Influences on the Adoption of Climate Resilient Water Innovation in Agri-food System: A Construal Theory Approach

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Thesis submitted to the University of Ottawa
in partial fulfillment of the requirements for the
M.Sc. in Management (Specialisation in Environmental Sustainability)

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Abstract

Global food systems are facing a grand challenge due to daunting food security targets, risk vulnerabilities (e.g., COVID-19 crisis), internal unsustainability regarding resource use and contribution to environmental degradation (e.g., GHG emissions, land degradation and biodiversity loss). Such a situation demands a transformation of the global food system towards more local, alternative, community, and sustainable food systems. Past studies of the food system have shown that major advances toward socio-environmental sustainability can be achieved through the application of technology and the push for innovation. Therefore, since water is at the center of all food system challenges this study focused on climate-resilient water innovation, which includes using hydroponics, aeroponics or aquaponics technologies within a Controlled Environment Agriculture (CEA) to bring about this change. This qualitative study was undertaken to uncover the individual, institutional, technological, and farm/organizational factors that influenced the adoption of such climate-resilient water technologies. Additionally, it also involved investigating the individual construals and their relation to sustainable water innovation adoption. The study was able to discover new constructs, namely- sustainability ethos, individual construals, land/soil characteristics, location of urban farm, farm size bias, inter-provincial variation, complex systemic technologies, localization, and all-year-round production, that act as barriers and facilitators to sustainable water innovation adoption. Finally, developed a sustainable water innovation adoption model using an inductive and deductive approach that can be used by technology providers, the government and policy institutions for insightful decision-making with respect to water innovation in the Canadian agri-food sector.

Acknowledgements

I would like to dedicate this master's thesis to my mom (Dr. Richa Puri, Professor, Panjab University, Chandigarh, India) for being my inspiration and strength. Special thanks to my thesis supervisor, Dr. Sharon O'Sullivan, for your guidance and patience throughout this incredible journey. Lastly, I would like to appreciate my thesis committee (Dr. Sandra Schillo and Dr. Mohamed Chelli) and family (Dad, Brother, Bhabhi, and Niece) for all the support and love.

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Introduction

Our food system is facing a global grand challenge; that is, socio-economic problems which are multidimensional and complex, and which, if resolved, could have a large spillover effect (George et al., 2016). There are three facets to this challenge: First, the food system has the daunting requirement to produce more food for a rising population; Second, as the recent COVID-19 pandemic has revealed, there is a vulnerability within our global food system, and therefore also an urgent need to create resilient systems (Laborde et al., 2020, Blay-Palmer et al., 2021); and third, there is a need to lower pollution by reducing GHG emissions, without wasting more energy, land, or water resources (Davidson et al., 2015; Máté et al., 2020). However, the conventional, or traditional, food systems that the world depends on for meeting this challenge are itself contributors to environmental degradation and unsustainability (Feenstra G., 2002). In summary, to meet global food security goals, the global food system needs to feed a growing population in a more resilient manner while also adapting to the extremities of climate and rising temperature (Smit & Skinner, 2002).

Consequently, communities around the world have turned their attention towards innovating alternative approaches to food systems (e.g., diverse sourcing, networking, and technology approaches). Such approaches aim to enhance both social sustainability (e.g., ensure food security by providing access to adequate and nutritious diets within communities and creating more direct links between farmers and consumers, as well as improve work conditions and opportunities for the local food system labour force by promoting local food production, processing, and consumption practises) and environmental sustainability (e.g., ensure the use of more environmentally sustainable production practices, and provide agricultural growth) (Feenstra, 2002).

In Canada, the food system is similarly being nudged to adopt this shift through government programs and research bodies. These include the Indigenous Agriculture and Food Systems Initiative by Agriculture and Agri-Food Canada, or Canadian university collaborations with sustainable food service corporations (Friedmann, 2007). Also, Protein Industries Canada's Food Convergence Innovation (FCI) Canada project to integrate food and beverage supply chains across Canada to create a localized food system (Protein Industry Canada, 2021). At the heart of such initiatives is the recognition that such a grand challenge to the food system requires a focus on innovation; that is, the innovation process needs to be strategized and diffused collaboratively, with all pertinent stakeholders having a distributed and distinct role in the process (Ferraro et al., 2015).

Given the central importance of water to all agricultural development, water innovation seems a particularly promising avenue for both Canadian and other global agricultural contexts to pursue, for several reasons. First, it devotes special attention to the distribution and management of irrigation water which may become scarce in the age of climate change (Wehn & Montalvo, 2018). Second, technological efficiencies related to its proper management can have not only environmental but also social benefits. Technologies related to hydroponics, aeroponics and fogponics not only promise higher water use efficiency and residual-free production of fresh local produce, but they can also allow for soilless cultivation (Benke & Tomkins, 2017, Khan et. al., 2020; AlShrouf, A., 2017). This means they can be applied to 'Built Integrated Agriculture' (BIA), whether over a rooftop greenhouse or a vertical wall or a container that provides a Controlled Environment (CE) agriculture, thereby offering a readily accessible, clean, green, and fresh food supply that is not only environmentally sustainable but also promotes social integration (Appolloni et. al., 2021; Benke & Tomkins, 2017). For this reason, water innovation-based controlled environment agriculture has been posited to be a game changer for the food system's grand challenge.

Nevertheless, just as some scholars have observed a reluctance to adopt general agricultural technologies by farmers despite the outward benefits (Bjornlund et al., 2009; Zhang et al., 2019), it seems possible that a similar reluctance arises for innovative, climate-resilient water-saving technologies (e.g., be they hydroponics or otherwise). To date, research on the adoption of other agricultural innovations has observed resistance by farmers due to differences in institutional factors, farm-level characteristics, technological attributes, and individual operator factors (e.g.. psychological factors) (Aubert et al., 2012; Barnes et al., 2019; Caffaro et al., 2019; Caffaro & Cavallo, 2019; Chuang et al., 2020; Drewry et al., 2019; Larson et al., 2020; Pino et al., 2017; Pivoto et al., 2019; Tamirat et al., 2018; Toma et al., 2018; Vecchio et al., 2020; Yoon & Lim, 2020). However, this literature has yet to examine how such socio-technical, institutional, and psychological factors may influence the adoption of new/innovative *water-related* agricultural technologies (or how to best circumvent barriers, when they arise). Additionally, the role of technology providers, which develop such water innovations, towards adoption decisions made by farmers requires a further inquiry.

Therefore, the aim of this study is to explore the phenomenon of the adoption of climate-resilient water technology in agriculture. It will seek to identify potential barriers to adoption and suggest measures to accelerate the implementation of this transformative change within the whole Canadian agri-food system. In addition, this study will investigate the potential role of psychological factors that have not yet been considered (e.g., construals about environmental issues). Accordingly, the following research questions are proposed:

Research Questions

RQ 1: *What are the facilitators and hindrances to the adoption of climate-resilient water innovation, and how are the hindrances surmounted, if at all?*

RQ2: *How do construals of farmers and technology providers about water innovation/technology influence decisions to adopt, if at all?*

The theoretical contributions of this research study are threefold: First, it will extend the innovation literature to the water innovation context. Second, it will extend construal theory to the context of agricultural environmental innovation. To achieve these objectives, this study adopts a 360-degree phenomenological research design to investigate the common phenomena of innovation adoption in the Canadian food system, by consulting those who have common experience related to this phenomenon, such as innovators, farmers, and distributors (Creswell, 2007). The experiences of innovators and distributors will give the study multiple perspectives on the barriers and facilitators for the adoption of water innovation by farmers. This methodology offers the third contribution to the environmental management and innovation literature because the qualitative approach to researching the agri-food water challenge and innovation adoption may reveal constructs that had previously been neglected.

The practical significance of the current study is that it offers insights about barriers that, if addressed, can help to accelerate the implementation of this transformative change within the whole Canadian food system. Shifting toward a sustainable and climate-resilient agri-food system in Canada can not only address the global agricultural grand challenge but potentially also offer large local spillover benefits. These include local fresh food with limited effect on material waste, the resilience of food supply chains, reduction in GHG emissions from agriculture, net carbon saving with reduction of crop transportation or energy saving in buildings and social integration of communities.

Empirical Lens: Water Innovation for the Global Food System Challenge

Global Food System

A Global food system is considered a "system of systems", meaning it consists of a food supply chain and environmental, industrial and trade systems (Hipel et al., 2010) and some studies regard it as a "process that turns natural and human-made resources and inputs into food" (Herforth et al., 2014).

This globally interlinked global food system is facing a 'Grand Challenge', as complex multi-dimensional factors have co-evolved to create a perfect storm. These include the need to ensure food security for the rising population (to provide a nutritional but also culturally acceptable diet) amidst competition for limited resources (i.e., land, water, air, and soil) while addressing environmental concerns and protection against climate shocks (George et al., 2016, Godfray et al., 2010; Hamilton et al., 2020).

The concerns and challenges faced by the food system represent a signal to push for a complete transformation, which means a paradigm shift from the 20th-century agriculture and food system (Hospes & Brons, 2016). Overall, the goal is to align the food system with the 2030 Agenda for Sustainable Development and Paris Climate Goals. However, there are different conceptualizations (See Table 1) of how to approach this transformation that is being researched, and each focus on different scales and levels of the system.

Table 1: Alternate Conceptualisation to the Conventional Food Systems

S.No.	Conceptualization	Literature
1.	Alternative Food Systems	Bazzani & Canavari, 2013; Kloppenburg et al., 2000
2.	Sustainable Food Systems	Blay-Palmer et al., 2016; Feenstra, 2002

3.	City Region/Urban Food System	Blay-Palmer et al., 2021; Pothukuchi & Kaufman, 1999; Appolloni et al., 2021; Orsini et al., 2013
4.	Local Food System	Hinrichs, 2000; Martinez et al., 2010
5.	Community Food System	Peters, 1997; Clancy, 2004

All these conceptualizations focus on robust action focusing on innovation; that is, the innovation process needs to be strategized and diffused collaboratively, with all pertinent stakeholders (at all levels) having a distributed and distinct role in the process to solve such a grand challenge to the food system r (Ferraro et al., 2015). Additionally, past literature on food systems has shown that any major advances toward sustainability were achieved through the push for innovation and the application of technology (Godfray et al., 2010). Given that the most important factor of production in any food system is water, a focus on water innovation can yield multi-level solutions to this grand challenge faced by humanity.

Water Innovation technology

Globally, agriculture is the greatest consumer of water. Yet, it is predicted that by the middle of 21st century, water supply is going to be severely challenged due to the 'Resource Competition' between municipal and commercial demands (Godfray et al., 2010). The other major risk to water resource availability will be climate change, as evapotranspiration will occur at a faster rate in a warmer climate. Predictive models say that these factors will together cause an 18 percent reduction in the availability of worldwide water for agriculture by 2050 (Strzepek & Boehlert, 2010). Therefore, such a situation demands urgent attention to water issues, especially increasing water-use efficiency in the food systems.

Water in the whole scheme of technology and innovation can allow 'Convergent Innovation' (Jha et al., 2014), which means it allows for convergence between different actors (public, private, and civil society), systems (economic, natural, and social) and sciences (natural, life, social, and engineering). Along with this, convergent innovation "aims to *innovate the way we innovate"* and such a framework is critical for tackling complex multi-dimensional problems of 21st-century society (Dubé et al., 2018). Indeed, one academic study has shown that water innovation technology through irrigation at the field, systemic or basin scales can work to address the food-water-environment nexus of our conventional food system (Cameira & Pereira, 2019).

Water Innovation studies have considered water innovation technology not only limited to agriculture or irrigation but in a much wider context. According to the United Nations Department of Economics and Social Affairs (UN DESA, 2008), the potential application domain for such technology encompasses 3 inter-related functional sectors- (1) Water resources management, which includes integrated water resources management and ecosystem restoration and remediation; (2) Water infrastructure, which includes the construction, operation and maintenance of water-related natural and man-made infrastructure; and (3) Water services, which include supplying and managing water services for economic, such as agriculture, energy and industrial use, and domestic use, such as municipal water supply, sanitation and hygiene (WWAP, 2016). Although these 3 sectors of water innovation are overlapping to some degree, improvement in one could have a spillover effect in the other two (Wehn & Montalvo, 2018). Therefore, the common aim of Water Innovation is to "*contribute to the continuous improvement of water management, in terms of efficiency and effectiveness."* (Wehn et al., 2016).

The focus of this study is on the third of these application domains, the *agricultural water service sector*. This is because past literature has suggested multiple needs for water innovation in this domain (Cameira & Pereira, 2019), namely- "(1) Evapotranspiration and crop water use; (2) Improving water management in Irrigated agriculture, particularly irrigation scheduling; (3) Adaptation of agricultural systems to enhance water use and water productivity to face water scarcity and climate change; (4) Improving irrigation systems design and management adopting multi-criteria and risk approaches; (5) Ensuring sustainable management for anthropic ecosystems favoring safe and high-quality food production, as well as the conservation of natural ecosystems; (6) Assessing the impact of water scarcity and, mainly, droughts; (7) Conservation of water quality resources, namely by preventing contamination with nitrates; (8) Use of modern mapping technologies and remote sensing information; and (9) Fostering a participative and inclusive governance of water for food security and population welfare."

Despite this need, it has been found that the overall water sector is the least innovative and financial investments in the sector are lagging behind (Wehn & Montalvo, 2018). This is attributable to the pre-commercialization challenges of new water innovation technology and the risks of scaling up operations as innovators fear not being able to reap the full economic benefits of their innovation (Gabrielsson et al., 2018). Therefore, adoption of water technology innovation requires urgent attention as the existing technology and policies may be inadequate (O'Callaghan et al., 2020).

Yet, from a sustainability standpoint, water innovations, namely hydroponics, aeroponics or aquaponics, are agricultural water irrigation services that represent a promising area for technology scale-up and market adoption. The innovation is about growing crops in nutrient-rich water or air medium without conventional soil. Additionally, these innovative hydroponic systems, which can be integrated with climate-proofing infrastructure within containers, greenhouses, and buildings, allow for a 'Controlled Environment Agricultural (CEA) system' (Srivani et al., 2019;

Orsini et al., 2013). Past studies show that such innovation can be adopted in urban areas through "Building Integrated Agriculture (BIA) either by rooftop greenhouse or enclosed vertical farm" (National Zero Waste Council, 2021) that allows control of the environment (Walters et al., 2020). More importantly, this climate resilient irrigation technology targets major innovation domains, as mentioned by Cameira & Pereira (2019), including (1) Reducing evapotranspiration and crop water use; (2) Improving water management through irrigation scheduling and efficiency; and (3) Adaptation of agricultural systems to face water scarcity and climate change. Such Controlled Environment technologies with water technologies are considered special because they address the 3 major sustainability challenges of the food system (Orsini et al., 2013): (1) Resource constraints like low soil fertility and/or water availability, (2) Future food security by disjointing land availability with production increase, and (3) Reducing the negative externalities of food production on the environment.

In the context of Canada, some of this work is being undertaken in a northern Canadian community where hydroponic innovation is being studied to retrofit a light industrial building for sustainable local production of fresh food (Udovichenko et al., 2021). Additionally, because this technology can also be used to provide nutritious food in distant, dry, and cold areas (Khan et al., 2020), a container-based hydroponic farming innovation could be beneficial for remote arctic communities and more so if the containers can run on solar energy, and storage (Sambor et al., 2020). It could help Indigenous communities living in remote areas, like Alaska (U.S.A) or Yukon (Canada), establish a community food system that sustainably provides culturally acceptable food to the community (Snyder & Meter, 2015). This also makes these technologies an ideal tool for meeting SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well Being). Lastly, this type of water innovation can enable our food system to mitigate and adapt to environmental externalities, like climate change. It is estimated that polar regions will have more extremities and rapid changes so Canada could be more prone to food system grand challenges arising from climate change (Avila-Diaz et al., 2021). A simulated study of Building Integrated Agriculture (BIA) study of tropical and high latitudes found that greenhouse-based hydroponic systems would reduce GHG emissions between 60% and 80%, whereas container systems would reduce GHGs between 40% and 80% depending on local climate (Benis et al., 2017). Thus, these technologies offer the world an opportunity to meet SDG 13 (Climate Action) and Paris Climate Deal targets within Canada.

In summary, water innovation technology represents a potential catalyst for convergent innovation toward the transformation of global food systems. Although there are multiple water innovation technology adoption options available to the Canadian agri-food system, this study will focus on broader barriers (and facilitators) to the adoption of water irrigation innovation. But the study specifically focusses on climate resilient irrigation technologies (like hydroponics and aeroponics etc.) that offer the greatest promise in bringing about these 4 sustainable transformations (Hospes & Brons, 2016): (1) Adaptive capacity and resilience of the food system, (2) Local or Localised food systems, (3) Promoting alternative food activities, and (4) Human-centric food system, to address the grand challenge faced by the Canadian food system.

Theoretical Lens- Sustainable Adoption Theory & Construal Theory

Past studies in the U.S.A show that, due to the increase in demand for locally grown food, there is a rising interest among researchers in the use of hydroponic-based, controlled environment technologies to improve production and quality (Walters et al., 2020). Yet, hydroponics and other water innovation-based controlled environment technologies remain an under-researched, untapped business opportunity that needs to be looked at from the adoption perspective, especially in the Canadian agri-food system.

Therefore, the primary focus of this section will be to review the innovation adoption literature in order to develop theoretical insights about the various influences on the adoption of innovative climate-resilient water technology – specifically, the adoption of water irrigation innovation technology, with special attention to water innovation-based irrigation systems. Because national contexts differ in their institutional, socioeconomic, and technical factors related to the water sector (Brewer et al., 2021; Alcon et al., 2011), and because Canada faces challenges due to the rate of climate change in its Northern region, this study devotes particular attention to the literature on Canadian contextual factors for water technology adoption n.

The second objective of this section is to demonstrate that, although there may be many deeper psychological factors that influence individual adoption decisions, most research in this area has focused on contextual and/or other individual factors. Academic studies have recommended that innovation adoption literature devote greater attention to the explanatory power of psychological theories to identify blind spots in adoption and advance the understanding of the different factors (Oorschot et al., 2018). Yet, certain psychological theories pertinent to decision-making remain neglected. Therefore, this section will aim to fill that gap as well, by exploring how a particular psychological theory, construal theory, may apply to the context of sustainable innovation adoption (Trope & Liberman, 2010, Steinbach et. al., 2019, Brügger et. al., 2016). This aim will be to develop insight into the deeper psychological information-filtering process with respect to construals about sustainable innovation technology adoption that may influence individual strategic considerations (Steinbach et. al., 2019)

The Stages of Sustainable Innovation Adoption

Any innovation undergoes various stages, namely ideation, basic research, prototype creation, manufacturing, adoption, diffusion, decline and replacement. Overall, these stages can be divided into two: the development and the adoption of innovations (Wehn & Montalvo, 2018).

The 'development' stage is about the technology push, which ensures the creation of marketable technology with a dominant design and standard (Rogers, 2010). This allows for the start of the adoption and diffusion stage which is a function of the market. During this stage the effects of change brought by innovation are experienced: 1) in organizations (in terms of new skills requirements, destruction and creation of jobs, changes in competitive positions in sectoral markets); and 2) at the broader societal level (changes in behaviours, consumption patterns, lifestyle, or structural change across economic sectors) (Ipektsidis et al., 2016, Antonelli, 2014)

Within the 'adoption of innovation' stage, there are 3 predominant threads of research: (1) factors that drive *adoption decisions* (e.g., at the company level or consumer preferences), (2) *promotion of the diffusion* of new technologies to solve societal problems, and (3) factors affecting the *implementation* of innovations at the organization level and resulting performance" (Wehn & Montalvo, 2018). The first two, the adoption and diffusion of innovation, focus on the improvement of market share and acknowledge that the disruptive potential of an innovation is a function of the market, rather than only innovation characteristics (O'Callaghan et al., 2020). For the reasons outlined earlier (above), this study focuses on the first of these, the innovation adoption decisions for a disruptive water innovation (like the hydroponic-based farming system) Nevertheless, potential implications are also drawn out for the second two domains (supplier promotion and buyer implementation).

Theories of Innovation Adoption

Several theories have emerged in the innovation management literature that attempts to explain the adoption process. These are reviewed below.

First, the Theory of Planned Behaviour predicts that a behavioural intention can turn into action (which in this study is the adoption of water-based technologies), depending on 3 psychological factors- (1) attitude towards the issue, (2) subjective norm, and (3) perceived behavioural control ("people's perception of the ease or difficulty of performing the behaviour of interest") (Ajzen, 1991). Yet, this theory has given insufficient attention to what contributes to each of these three perceptions.

Second, the Theory of Diffusion of Innovation generalized the idea of the spread of innovation in the market. The theory talked about the famous S-shaped curve of adoption that plotted the percentage of adaptors with time. According to this theory, the diffusion process has 5 determinants (Rogers, 2003): (1) Compatibility, (2) Relative Advantage, (3) Complexity, (4) Trialability, and (5) Observability. However, it, too, gave inadequate attention to psychological factors.

Third, the Technology Adoption Model (TAM) described the relationship between the level of technology acceptance and user factors using 3 constructs- (1) Perceived Usefulness, (2) Perceived Ease of Use, and (3) User Acceptance (Davis, 1989). (Refer to the 'generic innovation adoption column' of table 4 below). As with the other two theories, this theory, too, gave inadequate attention to any psychological factors driving these constructs.

Indeed, a deeper analysis of the innovation adoption literature with respect to the farming sector (see table 2 below) shows that the focus has mainly been on a variety of mostly contextual and technological factors that may influence adoption, including: (1) operator characteristics, (2) farm level characteristics and interactions, and (3) technological attributes. As an example of operator characteristics, one study found that adoption depends on the cropping pattern, farmer's human capital, hedging against production risks, and the social status and poverty status of the farmer (Namara et al., 2007; Koundouri et al., 2006). In addition, one study related to drip irrigation technology adoption in farming went beyond noting the importance of operator characteristics (namely education) and technological attributes (e.g., trialability), and identified how institutional factors (e.g, credit availability, information networks and government policy) played a role in adoption decisions (Alcon et al., 2011). However, attention to psychological factors that influence farming technology adoption decisions has been minimal. The findings of the current literature are summarized below in table 2 below, with column 4 highlighting variables pertinent to farming-specific tech adoptions.

Table *2*: Barriers to technology adoption (general & specific) in the agri-food sector (Next Page)

	Factors	Findings	Generic Innovation Adoption Literature	Specific Innovation Adoption Literature
Operator Characteristics	Age	Generally negative relationship between age and adoption decisions. Younger farmers are more inclined to adopt new technologies than older farmers.	Davis, 1989; Rogers, 2003	Chuang et al. (2020); Barnes et al. (2019)
	Education	Mixed results. Some found positive association, others negative and insignificant results.		Caffaro & Cavallo (2019); Pivoto et al. (2019)
	Income	Insignificant results		Barnes et al. (2019); Larson et al. (2008)
	Innovativeness	Positive impact on adoption		Yoon et al. (2020); Pino et al. (2017)
Farm Level Characteristics & Sectoral Service Providers	Farm Size	Positive and significant impact	Davis, 1989; Rogers, 2003	Pivoto et al. (2019); Tamirat et al. (2018)
	Consultant Services	Positive and significant impact		Larson et al. (2008)
	Extension services (Including institutions)	Positive and significant impact		Larson et al. (2008)

	Government support and its institutions	Positive and significant impact		Yoon et al. (2020)
Technological Attributes	Compatibility	Positive and significant impact	Davis, 1989; Rogers, 2003	Yoon et al. (2020); Drewry et al. (2019)
	Trialability	Negative and significant impact		Aubert et al. (2012)
	Relative advantage/Perceived usefulness	Positive and significant impact		Chuang et al. (2020); Yoon et al. (2020)
	Complexity/Perceived Ease of Use	Positive and significant impact		Vecchio et al. (2020); Aubert et al. (2012)
Psychological Factors	Attitude	Positive and significant impact.	Ajzen, 1991; Davis, 1989	Pino et al. (2017)
	Subjective Norm	Positive and significant impact.		
	Perceived Behavioral Control	Insignificant		

Although Table 2 clearly shows that several multi-level factors have been considered, several potential barriers within each of the above categories remain unexamined with respect to clean farm technology related to water. First, *at the farm level*, profit margins deserve attention. Profit margins and sunk cost are a consideration for the adoption of any new technology as it must break the existing cycle of innovation diffusion (Davis, 2003; Davis, 1989): The adaptors (i.e., farmers), must focus on payback, risk, and impact of technology. This may include the up-front cost of new technology, the business risk of the new technology, profit benefits in the future, and time for profit benefits to be realized (Kuehne et al., 2017). Second, Alcon et al (2011) also identified the importance of *institutional factors* for water technology adoption contexts that influence these dynamics among farmers, which are water availability (abundance), price of water and sustainability-oriented policy which may be related to the preceding two but were not addressed by any of the non-water tech adoption studies. It is especially important to study institutional factors pertinent to water technology adoptions because it may be that unique institutional factors and commercial situations combine to influence water technology adoptions. The water sector is considered a fragmented market with long replacement cycles, growing dependence on population, different regulatory regimes and lower disruption needs will require a independent approach (O'Callaghan et al., 2020). It has also been found that the overall water sector is the least innovative due to institutional factors like financial investments in the sector (Wehn & Montalvo, 2018). Accordingly, farmers' perceptions of those factors may matter in a way that differs from non-water technology adopted to reduce materials that have clearer costs associated with them.

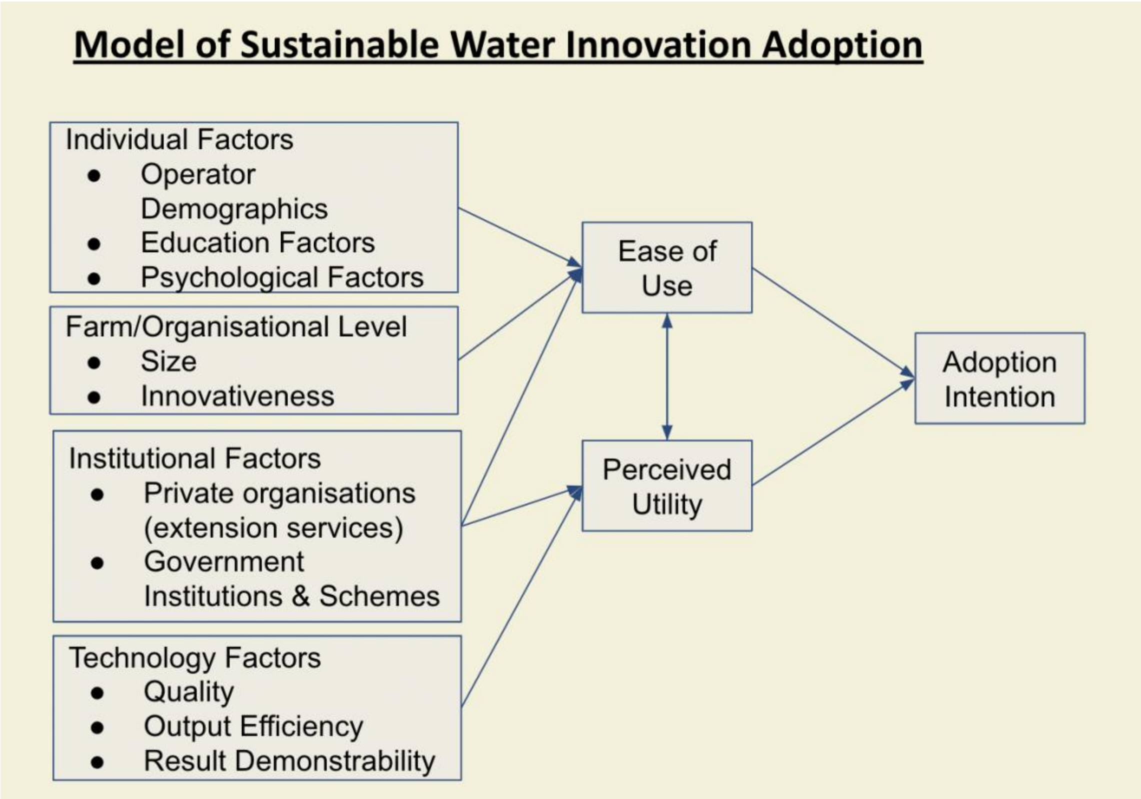
This underscores perhaps one of the more problematic gaps in the literature: Studies related to innovation adoption in the farming sector still have not paid much attention to *how* these specific factors drive the adoption of clean agri-food technologies (or more specifically, water-related technologies, especially with regard to water innovation-based Controlled Environment farming systems). Thus, not only is the water innovation sector understudied, but there is also an urgent need for closer attention to the processes for innovation (e.g., adoption) (O'Callaghan et al., 2020).

Relatedly, it is particularly interesting that the general innovation literature only mentions psychological factors through attitude towards the issue, subjective norms, and user acceptance. Indeed, all the mentioned factors in these theories give only a generic understanding of the psychological barriers and drivers of any innovation adoption within an organization or system. Water innovation will require an integrative focus as studies conducted in Brazil related to aquaponics technology, which combines hydroponics-based farming and fishery (not land agriculture) have shown widespread interest among farmers, but financing, human power and product placement are the factors that influence adoption decisions (Brewer et al., 2021). Moreover, studies don't necessarily address sector-specific environmental concerns pertinent to farming and water innovation.

Some studies came close to suggesting how psychological (or social-psychological) factors might matter. One empirical study that was conducted in Crete, Greece, among olive-producing farmers, found that building knowledge through social learning (& capacity through extension service and skills) had a strong correlation with water irrigation technology adoption (Genius et al., 2014). Another study showed that when economic factors, such as price of water, do not capture the true opportunity costs of water, behavioural factors will play a key role in adoption decisions (Ranjan & Athalye, 2009). Therefore, the current study aims to focus on individual construals to uncover the deeper psychological and subjective ethos that act as barriers or facilitators of water innovation adoption decisions. This is particularly important to study in the Canadian context due to the abundance of water in Canada, which means that water is often understood as an externality, unlike other resources. Therefore, individual psychological construal and behavioural factors need to be extensively studied.

With the aim of identifying a more robust set of barriers and facilitators at the individual, farm/business, institutional and technical levels that influence adoption intentions, we have created a simplified model for sustainable water technology adoption (See figure 1 below). This model integrates the generic technology adoption literature with specific agri-food factors and offers conjectures for the process by which different factors may influence one another.

Figure 1: Inductive Sustainable Innovation Adoption Model



Construal Theory Approach

Construal theory claims that choices and preferences, which impact human decisions, depend on the construal of objects rather than on the objects and situations themselves (Trope & Liberman, 2010). There seems to be a deeper information-filtering process at work by which objects [or situations] are construed, which in turn influences their salience and resultant strategic decisions (Steinbach et. al., 2019). Research on Construal theory suggests that there seems to be a construal distance, which is a psychological distance between the observer and the target while decision making. Such distance can be (1) temporal (time connection with the psychological object), (2) social (social association and local connection with the psychological object), (3) spatial (space connection with the psychological object), or (4) hypothetical (real/hypothetical understanding of the psychological object) (Trope, & Liberman, N., 2010). Temporal distance

Reducing psychological distance has been advocated as a strategy, for example with respect to climate change, to get a desired eco-friendly response and decision. But there has been some debate about whether proximity will increase or decrease engagement. This call for a more differentiated and nuanced perspective on the effects of psychological distance on individual decision making (Brügger et. al., 2016). Indeed, past research has shown that the high-level construal approaches can even influence participants that valued nature and the environment less (Griffioen. Et. al., 2019). Therefore, when designing interventions, one should consider the construal level and target high construal levels for pro-environmental behaviour, especially for sustainable technology adoption (Griffioen et. al., 2019).

This is important to investigate further because a farmer's decision to adopt a technology may not only depend on the technology and its characteristics, but also on their construal and information-filtering process related to the objectives of technology and how it will solve their and society's socio-economic problems. Past studies have shown that sustainable innovation adoption, like the one this study focuses on, not only requires a profit orientation but also will require a positive attitude toward the environment and an understanding of the environmental impacts of farming (Kemp et al., 2014).

Similarly, we see with irrigation technology (e.g., Zhang et al., 2019), it needs to adapt to local demand and specifications. For example, when most farmers adopted engineered water-saving irrigation technologies, it was to cope with clearly *perceived* water scarcity in the region. However, it also needs to avoid over-specialization in terms of perceived utility and provide multiple crop use, and ensuring the price is competitive to promote uptake and diffusion among farmers. A study conducted in Malaysia has shown that when there is an appropriate technology adoption then there is very high effectiveness of the hydroponics technology knowledge transfer program in the adoption, setting up and utilization of such new irrigation technology (Applanaidu et al., 2018). Therefore, gaining awareness of the potential impact is important as it may reduce the construal distance between the technology adoption objective. However, no studies have looked at how or what best enables construals of concrete tangibility with respect to sustainable technology adoption, especially hydroponics technology that can transform food systems. Therefore, this study will extend the application of construal theory within the water innovation and sustainable technology adoption domain.

Research Questions

RQ 1: *What are the facilitators and hindrances to the adoption of climate-resilient water innovation, and how are the hindrances surmounted, if at all?*

RQ2: *How do construals of farmers and technology providers about water innovation/technology influence decisions to adopt, if at all?*

Methodology

Research Design

This was a qualitative study with additional descriptive quantitative data collected from participants. Qualitative methods are best used when focused on understanding the 'why' and 'how' of a phenomenon (Yin, 2013). As this study focused on a group of individuals that are linked by a common phenomenon (i.e., adoption of climate resilient water innovation among a group of individuals that are part of a food system), a phenomenological research design was used to gain insights into the undiscovered nature and theoretical processes (Cavana, Delahaye, & Sekaran, 2001; Creswell, 2007). The use of qualitative research methods based on phenomenological research design helps uncover these common experiences and construals among the diverse Canadian food system participants about the new technology (Creswell, 2007). Qualitative methods helped to understand the common experience of individuals, their actions, and reasoning (i.e., towards adoption of new irrigation technology) (Myers, 2013), thus brought forth the full spectrum of gaps and barriers in the adoption phenomena of such new transformative water technology. Therefore, semi-structured interviews (Appendix A) were conducted in which participants were asked in-depth semi-structured questions during the interview. Later, the interviews were coded and analyzed to find answers to the research questions.

In addition, a quantitatively oriented survey (Appendix B) was conducted to collect descriptive individual differences data from the participants of the interview. These participants were given closed-ended questions about their experiences with clean water innovation technology, and psychological factors (e.g., importance, cognition, and action tendencies towards global environment issues) were tapped to add an additional individual perspective, using pre-established metrics for evaluating participants' interpretations and construal distances (Carson, Gilmore, Perry & Gronhaug, 2001; Trope, & Liberman, N., 2010). With respect to the questionnaire, the participants gave their rating (on the Likert Scale) to identify their relative distance from different construals related to their environment identity. The questionnaire also included a construal manipulation measure to provide a second way to tap into the nature of participants' individual characteristics.

Participants

A phenomenological design requires enough participants to understand the whole phenomenon and gather enough qualitative data to make conclusions. Therefore, the participants of the study included representation from the innovating firm that is commercially building climate-resilient water innovation technologies, farmers adopting, intending to adopt, or potential adaptors of such technology, crop distributors and transports, and consumers. These participants are a homogenous group within the food system that are expected to be experienced a common change within the system. The number of participants for a phenomenological design is required to be up to 30 (Creswell, 2007). However, the final number of interviewees in this study will depend on how quickly the iterative data analysis process reaches data saturation, as is the case with most qualitative research (Creswell, 2007).

Procedure for Data Collection

The individual ideas and experiences related to the phenomena of water technology adoption within a food system were studied. As the study was focused on the Canadian context, the data were collected from within the national boundaries. In the study, homogenous sampling was used to select the interviewees that have had a common adoption experience and are part of the Canadian food system (Creswell, 2007).

The qualitative data were collected through semi-structured interviews. A detailed single interview protocol was be used for the participants, where the protocol will be divided into sub-themes and specific questions about the individual's experiences and ideas about the technology(Patton, 2015). The interviews were conducted and recorded over the phone or internet and transcribed later for analysis.

Following this, each participant was given a questionnaire to complete, where participants answered a questionnaire that identified individual differences that may prove relevant to their decisions. For example, measures recorded (Brügger et. al., 2016 ; Griffioen. Et. al., 2019) in the questionnaire included 'Environmental self-identity', 'Pro-environmental behavior', and 'Personal intention to adopt clean technology'. Environmental self-identity will be measured on the scale developed by van der Werff et al., 2013 consisting of three items. For Pro-environmental behaviour, a questionnaire will ask about participants' several pro-environmental behaviours in their food system activities to assess how people behaved and acted towards water issues (based on Griffioen. Et. al., 2019). Last, for personal intentions to adopt clean technology the participants answered the question about which actions they were likely to take in the future on a five-point Likert scale related to the adoption of technology (based on Brügger et. al., 2016).

In addition, as a manipulation check, the questionnaire initially introduces water efficiency technology and its importance with either a proximal or distant focus (randomly assigned). This manipulation will create the proximal condition for some participants by explaining the importance of water efficiency technology in the Canadian agri-food system, whereas a distant condition by showings the technologies important to “all over the world”, “across the globe”, or to “the planet” (Brügger et. al., 2016).

Procedure for Analysis

The recorded interviews were transcribed verbatim and later coded for data analysis. After each interview to better handle voluminous data, a contact summary form was used and an overall summary of the main points from the interviewee was developed.

During the analysis, a mix of inductive and deductive approaches was taken while coding the interview. The final code list was developed after two cycles of coding. In the 1st cycle of coding, in-vivo and descriptive codes were used for summarizing the voluminous initial data. After this, the 2nd cycle of coding, where inferential or pattern coding was done by grouping those summaries into smaller categories, themes, or constructs. Using these cycles of coding, a code list was prepared for answering the final research question (Miles et. al., 2014). For the questionnaire data, descriptive statistical analysis was used for analysis.

The study used dual coders to avoid coder bias by starting the coding analysis together in detail. Later, the second coder revisited the codes in the middle of the coding stage and discussed the tricky ones. When there is a difference in opinion on coding an additional code was created, or existing code was clarified. In the end, both the coders co-coded 30% of the codes and achieved 100% agreement.

Analysis

Descriptive - Participant Characteristics

As a phenomenological research design, the aim is to understand the phenomena of water innovation adoption in the whole Canadian food system, such as innovators, farmers, distributors, and consumers (Creswell, 2007). Therefore, the participants included in the study were farmers (traditional and urban), technology providers, distributors, and Agri-retail business owners to give a 360-degree understanding. The study had a total of 25 participants, whose composition was as follows:

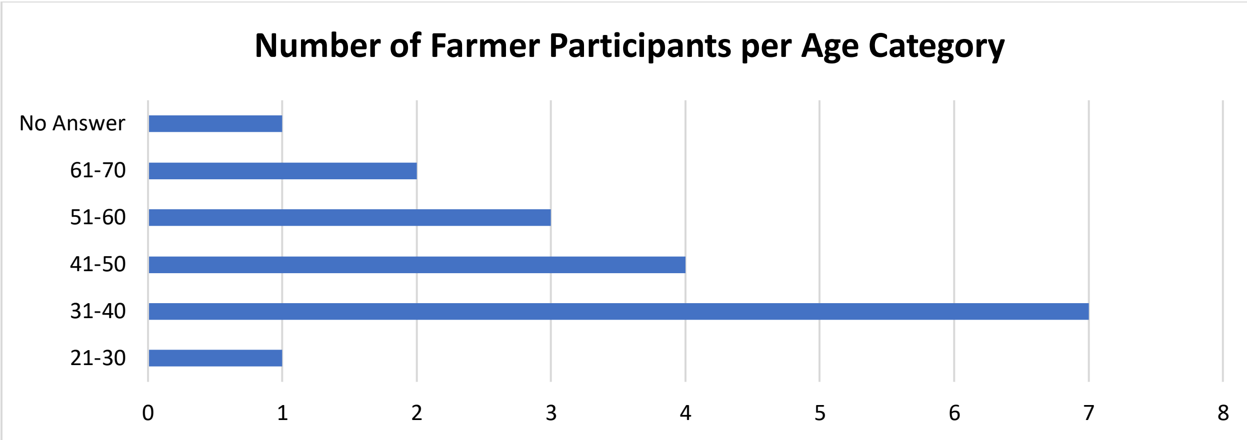
Table 3: Participants break-up

Participant Types	Count
Agri-food retailer	1
Farmer & Distributor	12
Technology Provider	7
Urban Farmer & Distributor	5
Grand Total	**25**

For an all-encompassing understanding of the water technology adoption phenomena in the agri-food system, the demographic characteristics of the participants were collected during the study. These demographics include the age of farmers, gross income, and educational background of farmers.

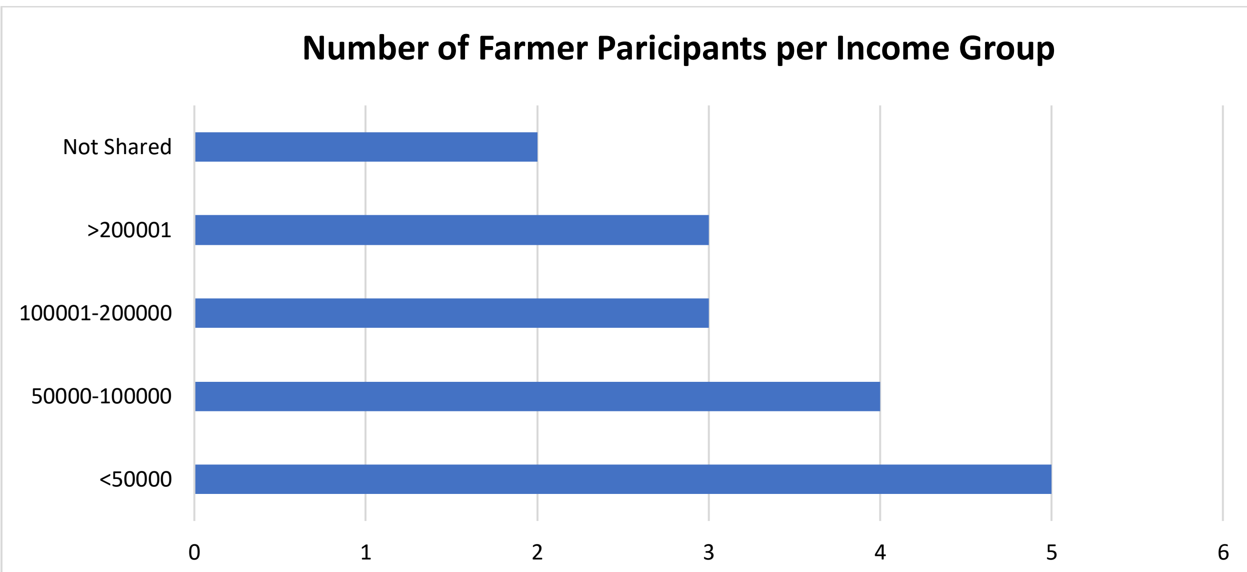
Age Demographics

With respect to age, the farmer participants had a very wide range of 22-70 and a mean age of 43.76. The age group distribution was as follows (see figure below).



Gross Income

The gross income (in CAD) characteristics showed a good variability. The distribution of gross income of participating farmers were as follows (See graph below)



Educational Background

Individual characteristics like education were also collected for noting their background in agriculture and technology. The study had got participants (see figure below) with college/university degrees in agricultural and non-agriculture domains and even high school diplomas, who started very young on their family farms.

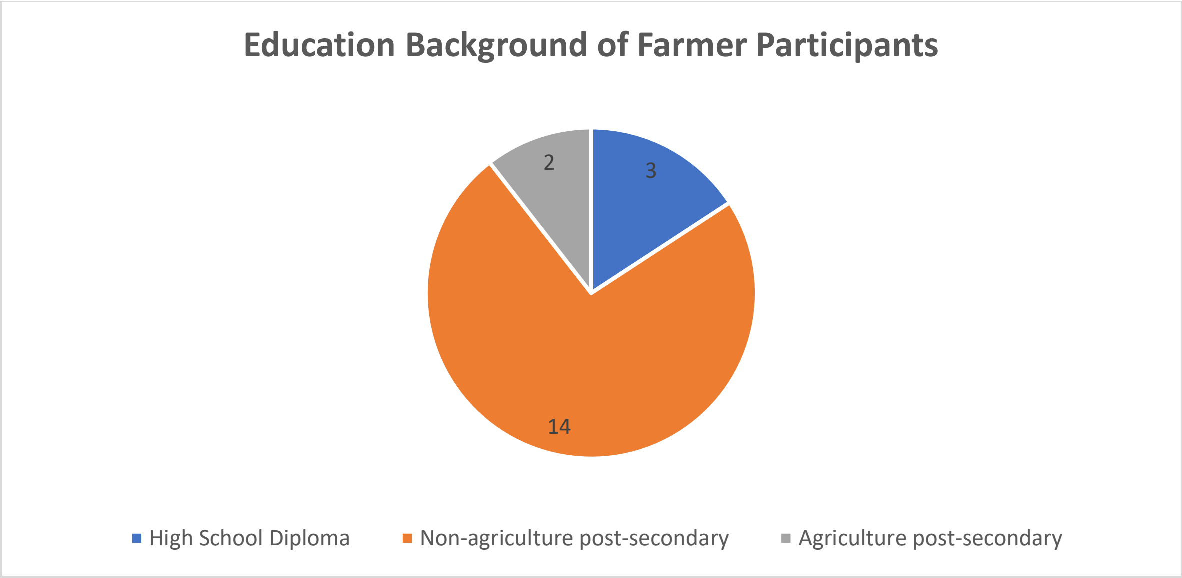


Table 4: Descriptive Characteristics of Farmer Participants

Farmers	Age	Income	Occupation	Educational Background	Adopted Clean Technology	Adopted Water Technology
Participant 1	36	50000-75000	Urban Farmer & Distributor	Non-Agriculture Degree	Yes	No
Participant 2	37	50000-75000	Farmer & Distributor	Non-Agriculture Degree	Yes	No
Participant 3	33	100000-125000	Farmer & Distributor	Non-Agriculture Degree	No	No
Participant 4	32	15000-30000	Farmer & Distributor	Non-Agriculture Degree	No	No
Participant 5	45	200000	Urban Farmer & Distributor	High School Diploma	Yes	No
Participant 6	38	10000-15000	Urban Farmer & Distributor	Non-Agriculture Degree	Yes	Yes
Participant 7	33	350000-375000	Farmer & Distributor	Non-Agriculture Degree	Yes	Yes
Participant 8	47	50000-75000	Farmer & Distributor	Non-Agriculture Degree	No	No
Participant 9	70	15000	Farmer & Distributor	Non-Agriculture Degree	No	No
Participant 10	32	25000-50000	Farmer & Distributor	Non-Agriculture Degree	No	No
Participant 18	22	Not Shared	Urban Farmer & Distributor	Agriculture degree	Yes	Yes
Participant 19	42	500000-525000	Farmer & Distributor	Non-Agriculture Degree	Yes	No
Participant 20	58	150000-175000	Farmer & Distributor	High School Diploma	Yes	No
Participant 21	62	75000-100000	Farmer & Distributor	Agriculture Degree	Yes	Yes

Participant 22	60	275000-300000	Farmer & Distributor	High School Diploma	Yes	Yes
Participant 23	55	10000-15000	Farmer & Distributor	Non-Agriculture Degree	No	No
Participant 24	N/A	Non-Profit	Urban Farming (Non-Profit)	Non-Agriculture Degree	Yes	Yes
Participant 25	42	Not Shared	Urban Farmer & Distributor	Non-Agriculture Degree	Yes	Yes

Although a diversity of individual characteristics and demographics was not actively sought, the presence of this diversity in the sample helped to reflect a variety of experiences and opinions around the sustainable water technology adoption phenomena and individual construals about the water issue. These experiences and opinions are analyzed in the subsequent sections to answer the research questions.

The study's research questions were: (1) Research Question 1 (*Why do some actively adopt water innovation/technology and others do not? What are the facilitator and hindrances to adoption, and how are the hindrances surmounted, if at all?)*, where the different facilitator and hindrances will be elaborated, and (2) Research Question 2 (*How do construal about water innovation/technology influence decisions to adopt, if at all?).* In the following exploratory analysis, we look at emergent themes arising in the response to these questions. We conclude by integrating the deductive sustainable technology adoption model with the inductive data collected during the study to strengthen the model.

Exploratory Analysis

This section will explore the research questions and address the factors responsible for the adoption decisions. These explorations were deduced based on an analysis of qualitative data from different stakeholders of the Canadian agri-food system.

RQ #1: What are the facilitators and hindrances to the adoption of climate-resilient water innovation, and how are the hindrances surmounted, if at all?

Past literature has shown that adoption of adoption intention depends on the perceived utility and ease of use of such water innovation. Here we describe background factors- (1) Individual, (2) Farm/Organizational, (3) Institutional, and (4) Technology that moderate perceived utility and ease of use of technology. Our semi-structured interviews with agri-food system participants asked questions on these factors to uncover their role as facilitators or barriers.

Facilitators

1. Individual Factor: Education

Participants of the study have both agriculture and non-agriculture educational backgrounds, we found that educational background can play facilitating role in adoption intention. The descriptive characteristics table (see table 3) shows that along with education there were other mixes of facilitators that could have influenced adoption decisions.

Table 5: Facilitator Education (Individual Factor)

EDUCATION		
Participant	Quote	Description
P1 (Urban Farmer)	*"…But then, I really don't mind me I'm not scared of changes so learning new technology and new tools…"*	Urban farmer is open to learning new technologies and tools for finding success.

P13 (Technology Provider)	*"We kind of highlighted this farming as a service platform is because we saw people were getting the farms not being able to run them. So, we've created a job board and we've built a network of farmers that we can send on site because it is a very niche profession, and not a lot of people know about it."*	Technology provider has started Farming as Service Platform to create a job network of farmers that know CEA. As it is often seen that farmer have adopted CEA but aren't able to run it.

The study found 2 underlying issues from the analysis of all participants- (1) Urban farmers that are more receptive to technology were more receptive to learning and educating others on water technologies, irrespective of their educational background, and (2) A technology provider found gaps in skills required to operate water innovations and sustainable technologies, so they started farming as a service to help provide critical human resource to run the farm.

2. Farm/Organization Factor: Farm Size

Our theoretical model shows that the farm/organizational factors include farm size, customer base or innovativeness of a stakeholder in the agri-food system. Past innovation adoption literature shows that farm size has a positive and significant impact on adoption intention. Traditional farmer participants expressed a similar facilitating role of farm size.

Table 6: Facilitator Farm Size (Farm Factors)

FARM SIZE		
Participant	Quote	Description

P4 (Traditional Farmer)	*"Because I am renting a small piece of land so those kinds of things so similarly some kind of future technology related to agriculture, but most likely be a large capital cost, and that would rule it out, for me, using it."*	Farmer fell that because he is renting a small piece of land so some futuristic technology with large capital cost is out of question.
P1 (Urban Farmer)	*"We don't require that much space, and the plant itself were small. So, it's ideal, it's our ideal for urban farming."*	Urban farmer doesn't feel space or farm size as a constraint as urban farming doesn't require much space.
P18 (Urban Farmer)	*"Because we have a higher sample size. We can test more. we can, we can try out different systems"*	Urban farmer feels that larger size allows for more experimentation and different technologies.

However, the urban farmer participants didn't feel that the space or size of their farming operation became a barrier in their adoption decision. These farmers feel that larger systems will allow them more space for experimentation and trying new technology. With respect to water innovation adoption, the study found new dimensions/factors- (1) Land Characteristics and (2) Location of Urban Farm, at that farm level that influence adoption intention of farmers participants.

Land and soil characteristics in terms of the natural topography, soil profile, and water holding capacity are dimensions that influence the adoption intention of farmers' participants. Therefore, any new water innovation technology needs to address and meet the needs of local land/soil characteristics.

Table 7: Land/Soil Characteristics

LAND/SOIL CHARACTERISTICS		
Participant	Quote	Description
P10 (Traditional Farmer)	*"…so my land here is very shallow I have maybe a foot or two until you hit straight limestone bedrock. So that doesn't give you a lot of kind of between growing roots space or vegetables and just kind of sponge capacity to hold water in that way so that was a factor for both growing challenge..."*	Farmer feels that his soil is very shallow with poor root growing space and water holding capacity. Thus, creating a challenge to grow and impacting his irrigation technology adoption choice.
P2 (Traditional Farmer)	*"You try to work with the natural topography so sometimes you know the best, the best approach to either the installation, or, or the use of a particular strategy or piece of technology use is partially dictated by topography, point of water departure to come up with effective strategy. But yeah, the placement and sort of the relative distance between all the different facets of farm is always in consideration."*	Farmer feels that in irrigation system and technology one needs to work with natural topography and come with an effective strategy with respect to that.

For urban farming, the location of the farm plays a significant role for adoption decisions. Participants have shared that localization for food and reduction of resource use is only possible if the location of these urban farms fitted with climate-resilient water innovation is as close to a customer as possible. But there are challenges in having such a location in urban/city areas. Therefore, it is fair to conclude location of an urban farm relative to the city/city center acts as a facilitator to the adoption of technology.

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Table 8: Location of Urban Farm

LOCATION OF URBAN FARM		
Participant	Quote	Description
P12 (Technology Provider)	*"…commercially grown hydroponic produce that is generally able to be grown closer to the end consumer. In our case, it's grown right in the community that eliminates a massive amount of the resources that are required…"*	Technology provider expresses that CEA is grown directly around community, that is closer to the end consumer, so that produce can be produced with least resources.
P16 (Technology Provider)	"*So one of the challenges is If you want to put a vertical farm in the middle of a city center. You can have a lot of hurdles to jump to get that approved by the city…."*	Location of an urban farm is around the city center that is a challenge.

3. Institutional Factor: Government Grants/Subsidies

Past literature on innovation adoption in the farming sector has shown that government has a positive and significant impact on adoption intentions. Our study shows that there is a mixed response with respect to the role of government in water technology adoption. The role of government can be either in the form of grants/subsidies or regulations.

The government subsidies/grants have a positive and significant influence on adoption intention. Certain participants have mentioned Quebec's green subsidy and grants have allowed them to adopt clean technologies. However, participants have also expressed concern with the sufficiency and targeting of government support towards such futuristic technologies.

Table 9: Facilitator Grant/Subsidies (Government Institution)

GOVERNMENT		
Participant	Quote	Description
GRANTS/SUBSIDIES		
P14 (Technology Provider)	*"I mean there's already lots of government programs and funding and grants and, you know, things like that, to support ag tech development, for the most part, so there's like the [st dc?] grant, I believe, where I think it's, you know, a quarter, it's $100,000 or a quarter of a million dollars for companies that are trying to create some sort of, you know, greener technology or greener product."*	Technology provider feels that there are lots of government programs that provide grants to create green products and technology.
P17 (Technology Provider)	*"We've had $0 in government support promoting this…in terms of you know Grants subsidies Things like that I think I*	Technology provider feels that government grants and subsidies

	generally think that government is so bureaucratic without the proper individuals to manage these projects that it's falling by the wayside."	have been zero supportive to his firm.

4. Institutional Factor: Farming Associations/Network

Participants have shared a positive experience and facilitating role of farmer associations and networks. As such associations allow them to get news ideas and inspirations, learning resources and knowledge sharing. A participant has also used such associations and networks to share and rent technology to offset the large capital cost.

Table 10: Facilitator Farming Association/Network (Institution)

FARMING ASSOCIATION/NETWORK		
Participant	Quote	Description
P1 (Urban Farmer)	"*And you know what's important to us to have a good network. if you have a lot of people surrounding you….I think having good network talked to a lot of people will get you inspired will give you the right ideas the right tools to be even more efficient."*	Farmer feels that having a good network helps us talk to right people and get right ideas to be more efficient.
P6 (Urban Farmer)	*"So there are some other micro green businesses that have put together, you know, classes or, you know, basically it's*	Farmer feels that an Urban farming community is very helpful that

	like a whole class on how to learn how to improve your setup and who to market and how to market, how to grow and basically that was there are a lot of resources and then there's also a lot of like how to videos and how to grow them different kinds of seeds, different kinds of plants that we do try to grow. So there is a lot of resources and it's a it's a pretty helpful community to be a part of."	provides a lot of resources, classes and videos to learn and improve.
P4 (Traditional Farmer)	*"Yeah! I think it would be the organization that I rent from if they had access to that technology my role would be to pay rent to help offset that capital costs."*	Farmer rents technology through his association/organization to offset the capital cost.

5. Institutional Factor: Education Service

Past literature shows that education and training programs can influence ease of use and perceived utility of any technology. This was particularly seen with respect to sustainable water innovations, where technology provider participants specifically focused on education while selling their technology.

Table 11: Facilitator Education (Institutional Factors)

EDUCATION

Participant	Quote	Description
P12 (Technology Provider)	*"…But once we explain the training program we have and how much we like spend time with them and invest them and teach them, then that concern is generally put at ease."*	Technology provider feels overwhelmed by the CEA. But training program helps ease their concerns put to ease.
F16 (Technology Provider)	"*We've kind of mitigated [ease of learning and operating] that is first of all we operate our farms as training facilities. We do offer like, I say, college courses through local colleges and high schools as well. And then we also have an online learning platform pulled up with a university. And this is like an online course. So you can enroll in and learn everything from, you know, just basic hydroponics all the way up to marketing your product or modeling your business. And these are some of the tools that we use to educate."*	Technology provider feels that ease of learning and operating is mitigated by training and online course that are tools for education.

6. Technology Factor: Sustainable Water Innovation Feature

The study found various facilitators to sustainable water technology adoptions, namely- (1) Allows control of the process (2) Better productivity and time efficiency, (3) Speeds up growth of produce, (4) Allows localization of production, (5) Better nutrient content and (6) Produce food all year round.

Table 11: Facilitators Technology Features (Technology Factors)

Participant	Quote	Description
P18	*"As a farming system maximize control. So be able to control all the nutrients that go in and out and know what nutrients you know, are actually in the water, and then being able to, you know, give the plant exactly what it needs at all times."*	Technology could maximize control of supply of exact amount of nutrients and water.
P16 (Urban Farmer)	*"But my yield per square meter is significantly higher, because I have more plants per square meter because of that system, and they need to evaluate that return on an investment...that improvement in labor efficiency. you know that sustainability factor must be proven"*	CEA allows higher yield per unit area, return on investment, and improves and labor efficiency.
F6 (Urban Farmer)	*"I think time like can it [technology] speed it up, can it make it grow faster is it*	CEA allows for faster growth of plants.

	better for the plants I think I would have to put that in consideration"	
F12 (Technology Provider)	"*We generally focus on the benefit that local produce provides. So it's much fresher. You like you know I'm sure you're aware of this but like, you know, the longer it is from the time something was harvested to when you eat it. You're constantly losing nutrients."*	Urban CEA allows for local fresh produce with higher nutritional value.

Barriers/Hindrances

1. *Individual Factor: Income*

Various participants have mentioned cost/capital/budget as a major individual constraint to adopting or upgrading to new water technology. As sustainable water technologies are capital intensive, the income factor could become a major barrier to adoption decisions. The descriptive characteristics table (see table 3) shows that along with income there were other mixes of facilitators that could have influenced adoption decisions.

Table 12: Income (Individual Factors) Barrier

INCOME		
Participant	Quote	Description
P8 (Traditional Farmer)	*"Because of the budget restraints, obviously we are trying to keep it [technology] fairly simple"*	Farmer feels that budget is responsible for him not buying new technology and keeping it simple.

P3 (Traditional Farmer)	*"We use small sprinklers, and we don't use the big cannon sprinklers. Well, mainly because we didn't have the money to buy it…."*	Farmer doesn't have the money to buy bigger technology.
P12 (Technology Provider)	*"Yeah, cost is definitely prohibitive, for a lot of potential customers it's an expensive product to buy and not everyone has the money to be able to pay for it"*	Technology provider feels that cost is a big factor that makes customers reluctant to buy new technologies.

2. *Individual Factor: Age*

Past literature had shown a negative relationship between age and adoption decisions. Younger farmers are more inclined to adopt new technologies than older farmers. Our participants in the study have expressed the same. According to them, the age of an adaptor has a relationship with risk appetite and receptiveness to innovation. Thus, water innovations having an element of risk and potential of change, the older generation are aversive to it compared to younger generations.

Table 13: Age (Individual Factors) Barrier

AGE		
Participant	Quote	Description
P15 (Technology Provider)	*"I think the agriculture industry is at a point where there are a lot of older people. When you start talking about newer technology and hydroponics and everything, it's hard to get people to*	Technology provider feels that agriculture industry has a lot of old people, who have a tough time switching to new technologies.

	switch from their ways to something more, different, and innovative and, right because it's scary to them"	
P12 (Technology Provider)	*"I would say the main theme that we've seen is the like older generation like the parent farmers if you will. They are generally a bit more like risk-averse and they're not as comfortable with taking it on. But oftentimes we've found good success with like the children of the farmers who are coming up and running the business with their parents. They're a lot more receptive and open to the idea."*	Technology provider feels that older farmers are risk aversive but the their younger generations are lot more open to new technologies.

3. Institutional Factor: Government Regulations

Past literature on innovation adoption in the farming sector has shown that government has a significant impact on adoption intentions. The study shows that the government through its regulation function at the federal, provincial, and municipal levels is negatively influencing adoption intention. Various participants have highlighted the negative impact in terms of outdated building codes and agriculture zoning policies for urban farmers and organic food regulations, where only soil grown is considered organic.

Table 14: Regulations (Institutional Factors) Barrier

GOVERNMENT

Participant	Quote	Description
REGULATION		
F12 (Technology Provider)	*"They still have a requirement that for produce to be considered organic it has to be grown in soil. Everything we use like all the inputs are organic the nutrients the rock will everything is all organic, but it's not grown in soil, it can't be marketed as Canadian organic produce can only be marketed as USDA organic."*	Technology Provider feels that government regulation like only soil grown is organic is counter-productive.
P17 (Technology Provider)	*"I think Canada's really lacking is on the maybe the public policy side i.e. municipal policy side. so, when it comes to things like building code. you know, zoning you know, taxing a dot adoption in that sense we're very behind….there are a lot of benefits to being zoned agricultural in the country. You don't get those benefits in an urban city center, because you're not zoned agricultural, and you never will be."*	Technology provider feels that municipal regulations related to building code and zoning is way behind. Zoning regulations is a major barrier is setting up a urban farm is the city center.

Farmer participants raised 2 new dimensions within the government institutions that have significant negative influence towards sustainable technology adoption- (1) Farmer Size, and (2) Inter-Province Variation. Government support seem to vary in terms of farm size and province the stakeholder resides, which leads to variability in sustainable water technology adoption decisions.

Table 15: Farm Bias/Inter-provincial variation

FARM SIZE BIAS/INTER-PROVINCE VARIATION		
Participant	Quote	Description
P2 (Traditional Farmer)	*"...in Quebec, the provincial government in Quebec has historically and continues to be very supportive of small scale, agriculture, in particular, whereas in Ontario, they've been more interested, and I think this is true federally as well, but they've been more interested in supporting larger scale."*	Farmer feels that provinces have different focus. Quebec support small farmer and Ontario support large scale farmers.
P7 (Traditional Farmer)	*"One of the reasons that we're in Quebec is because of the government support for agriculture in general, and there is specific support for environmentally friendly programs, and we've already received some of that. this is something that we really have seen a contrast between the backend any of the other*	Farmer feels that Quebec provincial government is more supportive towards environment friendly programs compared to other provinces. The farmer believes that because of government support they are in Quebec.

	Canadian provinces, the amount of support that there is there's generally for agriculture, but specifically for example, that the automated irrigation system."	

4. Institutional Factors: Private Financial Sector

Past agri-food innovation literature has shown that finance is a major extension service and support in the agri-food system. But participants have highlighted a major gap in the availability of finance from the banking sector to agriculture, especially new innovations. One of the technology providers seeing finance as a barrier to adopting new water innovations has started a capital fund to bridge this gap. Participants feel that the traditional banking sector is elusive to this technological opportunity.

Table 16: Private Financial Institution (Institutional Factors) Barrier

PRIVATE FINANCIAL INSTITUTIONS		
Participant	Quote	Description
P1 (Urban Farmer)	*"I find micro green is actually something so new that even the bankers themselves have to teach them what it is and also maybe if I was doing something a little bit more Orthodox something a bit more that the year before maybe it would be actually easier, but since we're coming up with something super new that's almost we*	Urban farmer felt that banks don't understand something new, in terms of innovation. One has to teach them about such super new projects.

	have to teach them about before presenting a project"	
P8 (Traditional Farmer)	*"We tried looking for it with the Bank to lend me when I started but they gave me worse interest rates than normal institutions."*	Farmer felt that bank gave him the worse interest rate when he was starting his business. Also be
P13 (Technology Provider)	*"So a lot of bankers don't understand all of the logistics that go into opening a farm and running a farm, so it is still a little hard. We started a capital fund with our last investor as part of our third part of our business model. so, we've set aside a couple of million dollars. If people come to us with projects, and we help them find funding."*	Technology provider say serious gaps in the banking sector lending to urban farms so it started a capital fund with their last investor

5. *Technology Factor: Water in Technology Design*

Participants (farmers and technology providers) were asked about water in their technical design and adoption process during the semi-structured interview. Participants highlighted that water wasn't the core factor of innovations but a side benefit with non-dependence on weather and a reduction in the use of resources to grow food. As the participants are part of the Canadian Agri-food system where water is considered an externality, so water is not the primary consideration for designing technology or later adopting it.

Table 16: Water in Technology Design

Participant	Quote	Description
P17 (Technology Provider)	*"The consideration of water was not the main consideration. The main consideration was energy efficiency, and proximity to customers."*	Innovation primary focus was energy efficiency and proximity to customer rather than water.
P6 (Urban Farmer)	*", the way we think about it anyways is not necessarily that like the water is core to the innovation. For us, we initially got into business more for like the accessibility to fresh food…."*	Water was not the core of innovation. Accessibility to fresh food, especially to remote locations was the focus.
P16 (Technology Provider)	*"…as going indoors into like a warehouse farm is just you know they're you're eliminating the seasonality of it. I would say necessarily specific to the Zip Grow technology. that's specific to controlled environment agriculture, and that's often what leads a lot of customers to us in the first place is they're looking to get away from weather being the limiting factor to the production system."*	Core of innovation was getting away for weather being the limiting factor in production. Thus, making water a subsidiary benefit.

6. Technology Factor: Sustainable Water Innovation Problems

The study has found participants mention various barriers to water technology, namely- (1) Technology is not universal to all products but more product specific, (2) Functional Old Technology, (3) Quality of produce, (4) Soil grown to be organic, and (5) Possibility of failure and problems in the whole system. These technology barriers cause participants' hindrance in understanding the perceived utility of a such new technologies.

Table 17: Technology features (Technology Factors) Barrier

Participant	Quote	Description
P1 (Urban Farmer)	*"If I want to water all my different type of plants at the same time, they all require different amounts of water, so this is why it makes it difficult because we decided to choose so many different products, and I think it's still the right way to go. But that's why we can't really have that automatic for because they're not really they're all different. They're all like human beings, they're all different."*	Newer water technologies are universal to produces that address water needs of crops differently.
P11 (Retail)	*"And yeah, we, we don't change easily. We just usually keep a try to keep the old technology. It's hard to make this switch, because then what do you do with the old…sell it?"*	Farmer wants to keep old technology and it is hard to change or sell it.

P11 (Retail)	*"There isn't a reliable supply from hydroponics there was, there's a local business that was trying to do aquaculture. They have their produce is very fragile and we have issues with holding for more than a day or two, like with it maintaining its freshness and our ability to sell it."*	Reliability of supply and quality with new technology is problematic.
P8 (Traditional Farmer)	*"If you don't have soil, that is micro-nutrients, then everything that plant health and quality is not that good."*	Soil is micro-nutrient, and it is important for quality
P15 (Technology Provider)	*"As much as it is easier you are adding more components for a mistake or failure. Drippers don't work, the lines clog, timer goes off."*	System has too many components with a possibility of failure.

Emergent Factors: Sustainability Ethos

The study found that participants had expressed an emergent factor for adoption or non-adoption of new technologies. These are the larger organizational/business ethos around sustainability and the environment expressed by various stakeholders of the Canadian agri-food system. These ethos and values are part of the farmer or business that broaden the socio-environmental considerations resulting to mixed response around sustainable water technology adoptions.

Table 18: Sustainability Ethos Factor

Participant	Quote	Description
P1 (Urban Farmer)	*"We are, we are working like that for a reason, and we have a lot of values around this business. And I find that we're working with, with pride you know so we want to do things properly, and we want to do things, fair for the environment and safer for everybody as well"*	Farmer has values around his business and wants to do things properly, which are fair to the environment and safter to everybody
P4 (Traditional Farmer)	*"One is that as organic farmers I think that we really see soil-based farming and soil health as one the sort of like primary motivators and something that's essential for production. And that's part of the sort of like environmental work that we're doing."*	Soil based farming and soil health is the primary motivator. This for the farmer is part of environmental work.
P15 (Technology Provider)	*"But we generally find that for most of our customers' sustainability isn't necessarily the number one driver in them making a purchasing decision. I'd say it's one of the, you know, one of the two or three like second tier factors that kind of helps them make a decision."*	According to a technology provider, sustainability is not the primary criteria for innovation adoption but that is secondary or tertiary.

P11 (Retail)	"We definitely share that information [with customers] we have a newsletter; we have social media. We share information on what our company does about our partners do that has an environmental benefit, and why organic farming is good for you carbon emission offset and all those different things. That's a big part of who we are and what we do."	Retail business owner has a newsletter, where she shares all the environmental benefits with the customers. This is big part of what they do.
P4 (Traditional Farmer)	*"I don't have intentions to expand or adopt new technology I want to continue doing what I'm doing, because I think that small-scale agriculture itself with less machinery with denser planting and more diverse planting, I think that itself is a more ancient form of technology that…"*	Farmer believes that ancient practices are a form of technology and wants to continue with that to converse biodiversity.

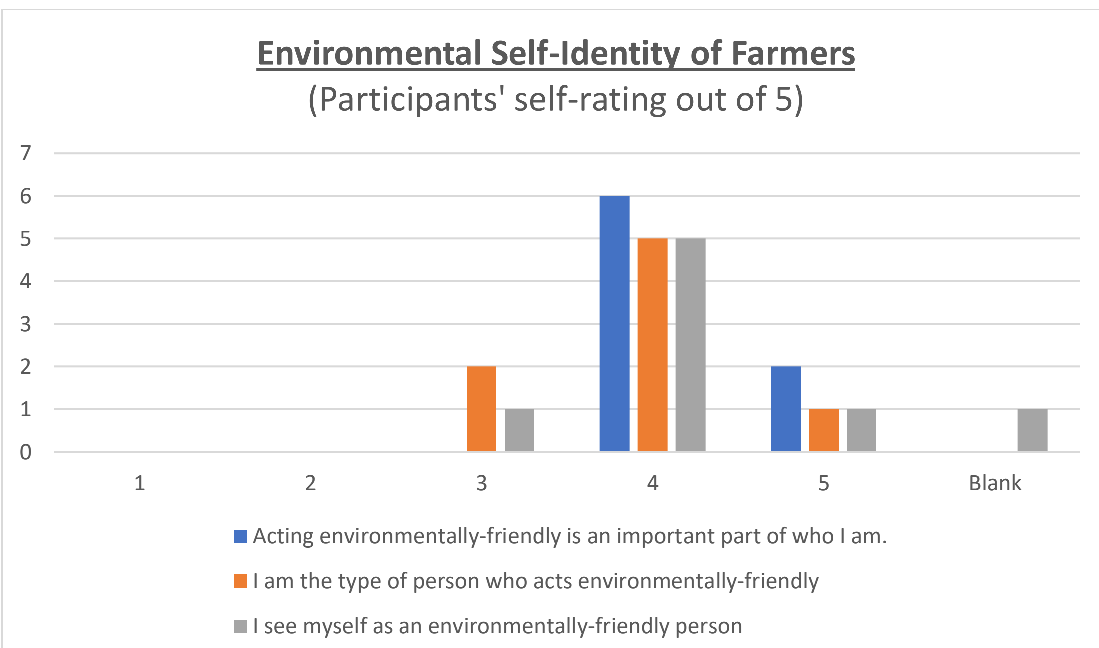
RQ#2: How do construals of farmers and technology providers about water innovation/technology influence decisions to adopt, if at all?

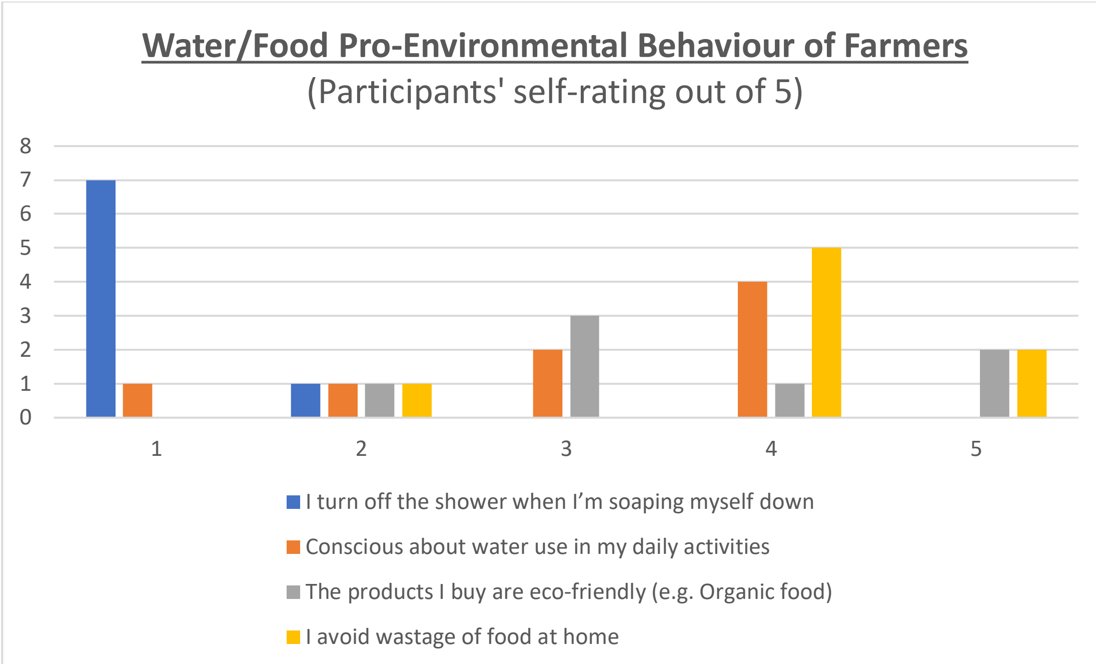
Past innovation literature shows that psychological factors that include attitude, subject norms and perceived behavioural control play a role in adoption decision-making. This study using the construal theory aims to understand the role of individual psychological construal in such decisions makings. To have a detailed understanding of this factor, data was collected through both questionnaires and interviews.

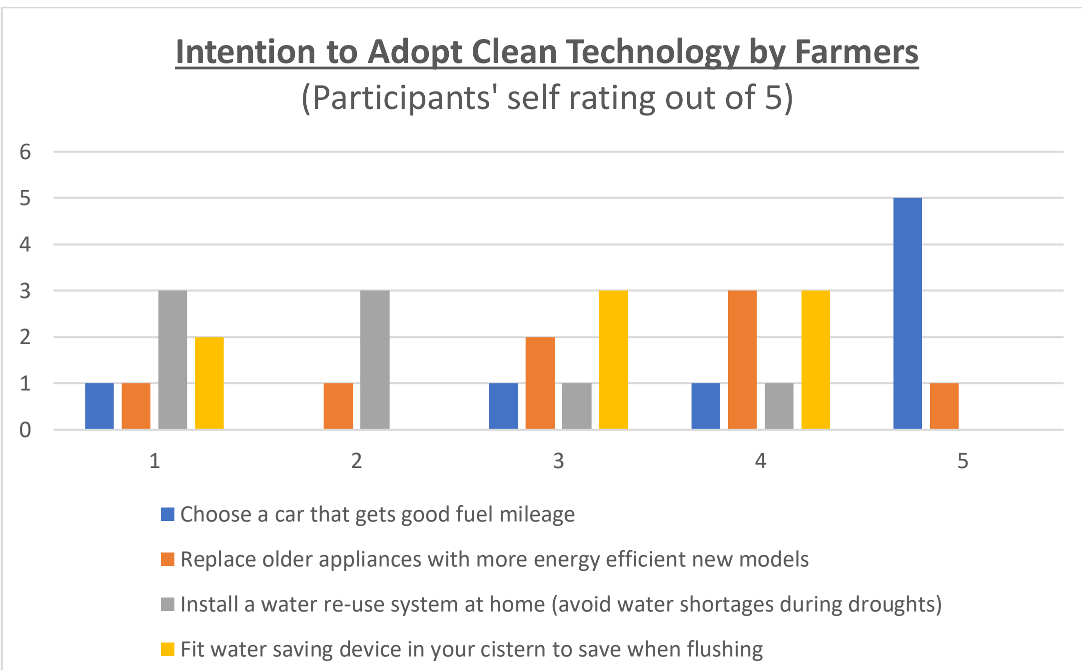
Descriptive

With respect to the questionnaire, the participants (farmers and technology providers) gave their rating (on Likert Scale) to identify their environmental self-identity (adopted from Brügger et. al., 2016), pro-environmental behavior (adopted from Griffioen. et. al., 2019), clean technology adoption intention (based on Brügger et. al., 2016), and global risk perception (based on Brügger et. al., 2016). Such data helped the study understand the individual and organizational differences that may prove relevant to their decisions.

Questionnaire Data of Farmers




Water/Food Pro-Environmental Behaviour of Farmers
(Participants' self-rating out of 5)
8
7
6
5
4
3
2
1
0
1
2
3
4
5
I turn off the shower when I'm soaping myself down
Conscious about water use in my daily activities
The products I buy are eco-friendly (e.g. Organic food)
I avoid wastage of food at home


Intention to Adopt Clean Technology by Farmers
(Participants' self rating out of 5)
6
5
4
3
2
1
0
1
2
3
4
5
Choose a car that gets good fuel mileage
Replace older appliances with more energy efficient new models
Install a water re-use system at home (avoid water shortages during droughts)
Fit water saving device in your cistern to save when flushing

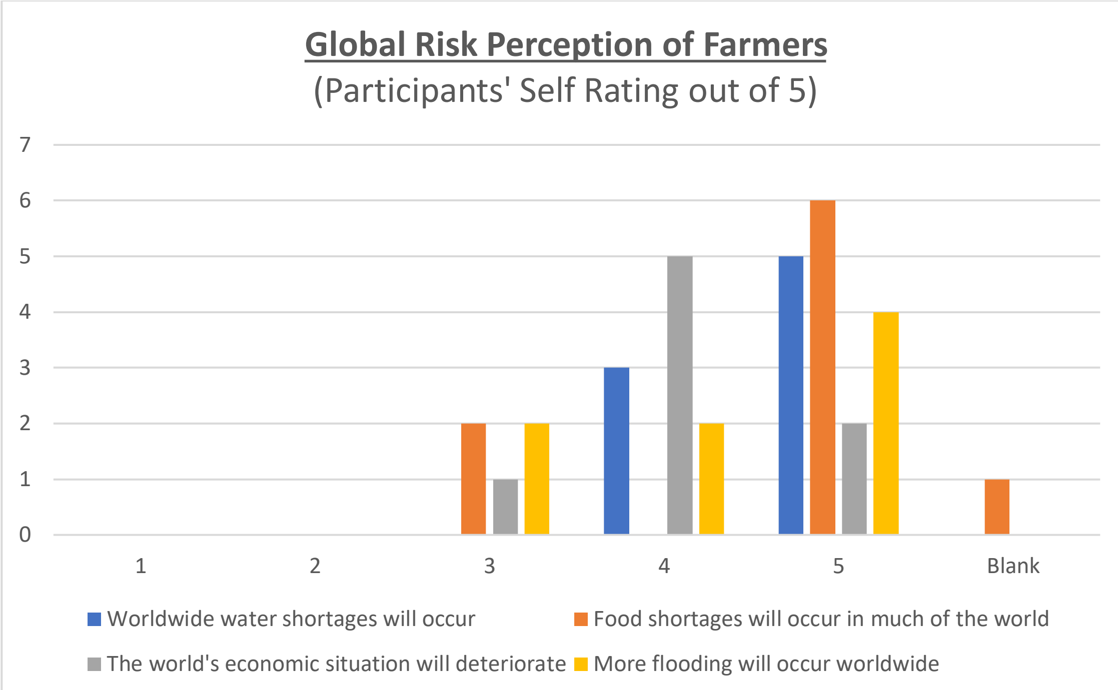
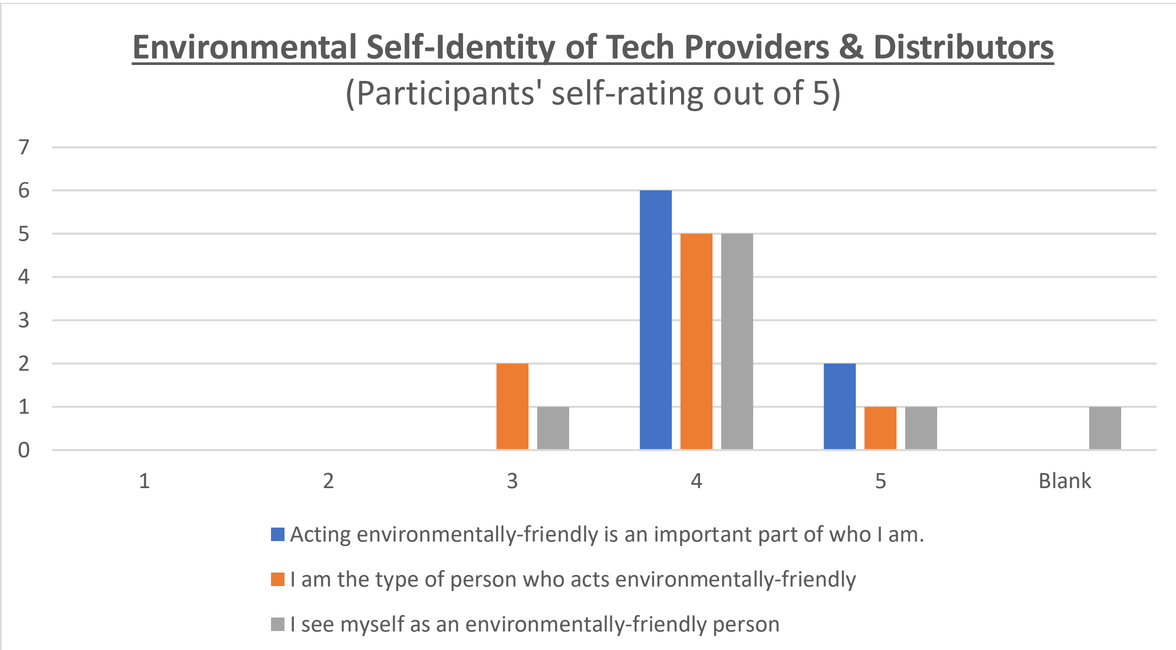


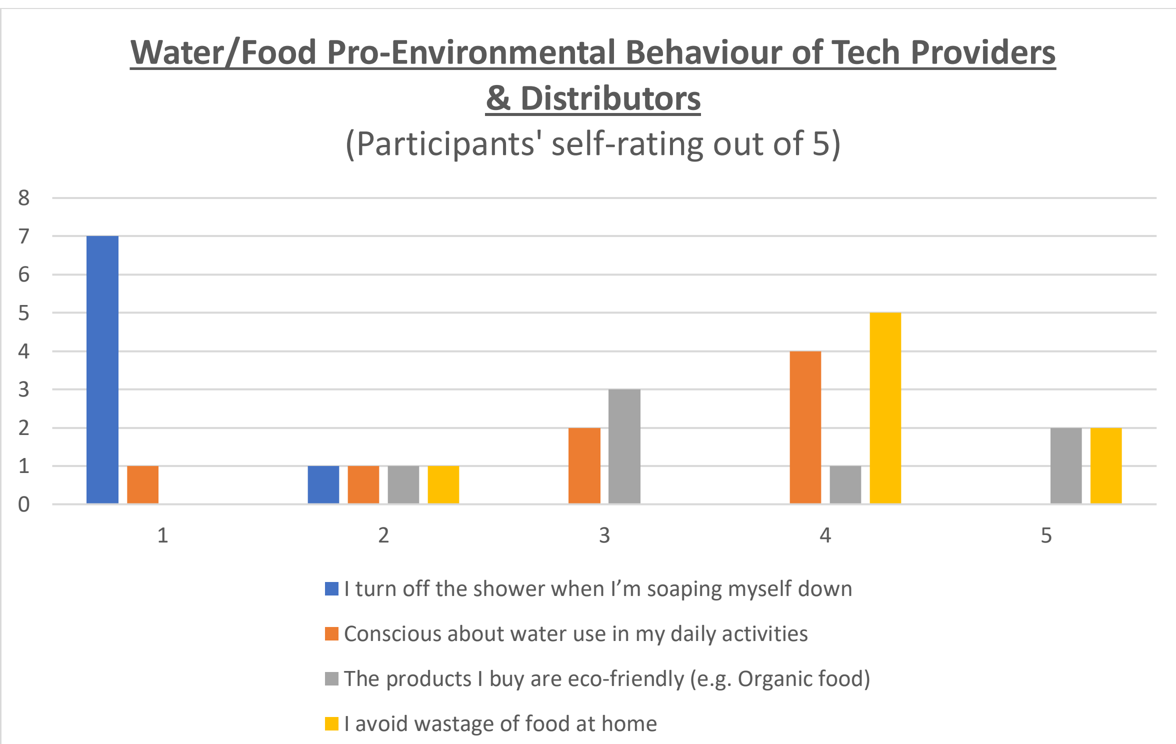
Table 19: Data Score of Farmers

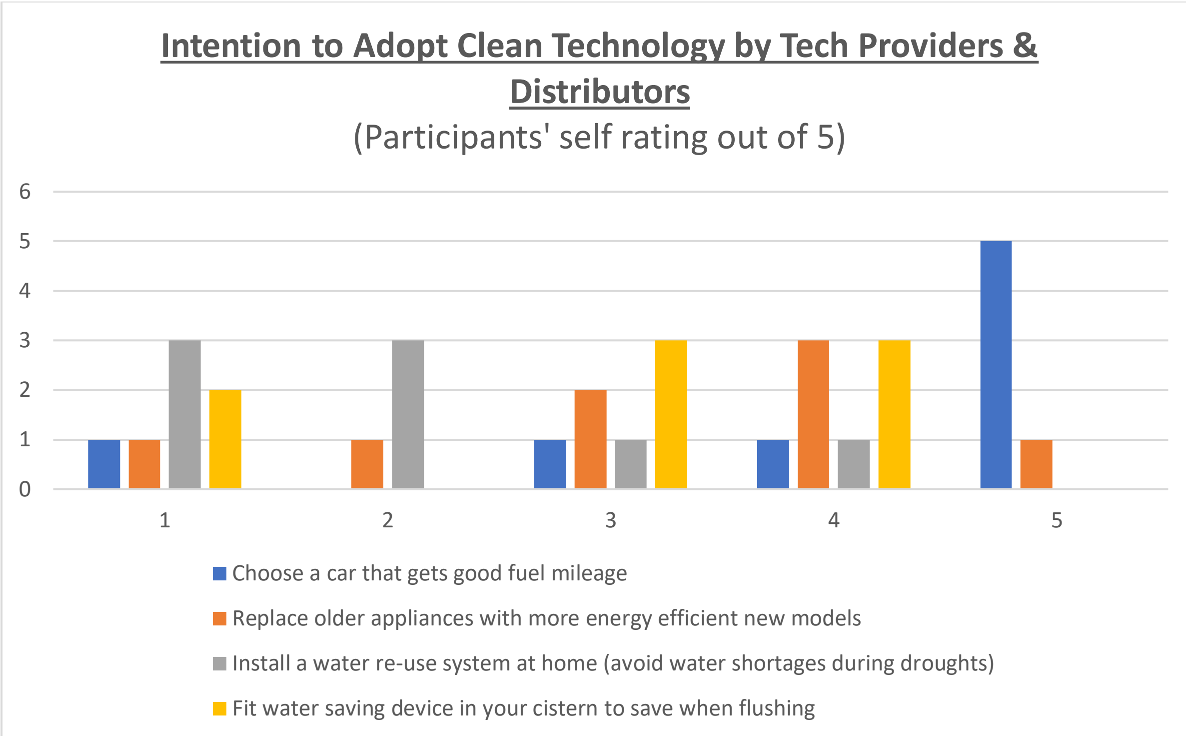
S.No.	Participants	Environmental Self-Identity (Average Likert Score)	Pro-environmental Behaviour (Average Likert Score)	Clean Technology Adoption Intention (Average Likert Scale)	Global Risk Perception (Average Likert Score)
1	Participant 2	5.00	4.75	4.50	5.00
2	Participant 21	3.66	3.25	2.75	4.75
3	Participant 4	4.33	3.25	2.00	4.75
4	Participant 22	4.00	3.25	2.50	3.75
5	Participant 8	5.00	4.50	3.00	5.00
6	Participant 20	5.00	2.75	4.00	3.25
7	Participant 6	4.33	2.50	4.00	4.50
8	Participant 26	5.00	3.50	4.25	5.00
9	Participant 1	4.33	3.25	3.25	4.00
10	Participant 19	5.00	5.00	5.00	5.00
11	Participant 3	5.00	3.50	2.00	5.00
12	Participant 5	4.33	2.25	1.75	4.75
13	Participant 10	5.00	3.75	2.75	4.75
14	Participant 7	4.00	3.00	2.75	5.00
15	Participant 23	5.00	5.00	5.00	4.75

16	Participant 24	4.00	4.25	3.00	3.00
17	Participant 9	4.00	2.50	2.00	3.25
AVERAGE		**4.5**	**3.5**	**3.2**	**4.44**

Questionnaire Data of Technology Providers






Intention to Adopt Clean Technology by Tech Providers & Distributors
(Participants' self rating out of 5)
6
5
4
3
2
1
0
1
2
3
4
5
Choose a car that gets good fuel mileage
Replace older appliances with more energy efficient new models
Install a water re-use system at home (avoid water shortages during droughts)
Fit water saving device in your cistern to save when flushing

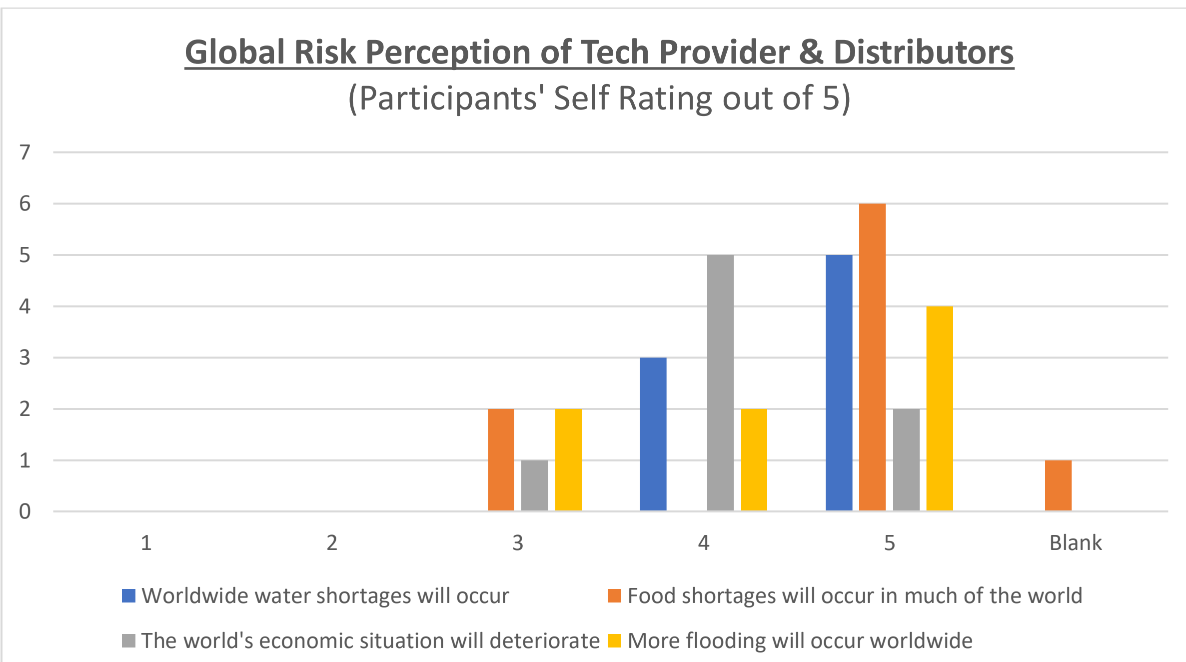

Global Risk Perception of Tech Provider & Distributors
(Participants' Self Rating out of 5)
7
6
5
4
3
2
1
0
1
2
3
4
5
Blank
Worldwide water shortages will occur
Food shortages will occur in much of the world
The world's economic situation will deteriorate
More flooding will occur worldwide

Table 20: Data Score of Technology Providers and Distributors

S.No.	Participants	Environmental Self-Identity (Average Likert Score)	Pro-environmental Behaviour (Average Likert Score)	Clean Technology Adoption Intention (Average Likert Scale)	Global Risk Perception (Average Likert Score)
1	Participant 11	4.00	3.75	3.75	3.75
2	Participant 12	2.33	2.75	3.50	4.75
3	Participant 13	4.00	3.50	2.50	4.00
4	Participant 18	4.00	2.75	2.00	4.75
5	Participant 17	3.33	1.50	2.00	5.00
6	Participant 15	4.33	2.75	3.75	3.25
7	Participant 14	5.00	3.00	3.75	5.00
8	Participant 16	4.00	4.75	3.25	4.50
AVERAGE		**3.87**	**3.09**	**3.06**	**4.37**

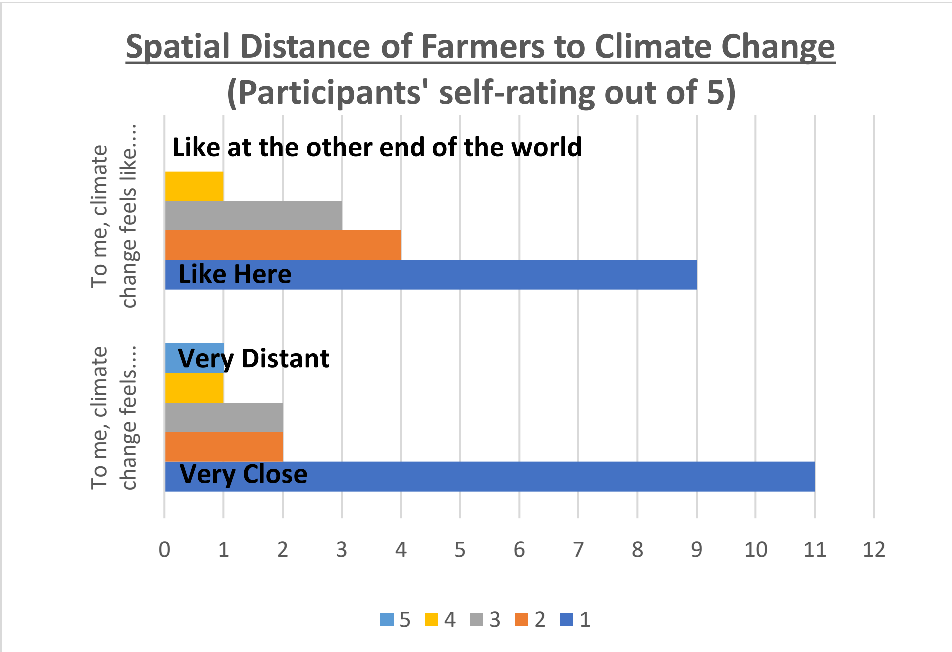
Individual construals of farmers, technology providers and food distributors allowed the study to uncover the full perspective on environmental, social, technology and economic questions within the agri-food system. Comparing the mean average of both the category of participants (Farmers & Tech Providers/distributors) show a similar understanding and construals around clean technology adoption and global risk perception at an individual level. However, both have a different psychological understanding of environmental-self-identity and environmental self-identity with farmer participants showing more proximity to it compared to technology providers or distributors.

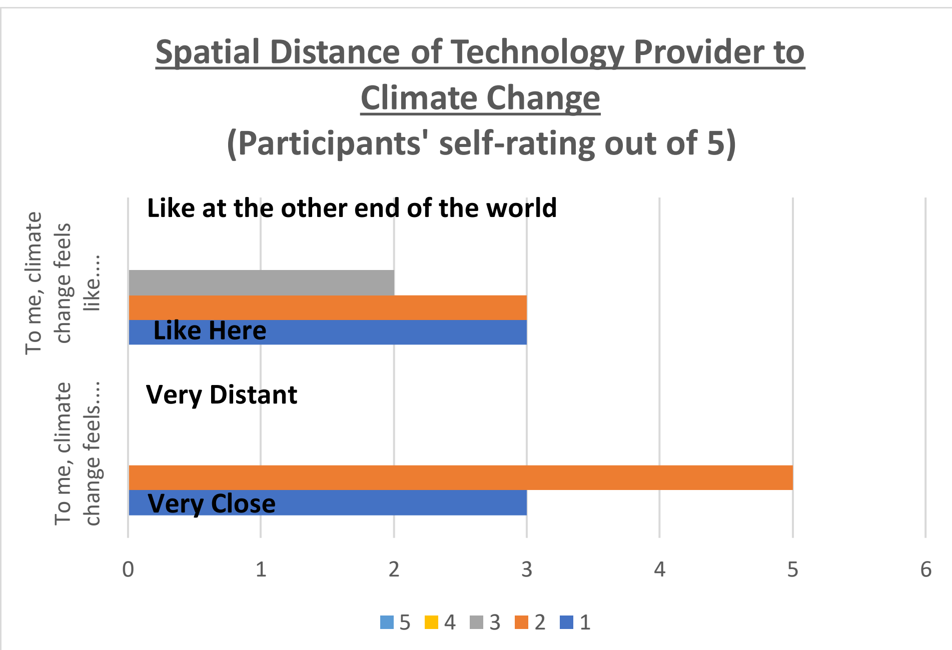
Descriptive: Construals around Climate Change

Using questionnaire surveys with farmer and technology provider participants, we recorded the construals around climate change (based on Brügger et. al., 2016). These construals were measured around the spatial, temporal, social and psychological distance to give a better understanding of food system participants' individual perceptions of climate change.\

Spatial Distance

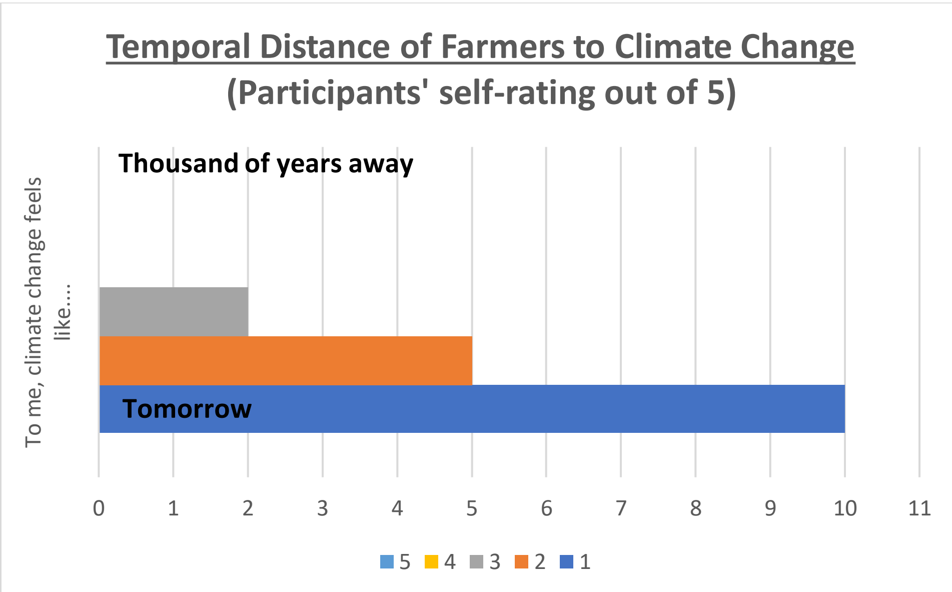
Canadian farmers' participants and technology providers have similar spatial distance to climate change, that is they feel that climate change is very close and here

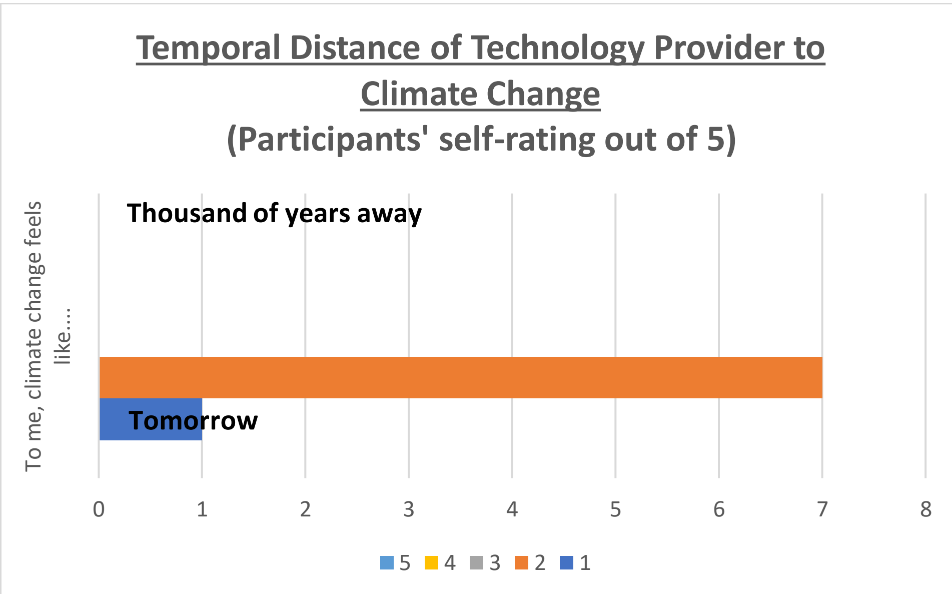




Temporal Distance

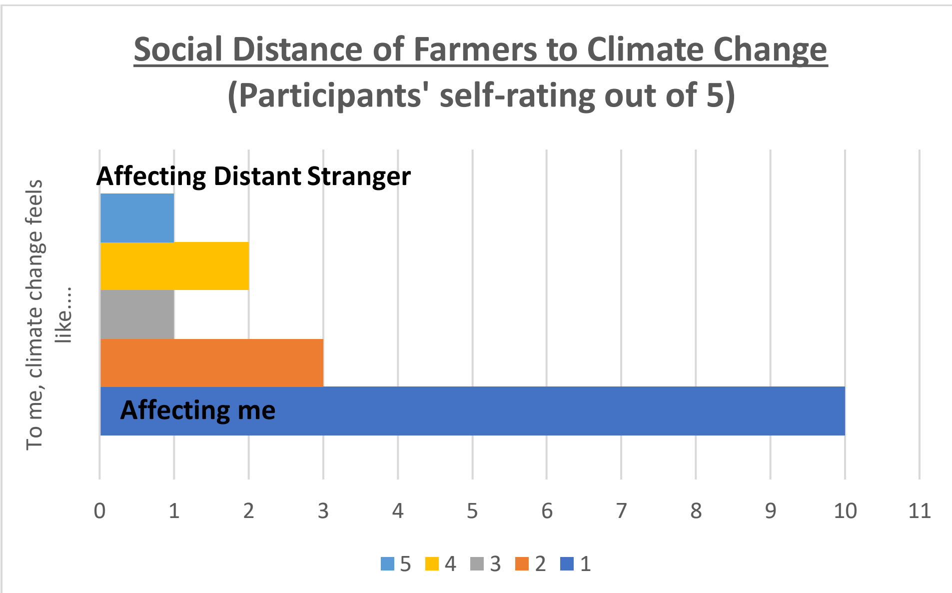
Canadian farmers' participants and technology providers have a similar temporal distance to climate change, that is they feel that climate change is going to take place in the very near future (tomorrow).

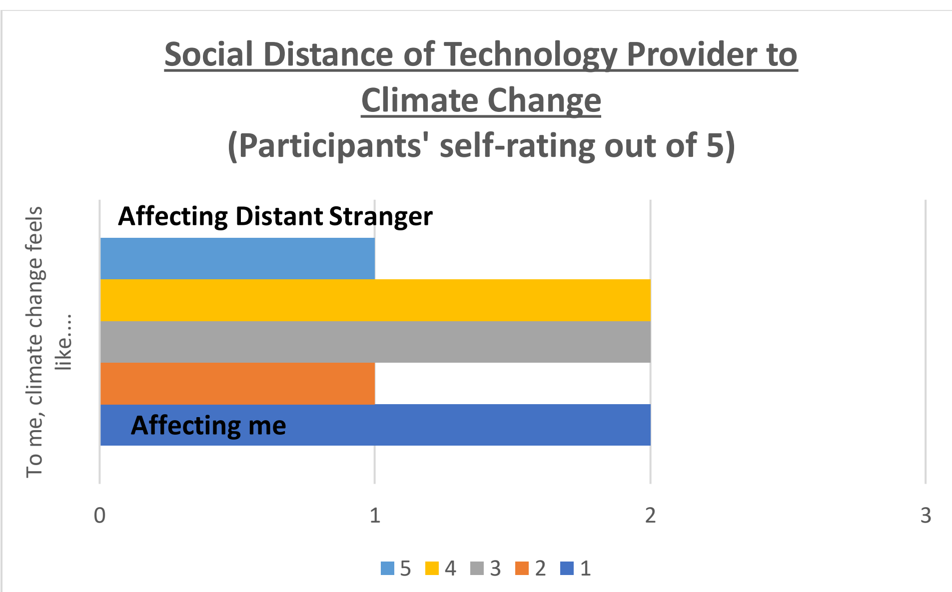




Social Distance

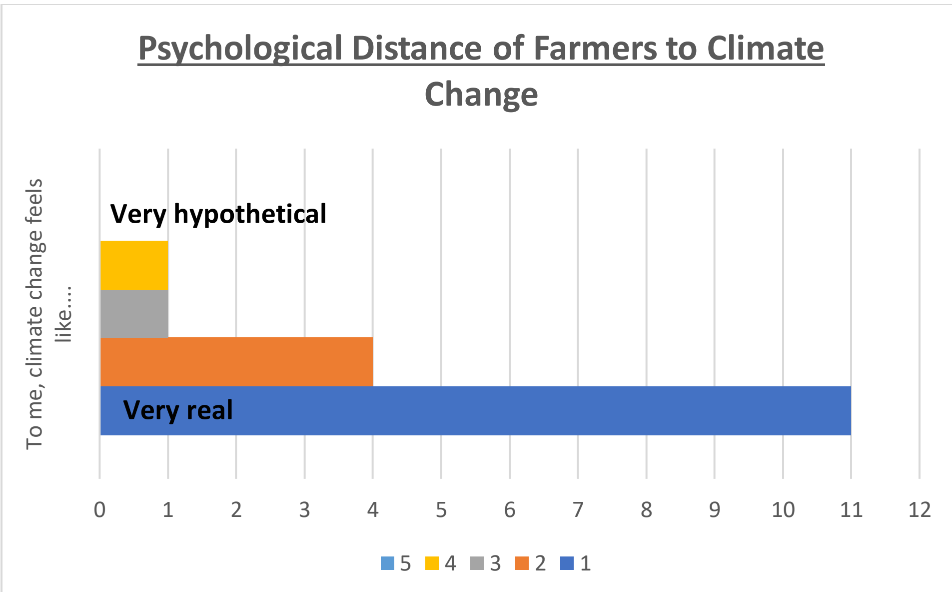
Canadian farmers' participants and technology providers have a varied social distance to climate change, that is they feel that climate change is a socially an important topic for them. The difference in construals among tech providers and farmers shows that the issue of climate change does not have a uniform social impact and concern. Surprisingly, most farmer participants feel that climate change will directly impact them.

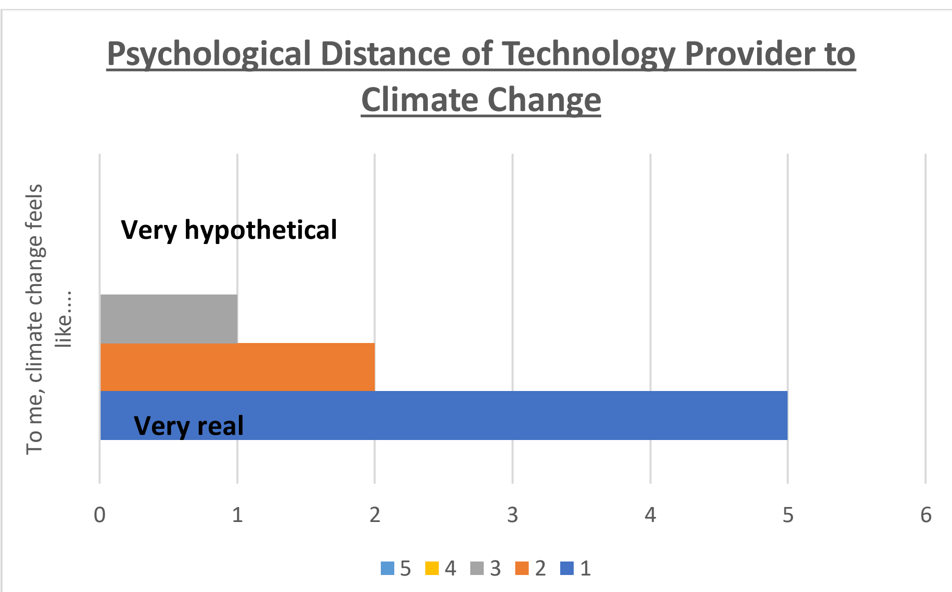




Psychological Distance

Canadian farmers' participants and technology providers have a similar psychological distance to climate change, that is they feel that climate change is very real and happening around them.





Full Name	Spatial Distance to Climate Change	Temporal Distance to Climate Change	Social Distance to Climate Change	Psychological Distance to Climate Change	Clean Technology Adoption Intention (Average Likert Scale)
Participant 2	1 (Very Close & Here)	1 (Tomorrow)	1 (Affecting me)	1 (Very Real)	4.50
Participant 21	4 (Distant)	2 (Soon)	5 (Affecting distant strangers)	4 (Hypothetical)	2.75
Participant 4	3 (Neutral)	3 (Normal)	3 (Neutral)	2 (Real)	2.00
Participant 22	1 (Very Close & Here)	2 (Soon)	2 (Sometimes Affects me)	2 (Real)	2.50
Participant 8	1 (Very Close & Here)	1 (Tomorrow)	1 (Affecting me)	1 (Very Real)	3.00
Participant 20	3 (Neutral)	3 (Normal)	4 (Affecting people around me)	3 (Neutral)	4.00
Participant 6	1 (Very Close & Here)	2 (Soon)	1 (Affecting me)	1 (Very Real)	4.00
Participant 1	1 (Very Close & Here)	1 (Tomorrow)	2 (Sometimes Affects me)	1 (Very Real)	3.25
Participant 19	1 (Very Close & Here)	1 (Tomorrow)	1 (Affecting me)	1 (Very Real)	5.00
Participant 3	2 (Close & Here)	2 (Soon)	4 (Affecting people around me)	2 (Real)	2.00
Participant 5	5 (Very Distant & Far)	1 (Tomorrow)	1 (Affecting me)	1 (Very Real)	1.75

Participant 10	1 (Very Close & Here)	1 (Tomorrow)	1 (Affecting me)	1 (Very Real)	2.75
Participant 7	1 (Very Close & Here)	1 (Tomorrow)	1 (Affecting me)	1 (Very Real)	2.75
Participant 23	1 (Very Close & Here)	1 (Tomorrow)	1 (Affecting me)	1 (Very Real)	5.00
Participant 24	2 (Close & Here)	2 (Soon)	2 (Sometimes Affects me)	2 (Real)	3.00
Participant 9	1 (Very Close & Here)	1 (Tomorrow)	1 (Affecting me)	1 (Very Real)	2.00
MEAN SCORE	**1.81**	**1.56**	**1.93**	**1.56**	**3.14**

Examining the relationship between construals and clean technology adoption (See the table above) shows some connections. There are farmer participants with high construals and have the intention to adopt clean technology. But there seem to be certain outliers too, which will require further inquiry.

<u>Exploratory Analysis</u>

Additionally, the participants were asked questions in the interview related to water issues and water innovation to assess the different types of construal distance, namely- (1) Temporal, (2) Spatial, (3) Social and (4) Psychological, with respect to water among the stakeholders of Canadian agri-food system. This is important as this deeper information filtration process analyses the construal object/distance and manifest in strategic decisions (Steinbach et. al., 2019).

Temporal Construal Distance

Presently, the Temporal construal of the Canadian agri-food system's participant with respect to water issues is optimistic due to the excess availability of water resources. But many noticed changes and sounded caution about a future likelihood of a water crisis in Canada. They feel this can be attributable to water consumption habits, droughts, heat waves, pollution, or climate change. Technology provider participants see this future water crisis as an opportunity to make necessary changes in water-efficient technologies that could ensure food security within the food system.

Table 21: Temporal Construal Distance Statements

TEMPORAL CONSTRUAL DISTANCE		
Participant	Quote	Description
P1 (Urban Farmer)	*"it's [Water Crisis in Future] a problem, I mean it's going to happen I'm pretty sure we're fortunate enough that we live in Canada is surrounded by water. We don't have it, which maybe it's a problem right now but we don't, if we use, we could use the amount of water we want, we're not paying for it right so I could see that that would become eventually a challenge, especially that we're not train to behave, to being careful about the water consumption that we're using."*	Farmer feels that Canada is surrounded with water, but water crisis is possible if we continue to main the status-quo on the usage and methods.

P19 (Traditional Farmer)	*"But here, locally in Canada, I think we are and have been experiencing changes, and the prairies are obviously more susceptible to severe drought. But I think it's an ongoing threat you know it's not something that's going to happen necessarily in 5 years or in 10 years."*	Farmer feels that water crisis will happen in Canada in next 5 or 10 years and the signals of change are being experienced.
F4 (Traditional Farmer)	*"I would like to be optimistic, but it [water crisis] seems fairly likely, either because of Climate change Or, like you, like the commodification of water and pollution."*	Farmer wants to optimistic, but the water crisis is fairly likely because of climate change, commodification of water.

Spatial Construal Distance

Generally, participants of the Canadian food system have expressed that Canada is blessed with abundant freshwater resources, with the exception to certain northern communities and First Nations people. A participant also pointed out that water resource is concentrated in certain geographical regions of Canada, for example, great lakes or lakes in Manitoba, that the participants don't have access to. However, the participants are also witnessing water issues in their spatial vicinity in terms of the seasonality of water supply, water pollution and lake drying.

Table 22: Spatial Construal Distance Statements

SPATIAL CONSTRUAL DISTANCE		
Participant	Quote	Description

P1 (Urban Farmer)	*"We're surrounded by water your right. But the concern has been around that, there's a lot of polluted Lake and polluted canals. So, this needs to be more restricted we need to really be more careful. Since we grew, we grew up around all these lakes and stuff we were able to watch them disappear."*	Farmer feels that we are surrounded with water, but it is getting polluted and lakes around us are disappearing.
P2 (Traditional Farmer)	*"I mean most of the fresh water is contained within you know very geographically specific areas, and the use of which is all strictly regulated. You know, so whether there's 100,000 lakes in Manitoba, you know I cannot have access to that supply of water..."*	Farmer feel that Canada's freshwater is mostly in specific area that doesn't provide me access to that.
P17 (Urban Farmer)	*"…locations where we are in Canada, where it's not an issue for water. There's also locations like Northern communities or you know. first nations, where there are a lot of water issues.*	Technology provider feels that the location in Canada that we are in there is no issue of water, but water is an issue in northern communities or First Nations.
P3 (Traditional Farmer)	*Sometimes there's like a dry season is in May instead of being in July or August. The water level in the pond, and in the*	Farmer is feeling that there is dry season in May now, level in ponds,

	rivers for us is an obvious concern. When you see the ponds going low. It's an everybody's talking about it so everybody goes through the river and then the river gets low	rivers are getting low and water is a issue in her spatial surroundings.

Social Construal Distance

The study received a mixed response on social construal distance with respect to water issues. Some participants feel that the water issue is a non-existent topic in their social circle whereas other have expressed that there is a lot of buzz around the water problem and the Agri-technology sector have become conscious and financially wise about the water issue.

Table 23: Social Construal Distance Statement

SOCIAL CONSTRUAL DISTANCE		
Participant	Quote	Description
P9 (Urban Farmer)	*I'm very few [co-farmers showing water concerns]. They don't give a damn I mean I think they realize it, but they're afraid because their income is based on conventional factory farming.*	Farmer feels that a very few co-farmers showing concern around a potential water crisis as most of their income is based on conventional factory farming.

P15 (Technology Provider)	*"So now, with the way industry is going they are realizing that I reduce water and use clean water more money I make. So with that said in a financial way, people are getting more conscious about it."*	Technology provider feels that agriculture industry is becoming conscious and financially wise.
P3 (Traditional Farmer)	*"I think a lot of things may be just like TV Netflix, any like anything you watch is always about water problems or climate change…"*	Farmer feels that TV, Netflix or other social actors are talking about water problems and climate issues.

Psychological Construal Distance

Participants of the study have expressed that water issues to be a reality in Canadian food system. These issues stem from water contamination, changing weather patterns, variability of droughts and floods. A technology provider has also pointed to the fact that impact of water is not being felt because stakeholders are not feeling the impact of water prices. According to the participant, the outlook on water prices points could make farming operations prohibitively expensive.

Table 24: Psychological Construal Distance Statement

PSYCHOLOGICAL CONSTRUAL DISTANCE		
Participant	Quote	Description
P4 (Traditional Farmer)	*"…we have a lot of abundance here yeah, but we do observe different weather patterns, all the time now and we you*	Farmer feels that water crisis is real as one is seeing uncertain rainfall and weather patterns that it seems

	know we have a drought in May. And that's seems unusual to me, so it seems like there will be uncertainty with respect to rainfall and even if we have enough water on total do we have it at the right times. We can't rely on the weather to water, the crops anymore."	that they can't rely on weather to water the crops anymore.
P12 (Technology Provider)	*"Right now we don't really feel the impacts of water prices on are like operating like on our farm operation expenditure. But I don't know what the, you know, long-term outlook of water prices will necessarily be it's not something I'm super familiar with. But it is believable that it would become much more expensive and potentially prohibitively expensive in the future."*	Technology provider feels water crisis will become real in the future. But as for now the true impact of water is not being felt on farm operation expenditure. But outlook of water prices show that water could become expensive in long term.

Results & Discussion

This research focused on studying climate-resilient water innovation that can help fight the grand challenge faced by the food system (George et al., 2016, Godfray et al., 2010; Hamilton et al., 2020). There are several outward benefits of such water innovation like ensuring convergent innovation and advancement toward food security and sustainability. There are accompanying challenges, like pre-commercialization challenges, lack of financial investment and government policy, that have been mentioned in past studies (Wehn & Montalvo, 2018; Gabrielsson et al., 2018; O'Callaghan et al., 2020).

This study contributes by extending the innovation literature to the water innovation domain, especially agri-food irrigation technology. The innovation adoption theory (Davis, 1989) is utilized to uncover the barriers and facilitators to water technology adoption with a special focus on institutional and individual psychological factors that were understudied. One limitation of this study is that the interview protocol did not actually include a direct question to participants about whether they would (or already did) ultimately adopt water innovation technology or not – it merely focused on having them describe the factors that support or hinder that decision. Nevertheless, their feedback on those factors adds informative value to the literature.

Individual psychological factors are studied through the application of the construal approach. Past studies have shown that the construal approach influences participants and their decision-making based on the valuation of nature and the environment (Griffioen. Et. al., 2019. Therefore, a construal approach can provide missing links to psychological factors with respect to sustainable technology adoptions, like climate-resilient water innovations. Understanding the psychological information-filtering construal process with respect to water issues in the Canadian agri-food system can help us understand the deeper psychological factors in sustainable innovation technology adoption and strategic decisions (Steinbach et. al., 2019). Water is an externality in the Canadian food system so this study helps to uncover the deeper temporal, spatial, social, and psychological construal with respect to water and water innovation.

Last, the phenomenological research design used to investigate the common phenomena of innovation adoption in the whole Canadian food system, by including technology providers, farmers (traditional and urban), distributors, and retailers can give us a 360-degree understanding. Additionally, this study can allow future collaboration and strategy for new water innovation.

Finding New Constructs

This qualitative study creates new constructs (see table below) for innovation literature with respect to agri-food irrigation technology adoption. These constructs can address past gaps and extend new dimensions to explore innovation adoption and construal theory.

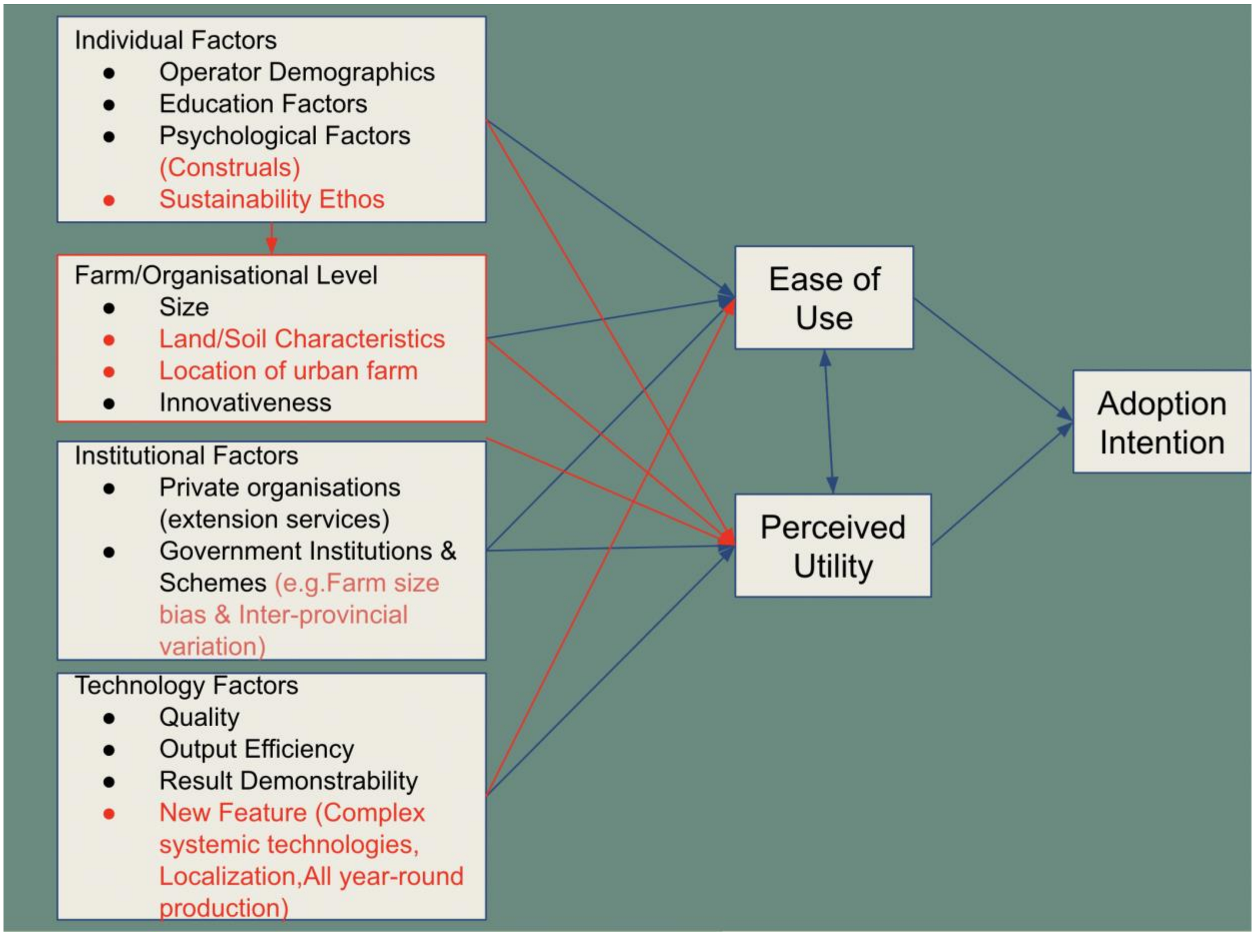
Table 25: New Constructs

S.No.	Adoption Factors	New Constructs
1.	Individual factors	• Individual construals • Sustainability ethos
2.	Farm factors	• Land/soil characteristics • Location of urban farm
3.	Institutional factors	• Farm size bias • Inter-provincial variation
4.	Technological factors	• Complex systemic technologies • Localization • All year-round production

Sustainable Water Innovation Adoption Model

This study develops a 'Sustainable Water Innovation Adoption Model' using an iterative, abductive approach: integrating the deductive data from past theories with inductive data gathered through the participants of the Canadian agri-food system.

Figure 2: Final Sustainable Water Innovation Adoption Model



The final model shows that factors, namely individual, farm/organization, institutional and technology, have dual roles in adoption decisions by influencing both ease of use and perceived utility. The model also shows that interlinkages within the model are far more complex than those inducted from past literature (see Figure 1). For example, the new constructs like Sustainability Ethos among participants of the agri-food system seem to influence other adoption factors (farm/business innovativeness, individual construal, and technology results). Similarly, individual construals drive deeper psychological processing towards other adoption factors (farm/business innovativeness, institutional and technology results). Therefore, the relationship and impact of the factors of water innovation adoption need deeper analysis, especially with the discovery of new construals. The study also found the difference in experiences with respect to technology adoption based on participant characteristics, like farmer type (urban or traditional), income and education.

Practical Implications

From a practical perspective - such a study can aid technology providers in better marketing and designing their technology to best-fit farmers' individual, farm/business, and technological needs. Moreover, as seen from past studies existing institutional factors are not adequate for water technology adoption but through this study, government policy and regulation can be improved to bring a positive change. For example, the building code and agricultural zoning regulations can be updated to provide impetus to urban agriculture using climate-resilient water innovations. A larger sustainability policy action that integrates major sustainable development goals, namely SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production) can also be achieved through the implementation of such water innovation within a city/urban setting. Lastly, this study can make communities understand the facilitators and hindrances of water innovations that can help them establish local sustainable food systems.

Limitations

This study was majorly focused on antecedents of sustainable water innovation adoption. This can also be seen in the final sustainability water innovation adoption model (see Figure 3), where the focus was more on individual, farm, institutional and technological factors. There was limited focus on directionality that showed the connection between each factor. New constructs like sustainability ethos have much wider connection with farm innovateness, technology results that needs deeper analysis. Additionally, the relationships established within the study were more correlational with no degree or order of preference. These issues can be a topic of future study and can help improve the interlinkages with the model.

This being a qualitative study, the study had limited time and participants so could have resulted in limited understanding of the construal. Therefore, any future study can use quantitative methods to study more participants to get a deeper understanding of individual construals and its implication on decision making.

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<u>Appendix A: Interview Protocol</u>

Time & Duration of interview: **Date:** **Place:** **Interviewer:** **Interviewee:** **Position of interviewee:**

This study is being conducted to uncover the *obstacles to adoption of climate resilient water innovation/technology in agriculture* sustainability. Such an understanding can guide further research and policy decisions on how to facilitate and accelerate changes towards building a *sustainable community food system that uses climate resilient water innovation*. Overall, such a change can transform the global food systems to create an alternative sustainable food system.

Interview Questions:

A. Interviewee Background: *I will begin with some basic questions about your background and role in the food systems.*
   1. What is your occupation?
   2. What is your role in ensuring food on the customer's table?
   3. What is your age, income, educational background?

B. Construals about Water Issues: *Now, I will ask them questions about the importance you give to water resource and its importance in your process*.

4. How important is water related to your work?
5. What are all the water related issues to your work?
    a. Do you see this as probable to occur? If not, why?
    b. Do you see it as imminent at this point in time? If not, when?
    c. Who are the players that make the water is a big/small concern for you?
    d. What is it about your geographic environment that makes it a big/small concern for you?
    e. If unimportant, please explain

C. Water Innovation Adoption: *Now, I would like to ask you some questions about adoption of new clean enviro-technology related to water and various factors influence it.*

6. In the past, have you adopted any enviro and clean innovation technology? Why/why not?
    a. What do you think of enviro-technology addressing water issues? (e.g., complexity of the technology, relative advantage – quality of it; hydroponic based climate-controlled farming systems?)
    b. Is there any institutional support for climate and water irrigation service innovation adoption?
    c. Does regulatory, municipal, financial sector or extension service influence adoption of water technology?
    d. Are there any other factors that influence your water technology adoption?

D. Facilitating a Systemic Transformation: I would like to ask you questions about how a sustainability transformation in the food system can be brought by can reducing construal distance.

7. What do you understand by having a sustainable community food system?
8. How, in your view, do "institutional factors" influence hydroponic farming system adoption? (e.g., institutional role: What can govt do? Or farming educators – agriculture schools? Nonprofit/lobbying institutions?)

E. Post Interview Comments or Leads: *I value all your responses to the interview questions, and I am sure they will help me complete my research study.*

9. Anything else that you would like to add to our discussion or past questions?

Thank the individual for participating in this interview. Assure him or her of confidentiality of responses and identity.

Appendix B: Questionnaire

Section 1: Environmental Self-Identity (Based on van der Werff et al., 2013)

Rate each item on a 5-point frequency scale (1 = never, 5 = always)

1. Question 1: *Acting environmentally-friendly is an important part of who I am?*
2. Question 2: *I am the type of person who acts environmentally-friendly?*
3. Question 3: *I see myself as an environmentally-friendly person?*

Section 2: Pro-environmental behaviour (based on Griffioen. Et. al., 2019)

Rate each item on a 5-point frequency scale (1 = never, 5 = always)

4. Question 4: *I turn off the shower when I'm soaping myself down?*
5. Question 5: *Conscious about water use in my daily activities?*
6. Question 6: *Are the products you buy eco-friendly (eg. Organic food)?*
7. Question 7: *I avoid wastage of food at home?*

Section 3: Personal intention to adopt clean technology (based on Brügger et. al., 2016)

Rate each item on a 5-point frequency scale (1 = never, 5 = always)

8. Question 8: *Choose a car that gets good fuel mileage?*
9. Question 9: *Replace older appliances with more energy efficient new models*
10. Question 10: *Install a water re-use system at home (avoid water shortages during droughts)?*
11. Question 11: *Fit water saving device in your cistern to save when flushing*?