research uses the CBH nexus to develop a holistic, multidimensional, and comprehensive analytical framework for identifying relationships, co-benefits, and trade-offs among climate action, biodiversity conservation, and community health in the context of local food systems. The research experiments with and applies the framework to advance practices in integrated food systems planning, sustainable community development, and resilience. This indicates a need for developing tools to support integrated approaches to regional planning and policy.

This research aims to build an understanding of how communities can better engage in integrated food systems planning and policy and to develop tools for supporting these efforts. This dissertation is a part of the larger project named “Climate-Biodiversity-Health Nexus” research project (TRIAS, 2024), and aims to address three questions:

- (1) How do CBH nexus objectives and strategies support or conflict with local food systems objectives?
- (2) How can a CBH nexus approach identify co-benefits and trade-offs of local food strategies?
- (3) How can a CBH approach reveal areas of integration identified and gaps in local plans?

4 Methodology

This research employs a pragmatic paradigm and a community-based participatory approach (Vaughn & Jacquez, 2020). The research engages provincial, regional, and local governments and community stakeholder groups and it applies the CBH nexus framework to the Comox Valley Regional District. The study consists of three phases, each with its own set of methods:

- i. stakeholder interviews and systems mapping;
- ii. workshops and analytical framework development, and
- iii. framework application and document analysis.

5 Research design and methods

5.1 Research approach

This research project employs a qualitative research design. The case study research method explores the interactions between CBH strategies and community food systems, as well as how systems interactions vary across different communities. Realizing the features of the case and the influences of policies on the challenges requires studying each communities’ situation separately. The case study method facilitates rich and context-specific understandings of an in-depth phenomenon.

This research employs a community-based participatory research (CBPR) approach—a bottom-up, problem-oriented, and context-based research approach. CBPR starts from a specific reality, issue, or problem and engages stakeholders’ involvement in understanding it holistically, as well as developing new plans and policies to address issues. Collaboration, diversity, and power and knowledge sharing are the features this approach focuses on (Hall, 1992). CBPR aims to explore

human problems and improve their living conditions. As done in this research, qualitative methods are common in the CBPR approach (Leavy, 2017).

5.2 Research methods

5.2.1 Data collection

The data collection involved three different activities: i) semi-structured interviews, ii) workshops, and iii) document analysis. A semi-structured interview method was used to determine the current strategies of other players, the co-benefits and trade-offs of CBH strategies, and the related internal documents. This method provided a flexible structure by which I could manage the interview and explain what the interviewees discussed to gather the needed documents for collected documents for the document analysis done in the third study in this project. It also helps to achieve rich data since interviewees' answers could be extended and opened room for follow-up questions.

Participant recruitment involved reaching out to food system stakeholders in the Comox Valley region including NGOs, community leaders, and community associations whose areas are related to food, climate action, biodiversity conservation, and human health in the Comox Valley (Figure 5). All study participants engaged in the research in their official capacities on behalf of their organizations. Participants were identified via an Internet search. A snowball sampling method was also used in interviews to identify other possible stakeholders, meaning invited participants were asked to suggest others interested in participating in interviews. All participants were contacted using their publicly available contact information. An invitation email and two further follow-up emails were sent to each stakeholder. Interviews continued until research achieved saturation (Dworkin, 2012).

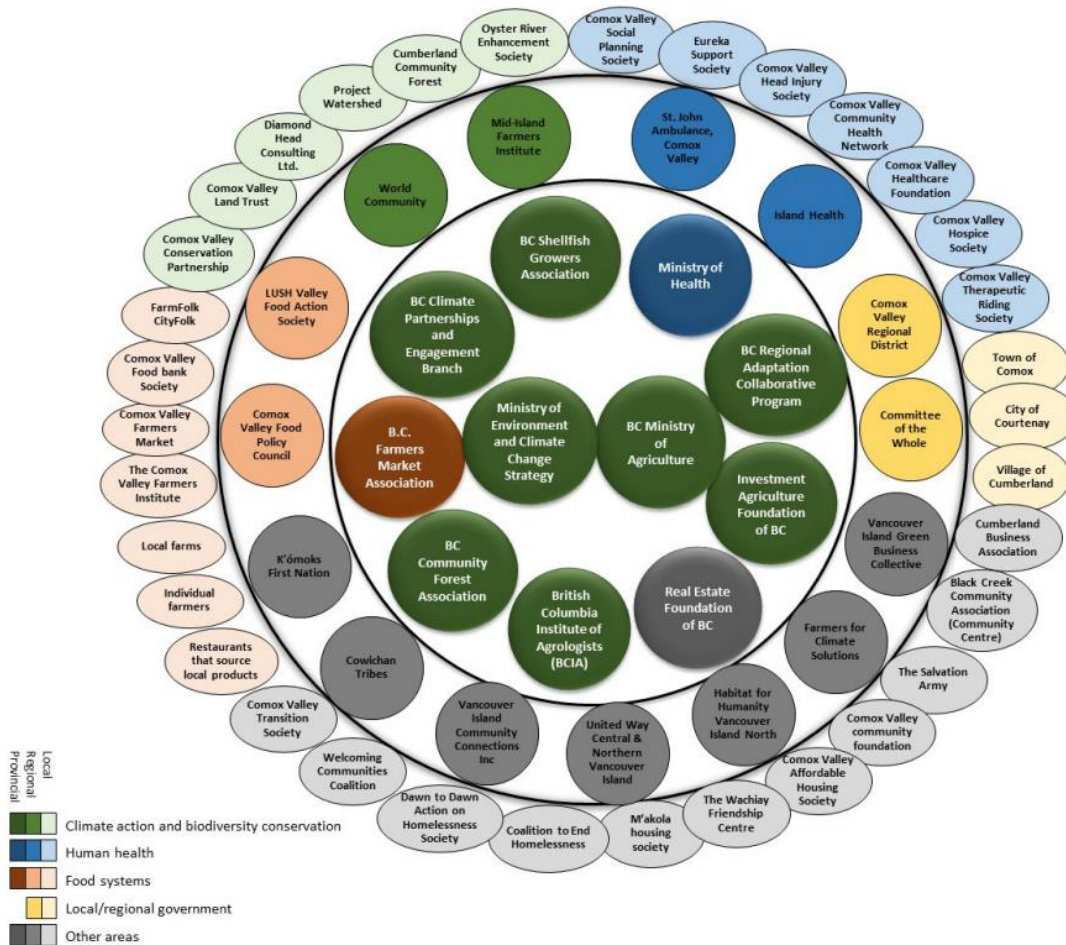


Figure 5. Key stakeholders
 Source: Own elaboration based on stakeholder mapping.

An interview protocol was developed (Appendix 1). The protocol includes a brief description of the research project, the interview process, confidentiality and data treatment, and the key themes and questions. It was sent to all research participants in advance of the interviews.

The confidentiality of the interview and survey participants' identities was ensured. All participants received consent forms to sign and were free to decline to participate in the research. In addition, the consent forms explained that participants can withdraw from the study and have their thoughts/input removed from the data, as long as their data had not yet been analyzed for publications. The protocol for participants withdrawing involved first, the participants contacting me, and then, removing their responses from the study. No participant reached out to me with a request to withdraw.

In total, 33 interviews were conducted online using the Zoom video-conferencing application. Each interview lasted approximately 45 minutes to 1 hour. Interview data were transcribed using the Trint transcription application. Transcript data contained participant IDs, and a database with full names and affiliations associated with the pseudonyms/IDs were stored in a separate

document. Data were saved on my personal computer. Data are stored until the end of my dissertation project (end of December 2024).

A series of seven workshops, involving three to nine participants, were held to examine, revise, and finalize the analytical framework developed from the interview data. All interviewees were invited via email to workshops. A consent letter was sent to participants before the workshops. During the workshop, participants were free to withdraw at any point. The protocol for participants withdrawing involved first, the participants contacting me, and then, removing their responses from the study before the study results are published. No participant reached out to me with a request to withdraw.

The study was reviewed and received approval from the Human Research Ethics Boards at the University of Victoria, as well as universities collaborating in the larger Climate-Biodiversity-Health Nexus research project: the University of the Fraser Valley and Royal Roads University. Participants were given consent forms to review and sign prior to participating in this study. The letter contained information on the purpose of the study, procedures to maintain anonymity and confidentiality, benefits and inconveniences to research participants, and withdrawal procedures.

5.2.2 Sampling method

I used purposive sampling for this study. Interviewee stakeholders were identified based on web searches, and invitation emails were sent to them. A snowball sampling method was used in interviews to reach other possible stakeholders. Interviews were conducted with key stakeholders to ensure a sectorally and professionally diverse representation of perspectives. The number of interviews were determined upon saturation (Dworkin, 2012), establishing that no new information is being obtained. Every effort was made to be comprehensive and include diverse perspectives essential to understanding food insecurity and the CBH nexus.

5.2.3 Data analysis and integration

This was an inductive study. In this research, I aimed to gather all the needed data to realize the co-benefits and trade-offs of CBH strategies. No theory was tested; instead, the research used data gathering and analysis to develop a theory (i.e., the application of the CBH framework to food systems issues) (Bryman & Bell, 2019).

The dissertation consists of three papers, and each paper uses different analytical methods. In the first paper, qualitative analyses were used to analyze the interviews and develop an analytical framework using the CBH nexus. As described in the second paper, the framework was then reviewed, revised, and finalized through a series of workshops. The third paper applied the analytical framework and used qualitative content analysis techniques to examine community plans in the case study region.

5.2.3.1 Methods to develop the analytical framework

I used interpretive qualitative analysis for this research. I also used an inductive coding approach, where codes were not preconceived and were instead derived based on interview transcripts. Thematic coding for this study was done to code each transcript based on the interviewee's

words. In the next step, I categorized the established codes and used thematic analysis coding for the second-round coding. NVivo software was used for the analysis (Delve, 2022). The results provided the basis for developing an analytical framework, prepared in the form of a systems map that can provide insights for integrated planning.

To finalize the developed analytical framework for supporting integrated planning in the Comox Valley, workshops were conducted in person and online using the Zoom video-conferencing application. In the workshops, I introduced the study, reviewed the consent letter (and invited participants to ask questions), and presented the research findings, including the initial iteration of the analytical framework. Then, I asked participants to review the first version of the analytical framework and provide feedback on refining it to better represent local and regional concerns and realities in the framework. The results of this work were used to revise and finalize the framework.

5.2.3.2 Document analysis

Qualitative content analysis (Krippendorff, 2018) using NVivo software was done on local plans developed by the communities in the Comox Valley. Content analysis enabled an in-depth analysis of the local plans, and better understand how much the internal documents consider CBH co-benefits and trade-offs with respect to food systems plans and goals.

5.2.4 Validity and reliability

The framework developed from the interview study was presented to the participants in the workshop. Any errors or gaps in the analysis and outcomes of the interview study were addressed (with respect to developing the analytical framework) through these workshops. For the content analysis, the framework was applied and the analysis was done twice to verify results.

5.3 Dissertation structure and contents

This document presents a paper-based dissertation structured with main chapters: the introduction chapter, three academic papers, and an overall conclusions chapter. In this introduction chapter, a literature review and background about food systems and their interactions with climate actions, biodiversity conservation, and human health was presented. The papers are written as academic articles submitted for peer-review and publication, and they respectively focus on (1) using a CBH lens to examine challenges and opportunities for food systems strategies, (2) developing an analytical framework for the CBH nexus and refine through workshops methodology, (3) analyzing related documents using the developed framework. A summary of each paper is provided in the following paragraphs.

The first paper employs an interview method to examine climate action, biodiversity conservation, and local health strategies in the Comox Valley region and develops an analytical framework using the CBH nexus. The case study involved semi-structured interviews with

representatives from provincial, regional and local governments, NGOs, and community associations (e.g., Burch et al., 2014). The interview protocol was designed to identify local concerns and issues related to climate change, biodiversity, and community health and the successes, benefits, challenges, and barriers associated with plans and strategies for addressing these issues (e.g., Dale et al., 2019; Shaw et al., 2014). Interview data were thematically coded (Gibbs, 2007; Seidel & Kelle, 1995) and analyzed to identify areas of overlap and conflicts within the CBH nexus, outcomes, and common barriers associated with implementing plans and executing strategies pertaining to food systems. The results were used to develop a framework that presents different food-related strategies, the outcomes of these strategies, and the systems interactions among the different strategies and outcomes.

The second paper presents work done to revise and finalize the framework with the participation of stakeholders. A series of workshops were held with local and regional government and community stakeholders. Based on discussions with participants, the systems map was refined to represent better local concerns and realities (e.g., Newell et al., 2020; Newell & Picketts, 2020), making it a more useful analytical tool for the case study.

The third paper uses document analysis methods to realize co-benefits and trade-offs of climate action, biodiversity conservation, and local health strategies in local and regional plans. In this paper, the related plans of Comox Valley were analyzed based on the CBH framework developed in the first paper to reveal the plan's gaps in terms of climate, biodiversity, health, and food sustainability objectives. These plans include official community plans, a comprehensive community plan, and the regional growth strategy for the Comox Valley. The outcomes of this phase are beneficial to Comox Valley governments and stakeholders in terms of informing the development holistic and comprehensive plans.

6 Knowledge contribution

Developing sustainable and resilient food systems is crucial to achieving food security (Schipanski et al., 2016). Despite the existence of research about the role of decentralization and localization in achieving sustainable and resilient food systems (Reynolds et al., 2019; Rotz & Fraser, 2015; Mendes et al., 2008), studies have not explained how best to do this. This study aims to address this gap by applying the CBH nexus to local food systems planning in Canadian communities. This framework comprehensively understands the benefits and trade-offs of different food strategies and approaches to enable effective transitions toward local sustainability. Canadian practitioners can use the nexus framework in community planning to gain a more effective, multi-dimensional, and holistic view of sustainable food systems.

The CBH nexus deliberately incorporates key strategic planning areas (e.g., climate action, biodiversity conservation, and community health) to serve as a goals-oriented framework for

providing clear direction for integrated planning and (in the case of this research) food security. This research examines its value as a potentially useful means for developing local food systems in a holistic manner, that is, in a way that recognizes and aligns with broader sustainable objectives.

The proposed research contributes valuable theory and scholarly insights to the fields of integrated planning and sustainable community development. The work also results in practical outcomes with the potential to support and enhance community planning practices. The evaluation tool applied in the third paper in this dissertation is publicly available for practitioners to use for their planning needs, accompanied by a report on its development and application prepared for non-academic audiences (Ghadiri et al., 2023).

The analytical framework developed through this study was done for Comox Valley specifically; however, this research can serve as a pilot for other cases across Canada for future studies. The research framework can be used by policymakers across Canada to better understand the potential outcomes of their policies in terms of different aspects of sustainability and whether their proposed policies may actually result in sustainable food systems.

The research contributes valuable insights to integrated planning and sustainable and resilient food systems scholarship. Paper 1 and 2 have been published in academic journals (respectively, *Journal of Environmental Management and Challenges*). Paper 3 has been submitted for publication and is currently under review. In addition, two reports have also been published based on the results of this research and the larger Climate-Biodiversity-Health Nexus research project (Ghadiri et al., 2022, 2023).

Chapter 2: Applying a climate-biodiversity-health framework to support integrated food systems planning and policy

Ghadiri, M., Krawchenko, T., & Newell, R. (2024). Applying a climate-biodiversity-health framework to support integrated food systems planning and policy. *Journal of Environmental Management*, 358, 120769. <https://doi.org/10.1016/j.jenvman.2024.120769>

Abstract

Food systems impact sustainability and human life, such as pollution, health, climate change, biodiversity loss, water shortage, and soil infertility. However, in many places, food systems are neither resilient nor sustainable. Integrated planning approaches can help overcome fragmented strategies and policies to improve the sustainability and resilience of food systems. This study explores such an approach by applying a *climate-biodiversity-health (CBH) nexus* to local and regional food systems in the Comox Valley region, British Columbia, Canada. The CBH nexus is used as an analytical lens to identify systems relationships among food systems, climate change, biodiversity and health issues and strategies in the region. The employs a place-based approach entailing semi-structured interviews with provincial, regional, and local stakeholders to develop a holistic understanding of planning challenges, strategies and their outcomes through the CBH lens. Outcomes of this work include a system map that can be used as a framework for elucidating how various strategies align or conflict with different CBH imperatives and can be used to support integrated community sustainability planning and policy-making efforts. The framework is developed within the Comox Valley context but can be adapted to other communities. This paper details the development of this framework, the interconnections between different components, and how this framework can be adopted in other communities.

Keywords: CBH nexus, food systems, sustainability, integrated planning

1 Introduction

Food systems are complex, multi-scaled and are increasingly under stress. Food systems consist of the production, aggregation, processing, distribution, consumption, and disposal of food products, and they involve diverse actors and activities operating at local, regional, national, and global scales (Issac et al., 2022; Lowan-Trudeau et al., 2020; von Braun et al., 2021). Climate change is at the forefront of threats facing food systems today as it increases the length and severity of heat events, changes patterns in precipitation, and contributes to a greater frequency of natural disasters (Masson-Delmotte et al., 2022; Shukla et al., 2019). Climate change has already had wide-ranging impacts on agriculture, including more frequent and severe storms, floods, drought, increase in crop losses, land degradation, and drastic shifts in temperature and precipitation alongside physiological and metabolic impacts (Arora, 2019; Shukla et al., 2019). In addition, as food and agricultural systems contribute to greenhouse gas (GHG) emissions, these effects are both influenced by food production, access, distribution and waste, and being impacted by them (Steiner et al., 2020). While climate change affects different regions in different ways, the cumulative effects challenge the agricultural sector and broader food systems, presenting a need to adapt (Arora, 2019; Aydinalp & Cresser, 2008). This raises the question of how to adapt in the face of change to ensure long-term resilience throughout all components of food systems.

The planning for and development of food systems have varying driving logic and objectives at different scales. Global food systems have been organized in ways, in which areas with favourable agricultural conditions have become centres for food production. Each area produces specific kinds of products, depending on the region's competitive advantages (Eva et al., 2017; Rotz & Fraser, 2015). In contrast, local food systems aim for diversity in food production to meet the food needs of local populations (Rotz & Fraser, 2015). Building food system resilience requires understanding the complexity and interactions among systems components, how they can work more effectively and how they can complement or harm one another. Understanding and recognizing complexity is best achieved through integrated approaches to local food planning and policy that draw from systems perspectives (Blay-Palmer et al., 2016).

Integrated and multi-scalar food systems planning approaches recognize how food issues link with other planning areas and issues. These approaches also involve identifying the relationships and linkages among different levels of government. Food systems strategies and policies that follow an integrated approach can improve local and regional resilience and sustainability (Horst, 2017; Pothukuchi & Kaufman, 2000).

To facilitate research on integrated approaches to local planning and policy, nexus frameworks have been widely employed in food systems and sustainability studies. Examples include water-energy-food (Vahabzadeh et al., 2023; T. Zhang et al., 2020), water-climate-food (Duan et al., 2019; Hoehn et al., 2021), and water-energy-food-climate nexus (Radini et al., 2021; Zhou et al., 2021). However, these nexuses can be challenging to operationalize. An example can be seen in the case of the water-energy-food nexus (WEF) which researchers have discussed in terms of its potential to support integrated resource management, local planning, and policy (Zhang et al., 2018). Gaps in data, information, and knowledge construction impede the comprehension of the

interconnections within the WEF nexus, and there is an absence of systematic tools to adequately address the various impacts involved (Liu et al., 2017). In addition, the WEF is vague in terms of the objectives of applying the framework, particularly concerning the food component, which can relate to a wide range of goals, including economic development, food security, tourism, and community health (Newell, 2023). Moreover, the targeted audience (decision-makers), may find the nexus approach highly conceptual and challenging to comprehend. Finally, despite various applications, there is a lack of a universally accepted or agreed-upon method for using the WEF nexus in research and practice, resulting in a fragmented understanding of its value and applications (Fayiah et al., 2020).

As an alternative to the WEF nexus, Newell (2023) proposes the climate-biodiversity-health (CBH) nexus, which focuses on clear sustainability objectives rather than planning and policy areas with more ambiguous goals and objectives. He argues that the CBH nexus is a 'goals-oriented' framework that prioritizes key sustainability issues and objectives, namely climate change and biodiversity loss, which are among the most critical challenges in the current Anthropocene epoch (Pörtner et al., 2021). The proposed framework also includes a 'human' component, that is, health (both mental and physical), and this is part of the framework to capture sustainability goals related to human well-being and quality of life (Newell, 2023). With the elaboration of the subdomains of this nexus, it could address the operationalization challenges in previous nexus frameworks due to vagueness and ambiguity.

Using the CBH nexus with context- and place-based approaches that engage stakeholders with knowledge and experience of a community and its issues has the potential to improve the effectiveness of the nexus in terms of addressing the challenges mentioned above (Albrecht et al., 2018). Such approaches can address the existing knowledge gaps in developing and implementing these frameworks. Engaging stakeholders in the application of a nexus (or similar integrated planning frameworks) can also be helpful in achieving a common understanding of the definitions and interpretation of different planning and policy areas and their respective objectives (Fayiah et al., 2020; Newell et al., 2018, 2022). Additionally, contextualization allows for the exemplifying of aspects of the nexuses in ways that are familiar to users of the framework, facilitating a deeper understanding of such frameworks (Balaican et al., 2023; Lowan-Trudeau et al., 2020; Mayor et al., 2018, 2018). A context-sensitive, place-based approach also clarifies the nature and degree of co-benefits and trade-offs that exist from different plans, strategies and policies, as they vary from case to case (Cabello et al., 2021; Marr et al., 2009; Sharmina et al., 2016).

This paper employs the CBH nexus framework and systems perspectives to produce knowledge that could be used to support integrated food systems planning. The research engages stakeholders through semi-structured interviews and uses a case study approach to elucidate how nexuses can be effectively applied to a particular place and context. The paper first presents a related literature review on food systems complexity, integrated planning, nexuses, and system mapping. It then introduces the case study, the Comox Valley region, before describing the research methods. The paper next discusses how a CBH nexus (Newell, 2023) is applied to guide the research, followed by a presentation and discussion of the study's findings.

2 Literature Review

2.1 Food Systems Complexity and Challenges

Food systems and the environment are highly interconnected, and they must sustain one another to be resilient. Agricultural productivity depends on natural and ecological conditions such as the quality of soils and water (Liverman & Kapadia, 2010; OECD, 2024; Rotz & Fraser, 2015). They also interact with and shape the environment of which they are a part, and unsustainable agricultural practices threaten both the sustainability of the agricultural sector alongside a wide range of environmental and biological factors. Agricultural production today is recognized as the greatest threat to species due to its water usage (70% of total water usage), the amount of land that it requires (about 40% of ice-free land surface) and the harmful inputs, like pesticides and fertilizers that can damage freshwater and coastal ecosystems (Dalin & Outhwaite, 2019; Liverman & Kapadia, 2010; Ramankutty et al., 2008). Beyond food production, practices within the broader food system are causing a wide range of environmental damage from excessive waste to food packaging that results in increased GHG emissions and contamination of water sources (Horst, 2017). Food waste contributes to methane emissions, an increase in fossil fuels (and thus CO₂ emissions), and freshwater consumption, which impacts the environment and contributes to climate change (Hall et al., 2009).

The industrialization of agriculture has changed the very nature of farming and connections to communities. In North America, agricultural industrialization has led to a reduction in crop diversity, an increase in pesticide usage, a loss of soil fertility and farm consolidation, with a great reduction in the number of smaller farms (Rotz & Fraser, 2015). In Canada, a downward trend can be seen in the number of small farms by 2021 (3.2% decrease in the 2016-2021 period), at the same time, the farms have grown in size (Statistics Canada, 2022). Such farm consolidation and industrialization influence food production and accessibility by increasing and normalizing long distances between the places where foods are produced and where they are consumed. Industrialized farming practices, economies of scale and competitiveness and the regulatory environment for farming and agricultural products have made it increasingly challenging for small farms to survive. Agricultural industrialization and mechanization led to a reduction in on-farm production diversity in the USA and Canada, and price support policies promote large-scale food production with limited diversity farming. Small farms' product prices are not competitive in the market; thus, small-scale farmers encounter difficulties in accessing mainstream buyers and actively contributing to food markets (Glibert, 2020; Rotz & Fraser, 2015).

These challenges are well-recognized and a number of food policies and strategies, both nationally and internationally, have been adopted in order to promote the sustainability of food systems. For example, the Milan Urban Food Policy Pact (MUFPP) (2015) is an international agreement of Mayors which offers a working tool for cities and a framework for recommended actions for improved food systems governance, the promotion of sustainable diets and nutrition, social and economic equity of the food system, sustainable food production, food supply and distribution and food waste (Martín & de la Fuente, 2022). In Canada, the first-ever federal Food Policy for Canada was launched in 2018 following public consultations. It provides funding to address food system issues such as: income support programs to reduce poverty; policies to

improve food environments and support healthier food choices; initiatives to reduce GHG emissions in the agriculture and food sector; and investments in innovation to increase the agriculture and food sector's capacity to produce high-quality food (Government of Canada, 2020). There are also a wide range of local initiatives across Canada such as the City of Vancouver's Food Policy Council which need to be bolstered by the implementation of supporting strategies (Valley & Wittman, 2019).

2.2 Integrated Planning and Nexus Frameworks

Concepts and frameworks have been developed to support and encourage integrated planning and broad systems thinking around sustainability issues (Steffen et al., 2015; Vanham et al., 2019). An example is nature-based solutions (NBS), which refers to implementing actions to address social challenges through approaches that also contribute to conserving ecosystems and natural resources, thereby considering both human and nature's benefits (Seddon et al., 2020). NBS aim to mitigate the impacts of climate change, conserve biodiversity and improve human health and well-being Raymond et al. (2017) developed a framework for implementing NBS in urban areas with four dimensions of (1) co-benefits for human health and well-being, (2) integrated environmental performance (e.g., the provision of ecosystem services), (3) trade-offs and synergies to biodiversity, health, or economy, and (4) potential for citizen's involvement in governance and monitoring.

There are other proposed frameworks such as water-energy-food (WEF), water-food-energy-climate (Beck & Villarroel Walker, 2013), and water-energy-food-environment (Hellegers et al., 2008) nexuses. However, shortcomings have been identified in these frameworks and their practical value, as they have been described as being ambiguous in terms of how they are applied to local planning and policy (Cairns & Krzywoszynska, 2016). This research uses an alternative approach recommended by Newell (2023), which focuses on goals and objectives that are critical for community sustainability planning. Developing a goals-oriented approach first requires recognizing which issues are important to sustainable development, at local and global scales. Climate change and biodiversity loss are among the most crucial sustainability issues facing, and acting on these issues is important (Newell, 2023; Newell et al., 2022).

This study considers climate actions and biodiversity conservation as critical elements of food systems planning, and thus, the framework is adapted here to study food systems. Human health (mental and physical) is the third component of Newell's (2023) framework, and this is also a key analytical element for this study due to the considerable relationships among health and food systems. The application of the CBH framework to food systems in this study is done to gain a better understanding of how various strategies align or conflict with different CBH imperatives and be used to support integrated community sustainability planning efforts (Figure 6). While the framework has been applied within the Comox Valley context, the methodological approach can be adapted to other communities and planning areas.

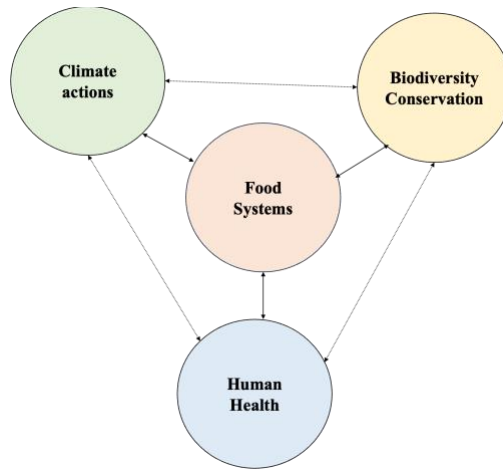


Figure 6. CBH framework

2.3 Systems Mapping and Planning

System mapping is a process of visualizing the links between elements of a subject (Rutter et al., 2019), and it can be a useful technique for supporting integrated planning approaches by showing influential factors of complex issues in ways that reveal potentially effective strategies and intervention. Studying complex issues using system theory helps to gain a comprehensive view of issues and identify the root causes of problems (Meadows, 2008). Systems thinking can be used in the development of possible scenarios and the predictions of their potential outcomes, which can inform effective solutions to address these issues (Meadows, 2008; Newell et al., 2020). For example, Borie et al., (2019) studied narratives of urban resilience in Manila, Nairobi, and Cape Town, and they illustrated the importance of system thinking to employ integrated approaches in urban resilience. System thinking has also been used to develop integrated models for waste management (Fuldauer et al., 2019). Rutter et al. (2019) emphasized the effective role of system mapping to comprehensively realize and address complex public health challenges. System thinking is also useful for food research since it enables multi-dimensional and comprehensive studies of factors that influence and affect food systems, such as agricultural challenges caused by biodiversity loss, food insecurity and climate change (Bijman & Höhler, 2023).

System mapping can help to facilitate community planning, improve public awareness and understanding of different aspects of problems, and increase participation in research. For example, Cone et al. (2012) studied how using system mapping approaches can facilitate community planning and awareness in the context of climate change. Targetti et al. (2021) used participatory modelling and fuzzy cognitive mapping to identify how various public goods and policies interact with rural society under different economic and social scenarios.

Engaging stakeholders and community members in studies is useful for identifying linkages among units of complex systems (Targetti et al., 2021). Engaging stakeholders in research can provide researchers with the opportunity to have a creative and wider involvement of disciplines and players (Collier et al., 2013). It can give the researchers knowledge of cultural and other contextual features of an issue. This knowledge helps them realize the components of a systems

and their interconnections, while also enabling insights into place-based strategies for addressing local issues (Ibid).

3 Case study: The Comox Valley

The Comox Valley region is located in the northern part of Vancouver Island in the province of British Columbia, Canada (see Figure 7). It encompasses an area of 1700 km² and has a total population of over 72,000 (Comox Valley Regional District, 2021). This region includes Comox, Comox Valley, Courtenay, Cumberland, and Puntledge (Comox Valley Regional District, 2022). Agricultural land uses constitute about 14% of the Comox Valley region (23,429 hectares), which includes both small and large farmlands (Ministry of Agriculture, 2014).

The Comox Valley region is chosen as a case study because of the complex challenges it faces and the nature of community-led climate actions. The region faces food insecurity (Prato & Cupelli, 2013). It has encountered considerable population growth, with 8.7% growth between 2011-2021 (Comox Valley Regional District, 2023), which could intensify food insecurity issues (Cheeseman, 2016). As with many communities, climate change is a strong concern to Comox Valley communities. The communities participate in the Partners for Climate Protection program run by the Federation of Canadian Municipalities (2008). In addition, climate action, biodiversity conservation, and health are identified as key elements in the sustainability plan for the Comox Valley Regional District, Village of Cumberland, Town of Comox, & City of Courtenay - the Comox Valley Sustainability Strategy (Comox Valley Regional District, 2010).



Figure 7. Comox Valley region, Vancouver Island

This research complements, but differs from, previous research done on Vancouver Island, aimed at studying the sustainability of food systems issues. Previous studies have focused on: climate change risk perception factors and how they impact the City of Courtenay's climate change adaptation strategies (Murugesan, 2020); how and which localized and contextualized food security policies should be adopted in urban, suburban, and rural areas (Buchan, 2019; Budd & Moryson, 2017); the impacts of social policies on food insecurity (Li et al., 2016);

Indigenous food insecurity issues, particularly with respect to children (Bagelman, 2018); how Indigenous knowledge can help to address food security challenges (Muller, 2018).

4 Methods

This exploratory research uses system thinking due to its effectiveness in elucidating complex problems such as those related to food systems (Monasterolo et al., 2016). Previous research has used system thinking in food studies, such as Kasper et al. (2017) research on how food systems and urban systems are connected. In another study, Zhang et al. (2018) recommend the use of system thinking by organizations with food missions to realize and address urban food systems' challenges. They also emphasize the need to use system thinking to study elements of eco-agri-food systems.

The CBH nexus is used as an analytical lens and applied to integrated food systems planning in the Comox Valley. This has yet to be done in an empirical local food system planning study, and it is the novelty of this research. The CBH nexus is applied in this research due to the clear links between its domains and food systems. Food systems issues are tightly connected with human health challenges and environmental degradation (Willett et al., 2019). They not only contribute to issues like Anthropogenic climate change, biodiversity loss, and water and air pollution, but are also negatively influenced by these issues (Ahmed et al., 2019; Horst, 2017; Willett et al., 2019). Climate change leads to a reduction in viable agricultural land, food production, and quality as well as an increase in food prices (Ahmed et al., 2019). Converting natural lands to agricultural lands can increase food production; however, this conversion contributes to climate change and negatively affects biodiversity (Wilhelm & Smith, 2018). Similarly, there are relationships between food security and health. The existence of food deserts leads local residents to choose available but unhealthy foods instead of travelling long distances to access healthy foods, which creates risks of nutritional diseases (Larsen & Gilliland, 2008; LeClair & Aksan, 2014).

The case study approach is used to test the CBH nexus in a practical and context-based study (Flyvbjerg, 2006) to realize how much this nexus is effective for integrated planning. The case study approach provides the opportunity for an in-depth place-based study, which is crucial to identify all the appropriate elements of system maps. Using this approach is helpful to gain a deep understanding of the application of CBH nexus by both researchers and practitioners.

Using the Comox Valley region as a case study, this research engaged stakeholders working at different scales, from local to provincial, and in the four main areas of food systems, climate action, biodiversity conservation, and human health. Stakeholder organizations were identified through an Internet search, involving the use of key terms such as 'climate action', 'biodiversity conservation', 'food', and 'community health' in combination with the Comox Valley municipalities. Further stakeholders and organizations were identified through snowball sampling. Figure 8 displays all the stakeholder organizations identified through this process. The figure shows how scale was considered in this research; organizations located on the border of this figure pertain to local ones while the central part of the figure represents provincial players. As illustrated in the figure, in addition to the main areas of the studies, housing-related organizations were also added to the stakeholder list due to how initial interviews revealed the

Table 1. Number of participants at provincial, regional, and local levels

Level	No of participants	
Organization/institution/NGO Representatives	Provincial	6
	Regional	10
	Local	16
Total	33	

An interview protocol was developed and sent to all of the participants before the interviews (see Appendix 1). The same interview protocol was sent to and used for all participants; however, following a semi-structured format, further questions were asked to expand upon key points in the interview and to leverage the participants knowledge in a particular area (i.e., food, biodiversity, climate change, health). The interview began with questions about the organizations’ mission and was followed by questions on their specific goals about CBH and food. The next sections asked about organizations' current and planned strategies, the co-benefits and trade-offs of these strategies, the scales on which these strategies operate, partnerships and collaborations, and how future strategies should be revised for performance improvement and increased effectiveness. Due to the COVID-19 pandemic, the interviews were conducted online rather in-person. All interviews were conducted online using the Zoom video-conferencing application. Each interview lasted 45 minutes to 1 hour. Interview data were transcribed using Trint transcription software.

The study was reviewed and received approval from the Human Research Ethics Boards at the University of the Fraser Valley, the University of Victoria, and Royal Roads University. Participants were given consent forms to review and sign prior to participating in this study. The letter contained information on the purpose of the study, procedures to maintain anonymity and confidentiality, benefits and inconveniences to research participants, and withdrawal procedures.

4.2 Data Analysis

Interpretive qualitative data analysis was employed in this research. An inductive coding approach was used in this study, meaning codes were derived from the transcript data. NVivo (v. 12) software was used to code each transcript based on the interviewee’s words. In the next step, researchers categorize the established codes and use thematic analysis coding for the second-round coding. The validity and reliability of the data analysis are addressed using a peer debriefing approach and by performing the coding process twice.

Initially, 263 codes were produced through the analysis, and these were then categorized into two main groups: strategies and outcomes. Using an axial coding approach, the inductive codes were subsequently organized into broader codes or groups, resulting in 20 of these for strategies and 25 for outcomes. These groups are categorized into eight themes. Table 2 shows the themes and codes of this research.

Table 2. List of codes

	Theme	Strategies	Outcomes
1	Biodiversity conservation practices	Water resource management	Water quality and quantity Ecosystem integrity and health
2	Knowledge exchange	Awareness Improvement strategies Training and Education	Public awareness Community integration
3	Climate actions and risks	Crisis management Emission reduction strategies Green space conservation Energy efficiency in Buildings	GHG Emissions reduction Increased adoption of renewable energy Natural disasters impacts Agricultural resilience
4	Government and social Supports	Governmental financial support Poverty reduction strategies	Human and financial resources Social concerns and needs Current and comprehensive dataset
5	Food systems	Food Justice Strategies Shellfish farming Support the global food market Support local food market Support local foods Farming techniques	Increased food distribution and accessibility Food affordability Food diet Farmers' sales improvement Increased local production Food resilience Reducing food miles
6	Human health	Community health strategies	Health risks Physical health Mental health and wellbeing
7	Land-use plans and transportation projects	Affordable housing strategies Enhancing active transportation Land-use governance	Traffic congestion Land availability and affordability Affordable housing availability
8	Waste challenges and management	Waste resource management	Food waste reduction

A coding matrix was produced to identify the links between codes, which was then used to develop a system map showing the co-benefits and trade-offs of strategies. The system map shows: (1) outcomes of strategies; (2) the impacts of strategies on outcomes; and (3) links among themes. Although beyond the scope of this paper, it is worth noting that the developed system map was reviewed by stakeholders (including both those who participated in interviews and new participants).

5 Results

In total, 1,148 references were coded in the data (Table 3). About one-third of these references belong to the food systems theme. Government supports, climate action, and biodiversity conservation practices were the next highest in terms of references. The waste challenges and management and human health themes are the least frequently coded, each comprising less than 1% of the total references.

Table 3. Distribution of references in themes and codes from interviews

Theme	Strategy/outcome	References			
		number of interviewees		Number of mentions	
Biodiversity conservation practices	Water resource preservation strategies	6	20	11	147
	Water quality and quantity	13		53	
	Ecosystem integrity and health	20		83	
Knowledge exchange	Awareness Improvement strategies	10	27	15	129
	Training and Education	10		28	
	Public awareness	21		67	
	Community integration	8		11	
Climate action	Crisis management	5	29	5	167
	Emission reduction strategies	9		14	
	Green space conservation	14		33	
	Energy efficiency in Buildings	2		2	
	GHG Emissions reduction	17		68	
	Increased adaptation of renewable energy	8		14	
	Natural disasters impacts	12		30	
Agricultural resilience	1	1			
Supports	Governmental financial	19	31	50	175
	Poverty reduction strategies	2		2	
	Human and financial resources	26		75	
	Social concerns and needs	15		35	
	Current and comprehensive dataset	11		13	
Food systems	Food Justice Strategies	12	28	35	322
	Shellfish farming	3		8	
	Support the global food market	9		16	
	Support local food market	12		27	
	Support local foods	19		75	
	Farming techniques	17		50	
	Increased food distribution and accessibility	4		5	
	Food affordability	6		7	
	Food diet	8		17	
	Farmers' sales improvement	10		25	
	Increased local production	16		49	
	Food resilience	1		2	
	Reducing food miles	4		6	
Human health	Community health strategies	4	25	7	61
	Health risks	15		22	
	Physical health	13		20	
	Mental health and wellbeing	6		12	
Land-use plans and transportation projects	Affordable housing strategies	2	18	6	95
	Enhancing active transportation	10		19	
	Land-use governance	13		42	
	Traffic congestion	2		2	
	Land availability and affordability	5		8	
	Affordable housing availability	8		18	
	Waste resource management	7	14	31	52

Waste challenges and management	Food waste reduction	10		21	
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An NVivo-generated matrix was used to identify the links between codes to develop system maps. A series of systems maps were developed to show the links between themes, strategies, and outcomes of each theme, as well as all strategies and outcomes. Figure 9. shows the themes' system map. Two-way direction links between all themes except waste management and knowledge exchange themes. These links show the complexity of the CBH system map of Comox Valley's food systems and a high interconnection among the strategies and outcomes. The links between strategies and outcomes of each theme will be discussed in the next section (see Figure 9).

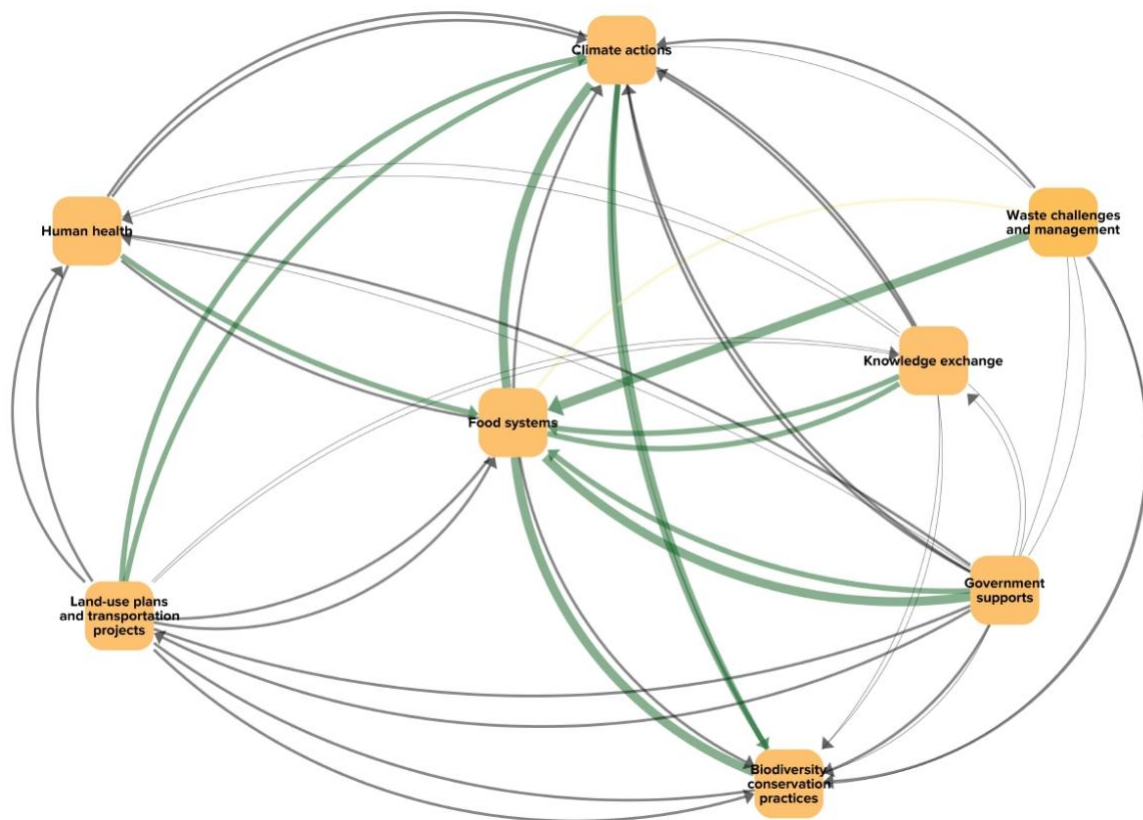


Figure 9. System map of themes, based on all interviews

5.1 Biodiversity conservation practices

Watershed planning is critical in this region.

The theme of biodiversity conservation practices includes water resource preservation strategies (watershed and agricultural water reserve plans), water quality and quantity, and ecosystem integrity and health outcomes. In addition to these two outcomes, there are four others influenced by this strategy: natural disaster impact, GHG emissions reduction (from climate actions theme),

physical health (human health theme), and increased local food production (food systems theme). Among these, ecosystem integrity and health were mentioned by most interviewees as the outcome of this group of strategies. For example, a participant explained the overall aims of watershed plans to be to achieve such outcomes:

“We're doing it, we've actually got a watershed assessment that's happening right now as well through that climate adaptation strategy, so that one is looking at sub-region watersheds in the area, and it includes the Tsolum River watershed here in Comox Valley and is really looking at all of those principles around water quantity, water quality, fish values, some of the biodiversity pieces around that...” (Interviewee 22014).

Another interviewee identified how these strategies can have outcomes in all three areas of the CBH nexus:

“The scope of our work is largely watershed stewardship in the Comox Valley. Specifically, we focus a lot on estuarine, coastal, and nearshore environments.... one of the main co-benefits of that work is blue carbon sequestration within a regional context. Another co-benefits that we work directly on is biodiversity. So, all of our projects aim to increase biodiversity in their application. So those are the kind of two main aspects. I would say that because we are working on projects that often we are planting trees or things like that. So, there is possible air quality benefits. So that's kind of more the human health lens....” (interviewee 22025).

Figure 10 shows the system map of this theme. Two types of nodes are presented: strategies (blue) and outcomes (yellow). In addition, two types of links are presented: positive relationships (green) and negative relationships (red). For example, the negative link between ‘water resource preservation strategies’ and ‘natural disaster impacts’ means improving water resource preservation strategies can decrease the impacts of natural disasters. The water reserve preservation node involves strategies such as Agricultural Water Reserve plans, Tsolum River Agricultural Watershed Plan, Comox Lake watershed plan, BC Groundwater License, Wastewater treatment plans, Watershed health assessments, and Comox Valley Project Watershed Societies’ plans.



Figure 10. Water resource preservation strategies system map

Blue nodes represent strategies, and yellow nodes represent outcomes. Green lines represent positive relationships, and red lines represent negative relationships.

5.2 Knowledge exchange

Community engagement through workshops

This theme involves training and education and awareness improvement strategies. Examples of training and education strategies involve farmers' training programs, certificate programs for groundwater, Salmon-Safe, and Good Agriculture Practices, first aid training, and the Neighbourhood Emergency and Preparation Program. Awareness improvement strategies include knowledge translation products and guides, as well as events and workshops related to challenges of food systems and how to produce sustainable local foods.

In addition to public awareness (both of the strategies) and community integration (for awareness improvement strategies), these strategies have outcomes from human health (mental health and wellbeing, physical health), climate actions (natural disasters impacts, GHG emissions reduction), biodiversity conservation (water quality and quantity, ecosystems integrity and health), government supports (social concerns and needs), food systems (increased local food production, farmer's sales improvement), and knowledge exchange (community integration) themes (see Figure 11.)

For example, the impacts of first aid training programs on human health and natural disasters management are explained by one of the interviewees as follows:

“We train people for first aid and we provide first aid services at events. And we also have a youth cadets group, so the youth from ages six to 17 could learn leadership skills.... And we also have therapy dogs where the dogs are trained to go to like the airport and long-term care homes.....Weather events, and we would be there to provide first a first responding surface.... if there's a big earthquake and we know how we fit in with other groups out there, more specifically, we will go to Disaster Reception Center and be able to treat any minor first....”(interviewee 22025)

As mentioned, various events have been held in the case study area that relate to public awareness, agriculture resilience, and community integration:

“When you spend time on our website, there's quite a few stories and some videos and lots of pictures from field days. And with the pandemic, we had to shift from doing in-person field days. But they've done some really amazing virtual field days where farmers are out on their fields with their cell phones and they're talking about what's happening there and people are watching them on whatever platform they're using.... We also did a series of focus groups, so we brought together farmers from different sectors and across the province....we're madly taking notes so that we could understand better from their conversations, what they're experiencing with regards to the climate change and what actions they're taking on their farms....”(Interviewee 220031)

“before we started the potato co-op, you know, I organized this thing called garden, the garden party series, where we would go around and do these little mini work bees on the various farms on the island that were practicing organic standards to basically supply free

labor, basically as a political act, as a social contract, to recognize the good fortune of having local food production.” (Interviewee 22027)

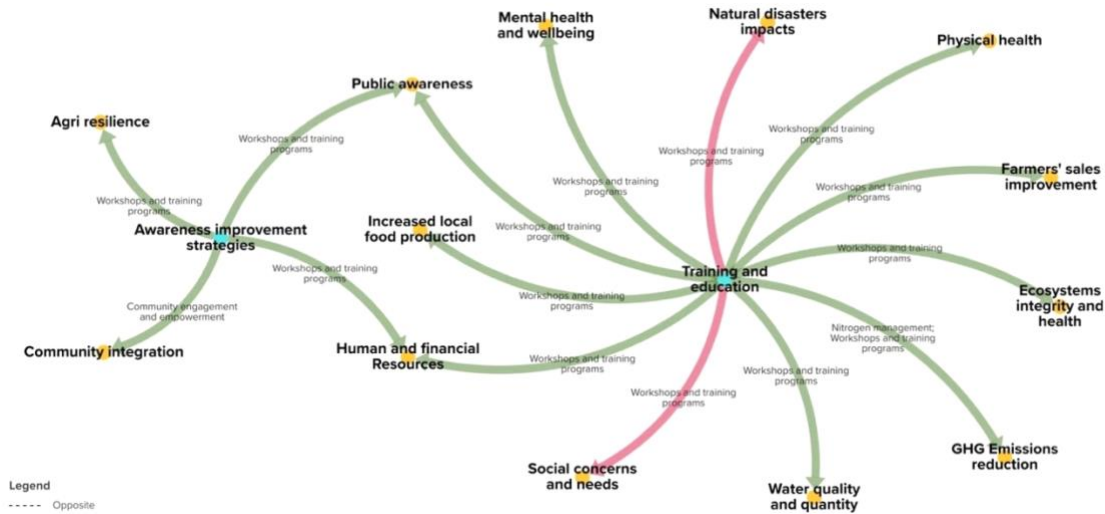


Figure 11. Knowledge exchange theme system map

Blue nodes represent strategies, and yellow nodes represent outcomes. Green lines represent positive relationships, and red lines represent negative relationships.

5.3 Climate actions

Climate mitigation and adaptation through reducing GHG emissions and managing climate crisis impacts

This theme includes four groups of strategies: crisis management; emission reduction strategies; green space conservation; and energy efficiency in buildings. Table 4 Shows the sub-nodes (identified inductive codes from interviews) of these groups:

Table 4. Sub-nodes of the climate actions’ theme

Node	Sub-nodes	Node	Sub-nodes
Crisis management	Coastal flood mapping Emergency planning Hazard management Stormwater management Update wastewater system	Green space protection	Adaptive urban vegetation Agricultural Land Reserve Clear cutting forestry Climate-resilient crops Crop diversification Planting marketable fruit trees Tree protection bylaws Urban agriculture Urban forest management Urban forest strategy Urban tree planting Urban vegetation
Emission reduction program	Clean energy program Corporate energy plan Heat pump incentives Net zero targets	Energy efficiency in buildings	Step three building code Waste heat usage for green houses

5.4 Supports

Governmental financial supports impact food systems as well as CBH

This theme involves governmental financial support and poverty reduction strategies of (see Table 5). Governmental financial supports have outcomes in both government supports and other themes, including outcomes in climate actions (like GHG emissions reduction, and agricultural resilience), biodiversity conservation practices (ecosystems integrity and health, etc.), Land-use plans and transportation projects (affordable housing affordability), knowledge exchange (public awareness), and food systems (food diet, etc.).

Table 5. Support theme strategies

Node	Sub-nodes	Node	Sub-nodes
Governmental financial support	Financial planning for disaster management Government funding Governmental staff support Subsidize food production and distribution Subsidize heat pumps Tax breaking	Poverty reduction strategies	Pathway of Hope Poverty Reduction Strategy

The majority of interviewees for this study have stressed that these strategies have a significant role to play in the development and implementation of new initiatives and the continuation of existing ones (as it can be seen in the Figure 13). By doing so, these strategies have the potential to impact all other areas of this research. However, interviewees have also highlighted the inadequate financial support from the government as a significant barrier to achieving their goals and implementing their strategies within the organizations of the Comox Valley region. Furthermore, it appears that there is a lack of understanding among local stakeholders regarding the rules, barriers, and limitations imposed by provincial governments when it comes to budget allocation. This issue points to communication and collaboration challenges between different organizations, a concern raised by almost all interviewees. This collaboration challenge is evident within local organizations, particularly among local NGOs, as they tend to pursue their objectives individually with limited collaboration. Despite the important work carried out by these local NGOs, their fragmented approach hinders the effective utilization of the capacities and resources available from other stakeholders. Hence, there is a need to enhance networks and promote collaborative actions among relevant NGOs.

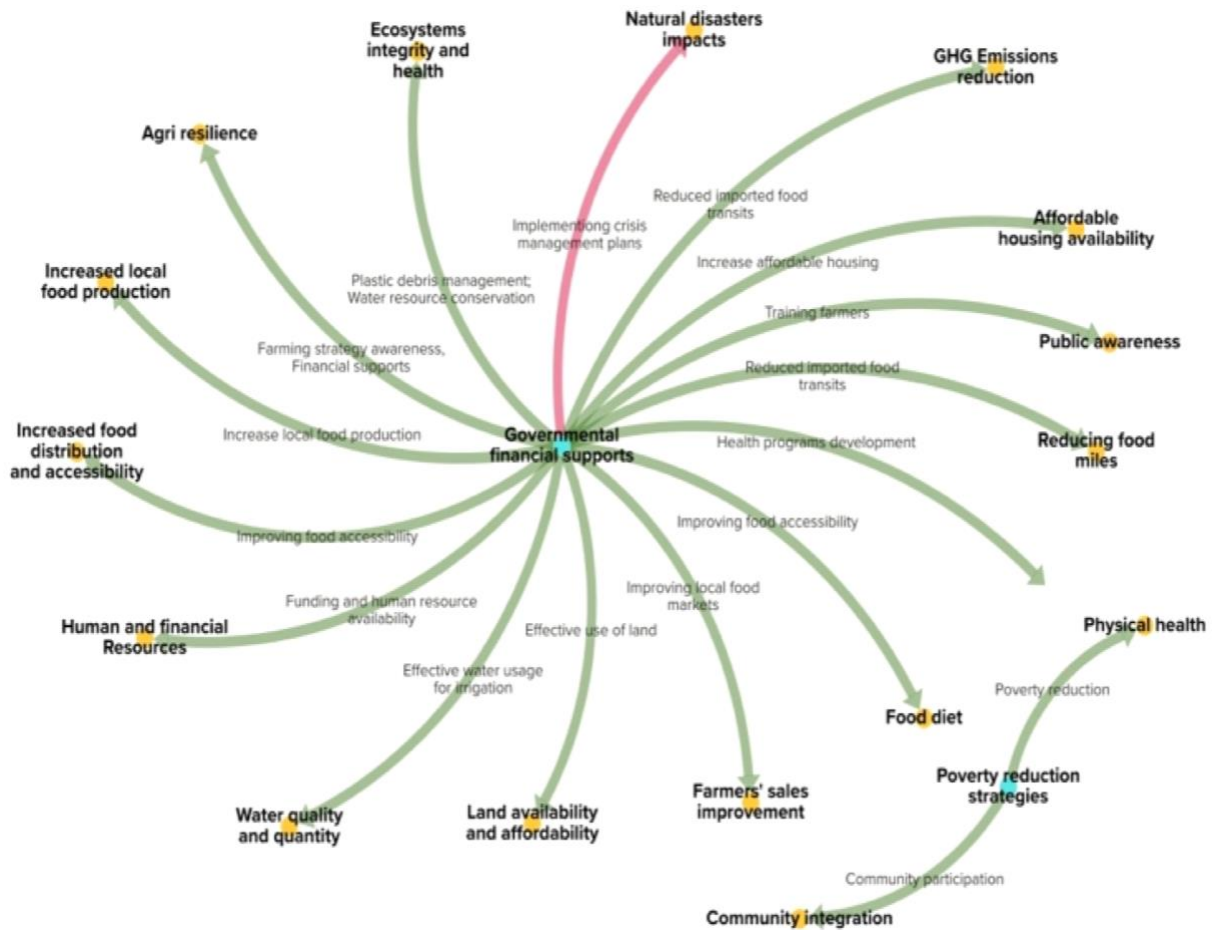


Figure 13. Governmental financial supports theme system map

Blue nodes represent strategies, and yellow nodes represent outcomes. Green lines represent positive relationships, and red lines represent negative relationships.

5.5 Food systems

Food systems strategies focus on improving local food production, market, distribution, and affordability.

This theme includes six groups of strategies: food justice, shellfish farming, support the global food market, support local food market, support local foods, and farming techniques (see Figure 14). As seen in Figure 14, these strategies have considerable impacts in different areas. The implementation of these strategies has consistently resulted in two shared outcomes: farmers’ sale improvement and increased local food production. Additionally, several other outcomes have been observed in at least three strategies within this theme. These include GHG emission reduction, reducing food miles, ecosystem integrity and health, food waste reduction, and increased food distribution and accessibility (see Table 6).

Table 6. Sub-nodes of the Food Systems theme

Node	Sub-nodes	Node	Sub-nodes
Food Justice strategies	<ul style="list-style-type: none"> Coupon program Food banks Good food boxes Lunch program Meal program Nutrition and healthy lifestyle program Salad bar program School Food programs Shopping cards program 	Support the global food market	<ul style="list-style-type: none"> Product size standardization Reliance on imported products Wholesale
Shellfish farming	<ul style="list-style-type: none"> Report All Poachers and Polluters (RAPP) program Shellfish aquaculture Shellfish industry association membership 	Support local food market	<ul style="list-style-type: none"> Farmers market Farmgate sales Food delivery services Local market and grocery Restaurants in local supply chains Supply chain management systems
Farming techniques	<ul style="list-style-type: none"> Agricultural technology Algae Animal based regenerative ag Conventional farming Cover cropping Diverse farming practices Ethical farming Greenhouses Livestock feed Local pest and pollinator research Organic farming plant-based agriculture regenerative farming shellfish health (aquaculture) small-scale farming Use fertilizers 	Support local foods	<ul style="list-style-type: none"> backyard food production Food gleaning Food hub Increase local food production

As it can be seen in the system map, community health strategies positively influence human health as one of the interviewees explains how their work has such impacts:

“I’m actually in a farm right now in the autumn times at the Pumpkin Festival. So by. Being a first aid service at events like this, we’re helping local farms. They promote their agro-tourism. And we were at the immunization centers to provide first aid in case people who get vaccines if they faint or they need more support, we’re there to help.... if there’s a big earthquake and we know how we fit in with other groups out there, more specifically, we will go to Disaster Reception Center and be able to treat any minor first. And so the hospital would not be overloaded so that they can focus on the more injured people.”
(Interviewee 22030)

Some health strategies related to concerns about food safety presented trade-offs. Examples include strategies that restrict informal food distribution, which can negatively influence food affordability. One participant explained that these policies can prevent the distribution of cooked foods by residents and other non-commercial entities (Interviewee 20019).

5.7 Land-use plans and transportation projects:

Land-use plans affect food systems and food justice; Transportation projects aim active transportation.

This theme includes affordable housing; enhancing active transportation; and land-use governance strategies (see Table 7). All of these strategies impact social concerns and needs. Ecosystems integrity and health, GHG emissions reduction, and increased adaptation of renewable energy are the common outcomes of enhancing active transportation; and land-use governance strategies. In addition to these, each of these strategies has other separate outcomes as can be seen in Figure 16. For example, in the case of Zoning Bylaws, one of the interviewees explains:

“We allow (by Zoning Bylaw) for market gardens and we allow for urban agriculture in a lot of our residential areas. We allow for the keeping of chickens... So the Zoning Bylaw tries to be pretty permissive for people to do their own urban agriculture in a fairly like urban context.... The Zoning Bylaw supports small-scale neighborhood-level food production....In terms of climate change or, we’re partnering with the province to put in electric vehicles, charging stations....”(Interviewee 22013).

Table 7. Land-use plans and transportation projects

Nodes	Sub-nodes	Nodes	Sub-nodes
Affordable housing programs	Affordable housing spread models Affordable housing strategies BC Housing projects Local affordable housing projects	Land-use governance	Densification Infill development Land Protection program Land use rules and management Regional adaptation strategy

Enhancing active transportation	Active transportation Expanding EV fleets and charging network Public transportation Reducing private vehicles usage Transportation Network plan	Regional growth strategy Urban growth Zoning Bylaw
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Figure 16. Land-use plans and transportation projects system map
Blue nodes represent strategies, and yellow nodes represent outcomes. Green lines represent positive relationships, and red lines represent negative relationships.

5.8 Waste resource management

Recycling and reusing facilities are implemented in the case.

As can be seen in Figure 17, the theme includes waste resource management strategies (compost management, Packaging reduction, plastic debris management, recycling, second-hand stores and reuse facilities) and food waste reduction outcomes. Waste resource management strategies have outcomes in GHG emissions reduction, increased adaptation of renewable energy (climate actions theme), ecosystems integrity and health (biodiversity conservation practices theme), social concerns and needs, human and financial resources (government supports theme), and increased local food production (food systems theme). The Salvation Army is one of the organizations actively engaged in this theme. Their strategies impact reducing resource consumption, enhancing affordability, and preserving ecosystem integrity and health:

“Part of the mandate of the Salvation Army is to ensure that we not only care for the people who are coming into the Salvation Army for services, but that we also protect the land that we’re on as well. So that means reducing the climate footprint that we have. So whether that’s reducing the amount of garbage that we have, helping people reduce their costs by utilizing reusable items such as clothing or household supplies or whatever. And

then, of course, taking whatever it is that we receive through our thrift stores, it's non-salable and finding alternate means of recycling..." (Interviewee 22009)

These strategies and outcomes impact food systems, both directly and indirectly. For example, recycling and reusing items result in resource conservation, including water, energy, and land, which are crucial for food production. Using reusable materials, farmers can afford to develop needed infrastructure (i.e. greenhouses, groundwater storages) due to climate change (Interviewees 22018, & 22017).

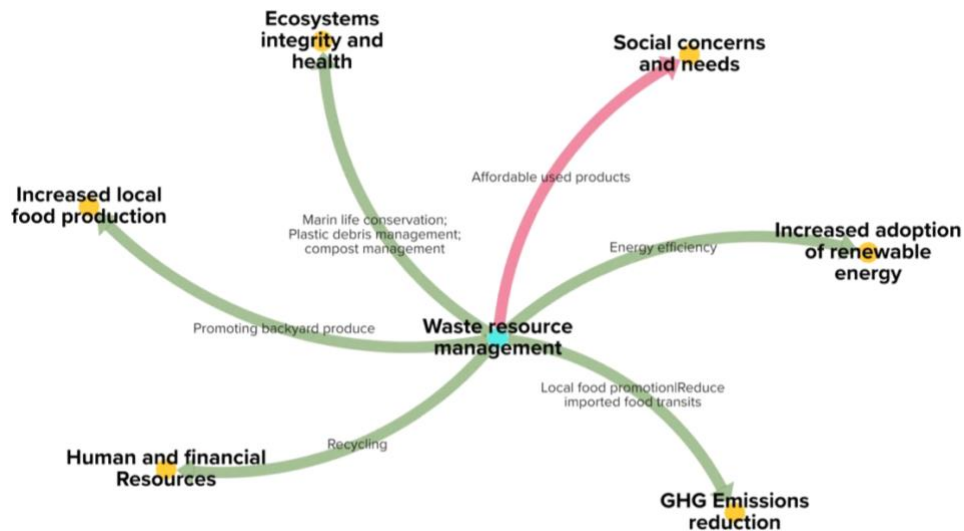


Figure 17. Waste challenges and management system map

Blue nodes represent strategies, and yellow nodes represent outcomes. Green lines represent positive relationships, and red lines represent negative relationships.

The comprehensive system map

The Comox Valley's food systems map can be developed based on recognized links between strategies and outcomes. Due to the considerable number of recognized links (384 links between strategies and outcomes), just those with more than two references are displayed in the comprehensive system map. A high complexity can be seen in the system map since strategies in each area can influence the other areas due to their outcomes. Examples can be seen in governmental financial supports, or food strategies. Among all of these links, support local foods and ecosystems integrity and health, support local food market and farmers sales improvement, and farming technics and ecosystems integrity and health involves more references (see Figure 18).

This map shows the identified links among strategies and outcomes¹. Regarding links within strategies, strong links are identified between food justice programs and support local foods, as well as governmental financial support strategies, awareness improvement programs, and training and education strategies. Notable links within outcomes involve those between ecosystems integrity and health and two other outcomes: water quantity and quality and GHG

¹ Only links with more than two references has been shown in the map.

emissions reduction, social concerns and needs, GHG emissions reductions, financial resources, increased local food production, and natural disasters impacts (see Table 8).

Illustrating the links among strategies and outcomes clarifies indirect links and how strategies in one area can influence the outcomes of another strategy in other area. An example can be seen in food justice strategies. Due to their impact on support local food strategies, strategies in food justice indirectly influence outcomes of support local food strategies. These links, those within strategies or outcomes or indirect links, can only be visualized in the comprehensive map and cannot be illustrated in theme-based maps due to their partial nature. This highlights the significance of developing comprehensive maps as they are key in reaching a holistic and comprehensive understanding of the impacts of strategies and outcomes.

Table 8. Significant links within strategies and outcomes

Nodes (kind of link)		Num of ref	Labels
Links between strategies	Awareness improvement programs & Training and Education (one-way relationship; positive)	5	Short events and workshops increase public awareness and encourage both joining and holding training programs. Training programs encourage holding short events
	Governmental financial support to Food Justice programs (one-way relationship; positive)	5	Financial support can increase and maintain food justice programs.
	Food Justice programs to Support local foods (one-way relationship; positive)	6	Food Justice programs use local food production as their main source and so lead to increased local food consumption and as an opportunity to show users the differences in local and imported foods qualities.
Links between outcomes	Water quantity and quality to Ecosystems integrity and health (one-way relationship; positive)	9	Water quality and quantity impact habitats and watersheds preservation and reinforce biodiversity.
	GHG emissions reduction to Ecosystems integrity and health (one-way relationship; positive)	8	GHG emissions reduction impacts air quality, and biodiversity, and preserves natural resources.
	Social concerns and needs & GHG emissions reduction (two-way relationship; positive)	6	Social concerns in GHG emissions and its implications lead the society to reduce their GHG emissions and such action reduces social concerns in this term.
	Social concerns and needs to Human and financial resources (one-way relationship; positive)	5	Social concerns in equity and justice lead to allocating a part of organizations' budget on lower-income and marginalized groups requirements.
	Natural disasters impacts to Increased local food production (one-way relationship; negative)	5	Natural disasters cause crop damage and loss of agricultural infrastructure.

It is important to note that using the number of references for identifying the most important links may not provide reliable results. It is possible that just one person with specialized knowledge mentioned an important or significant link with respect to the strength of the relationship and influence on the system, whereas moderately important link might be mentioned frequently. This is discussed in further detail in a subsequent paper (Ghadiri et al., 2024); however, it also requires recognition here, and it suggests that a holistic and comprehensive map developed from qualitative data cannot be visualized by ignoring links with fewer references.

6 Discussion

This study demonstrates the multiple relationships among food systems, climate, biodiversity and human health. As mentioned in the Results section, many of the coded references related to government supports, climate action, and biodiversity conservation practices. In contrast, the waste challenges and management and human health themes were not as frequently coded. Water quality and quantity were identified as being a key climate action area while also being central to food production, food price, and biodiversity conservation objectives. Watershed preservation strategies produce co-benefits for wildlife survival (Htun et al., 2016; Ziegler et al., 2007); however, trade-offs were also observed such as how water tax policies can rise food prices.

Other notable linkages seen through this study include those related to food waste. Food waste reduction strategies like those related to donating unsold products a before or after their best-before dates have co-benefits related to food affordability, food waste reduction, and the methane emissions caused by food waste disposal. However, such strategies also displayed trade-offs related to food safety, which may result in issues for human health. These findings show the complexity of such issues and confirm the importance of using an integrated planning lens for comprehensive and multi-dimensional understanding and effective planning and policy making (Mahajan et al., 2019).

The research illustrated tensions among the different CBH domains. Farming techniques can have different and contradictory impacts on CBH objectives (Aryal et al., 2020; Brooker et al., 2021; De Corato, 2020; Elahi et al., 2019; Tscharnke et al., 2021; Yamba et al., 2019). Conventional farming and using pesticides can have trade-offs on soil health and ecosystems as well as the farmlands' produce healthiness. Despite their effective impacts on farmers' income improvement, backyard livestock farming policies cause an increase in methane emission and also human-wildlife conflicts in cases of wild animals hunting livestock. Although these policies can improve local access to organic meat (Di Pillo et al., 2019; Sokołowicz et al., 2016), a lack of slaughterhouses in Vancouver Island and the existence of health policies banning on-farm and traditional slaughter prevents meat products from backyard operations in the Comox Valley from being processed in a timely manner. Accordingly, comprehensive and multi-faceted approaches are needed to be considered to address this issue through regulation and policymaking.

The results of this study and the system maps can be useful for planning and policy development and implementation. The comprehensive system map can be used as a guideline for different stakeholders to identify the implications of their strategies on different areas of sustainability. Using the system map gives stakeholders an initial understanding of how much their chosen decisions or strategies are beneficial or problematic, based on their possible co-benefits and trade-offs. Finally, the systems maps can be used to highlight awareness of other possible partners and stakeholders who may be impacted by their work or influence their actions and so their collaboration should be considered to improve the effectiveness of outcomes.

Planning studies that map local systems capture not only place-based context, but also a temporal context. In the case of the latter, this investigation transpired amid the COVID-19 pandemic. Although the research and interview inquiries were not explicitly centred on COVID-related matters, the pandemic became a salient topic during discussions with interviewees regarding

local health and food-related challenges. For example, during the COVID-19 pandemic, Comox Valley's health organizations focused on and prioritized policies to control and restrict the virus issues on human health, ranging from social distancing to restricting the activities of public transportation, different commercial land uses and other services. Such prioritization influenced other aspects of health and intensified food insecurity issues in the Comox Valley. For example, public transportation closure provides difficulties in accessibility to food banks, as the main food source of lower-income people, for those who just rely on this kind of transportation. Restricting different activities negatively impacts households' economic conditions, leading them to purchase and consume cheaper, unhealthy foods.

In addition to dimensions of the CBH nexus, this study identified four other domains that relate to integrated food systems planning. These include knowledge exchange, land-use plans and transportation projects, waste challenges and management, and supports. As it is explained before, strong interconnections can be seen **among** all of these domains. Concerning knowledge exchange, a lack of effective approaches to transfer Indigenous farming knowledge to other farmers may lead this knowledge to be lost, with such knowledge having the potential to contribute to sustainable farming (Bodapati & Chander, 2013; Mauro & Hardison, 2000; Senanayake, 2006). Strategies related to educational events and workshops provide a knowledge exchange opportunity among farmers and help them to find more solutions to tackle climate change issues, thusly contributing to improved productivity and waste reduction. Inadequate public awareness about the benefits of local organic foods to human health encourages continued consumption of cheaper imported foods. This trend reduces local food demand and may adversely affecting local food markets, increasing reliance on global foods (and their related food miles).

Land-use plans and transportation projects connect to other domains in various ways. Affordable housing strategies reduce financial and mental pressure on lower-income people by providing affordable accommodations (Donaldson & Yentel, 2019; Novasky & Rosales, 2020). With stronger economic positions, these groups can afford organic and healthy food, which influences their physical health (Stupplebeen, 2019). Enhancing active transportation strategies has great impacts on GHG emissions reduction and also human health. Expanding EV fleets and charging networks can also have such outcomes; however, the increase in EV usage would lead producing more electricity in the long term, which requires more infrastructure development and this could negatively impact the wildlife habitat, increase waste, and resource consumption.

Land-use and development plans influence all domains of this study these plans include strategies and considerations related to food and each of the CBH areas. Examples include strategies that promote urban agriculture, facilitate EV usage (Zoning Bylaw), protect forest, wildlife, and water assets (land protection program), control urban growth, and define land uses (official community plans). These strategies are supported by regional efforts toward guiding urban growth directions, preserving forest and biodiversity preservation, and food systems strategies (regional adaptation strategy and regional growth strategy).

7 Conclusion

This study presents the various one-way and two-way relationships between areas of food systems, climate, biodiversity and human health and demonstrates the importance of integrated perspectives for community food systems planning (Blay-Palmer et al., 2016) to comprehensively understand the benefits and trade-offs of different food strategies and approaches. Such understanding enables effective transitions toward local sustainability (Ericksen, 2008). Exploring the intersections of the CBH nexus provides opportunities for local and regional stakeholders to understand which food systems strategies can meet broader sustainability objectives, as well as see systems interactions within critical sustainability issues.

The analysis done in this study identified themes beyond those within the food-CBH framework: knowledge exchange, land-use plans and transportation projects, waste challenges and management, and support. These areas can be adapted to other cases as a part of their analytical framework. The results highlight the importance of collaboration among stakeholders in these areas to design and implement effective strategies and actions due to the interconnections between different planning and policy areas. The results of this study can be used as a tool for planners and policymakers to inform the development of an integrated plan.

It is worth adding that the CBH framework, as noted by Newell, (2023) who introduced the framework, can be refined and expanded. This was explored in a discussion paper by Newell et al. (2023), and it follows other work that expanded and added domains to the water-energy-food nexus (e.g., Mirzaei et al., 2022; Slorach et al., 2020). Such expansion could be informed by emergent themes found through the research and application of the CBH framework, such as exemplified by this study.

This research showed how collaboration among the actors of the CBH and food systems is critical for integrated strategies toward sustainability objectives, a finding that was mentioned by nearly all the interviewees. The establishment of a facilitatory body or organization that specifically links the actors within the food-CBH systems and planning domains would contribute to progress toward local and regional sustainability objectives. However, it was also noted by study participants that to make this collaborative decision-making possible, there needs to be a focus on not just improving outcomes, but also the planning process. Accordingly, although this work focuses on outcomes, the findings confirm the importance of also improving processes via addressing considerations around equity, diversity, reduced bias, etc. in planning to effectively facilitate collaboration.

Newell et al. (2023) posit that the CBH nexus is well suited to be applied at the local scale, primarily due to its application within place-based contexts (i.e., as done in this research). Nevertheless, they also note that the framework should be aligned with higher-level sustainability-oriented frameworks, such as the Sustainable Development Goals. Delving into the way to achieve such harmonization and multi-scalar integration necessitates additional scholarly inquiry (e.g., Dale et al., 2020). Further studies are required to systematically investigate the alignment of the CBH nexus with compatible frameworks, and such work could employ a multi-level governance perspective to illuminate the intricate dynamics of interplay across various governmental levels.

Chapter 3: Participatory system mapping for food systems: Lessons learned from a case study of Comox Valley, Canada

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Abstract

Food systems are complex and multifaceted, comprising a diverse range of actors, processes, and interactions. Participatory system mapping can be employed to help understand this complexity and support the development of sustainable and resilient food systems. This article shares a participatory mapping approach that has been developed as part of the Climate-Biodiversity-Health (CBH) Nexus project in the Comox Valley, British Columbia, Canada. This research pursues two main aims: (1) to ground truth in the CBH system map of food systems, developed with the participation of stakeholders; and (2) to explain how participatory system mapping can be employed to clarify the complexity of food systems in a clear and concise manner for all stakeholders. This research contributes to the literature on participatory system mapping, including critiques of its practical utility, by employing participatory approaches to visualize multi-dimensional and multi-level system maps with an emphasis on verifying that they are clear, understandable/useful, and reliable for diverse stakeholder audiences.

Keywords: system mapping, food systems, participatory approaches

1 Introduction

Food systems issues are complex and connected to numerous other planning and policy areas and challenges (Monasterolo et al., 2016). For example, food production can contribute to issues like climate change, greenhouse gas emissions, biodiversity loss, and water and air pollution, while also being adversely affected by these issues (Ahmed et al., 2020; Horst, 2017; Willett et al., 2019). In terms of the latter, climate change leads to a reduction in the amount of viable agricultural lands, food production, and quality as well as an increase in food prices (Ahmed et al., 2020). Converting natural ecosystems to agricultural lands can increase food production; however, a loss of these ecosystems contributes to climate change and adversely influences biodiversity (Wilhelm & Smith, 2018). As an example related to food access, the existence of food deserts (i.e. areas with limited access to grocery stores (Brandt et al., 2019) can lead to local residents choosing available but unhealthy foods instead of travelling long distances to access healthy foods, which increase the risks of suffering from nutritional health issues (Larsen & Gilliland, 2008; LeClair & Aksan, 2014).

The complexity of food systems issues presents a need to apply system mapping to food planning and policy in order to develop a comprehensive, multi-dimensional, and multi-scalar picture for studying complex issues (Von Bertalanffy, 1972). For example, Elyasi and Teimoury use critical systems practice to study aspects of the sustainability of rice agriculture and its supply chain (Elyasi & Teimoury, 2023). Herrero et al. consider links between food systems innovations and the UN Sustainable Development Goals (SDGs), explaining how new technologies' impacts, both intended and unintended, can influence sustainability (Herrero et al., 2021). Lajoie-O'Malley, et al. emphasize the two-way links between food systems and ecosystem services and how using technology in food production can influence these relationships (Lajoie-O'Malley et al., 2020). Béné et al. develop a framework of the interactions among food systems, sustainability and healthy diets to provide a more comprehensive interpretation of sustainability that shows the trade-offs between different aspects of food systems' sustainability (Béné, Prager, et al., 2019). Klassen and Murphy evaluate the links between food accessibility and economic distribution and political accountability during the COVID-19 pandemic to show how they connect to the possible needed changes to achieve food justice and food resilience (Klassen & Murphy, 2020). Tornaghi and Dehaene identify how urban-rural linkages can transform food systems, arguing the impacts of urbanism and urban growth on the displacement of farmlands and land-use changes and proposing an agenda to tackle these issues (Tornaghi & Dehaene, 2020). Béné et al. use system mapping to elucidate a comprehensive understanding of elements, actors and drivers of food systems in their articles (Béné, Oosterveer, et al., 2019). Karoliina et al. examine how Finnish food systems have been affected by the COVID-19 pandemic and war in Ukraine, the interconnections among the different actors in food systems, and the ways they can be resilient under such conditions (Karoliina et al., 2023). In this way, system mapping can help identify various aspects of food systems, including their links with other areas, and offer insights into existing challenges and solutions to foster food resilience and justice.

Identifying the interconnections among the components of these complex systems can be challenging and complex. Linkages cannot be recognized based on academic or theoretical understanding alone; they should be established according to the particular context. Participatory

approaches can help identify the components and relationships of complex systems (Barbrook-Johnson & Penn, 2022). The participation of stakeholders provides researchers with the opportunity to have a creative and inclusive involvement of wider disciplines, players, knowledge, and expertise (Collier et al., 2013). Participatory approaches can be used to build collaboration between players and researchers and provide a realistic scope for creating a systems model. Such approaches can support the collection the substantial amount of data needed to model a system (Allender et al., 2019). Through participatory research approaches, researchers gain a depth of knowledge of cultural, environmental and other contextual features of a place and help them not only realize components of systems and their interconnections but also find effective strategies to address challenges in areas. Accordingly, using participatory approaches in the process of studying complex systems is valuable and in some cases, necessary (Collier et al., 2013).

Participatory system mapping can draw on a variety of methods. For example, De Moor et al use a CommunitySensor methodology and the Kumu visualization application to examine the impacts of different urban design innovations and initiatives, which were developed to tackle complicated environmental problems, increase public awareness and adopt the lessons learned for future initiatives (De Moor et al., 2022). Balaican et al. argue that identifying different place-specific elements of the food-water-energy nexus requires participatory approaches, and they apply the nexus in Tulcea, Romania to food systems using stakeholder workshops and interview methods (Balaican et al., 2023). In research in Tanzania, Johansson et al. explore the links between agroecology and just and sustainable food systems in stakeholder workshops, with an aim of visualizing how agroecology can influence farming in the future and which policies are needed to support agroecology (Johansson et al., 2023). Nemes et al. explore different dimensions of Values-based Territorial Food Networks (VTFN), their benefits, and challenges in European community case studies, emphasizing the role of participatory approaches in interpreting and applying VTFN (Nemes et al., 2023). Horstink et al. use participatory rural appraisal in the case of Odemira, Portugal, to study food systems conditions in depressed areas and support their residents from democratic and ecological lenses (Horstink et al., 2023). Morales-García et al. incorporate participatory methods into a document analysis study to reveal how using the water-energy-food nexus can be useful for economic sustainability (Morales-García & Rubio, 2023). In an Indonesian case study, Purwanto et al. use participatory model building to identify issues in water, energy, and food security and then may the ways that these areas influence each other and show it in a framework (Purwanto et al., 2019). Winans et al. studied the sustainability of California almond growing and California winegrowing systems. They propose a stakeholder engagement approach, sustainable value mapping and analysis (SVMA), and argue how it could be helpful to improve stakeholders' participation in studies of such systems (Winans et al., 2021). These studies demonstrate how applying participatory methods in system mapping is beneficial for increasing public awareness and for comprehensively realizing and addressing complex environmental problems.

Although valuable, using participatory methods in systems studies presents challenges, such as with the nature of and meaning of the term 'participatory methods' for researchers, institutions, decision-makers, and funders (Cvitanovic et al., 2019). Terms like 'participation', 'community engagement,' 'partnership,' and 'collaboration' mean different things to different people, leading to different expectations among participants about participatory processes and outcomes (Lasker

et al., 2003). Moreover, participation in research can have one of two goals: as a method for improving efficiency in projects or as an opportunity for people, especially marginalized groups, to improve their living conditions. Depending on which goal is being pursued, the results of one participatory research study can be considerably different from another study (Cleaver, 1999). Additionally, participatory system mapping lacks a systematic framework with which strategies and action plans can be evaluated for management and decision-making objectives (Mendoza & Prabhu, 2006). Furthermore, participatory researchers face challenges related to comprehension and communication difficulties. There are differences between what a person has in their mind and what they explain, meaning that some have difficulty articulating their thoughts exactly and completely when discussing complex issues. Moreover, participants interpret the ideas and comments of other participants based on their context (belief, culture, knowledge, etc.); thus, there are always differences between what a person aims to express and how it is interpreted and internalized by others. Since participatory processes generally involve dialogue, this is a common issue in participatory research (Falzon, 2006). Finally, participatory processes are time-consuming, thusly requiring sufficient financial resources to support lengthy research efforts (Cleaver, 1999).

Participatory research approaches span different levels of participation. Arnstein's foundational 'participation ladder' describes a range of practices, from manipulation to citizen control (Arnstein, 1969). In his wheels of participation theory, Davidson proposed four scales of participation including inform, consult, participate, and empower, and his and the participation ladder framework have been applied to environmental issues (Davidson, 1998). Wiedemann and Femers used Arnstein's participation ladder for waste management decisions (Wiedemann & Femers, 1993). Luyet et al. measure five levels of stakeholder's engagement, from information to empowerment, and they propose a framework for participatory research in this field, from identifying stakeholders to evaluation (Luyet et al., 2012). Soma et al. consider the importance of the level of stakeholders' involvement in environmental sustainability and categorize stakeholders' participation into five levels (from highest to lowest): stakeholder-based initiatives, government-based initiatives, science-based initiatives, voting, and no responsibility (Soma et al., 2018).

The challenges of using participatory approaches are accentuated in deep participatory research, that is, studies that apply participatory methods in all or most of their phases. Such challenges are particularly pronounced when the research focuses on a wicked problem, complicated and ambiguous problems with considerable numbers of stakeholders involved (Davies et al., 2015). However, due to the benefits of deep participation, using such approaches is still useful, and finding ways to tackle the challenges around employing such approaches is beneficial. Suggestions for tackling such challenges include using visualization technology to facilitate participation and reduce time consumption (Winans et al., 2021), targeted selection of participants, developing conflict management mechanism, providing review options at different stages of research (Cvitanovic et al., 2019), and designing a context-based approach (Quick & Bryson, 2022).

Despite all of the previous research, there is no one 'perfect' way of conducting participatory system mapping on complex issues using a place-based approach. More research is needed to explore and improve these approaches to studying complex problems (Cvitanovic et al., 2019;

Puskás et al., 2021). The sustainability of food systems and their connections to climate actions, biodiversity conservation, and human health is chosen as an example of a wicked problem in this research. This methods-focused paper: i) explains how a participatory system map can be developed, reviewed and finalized through stakeholder engagement; ii) the challenges encountered with this process and how they were tackled, and; iii) lessons learned and leading practices for the design of participatory systems approaches. The purpose of the study is to reveal the complexity of relationships and to identify key linkages which allow pinpointing interventions and strategies for fostering food resilience and justice. The practical result of this research is a tool that provides a comprehensive understanding of the complexity of food systems and how they link to other aspects of sustainability. The methodological results of this research also can be adapted to other participatory system mapping studies.

2 Research context

This study is the second part of this dissertation aiming to enhance the integration of community planning by creating an experimental framework focused on three vital areas for sustainable development: climate change, biodiversity conservation, and human health (Newell, 2023). As explained in Chapter 2, the framework, referred to as the climate-biodiversity-health (CBH) nexus, can be applied to various community planning domains to examine how strategies, policies, and actions either align or conflict with objectives and considerations within these sustainable development areas. In this project, the CBH nexus is applied to the goal of achieving sustainable local food systems.

Employing a community-engaged participatory research approach (Vaughn & Jacquez, 2020), the project involves engaging stakeholders and local governments in the Comox Valley region, British Columbia. The objective of the research is to foster a deeper understanding of how communities can actively participate in integrated food systems and sustainable community development planning. The project aims include producing practical outcomes by developing frameworks and tools that practitioners can employ to address their planning requirements and by generating findings and recommendations for integrated food systems planning and policy (Ghadiri et al., n.d., 2022).

Figure 19 shows the system map of Comox Valley's food systems based on CBH nexus that was developed in the first phase of this research (see Chapter II). This system map was developed through qualitative analysis of semi-structured interviews with 33 stakeholders in the Comox Valley. Inductive coding was used to code the interview data. The codes (i.e., sub-nodes) were then organized into categories (nodes which are strategies and outcomes in this case). The map captures relationships among different food systems strategies (green nodes) and outcomes (yellow nodes), and it shows how various strategies align or conflict with different CBH imperatives and can be used to support integrated community sustainability planning efforts. More information on how the systems maps were developed can be found in Chapter 2.



Figure 20. The Comox Valley region

Participatory system mapping is an effective approach in the Comox Valley region, which has been successfully employed in previous studies. For instance, Poon et al. adopt a group modelling building process in two cases of Kamloops and Comox Valley in British Columbia and develop a system map of children's social and emotional well-being and its influential factors (Poon et al., 2022). Studying similar cases, Karsten conducts research using participatory system mapping to identify the influential factors and impacts of drug poisoning (Karsten, 2023). In their study in this case, Hunsberger et al. emphasize the importance of citizen participation in environmental assessment projects, and they give suggestions to improve participation (Hunsberger, 2004).

4 Methodology

This participatory study was conducted in the Comox Valley region of British Columbia, Canada using the participatory system mapping approach. The research engaged stakeholders who work at various scales (i.e., local, regional, provincial) and are involved in food systems, climate action, biodiversity conservation, and/or human health strategies, programs, or policies. Participant recruitment involved an identification of stakeholder organizations, which was carried out through an Internet search that involved the use of keywords such as 'climate action,' 'biodiversity conservation,' 'food,' and 'community health' in conjunction with the Comox Valley municipalities. Additional stakeholders and organizations were identified through the snowball sampling techniques. The broader research project began with a series of interviews, which informed the development of a systems map, and the methods and outcomes of this research are reported elsewhere (Ghadiri et al., n.d.). This study focuses on the testing and revising of the systems map using a participatory workshop-based research approach.

Before each workshop, participants were given consent forms to review and sign prior to participating, which contained information on the purpose of the study, procedures to maintain anonymity and confidentiality, benefits and inconveniences to research participants, and withdrawal procedures. With respect to the latter, the consent form explained that participants can have their transcripts removed from the dataset if they decide to withdraw, as long as the studies have not yet been published.

4.1 Workshop Series

The data collection was done through two different series of workshops (see Figure 21). The first series of workshops, which are referred to as ‘test workshops’ in this paper, involved students and academics. This workshop series was conducted in three sessions to test the system map and ways of engaging stakeholders in systems thinking. From this work, a revised system map and workshop activities were produced, and these were then tested/refined through a series of four workshops with stakeholders in the Comox Valley (referred to in this paper as ‘stakeholder workshops’).

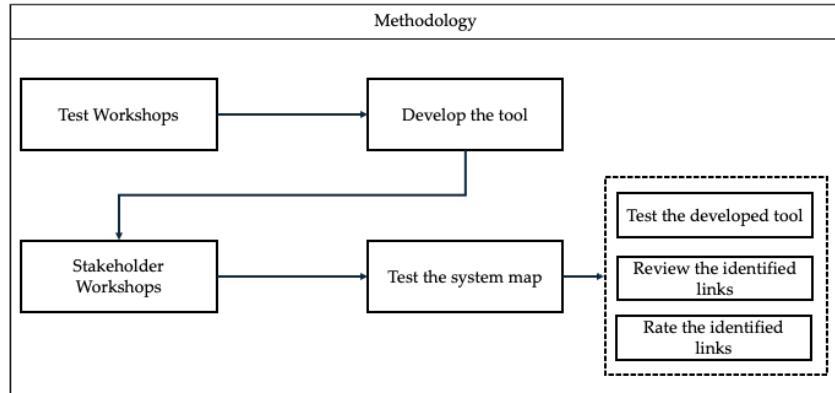


Figure 21. The methodology
Source: Authors

4.1.1 Test workshops

The test workshops were each one hour in duration and were held in the months of September and November 2022. Participants consisted of academics and students in the fields of environmental studies, food systems, and public administration, and they were recruited via e-mail through the faculty and classmate networks of the researcher team. The first two workshops were held in person on the Royal Roads University campus (Victoria, Canada) and the final one was run online using Zoom. The numbers of participants in each of these workshops fell between 5 and 9 people. Workshop sessions were audio recorded, and the recordings were later transcribed using the Trint transcription application (see Table 9).

Table 9. Details of Test Workshops

Description	Date	Holding method	Number of participants	
			Faculty /researchers	Students
Workshop 1	September 2022	In-person	3	6
Workshop 2	November 2022	In-person	2	3
Workshop 3	November 2022	Online	4	0

The aims of the workshops were to (1) examine and evaluate the system map in terms of the clarity of the nodes and validity of the links, (2) assess the format in which the systems map was presented to participants and how well it can be used as a tool; and (3) identify how the map and workshop activities can be improved. To this end, the workshop consisted of four parts, as detailed in Table 10.

Table 10. Test Workshops' process

Workshop part	Description
Ice breaker	Participants provided a short introduction to themselves at the beginning of each workshop helps all participants to know each other a little more. This was done in five minutes.
Introduction and explanation	In this step the objectives of the greater research project and the process of developing the system maps were explained. This was done in about 15 minutes.
Workshop activity	In this step, participants are given 20-30 minutes to review the system map. In this section three guiding questions were provided for them: Do the relationships that are shown make sense? Are there any missing linkages? If yes, can you draw it on the map? Are there any key effects/outcomes that are missing? Why or why not
Discussion	Participants are engaged in an unstructured discussion which is guided by open-ended questions as follows: Which strategies are most important? Why? Which strategies are particularly important for integrated sustainability planning (and why)? Which outcomes represent critical objectives? How (if at all) could these systems maps assist you with your work? How could these maps be improved as tools for supporting your work? What is your feedback for this experience?

4.1.1.1 Test workshop 1

Due to the system map's high complexity and the time limitations of workshops, the complete system map was divided into four sub-systems (see Figure 23) based on the strategies' areas: food, climate actions, biodiversity conservation and health, and governance. The purpose of creating these sub-system maps was to create visualizations that better facilitate comprehension of the system by focusing on one planning and policy area. When reviewing the sub-system maps, participants engaged in thinking about how their planning and policy area impacts other areas; thus, they still engaged with the full system, without needing to review the whole system map (which can be visually overwhelming due to its complexity).

The system maps were shared with participants in paper format (Buckle et al., 2010). Four sheets were printed in A2 size with a two-page legend listing the sub-nodes of each outcome or strategy (i.e., the codes that informed the developed of the nodes) (Ghadiri et al., n.d.). Each sheet included four sub-system maps, and one of these maps was larger than the others (see Figure 22). Participants were divided into groups of 2 to 3 people. The groups were asked to initially examine the larger map and subsequently review the remaining three maps. Participants were encouraged to write their feedback on the maps with respect to whether the systems maps were comprehensible, useful, and/or missing key elements. Then, a group discussion was held, where participants are asked to explain their thoughts and feedback using the guiding questions (see Table 10).

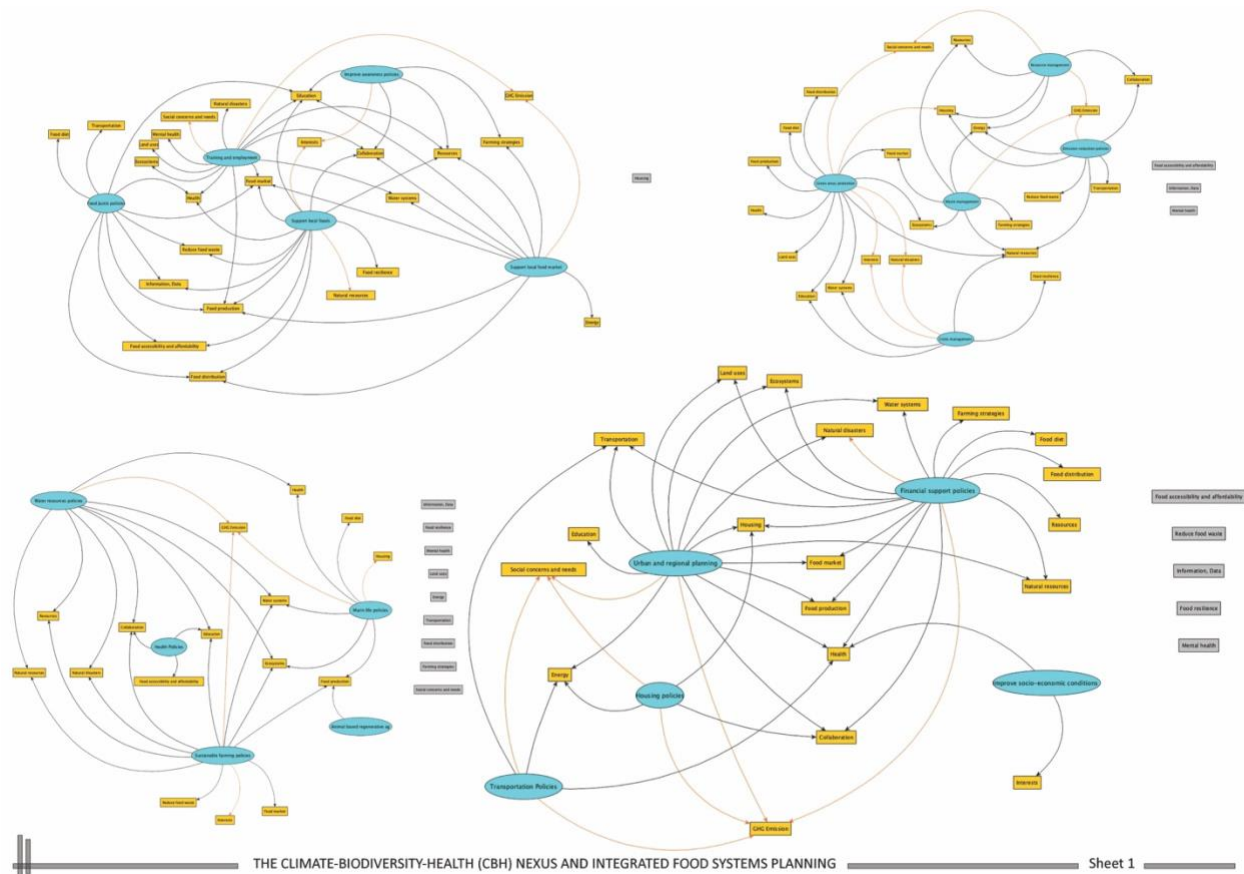


Figure 22. An example of system map sheets
Source: Authors

4.1.1.2 Test workshop 2

The results of the first workshop demonstrated that dividing the whole system map did not help improve the clarity and comprehensibility of the system (see Results for more detail). In addition, some nodes were noted to be vague and need to be revised. Based on this feedback, the system map design and workshop activities were revised prior to running the second test workshop.

In the second workshop, the system maps were prepared in a digital format using Kumu and uploaded to the CoLabS online collaboration and engagement platform (Jost et al., 2021) to share with participants. Instead of the presenting the system as four sub-systems (as done in the first workshop), an individual system map was designed for each strategy and their respective outcomes (18 maps total). Labels were added to each link/connection between nodes to describe the nature of the relationships. In addition, short descriptions and illustrative examples were added for each node to explain to what they refer (participants could see these by clicking on the nodes). Figure 5 provides examples of strategy-centered system maps.

To facilitate participant engagement in the systems map, three questions were asked. The questions were designed to collect feedback on (1) the importance or relevance of the outcomes

to the strategies, (2) possible missed outcomes of strategies, and (3) the impact of each strategy on different areas of the CBH nexus and food. The questions were as follows:

- How important is each outcome for this strategy?
- Are there any other co-benefits produced through this strategy? Are there any trade-offs?
- How much does this strategy influence climate actions, biodiversity conservation, human health, and food systems areas?

For the first and last questions, participants could rate to each option from one (very low) to five (very high). The 18 individual system maps (see Figure 23) were categorized into five groups (see Table 11), and (due to time limitations) participants were asked to choose one of these groups based on their interest in the review. Participants were permitted to review other groups if they had time or interest. They also had the option to add their review after the workshop since the materials were open access to all of them.

Table 11. Individual system map division

Group No	System maps involved
1	Animal-based regenerative agriculture Green space protection Shellfish farming Farming techniques
2	Food justice policies Support local food market Support local foods
3	Awareness improvement Improve socio-economic conditions Waste resource management Training and employment
4	Crisis management Governmental financial support Affordable Housing strategies Enhancing active transportation
5	Poverty reduction strategies Emission reduction strategies Community health programs Governance of Land-uses

Finally, participants were asked to review the whole system map. Note that the whole system map simplified the system, as it only displayed links between strategies and outcomes that appear more than two times in the interview data to make the map more legible and comprehensible, whereas the individual strategies maps showed all links and outcomes. Labels have been added to demonstrate the reasons behind links like the individual system maps. Participants were asked to first review the whole system map, and then provide feedback guided by the questions:

- Which strategies are particularly important for integrated sustainability planning (and why)? Which outcomes represent critical objectives?
- How (if at all) could these systems maps assist you with your work? How could these maps be improved as tools for supporting your work?

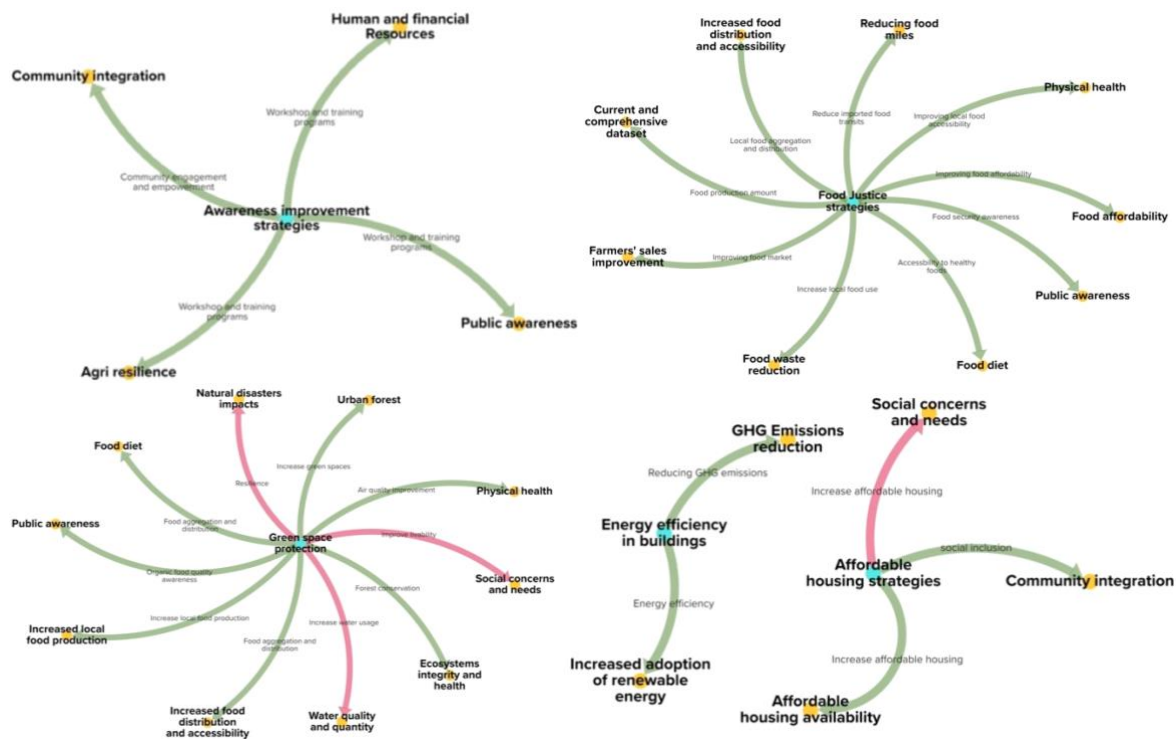


Figure 23. Examples of individual system maps

4.1.1.3 Test Workshop 3

The results of the second test workshop indicated that most of the issues around interacting and understanding the systems map mentioned in the first workshop were resolved. The major issues noted in the second workshop related to time limitation and the vagueness of some nodes, and based on this feedback, nodes names were revised and clarified. To address the first issue, individual maps were organized into eight groups that gather similar/related strategies (see Table 12). To address the second issue, a third test workshop was held to review the revised nodes and confirm their identities and naming. In this workshop, a list of updated nodes with their sub-nodes was shared with participants, and they were asked whether the names are clear and can represent their appropriate meanings, as well as any suggestions to improve the clarity and adequacy of the nodes.

The nodes were revised in this workshop. Also, to improve the clarity of nodes, especially in the case of strategies, some examples (e.g., name of plans, or programs) were added to their description part.

Table 12. Individual system map division (revised)

Group No	System maps involved
1	Awareness improvement Crisis management Affordable housing
2	Food justice Poverty reduction
3	Emission reduction

	Governmental financial support
4	Green space protection Community health programs
5	Land-use governance Shellfish farming
6	Support local food Support local food market
7	Farming techniques Training programs
8	Enhancing active transportation Waste resource management Water resource management

4.1.2 Stakeholder workshops

After revising the system maps' visualization method and content based on the test workshops, the finalized versions were prepared for the stakeholder workshops. Recruitment was done by sending invitation emails to the stakeholder list prepared for the interview phase of the greater research project (Ghadiri et al., n.d.). The stakeholders included all working in four main areas of food systems, climate action, biodiversity conservation, and human health from the local to provincial level. The invitation email first provided an update on the progress of the project and then invited them to join in a workshop session.

The content and activities of the stakeholder workshops were similar to the second test workshop, and they each ran for 1.5 hours. Both in-person and online options were provided to participants, allowing them to join the workshop that best suited their preferences and availability. The first two workshops were planned as in-person sessions, but due to an unexpected snowstorm, the first of these sessions was cancelled. The second session was held in a conference room at the Old House Hotel in the Comox Valley. The next three workshops were held online over Zoom. A total of 14 people participated in the stakeholder workshops, with each engaging 3 to 5 people (Table 13).

Table 13. Details of stakeholder Workshops

Description	Date	Holding method	Number of participants
Workshop 1	November 2022	In-person	3
Workshop 2	December 2022	Online	3
Workshop 3	December 2022	Online	5
Workshop 4	February 2023	Online	3

Similar to the test workshops, the stakeholder workshops consisted of four parts: icebreaker, introduction, participation, and discussion. Workshop discussion sessions were recorded. The main aim of these workshops was to test the how much the proposed method, showing the participant 2 to 3 single system maps before the whole one, can facilitate understanding of the complex system. Additionally, the clarity of the nodes and validity of the recognized links were tested in these workshops.

4.2 Data collection and analysis

Interpretive qualitative data analysis was employed in this research. An inductive coding approach was used in this study, meaning codes were derived from the transcript data and all written notes on the Colabs platform. NVivo (v. 12) software was used to code each transcript, and an inductive coding approach was conducted, involving adding to and revising the coding list as data were reviewed. The validity and reliability of the analysis were strengthened by running the coding process multiple times.

The results have been organized into two categories: (1) those that are related to reviews about the effectiveness of engaging participants with the system maps and (2) those related to the content of system maps. The former was analyzed based on thematic coding results. The latter used a matrix coding method to identify data coded with two different nodes, using this overlap in coding to recognize links among strategies and outcomes. The new links were subsequently used to revise the system map.

5 Results

5.1 Test workshops

5.1.1 Test Workshop 1

The participants agreed that the system maps shows the complexity of food systems, its different players, and the crucial need of using integrated approaches to tackle this area; however, there were some critiques of the presentation and format of the maps. Firstly, some participants explained it is expected that developing a system map for food systems based on a three-dimension nexus (CBH) is highly complex. The used approach of dividing the full system map into four different maps did not effectively facilitate comprehension and so other approaches were needed to address this issue. The high complexity of system maps makes it confusing, and creates difficulties in realizing the links and how they influence each other, as one participant noted:

“I don't know how to make use of it. I just know it is complicated. And that's all. And I like simple things. I like things that I can grasp. It's just too hard to comprehend. It's too big. It's too amorphous. We don't know what to do. And your system actually kind of makes me feel that way because it's too much in the way, I think. But I would get more out of it...”(Participant 220010)

To tackle this complexity issue, a number of solutions were proposed by participants. These solutions focused on the reduction of links in the full system map. One of the participants proposed to remove the links that only appear a one or two times in the interview data, since links just mentioned by few interviewees may not reliably represent real-world phenomena or relationships. By just showing the more frequently identified links, the system map's complexity can be reduced.

Another suggestion to address the system complexity was to identify the main themes based on the subject of strategies and outcomes and dividing the full system map into these themes. The result being systems maps that are both less complex and capture areas in which relate to the work of intended users. The users can then select a map of interest to see related co-benefits and

trade-offs associated with relevant strategies. Participants also recommended placing the outcome nodes at the center of system maps and developing maps showing which strategies produce such outcomes.

Participants commented on challenges navigating the systems map. The maps contained legends with sub-categories of each node to help participants understand the different aspects of the visualized system; however, the process of finding each node at the legend and go back to the system map adversely influence participants' comprehension. Additionally, participants of the first workshop explained some nodes are vague and there is a need for reviewing the nodes' chosen names. It was mentioned that the scales of nodes are different, and in some cases, the chosen names include meaning more than their sub-nodes. Additionally, comments were made about how relationship types (positive or negative) were displayed with no directionality toward the outcomes. For example, use a green line to show co-benefits between food justice strategies and food miles was not found clear by participants and instead, they suggest showing the direction of outcomes by writing 'reduced food miles' in this case:

"I think it's also an absence of directionality within the outcomes. So you have like a statement, like academic partnership, but is it an increasing? Is it a decreasing? Is it more, less better, worse? Like it requires some adjective attribution for an outcome to then be like fits into this?" (Participant 220013)

Participants also expressed that the nature and rationale for creating links between nodes were unclear in some cases, as well as why these were identified as co-benefits or trade-offs. This issue contributes to difficulties around system map comprehension and makes the process of reading the map time-consuming. For example, one of the participants said:

"You want to turn to, I think something you were just generally struck by how it is, is it is difficult to kind of figure out the logic of the connection between strategies and outcomes. We spent a significant amount of time like identifying specific strategies and then trying to discuss how those specific strategies relate to that specific, uh, outcome with being the worst, right?" (Participant 220014)

5.1.2 Test Workshop 2

The system maps presentation was changed from paper-based to web-based prior to the second workshop; this appeared to help user navigation and comprehension. In addition, preparing the system as a series of individual system maps centered on strategies gave participants an opportunity to get familiar with the map and realize how to read it in a simplified form.

Other revisions include the addition of labels for each link, and these appeared to help participants understand relationships between nodes. Adding the sub-nodes of each strategy or outcome facilitates their understanding of the nodes' meaning. Showing only links that appeared more than two times in the interview in the whole map may reduce its complexity in comparison with the previous version and so improved its legibility. Rewording nodes improved their clarity. Finally, the zoom-in and out feature of Kumu helped participants focus on different parts of the system map, facilitating their comprehension. For instance, two of the participants explain:

“Yeah. Now, before, you might remember from the first run we did, we were given the full system, but now it's broken down into little bits and pieces. So at least personally, I've definitely found this exercise is actually just much easier to actually get to. It is better.”
(Participant 220022)

“It's interesting the way you kind of work through the system. Yeah, I guess. I guess right, this tool is more helpful”

“For me it's, it helps also to be very aware and not to miss anything of these points within the food systems for my research. Like, it's quite interesting to have this overview.”
(Participant 220024)

Participants also provided suggestions to improve the map in the second test workshop. Such suggestions include comments about how concepts like food justice, can be defined in various ways by different people, and it is possible that those definitions differ from how the concept is being used in this research. Participants also noted how some nodes are vague in their naming and need to be reworded. Finally, a review of categorization could be worth being sure about categorizing nodes with similar meanings. Additionally, it was mentioned in the workshop that system maps are highly context-based and relationships differ depending on place and context. Participants mentioned the system maps should be reviewed by people that have knowledge and experience with different contexts and places, the implications of such comments are that stakeholders are the most qualified people to review and revise the system map.

“I think it was a challenge for us and I think we need to encourage people to look at different scenarios and then it fleshes out. And so, you know, given these circumstances, yes, it would be good for food justice or whatever, but given other circumstances, it would not be. And so I think we have to know that there's a lot of complexity to all of these issues.” (Participant 220021)

5.2 Stakeholder workshops

Feedback from the stakeholder workshops indicate that the refinements made based on the test workshops improved the readability of the system maps; however, there were still critiques, with some of these critiques being in contradiction. In particular, participants had differing views about the presented complexity of the whole system map. Some participants expressed that more detail should be added. They believe the system map could show more complexity and still be legible. In addition to showing the links between strategies and outcomes, participants mentioned that it is worth adding outcomes-outcomes and strategy-strategy links.

Contrarily, some participants expressed that the system map is still too complex. These participants suggested that just the key components should be shown in the map, and the map needs to be divided into parts to be understood. Based on the feedback and identity of the participants, it appeared as if those whose affiliation relates to interdisciplinary work (i.e., urban planners) like to see more complexity in system maps. Such a finding suggests that it might be worthwhile to vary the level of complexity of a system maps in accordance with the intended users and the reasons behind using it, in order for the systems maps to effectively serve as tools to develop plans and policies or to improve understanding of systems components and relationships.

Some participants mentioned that there are risks of ‘misreading’ the system maps. The nodes can be defined differently by each participant so participants may interpret the nodes and (as a consequence) understand the system based on their differing knowledge, perspectives, and experiences. For example, one of the participants explained:

“I guess I'm a little bit curious how you get a lot of people who make up these things. There are a lot of assumptions that you understand. Sort of definitional stuff. I like a baseline of this is what we are talking about. I mean, you know, especially like context is really important, but even just definitional stuff. Yeah. like just what does this mean? Something means different to different people. One of the I think assumptions can get inadvertently when you hear based on who you are. You might be more knowledgeable in other areas you might not be. “ (Participant 220033)

Table 14. The influential level of strategies on their outcomes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
A		4.5	4.5										5								5						
B									4										5		5						5
C											4.5			4.5													
D	5		5																				5				
E				5		5	4	4		4					5						4	4	5				
F			4																		5						
G					4.7						5			4.7							3.7						
H	5	5			5	5		5			4		5		4	5	5		5	4	5	5					5
I					5			5							5	5			5	5	4.5		4.5			5	5
J							4					4							4.5		4.5						
K					3						4			4		4				4.5	2.5			2		5	4.5
L					5						1					3						4		3			
M						4					3				5	5						4					
N					4	5							4								3						
O					4.3	4.3					4	5				3.7				4.7							4.5
P					4	4					4		4			4		4	3.5	2	5		4				3
Q					4.5						4.3			4	3									3.3	4.3		
R					4.5						3		5	4		4.5							5				
S					4						3					5				4.5	3.5						5

Legend:

The level of the effect of a source (an impacting strategy/ outcome) on a target (impacted strategy/outcome)

1 (very low)	2 (low)	3 (Medium)	4 (high)	5 (very high)
A: Awareness improvement strategies B: Crisis management C: Energy efficiency in buildings D: Housing strategies E: Food justice strategies F: Poverty reduction strategies G: Emissions reduction strategies H: Governmental financial supports I: Green space protection J: Community health strategies K: Land-use governance L: Shellfish farming M: Support local food market N: Support local food strategies O: Farming techniques P: Training and education Q: Enhancing active transportation R: Waste resource management S: Water resource preservation strategies		1: Affordable housing availability 2: Agricultural resilience 3: Community integration 4: Current and comprehensive dataset 5: Ecosystem integrity and health 6: Farmers' sales improvement 7: Food affordability 8: Food diet 9: Food resilience 10: Food waste reduction 11: GHG Emissions reduction 12: Health risks 13: Human and financial resources 14: Increased adoption of renewable energy		15: Increased food distribution and accessibility 16: Increased local production 17: Land availability and affordability 18: Mental health and wellbeing 19: Natural disasters impacts 20: Physical health 21: Public awareness 22: Reducing food miles 23: Social concerns and needs 24: Stakeholder buy-in 25: Traffic congestion 26: Urban forest 27: Water quality and quantity

Insights into the development of the systems map were also gained through the exercise where all stakeholder workshop participants rated the strength or importance of a relationship. The majority of strategy-outcomes relationships were given a rating of 4 and 5. This means that they are recognized as influential ones on other areas and should be considered in developing future strategies. Table 14 shows the mean ratings for each outcome. Sources are shown in the first column of this table and targets are placed in its first row. According to these results, it seems even the recognized links that appear less than two times in the interview data are important and

not negligible with respect to their influence on the system, meaning that ignoring links just because they show up in the data infrequently is not reliable.

When asked about missed outcomes for strategies, some suggestions were provided. In this exercise, participants indicated that many (if not most) notable outcomes of strategies were effectively identified through the systems map, but also that the map could be enhanced with the addition of a few more strategies (Table 15).

Table 15. New identified links between.

Strategy	Strategy/Outcome
Poverty reduction strategies	Increased food accessibility
	Food affordability improvement
	reduced financial supports for farming
Emission reduction strategies	Natural disaster impacts
	Improve local economic profits
	Increased construction and infrastructure costs
Green space protection	Improve active transportation
	Increased housing and land price
Shellfish farming	Increase unrecyclable waste
Support local food market	Increased local agriculture job market and training opportunities
	increased vulnerability to localized climate disruption
Support local food	Preserve indigenous food knowledge
	Increase population
Enhancing active transportation	Increase physical injury risk

Note: Green cells of this table represent co-benefits and orange cells refer to trade-offs.

Through the workshop process, two main changes were made to initial system map shown in Figure 19. Firstly, the map was made to be more detailed with all outcomes of strategies displayed. Secondly, new links and relationships were drawn in the map. Figure 24. show the revised version of the map.

inclusiveness, cannot be effective in this regard. By considering the roles and contributions of a range of actors, from individuals to organizations, participatory processes can help to achieve this goal (Barreteau et al., 2017). Additionally, a comprehensive understanding of wicked problems elucidates relationships among different aspects of a system, like social, economic, physical, cultural, and environmental, and influential factors of complex problems, which can vary at different levels in terms of their cause-and-effect interactions. These links cannot be comprehensively identified based on the narrow knowledge-based of limited and specific groups and can be achieved only through engaging diverse stakeholders. The data collected from stakeholders not only reveals the correlations between various factors but could help researchers to realize the key causes of problems, which is helpful to prioritize action plans and specify from which part addressing issues should be started (Kaethler et al., 2015).

Despite the advantages of applying participatory methods in system mapping, the ways these methods can be employed vary and have a wide range of associated challenges. In order to mitigate potential challenges in the stakeholder workshops, this study conducted three test workshops. These workshops serve the purpose of evaluating the developed system maps, identifying any deficiencies in terms of visualization and language, and gathering suggestions for improvement from scholars external to the research team. This approach enables researchers to thoroughly review and enhance the system maps by incorporating a broader range of ideas, as well as test and refine the workshop activities. Such insights allowed for valuable refinement of the systems maps and workshop activities prior to their presentation to stakeholders during the stakeholder workshops.

This study demonstrates the importance of using interactive, digital technologies in participatory system mapping. Computer-based tools bring various benefits to presenting system maps in an understandable way for participants. The level of complexity that people can comprehend on a map varies (Krieglstein et al., 2022). Users also can bold each node (strategy or outcome in this study) and its connections and blur other parts of system maps, which helps them to focus on the impacts of single nodes and facilitate their understanding of the whole system. Additionally, these tools provide the zooming in and out feature and the opportunity of dividing complex system maps into smaller parts, as much as needed, in an accessible area, which makes them an understandable and accessible map for different groups. These tools also give the opportunity to add more information and details about the nodes and links, which facilitates communication and could reduce misunderstanding risks, which has been used in this research in the CoLabS platform.

This study confirms the challenges in identifying the influential links and negligible ones. The approach used in this study to reduce the complexity of the whole system was done based on an assumption the identified links with less than two references can be assumed as negligible influential elements and so can be removed from the whole system. However, when sharing the links with participants using the individual strategy-outcomes system maps, participants rated most of the links as highly influential with respect to the effects of different outcomes of the strategies. Such findings challenge the assumption that a systems map could be effectively developed from qualitative data by focusing only on data that has been coded with references that exceed a certain threshold number (i.e., such as 2, in the case of this research). This indicates

that such simple quantitative techniques cannot be a reliable approach for deciding what to include or exclude within a system map.

As indicated by this study, finding the right balance of the level of complexity in a system map is crucial for these to be useful tools (Wilkinson et al., 2021). The expectations of the system maps' complexity are different among participants (Penn & Barbrook-Johnson, 2022). System mapping and visualization tools should include functions for presenting complexity at different levels. Although recognizing the influential factors on the needed complexity needs further research, this study shows people's affiliations, the aim of using the maps, and the area of expertise that can influence the level of complexity they want to see in system maps. According to the results, a possible way to develop a system map equivalent to different groups' needs would be to separate the whole system map into different parts and show each dimension of the system map in each part.

7 Conclusion

Participatory system mapping supports the comprehensive, multi-dimensional, and multi-scalar analysis of food systems (Monasterolo et al., 2016). However, unravelling the interconnections within these intricate systems' components can be challenging and intricate. This study demonstrates the application of a participatory system mapping approach alongside its limitations and strategies to overcome this. The difficulties in employing participatory approaches intensify in deep participatory research, where these methods are applied in most or all phases, especially when dealing with wicked problems – intricate and ambiguous issues involving numerous stakeholders (Davies et al., 2015). Despite the challenges, the benefits of deep participation make these approaches worthwhile. Existing research suggests several strategies to overcome these challenges, including leveraging visualization technology, carefully selecting participants, implementing conflict management mechanisms, offering review options at different research stages, and adopting a context-based approach (Cvitanovic et al., 2019; Quich et al., 2022; Winans et al., 2021).

This study contributes to this literature by sharing recommendations from stakeholder engagement for improved participatory system map visualization (Wilkinson et al., 2021). This research demonstrates that removing 'less important links', as identified quantitatively, is not a reliable method for simplifying the map while accurately depicting the system. Although these methods may help to improve systems comprehension, the resulting map based on this approach lacks comprehensiveness. Dividing the whole system map into different parts is a recommended idea (Barbrook-Johnson & Penn, 2022), but it may cause oversimplification and also prevent the opportunity to review all connections in one system map. Additionally, the results show participants want to see different levels of complexity in system maps. Accordingly, it seems the proposed system map presentation should avoid reductionism or simplification to tackle its complexity issue and also have the capacity to show different levels of complexity.

Learning from the stakeholder engagement, this research demonstrated the utility of developing a digital application with features that address the aforementioned issues of system map visualizations. Ideally, such an application should be open access to the public and easy to use for different groups. The application should allow for the exploration of a system at different

levels, from a map of themes to a map showing the links between all sub-nodes. It should also have the feature of highlighting links based on their type. Finally, such applications should include a feature that enables users to select any specific nodes or group of nodes to highlight and view all of its positive and negative relationships. These elements of user design will improve the utility and comprehensibility of participatory system approaches.

Chapter 4: Evaluation of local plans using an integrated planning lens: A case study of the Comox Valley Region, British Columbia

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Abstract

An integrated planning lens in strategic and comprehensive plans plays an important role in the sustainability of local food systems since these plans include strategies and considerations related to food system objectives. This study firstly employs the content analysis method to evaluate the degree to which integration is present in six local and regional plans in the Comox Valley region of British Columbia, Canada. The content analysis builds upon previous research that developed a framework to depict linkages among different aspects of food systems sustainability, climate action, biodiversity conservation, and human health by conducting and analyzing 33 semi-structured interviews and seven workshops with stakeholders. This content analysis qualitatively and quantitatively analyzes six regional and urban plans and identifies their thematic linkages. This research then draws on the interviews, workshops, and document analysis findings to develop an analytical framework to analyse the six plans. The resulting framework encompasses all identified elements and their linkages across eight main themes: i) biodiversity conservation practices, ii) knowledge exchange, iii) climate actions and risks, iv) government and social support, v) food systems, vi) human health, vii) land and infrastructure, and viii) waste challenges and management. The results reveal a high level of integration in three themes: land and infrastructure, climate actions and risks, and biodiversity conservation practices. The study also confirms the relevance of the analytical framework to other types of plans, underscoring its significant potential as a powerful instrument for enhanced integrated planning design. The resulting analytical framework can help planners and policy makers understand and map the multifaceted interplay between different themes, fostering more comprehensive and effective approaches to multi-level development and governance.

Keywords: integrated planning, local plans, regional plans, sustainability planning, nexus frameworks

1 Introduction

Nexus frameworks, such as the water-energy-food nexus, have the ability to support integrated sustainability planning (Sperling & Berke, 2017). Employing place-based approaches to develop and apply these nexus frameworks strengthens integrated planning and can help researchers, planners and decision makers address sustainability challenges in a context-sensitive manner (Alrøe et al., 2016; Ghadiri et al., 2022, 2024). Such approaches can involve engaging stakeholders with a deep understanding of local issues and knowledge, which in turn can bridge knowledge gaps in the development and implementation of nexus frameworks and foster a common understanding of terminologies and interpretations. Contextualization offers the opportunity to elucidate specific elements of nexuses, enhancing comprehension. Moreover, this approach can shed light on the co-benefits and trade-offs embedded in different plans, strategies, and policies, given their varying nature across different cases (Cabello et al., 2021; Marr et al., 2009; Sharmina et al., 2016).

A recent example of this type of work is the climate-biodiversity-health nexus as introduced by Newell (2023) and adapted to a case study (Ghadiri et al., 2024). As a goal-oriented approach, the climate-biodiversity-health nexus focuses on key community sustainability planning objectives in the areas of climate actions, biodiversity conservation, and human health well-being which is considerably impacted by the former two (Newell, 2023). Two recent previous studies employed participatory approaches and extended the framework to food systems, highlighting the significance of climate actions, biodiversity conservation, and human health (both mental and physical) in order to improve strategy alignment or reduce conflicts with CBH imperatives. Such work is foundational to comprehensive community sustainability planning.

The results of these studies have led to the development of a tool, prepared in a system map format, for stakeholders in the Comox Valley to use to gain a comprehensive picture of the direct and indirect impacts of strategies. The system map underscores the importance of collaborative planning among stakeholders due to the significant connections between strategies. Therefore, it can facilitate and drive the collaborative planning process in the case study, improving coordination and motivation among involved parties. This visualization also can improve public awareness about the links between different actions and also be considered in future planning and strategic efforts to improve their effectiveness and integrated planning lens. Moreover, this tool can be used to effectively assess the integrated planning lens in existing programs and strategies, providing a resource for their enhancement (Ghadiri et al., 2024), which is considered in this study.

This research employs the content analysis method to expand upon the previously mentioned tool and create a comprehensive analytical framework for integrated planning. This analytical framework demonstrates the intricate connections between various areas and how they can mutually influence or be influenced by each other. The analytical framework is employed to assess six distinct plans in the Comox Valley Region, including one at the regional level and five at the local level. Beyond its immediate application, this analytical framework has significant potential as a powerful instrument for planners and policymakers. It equips them with the means to develop integrated plans and policies considering the multifaceted interplay between different

aspects, fostering more holistic and effective approaches to multi-level development and governance.

2 Context

This research is the third part of this dissertation, focusing on the Climate-Biodiversity-Health Nexus project (TRIAS, 2024), which is an applied research initiative. The dissertation's primary goal is to improve integrated community planning by developing and testing an experimental framework that concentrates on three key areas of sustainable development: climate actions, biodiversity conservation, and human health (Newell, 2023). This framework, known as the climate-biodiversity-health (CBH) nexus, can be refined, adapted, and utilized across various community planning sectors to assess how strategies, policies, and actions either align with or contradict the objectives and considerations within these sustainable development domains. In this particular project, the CBH nexus is employed to food systems, and the analytical framework produced through this work and employed in this study emerged from this application.

Food systems was selected as a focus for the Climate-Biodiversity-Health Nexus project for multiple reasons. Food systems encompass a spectrum of processes required for feeding a population, and they operate within and are influenced by social, political, economic, and environmental contexts (Vermeulen et al., 2012). While they share elements with agricultural systems, food systems extend to include a diverse range of institutions, technologies, and practices governing food from production to consumption (Issac et al., 2022; Klerkx & Begemann, 2020; Wezel et al., 2020). These systems shape consumption patterns, production methods, impact food accessibility and quality, encompass both natural and managed processes that yield food and non-food items like fuel and fibre through cultivation, livestock rearing, fishing, and forestry (Capone et al., 2014; Ghadiri et al., 2022; Rutter et al., 2019).

Food systems are impacted by the interplay among natural, institutional, and social strategies (Hubeau et al., 2017). These strategies impact the variety of products a country can produce and consume, food production and distribution methods, and so influence food security and system sustainability (Campi et al., 2021). Restricting water allocation to agricultural sectors because of climate mitigation or transferring water to industrial sections impacts local economies relying on food production and reinforces the need for food imports (Gomez-Zavaglia et al., 2020; Rosegrant & Ringler, 2000). Transportation and spatial strategies, especially in lower-income communities, can cause the existence of food deserts and impact households' food diets (Gawiak, 2023). Affordable housing strategies reduce the share of housing from households' income and so can improve food affordability (Stupplebeen, 2019).

Additionally, food policies can influence different areas of planning. Agriculture digitalization encouragement policies impact ecosystems sustainability and biodiversity conservation (Lajoie-O'Malley et al., 2020). Food production practices have the potential of causing environmental issues like pollution and biodiversity loss (Béné et al., 2019; Campi et al., 2021). Urban agriculture strategies have the potential to support sustainable development and urban resilience since various local factors like climate, urbanization rates, land availability, and commodification impact the type of agricultural practices suitable for each area (Gulyas & Edmondson, 2021; Langemeyer et al., 2021). For instance, compact cities with limited land may benefit from

vertical farming and container gardens, while arid regions should promote water-efficient technologies and wastewater recycling in urban agriculture(Azunre et al., 2019).

Integrated and multi-scalar approaches to food systems are required to effectively study and address food systems challenges since these approaches acknowledge the interconnectedness of food-related challenges with other planning areas and issues, offering the potential for more effective planning and policy-making processes(Ghadiri et al., 2024). This involves recognizing the intricate relationships and linkages among different levels of government. Strategies and policies that use integrated perspectives to address food systems challenges contribute to enhancing local and regional resilience and sustainability(Horst, 2017; Hubeau et al., 2017; Pothukuchi & Kaufman, 2000). Accordingly, this research applied the CBH nexus to local food systems planning to develop an analytical framework for addressing food issues and the multitude of related sustainability issues.

This study centres on the Climate-Biodiversity-Health Nexus that employs a community-engaged participatory research method(Vaughn & Jacquez, 2020), working with stakeholders and local government to develop frameworks for supporting planning. The objective is to facilitate a deeper comprehension of how communities can actively take part in integrated food systems and (broadly) sustainable community development planning. This project produces practical outcomes by creating frameworks and tools that practitioners can utilize to meet their planning requirements and seeks to produce insights and suggestions for integrated food systems planning and policy(Ghadiri et al., 2024).

This study is conducted in three phases. In the first phase (see Chapter II), a system map of Comox Valley's food systems based on CBH nexus was developed using qualitative analysis of semi-structured interviews with thirty three stakeholders(Ghadiri et al., 2022, 2024). The systems map was finalized in the second phase through six stakeholder workshops (see Chapter III). The data was coded using a conductive coding approach, where the codes (also referred to as sub-nodes), were grouped into categories, which represent strategies and outcomes in this context. The resulting map visually represents the connections between different strategies (indicated by green nodes) and outcomes (depicted as yellow nodes). It illustrates how these strategies either align or conflict with various CBH imperatives and can be valuable in supporting integrated community sustainability planning endeavors (see Figure 25).

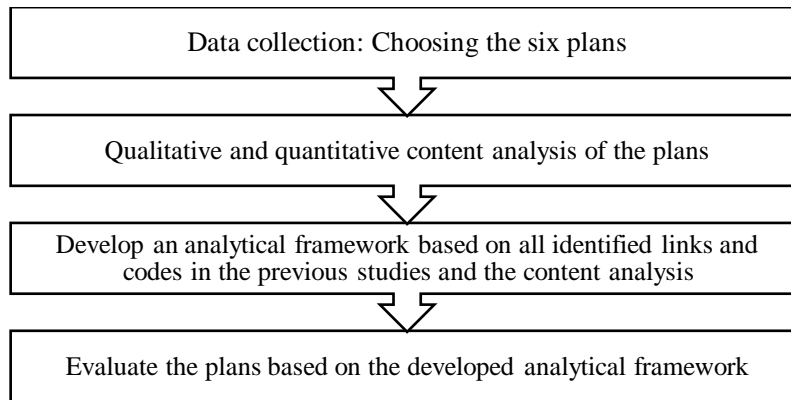


Figure 26. The process of the study

3.1 Data collection

Data collection is conducted through a qualitative and quantitative analysis of six documents, but it builds on two previous phases that used interview and workshop methods (see Chapter 2 and 3), to develop the analytic framework.

3.1.1 Description of the selected documents

Table 16 shows the overall content of the six chosen plans. The plans are mostly developed based on seven main sections: land uses, housing, infrastructure, transportation, environment and climate change, food systems, and cultural heritage and resources. These plans begin with a vision and main objectives to achieve them, then develop policies for each of these strategies and finally the implementation section. The methods for creating these these plans cannot be found in the documents, except the city of Courtenay OCP and K’ómoks First Nation CCP. Participatory approaches and stakeholder engagement are employed to develop these plans.

Table 16. Description of the chosen plans

Plan names	No of pages	Policy areas		Plan Bylaw No.
Town Of Comox Official Community Plan (Oct 20, 2021)	209	<ul style="list-style-type: none"> • Land use (housing, mixed-use, institutional, parks, agriculture and aquaculture) • Age-friendly planning • Environment 	<ul style="list-style-type: none"> • Infrastructure (transportation, utilities, water, sewer, stormwater) • Economic strategy • Historical and cultural resources • Inter-jurisdictional planning 	1976
City of Courtenay Official Community Plan (June 27, 2022)	279	<ul style="list-style-type: none"> • Street and transportation • Building and landscape • Affordable housing • Natural environment • Parks and recreation 	<ul style="list-style-type: none"> • Municipal infrastructure • Social infrastructure • Arts, culture and heritage • Food systems • Local economy 	3070, 2022
Village of Cumberland	183	<ul style="list-style-type: none"> • Future land use • Housing, growth management 	<ul style="list-style-type: none"> • Local food production • Environmental conservation 	990, 2014

Official Community Plan (Oct 3, 2022)		<ul style="list-style-type: none"> • Heritage preservation • Municipal infrastructure • Transportation • Sand and gravel extraction • Tourism 	<ul style="list-style-type: none"> • Views and landscapes • Climate change adaptation • Wildfire urban interface • Recreation and parks 	
K'ómoks First Nation Comprehensive Community Plan (Oct31, 2021)	77	<ul style="list-style-type: none"> • Governance and administration • Lands • Housing • People • Education 	<ul style="list-style-type: none"> • Environment and wildfire • K'ómoks estuary • Infrastructure • Economic development 	Version 1.0
Comox Valley Regional District Regional Growth Strategy (Dec18, 2018)	132	<ul style="list-style-type: none"> • Housing • Ecosystems, Natural Areas & Parks • Local Economic Development • Transportation 	<ul style="list-style-type: none"> • Infrastructure • Food Systems • Public Health and Safety • Climate Change • Growth management 	120, 2010
Rural Comox Valley Official Community Plan (Nov 24, 2020)	197	<ul style="list-style-type: none"> • Natural environment • Sensitive ecosystems • Parks and greenways • Climate change • Natural hazards • Economy and industry 	<ul style="list-style-type: none"> • Transportation • Infrastructure, cultural heritage resource • Housing • Land uses 	337, 2014

3.1.2 Previous Work and Initial Framework Development

In the second chapter of the dissertation, an initial framework was developed using interview and workshop methods (Ghadiri et al., 2024 a,b). Semi-structured interviews with 33 participants were conducted until the researchers reached saturation (Dworkin, 2012). An interview protocol was developed for these interviews and was sent to all of the participants before the interviews. The interview script began with questions about the organizations' mission and was followed by questions on their specific goals about CBH and food. The next sections asked about organizations' current and planned strategies, as well as their respective co-benefits and trade-offs; scales on which these strategies operate; partnerships and collaborations; and how future strategies should be revised for performance improvement and increased effectiveness.

Interpretive qualitative data analysis was employed to analyze interview transcripts using NVivo12 software. An inductive and axial coding approach was used in this study, meaning codes were derived from the transcript data. The results of this analysis can be seen in Table 2. As it is shown, all codes are categorized initially into eight themes and two main groups of strategies and outcomes and subsequently organized into 20 groups of strategies and 25 outcomes. A system map showing how the links between these codes was illustrated based on the results of this phase.

Following the interview data analysis, two series of workshops were conducted. The first series consisted of ‘test workshops’ that ran for an hour; involved students and academics (18 in total) and were conducted in three sessions to test and refine the workshop methods. The second series were “stakeholder workshops” that each ran for 1.5 hours. Four workshops were conducted with stakeholder participants and a total of 14 people participated in the stakeholder workshops, with each session involving 3 to 5 people. Both in-person and online options (via Zoom) were provided to participants. Workshops consisted of four segments: ice-breaking, introduction, participation, and discussion. Workshop discussion sessions were recorded. In these workshops, the visualized system map showing all identified links from the interview analysis were shared with the participants to test the clarity of the nodes and the validity of the recognized links. All identified nodes were reviewed and finalized based on the results of this section (see Table 17).

Table 17. The revised identified codes based on the interviews and workshops’ results

No	Theme	Strategies	Outcomes
1	Biodiversity conservation practices	Water resource management	Water quality and quantity Ecosystem integrity and health
2	Knowledge exchange	Awareness Improvement strategies Training and Education	Public awareness Community integration
3	Climate actions and risks	Crisis management Emission reduction strategies Green space conservation Energy efficiency in Buildings	GHG Emissions reduction Increased adoption of renewable energy Natural disasters impacts Agricultural resilience
4	Government and social Supports	Governmental financial support Poverty reduction strategies	Human and financial resources Local economic improvement Social Justice and equity ² Current and comprehensive dataset
5	Food systems	Food Justice programs Shellfish farming Support the global food market Support local food market Support local foods Farming techniques	Increased food distribution and accessibility Food affordability Food diet Farmers’ sales improvement Increased local production Food resilience Reducing food miles
6	Human health	Community health strategies	Health risks Physical health Mental health and wellbeing
7	land and infrastructure ³	Affordable housing programs Enhancing active transportation Land-use governance	Traffic congestion Land availability and affordability Affordable housing availability Increased accessibility ⁴

² Two nodes of “local economic and improvement” and “ Social justice and equity” were aggregated under a node named “ social concerns and needs” in Chapter 2.

³ This theme was named “ land-use plans and transportation projects” in Chapter 2.

⁴ This node was “increased food distribution and accessibility” under the food systems theme in Chapter 2.

addition to 0: 1 refers to those links of the source matrix which are also identified in the plan, and two refers to the links which have not been seen in the plan.

4 Results

The results of the analysis and application of the analytical framework to the plans can be seen in Table 18. The table displays two kinds of data for each plan: (1) the number of identified references (count) for each theme and its belonging nodes, and (2) the number of mentioned impacts each theme or node has on other nodes. Land and infrastructure theme constitute the greatest number of references and impacts in all of these plans. A strong triangle of this theme, biodiversity conservation practices, and climate actions and risks considering the impacts of each on the two others can be seen in all of these plans.

Table 18. Number of identified references and impacts

Nodes	RGS		Rural Comox OCP		Comox OCP		Courtenay OCP		Cumberland OCP		Komox First Nations CCP	
	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts
1- Biodiversity conservation practices	115	13	173	11	111	11	121	10	72	7	30	7
• Ecosystems integrity and health	36	2	60	2	53	1	69	2	51	2	18	1
• Water quantity and quality	22	2	56	2	23	2	17	2	9	1	4	2
• Water resource management	57	9	57	7	35	8	35	6	12	4	8	4
2- Knowledge exchange	8	4	10	9	8	5	46	18	56	16	19	4
• Training and education	0	0	3	3	0	0	0	0	0	0	0	0
• Awareness improvement programs	8	4	4	4	2	2	27	11	51	13	19	4
• Community integration	0	0	0	0	0	0	0	0	5	3	0	0
• Public awareness	0	0	3	2	6	3	19	7	0	0	0	0
3- Climate actions and risks	231	31	132	31	173	45	284	56	179	37	27	11
• Crisis management	25	5	33	10	14	6	22	8	43	12	6	3
• Emission reduction programs	67	11	8	4	9	7	49	15	24	4	3	2
• Energy efficiency in buildings	14	3	1	1	10	6	45	10	5	2	0	0
• Green space conservation	92	10	70	11	100	15	113	15	87	16	7	3
• Agri resilience	0	0	2	1	6	3	10	2	0	0	0	0
• GHG emissions reduction	19	1	8	2	8	3	23	3	10	1	2	1
• Natural disasters and climate risks impacts	14	1	10	2	21	3	20	2	10	2	9	2

Nodes	RGS		Rural Comox OCP		Comox OCP		Courtenay OCP		Cumberland OCP		Komox First Nations CCP	
	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts
• Increased adoption of renewable energy	0	0	0	0	5	2	2	1	0	0	0	0
4- Government and social support	16	5	30	11	19	10	69	22	49	14	7	5
• Governmental financial supports	1	1	11	6	4	3	20	12	19	6	0	0
• Poverty reduction programs	0	0	0	0	0	0	4	2	0	0	0	0
• Current and comprehensive dataset	8	2	2	1	1	1	25	5	2	1	2	1
• Local economic improvement	3	1	6	2	10	2	8	2	13	6	3	3
• Social justice and equity	4	1	11	2	1	1	12	1	15	1	2	1
• Human and financial resources	0	0	0	0	3	3	0	0	0	0	0	0
5- Food systems	87	29	102	25	32	18	77	31	27	11	5	5
• Farming techniques	10	8	6	5	3	3	7	6	0	0	0	0
• Food Justice programs	0	0	0	0	0	0	8	5	0	0	0	0
• Shellfish farming	12	4	5	3	4	3	0	0	0	0	2	2
• Support global food market	0	0	0	0	0	0	0	0	0	0	0	0
• Support local food market	5	3	3	3	4	4	23	7	2	2	0	0
• Support local foods	45	8	36	8	8	3	31	9	18	7	2	2
• Food affordability	0	0	0	0	0	0	1	1	0	0	0	0
• Food diet	0	0	0	0	0	0	2	1	0	0	0	0
• Food resilience	3	3	0	0	1	1	3	1	1	1	1	1
• Increased local food production	12	3	52	6	10	3	2	1	6	1	0	0
• Reducing food miles	0	0	0	0	2	1	0	0	0	0	0	0
6- Human health	47	8	5	3	8	3	35	8	27	9	6	3
• Community health programs	9	3	4	2	8	3	7	2	9	5	1	1
• Health risks	0	0	0	0	0	0	0	0	0	0	0	0
• Mental health and wellbeing	18	3	0	0	0	0	17	4	9	2	1	1
• Physical health	20	2	1	1	0	0	11	2	9	2	4	1
7- Land and infrastructure	308	45	282	35	284	43	501	58	291	44	42	13
• Affordable housing programs	54	7	11	4	41	8	65	9	38	11	3	2
• Enhancing active transportation	72	10	12	2	56	11	62	13	43	9	4	2

Nodes	RGS		Rural Comox OCP		Comox OCP		Courtenay OCP		Cumberland OCP		Komox First Nations CCP	
	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts	Ref	Impacts
• Land-use governance	150	21	240	23	139	15	318	25	188	20	35	9
• Affordable housing availability	23	3	8	2	21	2	17	4	12	2	0	0
• Increased accessibility	6	3	5	1	8	2	28	2	8	1	0	0
• Land availability and affordability	0	0	0	0	6	2	4	2	0	0	0	0
• Population needs and demographic changes	3	1	4	2	10	2	6	2	0	0	0	0
• Traffic congestion	0	0	2	1	3	1	1	1	2	1	0	0
8- Waste challenges and management	4	1	2	1	8	5	14	6	2	2	0	0
• Waste resource management	4	1	2	1	6	3	14	6	2	2	0	0
• Waste reduction	0	0	0	0	2	2	0	0	0	0	0	0
Total	816	136	736	126	643	140	1147	209	703	140	136	48

Figure 28 compares the percentage of impacts in each plan to the total number of impacts possible as per the analytical framework. In both the source data and plans, three themes of land and infrastructure, Food systems, and Climate adaptation and risks are the most impactful themes. Although they do have not considerable impacts on other areas, the biodiversity conservation and human health themes are influenced considerably by the three mentioned themes (land and infrastructure, food systems, and climate adaptation and risks). A significant difference between the figures for the impacts of the knowledge exchange theme in the source data and plans can be seen. It may be due to the scope of the plans since they are supposed to focus on more strategic and larger scales, and areas like knowledge exchange may emerge as an action plan of the strategies developed in these plans.

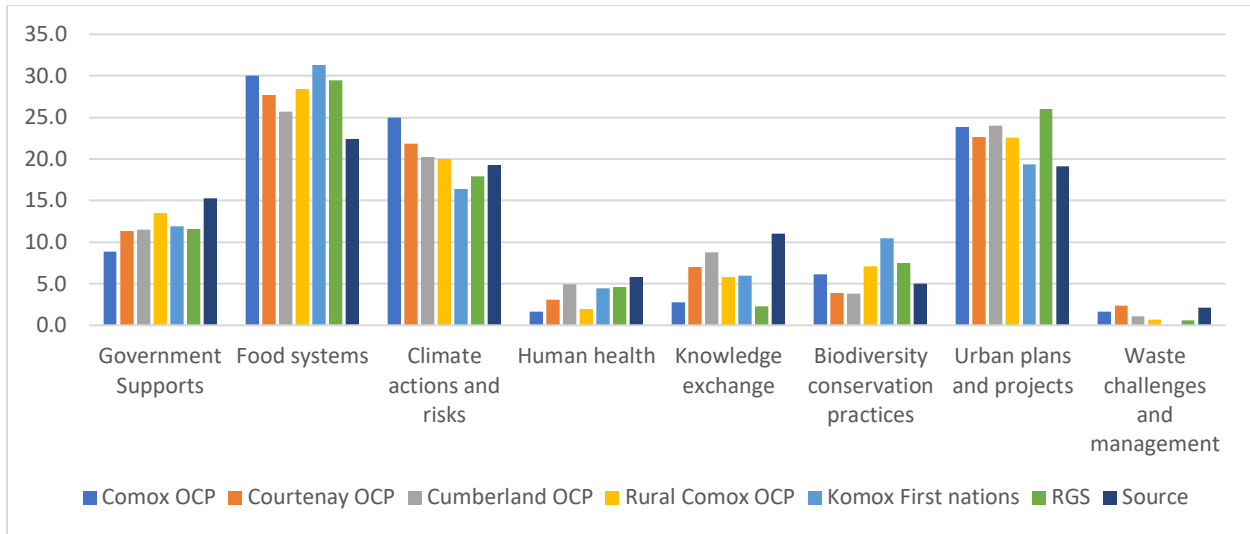


Figure 28. Interconnectedness Percentage of Identified Themes

4.1 Regional Growth Strategy plans

4.1.1 Comox Valley Regional Growth Strategy

As is seen in the Table 16, this plan focused on six themes of the framework: land and infrastructure, climate actions and risks, biodiversity conservation practices, government financial supports, human health and food systems.

Table 18 shows the number of identified links for RGS. A total of 816 references are identified in this plan. The land and infrastructure theme involves the highest number of codes, mostly focusing on land-use governance and transportation, and the theme of waste challenges and management has the lowest number of identified codes. It may be because of the scope of this plan, which does not involve areas like recycling. In the land and infrastructure theme, most codes demonstrate impacts on aspects of the biodiversity and conservation practices and climate actions and risk themes. Secondly, the climate actions and risks theme, with 91 total codes, constitutes the largest codes. These codes focus on the relationships between this theme and biodiversity and conservation and land and infrastructure themes. Examples can be seen in the text of the second goal of this plan, *ecosystems, natural areas and parks*, such as sections 2C2, 2C5-2C8, and 3C-8.

4.2 Official Community Plans (OCPs)

4.2.1 Rural Comox Valley OCP; Town of Comox OCP; City of Courtenay OCP; & Village of Cumberland OCP.

Each OCP's main policy sections revolve around distinct themes, while focusing on relatively similar themes. In the case of the Rural Comox OCP, it encompasses six overarching themes: communities' physical aspects, climate actions and risks, biodiversity conservation practices, and government and social supports. Meanwhile, the Town of Comox OCP focuses on seven main policy sections related to communities' physical aspects, government and social supports, and climate actions and risks. Similarly, Courtenay's OCP addresses themes such as communities' physical aspects, climate actions and risks, government and social supports, and food systems. In

Cumberland's OCP, the main sections are centred on communities' physical aspects, climate actions and risks, biodiversity conservation practices, and food systems. This diversity in thematic emphasis reflects the unique priorities and concerns of each community's Official Community Plan.

The land and infrastructure theme involves the most references in all of the OCPs and the theme of waste challenges and management and knowledge exchange have the lowest codes. Strong integration between policies of land and infrastructure, biodiversity and conservation practices, climate actions and risk themes and food systems can be seen in all of these plans. Examples are the policies pertaining to considering environmentally sensitive areas and agricultural preservation in housing and land-use planning, linking transit networks to greenways to improve active transportation and GHG emission reduction, consideration of the links between GHG emission and land-uses patterns in planning; provision of local food services and markets in land-use planning, suggesting a reduction in pesticide usage to integration of agricultural lands with other land-uses while reducing the potential trade-offs on human health, and integrating food production spaces in land-use planning.

4.3 Comprehensive Community Plans

4.3.1 K'ómoks First Nation Comprehensive Community Plan

As is seen in Table 16, this plan involves five themes of the analytical framework: land and infrastructure, climate actions and risks, biodiversity conservation practices, government financial support, and human health.

Table 18 shows the number of identified links for K'ómoks CCP. A total of 136 codes are identified in this plan. The theme of land and infrastructure involves the most codes and the theme of waste challenges and management has the lowest codes. In the land and infrastructure theme, similar to the OCPs, most codes focus on the impacts of the codes of this theme on biodiversity and conservation practices and climate actions and risk themes. Secondly, the knowledge exchange theme, with 19 total codes, constitutes the greatest number of recognized codes. Concerning the identified impacts of the themes, they focus on the effect of land ownership, and authority on environmental resources, habitat preservation and local food production. An example is the section 3.6 of this plan. This section underscores the significance of hunting, trapping, and fishing within the local economy of the First Nations communities, while there are jurisdiction restrictions for them over wildlife, primarily concerned with resource allocation rather than the direct management of wildlife.

This plan includes considerations pertaining to Indigenous people's rights to have the authority to manage their land and its environment and also the importance of improving urban management systems to improve Indigenous communities' authority and power over their own areas. However, due to CBH and food focus and the way the analytical framework was developed, these types of considerations were not included in the matrix built and used for document analysis; thus, they did not appear through the evaluation process, demonstrating a limitation of the framework.

5 Discussion

This study involved an analytical framework that was developed using systems-based participatory approaches and applied to a document analysis. This process identified the main themes of the analytical framework, which are considered for the evaluation process. Using the participatory approaches in developing the analytical framework has the benefits of leading to the collection of great amount of local knowledge and data from an inclusion of people from diverse disciplines, practices, sectors, and expertise (Allender, et al., 2019; Collier et al., 2013). These benefits make the analytical framework an effective tool for evaluating plans in terms of integrated planning.

The results of this study show a good level of integration in the evaluated plans. Among eight themes of the study, the links between three areas of urban planning projects, biodiversity conservation and climate actions and risk are found strongly in all evaluated plans. However, a shortage in consideration of the impacts of knowledge exchange and waste management themes on other areas can be seen in the plans. It signals an opportunity for the integration of these themes and their potential impacts into the planning strategies, potentially enriching the comprehensiveness of the plans. Addressing these aspects could further improve the efficacy and sustainability of the plans, ensuring a more holistic and integrated approach to the future development and management of the Comox Valley.

The results shows the analytical framework may not suitable to be used for evaluating all plans. Not only do the similarities of the plans' areas, but the existence of common lenses and objectives of plans should exist. Otherwise, the evaluation results may encounter errors since it may exclude a considerable number of elements, which may show other areas of integrated planning, and so a part of the links between different considered elements of plans can be seen in the evaluation. An example of this limitation is the K'ómoks First Nation Comprehensive Community Plan. A few reasons are identified for this shortcoming. Firstly, it seems that the initial process of conducting this analytical framework has not use any specific measures to increase marginalized groups' participation, which may be one of the reasons behind the participation of one person from this community in this research. This low level of participation leads to the absence of some important components, like authority and power, in the themes and the guidelines. Employing Indigenous research methodologies in separate framework development effort to adapt the CBH nexus to food systems (and other) issues can improve its appropriateness for such plans. Secondly, some parts of this plan like those about the transferring land governance to indigenous communities and its impacts on climate actions do not fit with the framework's scope, while they are significant parts of this plan, so the evaluation cannot show all integrated planning elements in this plan.

In conclusion, this framework can be used to expand the understanding and perspectives of planners and policymakers about the identified links between different areas of CBH and other planning areas, such as food, housing, etc. However, it may not be employed as an effective tool for evaluating all plans and in all contexts without any adaptations. It is worthwhile to consider and include in the framework, the influential factors and key planning priorities based on features of a place and its conditions, concerns, and community needs.

6 Conclusion

This study employs a comprehensive integrated planning analytical framework to evaluate different plans in the case of the Comox Valley Region, which was initially developed based on previous sections. The analytical framework of this research is finalized by adding all identified links based on a document analysis of plans developed for the case, and it was then employed to evaluate six plans on both regional and local scales to see their integration.

The results of this research show the analytical framework is not fit for any plans such as CCPs, despite its effectiveness in evaluating RGSs and OCPs. The main reason behind this ineffectiveness is the existing gap of not having enough voices for Indigenous communities. It may be due to incorporating general research methods and processes to involve all stakeholders in the first phase of the study, instead of adapting specific methods to improve indigenous group participation. The other reason is the difference between CCPs content and strategic objectives, and other plans whose objectives are aligned with the content of the eight identified themes. The developed analytical framework of this research can be expanded to address its current limitations and use for improving the level of integration in future iterations of local and regional plans, improve awareness of policymakers about the potential direct and indirect impacts of policies, and evaluate other plans and strategic documents (e.g., housing strategies, transportation plans, climate plans, local food strategies, etc.) using an integrated planning lens.

Chapter 5: Conclusion

1 Conclusion

This dissertation explored the complex challenges and potential strategies for improving local food systems through the application of the CBH nexus, an integrating planning framework used to examine relationships among climate action, biodiversity conservation, public health, and other sustainability priorities. Using a participatory research approach and the Comox Valley, British Columbia, as a case study, this research developed and tested an analytical framework based on the CBH nexus, demonstrating its effectiveness in fostering sustainable and resilient local food systems. The dissertation consists of three papers, each contributing unique perspectives on the integration of food systems planning with sustainability goals.

The first paper introduced the CBH nexus framework as a method to address the interconnected challenges of climate change, biodiversity loss, and health and their relationships to local food systems. The research used interviews with local stakeholders as data, and it highlighted how food systems were not only vulnerable to environmental degradation but also contributed to environmental issues, such as climate change and biodiversity decline, through practices like industrial agriculture and unsustainable land use. The findings emphasized the necessity of integrated planning to address the bidirectional relationships between food production and environmental health. The application of the CBH framework facilitated a systems perspective, allowing for a nuanced understanding of the co-benefits and trade-offs involved in aligning food systems strategies with sustainability imperatives. The work resulted in an adaptable analytical framework designed to be a versatile tool for supporting efforts toward food systems resilience.

The second paper revised and refined the analytical framework through the use of participatory system mapping techniques that engaged stakeholders from various sectors in the Comox Valley. This approach uncovered the complexity of local food systems and highlighted the value of stakeholder engagement for ensuring that sustainability strategies are context-specific and actionable. Through the use of participatory research, the study identified key challenges in food accessibility, particularly for vulnerable communities, and it highlighted the need for strategies that addressed both environmental and social dimensions of food security. The analytical framework was refined based on the feedback and insights of local stakeholders, ensuring that it better reflects the on-the-ground realities of the Comox Valley region. The study underscored the importance of engaging local stakeholders in the decision-making process to foster ownership and support for sustainable food systems.

The third paper applied the analytical framework to evaluate local plans and strategies in the region, revealing both strengths and areas for improvement. While the Comox Valley has made progress in incorporating sustainability into its food systems planning, the analysis identified gaps in policy integration, particularly in addressing food insecurity and adapting to the impacts of climate change. The research showed that although local initiatives had embraced sustainability goals, more work is needed to ensure that plans, strategies, and policies fully align with goals related to resilience, biodiversity conservation, and public health. The analysis of the local plans and strategies highlight the need for more comprehensive and context-specific strategies to address the interconnected challenges posed by climate change and food system sustainability.

This dissertation research revealed the importance of fostering stronger collaboration between different levels of government and local stakeholders. Using the CBH nexus as framework for developing analytical tools provided a deep understanding of the co-benefits and trade-offs of various policy choices, allowing for more informed decisions that balance the competing demands of food production, biodiversity conservation, and climate mitigation. As evidenced by this research, the framework serves as a useful tool for policymakers aiming to create more sustainable, resilient, and equitable food systems. Additionally, the results can help to revise communication methods in order to effectively share decisions and analyses with diverse stakeholders. This helps to ensure that all voices are heard and that the rationale behind policy choices is clearly conveyed, fostering transparency and trust in the policymaking process. Finally, the results can support the redevelopment of urban and regional plans and programs through an integrated planning lens, and enable policymakers and planners to consider the impacts of their chosen policies on different aspects of sustainability.

2 Overall Contributions

This dissertation makes several critical contributions to the fields of food systems planning and sustainability. First, it explores the application of a comprehensive framework (i.e., the CBH nexus), and it uses this framework to integrate food systems with broader sustainability goals. The framework not only enhances the understanding of the complex interconnections between food production, climate change, biodiversity, and human health but also enables the development of practical tools (e.g., the analytical framework developed in this research) for guiding policy and planning efforts in local and regional contexts. This study also expands the CBH nexus and adds five other areas to this framework, strengthening its applicability to other studies.

Second, the dissertation demonstrates the value of participatory approaches in planning research, showing how engaging local stakeholders in the process of system mapping can lead to strategies that are more context-sensitive and actionable. This participatory approach enhances the analytical framework's applicability to real-world planning challenges and objectives in the Comox Valley and ensures that it resonates with the specific needs and challenges of the communities involved.

Lastly, the application of the CBH framework to the evaluation of local plans and strategies demonstrates its utility in identifying both co-benefits and trade-offs in efforts to improve local food systems sustainability and resilience. By evaluating existing policies through the lens of the CBH nexus, this research provides critical insights into how policies can be refined to better address the interconnected challenges of food insecurity, climate action, and biodiversity loss.

This dissertation provides a foundation for future research and policy development. The analytical framework developed through this research can be adapted to other regions and contexts to support integrated food systems planning and promote local food system sustainability, resilience, and equity. Future studies should adapt and continue to refine this framework, ensuring its effectiveness in a variety of local and regional settings while also exploring its broader applications in food systems planning.

3 Gaps in the study

This study has identified several significant gaps that have affected its scope and outcomes. Firstly, stakeholder engagement in Chapter 2 was limited; only 32 out of over 100 invited stakeholders participated in the interview process, representing only a partial range of voices and perspectives. This limitation underscores the challenge of achieving comprehensive inclusivity in research. Secondly, unexpected weather conditions, including heavy snow, disrupted the in-person stakeholder workshop sessions. Consequently, most of the workshops had to be rescheduled and held online, which may have impacted the depth and quality of discussions, as virtual settings can hinder dynamic interactions and informal exchanges. Lastly, the evaluation framework developed during the study revealed shortcomings in its applicability to diverse plans. For instance, it was considered unsuitable for evaluating Comprehensive Community Plans. These limitations highlight areas for refinement in future studies to ensure broader engagement, adaptability, and robustness in evaluation tools.

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Appendix 1: Interview Protocol

Institutions: _____
Interviewee (Title and Name): _____
Interviewer: _____
Participant ID (check database for name and affiliation): _____
Date: _____
Interview length: _____

PART 1. ABOUT YOUR ORGANIZATION/INITIATIVE

What is the main mission and vision of your organization?
How would you describe your current job position and duties?
Does your community primarily operate on a local or regional scale (or both)?

PART 2. SUSTAINABILITY GOALS (adapt to the specific interviewee)

What (if any) are your organization's major objectives and targets regarding climate action, biodiversity, and/or health?
Are any of these objectives considered as interlinked goals, or are they considered separately (e.g., separate indicators, different departments, different plans, etc.)?
Ask for planners/government organizations
Are any of these targets/objectives related to local or regional objectives for food systems (and how)?

PART 3. STRATEGIES, CO-BENEFITS, AND CHALLENGES

What strategies does your organization currently implement toward climate action, biodiversity conservation, or community health?
Are these strategies helpful for other organizations or institutions to achieve their goals, and how? Do you have any examples of how your strategies support other local and regional organizations with their work and objectives?
What challenges and barriers do (or could occur) with these strategies?
What unintended consequences or trade-offs do (or could occur) with these strategies?
What factors, resources, or supports, collaborations are needed for the success of these strategies?

PART 4. PARTNERSHIPS AND COLLABORATIONS

What partnerships (if any) are involved in these strategies?
Which strategies of other organizations (if any) are beneficial to your work and goals in terms of CBH/food systems?
Are there other strategies and community objectives (if any) that conflict or present challenges for your organization's goals about CBH or food systems?

PART 5. SCALE

What CBH/food-related effects do your strategies have on Comox Valley? (Both direct and indirect benefits or unintended impacts and consequences)
What CBH/food-related effects do your strategies have on Vancouver Island and/or B.C.?

Are there differences (or conflicts) in CBH/food strategies and objectives among the local, regional, and/or provincial levels? (If so, what are these?)
Are there any documents or reports about these subjects that we've discussed and you think would be useful for the project?

PART 6. FUTURE STRATEGIES (ask if not previously addressed and if time permits)

Can you think of any changes or new strategies you think are necessary for your organization to implement to address the concerns discussed above? Are there plans to implement these strategies?

What are the co-benefits of the future/proposed strategies?

What are the trade-offs of the future/proposed strategies?

What partnerships are necessary to support the future/proposed strategies?

Is there any other thing you want to add?

Is there anyone else that we should contact?