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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

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1. Introduction

Food systems issues are complex and connected to numerous other planning and policy areas and challenges [1]. 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 [2–4]. 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 [2]. Converting natural ecosystems to agricultural lands can increase food production; however, a loss of these ecosystems contributes to climate change and adversely influences biodiversity [5]. As an example related to food systems, the existence of food deserts (i.e., areas with limited access to grocery stores [6]) can lead to local residents choosing available but unhealthy foods instead of traveling long distances to access healthy foods, which increases the risks of suffering from nutritional health issues [7,8].

The complexity of food systems issues presents a need to apply system thinking to food planning and policy in order to develop a comprehensive, multi-dimensional, and multi-scalar understanding of complex issues [9]. For example, Elyasi and Teimoury use critical system practices to study aspects of the sustainability of rice agriculture and its supply chain [10]. 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 [11]. 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 [12]. Béné et al. develop a framework of the interactions among food systems, sustainability and healthy diets that can be applied to gain a more comprehensive interpretation of sustainability that includes trade-offs between different aspects of food systems' sustainability [13]. Klassen and Murphy evaluate the links between food accessibility, 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 [14]. Tornaghi and Dehaene identify how urban–rural linkages can transform food systems, pointing to the impacts of urbanism and urban growth on the displacement of farmlands and land-use changes and proposing an agenda to tackle these issues [15]. Béné et al. use system mapping to elucidate a comprehensive understanding of elements, actors, and drivers of food systems in their articles [16]. 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 to improve resilience under such conditions [17]. In this way, system thinking techniques, such as systems 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 complex systems can be challenging. Linkages cannot be recognized based on academic or theoretical understanding alone; they should be identified and characterized according to the particular context. Participatory approaches can help identify the components and relationships of complex systems [18]. The participation of stakeholders provides researchers with the opportunity to have a creative and inclusive involvement of wider disciplines, actors, knowledge, and expertise [19]. Participatory approaches can be used to build collaboration among stakeholders and researchers and provide a realistic scope for creating a systems model. Such approaches can support the collection of the substantial amount of data needed to model a system [20]. Via participatory research approaches, researchers can 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 [19].

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 that aim to tackle complicated environmental problems, increase public awareness, and adopt the lessons learned for future initiatives [21]. Balaican et al. argue that identifying different place-specific elements of the food–water–energy nexus requires participatory approaches, and they apply this nexus to food systems in Tulcea, Romania, using stakeholder workshops and interview methods [22]. In research in Tanzania, Johansson et al. explore the links between agroecology and just and sustainable food systems in stakeholder workshops, with the aim of visualizing how agroecology can influence farming in the future and identifying the policies that are needed to support agroecology [23]. 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 [24]. 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 [25]. 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 [26]. 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 [27]. Winans et al. studied the sustainability of California almond growing and California wine-growing 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 [28]. 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 [29]. Terms like 'participation,' 'community engagement,' 'partnership,' and 'collaboration' mean different things to different people, leading to varied expectations about participatory processes and outcomes [30]. Moreover, participation in research can have different goals, such as being a method for improving efficiency in projects or as a way to provide opportunities for people, especially marginalized groups, to improve their living conditions. Depending on the goal being pursued, the results of one participatory research study can be considerably different from another study [31]. Participatory system mapping specifically also has challenges, as it lacks a systematic framework with which strategies and action plans can be evaluated for management and decision-making objectives [32]. 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 can have difficulties 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 [33]. Finally, participatory processes are time-consuming, thusly requiring sufficient financial resources to support lengthy research efforts [31].

Participatory research approaches span different levels of participation. Arnstein's seminal 'participation ladder' describes a range of practices, from manipulation to citizen control [34]. Relatedly, 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 [35]. Wiedemann and Femers used Arnstein's participation ladder for waste management decisions [36]. Luyet et al. measure five levels of stakeholder engagement, from information to empowerment, and they propose a framework for participatory research in this field, from identifying stakeholders to evaluation [37]. 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 [38].

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, these being complicated and ambiguous problems with considerable numbers of stakeholders involved [39]. 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 [28], targeted selection of participants, developing conflict management mechanisms, providing review options at different stages of research [29], and designing a context-based approach [40].

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 study complex problems [29,41]. The sustainability of food systems and their connections to climate actions, biodiversity conservation, and human health is an example of a wicked problem, and it is the focus of this research. This methods-focused paper (i) explains how a participatory system map can be developed, reviewed, and finalized via 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 that allow for pinpointing interventions and strategies for fostering food resilience and justice. Outcomes of this research include a tool that provides a comprehensive understanding of the complexity of food systems and how they link to other aspects of sustainability. The methodological insights and process of this research can also be adapted to other participatory system mapping studies.

2. Research Context

This study is part of an applied research effort: the Climate–Biodiversity–Health Nexus project [42]. The project aims to enhance the integration of community planning by creating an experimental framework focused on three critical areas for sustainable development: climate change, biodiversity conservation, and human health [43]. 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 in 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 [44], the project involves engaging stakeholders and local governments in the Comox Valley region, British Columbia. The objective of the research is to develop an understanding of how communities can actively participate in integrated food systems and sustainable community development planning. The project aims to 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 [45,46].

Figure 1 shows the system map of Comox Valley's food systems based on the CBH nexus that was developed in the first phase of this research. This system map was developed via 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 (orange 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 system maps were developed can be found in [45].

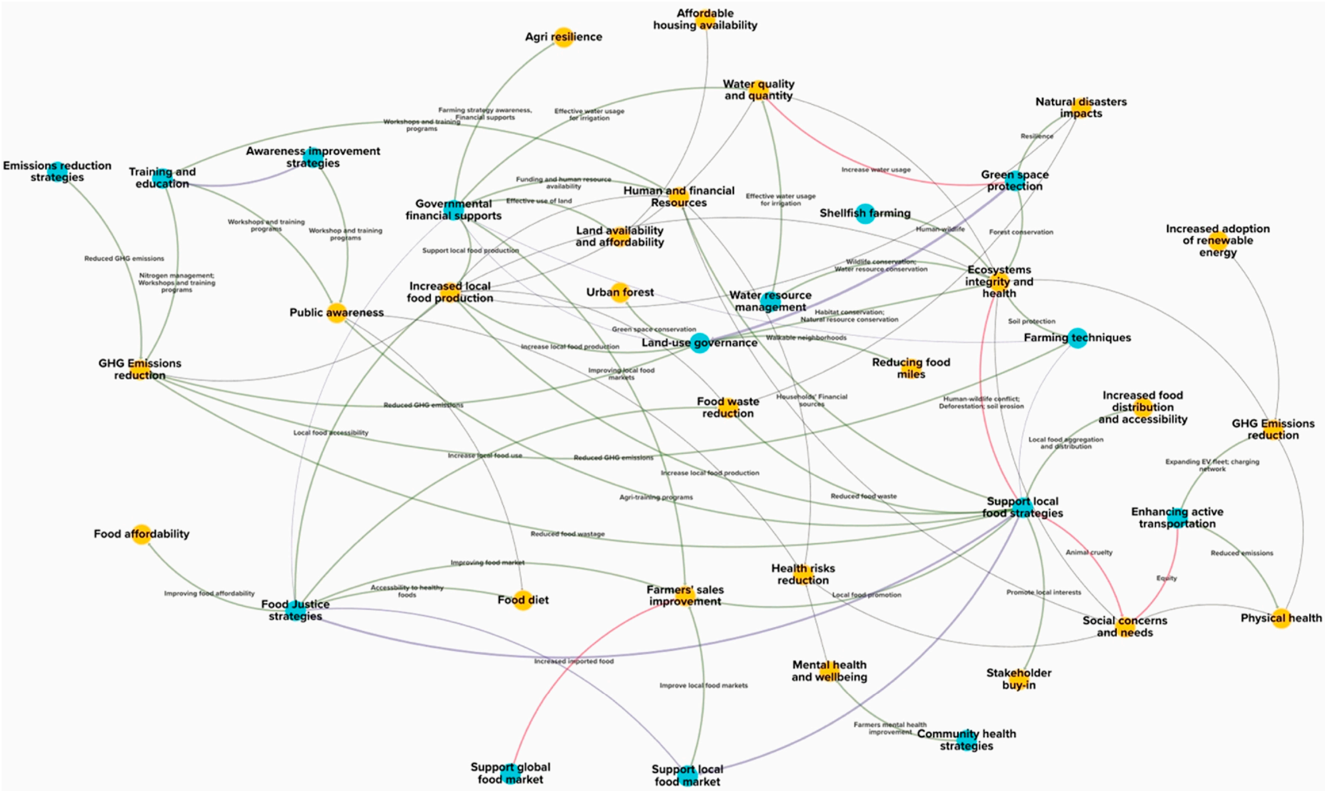

Figure 1. System map of food systems issues, strategies, and outcomes in the Comox Valley. Source: [45].

3. Case Study

This research focuses on the Comox Valley region in British Columbia, Canada, as a case study(see Figure 2). The Comox Valley region is situated in the northern section of Vancouver Island, covering an expansive area of 1700 km^2, and is home to a population of over 72,000 people as of 2021. It encompasses both rural areas and municipalities, including Comox, Courteney, and Cumberland [47]. Within the region, agricultural activities occupy approximately 14% of the land, amounting to approximately 23,400 hectares. These agricultural lands consist of both small and large-scale farms [48].

Food insecurity is one of the most pressing challenges in the Comox Valley [49]. The area has experienced a significant population growth of 8.7% between 2011 and 2021 [47], and rapid population growth has the potential to exacerbate the issues around food insecurity [50]. The communities in the Comox Valley region also recognize the food-related challenges presented by climate change; thus, these communities are participants in the Partners for Climate Protection program, administered by the Federation of Canadian Municipalities [51]. The region's community sustainability plan, known as the Comox Valley Sustainability Strategy, includes details on climate action, biodiversity conservation, and local health goals, and it has been adopted by the Comox Valley Regional District, Village of Cumberland, Town of Comox, and City of Courtenay [52].

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 modeling building process in two cases of Kamloops and Comox Valley in British Colombia and develop a system map of children's social and emotional well-being and its influential factors [53]. Studying similar cases, Karsten conducts research using participatory system mapping to identify the influential factors and impacts of drug poisoning [54]. 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 [55].

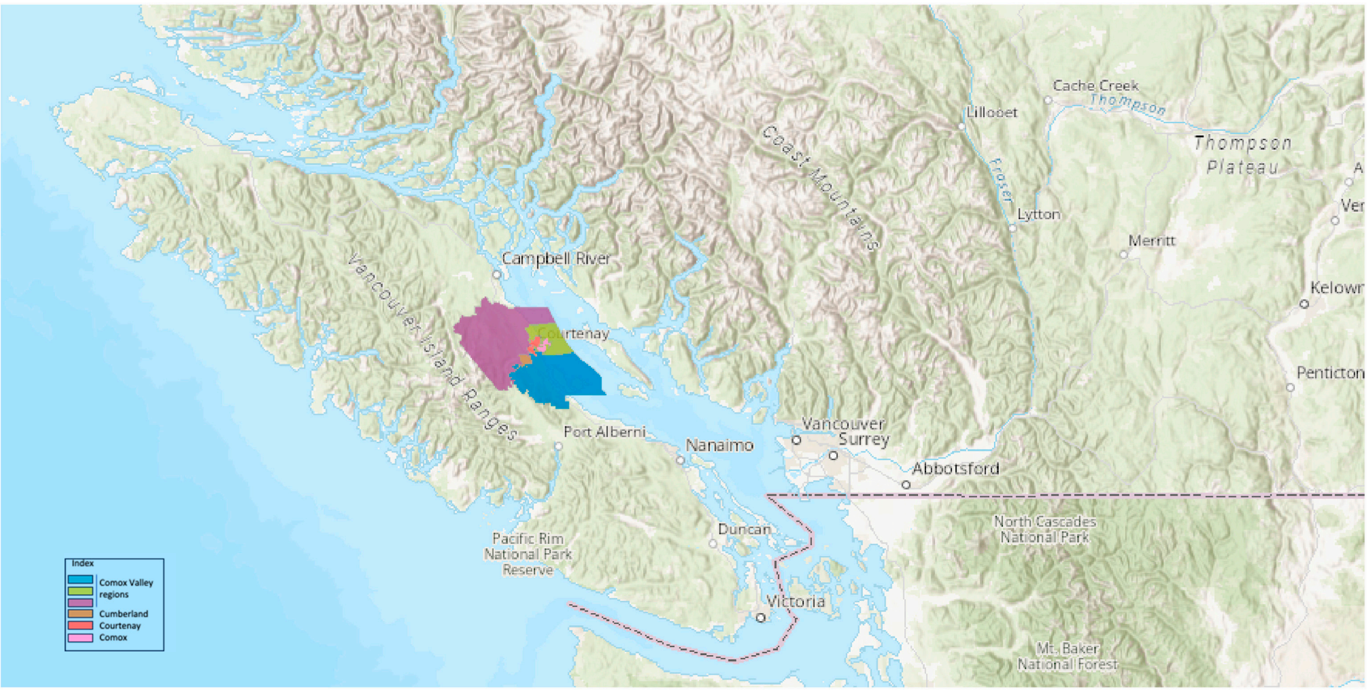

Figure 2. The Comox Valley region. Source: [45].

4. Methodology

This 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 via an Internet search using keywords such as 'climate action', 'biodiversity conservation', 'food', and 'community health' in conjunction with the Comox Valley municipalities. Additional stakeholders and organizations were identified via the snowball sampling techniques. The greater research project began with a series of interviews, which informed the development of a system map, and the methods and outcomes of this research are reported elsewhere [45]. This study focuses on the testing and revising of the system 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

Data collection was carried out via two different series of workshops (see Figure 3). 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 via a series of four workshops with stakeholders in the Comox Valley (referred to in this paper as 'stakeholder workshops').

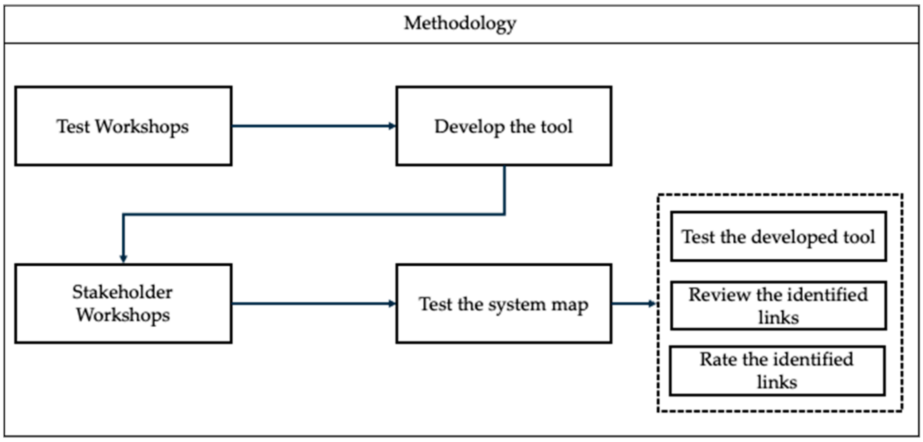

Figure 3. The methodology. Source: Authors.

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 via 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 number of participants in each of these workshops were between 5 and 9 people. Workshop sessions were audio recorded, and the recordings were later transcribed using the Trint transcription application (see Table 1).

Table 1. 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 system 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 2.

Table 2. Test workshops' process.

Workshop Part	Description
Ice breaker	Participants provided a short introduction to themselves at the beginning of each workshop to help all participants get to know each other a little more. This was completed 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 completed in about 15 min.
Workshop activity	In this step, participants were given 20–30 min 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?

Table 2. *Cont.*

Workshop Part	Description
Discussion	Participants were engaged in an unstructured discussion, which was 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 feedbacks for this experience?

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 4) based on the strategies' areas: food, climate actions, biodiversity conservation and health, and governance. In these maps, strategies are depicted using blue ovals and outcomes are depicted using orange rectangles. The links between strategies and outcomes are illustrated with black (positive links) or red (negative links) lines. 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).

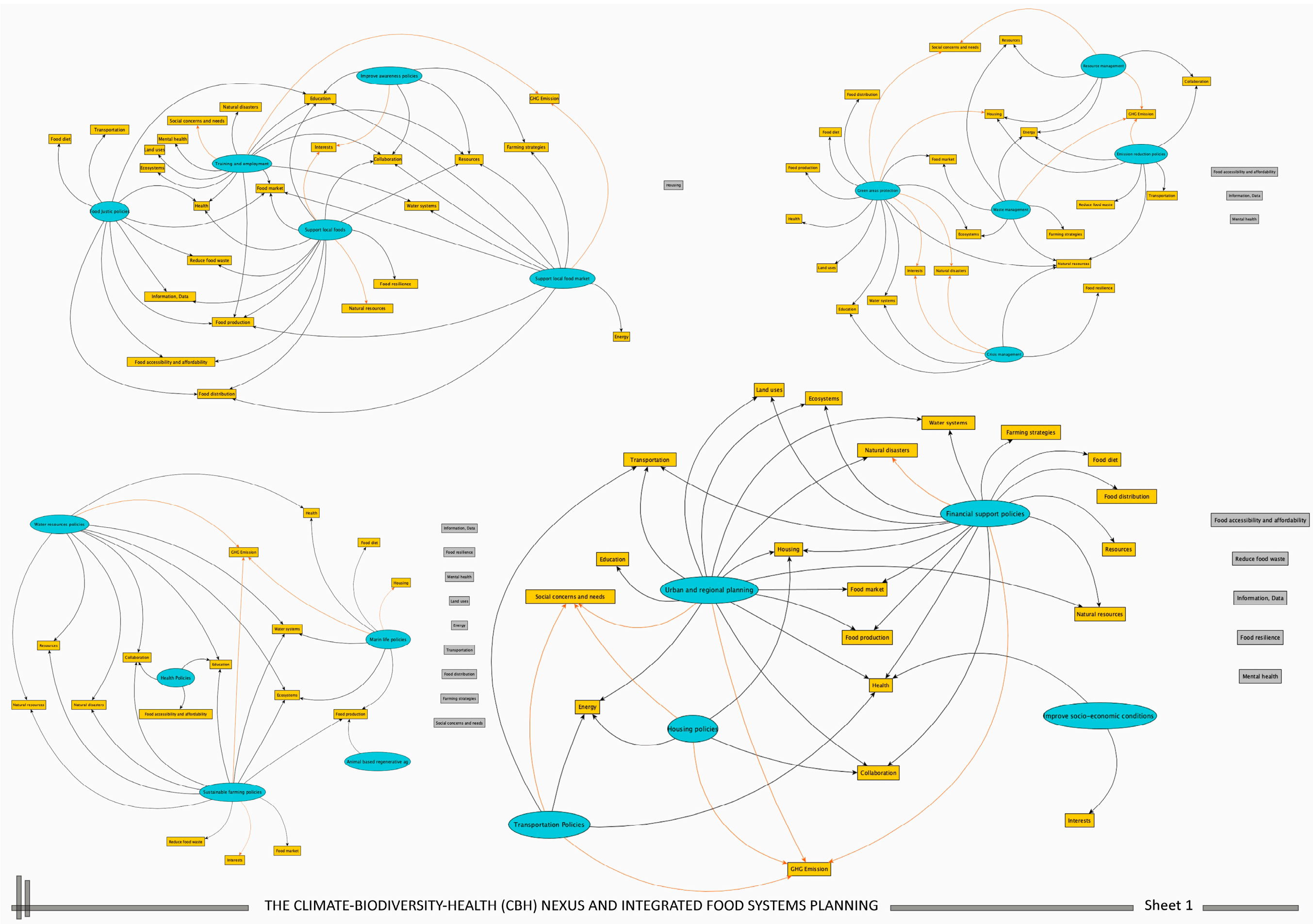

Figure 4. An example of system map sheets. Source: Authors.

The system maps were shared with participants in paper format [56]. 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 development of the nodes). Each sheet included four sub-system maps, and one of these maps was larger than the others (see Figure 4). 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 system maps were comprehensible, useful, and/or missing key elements. Then, a group discussion was held, where participants were asked to explain their thoughts and feedback using a series of guiding questions (see Table 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 [57] to share with participants. Instead of 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.

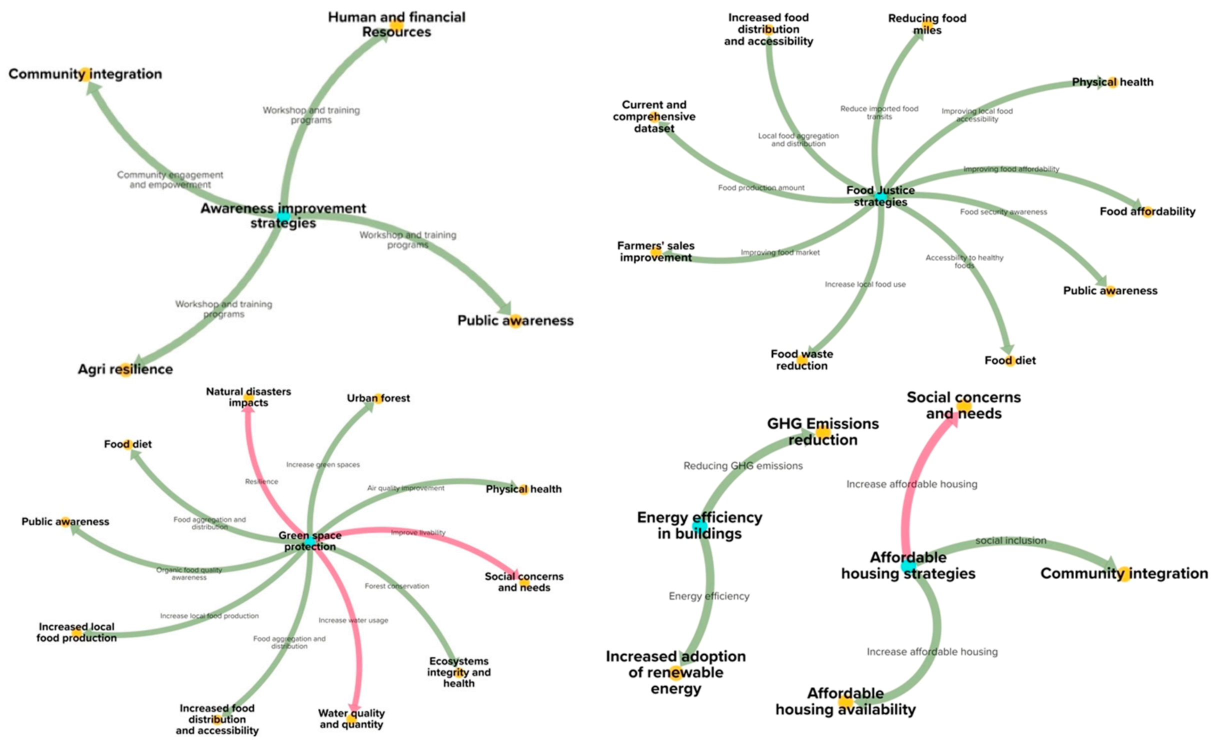

Figure 5. Examples of individual system maps.

To facilitate participant engagement in the system 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 each option from one (very low) to five (very high). The 18 individual system maps were categorized into five groups (see Table 3), 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 3. 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 appeared 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 following 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?

Test Workshop 3

The results of the second test workshop indicated that most of the issues around interacting and understanding the system 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 gathered similar/related strategies (see Table 4). 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 were clear and could represent their appropriate meanings, as well as any suggestions to improve the clarity and adequacy of the nodes.

Table 4. 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

The nodes were revised based on the feedback given in this workshop. Also, to improve the clarity of nodes, especially in the case of strategies, some examples (e.g., the name of plans or programs) were added to the node description fields in Kumu.

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 carried out by sending invitation emails to the stakeholder list prepared for the interview phase of the greater research project [45]. The stakeholders included those who work in the areas of food systems, climate action, biodiversity conservation, and/or human health, and they include people who work at various scales, from the local to the provincial levels. The email used for recruitment included an update on the progress of the greater research project and an invitation to join 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 h. 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 canceled. 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 5).

Similar to the test workshops, the stakeholder workshops consisted of four parts: icebreaker, introduction, participation, and discussion. Workshop discussion sessions were recorded. A main aim of these workshops was to test how the method of 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 identified systems relationships were tested in these workshops.

Table 5. 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

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 include analysis of data that (1) are related to reviews about the effectiveness of engaging participants with the system maps and (2) are 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 noted that the system maps showed the complexity of food systems, their different actors, and the crucial need to use 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 approach of dividing the full system map into four different maps did not effectively facilitate comprehension, so other approaches were needed to address this issue. The high complexity of system maps makes it confusing and creates difficulties in realizing the relationships 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 included a reduction in links/relationships in the full system map. One of the participants proposed to remove the links that only appear one or two times in the interview data since links just mentioned by a 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 divide the full system map into these themes. The result is system maps that are both less complex and capture areas that 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 system 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 returning to the system map adversely influenced participants' comprehension. Additionally, participants of the first workshop explained some nodes are vague, and there is a need to review 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, the use of a green line to show co-benefits between food justice strategies and food miles was not found clear by participants, and instead, they suggested 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 the following:

> "*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 map 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 become 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 improve 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. 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 who 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 indicates 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 on 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 map in accordance with the intended users and the reasons behind using it in order for the system 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 the following:

> "*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)

Insights into the development of the system map were also gained via 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 in other areas and should be considered in developing future strategies. Figure 6 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 a reliable method for developing a robust system map.

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 via the system map, but the map also could be enhanced with the addition of a few more strategies (Table 6).

Table 6. New identified links between. Note: green cells of this table represent co-benefits, and orange cells refer to trade-offs.

Strategy	Strategy/Outcome
Poverty reduction strategies	Increased food accessibility
	Food affordability improvement
	Reduced financial support 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
	Increased population
Enhancing active transportation	Increased physical injury risk

Based on the workshops, two main changes were made to the initial system map shown in Figure 1. Firstly, the map was made to be more detailed, with all outcomes of strategies displayed. Secondly, new links and relationships were drawn on the map. Figure 7 shows the revised version of the map.

	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					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

Figure 6. *Cont.*

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			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

Figure 6. The influential level of strategies on their outcomes.

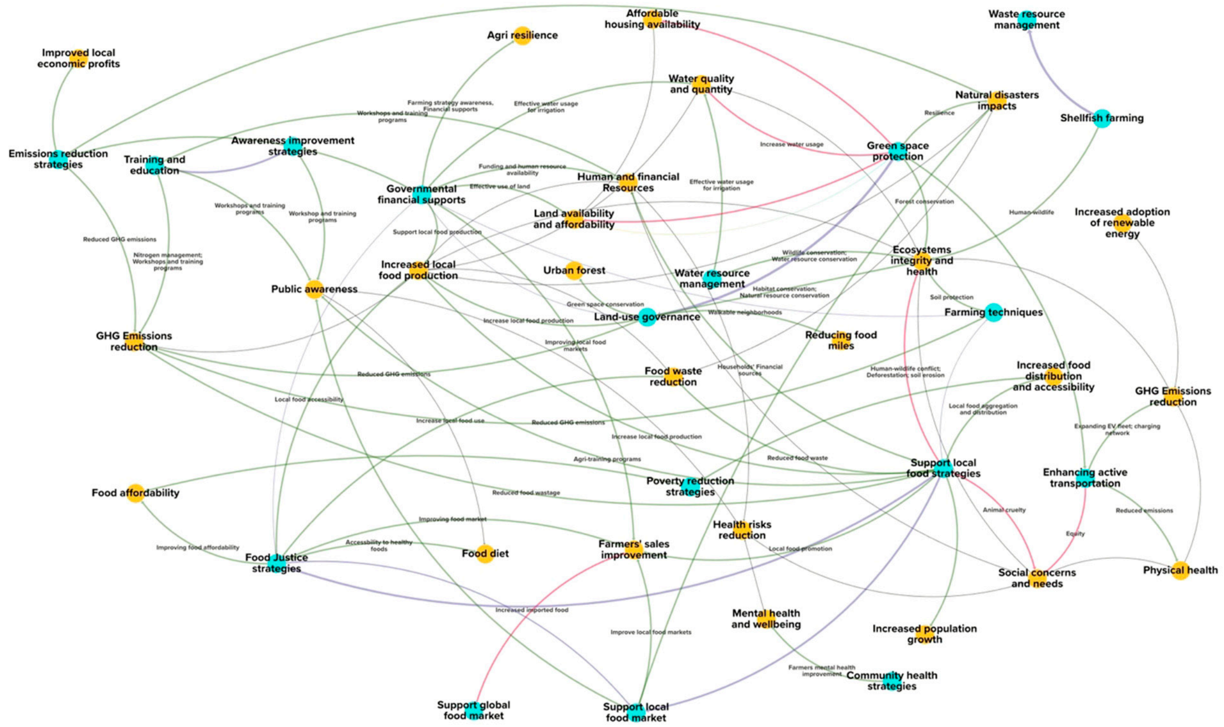

Figure 7. The revised system map.

The final system map is intended to be a planning and strategizing tool for local government and stakeholders in the Comox Valley. It provides a comprehensive visualization of the direct and indirect impacts of strategies, thereby necessitating their consideration in future planning and strategic initiatives. Furthermore, the system map can be used as an analytical framework for evaluating the integrated planning qualities of existing programs, plans, and strategies in ways that inform their improvement and revision, as carried out by Ghadiri et al. [58]. Additionally, the system map underscores the critical importance of collaborative planning among stakeholders, given the significant interconnections between strategies. As such, the map can serve as a facilitator and catalyst for the collaborative planning process within the case study, thereby enhancing coordination and motivation among the involved parties.

6. Discussion

This study explores how system mapping can be employed to study complex issues effectively and holistically. In the case of food systems, the application of this approach results in the identification of various aspects of food systems, their connections with other planning and policy areas, and valuable insights into the potential interventions required to address challenges and promote food system sustainability and resilience. In this way, the study confirms the reasons why system mapping is useful for research on complex sustainability issues.

Participatory research in systems studies is crucial for better understanding wicked problems, like those related to food systems, as these problems can only be holistically tackled by knowing and involving different views of various stakeholders. Non-participatory approaches, lacking 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 [59]. 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 of limited and specific groups and can be achieved only via engaging diverse stakeholders. The data collected from stakeholders not only reveal the correlations between various factors but could also help researchers realize the key causes of problems, which is helpful to prioritize action plans and specify from which part addressing issues should be started [60].

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 broad range of ideas, as well as allowing for testing and refining of the workshop activities. Such insights allowed for valuable refinement of the system maps and workshop activities prior to their presentation to stakeholders during the stakeholder workshops.

This study demonstrates the value 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 [61]. Users can also highlight each node (strategy or outcome in this study) and its connections, 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 to divide complex system maps into smaller parts, which makes them more understandable and accessible to a variety of users and people. Digital engagement tools, such as the CoLabS platform, give opportunities to add more information and details about the nodes and links, which facilitates communication and could reduce risks of misunderstanding the meaning of systems elements and relationships.

This study confirms the challenges in identifying and discerning the significant links from negligible ones when mapping systems. 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 negligibly influential elements and thus can be removed from the whole system. However, when sharing these 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 system map can be effectively developed from qualitative data by focusing only on data that have 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 in or exclude from 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 [62]. The expectations of the system maps' complexity are different among participants [63]. System mapping and visualization tools should include functions for presenting complexity at different levels. Although recognizing the influential factors on the needed complexity requires further research, this study shows that the affiliations and expertise of users, as well as their aim for using the maps, can influence the level of complexity people want to see in a system map. According to this study, a possible way to develop a system map to meet the needs of different groups would be to separate the whole system map into different parts and show each planning and policy area represents in the system map in these parts.

7. Conclusions

Participatory system mapping supports the comprehensive, multi-dimensional, and multi-scalar analysis of food systems [1]. However, unraveling the interconnections within the components of these intricate systems can be both 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 [39]. 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 [28,29,40].

This study contributes to this literature by sharing recommendations from stakeholder engagement for improved participatory system map visualization [62]. This research demonstrates that removing 'less important links' that are identified as such 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 [18], 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, the study shows that the presentation of a system map 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 their positive and negative relationships. These elements of user design will improve the utility and comprehensibility of participatory system approaches.

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