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PUBLIC PERCEPTIONS OF VERTICAL AGRICULTURE AND ITS POTENTIAL CONTRIBUTION TO FOOD SYSTEMS

Outcomes of a public survey in Vancouver, British Columbia

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AUTHORS

Dr. Alesandros Glaros
Researcher
Food and Agriculture Institute
University of the Fraser Valley

Dr. Stefania Pizzirani
Associate Director
Food and Agriculture Institute
University of the Fraser Valley

Dr. Robert Newell
Canada Research Chair in Climate Change, Biodiversity and Sustainability
School of Environment and Sustainability
Royal Roads University

COLLABORATING ORGANIZATIONS

Food and Agriculture Institute,
University of the Fraser Valley

Royal Roads University

QuantoTech Solutions Ltd.

i-Open Technologies Group

TABLE OF CONTENTS

Executive Summary

Vertical agriculture (VA) is an emerging food production approach, where crops are grown indoors in stacked production systems. It holds much potential to localize food systems, and generate the environmental, social, and economic benefits associated with decentralized production with short supply chains. This survey study examines consumer perceptions and willingness to pay for vertical agriculture products. This work is part of a larger research effort undertaken at the Food and Agriculture Institute at the University of the Fraser Valley to assess the benefits and challenges facing VA, as it is implemented in communities in British Columbia and beyond. More details on the research project can be found by clicking on this link.

This study explores relationships between attitudes toward VA and a variety of different factors, including demographic characteristics, food purchasing habits, participation in environmental initiatives as well as local food initiatives, sustainability values, and perceptions of vertical agriculture. This report presents the results of a survey of consumers in the metro-Vancouver area (n=476). Key findings include:

- Individuals from **higher income brackets** and those who **identify as male** have strong associations with willingness to pay more for VA. Further, interest in environmental sustainability-related issues and increased participation in environmental and local food initiatives have statistical relationships with willingness to pay more for VA.
- Key concerns regarding VA are to do with its **affordability**. To access the broadest consumer markets, VA products would have to compete with lower cost produce currently available on the market. Given recent prices for lettuce and California-grown produce (as of February 2023), the **cost and supply stability** of vertical agriculture may be one of its selling features.
- A second key set of concerns regarding VA are to do with its **perceived artificiality**. Further research into public outreach and education is necessary to explore **effective communication strategies** regarding the perceived safety issues of VA.
- Willingness to pay statistically varies between the communities examined in this study. Thus, VA might not be accepted and thus might not perform well within specific communities without **local market research** undertaken prior to its implementation. Further research is required to ascertain the specific demographic or cultural factors that might explain this spatial variation.

and business development strategies can be developed to take into consideration associations between willingness to pay more for VA products and income, local food purchasing habits, participation in various environmental and local food initiatives, environmental sustainability values, and perceptions of VA technologies. Further research is required that explores various education and outreach strategies regarding the safety and environmental concerns of VA. Exploring these tensions through open and transparent public discussion is a potentially fruitful approach to navigate more hesitant and skeptical attitudes toward VA.

1. Background

Agricultural practices, food processing, transportation, and retailing all contribute to global environmental challenges, such as climate change, land use change, biodiversity loss, and water depletion[1]. At the same time, these environmental challenges compound and exert impacts that undermine the resilience of food systems across scales, from farm to fork[2]. There is an urgent need to make our food systems more resilient, in face of these challenges, and to lessen the impact of food system processes on critical ecosystem services. Vertical agriculture (VA) is a food production method that holds promise for making progress toward these goals.

VA refers to a suite of production approaches, which typically use hydroponic, aeroponic, and/or aquaponic methods to grow food in controlled, indoor environments[3]. Hydroponic and aeroponic growing systems circulate water and nutrient solutions to plant roots through water pumps, reservoirs, channels, and/or (in the case of aeroponics) sprays; aquaponic systems are similar in structure and technologies, but differ in that they utilize fish waste as the source of plant nutrients. A key benefit of vertical growing is the minimization of land use for agriculture, while hydroponic, aeroponic, and aquaponic growing methods reduce water and nutrient input use[4]. Overall, theoretically, higher volumes of produce can be grown in a reduced land area and with fewer inputs. A key promise for VA is that it provides an opportunity to grow food anywhere, that is, outside of traditional agricultural areas, due to it being an indoor, controlled-environment farming method[5]. When established in urban and peri-urban areas, VA can provide local, fresh produce available all year long to population centres, while also providing opportunities for consumer engagement with farmers and agricultural education[6].

All agricultural technologies carry potential tradeoffs when implemented in practice[7]. With respect to VA, the factors that may lead potential consumers to accept or reject this food production approach have not been fully ascertained, and there are risks with implementing these technologies in terms of how it fits within social-cultural aspects of food systems, as well as the viability of VA businesses. Indeed, recent research has found that public perceptions of VA range substantially. These perceptions include optimism around the potential environmental impacts of VA, skepticism about the use of chemicals to produce food, and reluctance to repurpose urban land for food production.[8]

This research contributes to a developing understanding of consumer perceptions toward VA[9]. This report presents the results of a large consumer survey (n=476) conducted in the Metro Vancouver region of British Columbia, Canada. The survey asked how much potential consumers would be willing to pay for vertically farmed produce, and using descriptive and statistical analyses, the study elucidated the various factors that contribute to consumers' willingness to pay for VA.

2. Methods

2.1 Study Area and Survey Respondent Demographics

The Metro Vancouver Area region has a population of approximately 2.8 million people, as of 2021[10]. The average age of the population in 2016 is 41 years of age, with the majority (~57%) as married or living as common law. Most occupied dwellings in 2016 are single detached homes (~300,000 occupied private dwellings), followed by apartments that are fewer than five stories (~250,000 occupied private dwellings).

The survey was available to residents living in places throughout Metro Vancouver. Responses were received from residents of the municipalities of Richmond, Burnaby, and New Westminster, but no responses from municipalities more peripheral to the city of Vancouver itself (e.g., Surrey, Langley, Delta, Port Coquitlam). The majority of respondents lived in the Vancouver downtown area (~57%) and Richmond (~16%).

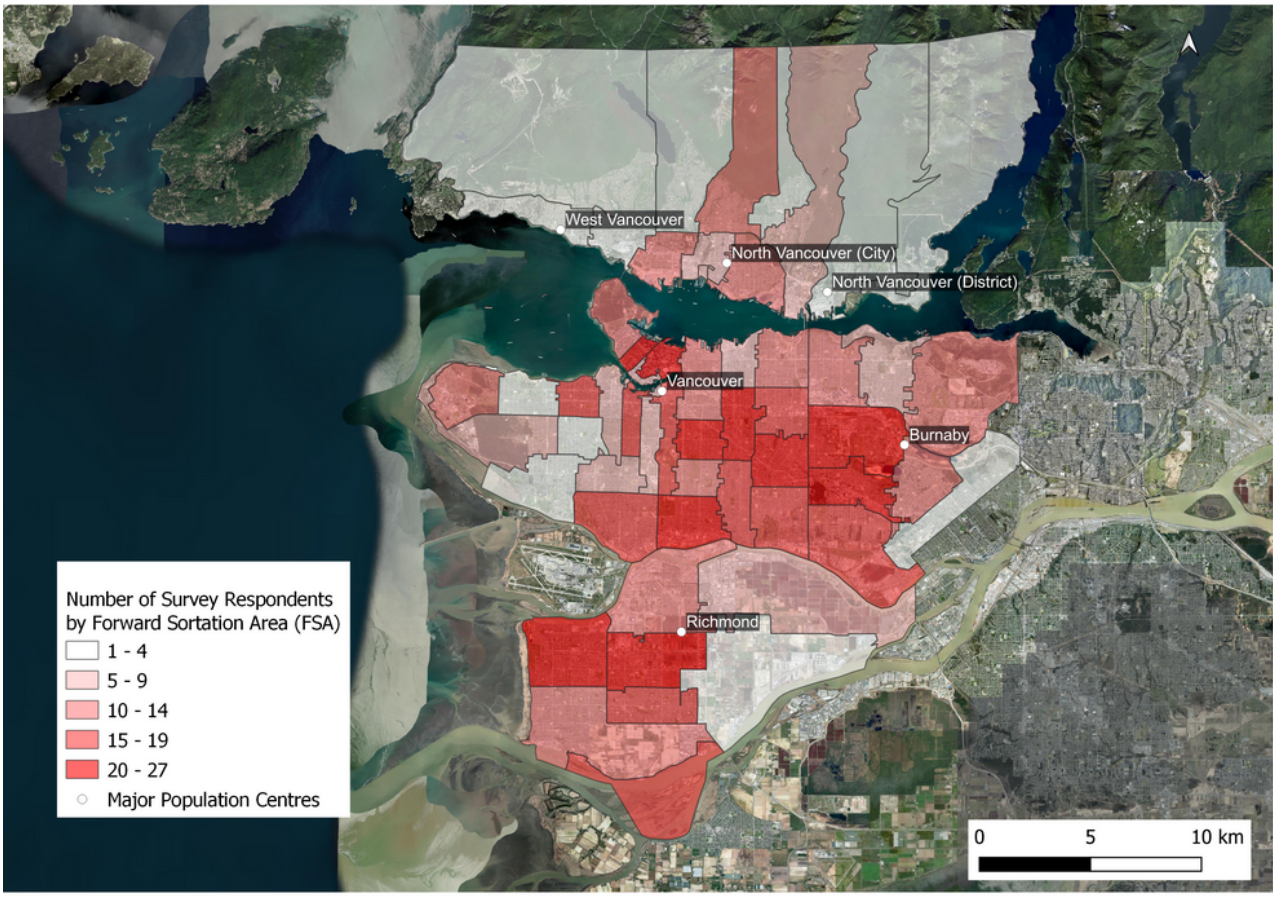


Figure 1. ***Heat Map of Survey Responses by Forward Sortation Area***

2.2 Recruitment

The survey was delivered with the assistance of a Vancouver-based market research company, Kai Analytics. Participants were excluded if their postal code was outside the boundaries of our study area (i.e., Metro Vancouver) or if they were younger than 18 years of age. The data were cleaned by excluding incomplete survey responses, surveys that were finished too quickly (~2 minutes) to allow for sufficient time to read/review questions, and/or responses that did not reflect likely attitudes and options such as when participants selected the first option for every question. A total of N=1322 survey responses were initially collected; N=644 were disqualified automatically due to participants being located outside of the study area and/or submitted incomplete responses. A further N=204 responses were excluded through the data cleaning procedures detailed above (short response time, or responses that did not reflect likely attitudes and opinions).

2.3 Survey Design

The survey was designed to examine how much consumers were willing to pay for vertically farmed produce and what factors are associated with their willingness to pay. The survey instrument was developed in partnership with industry collaborators at QuantoTech and iOpen Technologies, and it was tested by Food and Agriculture Institute researchers, colleagues, and affiliates with respect to comprehensibility, grammar, organization, and flow. When finalized, the survey instrument was sent to Kai Analytics for dissemination. Survey questions that used rating scales were all structured as 7-point scale responses for consistency in data collection and analyses (see tables below for survey questions).

The first half of the survey asked respondents questions about their demographics, food purchasing behaviours, and participation in food and environmental initiatives. The second half of the survey focused on values and perceptions regarding food system sustainability and vertical agriculture. Participants were asked to rate the importance of a series of 18 actions with respect to making food systems more sustainable. Following this, participants were given a short description and picture of a VA system, and were asked questions on what they like the most about VA (and its potential), what they like the least, and what concerns they might have regarding indoor growing technologies. Participants were then asked how much they would be willing to pay for VA products, with the questions being framed as comparisons between vertically-farmed and conventionally-farmed products. Participants first were asked if they would be willing to pay the same, more, or less for vertically-farmed lettuce (as this is the most common VA crop) using a 7-point scale (Table 3), and then using a simpler 'less, same, or more' scale, they were asked about several other potential VA crops: bok choy, alliums, berries, and other leafy greens.

Table 1. ***Survey themes***

Theme	Variables
General Demographic Traits	Age, income, ethnicity, gender, dwelling type, family size
Food Purchasing Habits	Where consumers shop the most, what product qualities they value (e.g., cost, organic certification, cleanliness, etc.)
Participation	How frequently surveys respondents participate in local food initiatives and environmental initiatives
Food System Sustainability Priorities (18 action statements)	Environmental dimensions (e.g., reducing greenhouse gas emissions in agriculture), economic dimensions (supporting local farmers), social dimensions (e.g., increasing availability of culturally diverse food options)
VA Benefits and Concerns	Cost, environmental impact, social implications, urban planning considerations
VA Technology Concerns	Perceived healthfulness, naturalness, concerns regarding technology
Willingness to Pay for VA Products	Willingness to pay for lettuce, bok choy, alliums, other leafy greens, and berries

2.4 Analysis

We wanted to explore, using descriptive, geospatial, and statistical techniques, the characteristics of consumers who are willing to pay more for VA.The analysis involves three components:

Table 2. ***Analysis Procedures***

Type of Analysis	Description
Demographic and Purchasing Habits Analysis	Describing general characteristics of survey respondents and assessing their relationships with willingness to pay, using two sample t-tests and chi-squared tests to search for statistically significant relationships between willingness to pay and various demographic characteristics as well as shopping habits.
Sustainability and VA Values Analysis	Analyzing relationships between sustainability values, perceptions of VA and willingness to pay, using factor analysis techniques and two sample t-tests to search for statistical associations between food system development priorities, attitudes toward VA, and willingness to pay.
Geospatial Analysis	Mapping spatial patterns of VA willingness to pay, using hotspot analysis in QGIS to search for spatially significant clusters of individuals who were willing to pay for VA.

Willingness to pay data were transformed into an ordinal seven point scale from which we could collect average median values, as well as into a categorical variable from which we could run chi-squared tests. The research examined associations between willingness to pay as an independent variable and various other dimensions (demographics, habits, sustainability values, perceptions of VA), and the aim was not to develop predictive models of willingness to pay. Thus, for all results presented in this report, willingness to pay data was treated as independent and/or categorical variables.

Table 3. ***Willingness to pay data transformations***

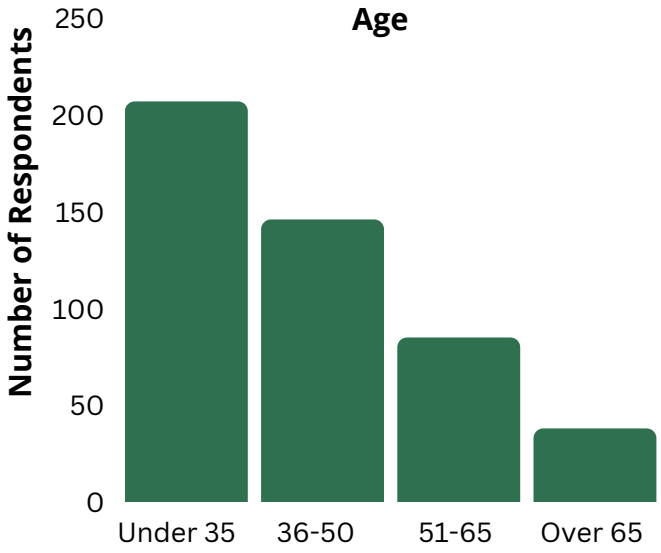
Options Provided in Survey	7-Point Scale Transformation	Categorical Transformation
I would be willing to pay double the price for vertically-farmed vegetables ($6.00 per head)	7	Willing to Pay More
Around 50% more ($4.50 per head)	6	Willing to Pay More
Around 25% more ($3.75 per head)	5	Willing to Pay More
Around 10% more ($3.30 per head)	4	Willing to Pay More
I would only purchase if it cost the same as conventionally farmed lettuce	3	Willing to Pay the Same
I would only purchase if it cost less than conventionally farmed lettuce	2	Not Willing to Pay More
I wouldn't be willing to purchase vertically-farmed produce	1	Not Willing to Pay More

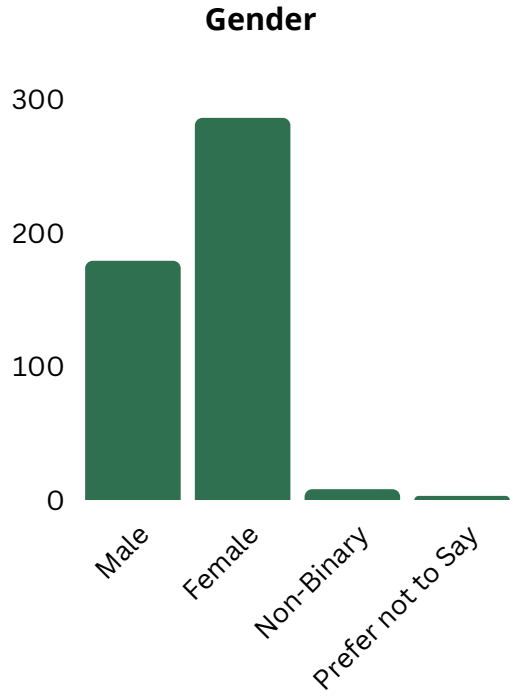
3. Insights

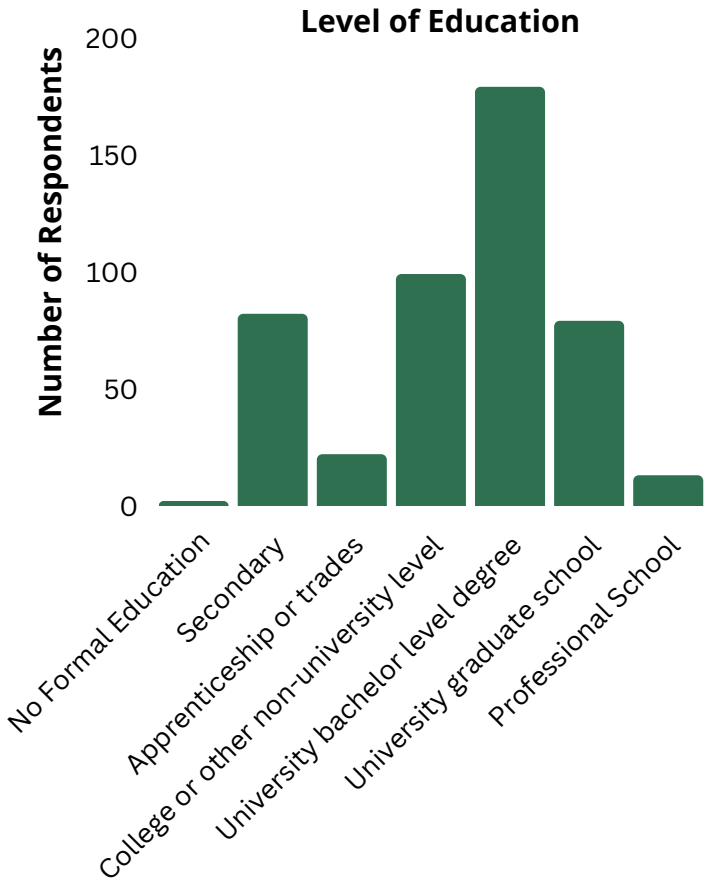
3.1 Demographics, Purchasing Habits, and Willingness to Pay

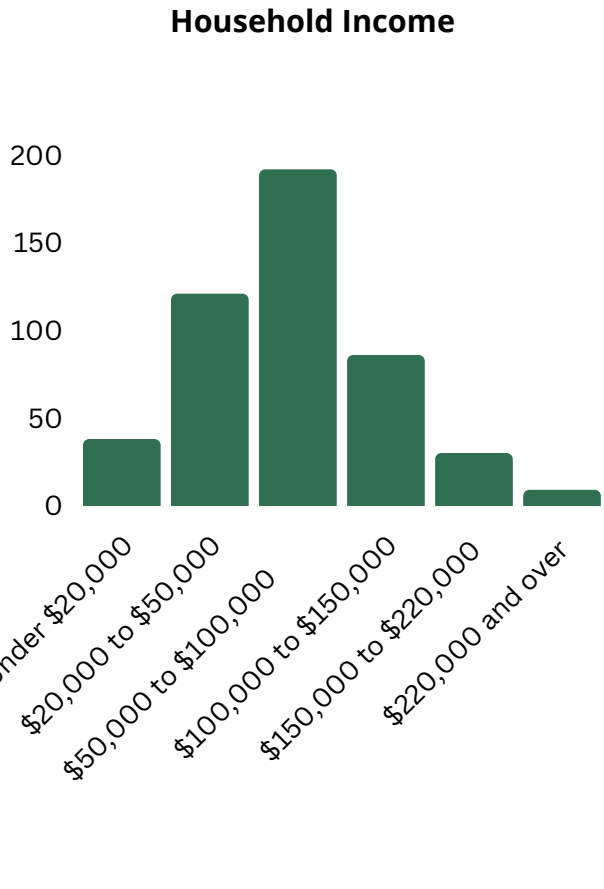
The majority of survey respondents identified as female (~59%), earning between $50,000 to $100,000 per year. The vast majority of participants had completed some form of post-secondary education (primarily Undergraduate-level) (~80%). The most common age group of survey respondents was under the age of 35 (~30%). The three most common places from which survey respondents sourced their produce were from supermarkets/superstores, locally owned grocery stores, and farmers markets (in that respective order). The two most commonly considered factors that participants identified when they considered purchasing produce were 'cost' and 'freshness', while the least selected factor was if the produce was grown using environmentally-friendly production practices. The vast majority of participants (~71%) indicated that they

purchase local food regularly (a few times per week) or more, and did most of the household shopping themselves (~70%).









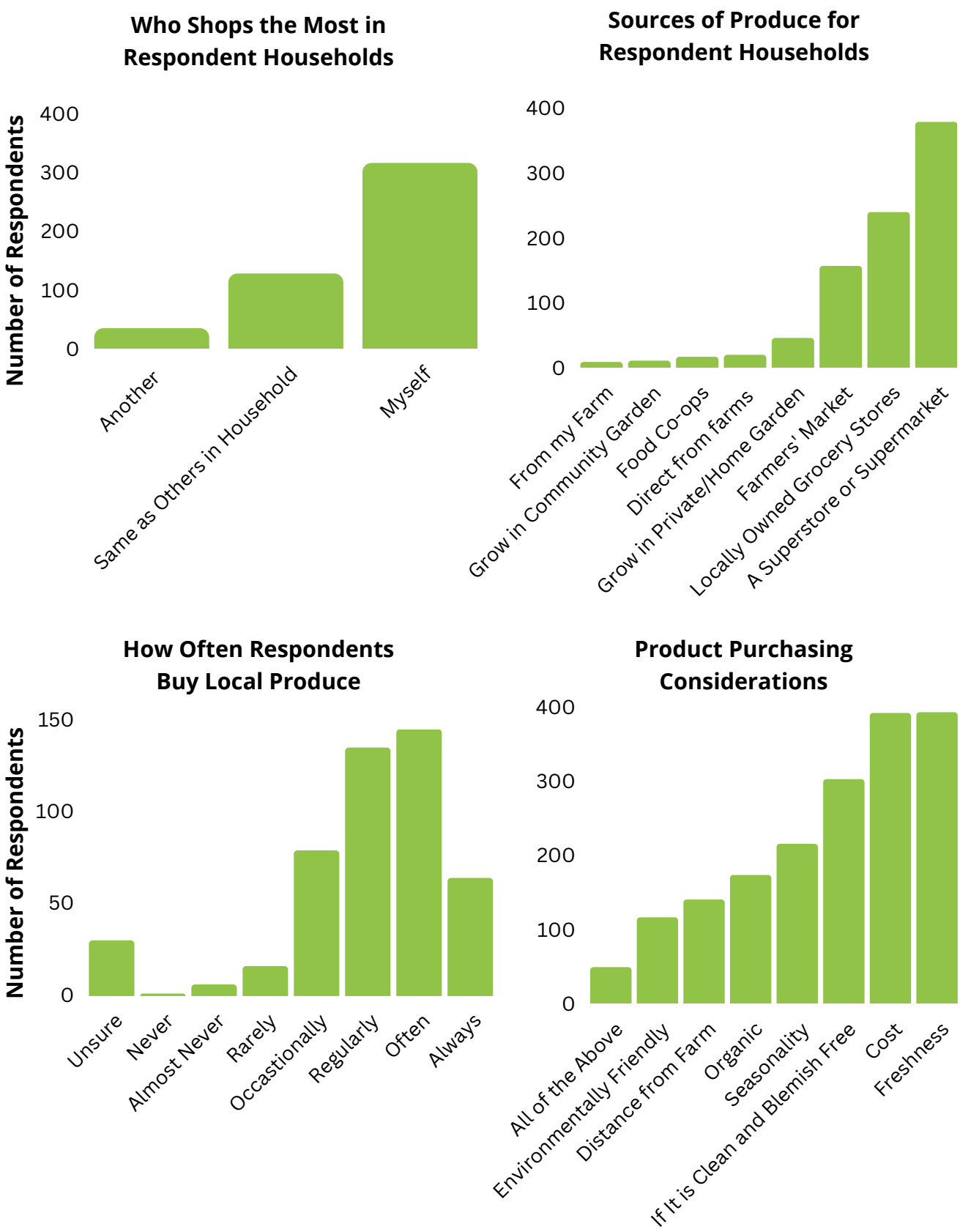


Figure 2. ***Respondent demographics and purchasing habits***

Across all demographic categories (income, age, level of education, ethnicity, and gender) gender (df=465, X2 = 5.161, p<0.05) and income (df= 476, X2 = 5.6281, p<0.05) were the only variables where total frequencies of willing to pay more, the same, and less were statistically different between groups. For gender analyses, answers that were

"non-binary/gender diverse" and "prefer not say" were omitted due to low response rates (<15). Those who identified as male were more frequently willing to pay more for VA, as compared to those who identified as female (Appendix 1). Further, those who identified as female were more frequently willing to pay less for VA, as compared to those who identified as male. For income analyses, there was no significant relationship between all income brackets and willingness to pay. However, when selecting the most common lower income bracket ($20,000 to $50,000) and the most common upper income bracket ($100,000 to $150,000), statistical evidence indicated that respondents willing to pay more for VA were more frequently from upper income brackets, and respondents only willing to pay less for VA were more frequently from lower income brackets.

All food purchasing behaviour variables (i.e., frequency respondents buy lettuce, frequency respondents buy their groceries online, and frequency respondents buy local produce) significantly correlated with willingness to pay ($p<0.01$). However, all Pearson's correlations were weak ($r<0.20$), with the strongest being between willingness to pay and the frequency that participants buy lettuce ($r=0.20$, $p<0.01$). Thus, we do not report these results here. A series of ANOVA and post-hoc-tests were conducted to analyze the relationship between willingness to pay more, the same, and not willing to pay more as independent variable categories, and food purchasing behaviours. We found only one significant relationship ($p<0.1$), between willingness to pay more and not willing to pay more that is associated with higher reported frequencies of purchasing local produce. In this case, those who indicated they were willing to pay more for VA report that they purchase local produce more frequently *(Med=6)* than those not willing to pay more *(Med=5)*. All comparisons between willingness to pay more and only willing to pay the same were statistically significant ($p<0.01$) for each food purchasing behavioural variable.

Figure 3. ***Demographic as well as purchasing habit variables and willingness to pay. The "+" sign denotes a significantly higher average (i.e. the average is higher for the variable for those willing to pay more than those not willing to pay more).***

3.2 Values and Willingness to Pay

3.2.1 Food System Development Priorities

Factor analysis is a statistical technique that reveals patterns and groupings among responses, and applying it here reveals two clusters (i.e. factors) of food system development actions, from the eighteen original priority statements. Thirteen of the priority statements clustered into two groups, referred to here as socio-economic (n=8) and environmental factors (n=5) (Figure 4). The socio-economic factor includes actions and priorities around support for farmer livelihood and local food system development. It also included social priorities such as increasing access to culturally important foods, building relationships between producers and consumers, and supporting community food development efforts. The environmental factor included priority statements that emphasized input and resource use reductions in agriculture (particularly water, greenhouse gas emissions, and food packing).

There were no significant associations between willingness to pay and each of the total factor groups (calculated as the sum of all factor statement values). However, willingness to pay was associated with higher average values for four of the eighteen individual food system development priority statements. The strongest relationships ($p<0.01$) were between willingness to pay and two environment-related statements: reducing greenhouse gas emissions due to agriculture ($df=2$, $F=3.362$, $p<0.05$), and reducing agriculture land use ($df=2$, $F=11.46$, $p<0.001$). Survey respondents who were willing to pay more for VA had significantly higher average values for both of these statements (*Med=6* and *Med=5*, respectively) than participants who were not willing to pay more for VA (*Med=5* and *Med=3*, respectively). Willingness to pay for VA was also statistically associated with the following socio-economic priority statements: increasing the affordability of healthy foods ($df=2$, $F=2.72$, $p<0.1$) and enhancing public procurement of local food ($df=2$, $F=5.048$, $p<0.1$). The average median value for healthy food affordability was the same for survey respondents who were willing to pay more for VA (*Med=7*) than those who were not willing to pay more (*Med=7*), so we do not include this as a key finding. However, the average median value for public procurement of local food was significantly higher for those willing to pay more for VA (*Med=6*) than those not willing to pay more (*Med=5*).

While we focused much of our reporting and analysis toward comparisons between willingness to pay more versus only willing to pay less, it is worth noting the statistically relevant results between willingness to pay more and willingness to pay the same. There was moderate statistical evidence ($p < 0.05$) that those willing to pay more for VA ranked the following statements: “increase funding for community food programs”, “increasing the available number of culturally diverse food and produce options”, and “financially supporting farmers” higher (*Med=6*) than those willing to pay the same (*Med=5*) for VA.

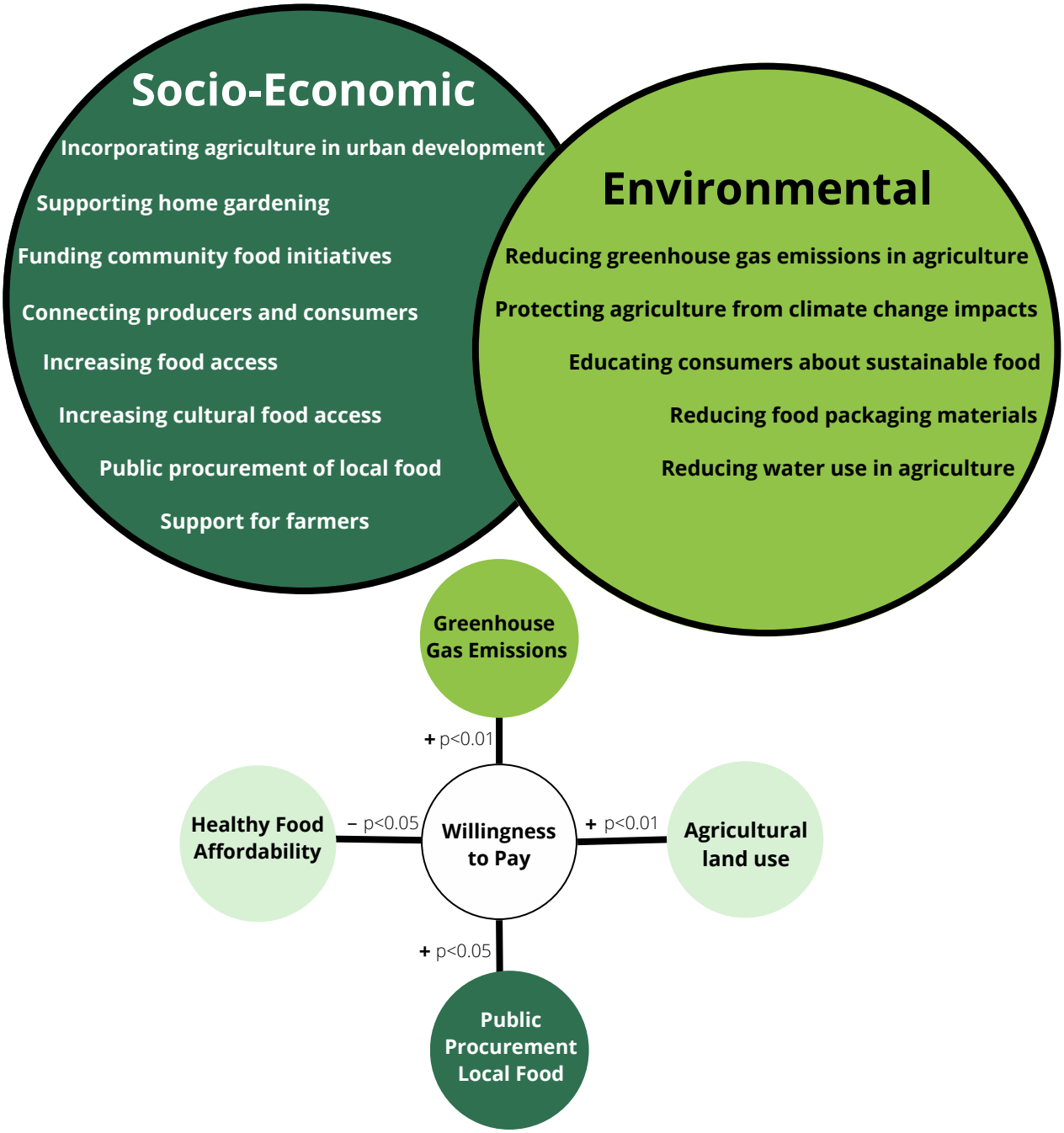


Figure 4. ***Food system development priority factors and willingness to pay. The "+" sign denotes a significantly higher average (i.e. the average is higher for the variable for those willing to pay more than those not willing to pay more). The statement in light green is not reflected within either factor group.***

To examine whether sustainability behaviours were related to willingness to pay for VA, ANOVA and post-hoc tests were conducted on willingness to pay data and reported participation in environmental initiatives (e.g., garbage pickups) and local food initiatives e.g., community gardening). Strong statistical evidence indicated higher average participation in environmental initiatives in those willing to pay more (Med=3) than those not willing to pay more (Med=1.5) for VA ($df=2$, $F= 19.12$, $p<0.001$). Moderate statistical evidence supports a claim that higher average participation in local food initiatives is associated with those willing to pay more (Med=2) than those not willing to pay more (Med=1) for VA ($df=2$, $F=9.705$, $p<0.1$). The same patterns were present when

comparing willingness to pay more to willingness to pay the same, for both sustainability behaviours. Strong statistical evidence ($p<0.001$) indicated that those willing to pay more for VA reported higher average participation in environmental initiatives and local food initiatives (*Med=3* and *Med=2*, respectively) than those willing to pay the same (*Med=2* and *Med=1*, respectively).

3.2.2 Vertical Agriculture Preferences

Data collection and analysis include examining whether consumer preferences and attitudes vary for VA crops other than lettuce. A series of chi-square tests were conducted to assess if and how willingness to pay for VA lettuce is associated with willingness to pay for VA alliums, other leafy greens, bok choy, and berries. All tests returned highly significant results ($p<0.01$), indicating that frequencies of willingness to pay for lettuce are highly correlated with willingness to pay for diverse VA crops. From these results, preference for vertical agriculture appears not to be crop-dependent.

The analysis included explorations of what potential VA benefits are of most interest to consumers, as well as what challenges are perceived to be the largest hurdles to overcome for the industry. Survey respondents were provided with a list of the most commonly considered benefits and challenges facing VA as a sustainable approach to food production, and asked to select which they thought to be the most beneficial or presented the largest barriers, respectively. Respondents most often selected food supply (consistent year-round crop production, increasing locally available food) and environment-related benefits. Respondents most often selected the cost of VA (to start a farm and its produce) as well as its high energy requirements as the key challenges facing the industry.

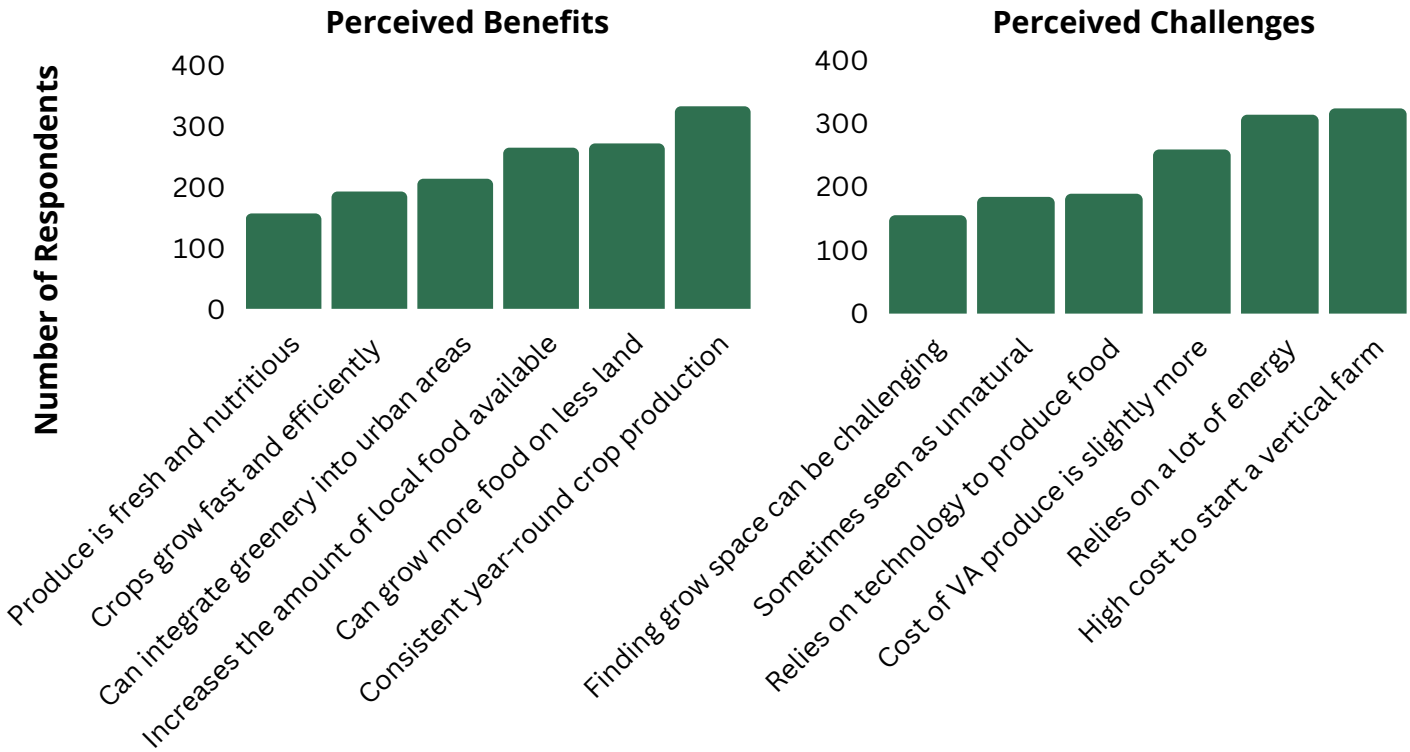


Figure 5. ***Most frequently selected benefits and challenges facing vertical agriculture***

Survey respondents who were not willing to pay more for VA identified cost as their major concern regarding this food production approach (N=88, ~80% of written comments). These individuals identified rising inflation as a key factor that would deter them from spending more on VA:

- "In order to save money, or to make ends meet, I will not pay more for the same product."
- "Food is expensive enough as it is."
- "Food prices have already risen so much, the idea of paying more is worrisome."

Some comments were more critical of the price of VA and its potential as a food security strategy:

- "Because if [vertical farming] costs more, then it is doing nothing to alleviate food insecurity and the provision of healthy foods to everyone. It would just be another luxury product that many people would be priced out of, and I do not think that healthy food should be a luxury."

The second most common concern (N=8, ~7% of written comments) regarded the perceived artificiality of VA. Respondents described concerns over the use of indoor production technology to produce food:

- "[I wouldn't pay more] because I feel vertical farming is kind of artificial."
- "Food needs sun and rain to receive the proper energy source for growing. This is not natural and not optimal for the body."
- "I don't find this a nutritional way to grow lettuce."

Respondents who would pay more for VA indicated they would do so for three main reasons. Approximately one third (~37% of written comments) expressed satisfaction and belief that VA produce was higher quality and healthier than conventionally grown produce. They highlighted taste, freshness, and product quality as reasons for purchasing VA products:

- "I will pay more because I think that the products will taste better this way."
- "More nutritious, less spoilage and waste if fresher when we get [vertically grown produce]."

In addition, almost a sixth of respondents (~16% of written comments) appreciated the environmental implications of VA. This was both in terms of reduced resource consumption (particularly space), as well as potential benefits for maintaining supply chains and safeguarding production from climate change impacts:

- "If [vertical grown methods] don't ruin the soil and save space, it's a win for me."
- "I just love the idea they are growing UP and not OUT."
- "With changing weather patterns, it is important that we have alternative solutions."

Finally, approximately 30% of respondents highlighted their desire to support local business and local food systems as a key driving force behind their willingness to pay more for VA:

- "Closer to home, supporting local community"

3.2.3 Vertical Agriculture Attitudes and Values

A factor analysis of VA-specific perception statements revealed two factors in the data, respectively referred to here as 'positive' and 'negative' (Figure 6). The positive factor includes two statements that represent welcoming attitudes toward VA, that VA is as natural as conventional production and that the respondent welcomes the use of technology to produce food indoors. The negative factor includes four statements that represent hesitant and skeptical attitudes toward VA, that it is less healthy and strange, it makes us too reliant on technology to produce food, and that the respondents values is less, overall, than traditional food production.

Five of the six statements were statistically different between those willing to pay more for VA and those only willing to pay less. There was no significant relationship observed between responses to the statements that VA is a strange practice and respondents' willingness to pay for VA products. The responses to the statement 'VA is as natural as conventional production' was found to be higher for those willing to pay more for VA (*Med=4*) than those not willing to pay more for VA (*Med=3*), ($df=2$, $F=14.21$, $p<0.001$). Further, responses to the statement "I welcome the use of technology to produce food indoors" was higher for those willing to pay more (Med=5) than those who were not willing to pay more for VA (*Med=4*), ($df=2$, $F=9.077$, $p<0.001$).

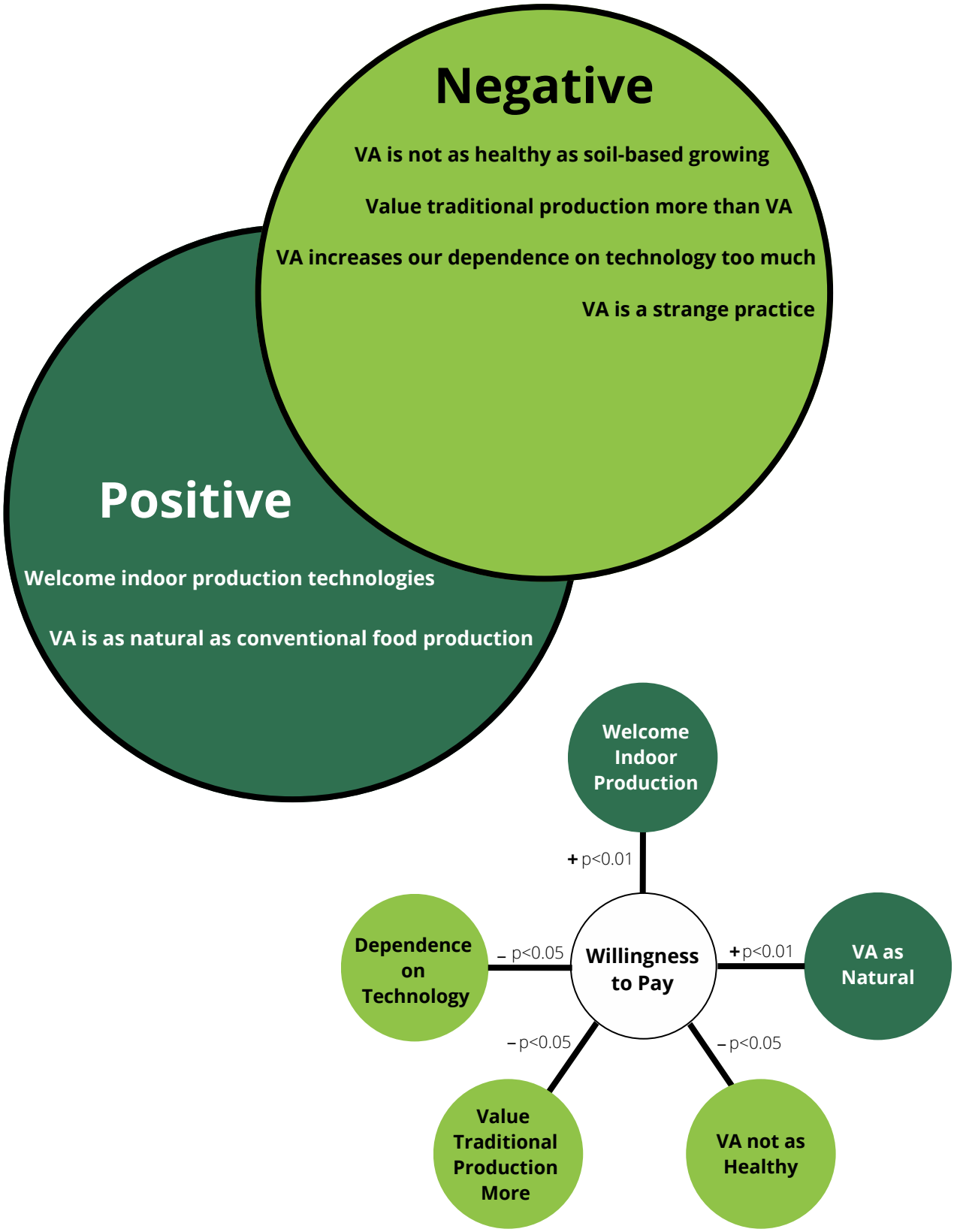


Figure 6. ***VA value factors and willingness to pay. The "+" sign denotes a significantly higher average (i.e. the average is higher for the variable for those willing to pay more than those not willing to pay more). The "-" sign denotes a significantly lower average (i.e. the average is lower for the variable for those willing to pay more than those not willing to pay more).***

3.3 Geospatial and Habitation Patterns

'Hot spot analysis' in ArcGIS is a tool for identifying statistically significant clusters of similar values, and in this study, this analysis was applied to willing to pay for VA products data (Figure 7). The analysis was done using a 1km grid as the geographic boundary within which responses and associated willingness to pay values were counted. There are clear hotspots (>99% confidence) of willingness to pay for VA within North Vancouver, Vancouver downtown, and Richmond. There are also clear 'cold spots' (i.e. statistically significant clusters of survey respondents would not pay more for VA) located in West Vancouver as well as the south eastern edge of Vancouver moving toward New Westminster. It is worth noting that no significant relationships between frequency of dwelling type, the number of years respondents had lived in their neighbourhood, or population density and willingness to pay categories ($p>0.1$) were found.

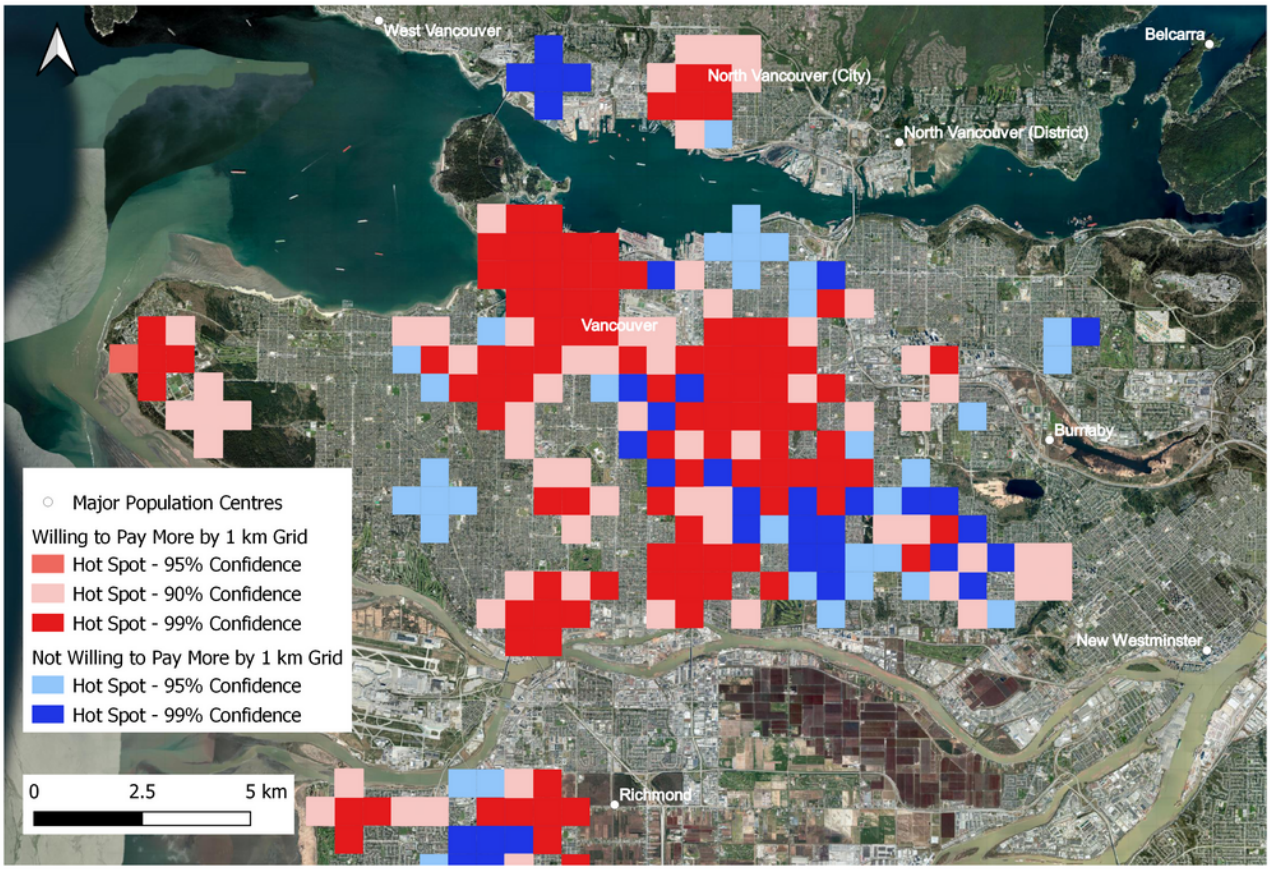


Figure 7. ***Hotspot analysis of willingness to pay data.***

4. Discussion

This report explores questions around who is most willing to pay for VA products and what the characteristics are of individuals who are more or less willing to pay for VA. The study examines associations between willingness to pay for VA and various demographic variables, shopping habits, food system sustainability values and practices, as well as perceptions regarding VA. With a greater understanding of these considerations, we can determine where and in what forms VA can be implemented to achieve the most desirable socially, environmentally, and economically sustainable outcomes.

In terms of demographics, individuals who identify as male are statistically more likely, on average, to be willing to pay for VA. This echoes other studies that have found that individuals who identify as male are more receptive or open to eating novel foods such as cell-based meats[11]. In addition, the findings of this study align with a common contention that VA is perceived as too expensive to be a food security solution, given its real estate costs, energy costs, infrastructure requirements, etc.[12], and it is more of a niche approach to vegetable production. The study findings include statistical evidence indicating individuals who were willing to pay more for VA are from upper income brackets ($100,000 to $150,000). Further, the majority of comments in the survey (~80%) stressed that they could not afford to pay a price premium on a food product, especially in the context of the rising inflation occurring in Canada at the time of the study.

Regarding shopping habits, moderate statistical evidence indicates individuals who are willing to pay more for VA also reported that they purchase local food more regularly, on average. The survey comments from those who indicated they would pay more for VA confirmed these findings, where contributing to local food economies was a key priority for these individuals. This confirms the findings from other studies of vertical agriculture and consumer acceptance, where local food production is a key factor consumers consider when buying their food [13]. However, this median value for purchasing local food, though higher in those willing to pay more for VA, was still skewed below the midpoint of the scale (3.5). Thus, it is not certain if purchasing local food is indeed a key factor associated with willingness to pay for VA. Willingness to pay is also statistically related to volunteerism and reported participation in environmental and local food initiatives; however, further research is required to assess if actual (i.e. not reported) participation in environmental and local food initiatives is related to willingness to pay for VA products. The research findings echo that of other studies that explore WTP for and consumer perceptions of vertical agriculture, urban agriculture, and an array of 'alternative' food systems[14]. Survey respondents who were willing to pay more for VA had higher average sustainability values related to the environment (GHG emissions reductions in agriculture and land use reductions, specifically) and society (increasing public procurement of local food, supporting farmers).

The study directly examines concerns consumers may have for VA growing technologies, such as their perceived artificiality. Indeed, willingness to pay had a moderate or strong relationship with five of six average vertical agriculture attitude values we examined in our survey. Further, these associations confirmed our factor analysis results, where willingness to pay more was associated with higher average positive factor statements and where not willing to pay more was associated with higher average negative factor statements. Thus, willingness to pay for VA has strong associations with attitudes toward VA technologies themselves. Educating the public regarding the safety of these tools and food growing technologies and making them more accessible will be crucial to access broader markets. Exploring education and communication strategies to dissect key tensions regarding the perceived artificiality and unnaturalness of VA is one potential avenue for further inquiry.

The spatial analysis reveals where WTP is clustered among residents. Several specific communities appear to have distinct attitudes toward VA. Such relationships do not appear to be dependent on dwelling type, the number of years individuals have lived in their community, population density in the area, or the size of household. This hotspot analysis was exploratory in nature. Further analysis would reveal nuances in spatial relationships, such as integrating census data including income and gender into spatial willingness to pay analyses. This spatial analysis could be paired with in-depth qualitative research to assist in determining the factors that lead to acceptance or rejection of VA within unique communities.

5. Key Conclusions and Recommendations

Vertical agriculture is a promising solution to food system sustainability challenges. This study advances several key considerations for the potential implications of this technology for consumers. Crucially, as the VA industry grows, the following considerations are important for targeting potential consumer markets and assuaging likely consumer concerns:

1. Our findings indicate that individuals from **higher income brackets** and those who **identify as male** have strong associations with willingness to pay more for VA. Further, **interest in environmental sustainability**-related issues and **increased participation in environmental and local food initiatives** have statistical relationships with willingness to pay more for VA.

2. Key concerns regarding VA are to do with its **affordability**. To access the broadest consumer markets, VA products would have to compete with lower cost produce currently available on the market. Given recent prices for lettuce and California-grown produce (as of February 2023), the **cost and supply stability** of vertical agriculture may be one of its selling features.

3. A second key set of concerns regarding VA are to do with its **perceived artificiality**. Further research into public outreach and education is necessary to explore effective communication strategies regarding the perceived safety issues of VA.

4. Willingness to pay statistically varies between the communities examined in this study. Thus, VA might not be accepted and thus might not perform well within specific communities without local market research undertaken prior to its implementation. Further research is required to ascertain the **specific demographic or cultural factors** that might explain this spatial variation.

Appendices

Appendix 1. Household Survey

Household Survey

UNIVERSITY OF THE FRASER VALLEY
FOOD AND AGRICULTURE INSTITUTE

The Potential Role of Vertical Agriculture in Building Sustainable and Resilient Community Food Systems

Thank you for participating in our survey! This survey is part of a research project led by the Food and Agriculture Institute at the University of the Fraser Valley.

Research Goal: We want to know what the potential contributions of vertical farms to sustainable and resilient local food systems in Metro-Vancouver and the Fraser Valley Regional District might be.

Results and Reporting: The study will examine different scenarios for building vertical farms at a neighbourhood and community scale. The information from this survey will be integrated into a map-based platform. On this platform, multiple scenarios can be mapped, which will help us investigate the implications of vertical farms. How might these farms relate to local food policy, food security, economic development, and climate change mitigation?

Approach: In this survey, you will be asked questions about your background, your knowledge about vertical farming, preferences and attitudes toward vertically-farmed vegetables, and willingness-to-pay for a local and vertically-farmed produce (lettuce). The survey will take between 10 to 15 minutes to complete.

Contact: For more information about our study please see us at www.tinyurl.com/FAI-vertag. To find out more about our research partners visit the following links:
i-open Group: https://www.i-opentech.com/
directfood.store: https://vancouver.directfood.store/
QuantoTech: https://www.quantotechltd.com/

Thank you again for your participation. We appreciate your input!

Household Survey

SECTION 1. CONSUMER PREFERENCES

1.0 Please indicate your postal code (please note this information will be used for research purposes to get a sense of the neighbourhood you live in, and NOT for any follow up mailing, marketing, or contact): _____

1.1 How often do you buy locally produced vegetables?

Always (every time I shop) ☐
Often (most times I shop) ☐
Regularly (about half the times I shop) ☐
Occasionally (about once every month) ☐
Rarely (about a few times a year) ☐
Almost Never (have purchased in the past a few times) ☐
Never ☐
I don't know if my vegetables are local or not ☐

1.2 Where do you get most of your vegetables? (choose all the options that apply)

Direct from farms (including Community Supported Agriculture) ☐
A Superstore (e.g., Costco) or Supermarket (e.g. Loblaws) ☐
Locally owned grocery stores ☐
Food- Co-ops ☐
Farmers' market ☐
Grow in community garden ☐
Grow in private/home garden ☐
From my farm ☐
Other (please explain): _____

1.3 How often do you buy your vegetables online (e.g., grocery delivery, online farmer's market/food hub, etc.)?

Always (every time I shop) ☐
Often (most times I shop) ☐
Regularly (about half the times I shop) ☐
Occasionally (about once every month) ☐
Rarely (about a few times a year) ☐
Almost Never (have purchased online in the past a few times) ☐
Never ☐

1.4 How often do you eat lettuce in your weekly food consumption?

Always (every time I shop) ☐
Often (most times I shop) ☐
Regularly (about half the times I shop) ☐
Occasionally (about once every month) ☐

Rarely (about a few times a year) ☐
Almost Never (have purchased online in the past a few times) ☐
Never ☐

1.5 When I buy vegetables, the most important factors to me are…(Select the factors that most apply)

How much it costs ☐
How far it was produced from where you live ☐
If it was organically produced ☐
How fresh it is (i.e. if it was picked recently) ☐
If it is currently in season ☐
If it was produced using environmentally friendly methods ☐
If it is clean and blemish free ☐
Other _____

SECTION 2. LOCAL FOOD SYSTEMS

2.1 Either personally or professionally, how often do you participate in local food initiatives (e.g., working on a farm, community gardening, Community Supported Agriculture etc.)

Daily (most days) ☐
Weekly (at least once a week) ☐
Semi-Regularly (a few times per month) ☐
Monthly (once per month) ☐
Sometimes (a few times per year) ☐
Yearly (once or twice per year) ☐
Never ☐

2.2 Either personally or professionally, how often do you participate in environmental initiatives (e.g., garbage clean ups, donating to environmental NGO's, etc.)?

Daily (most days) ☐
Weekly (at least once a week) ☐
Semi-Regularly (a few times per month) ☐
Monthly (once per month) ☐
Sometimes (a few times per year) ☐
Yearly (once or twice per year) ☐
Never ☐

2.3 Below are different ways and strategies for developing food systems. Please indicate which of the following are most important to you by rating on a scale of 1 ("of little to no importance") to 7 ("extremely important")

	Of no or little importance						Extremely Important
Making use of vacant spaces in/close to cities that could produce food	☐	☐	☐	☐	☐	☐	☐
Training more people to become farmers	☐	☐	☐	☐	☐	☐	☐
Increasing access to healthy foods	☐	☐	☐	☐	☐	☐	☐
Educating consumers about sustainable food systems	☐	☐	☐	☐	☐	☐	☐
Protecting food production against natural disasters such as flooding or wildfires	☐	☐	☐	☐	☐	☐	☐
Reducing the greenhouse gas emissions of agricultural production systems	☐	☐	☐	☐	☐	☐	☐

Household Survey

Reducing water use in agricultural production systems	☐	☐	☐	☐	☐	☐	☐
Building relationships between consumers and food growers	☐	☐	☐	☐	☐	☐	☐
Increasing access to culturally appropriate foods	☐	☐	☐	☐	☐	☐	☐
Reducing the amount of local land used for agriculture	☐	☐	☐	☐	☐	☐	☐
Providing resources (e.g., garden plot, seeds, water) for people to grow their own food	☐	☐	☐	☐	☐	☐	☐
Encouraging consumers to buy locally produced food	☐	☐	☐	☐	☐	☐	☐
Reducing food packaging materials	☐	☐	☐	☐	☐	☐	☐

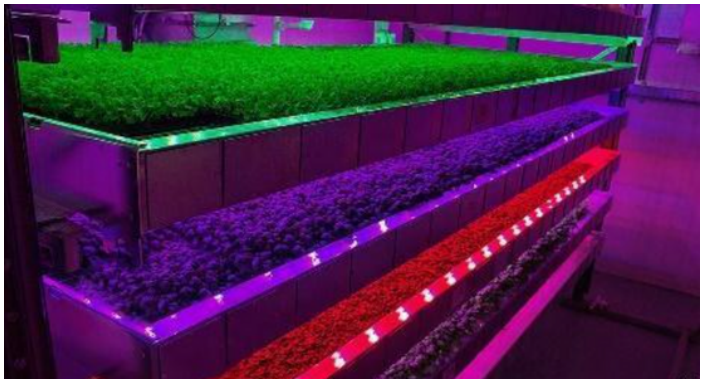
Having places like hospitals and schools buy local food instead of non-local food	☐	☐	☐	☐	☐	☐	☐
Treating food as a public good/utility (like electricity, or water)	☐	☐	☐	☐	☐	☐	☐
Incorporating farms into new or proposed commercial and residential developments	☐	☐	☐	☐	☐	☐	☐
Increasing the number of farms in or nearby cities	☐	☐	☐	☐	☐	☐	☐

SECTION 3. VERTICAL FARMING KNOWLEDGE AND PREFERENCES

3.1 Have you ever heard of 'vertical farming'?

Yes ☐
No ☐

Please refer to the following table to give you some basic ideas about vertical farms



Vertical Farm

Household Survey

Vertical farms use soilless growing systems where plants are grown indoors in growing trays that are stacked on top of each other. Vertical farms use nutrient-enriched water to deliver nutrients to the plants root system and LED light instead of rain or sunlight to support plant growth.

Benefits:

- Consistent year-round crop production
- Crops grow fast using variable growing conditions
- No risk of pest- or weather-related crop damage
- Small spaces can be optimized for large yield
- Can produce food in urban centres
- No use of pesticides
- Less use of water and other agricultural inputs

Challenges:

- High start-up cost
- High labour cost
- Produce cost a little expensive
- High dependence on technology
- Grows limited crop variety
- Sometimes perceived as 'unnatural' way to grow food
- Finding growing space is a challenge

4.1 Please indicate your responses about vertically farming vegetables.

	Strongly disagree						Strongly agree
Vertically-farmed vegetables are as natural as those farmed in agricultural fields	☐	☐	☐	☐	☐	☐	☐
Produce grown without soil is not as healthy as conventionally grown produce in soil	☐	☐	☐	☐	☐	☐	☐

Household Survey

I welcome and/or can easily adapt to the idea and practice of using technology to commercially produce food using indoor systems	☐	☐	☐	☐	☐	☐	☐
I value traditional food production (e.g., outside, in fields) more than in enclosed environments	☐	☐	☐	☐	☐	☐	☐
Food production in a fully-controlled environment is a strange practice	☐	☐	☐	☐	☐	☐	☐
I do not like that vertical farms will increase our dependence on technology to solve food systems problems	☐	☐	☐	☐	☐	☐	☐

4.2 If vertically-farmed vegetables (e.g., lettuce) became available in your local area, where would you prefer to source the products from? (choose the retailers that you would most prefer)

4.2 If vertically-farmed vegetables (e.g., lettuce) became available in your local area, where would you prefer to source the products from? (choose the retailers that you would most prefer)

Direct from the farm ☐
Superstores or Supermarkets ☐
Local grocery stores ☐
Food Co-ops ☐
Farmers' market ☐

4.3 To what extent would you be interested in touring a vertical farm?

Not Interested at all						Very Interested
☐	☐	☐	☐	☐	☐	☐

4.4 To what extent would you be interested in your local restaurants starting to serve vegetables (lettuce) produced in local vertical farms?

Not Interested at all						Very Interested
☐	☐	☐	☐	☐	☐	☐

4.5 Assume that the price of a conventionally-farmed or imported Green Leaf Lettuce costs about $2.50 per package in the local supermarket at present. What price or price range would you be willing to pay for vertically-farmed lettuce?

A. Around 10% more ($2.75 per head) ☐
B. Around 25% more ($3.15 per head) ☐
C. Around 50% more ($3.75 per head) ☐
D. I would be willing to pay double the price for vertically-farmed vegetables ($5.00 per head) ☐
E. I would only purchase if it cost less than conventionally farmed lettuce ☐
F. I wouldn't be willing to purchase vertically-farmed produce ☐

4.6 Aside from lettuce, please indicate which of the following you would purchase if made available by a local vertical farm, and identify whether you would pay more, the same, or less than conventionally-farmed products.

	Less	Same	More
Berries (strawberries, raspberries)	☐	☐	☐
Herbs (cilantro, basil)	☐	☐	☐

Alliums/onions (chives, shallots)	☐	☐	☐
Other leafy greens (kale, arugula)	☐	☐	☐
Bok choy	☐	☐	☐
Other (please explain)	☐	☐	☐

The below are follow-up questions to be answered only by those who will choose (choice E or F) from Q 4.5, or indicated 'less' in 4.6.

4.7.1 If you expressed that you will only pay the same price or less for any of the vertically-farmed products than conventionally-farmed products, please respond to the following questions:

	Strongly disagree						Strongly agree
Vertical farms cannot address food security issues related to access to nutritious and affordable local produce	☐	☐	☐	☐	☐	☐	☐
Available commercial and industrial spaces in my city are better used for purposes other than vertical farms	☐	☐	☐	☐	☐	☐	☐
Vertical farms will push residential and commercial real estate development away from my local area	☐	☐	☐	☐	☐	☐	☐

Household Survey

Vertical farm crops are mostly limited to leafy greens or herbs and are less interesting to me	☐	☐	☐	☐	☐	☐	☐
I don't think vertical farming is a healthy way to grow vegetables	☐	☐	☐	☐	☐	☐	☐
People should grow their own food, rather than relying on commercial production of food	☐	☐	☐	☐	☐	☐	☐
Vertical farming will be a competitive system and thus will threaten conventional/traditional vegetable producers	☐	☐	☐	☐	☐	☐	☐
I would only pay the same or more for produce from organic farms	☐	☐	☐	☐	☐	☐	☐
Other (please specify)							

Household Survey

The below are follow-up questions to be answered only by those who will choose any price range from A to D.

4.7.2 You expressed that you are willing to pay an additional price or price range for a vertically-farmed lettuce compared to the conventionally-farmed lettuce. Please respond to the following questions that match your reasons for choosing so.

	Strongly disagree						Strongly agree
I want to have access to locally produced vegetables with short distances between producer and consumer	☐	☐	☐	☐	☐	☐	☐
It is a healthier and safer food source option than conventional produce	☐	☐	☐	☐	☐	☐	☐
It is a source of fresh and local food I support seeing urban spaces used for agriculture	☐	☐	☐	☐	☐	☐	☐
Vertical farms provide more product sources for grocery stores and restaurants and thus support the local economy	☐	☐	☐	☐	☐	☐	☐

Year-round availability of vertically-farmed produce motivates me to buy the product	☐	☐	☐	☐	☐	☐	☐
Vertically-farmed vegetables are better for the environment	☐	☐	☐	☐	☐	☐	☐
Vertical farms will make my neighbourhood better by attracting more residential and commercial development	☐	☐	☐	☐	☐	☐	☐
Other (please specify)							

SECTION 4. SOCIO-DEMOGRAPHIC INFORMATION

5.3 Your gender is:

Male ☐
Female ☐
Non-binary person (gender diverse) ☐
Prefer not to say ☐

5.4 Please write your age

5.5 What is your combined household income before tax?

Under $20,000 ☐
$50,000 to $100,000 ☐
$100,000 to $150,000 ☐
$150,000 to $220,000 ☐
$220,000 and over ☐

5.6 Which of the following describes your ethnic origin?

North American Indigenous (First Nations, Inuit, Metis) ☐
African (e.g., Central and West African, North African, Southern and East African) ☐
Asian (e.g., West Central, South, East, and Southeast) ☐
Caribbean ☐
Middle Eastern, Arab, and North African ☐
European (e.g., British Isles, French, Western European) ☐
Latin, Central and South American ☐
Oceania (Australian, New Zealander, Pacific Islander) ☐
Other (mixed origin) ☐

5.7 What is your household type (family composition)?

Family with children ☐
Couple sharing accommodation ☐
Multigenerational (two or more families living together) ☐
One-person ☐
Shared accommodation (e.g., roommates) ☐
Other (please specify)

5.8 What is your household (family) size?

One ☐
Two ☐
Three ☐
Four ☐
Five and above ☐

5.9 Who does the most grocery shopping in your household?

Myself ☐
Another ☐
I shop the same amount as others in my household ☐

5.10 Your highest level of education completed is:

No formal education (less than high school diploma) ☐
Secondary (high school diploma or equivalent) ☐
Apprenticeship or trades ☐
College or other non-university level ☐
University bachelor level degree ☐
University graduate school ☐
Professional School ☐

Household Survey

5.11 Your current dwelling type is:

Single-detached house ☐
Apartment in a building (five or more storeys) ☐
Other attached dwelling (apartment fewer than five storeys, semi-detached house, townhouse, flat in a duplex) ☐
Mobile dwelling ☐
Other (please specify):

5.12 How long have you been living in the Lower Mainland (i.e., Metro Vancouver or the Fraser Valley)?

Less than a year ☐
1 to 4 years ☐
5 to 9 years ☐
Mobile dwelling ☐
Other (please specify):

Appendix 2. Statistical Output

3.1 Demographics, Purchasing Habits and Willingness to Pay

Chi-Squared Test of Independence for gender and income

	Willingness to Pay for VA		
Gender Identity	Less	Same	More
Male	11(18)	61(64)	107(97)
Female	36(29)	104(101)	146(155)

Note: X2 = 6.22, df = 2, p-value = 0.045 (Expected values in parentheses)

	Willingness to Pay for VA		
Income Bracket	Less	Same	More
$20,000 to $50,000	16(11)	42(45)	63(65)
$100,000 to $150,000	2(7)	35(32)	49(46)

Note: X2 = 7.57, df = 2, p-value = 0.023 (Expected values in parentheses)

ANOVA Test for Food Purchasing Habits

		Df	Sum of Squares	Mean Square	F Value	Pr(>F)
Frequency of Local Food Purchasing	Willingness to Pay Categories	2	36	17.99	8.05	p<0.001
	Residuals	473	1057	2.24		
Frequency Respondents Purchase Lettuce	Willingness to Pay Categories	2	42.0	21.02	14.96	p<0.001
	Residuals	473	664.7	1.41		
Frequency Respondents Purchase Their Food Online	Willingness to Pay Categories	2	23.3	11.64	3.60	0.028
	Residuals	473	1531.5	3.24		

Tukey's Post-Hoc Test for Food Purchasing Habits

	Willingness to Pay	Difference	p	95% Confidence Interval Bounds	
				Lower	Upper
Frequency of Local Food Purchasing	More-Less	0.52	0.067	-0.029	1.08
	Same-Less	-0.036	0.99	-0.61	0.54
	Same-More	-0.56	p<0.001	-0.91	-0.21
Frequency Respondents Purchase Lettuce	More-Less	0.32	0.21	-0.12	0.75
	Same-Less	-0.32	0.22	-0.78	0.13
	Same-More	-0.64	p<0.001	-0.91	-0.36
Frequency Respondents Purchase Their Food Online	More-Less	0.21	0.73	-0.45	0.88
	Same-Less	-0.26	0.64	-0.96	0.43
	Same-More	-0.48	0.021	-0.89	-0.059

3.2.1 Food System Development Priorities

ANOVA Test for Food System Development Priorities

		Df	Sum of Squares	Mean Square	F Value	Pr(>F)
Reducing agricultural greenhouse gas emissions	Willingness to Pay Categories	2	15.2	7.58	3.36	0.036
	Residuals	473	1065.7	2.25		
Reducing the amount of local land used for agricultural production	Willingness to Pay Categories	2	69	34.52	11.46	p<0.001
	Residuals	473	1424	3.01		
Having places like hospitals and schools buy local food instead of non-local food	Willingness to Pay Categories	2	20.6	10.30	5.048	0.0068
	Residuals	473	965.4	2.041		
Reducing water use in agricultural production systems	Willingness to Pay Categories	2	2.6	1.32	0.58	0.56
	Residuals	473	1082.9	2.29		
Treating food as a public good/utility (like electricity, or water)	Willingness to Pay Categories	2	1.7	0.86	0.334	0.716
	Residuals	473	1224.8	2.59		

Making healthy foods more affordable	Willingness to Pay Categories	2	11.3	5.65	2.72	0.067
	Residuals	473	982.4	2.077		
Educating consumers about sustainable food systems	Willingness to Pay Categories	2	3.4	1.72	0.77	0.47
	Residuals	473	1059.4	2.24		
Increasing the number of farms in or nearby cities	Willingness to Pay Categories	2	6.5	3.24	1.62	0.20
	Residuals	473	945.4	2.00		
Protecting food production against natural disasters such as flooding or wildfires	Willingness to Pay Categories	2	0.8	0.41	0.21	0.81
	Residuals	473	911.2	1.92		
Increase funding for community food programs (e.g., community food centers, food banks, community gardens)	Willingness to Pay Categories	2	14.6	7.32	3.56	0.029
	Residuals	473	971.1	2.053		
Reduce food packaging materials	Willingness to Pay Categories	2	1.4	0.69	0.34	0.71
	Residuals	473	972.8	2.057		
Building relationships between consumers and food growers	Willingness to Pay Categories	2	5.5	2.77	1.31	0.27
	Residuals	473	998.0	2.11		

Increasing the available number of culturally diverse food and produce options	Willingness to Pay Categories	2	10.9	5.46	2.70	0.068
	Residuals	473	955.7	2.021		
Providing resources (e.g., garden plot, seeds, water) for people to grow their own food	Willingness to Pay Categories	2	4.3	2.15	0.96	0.38
	Residuals	473	1061.1	2.24		
Incorporating food production into new or proposed commercial and residential developments	Willingness to Pay Categories	2	1.5	0.73	0.34	0.71
	Residuals	473	1018.4	2.153		
Increasing the number of places people can access (i.e. buy, grow, share) food within or nearby their neighbourhood	Willingness to Pay Categories	2	4.0	2.005	1.002	0.37
	Residuals	473	945.8	2.00		
Making use of vacant spaces in/close to cities that could produce food	Willingness to Pay Categories	2	2.1	1.05	0.50	0.61
	Residuals	473	992.1	2.097		
Financially supporting farmers	Willingness to Pay Categories	2	20.1	10.027	4.81	0.0085
	Residuals	473	985.2	2.083		

Tukey's Post-Hoc Test for Food System Development Priorities

	Willingness to Pay	Difference	p	95% Confidence Interval Bounds	
				Lower	Upper
Reducing agricultural greenhouse gas emissions	More-Less	0.61	0.027	0.055	1.16
	Same-Less	0.55	0.068	-0.030	1.12
	Same-More	-0.063	0.91	-0.41	0.29
Reducing the amount of local land used for agricultural production	More-Less	1.02	p<0.001	0.38	1.66
	Same-Less	0.37	0.40	-0.30	1.03
	Same-More	-0.66	p<0.001	-1.06	-0.25
Having places like hospitals and schools buy local food instead of non-local food	More-Less	0.50	0.068	-0.028	1.028
	Same-Less	0.11	0.88	-0.44	0.66
	Same-More	-0.39	0.017	-0.72	-0.056
Reducing water use in agricultural production systems	More-Less	0.22	0.62	-0.34	0.78
	Same-Less	0.11	0.90	-0.47	0.69
	Same-More	-0.11	0.24	-0.46	0.24

Treating food as a public good/utility (like electricity, or water)	More-Less	-0.19	0.73	-0.78	0.40
	Same-Less	-0.21	0.70	-0.83	0.41
	Same-More	-0.020	0.99	-0.39	0.35
Making healthy foods more affordable	More-Less	-0.53	0.053	-1.060	0.0050
	Same-Less	-0.43	0.17	-0.98	0.13
	Same-More	0.10	0.76	-0.23	0.44
Educating consumers about sustainable food systems	More-Less	-0.045	0.98	-0.60	0.51
	Same-Less	-0.21	0.66	-0.79	0.36
	Same-More	-0.17	0.49	-0.52	0.18
Increasing the number of farms in or nearby cities	More-Less	-0.36	0.24	-0.88	0.16
	Same-Less	-0.41	0.18	-0.95	0.13
	Same-More	-0.049	0.94	-0.38	0.28
Protecting food production against natural disasters such as flooding or wildfires	More-Less	-0.099	0.89	-0.61	0.41
	Same-Less	-0.021	0.99	-0.55	0.51
	Same-More	0.078	0.84	-0.24	0.40

Increase funding for community food programs (e.g., community food centers, food banks, community gardens)	More-Less	0.18	0.69	-0.35	0.71
	Same-Less	-0.19	0.69	-0.74	0.36
	Same-More	-0.38	0.022	-0.71	-0.044
Reduce food packaging materials	More-Less	0.060	0.96	-0.47	0.59
	Same-Less	-0.056	0.97	-0.61	0.50
	Same-More	-0.12	0.69	-0.45	0.22
Building relationships between consumers and food growers	More-Less	-0.085	0.93	-0.62	0.45
	Same-Less	-0.29	0.44	-0.85	0.27
	Same-More	-0.21	0.32	-0.54	0.13
Increasing the available number of culturally diverse food and produce options	More-Less	0.026	0.99	-0.50	0.55
	Same-Less	-0.29	0.42	-0.84	0.25
	Same-More	-0.32	0.060	-0.65	0.010
Providing resources (e.g., garden plot, seeds, water) for people to grow their own food	More-Less	0.033	0.99	-0.52	0.59
	Same-Less	-0.17	0.77	-0.75	0.41
	Same-More	-0.20	0.36	-0.55	0.15

Incorporating food production into new or proposed commercial and residential developments	More-Less	0.10	0.89	-0.44	0.65
	Same-Less	-0.0078	0.99	-0.57	0.56
	Same-More	-0.11	0.72	-0.45	0.23
Increasing the number of places people can access (i.e. buy, grow, share) food within or nearby their neighbourhood	More-Less	0.0053	0.99	-0.52	0.53
	Same-Less	-0.19	0.70	-0.73	0.36
	Same-More	-0.19	0.35	-0.52	0.14
Making use of vacant spaces in/close to cities that could produce food	More-Less	0.23	0.58	-0.31	0.76
	Same-Less	0.18	0.72	-0.38	0.74
	Same-More	-0.046	0.94	-0.38	0.29
Financially supporting farmers	More-Less	0.13	0.85	-0.41	0.66
	Same-Less	-0.32	0.37	-0.87	0.24
	Same-More	-0.44	0.0059	-0.78	-0.11

ANOVA Test for Sustainability Behaviours

		Df	Sum of Squares	Mean Square	F Value	Pr(>F)
Frequency of Participating in Local Food Initiatives	Willingness to Pay Categories	2	50	24.99	9.71	0.000074
	Residuals	473	1218	2.58		
Frequency of Participating in Environmental Initiatives	Willingness to Pay Categories	2	120.9	60.44	19.12	0.000000010
	Residuals	473	1495.4	3.16		

Tukey's Post-Hoc Test for Food System Development Priorities

	Willingness to Pay	Difference	p	95% Confidence Interval Bounds	
				Lower	Upper
Frequency of Participating in Local Food Initiatives	More-Less	0.55	0.073	-0.039	1.15
	Same-Less	-0.12	0.89	-0.74	0.50
	Same-More	-0.67	p<0.001	-1.046	-0.30
Frequency of Participating in Environmental Initiatives	More-Less	0.86	0.0063	0.20	1.52
	Same-Less	-0.19	0.79	-0.87	0.50
	Same-More	-1.047	p<0.001	-1.46	-0.63

3.2.3 Vertical Agriculture Attitudes and Values

ANOVA Test for Vertical Agriculture Attitudes and Values

		Df	Sum of Squares	Mean Square	F Value	Pr(>F)
Produce grown without soil is not as healthy as conventionally grown produce in soil	Willingness to Pay Categories	2	39.6	19.78	8.056	p<0.001
	Residuals	473	1161.6	2.46		
I welcome and/or can easily adapt to the idea and practice of using technology to commercially produce food using indoor systems	Willingness to Pay Categories	2	32.3	16.17	9.077	p<0.001
	Residuals	473	842.5	1.78		
I value traditional food production (e.g., outside, in open fiends) more than in enclosed environments	Willingness to Pay Categories	2	18.3	9.16	3.87	0.022
	Residuals	473	1118.6	2.37		
Food production in a fully-controlled environment is a strange practice	Willingness to Pay Categories	2	14.9	7.34	2.56	0.079
	Residuals	473	1375.4	2.91		
I do not like that vertical farms will increase our dependence on technology to solve food systems problems	Willingness to Pay Categories	2	14.3	7.14	2.5	0.083
	Residuals	473	1350.7	2.86		
Vertically-farmed vegetables are as natural as those conventionally farmed in agricultural fields	Willingness to Pay Categories	2	61.4	30.68	14.21	p<0.001
	Residuals	473	1021.5	2.16		

Tukey's Post-Hoc Test for Food System Development Priorities

	Willingness to Pay	Difference	p	95% Confidence Interval Bounds	
				Lower	Upper
Produce grown without soil is not as healthy as conventionally grown produce in soil	More-Less	-0.56	0.061	-1.14	0.020
	Same-Less	-0.97	p<0.001	-1.57	-0.37
	Same-More	-0.41	0.023	-0.77	-0.044
I welcome and/or can easily adapt to the idea and practice of using technology to commercially produce food using indoor systems	More-Less	0.80	p<0.001	0.30	1.29
	Same-Less	0.44	0.12	-0.085	0.94
	Same-More	-0.37	0.014	-0.68	-0.060
I value traditional food production (e.g., outside, in open fiends) more than in enclosed environments	More-Less	-0.49	0.10	-1.06	0.076
	Same-Less	-0.69	0.016	-1.29	-0.10
	Same-More	-0.20	0.38	-0.56	0.16
Food production in a fully-controlled environment is a strange practice	More-Less	-0.19	0.75	-0.82	0.44
	Same-Less	-0.51	0.16	-1.17	0.14
	Same-More	-0.32	0.14	-0.72	0.077
I do not like that vertical farms will increase our dependence on technology to solve food systems problems	More-Less	-0.57	0.084	-1.19	0.058
	Same-Less	-0.59	0.087	-1.24	0.064
	Same-More	-0.019	0.99	-0.41	0.37
Vertically-farmed vegetables are as natural as those conventionally farmed in agricultural fields	More-Less	1.024	p<0.001	0.48	1.57
	Same-Less	0.45	0.15	-0.12	1.012
	Same-More	-0.58	p<0.001	-0.92	-0.24

Appendix 3. Factor Analyses

Statement	Factor 1: Socio-Economic	Factor 2: Environmental
Reducing water use in agricultural production systems	0.078	**0.525**
Treating food as a public good/utility (like electricity, or water)	0.282	0.507
Making healthy foods more affordable	0.359	0.675
Educating consumers about sustainable food systems	0.341	**0.509**
Increasing the number of farms in or nearby cities	0.399	0.338
Protecting food production against natural disasters such as flooding or wildfires	0.252	**0.657**
Increase funding for community food programs (e.g., community food centers, food banks, community gardens)	**0.728**	0.263
Reducing food packaging materials	0.346	**0.460**
Building relationships between consumers and food growers	**0.595**	0.276
Reducing the amount of land used for agriculture	0.115	0.029
Increasing the available number of culturally diverse food and produce options	**0.542**	0.400
Having places like hospitals and schools buy local food instead of non-local food	**0.500**	0.303
Providing resources (e.g., garden plot, seeds, water) for people to grow their own food	**0.529**	0.272
Incorporating food production into new or proposed commercial and residential developments	**0.456**	0.179
Reducing the greenhouse gas emissions of agricultural production systems	0.333	**0.462**
Increasing the number of places people can access (i.e. buy, grow, share) food within or nearby their neighbourhood	**0.573**	0.299
Making use of vacant spaces in/close to cities that could produce food	0.391	0.272
Financially supporting farmers	**0.582**	0.259

Note: bold values indicate factor associations. Some factors with high factor loadings not considered conceptually consistent and therefore omitted from factor group.

Statement	Factor 1: Negative	Factor 2: Positive
Produce grown without soil is not as healthy as conventionally grown produce in soil	**0.722**	-0.132
I welcome and/or can easily adapt to the idea and practice of using technology to commercially produce food using indoor systems	-0.134	**0.989**
I value traditional food production (e.g., outside, in open fiends) more than in enclosed environments	**0.720**	-0.104
Food production in a fully-controlled environment is a strange practice	**0.779**	-0.108
I do not like that vertical farms will increase our dependence on technology to solve food systems problems	**0.694**	-0.231
Vertically-farmed vegetables are as natural as those conventionally farmed in agricultural fields	-0.112	**0.533**

Note: bold values indicate factor associations.

Endnotes

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