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VERTICAL AGRICULTURE EDUCATION WORKSHOP REPORT

UNIVERSITY OF THE FRASER VALLEY
FOOD AND AGRICULTURE INSTITUTE

TRIAS

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This workshop series engaged agriculture industry professionals, students, government agency representatives, food-related NPO staff, and academics in British Columbia to identify key topics and learning approaches for the development of vertical agriculture training materials and courses. Three workshops were held from January to February 2024, and they were attended by a total of 78 individuals. In addition, a survey was distributed to 12 participants following their attendance at a workshop. Through this workshop series, we explored the following questions:

- What drew participants to workshops?
- What educational themes did workshop participants highlight?
- What are desirable learning methods and outcomes for this industry?

The workshops involved activities where participants posted comments and engaged in discussions. Following the workshop, we thematically analysed the comments and discussion transcripts. From this analysis and analysis of the surveys, we produced the following recommendations for developing vertical agriculture training content and courses:

1) Balance specific, technical insights with high-level reflection on considerations and opportunities for vertical agriculture to appeal to the diversity of audiences interested in pursuing vertical agriculture training.

2) Situate vertical agriculture among a broader portfolio of food production strategies to sustainably transform just food systems.

3) Explore the potential for a diversity of crops to include in grow systems, including traditional/culturally significant plants and genetically modified cultivars.

4) Include the practical, day-to-day skills required for managing and operating a vertical farm.

5) Consider the operational dimensions of vertical growing (including business and horticultural techniques), recognizing that many individuals entering the industry come from technology, not agricultural, backgrounds.

6) Include discussion and/or case studies that highlight the place-based, geographical considerations for establishing and operating a vertical farm (i.e., by land use or within rural/dense urban areas).

7) Offer blended online and in-person learning opportunities (i.e., on-campus vertical farm, site-visits, virtual classrooms).

These recommendations will inform the development of online materials for a vertical agriculture micro-credential program. The micro-credential courses will be supported by an online collaboration platform and digital engagement tools, including an interactive vertical agriculture and food systems planning tool that is currently being developed by the research team.

1. INTRODUCTION

Contemporary food systems that consist of long supply chains and centralised processing and distribution are vulnerable to social, economic, and environmental changes and disturbances. The tight coupling of global trade, water, energy, distribution, and governance systems has revealed food system vulnerabilities as seen in the COVID-19 pandemic (Clapp and Moseley, 2020) and with climate change (Newell and Dale, 2021). Drivers for these vulnerabilities include global monopolies of multinational agri-food corporations (Clapp, 2023), input intensive monocultures (Altieri et al. 2015), and poverty (Azzam and Rettab, 2012).

Addressing food system vulnerabilities is a critical challenge for action research, policy and planning, and technological innovation. The scale of impacts on human systems and ecosystems from unsustainable and fragile food systems has spurred extensive scholarship in food system resilience (see Townsend et al., 2021; Zeuli and Whalen, 2017). Changes to food production and farming practices are done based on the recognition that solutions and alternatives are needed to address pressing concerns of food system vulnerability. Such changing and emerging farming practices should be integrated into broader food system transformation.

Vertical agriculture is posited to be a farming practice that can contribute to food system resilience and potentially food system transformation. Despommier (2010) describes vertical agriculture as a suite of tools and technologies for growing food 'upward' through the use of hydroponic, aeroponic, aquaponic nutrient cycling systems with vertically stacked growing beds. Vertical agriculture has been found to be more water-, nutrient-, and land-efficient than conventional production (Kozai et al., 2019; Halgamuge et al., 2021). The controlled environment of vertical agriculture allows for year-round crop production, optimal growing conditions, and higher yields of food production (Glaros et al., 2022). From a food planning perspective, vertical agriculture can contribute to strategies to decentralise food production and enable year-round food production.

As an emerging food production method in North America, vertical agriculture (and other controlled environment forms of agriculture) are generally absent from much of the post-secondary curriculum in food planning education (see Greenstein et al., 2015), sustainable food systems education (Edwards, 2023), and conventional agricultural production (Julseth-White and Glaros, 2024; Stackhouse, 2019). Vertical agriculture education tends to be included in few technical disciplines such as engineering (Jensen, 2016; Lau, 2021) and horticulture (Yamaguchi et al, 2016), as well as specific programs for controlled environment agriculture, urban agriculture,

and hydroponic agriculture (see University of Arizona, Cornell University, Ohio State University, Olds College, Oregon State University, Purdue University). Vertical agriculture education is timely and necessary as the kinds of skills and training needed are substantially different from conventional agriculture systems (Julseth-White and Glaros, 2024; Stackhouse, 2019).

This project aims to address the gaps in vertical agriculture education by identifying the educational needs (e.g., knowledge content, skills, tools, competencies, learning outcomes) for the range of students and practitioners that engage with vertical agriculture. These students/practitioners include not only those who are implementing vertical agriculture systems, but also those who wish to support, manage, and integrate vertical agriculture in local and regional food systems. The project objectives are:

1) To assess general interest around the creation of a vertical agriculture education program (based in British Columbia (BC)), and

2) To identify the necessary content, skills, tools, and values that would inform the development of vertical agriculture education materials and curricular programming (i.e., micro-credentials, curriculum, courses, etc.).

2. BACKGROUND AND CONTEXT

British Columbia is an ideal place to develop a vertical agriculture education and training program to promote the growth of a local industry. The geography of the province is primarily mountainous with approximately 5% of land within the Agricultural Land Reserve (ALR). The ALR was established in 1973, which created a province-wide agricultural zone intended to protect farmland from urban expansion and land conversion. As a zoning instrument, the ALR determines permitted land uses which are often categorised as farm and non-farm uses. Across the province, 2.7% of land is capable of growing a wide-range of crops (BC Agricultural Land Commission, 2023). Vertical agriculture is an allowed use under the ALC Act and as an accepted best practice under the Farm Practices Protection Act of British Columbia.

With a constrained land base, particularly in rural and peri-urban areas, land availability, access, and suitability are barriers to agricultural expansion in existing agricultural landscapes. To allow for novel forms of agricultural production, legislative changes in February 2022 by the provincial government allow controlled environment agriculture (e.g., vertical agriculture) as an allowable farm use in the ALR. This sets the foundation for vertical farming to be situated within the ALR and within agriculturally-zoned areas across BC. Increasingly, municipal and regional governments will need to develop capacity to both manage and support these farming practices and initiatives.

3. METHODOLOGY

This study contributes to the knowledge on approaches to vertical agriculture educational initiatives and content delivered through post-secondary, non-profit, and private organisations (e.g., Julseth-White and Glaros, 2024). Responding to calls to understand what students and practitioners desire and value in choosing to work and study vertical farming (Stapleton and Meier, 2021), we aim to gain insights into stakeholder perspectives of the relationship between vertical agriculture and sustainable food systems education, which in turn, can be used to inform the development of effective vertical agriculture educational programs.

The study consisted of three virtual workshops that explored different topics and subject areas related to vertical agriculture (Table 1). The workshops gathered private individuals, agricultural industry professionals, students, government staff, non-profit organisation (NPO) staff, and academics. These participants were presented with information and ideas about an emerging vertical agriculture industry in BC, and they then engaged in activities and discussion about effective vertical agriculture educational content, skills, tools, learning activities, and attitudes.

3.1 Survey Questionnaire

An online survey was developed online using SurveyMonkey software, and it was distributed to workshop participants following the completion of each workshop. If participants attended multiple workshops, we asked them only to complete the survey once. We received twelve (n=12) survey responses in total.

The survey asked participants to rate their satisfaction with the workshop delivery and content. Additionally, respondents were asked to identify educational materials that they would most like to see implemented for vertical agriculture training with respect to virtual/online training materials (e.g., online videos, podcasts, interactive games, mapping applications), in-person training, and internship/co-op opportunities. Finally, we asked participants to rate their interest in receiving vertical agriculture training.

3.2 Workshop Series

The project consisted of three workshops held between January 15 to Feb 15, 2024 (Table 1). Each workshop was held virtually using the Zoom platform and lasted two hours. A total of 78 people participated in the workshop series.

Table 1. Vertical Agriculture Education Workshop Information

	Workshop date	Number of attendees	Participant affiliation (i.e., student, planner, etc.)
Workshop 1 - Fundamentals of Vertical Agriculture Practices and Techniques	January 16, 2024, 1-3pm PDT (virtual)	34	Personal interest (1) Agriculture industry professional (11) Undergraduate Student (3) Government agency representative (6) NPO staff (5) Academia (8)
Workshop 2 - Relationship Between Emerging Agricultural Technologies, Sustainable Food Systems, and Resiliency	January 30, 2024, 1-3pm PDT (virtual)	22	Personal interest (1) Agriculture industry professional (9) Government agency representative (7) Academia (5)
Workshop 3 - Planning and Policy Considerations/ Key Challenges and Future Directions for Vertical Farming	February 13, 2024, 1-3pm PDT (virtual)	22	Agriculture industry professional (6) Undergraduate Student (1) Government agency representative (9) NPO staff (2) Academia (4)

The first workshop gathered 34 participants, who explored the question: What is vertical farming? The workshop focused on the fundamental characteristics of vertical agriculture including practices, techniques, and historical developments (Table 2).

The workshop began with two presenters (Dr. Lenore Newman, University of the Fraser Valley and Nandish Khaliwal, QuantoTech) who described the history of vertical agriculture and an overview of vertical farming practices and techniques. Following the presentations, participants were organised into three breakout groups to explore and provide thoughts on the knowledge content, skills, and values that are needed for a vertical agriculture education program. The breakout groups engaged in discussions guided by the following questions:

- What do you think are the key goals of vertical agriculture? What might draw someone to vertical agriculture?
- What do you think are the fundamental knowledge areas (subjects, concepts), applications, skills, and tools for vertical agriculture practices and techniques?
- What kinds of teaching activities do you think would best support learning about the techniques and practices?

The workshop concluded with an evaluation of the workshop structure and activities, which was done via the survey questionnaire.

Table 2. Workshop 1 Schedule - Fundamentals of Vertical Agriculture Practices and Techniques

Order	Activity Type	Description
1	Researcher presentation	Introductions to the project and workshop objectives
2	Speaker presentation	Dr. Lenore Newman - Food and Agriculture Institute, University of the Fraser Valley
3	Speaker presentation	Nandish Kandelwal - QuantoTech
4	Participant input	Discussion on educational materials (content, techniques, resources)
5	Researcher presentation	Closing and next steps

The second workshop gathered 22 participants, and it centred on the question: Why implement vertical farming? This question stimulates thinking about the desired goals and expected outcomes of vertical farming, as well as the relationship between vertical agriculture and a range of social, environmental, and economic sustainability considerations. To this end, the workshop explored the relationship between vertical farming, sustainable food systems, and resiliency (Table 3).

The workshop began with a presentation (Dr. Robert Newell, Royal Roads University) who described the relationship between agricultural technologies, sustainable food systems, and resiliency. Through a plenary discussion, participants explored two questions: 1) What makes contemporary food systems unsustainable; and 2) What are the characteristics of sustainable food systems? Participants were then organised into two breakout groups to conduct a strengths, weaknesses, opportunities, threats (SWOT) analysis of vertical agriculture and its potential to contribute to sustainability characteristics (previously identified). The workshop concluded with evaluation of the workshop activities and structure via a survey questionnaire. The survey also provided participants with the opportunity to elaborate and expand on their ideas regarding vertical agriculture education.

Table 3. Workshop 2 Schedule - Relationship Between Emerging Agricultural Technologies, Sustainable Food Systems, and Resiliency

Order	Activity Type	Description
1	Researcher presentation	Introductions to the project and workshop objectives
2	Speaker presentation	Dr. Robert Newell - Canada Research Chair in Biodiversity, Sustainability and Climate Change, Royal Roads University
3	Participant input	Discussion on (un)sustainability of contemporary food systems and characteristics of sustainable food systems
4	Participant input	Strengths, Weaknesses, Opportunities, Threats Analysis of the relationship between vertical agriculture, sustainable food systems, and resiliency
5	Researcher presentation	Closing and next steps

The third workshop gathered 22 participants, and it focused on the question: How to support vertical farming? The aim of the workshop was to identify key vertical agriculture-related considerations and challenges for planning and policy, key as well as future directions for the vertical agriculture industry in BC (Table 4).

The workshop began with a presentation (Jeffrey Weightman - BC Ministry of Agriculture). A panel discussion was held to explore key challenges, future opportunities, and ways to support vertical agriculture. Panellists included Alycia van der Gracht (QuantoTech), Dr. Robert Newell (Royal Roads University), and Jeffrey Weightman (BC Ministry of Agriculture). Panellists responded to pre-prepared (PP) questions and audience (A) questions:

- Where does vertical agriculture fit into visions of the future circa 2050? (PP)
- What are the promises of vertical agriculture? What about perils? (PP)
- What kinds of challenges are there in finding skilled labour? How long does it take to train someone to operate a vertical agriculture system? (A)
- What about specific challenges/opportunities for rural/remote communities? (PP)
- What role does local government play in vertical agriculture support and/or control? (PP)

The workshop concluded with participants filling out workshop feedback forms, and they were directed to complete the survey questionnaire.

Table 4. Workshop 3 Schedule - Planning and Policy Considerations/Key Challenges and Future Directions for Vertical Farming

Order	Activity Type	Description
1	Researcher presentation	Introductions to the project and workshop objectives
2	Speaker presentation	Jeff Weightman - BC Ministry of Agriculture
3	Speaker input	Panel discussion: Dr. Robert Newell - Canada Research Chair in Biodiversity, Sustainability and Climate Change - Royal Roads University, Alycia van der Gracht - QuantoTech, and Jeff Weightman - BC Ministry of Agriculture
4	Participant input	Large group discussion - planning and policy considerations, key challenges, and future directions for vertical farming
5	Researcher presentation	Closing and next steps

3.3 Analysis

Data analysis involved examining the workshop outputs, participant responses, feedback forms, and survey responses, and organising the findings into three categories: knowledge content/skills (i.e., technical, analytical), planning tools and resources, and values. These categories were derived from previous research on food system courses and education (Hammer, 2004; Greenstein et al., 2015).

The Understanding by Design (UbD) framework was used in this analysis (Wiggins and McTighe, 2005), as it is regularly employed by educational professionals in course design. Described as a backward design process, Wiggins and McTighe (2005) identify three stages of course design: i) desired results; ii) results; and iii) learning plan. The framework was developed to address a common issue of instructional design, that is, content delivery being isolated from learning activities and evidence of learning.

Stage 1 (Desired Results) in the UbD framework involves establishing goals from external standards (e.g., stakeholder input, current practitioners), in this case, a combination of presenter content in the three workshops, participant response from workshop activities, and a follow-up survey questionnaire). Stage 1 consists of “understandings'' and “essential questions” components (Wiggins and McTighe, 2011, p. 14-15), and it involves gaining both declarative and procedural knowledge. This includes identifying specific, measurable, short-term learning outcomes that articulate the content and skills learners should know and be able to use by the end of the course (Wiggins and McTighe, 2011).

An inductive thematic analysis of the workshop data was done, using the four educational themes described above (i.e., knowledge, skills, planning tools/resources, and values). An inductive thematic analysis is a qualitative approach to data analysis that highlights the themes within the data that emerge, without a predetermined analytical framework (Braune and Clarke, 2006). We undertook this thematic analysis with the goal of assessing the following questions:

- What drew participants to workshops?
- What educational themes did workshop participants highlight?
- What are desirable learning methods/approaches for this industry?

We focused our data examination to breakout group and Q&A discussions, in order to scope our analysis to workshop participants (not facilitators or presenters, per se). During the first round of open coding, we identified key concepts expressed by workshop participants that spanned these three questions. Following this first round of coding, concepts that were similar in nature were binned together into themes following an axial coding process (Williams & Moser, 2019).

4. RESULTS/DISCUSSION

4.1 Workshop Results

4.1.1 What drew participants to workshops?

Participants attended the workshops for a variety of reasons. Several participants came with the intent of simply learning about vertical agriculture, with little experience with or intention to use vertical growing equipment. Many of these participants had heard of the potential benefits of vertical agriculture and were curious to explore these further. One workshop participant expressed:

> *"I am joining these webinars to learn as much as I can. I'm very interested in the sustainability aspect of it all. Both in the environmental aspects, such as energy efficiency, water conservation, reduced carbon emissions, but also the social sustainability (University Staff, Workshop 1)."*

Other participants attended due to practical reasons, based on an interest in using, investing in, or adopting vertical agriculture technologies. Several participants noted that their community food organisations were interested in incorporating grow units/systems into their food security operations. Participants who worked on university campuses noted an interest in setting up and running vertical farming units on-site. A provincial government participant was interested in learning more about vertical agriculture due to the growing government interest in financing these technologies. Other participants were interested in implementing their own grow units as commercial farmers. The following participant quotes exemplify some of these motivations:

> *"We've ordered a...hydroponic unit and are hoping to get that up and running about April (Community Food Organization Representative, Workshop 2)."*

> *"But we're hoping to expand to have mini greenhouses on campus as well, to bridge the gap with food security within our own student body. It's an issue that's increased exponentially, especially over the past year with the cost of living and the increase in inflation with everything (University Staff, Workshop 1)."*

> *"...Our younger generation...we want to get out there, we want to farm, it's just that logistically it's very difficult without taking on massive amounts of debt (Undergraduate Student, Workshop 1)."*

The workshop participants represented a wide spectrum of interests and experiences with vertical growing technologies, from working professionals and

prospective farmers to a more generalised audience. Future educational materials should blend specific and technical insights with broader materials related to the high-level opportunities and considerations of this technology. Incorporating both content-specific and general food system-related materials will attract the broadest audience interested in vertical agriculture.

4.1.2 Thematic Analysis

4.1.2.1 Knowledge Content

Opportunities to Grow Diverse Crops

A common topic of discussion across all workshops was the diversity (or lack thereof) of crops that are currently suitable for cultivation in vertical agriculture systems and what efforts/opportunities exist to expand this range. Besides just leafy greens, where may other (and possibly more nutritious) crops fit into this emerging industry? One participant shared:

> *"Thinking about what other types of plants can we grow, that aren't just the leafy greens, but maybe like you'd like microgreens or different options that can help replace those nutrients that we might lose if we lose the California leafy greens (University Staff, Workshop 1)?"*

Strawberries and tomatoes emerged frequently in discussions of the potential future crops to explore for vertical farming in BC. Integrating diverse production systems and highlighting both practical crops for cultivation (i.e. lettuce, greens), as well as theoretical crops of interest will be crucial for the design of future vertical agriculture educational materials.

Some participants were keen to explore the possibilities beyond just growing common commercially (and widely) available supermarket produce. In BC and Canada, vertical agriculture farmers may wish to consider novel crops for production in vertical systems that fit into an array of cultural contexts, including culturally significant and traditional plant species. As noted by one of the workshop participants:

> *"I had a similar conversation with someone who was interested in our project, he was Stólō. And he's worked with a number of communities around various innovations to support and help communities. In this particular case, they're interested. They toured the demonstration vertical farm and he was interested in learning a little bit more about it, and how it could be modified to grow some of these traditional plants (University Staff, Workshop 2)."*

Careful consideration is needed about the cultural sensitivities surrounding traditional foods before adapting vertical agriculture grow systems to produce these crops. For instance, understanding how Indigenous food sovereignty intersects with the exploration of culturally significant plant species for vertical growing could be a unique consideration for future training materials (i.e., values related to vertical growing). One workshop participant described how in some cases, vertical agriculture growing techniques may both support and/or hinder relationships communities have to traditional foods; this requires further consideration and conversation for the possible implementation of this technology by and with community:

> *"...to again, have a conversation about what food means, and what does food security and traditional food systems look like for them where they're at today (Government Staff, Workshop 2)."*

Exploration of additional crops may also include the application of genomics to indoor agriculture. There is an emerging role for genomic technologies that are facilitating the introduction of new crops and cultivars into these grow systems, as described by a workshop facilitator:

> *"One of the least developed areas, if you're looking for something interesting, is genomics. We do use a lot of outdoor cultivars, and we could be shifting and are shifting into specific indoor plants (Workshop Facilitator, Workshop 1)."*

Future training materials would benefit from introducing critical discussions regarding the incorporation of diverse conventional crops, culturally appropriate crops, as well as genetically selected and/or modified plants for vertical cultivation.

Nutritional Information and Safety

The nutritional composition of vertically grown produce versus conventionally grown/soil-based systems is important to consider in future training materials. From the perspective of general engagement with the public, it is important to clarify misconceptions and/or misunderstandings of hydroponic or soilless growing methods. Training materials should also include content on how to engage and communicate to the public about vertical agriculture, as this content would be important to prospective growers who may be asked about nutritional differences of their product from members of the public that are less familiar with this technology. As one workshop facilitator, a vertical grower themselves, describes:

> *"So all in all, the nutritional value: the nutritional value of a produce that was grown in a vertical farm can be equal to, less than, or more than a conventional farms, you have to do a case by case review what was what went into growing that produce (Workshop Facilitator, Workshop 1)."*

Content for vertical agriculture training materials can be developed through reviewing key research on these nutritional differences, how nutrition is evaluated within each system (i.e., soil-based vs hydroponic), and communication strategies for this information.

4.1.2.2 Technical/Analytical Skills

Data and Day-to-Day Operations

Key technical and analytical skills identified by participants included the use and management of data in vertical agriculture systems, as well as getting a sense of day-to-day practices of vertical agriculture workers. A wide variety of data are collected in many commercial vertical agriculture systems (e.g., fertiliser and nutrient dosing, light and water flow timing, pH readings, electricity consumption). Knowing how to understand and/or manipulate this data is important for future growers, as highlighted by one participant:

> *"We can also look at data management, like how many sensors do you have and what do you get from that data? How do you manage it?" (Government Staff, Workshop 1)."*

Many participants discussed the labour implications of vertical agriculture, such as what skills it requires and what working conditions are vis-a-vis conventional agriculture systems. These are important topics to consider, given the hands-on nature of vertical growing approaches. One participant explained:

> *"Maybe you think it's going to be all robots, but it's not the way it is (Government Staff, Workshop 2)."*

Including the types of day-to-day activities involved in vertical farming in training materials (e.g., managing light levels, electrical conductivity, acidity, carbon dioxide levels) will allow learners to better understand the practical realities of these vertical farming systems. Such training materials would be effectively supported by vertical agriculture practitioners giving guest lectures to share real-world experiences with vertical farming.

Agronomy, Business, and Labour Considerations

One of the most common themes discussed within workshops centred on the challenges facing vertical agriculture as a viable business and industry as a whole. When considering the economics of vertical farming, questions emerge such as:

- What might ensure a productive and commercially viable venture?
- What work opportunities exist?
- What is the 'day-to-day' like when working in one of these facilities?
- What are industry-wide challenges were all key topics of discussion in workshops?

In terms of the industry as a whole, a few participants with previous experience working with vertical growers described some key challenges with building the industry due to gaps in practitioner knowledge. Many individuals interested in becoming vertical farmers do so with a strong background in technology or business, with little agronomic or agricultural knowledge. Thus, vertical agriculture training materials should be comprehensive and include horticultural/agronomic, as well as business-related, topics. Two workshop participants noted:

> *"I want to learn as much as possible on vertical farming to help the producers [we work with]. And what I've noticed is sometimes people from outside of agriculture are really attracted to this new business, they don't consider all the agronomic aspects (Government Staff, Workshop 1)."*

> *"So I see a weakness is not that we're attracting a lot of people that don't know anything about farming and don't seem to have any talent for farming, wasting a lot of resources, trying to implement things that don't factor in what we already know (Technology Developer Workshop 2)."*

Workshop participants also described the challenge of setting up viable vertical agriculture businesses in a competitive industry landscape. Competition with robust

international markets and highly competitive large-scale vegetable producers within and outside Canada make business viable a significant challenge. One workshop participant expressed:

> *"So you have the production issues and then after you will have to sell your products. So that's another issue for someone… you have market competition from California; California won't stop selling. So you have to sell at a good price to be profitable (Government Staff, Workshop 1)."*

Key topics to include in vertical agriculture training materials include the landscape of conventional horticultural value chains, how these work within the Canadian economy (e.g., what supports are available for Canadian growers), and how these manifest in challenges for vertical agriculture producers.

Considerations for Remote Communities

Many participants were interested in exploring the opportunities for vertical agriculture in remote communities. There is potential to integrate vertical growing technologies within communities that rely on long distance flows of fresh produce and are thus vulnerable to supply disruptions:

> *"Very small communities at the end of a long road are really up the creek when it comes to getting this nutritional food. And I think that there will be an uptake of interest in doing this type of agriculture (Government Staff, Workshop 1)."*

Exploring the considerations and challenges around vertical growing in remote communities is an important topic to consider in vertical agriculture training materials. For example, lack of consistent and/or cheap energy may be a key factor to consider when setting up a vertical farm in a remote region. Ongoing farm maintenance and/or repairs may also be challenging, in cases where technology and replacement pieces are imported from afar. Other vulnerabilities related to climate change and hazards may also affect vertical agriculture, despite being a contained system. One participant noted:

> *"…speaking of land further in central and northern BC, what is the risk when it comes to vertical agriculture? And the increased risk of wildfires in those areas of BC? Because I know with a traditional farm on land, it's recoverable. But what is that loss of capital, when it comes to a vertical agriculture setup (Undergraduate Student, Workshop 1)?"*

Vertical agriculture training needs to consider the requirements of a diversity of communities, such as those in remote regions. Future research and engagement is required that works with remote growers to develop tailored and relevant training content for these settings.

Land use and Planning Tensions

A key topic for vertical agriculture educational materials are planning and land use considerations. Specifically, siting for these facilities requires careful planning and work with local government to assess land use implications and determine suitable site energy considerations, water access, among other permitting needs. This was described by one workshop facilitator as follows:

> *"We can find a slightly lower cost site [for vertical agriculture] in an agricultural area. However, it can't be just anywhere, it needs to be near the energy grid, clean water and transportation infrastructure. And to me the sweet spot is in what we call peri-urban regions that are near cities but not in cities. The site once approved must be prepped to carry a heavy load. These farms are really heavy (Workshop Facilitator, Workshop 1)."*

What makes vertical farming planning a challenging topic to engage with is the lack of existing allowances and explicit recognition of this farming method in local land use plans and policies. As one urban planner described, there is so far little consideration for vertical agriculture as a strategy to improve local food availability:

> *"People talk about increasing the availability of local food as a high level goal, but I've never seen any zoning bylaws or reviewed any in an urban area that specifically looks at, you know, vertical farming or closed environmental structures as an allowable use (Workshop 3, Workshop Facilitator)."*

Much discussion within workshops involved the tensions, trade offs, and co-benefits of implementing vertical agriculture on agriculture land. In the BC context, land for agricultural use is conserved via the ALR, which as of 2022 was amended to include vertical agriculture as permitted land use. Some participants voiced concerns for the implications of grow structures and infrastructure being built on quality agricultural soils:

> *"I guess it could, potentially the vertical farms be put on to areas where soil based agriculture could be put in place instead. So it could take up land based in ALR that basic agriculture could do (Government Staff, Workshop 2)."*

However, other participants noted that vertical agriculture may also produce land-sparing benefits:

> *"...but [vertical agriculture] also can open up lands that are needed for soil based crops. So it can prioritise those to go on the lands that are arable, for soil based crops (Government Staff, Workshop 2)."*

Future vertical agriculture training materials would benefit from unpacking land use and zoning considerations pertinent to this emerging industry. Using a holistic land use planning lens enables better understanding of the possible implications of *where* vertical agriculture physically fits into the urban or agricultural fabric of local and regional food systems. Such understanding will stimulate important thinking for students and prospective growers.

4.1.2.3 Values

Need for a Holistic, Systems Lens

Although the workshops focused on vertical farming, participants appreciated the way that the workshop presentations, activities, and discussions situated vertical farming and technologies within the broader landscape of food production, ag-tech, and diverse approaches to addressing food insecurity, and environmental challenges. One participant articulated:

> *"...there's a risk or a threat that [vertical agriculture] could be seen as a silver, the silver bullet to all of our agriculture challenges, or just whatnot, and forgetting that it is one piece that has a great deal of potential within a broader system (Government Staff, Workshop 2)."*

Including a broader systems lens in vertical agriculture training will enable training and education that offers a comprehensive and integrated approach to learning. Training materials should/will be developed for an wide range of ages, career stages, and sectoral contexts (i.e., for use on campuses, in communities, and for commercial purposes), and this broader lens can support students to develop a more nuanced understanding of the technology and its possible limitations to addressing food system issues.

Applying a systems lens to vertical agriculture training will involve exploring the possible tradeoffs and co-benefits of these technologies. Beyond solely considering needs for business viability or economic productivity, including environmental, social, and justice-based considerations in educational programming could create a unique training offering. For example, regarding the environmental sustainability of vertical agriculture, if farms are incorporated into carbon intensive grids or if land that is saved/spared from agricultural production is repurposed for purposes besides conservation, the potential environmental benefits of vertical agriculture may not come to fruition:

> *"So long as the energy is green, that's the key thing. 95% land savings allows for land based banking and maybe allowing some wilderness restoration (Workshop facilitator, Workshop 1)."*

4.1.3 What are desirable learning methods/approaches for this industry?

Hands-On Learning and Demos

Participants described the incorporation of hands-on learning and/or real industry experience as key to developing effective vertical agriculture training materials. This type of learning is important for a variety of reasons. First, it attracts those who have interests in more tangible aspects of the education, thereby potentially attracting a wider variety of students than if the course consisted of online materials alone. One participant who was interested in the potential for including grow systems in schools or on campuses explained:

> *"If the growing system is on a school property…it can get kids interested in agriculture. And doing it in a different space, different way, not just soil based agriculture. So the people that are interested in technology, maybe don't want to be playing in the dirt that might make them more interested in taking a career in agriculture (Government Staff, Workshop 2)."*

Besides increasing interest in the growing system technology, incorporating a practical component in the training program allows for students to experience on-farm issues and problems they may encounter in the 'real world'. While being told about these challenges or hearing of them second-hand may offer some form of preparedness, experiencing those challenges firsthand may develop a deeper and more contextual understanding of how to problem-solve and navigate these issues in practice:

> *"But when you see stuff firsthand, I think that's when you really, truly understand the essence of what's going on and get a feeling for the challenges that they're dealing with as well as their successes (Government Staff, Workshop 1)."*

Online/Hybrid Training

In addition to widespread interest in hands-on training opportunities, some participants noted the potential for online demonstrations and social media engagement to drive interest in and knowledge of vertical agriculture. Participating in online tutorials and working with systems at small scales could allow for individuals to begin to learn the basics of vertical agriculture practices. One participant shared:

> *"I know that scrolling on Tik Tok and watching people just do vertical gardening or there's a full page on it, you could definitely get people involved that way (University Staff, Workshop 1)."*

Future training materials could include do-it-yourself lab exercises and/or provide kits for small-scale vertical growing at-home, in order to drive interest in vertical agriculture technologies and also to promote some exposure to these vertical growing practices.

In-person and hands-on training may not be possible for some communities, such as remote communities that may have a strong interest in vertical growing technologies. This requires hybrid educational delivery, with a substantial portion of training taking place in an online setting. One participant suggested:

> *"So perhaps a training package that included some in person, some online, mostly online...I don't know, because I'm not an expert in delivering training to those types of [remote] communities (Government Staff, Workshop 1)."*

Image credit: Lufa Farms, 2012

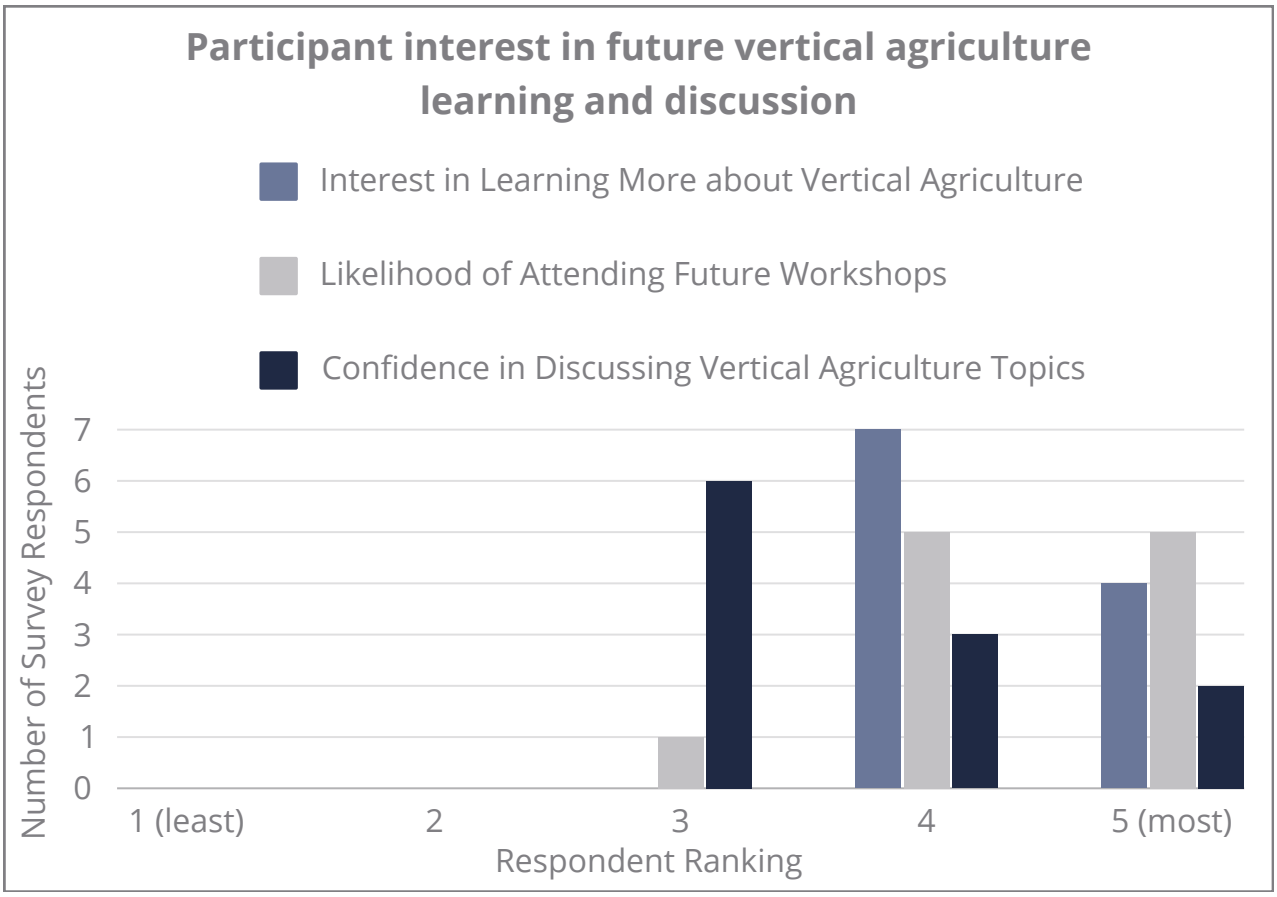
4.2 Survey Results

4.2.1 General Workshop Perceptions

Survey respondents indicated high levels of satisfaction with the workshops, with sixty seven percent (67%) ranking their satisfaction a four or five out of five. Many survey respondents indicated that the breakout rooms were their preferred activity, as they were able to connect with others to share ideas and dive into concepts more deeply. When asked what they found most effective during workshops, one survey participant responded:

> *"The breakout rooms - allowed me to think more critically and hear from different perspectives! I liked that they were longer to ensure we had enough time to spend on each question."*

Survey respondents ranked engagement in future vertical agriculture training discussions (i.e. interest in learning more, attending future workshops, and confidence discussing vertical agriculture) above three. Survey respondents ranked interest in learning more about vertical farming (mean = 4.36) and likelihood of attending future workshops (mean = 4.18) higher than confidence in discussing vertical farming (mean = 3.64), suggesting that there is an interest and need for future training.

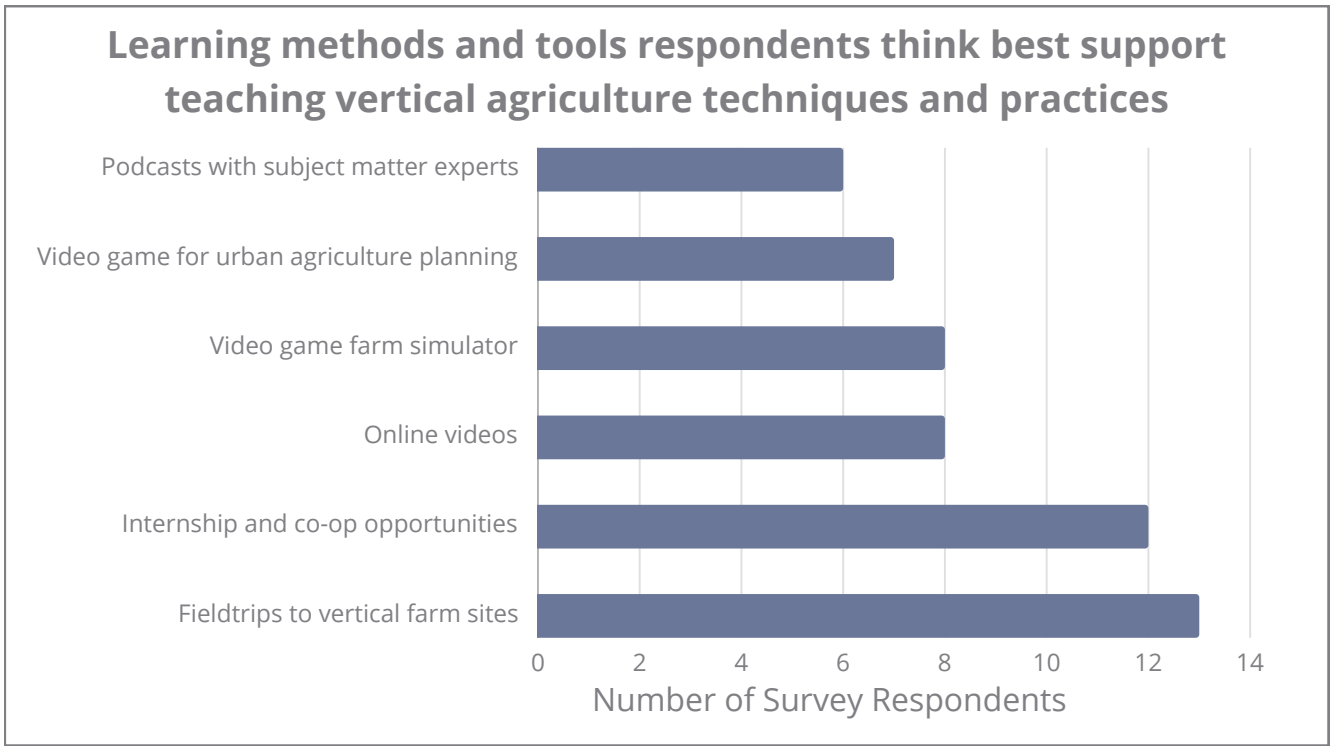


Survey respondents indicated that they found information regarding the current state of vertical agriculture as an industry and its potential contributions to food system resilience as well as food security highly interesting. Survey respondents suggested increased use of visuals to convey ideas and topics related to vertical farming, across the presentations. This was captured in the following open-ended answers from anonymous survey respondents, where we asked participants to describe what they liked the most about the workshops:

- "The importance behind vertical agriculture for our future - food security"
- "Insight into the emerging approaches in the field and what vertical agriculture could look like in the food market, both in the province and globally including the impacts of it"
- "Good overview of current situation of vertical farms in Canada, current challenges and opportunities."

4.2.2 Recommendations for Future Content

At least half of the survey respondents (n=6 or greater) indicated interest in all of the possible learning methods we identified, with exception of podcasts (n=5). Field trips to vertical farm sites were the most frequently selected preferred learning method, followed by internship and co-op opportunities. These results suggest that integrating in-person and interactive learning tools could enhance the effectiveness of vertical agriculture education training materials.



Survey respondents identified specific technical training as something they would be interested in having included in vertical agriculture training materials. Such training includes knowledge about crop biology in vertical systems, as well as business management considerations (e.g., how to achieve commercial scales for growth systems). These were described in the following anonymous survey responses:

"More specifics on what crops do well, and why some don't do well."

"All things that would help with business planning and what skills you would need on your team to start a vertical farm. How to bridge the issue of current competition and getting to profitability."

"Packaging, labelling, and requirements for marketing vertical agriculture products, trends in the market in terms of demand and buyer acceptance of vertical agriculture."

Survey respondents also identified a need for specific knowledge on how to incorporate a variety of sustainability-related goals into vertical agriculture businesses. This need is exemplified by the following anonymous survey response:

"How can we scale up vertical farming to reduce costs and improve agriculture production and sustainability? Particularly how can we grow locally to reduce shipping costs and growing in food deserts?"

Image credit: Lufa Farms, 2012

5. CONCLUSION AND RECOMMENDATIONS

From our analysis, we outline the following seven key recommendations to inform the development of vertical agriculture training materials:

1) **Educational materials should balance technical knowledge with broader information on the opportunities and considerations of vertical agriculture to appeal to a wider audience.** Workshop participants showed diverse levels of interest and experience in vertical growing technologies, including aspiring commercial growers, grower advisors, community food organisations interested in funding vertical growing projects, as well as general enthusiasts.

2) **Training materials should adopt a holistic systems lens to provide a nuanced understanding of vertical agriculture's role within diverse agricultural systems and its potential tradeoffs and co-benefits, including environmental and social considerations.** Participants highlighted the importance of situating vertical agriculture within broader food production and sustainability contexts, cautioning against viewing it as a singular technological solution. Additionally, planning and policy considerations should be included in vertical agriculture training materials to highlight how approaches to planning and policy can influence whether sustainability benefits are produced through vertical farming (and to what extent), as well as the challenges and barriers to growing the industry. This holistic lens will enable learners to develop a comprehensive perspective and address sustainability challenges more effectively.

3) **Future knowledge content topics to include in training materials include possibilities for diverse crop options, as well as nutritional information regarding soil-based vs soilless growing methods.** Possibilities (and challenges) around producing crops other than leafy vegetables and microgreens could include other common commercial varieties (e.g., strawberries, tomatoes), culturally significant plants, and genetically-selected or modified cultivars.

4) **Training materials should present the practical, day-to-day skills required for managing a vertical farm.** These might include data management skills to understand, process, and make adjustments based on various types of collected data such as nutrient levels and environmental conditions. Additionally, the workshop discussions revealed a need to address labour implications and practical skills required for vertical agriculture, particularly as we have not achieved full automation yet and still require hands-on work in this farming method.

5) **Training materials should comprehensively cover the horticultural and business aspects of vertical agriculture to equip learners with knowledge about the complexities of setting up and sustaining successful farms.** Workshop discussions underscored the many challenges facing the economic viability of standalone (i.e., not associated with a grocery store or other food business) vertical agriculture businesses, which impacts the industry as a whole.Participants highlighted the need to address agronomic knowledge gaps among tech-oriented individuals who enter the field, as well as learning about how to navigate the competitive market landscape against established producers (including international competition).

6) **There is a need to consider the place-based nuances of different potential locations for vertical farms in training materials.** Where vertical agriculture happens (i.e., in peri-urban regions, on industrial land, within the ALR, and/or in remote communities) influences the different opportunities and challenges for establishing vertical farms. Such considerations require careful reflection on topics such as available infrastructure, zoning restraints, and possible vulnerabilities.

7) **Training programs should include hands-on learning experiences and real industry exposure to vertical agriculture operations to enable tangible understanding of farming practices and problem-solving skills.** These hand-ons learning experiences can be included in education that takes a hybrid format, combining online demonstrations, social media engagement, and online learning materials design (e.g., interactive games), and in-person sessions. Such hybrid educational offerings cater to diverse learning needs and geographical constraints, promoting wider access to vertical agriculture knowledge and skills.

The next phase of the work will involve applying the lessons learned in this workshop series to develop online content for a vertical agriculture micro-credential. This will be paired with an interactive, online vertical agriculture and food systems' planning game being developed by the research team.

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