

**“We see a real opportunity around food waste”:  
Exploring the Relationship Between On-Farm  
Food Waste and Farm Characteristics**

by

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## Approval

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## Ethics Statement



The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

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## **Abstract**

This research study aims to provide an understanding of on-farm food waste on conventional and organic farms. Through interviews with food producers, I addressed three research questions: 1) do organic food producers produce more or less waste than conventional food producers?, 2) do food waste management practices differ between organic and conventional food producers?, and 3) What role do producer food waste practices play in agricultural sustainability? I found no conclusive differences between organic and non-organic food producers regarding volume and management of on-farm food waste; however, I found that different farm characteristics intersect in numerous ways, resulting in a variety of impacts on on-farm food waste. Additionally, all research participants indicated that the factor most likely to encourage them to address on-farm food waste is cost savings. To fully address food waste, actions oriented towards minimizing and sustainably managing food waste must be undertaken in a collaborative manner across all stages of the food supply chain.

**Keywords:** organic agriculture; sustainable agriculture; food waste; sustainability transitions; farm characteristics

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## List of Acronyms

ALC	Agricultural Land Commission
ALR	Agricultural Land Reserve
BC	British Columbia
CSA	Community Supported Agriculture
FSC	Food Supply Chain
GHG	Greenhouse Gas
IFOAM	International Federation of Organic Agriculture Movements
SFU	Simon Fraser University
USD	United States Dollar

# Chapter 1.

## Introduction

The agriculture industry is responsible for global-scale social, environmental, and economic impacts, and is facing pressures from population growth, changing diets, and climate change, among other factors. To address the complex challenges associated with the global agricultural industry, researchers generally agree that sustainable food production, which integrates sustainable patterns of production and consumption while respecting the carrying capacity of natural ecosystems to allow for the maintenance of ongoing food production, is an optimal strategy (FAO, 2016; Rigby & Cáceres, 2001). Despite the desire to transition towards sustainable food production, assessing the sustainability of food systems and integrating practices to increase agricultural sustainability is a difficult undertaking, particularly due to complex interactions between agriculture and the environment (Rigby & Cáceres, 2001). In Canada specifically, more research is necessary to assess the effectiveness of agricultural sustainability policies (Lynch, 2009). Unfortunately, an overall lack of understanding about how to best reach the goal of sustainable food production remains.

While agricultural sustainability is an articulated international and national goal, food waste has been addressed minimally across the literature despite estimations that up to 30% of food grown globally is not consumed (Buzby, & Hyman, 2012). All food production requires inputs including water, energy, and labour. Globally food production is one of the world's most resource intensive practices, making it a sustainability focus area (Freibauer et al., 2011). In Canada, for example, the agriculture industry is the largest net consumer of water, and accounts for approximately 7% of Canadian land use (Statistics Canada, 2013). Furthermore, the agriculture industry is responsible for 15-30% of Canada's greenhouse gas (GHG) emissions (MacRae, Cuddeford, Young & Matsubuchi-Shaw, 2013; Rigby & Cáceres, 2001). Wasted food represents a waste of

resources, further undermining the sustainability of the global food system. Researchers including Hickey & Ozbay (2014) state that the global food system needs to be transitioned towards sustainability, and that addressing the problem of food waste is a key component to meeting this objective.

As outlined in the following literature review, minimizing and addressing food waste is socially, economically, and environmentally beneficial, yet there is a lack of research regarding food waste. Researchers including Buzby et al. (2011), Buzby & Hyman (2012), Gunders (2012), Hodges et al. (2011), Kantor et al. (1997), Parfitt et al. (2010), and Smil (2004) call for additional research on food waste. Further research on food waste may assist to reduce food waste across the food system and to enable the sustainable management of existing food waste, contributing to the overall goal of creating a sustainable food production system.

Although food waste occurs at all stages of the food supply chain (FSC), food waste occurring at the farm stage is rarely considered in estimations of food waste across the literature. On-farm food waste is difficult to measure; however, addressing food waste at the farm stage may be particularly effective as food wasted on-farm is likely still in edible condition (Kantor et al., 1997). This research study seeks to gain an in-depth understanding of on-farm food waste in the Lower Mainland region of British Columbia, Canada, with a particular focus on food producers' perceptions of on-farm food waste. The overarching aim of this research is to gather fundamental information regarding on-farm food waste in certified organic and non-certified organic food production systems and to provide food producers with real-world strategies for increasing the sustainability of their agricultural operations through minimizing and sustainably managing on-farm food waste. To address these topics, this study seeks to answer three research questions:

- Do organic food producers produce more or less waste than conventional food producers?
- Do food waste management practices differ between organic and conventional food producers?
- What role do producer food waste practices play in agricultural sustainability?

## **Chapter 2.**

### **Literature Review**

This literature review aims to provide key contextual information and theoretical grounding for research in the area of on-farm food waste in organic and conventional food production systems. Additionally, this literature review identifies knowledge gaps in research that has been conducted regarding on-farm food waste generation and on-farm food waste management as these concepts relate to agricultural sustainability. Due to the interdisciplinary nature of food systems research, I reviewed literature from a range of fields including food policy, environmental science, sustainable food systems, sustainable development, supply chain management, and resource management.

This chapter consists of four sections. Section one outlines the concept of sustainable development and the relationship between sustainable development and food production. Section two links the concept of sustainable development to the newer research field of sustainability transitions. Section three explores sustainable food production. Finally, section four examines food waste with a particular focus on on-farm food waste, as well as the relationship between food waste and sustainability.

#### **2.1. Sustainable Development**

Since emerging in the 1987 report published by the World Commission on Environment and Development (The Brundtland Commission), the concept of sustainable development has been internationally supported as a paradigm for future development (Kareiva & Marvier, 2011; World Commission on Environment and Development, 1987). While “sustainable development” is defined in different ways across the literature, it generally encompasses “development that meets the needs of the current generation while ensuring that a healthy and viable world remains for future

generations” (Kareiva & Marvier, 2011, p. 87). Sustainable development requires changing current economic, social, and environmental practices to establish systems that are optimal for sustaining human existence on earth (Roseland, 2012). In terms of resource use, sustainable development supports using resources at a rate that can be regenerated by natural systems. As the global food system is one of the world’s most resource intensive practices, it is a focus area for sustainable development (Freibauer et al., 2011). Much of the literature on increasing food system sustainability, including reducing food waste, is guided by the overarching concept of sustainable development.

Sustainable development is necessary due to a number of environmental, social, and economic challenges. Globally, humans are responsible for numerous environmental impacts including biodiversity loss, climate change, and ocean acidification (Kareiva & Marvier, 2011). Additionally, population growth is placing an increasing demand on global resources. The UN has projected that the human population will peak at approximately 9.3 billion people in 2050; this will increase the demand for resources including water, land, and food (Buzby & Hyman, 2012; Roseland, 2012). Furthermore, economic disparity is evident with the poorest 20% of the global population representing only 2% of the global economic product, and approximately 75% of global resources being consumed by the wealthiest 20% of the population (Roseland, 2012). Interconnected economic, social, and environmental challenges have resulted in increasing public awareness and concern for environmental issues, as well as support for the inclusion of sustainability goals in government policies (Field & Olewiler, 2011).

## **2.2. Sustainability Transitions**

To conduct development in a sustainable manner, numerous large-scale transitions must occur. “Sustainability transitions” is an emerging and growing research discipline that focuses on the process of transitioning complex socio-technical systems, such as the energy supply, the food supply, and the transportation system, from current structures to sustainable systems (Markard, Raven & Truffer, 2012). In a 2012 analysis of the prospects of sustainability transitions research, Markard et al. defined sustainability transitions as, “long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to

more sustainable modes of production and consumption” (p. 956). Overall, research conducted from the sustainability transitions perspective aims to provide insights on social and technical changes that have the capacity to foster increased sustainability.

Sustainability transitions research examines change related to sustainability in a number of ways. While topics from a diverse range of research areas, such as energy, water, and food systems, are examined through the lens of sustainability transitions, the field seeks to find commonalities among these diverse topics, such as common processes or frameworks that may facilitate movement towards sustainable development across a variety of circumstances. Additionally, this field examines the challenges and possibilities associated with facilitating societal transitions to more sustainable modes of production and consumption, with a particular focus on socio-technical innovations and practices that align with sustainability agendas (Hinrichs, 2014; Markard et al., 2012). Research conducted through the lens of sustainability transitions can be considered complementary to the sustainable development paradigm (Hinrichs, 2014).

While the sustainability transitions field is relatively new, it may be a particularly useful lens for examining challenges in the global food system. Hinrichs (2014) strongly suggests integrating food system research with sustainability transitions research, stating that the sustainability transitions perspective “offer[s] different and useful ways to think about the dynamics, durability and significance of innovations in food and agriculture, and the part they play in transitions to sustainability” (p. 143). Currently, sustainable food systems research and sustainability transitions research are disconnected: a recent assessment found that only 3% of the sustainability transitions literature focuses directly on food systems (Markard et al., 2012). Moreover, Hinrichs (2014) suggests that by researching food systems issues from a sustainability transitions perspective, researchers can critically examine questions such as, “[w]hen and why do farmers develop and use more sustainable farming practices?” (p. 143). Conducting food waste research from a sustainability transitions perspective may provide an understanding of if and how farmers are transitioning towards sustainable waste management and the conditions that lead to, facilitate, and/or hinder these transitions.

## 2.3. Sustainable Food Production

Due to concerns that the current global food system lacks long-term viability, particularly regarding dependence on non-renewable resources and negative impacts on biodiversity, researchers generally agree that it is desirable to transition towards sustainable food production (Rigby & Cáceres, 2001). Sustainable food production can be defined as producing enough food to meet current demand without compromising the ability of future populations to meet their demand for food (Kareiva & Marvier, 2011). Rigby & Cáceres (2001) elaborate on this definition, and state that sustainable food production can be described as an agricultural system that is capable of maintaining its productivity while being economically, socially, and environmentally sound. Rigby & Cáceres (2001) also highlight that establishing a precise, operational definition of sustainable agriculture is difficult as stakeholders have different views regarding which elements of food production are or are not sustainable.

As the global food system has numerous and widespread economic, social, and environmental impacts, conducting food production in a sustainable manner is critical to enabling an overall transition towards sustainable development. Food production is economically beneficial, and provides livelihoods for farmers all over the world (Kattides & Lima, 2008). In British Columbia alone, the agriculture industry generates \$12 billion annually (Province of British Columbia, 2016). Negative economic impacts are also associated with food production: in the United States, the health and environmental impacts of agricultural pesticide use cost approximately \$12 billion per year (Pimentel, Hepperly, Hanson, Douds & Seidel, 2005). Socially, the availability or lack of availability of food strongly affects human health, and different methods of food production can impact the sustainability of communities in positive and negative ways (Kattides & Lima, 2008). In terms of environmental impacts, the agriculture industry is Canada's largest net consumer of water, and accounts for approximately 7% of Canadian land use (Statistics Canada, 2013). Additionally, the agriculture industry is responsible for 15-30% of Canada's GHG emissions, and is heavily reliant on non-renewable resources (MacRae, Cuddeford, Young & Matsubuchi-Shaw, 2013; Rigby & Cáceres, 2001).



In addition to causing widespread impacts, the global food system is currently facing pressure from a number of factors including climate change, population growth, urbanization, changing diets, and public dissatisfaction. Climate change is projected to impact food production due to increased drought and extreme weather conditions, hazards that are exacerbated by an increasing population and a growing demand for food (Buzby & Hyman, 2012). Furthermore, globalization and urbanization have resulted in large and complex food supply chains (FSC) to feed urban populations. Global FSC have increased access to a variety of foods, but have also produced more food waste (Parfitt, Barthel & Macnaughton, 2010). Globally, diets are shifting away from starchy staple foods towards foods that are protein rich and have shorter shelf lives, resulting in greater resource use and increased food waste (Parfitt et al. 2010). Lamine (2015) states that there is public pressure to transition the food system to one that is more sustainable due to the cultural de-legitimization of the current industrial food regime. In Canada, Canadian federal policy and organizations such as the Canadian Agri-Food Policy Institute support the transition to sustainable agriculture (Agriculture and Agri-Food Canada, 2013; Canadian Agri-Food Policy Institute, n.d.). In combination, pressures on the global food system intensify the need to transition the food system to one that is able to feed a growing population while reducing its impact on natural resources and the environment.

Despite the general consensus that sustainable food production is an advisable goal, it remains difficult to assess the sustainability of food systems. Lynch (2009) states that while establishing goals for agricultural sustainability is a positive undertaking, more research is needed regarding how to best assess the effectiveness of Canada's agricultural sustainability policies. Rigby & Cáceres (2001) state that due to complex interactions between agriculture and the environment, it is difficult to know which agricultural methods and systems will lead to sustainability. Rigby & Cáceres (2001) also raise concerns about accurately measuring agricultural sustainability, stating that converting general principles of agricultural sustainability into specific practices is challenging. Unfortunately, an overall lack of understanding about how to best reach the goal of sustainable food production remains.

### **2.3.1. Organic Agriculture**

Organic agriculture is a food production method that has been proposed as a way to increase agricultural sustainability. Organic agriculture is a farming system that restricts the use of synthetic agrochemicals, synthetic food additives, and genetically modified organisms. Additionally, organic agriculture strives to incorporate ecological cycles, enhance soil fertility, maximize efficient resource use, and minimize the use of non-renewable resources (Pimentel, Gomiero & Paoletti, 2011). Mondelaers, Aertsens, & Van Huylenbroeck (2009) state that due to its integration with natural systems and restriction of synthetic and genetically modified inputs, organic agriculture is largely thought to be more sustainable than conventional agriculture. In Canada, organic agriculture is promoted by federal policy as a way to meet agricultural sustainability goals (Lynch, 2009).

Rigby & Cáceres (2001) highlight that while organic agriculture and sustainable agriculture are closely related, the nature of the relationship between these concepts is disputed. Some researchers use the terms sustainable agriculture and organic agriculture interchangeably, while other researchers, such as MacRae, Martin & Frick (2007), state that organic agriculture is just one form of sustainable agriculture. Rigby & Cáceres (2001) argue that while organic food producers may aim to have positive social and economic impacts, the only factors that are typically regulated by organic certification bodies are the restriction of synthetic chemicals and genetically modified organisms and that this in itself is not enough to fully satisfy the criteria for sustainable agriculture.

Despite uncertainty concerning whether or not organic agriculture is the optimal way to increase agricultural sustainability, the adoption of organic agriculture is growing globally (Mondelaers et al., 2009). While many aspects of organic agriculture sustainability remain under researched, a number of studies have compared organic and conventional agriculture on economic, social, and environmental factors. Economically, MacRae et al. (2007) found that organic farms performed better than conventional farms due to reduced input costs, diversified production and marketing channels, increased resilience to market conditions, increased price premiums on food products, and an increased ability to adapt to weather extremes. Additionally, organic farming may reduce

the need for governments to provide agricultural subsidies as organic farmers receive a higher premium for their product, and because organic products are less susceptible to the impacts of climatic variability (MacRae et al., 2007). Socially, Pimentel, Hepperly, Hanson, Douds & Seidel (2005) state that implementing organic food production may alleviate some negative health effects associated with pesticide use in conventional agriculture. Furthermore, Pimentel et al. (2011) state that organic agriculture may assist in preserving provisioning ecosystems services, improving long-term food security.

The majority of research comparing conventional and organic agriculture examines environmental differences between the two food production methods including assessments of energy, biodiversity, soil quality, climate change adaptation potential, and yields. In a meta-analysis of 130 studies, MacRae, Martin & Lynch (2011) found organic farming to be more efficient than conventional farming in terms of whole-farm energy use both on a per hectare and per farm basis. Numerous other researchers state that organic food production tends to be more energy efficient than conventional food production, particularly because organic agriculture does not employ fossil fuel intensive synthetic fertilizers (Hoepfner, Entz, McConkey, Zentner & Nagy, 2006; Lynch, 2009; Pimentel et al. 2005; Pimentel et al. 2011). In terms of biodiversity, Lynch (2009) found that organic farms consistently harbor more native and exotic plant species than conventional farms, Pimentel et al. (2011) found that organic farms tend to host higher biodiversity than conventional farms depending on farm management, and Mondelaers et al. (2009) found that organic farms tend to have higher natural plant biodiversity as well as higher planted-crop biodiversity. Regarding soil quality, a literature review found that organic food production systems typically had better soil management than conventional food production systems, resulting in higher soil organic matter and soil nutrient intensity (Lynch, 2009). Other research has found that organic agriculture may benefit soil quality by increasing soil organic matter, moisture, nitrogen content, and carbon sequestering ability (Mondelaers et al., 2009; Pimentel et al., 2005; Pimentel et al., 2011). Furthermore, multiple researchers have found that organically managed soil performs better than conventionally managed soil under conditions of water scarcity (MacRae et al., 2007; Pimentel et al., 2005; Lynch, 2009).

While the literature indicates that organic agriculture has benefits when compared to conventional agriculture, organic agriculture is typically not as productive as conventional agriculture. A meta-analysis found that organic yields average 25% lower than conventional yields, increasing the need for inputs and land, which may undermine the environmental benefits of organic agriculture (Foley, Ramankutt & Seufert, 2012). Similarly, Lynch (2009) and Pimentel et al. (2011) found that organic yields are less than conventional yields, indicating that considering trade-offs between the productivity of conventional food production and the economic, social, and environmental benefits of organic food production is necessary. In a trial of organic and conventional farming methods, Pimentel et al. (2005) found that organic and conventional plots yielded similar results, indicating that farm management practices and local conditions may impact crop yields. Foley et al. (2012) also highlight that the relationship between production method and yield is not straightforward as organic crops may perform better over long time periods and in conditions with variable moisture.

The Canadian *Organic Production Systems: General Principles and Management Standards* (2015) states that, “organic production is a holistic system designed to optimize the productivity and fitness of diverse communities within the agro-ecosystem, including soil organisms, plants, livestock and people. The principal goal of organic production is to develop operations that are sustainable and harmonious with the environment” (p. 7). While this description of organic food production may be interpreted to address all aspects of food production, including on-farm food waste, the standards do not specifically outline sustainability goals related to the minimization and sustainable management of agricultural food waste in organic farming operations.

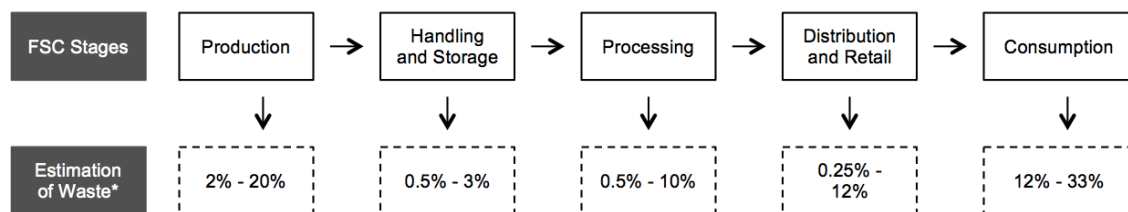
## **2.4. Food Waste and Food Waste Management**

While there are multiple definitions of food waste across the literature, food waste can generally be defined as food that was intended to be eaten by people, but was discarded, lost, degraded, and/or consumed by pests at some point in the food supply chain (Parfitt et al., 2010). The terms “food waste” and “food loss” are used interchangeably in the literature without standardized definitions. Typically, food waste is

measured by weight, but can also be measured by caloric value, GHG emissions, nutrients, or water loss.

The process of moving food products from producers to consumers occurs through complex, geographically disperse food supply chains consisting of multiple stages, including production, processing, distribution, retail, and consumption (Figure 1). Research indicates that food waste occurs at every stage of the FSC (Buyukbay, Uzuno, & Bal, 2011; Gunders, 2012; Prusky, 2011). Some research has found that in developed countries, most food waste occurs at the retail and consumer stages, and in developing countries, most food waste occurs prior to the retail stage (Hodges, Buzby & Bennett, 2011; Prusky, 2011). However, this statement is inconsistent with Gunders (2012), who found that there is food loss across all stages of the North American food supply chain. Additionally, Ridoutt, Juliano, Sanguansri, & Sellahewa (2010) found that improper storage and transportation practices caused food waste prior to the retail stage in a case study of the Australian mango industry. As indicated in Figure 1, estimates of food wasted at each stage of the FSC vary widely.

**Figure 1. Estimates of Food Wasted Across the FSC**

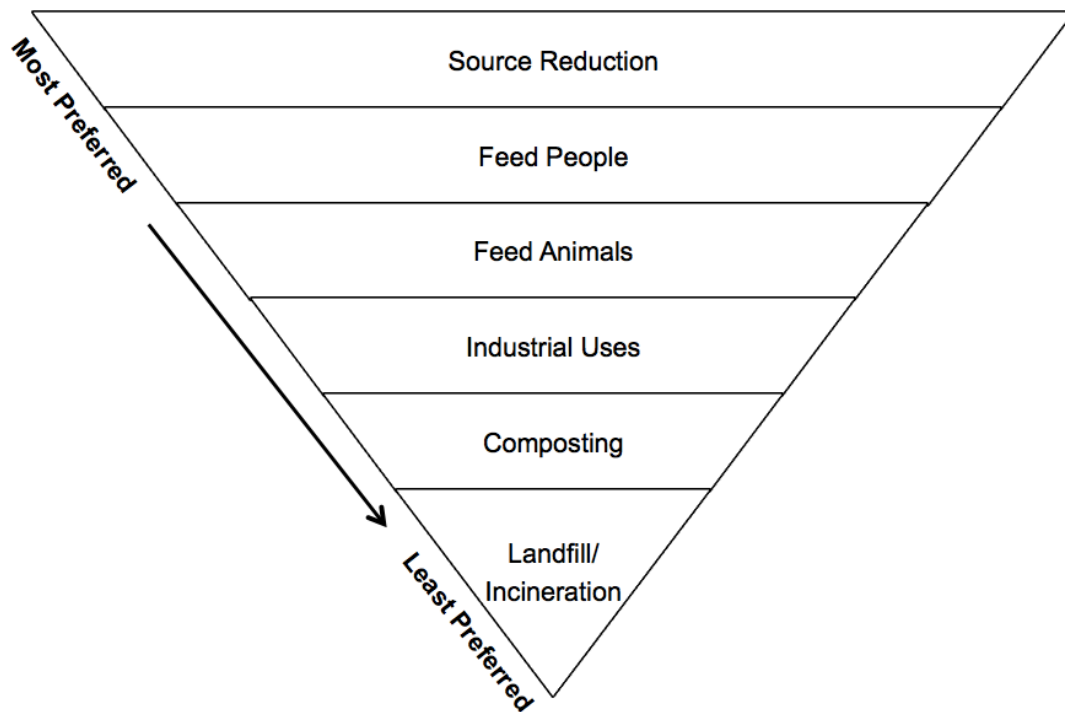


(\*Estimations of food waste indicate percentages of total food produced that may be wasted at a given stage. Estimates vary depending on food type. Based on data collected in USA, Canada, Australia, and New Zealand. Adapted from Gunders, 2012; Gustavsson et al., 2011.)

Food waste management refers to the process of food waste creation, handling, monitoring, and disposal. Numerous waste management options exist, including redesigning systems to stop waste from being generated, reducing waste, reusing waste, recycling waste, recovering waste, and disposing of waste (Roseland, 2012). In terms of food waste management specifically, source reduction is the preferred strategy, followed by feeding people, feeding animals, industrial uses, composting, and landfill/incineration, as indicated in the food waste hierarchy (Figure 2) (US Environmental Protection Agency, 2016). Waste management strategies that provide

little value in terms of nutrition or useable products, such as disposing of food waste in landfills, are considered to be less favourable, while waste management strategies that reclaim some of the nutrients and resources found in food waste, such as feeding animals and composting, are considered to be more favourable. Hickey & Ozbay (2014) state that considerable efficiency improvements in food waste control and management are necessary, and that efforts to reduce and recycle food waste should be promoted. MacRae et al. (2011) also call for improvement of the Canadian waste handling system, stating that the current system is immature and does not minimize losses.

**Figure 2. Food Waste Management Hierarchy**



(Adapted from US EPA, 2016.)

Researchers agree that food waste reduction should be targeted as a sustainability issue (Gunders, 2012; Hodges et al., 2011; MacRae et al., 2011; Parfitt et al., 2010; Ridoutt et al. 2010; Smil, 2004). Hickey & Ozbay (2014) state that the global food system needs to transition towards environmental sustainability, and that addressing food waste is a key component to meeting this objective. Similarly, Buzby, Hyman, Stewart & Wells (2011) state that, “reducing food waste across the entire food

chain will be a critical part of any strategy to sustainably and equitably feed the rapidly growing world population” (p. 493).

Food producers, retailers, and consumers experience financial losses associated with food waste stemming from direct losses, sales losses, and the cost of waste management. Researchers including Gunders (2012) and Hickey & Ozbay (2014) acknowledge that food waste results in substantial financial losses for people at all stages of the FSC. Retailers and consumers experience direct financial losses from wasting purchased food: Buzby & Hyman (2012) found that in the United States, food loss at the consumer and retail stages of the FSC was equivalent to \$165.5 billion, or approximately \$390 per capita in 2008. In Canada, Gooch & Felfel (2014) estimate that the cost of food waste across the Canadian food supply chain is equivalent to approximately \$31 billion annually, which is higher than the combined GDP of the world’s 29 poorest countries. Consumers may also be economically impacted by food wasted at other stages of the food supply chain, as this can limit food supply and result in higher food prices (Shahzad, Qureshi, Jehan, Ullah & Khan, 2013). Costs associated with food waste management include tipping and hauling fees for organic waste pick-up, as well as the cost of landfill maintenance.

In addition to economic impacts, food waste also has social impacts. In their study on food waste in the United States, described as seminal by Buzby et al. (2011), Kantor, Lipton, Manchester & Oliveira (1997) state that while not all food waste is recoverable, large amounts of the food that is wasted could potentially feed those who are experiencing food insecurity. Gunders (2012) expands upon this finding, stating that reducing food waste in the United States by 15% would result the ability to feed over 25 million Americans a year. Furthermore, Buzby et al. (2011) highlight that food waste represents a waste of labour.

Finally, food waste is also responsible for a variety of environmental impacts. Food waste represents a waste of energy, water, and agricultural chemicals, and has impacts on land use, pollution, GHG emissions, and resource management (Buzby et al., 2011; Katajajuuri, Silvennoinen, Hartikainen, Heikkilä & Reinikainen, 2014; Shahzad et al., 2013). Food waste accounts for 13% of waste in American landfills, which

contributes to climate change by releasing GHG such as methane during decomposition (Buzby et al., 2011; Gunders, 2012; Hickey & Ozbay; 2014). In a 2013 study on landfill composition conducted by Tetra Tech EBA Inc. for the Metro Vancouver regional government, compostable organic material made up the highest proportion of solid waste at 36.2% (Tetra Tech EBA Inc., 2013). Moreover, Hickey & Ozbay (2014) state that food waste results in damage to ecosystems, particularly due to land use change required to grow food that is ultimately not consumed. In terms of resource management, Hodges et al. (2011) state that reducing food waste can provide more food while reducing the resources needed to produce it. Of course, the economic, social, and environmental impacts of food waste are interrelated. For example, many of the environmental impacts of food waste have associated economic costs, such as the cost of managing GHG emissions from decomposing food waste.

While food waste reduction is a key component in transitioning towards sustainability, there is an acknowledged lack of information about food waste. Buzby et al. (2011) and Buzby & Hyman (2012) state that gathering baseline data on food waste will enable waste minimization targets to be set, and will allow for the development of waste management and conservation initiatives. Kantor et al. (1997) support further food waste research, stating that additional information will increase the accuracy of food waste estimates and provide a more holistic view of food loss across the FSC. Gunders (2012) suggests a comprehensive study of food waste across the food supply chain, highlighting that food waste has been given little attention by researchers to-date. Smil (2004) states that the lack of research about food waste is particularly disconcerting when compared to the thousands of studies published on the topic of increasing crop yields. Researchers note that much of the food waste data that is available is based on estimates and/or on data collected in the 1970s or earlier, highlighting the need to collect current food waste data (Hodges et al., 2011; Kantor et al., 1997; Parfitt et al., 2010).

While additional research on food waste is clearly needed, a number of factors make collecting accurate food waste data difficult. First, there is no efficient, universal method for measuring, estimating, or predicting food waste (Prusky, 2011; Shukla & Jharkharia, 2013). Second, physically measuring food waste is labour and time intensive, resulting in food waste research that is based on self-reporting and



estimations, which may cause inaccuracies. Third, food waste is highly variable and can change depending on country of production, climate, and crop type, among other factors (Prusky, 2011). Fourth, the perishable nature of food products may cause difficulty in assessing food waste (Shukla & Jharkharia, 2013). Fifth, the current literature on food waste is fragmented, in silos, and spread across multiple disciplines without interaction, making it difficult to access (Shukla & Jharkharia, 2013).

Because food waste is difficult to assess accurately, estimates of food waste vary across the literature and are often vague. There are multiple estimates of global of post harvest food waste ranging from 10%-40% (Prusky, 2011), to 30%-50% (Ridoutt et al., 2010), to 20%-60% (Shukla & Jharkharia, 2013). Katajajuuri et al. (2014) state that approximately 1.3 billion tonnes of food is wasted annually. MacRae et al. (2011) state that up to 40% of food that is planted is never eaten and specify that 10%-70% of fruits and vegetables are wasted at various points in the FSC. Parfitt et al. (2010) state that while it is generally estimated that up to 50% of food that is grown is never eaten, these estimates tend to link back to data sets that were collected in the 1970s and 1980s.

Further exacerbating the lack of accurate information about food waste is the tendency to exclude producer stage food waste, i.e. food waste that arises on-farm, when conducting food waste estimations. Numerous articles attempting to calculate food waste do not take producer stage food waste into consideration including Buzby et al. (2011), Buzby & Hyman (2012), Kantor et al. (1997), Katajajuuri et al. (2014), and Ridoutt et al. (2010). The exclusion of producer stage food waste is problematic as Gunders (2012) states that in North America, up to 20% of food may be wasted at the producer stage (Figure 1). Similarly, Shahzad et al. (2013) found that on-farm waste accounted for 23% of the waste in the plum food supply chain. Several researchers express concern regarding the omission of producer stage food waste in food waste calculations, including Gunders (2012), who states that many studies on food waste omit the on-farm, post-harvest, and processing stages of the food supply chain, and highlights the importance of gathering data about production stage food waste. Kantor et al. (1997) state that the exclusion of waste at pre-harvest, on-farm, processing, and transportation stages of the food supply chain likely resulted in an underestimate of total

food loss in their study. Similarly, Katajajuuri et al. (2014) state that more information about food losses in primary production is necessary.

Although food waste at the producer stage of the FSC remains an understudied topic, numerous articles discuss the potential causes of producer stage food waste (Buyukbay et al., 2011; Gunders 2012; Hodges et al. 2011; Prusky, 2011; Shahzad et al. 2013). Shukla & Jharkharia (2013) attribute food waste across the FSC mainly to a lack of communication between different actors in the FSC. Economic factors contributing to food waste include discrepancies between supply and demand for food products and rejection of food that does not meet aesthetic and/or quality standards. Numerous environmental factors can contribute to on-farm food waste including biological spoilage, spoilage due to pests, poor soil fertility, and poor weather conditions. Food producers and processors can also cause food loss through inappropriate irrigation, inappropriate use of fertilizers, inappropriate packaging choices, selection of unsuitable crops or crop varieties, inappropriate harvesting, unsuitable storage methods, inappropriate packaging, and mechanical damages.

There are many suggested food waste reduction strategies. Buzby et al. (2011), Buzby & Hyman (2012), and Kantor et al. (1997) suggest focusing on consumer education to reduce food waste. Multiple researchers promote incentives to alter food waste practices such as enacting regulatory measures that incentivize complete harvest, providing funding to food producers who redirect waste to charitable organizations, or charging food producers for waste disposal (Buzby & Hyman, 2012; Gunders, 2012; Hodges et al., 2011). Furthermore, Hickey & Ozbay (2014) suggest increasing the shelf life of products, Kader (2005) encourages integration between food producers and food marketers, and Prusky (2011) calls for the establishment of optimal treatment practices for each food product. Shukla & Jharkharia (2013) suggest that fresh produce supply chain management should shift its focus from profit maximization to waste minimization. Finally, Smil (2004) calls for reducing the inefficient use of fertilizers, irrigation water, and pesticides, as well as more closely matching food production to actual food needs.

The literature provides support for reducing food waste at the producer stage, and highlights a number of waste reduction strategies specifically for on-farm food

waste. Kantor et al. (1997) suggest that addressing food waste at the farm stage may be particularly effective as the food wasted at this stage of the supply chain is likely still in edible condition. Kantor et al. (1997) also suggest using surplus crops as fertilizer or animal feed. Shahzad et al. (2013) suggest harvesting at optimal times, creating product-appropriate storage and processing facilities, using experienced workers, and using appropriate harvesting methods. Additionally, Shahzad et al. (2013) recommend an overall increase in awareness of post harvest losses, particularly through training sessions for food producers. Gunders (2012) suggests practicing farm-level food recovery. Few, if any, studies have been conducted to assess which waste reduction strategies are optimal, highlighting this as a future area of research.

While organic agriculture has been assessed on a number of environmental factors, there is little research regarding how food waste affects the sustainability of food production methods. There is also little information regarding how food production type impacts food waste volume and food waste practices. The International Federation of Organic Agriculture Movements (IFOAM) states that organic agriculture is a holistic production management system and should be designed to recycle plant and animal waste in order to return nutrients to the land, thus minimizing the use of non-renewable resources (Pimentel et al., 2011). In terms of Canadian organic agriculture regulations, there does not appear to be strict specifications regarding reducing and sustainably managing on-farm food waste in organic agriculture (Organic Products Regulations, 2009; Organic Production Systems Permitted Substances List, 2006). The Canadian Organic Production Systems General Principles and Management Standards (2015) document does, however, state that, “pest, disease and weed control practices shall focus on organic management practices that enhance crop health and reduce losses due to weeds, disease and pests” (p. 14), and that nutrient losses should be minimized. MacRae et al. (2011) state that few studies examine organic food from a supply chain perspective and call for research on organic food supply chains compared to conventional food supply chains. Overall, food waste practices may vary by food production method, but currently there is a lack of research on this subject.

Examining the literature on sustainable development, sustainable transitions, sustainable food production, organic agriculture, and food waste provides the context

and rationale to conduct research about on-farm food waste. Assessing agricultural sustainability is a complex challenge, but due to the economic, social, and environmental impacts associated with food waste, it is important to integrate the topic of food waste into the dialogue about agricultural sustainability. Currently, there is a lack of research about on-farm food waste and the relationship between food waste and food production method. Conducting research on food waste in as an indicator of agricultural sustainability may provide insights on how to transition to a more sustainable agricultural system.

## **Chapter 3.**

### **Study Context and Methods**

To answer the research questions posed in Chapter 2, I conducted interviews with food producers and other individuals working in the food industry. Chapter 3 describes the context of agriculture in British Columbia (BC) as well as the methods used in this study. The study context provides a brief overview of necessary background information regarding agriculture in BC; please consult the cited references for more detail.

#### **3.1. Study Context**

British Columbia, the westernmost province of Canada, has a long history of agricultural activity. Large-scale agriculture developed in BC during the 1800s, and multiple farming associations, such as the BC Fruit Growers Association, have been in existence for over 100 years (Dick & Taylor, 2007). As the population of BC grows, pressure to use viable farmland for non-agricultural purposes such as residential, commercial, and industrial development has increased. Public and governmental concern led to the establishment of the Agricultural Land Reserve (ALR) in 1973 to protect agricultural land from being used for non-agricultural purposes. The ALR is still in place today and protects approximately 4.6 million hectares of farmland in BC (Stobbe et al., 2015). Pressure to use farmland for other purposes is particularly high in southwestern British Columbia, where this study took place (BC Stats, 2015).

The agriculture industry in BC continues to be a major source of economic revenue: BC's agrifood and seafood industries contributed \$12.3 billion to BC's economy in 2014, an increase of 5.9% from 2013. Sales from primary food production were \$2.9 billion in 2014 (British Columbia Ministry of Agriculture, 2015). Almost 600,000 hectares

of land in BC are used for growing crops and, “in 2014, approximately 320,000 people were employed in the BC agrifood and seafood value chain” (British Columbia Ministry of Agriculture 2015, p. 46). In the lower mainland region of British Columbia, there is concern about the continuing economic viability of the agriculture sector, and many of the farms in the Lower Mainland are considered to be small farming operations (Artemis Agri-Strategy Group, 2002).

The Government of Canada, the Government of British Columbia, and the Metro Vancouver Regional Government appear to increasingly value sustainable agricultural systems, as demonstrated through recent programming and policy. For example, the British Columbia Ministry of Agriculture, in conjunction with the Government of Canada and the BC Agricultural Research and Development Corporation, established the Environmental Farm Plan Program, a no charge, voluntary program that allows food producers to address environmental opportunities and risks on their farms and provides funding for approved environmentally beneficial projects (ARDCorp, 2013). The Environmental Farm Plan program addresses a variety of aspects of agricultural sustainability, and offers some guidance regarding on-farm food waste including information about best practices for using crop waste as a soil amendment (BC Ministry of Agriculture, 2010). Additionally, the Metro Vancouver Regional Food Systems Strategy (2011) highlights food waste reduction as an overall goal, emphasizing the benefits of diverting food waste from landfills and promoting food recovery programs.

Despite the prevalence of agriculture in BC and the desire to increase agricultural sustainability at a regional, provincial, and federal level, there is a lack of regulation that specifically addresses on-farm food waste as a sustainability issue. In Canada, agriculture is under the shared jurisdiction of the federal and provincial governments. Numerous policy documents touch upon the subject of agricultural food waste, including the BC Agricultural Waste Control Regulation (1992), which aims to ensure environmentally sound practices for using, storing, and managing agricultural wastes and by-products, such as manure and composted materials. The BC Agricultural Waste Control Regulation (1992) mainly focuses on protecting human health and the environment from adverse impacts of poorly managed agricultural waste, and is currently under review. Similarly, the Agricultural Land Reserve Use, Subdivision and

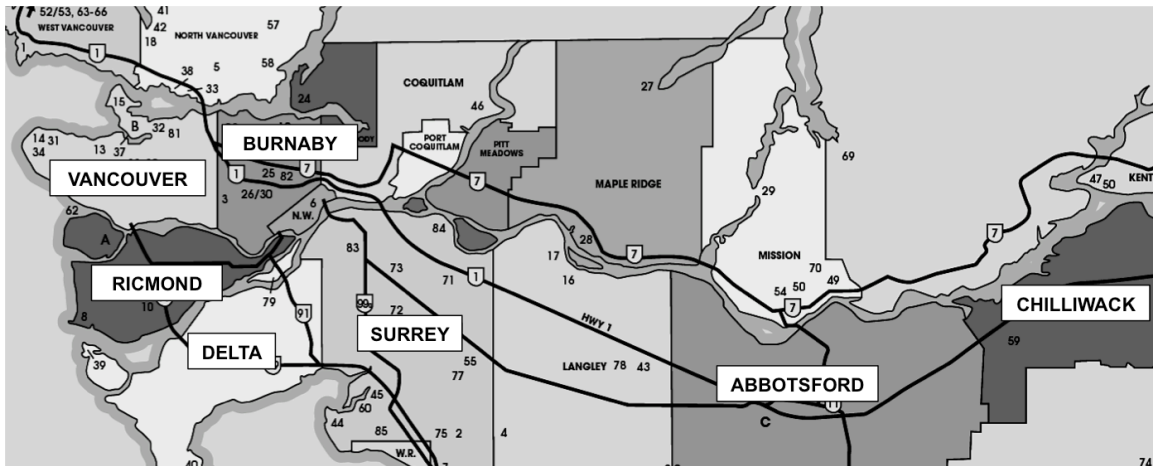
Procedure Regulation (2002), the Drinking Water Protection Act (2001), the Environmental Management Act (2003), the Public Health Act (2008), and the Fisheries Act (1985) regulate agricultural food waste to varying degrees with a focus on reducing the impact of improper waste management on human health and the environment. These acts do not specify sustainability goals for food waste management related to minimizing or sustainably managing on-farm food waste.

Overall, Canada, British Columbia, and the Metro Vancouver region appear to be taking steps to increase agricultural sustainability, but may be missing an opportunity to further meet sustainable agriculture goals by failing to address on-farm food waste more thoroughly in programming and policy. While some programs exist, such as the Environmental Farm Plan Program and the recently established BC Farmer's Food Donation Tax Credit, these programs are generally voluntary and only address some aspects of on-farm food waste (BC Ministry of Agriculture, 2010; Government of British Columbia, n.d.). Food waste in Canada is a large scale economic issue, with total annual food waste in Canada estimated to be valued at \$31 billion, and on-farm food waste, with approximately 2 – 20% of food being wasted on-farm, contributes to this economic loss (Gooch & Felfel, 2014; Gunders, 2012). Food waste also represents a loss of natural resources used to grow food, and is related to social issues such as food insecurity. Increased prioritization of food waste issues in all levels of agricultural programming and policy may provide economic, environmental, and social benefits.

### **3.2. Study Location**

This study was conducted in the lower mainland region of British Columbia, Canada (Figure 3). This region was chosen for a number of reasons, including a high level and wide range of agricultural activities, regional interest in agricultural activities, and proximity to the researcher. Specifically, the farms represented in this study were located in Vancouver, Burnaby, Surrey, Chilliwack, Richmond, Abbotsford, and Delta.

**Figure 3. Map of Study Area**



(Adapted from Greater Vancouver Parks, n.d.)

### **3.3. Research Participants**

To conduct this study, I interviewed ten food producers. Additionally, I interviewed two food industry representatives: one food systems expert, and one representative from the food waste management industry (Table 1). Research participants were contacted primarily by email using publically accessible information. As indicated in the Chapters 1 and 2, there is a lack of information available regarding on-farm food waste; therefore, I aimed to interview food producers from a range of different types of farms for this exploratory study. I selected a sample of food producers illustrative of a variety of farm types. Farms ranged in terms of food produced, size, sales method and production method, as outlined in Table 1. The number of participants interviewed in this study was relatively small; however, all twelve interview participants are highly informed about the study topic and provided in-depth information about on-farm food waste. Ethics approval was obtained prior to conducting this research project.

For the purposes of this study, participants 2, 3, 5, and 7 are classified as certified organic food producers as these farms are certified organic or in the process of becoming certified organic through the Certified Organic Association of BC. Participants 1, 4, 6, 8, 9, and 10 are classified as non-certified organic food producers. As mentioned in subsequent chapters, it was more difficult than anticipated to differentiate between organic and conventional food producers as many of the non-certified organic food



producers that participated in this study consider themselves to be organic food producers despite not being certified. While I initially planned on examining the differences and similarities between certified organic and non-certified organic food producers regarding on-farm food waste, throughout the course of this study it became clear that many farm characteristics in addition to production method impact on-farm food waste. This discovery resulted in shifting from focusing strictly on comparing and contrasting certified organic and non-certified organic farmers to more broadly examining different farming characteristics and their impact on agricultural sustainability related to on-farm food waste.

**Table 1. Outline of Research Participants**

Food Producer Participants				
Participant No.	Farm Size	Foods Produced	Sales Method	Production Method
1	Site 1: 1.5 acres, Site 2: 50 acres	Mixed vegetables and herbs	Farmers' market, restaurants	Not certified organic
2	5 acres	Mixed vegetables and fruit	CSA, farm gate sales, farmers' market (stopped in 2015), restaurants	Certified organic
3	1.5 acres	Mixed vegetables and fruit	CSA, farm gate sales, farmers' market, restaurants	Certified organic
4	1 acre	Mixed vegetables	CSA	Not certified organic
5	Field: 24 acres Greenhouse: 3 acres	Mixed vegetables	Farm gate sales, farmers' market, retail outlets through a distributor	Certified organic
6	780 acres	Mixed vegetables	Restaurants, retail outlets directly and through a distributor	Not certified organic
7	60 acres	Mixed vegetables and fruit	CSA, farm gate sales, farmers' market, restaurants	Organic, currently becoming certified
8	15 acres	Mixed vegetables and fruit	Farm gate sales, restaurants	Not certified organic
9	3.5 acres	Mixed vegetables	CSA, farm gate sales, farmers' market, restaurants	Not certified organic

10	3.5 acres	Mixed vegetables and fruit	CSA, farmers' market, restaurants	Not certified organic
<b>Other Participants</b>				
11	Representative from an industrial food waste processing facility			
12	Food systems expert; manages provincial-level food systems projects			

I conducted semi-structured interviews over an eight-month period, from July 2015 to March 2016. Interviews are an appropriate method for this research project as this research seeks to understand the relationship that food producers have with on-farm food waste, and interviews have the ability to “vary according to the interests, experiences and views of the interviewees” (Flowerdew & Martin 2005, p. 111). Interviews also allow interviewees to explain the complexities of the issues discussed in their own terms, as well as bring up topics that the interviewer did not anticipate, which may be valuable in this case as the topic of on-farm food waste is under-researched. Interview questions were based on findings from the literature review outlined in Chapter 2, and were oriented around five themes: farm characteristics, describing on-farm food waste, on-farm food waste management, food waste policy, and sustainability transitions relating to on-farm food waste. See Appendix A for an outline of the interview schedule.

Prior to conducting formal interviews, I piloted the interview questions with a farmer acquaintance, and updated the questions based on suggestions made by the pilot interview participant. I administered all of the interviews in this study, and all of the interviews were conducted in-person or over the phone, ranging in length from 30 minutes to 1 hour and 30 minutes. The interview process was based on the assumption that research participants would answer questions in a way that truthfully represented their experiences. In an attempt to ensure the truthfulness of responses, I provided research participants with an assurance of confidentiality and informed research participants that they could leave the study at any time without any negative ramifications. Additionally, I assumed that the participants did not have ulterior motives for participating in the research; research participants were informed that they would not be paid and would not receive any direct benefits from participating in the study.

Data gathered from the interviews was analyzed using Nvivo, a qualitative analysis software program. Interview transcriptions were first scanned for initial themes. Next, interview transcriptions were conceptually organized through open coding, and sorted into categories based on themes that arose during coding. Coded interview data was further analyzed for patterns and relationships. The following steps, adapted from Taylor, Bogdan, & DeVault (2016) were implemented in my analysis: read and reread data, track ideas, establish commonly occurring themes, construct categories, interpret data to develop theoretical propositions, and develop charts, diagrams, and figures to highlight patterns in the data.

## Chapter 4.

### Findings

This chapter outlines the main findings of this study based on interviews and analysis outlined in Chapter 3. The findings of this study are concentrated and organized around three main themes as outlined in Table 2: on-farm food waste, farm characteristics, and addressing food waste.

**Table 2. Findings Summary**

Major Theme	Sub-Theme	Key Questions	Key Findings
<b>4.1 On-Farm Food Waste</b>	4.1.1 Defining on-farm food waste	How do you define on-farm food waste?	<ul style="list-style-type: none"> <li>• No common definition</li> <li>• Challenging to define on-farm food waste with a single definition</li> </ul>
	4.1.2 Measuring on-farm food waste	How do you measure on-farm food waste, and how much on-farm food waste do you produce?	<ul style="list-style-type: none"> <li>• No common measurement strategy</li> <li>• Approximately 1% - 20% of total food produced is wasted on-farm</li> <li>• On-farm food waste is often estimated rather than measured</li> <li>• Unharvested food is often not included in estimations of on-farm food waste</li> </ul>
	4.1.3 Causes of on-farm food waste	What factors cause on-farm food waste on your farm?	<ul style="list-style-type: none"> <li>• There are a variety of causes of on-farm food waste including aesthetic standards, pests and disease, weather, inability to sell excess produce, timing of farming practices, and the cost of labour</li> <li>• All food producers interviewed experienced on-farm food waste caused by aesthetic standards, pests, and disease</li> <li>• Causes of on-farm food waste are interrelated</li> </ul>

<b>4.2 Farm Characteristics</b>	4.2.1 Volume of food produced	How much food does your farm produce?	<ul style="list-style-type: none"> <li>• Volume of food produced ranged from 8,300 pounds to 13,000 tonnes</li> <li>• Higher volume food producers produce higher total volume of food waste</li> <li>• In terms of waste management options, higher volume food producers participated in commercial-scale secondary processing, selling for animal feed, and industrial processes, whereas lower volume food producers did not</li> </ul>
	4.2.2 Sales method	How do you sell the food that your farm produces?	<ul style="list-style-type: none"> <li>• Higher volume food producers are more likely to sell food indirectly, while lower volume food producers are more likely to sell food directly to customers</li> <li>• Participants sell food directly through CSA, farmers markets, and on-farm sales, as well as indirectly through distributors</li> <li>• Most food producers use more than one sales methods</li> <li>• CSA may reduce on-farm food waste when compared to farmers markets</li> <li>• Selling food through major retailers may cause both challenges and opportunities for on-farm food waste</li> </ul>
	4.2.3 Organizational structure	How do you manage and structure your farm?	<ul style="list-style-type: none"> <li>• Farm organizational structure may impact on-farm food waste</li> <li>• Food producers may prioritize social initiatives as well as food production</li> <li>• There are many different structures that farms may operate under including teaching farms and social enterprises</li> </ul>
	4.2.4 Production method	Is your farm certified organic or conventional?	<ul style="list-style-type: none"> <li>• It is difficult to differentiate between organic and non-organic farms</li> <li>• Organic certification does not appear to have a direct impact on on-farm food waste</li> <li>• Organic certification may have an indirect impact on on-farm food waste</li> </ul>

<b>4.3 Addressing Food Waste</b>	4.3.1 Factors encouraging sustainability transitions	What factors encourage you to minimize and sustainably manage on-farm food waste?	<ul style="list-style-type: none"> <li>• All food producers interviewed indicated that cost savings encourages them to minimize and sustainably manage on-farm food waste</li> <li>• Most food producers interviewed indicated that environmental impacts, branding, and personal beliefs encourage them to minimize and sustainably manage on-farm food waste</li> <li>• Most food producers interviewed indicated that public pressure and regulations do not encourage them to minimize and sustainably manage on-farm food waste</li> </ul>
	4.3.2 Options for reducing on-farm food waste	What do you do to minimize on-farm food waste?	<ul style="list-style-type: none"> <li>• Research participants take part in a number of strategies to reduce on-farm food waste during the growing cycle including treating food products optimally</li> <li>• On-farm food waste minimization also includes sales, marketing, and educational strategies</li> </ul>
	4.3.3 Options for increasing on-farm food waste sustainability	What do you do with existing on-farm food waste?	<ul style="list-style-type: none"> <li>• All food producers interviewed donate and compost on-farm food waste</li> <li>• Only the highest volume food producers interviewed sell food to livestock producers and participated in industrial processes</li> <li>• Smaller scale farms with lower food waste volume may face limited options for waste management</li> </ul>
	4.3.4 Barriers to adopting practices that minimize and sustainably manage on-farm food waste	What prevents you from minimizing and sustainably managing on-farm food waste?	<ul style="list-style-type: none"> <li>• Financial barriers, logistical barriers, infrastructure barriers, time-based barriers, market-based barriers, barriers related to food standards, regulatory barriers, and barriers related to non-farmer food waste may prevent food producers from minimizing and sustainably managing on-farm food waste</li> <li>• Small scale farms may face barriers due to small volumes of food waste</li> <li>• Large scale farms may have more management options, but may face</li> </ul>

			additional barriers such as strict product size specifications and variable contracts
	4.3.5 Policy options	Which policy options to encourage minimizing and sustainably managing on-farm food waste would you support?	<ul style="list-style-type: none"> <li>• Food producers generally support policy options requiring minimal mandatory action from food producers, with the exception of providing incentives for addressing on-farm food waste</li> <li>• Only three participants support stricter mandatory regulations, and only two participants support taxing food producers for producing on-farm food waste and/or for managing on-farm food waste unsustainably</li> </ul>

## 4.1. On-farm Food Waste

The study investigated three major themes relating to on-farm food waste: defining on-farm food waste, measuring on-farm food waste, and exploring the causes of on-farm food waste. These three themes are discussed in sections 4.1.1 – 4.1.3.

### 4.1.1. Defining On-farm Food Waste

To gain an understanding of how research participants define on-farm food waste, I read the participants the following definition of food waste: “wholesome edible material intended for human consumption, arising at any point in the FSC that is instead discarded, lost, degraded or consumed by pests” (Parfitt, Barthel, & Macnaughton, 2010, p. 3065). Participants then discussed their views about how to define on-farm food waste including what they would add, remove, or change in the aforementioned definition, if anything. Overall, there was no consensus among research participants regarding how to define on-farm food waste, and most research participants did not have a specific definition of on-farm food waste that they used in their day-to-day work. There does not appear to be a standard definition of on-farm food waste used by food producers.

While no common definition of on-farm food waste emerged from the interviews, three food producers stated that their definitions of on-farm food waste are shaped by whether or not they are able to sell harvested food. These food producers stated that when food has been grown and harvested but then is rejected or returned by customers, causing a financial loss to the food producer, they consider it to be food waste, as stated by Participant 10 below. Participant 1 stated that food that is harvested but not sold makes up approximately 1% of the total food produced on their farm, but that there is a much larger, unknown portion of food that is grown but is not harvested, does not get consumed, and is eventually tilled back into the soil. Similarly, Participant 10 stated that an unknown quantity of potentially edible food gets tilled into back into the soil at their farm:

I guess we would be defining [food waste] as food that has been harvested and hasn't been sold.... These plants that we're tilling over would generally be not aesthetically appropriate by market standards, or not in their prime... for all intents and purposes, yes, they could be harvested, and unfortunately that portion of our data on waste, we don't actually have any numbers for. I think that that's a really interesting area of waste. Stuff that could be eaten technically but ends up getting tilled over or put into the compost. (Participant 10)

Overall, I found that on-farm food waste is difficult to define with a single, all encompassing definition. Participant 10 stated that while they felt that Parfitt, Barthel, & Macnaughton's (2010) definition encompasses what food waste is in a general sense, it is missing pieces that are important to individual food producers:

By nature, definitions are static and complex problems are dynamic. So I think that in itself creates a problem with definitions and that as food waste and our understanding of food waste and our management of it evolves, the definition almost needs to be able to take on and embody more of a dynamic sort of ability to it... but I do think that... a lot of these sort of generalized ideas are included within the definition, but there do exist a lot of - I think - individualized nuances in the problem of food waste that are particular to each farm or producer, and a lot of these nuances are then compounded by a multi-level of issues with respect to capacity and logistics of salvaging food, both on the farm and off the farm. (Participant 10)



#### 4.1.2. Measuring On-farm Food Waste

Next, I asked food producers about how they measure on-farm food waste, and how much on-farm food waste they produce. I found that measurements of on-farm food waste are often estimated and that there does not appear to be an industry standard practice for measuring on-farm food waste. As depicted in Table 3, estimates of on-farm food waste ranged from 1% to 20% of total food produced, and measurements were described by research participants in a variety of units including pounds, dollars, and percentage of total food produced. Additionally, none of the estimations of on-farm food waste provided by the research participants included food that was unharvested, potentially resulting in an underestimation of on-farm food waste volume. In the following quotations, Participant 9 emphasizes that estimations of food waste may vary widely depending how on-farm food waste is defined, and Participant 2 states that unharvested food may be responsible for an unknown volume of on-farm food waste:

I'd say 10% would be considered food waste. That's the actual edible portion of the vegetable, but if you include the tops of the turnips and the beet tops and stuff like that – the stalks of chard plants – it could be higher than that. I would say of total organic volume that's grown, it might be more like 20% then. (Participant 9)

I can't even quantify the amount of things that we just didn't harvest that could have been consumed. (Participant 2)

**Table 3. Estimations of On-farm Food Waste**

Participant No.	Approximate Volume of Food Produced Annually	Approximate Percentage and Volume of On-farm Food Waste	Measurement Technique
1	31,500lbs	1% (315lbs)	Estimate of food that was harvested and rejected by customers
2	56,000lbs	1% (700lbs)	Estimate based on one crop
3	8,3000lbs	2%-3% (200lbs)	Estimate based on what is composted
4	\$24,000 in sales	2%-3% (\$480 - \$720 of sales)	Estimate based on food not picked up from CSA boxes
5	738,500lbs	20% (89,000lbs)	Estimate of food hauled off-site in 2014

6	12,000 – 13,000 tonnes (27-28 million pounds)	5-10% (1.3 million - 2.4 million pounds)	Estimate of food hauled off-site
7	Does not know	Does not know	N/A
8	N/R	10% - 20%	Estimate of food grown that was not consumed by humans
9	18,000lbs	10% - 20% (1,800lbs – 3,600lbs)	10% only edible material, 20% total organic volume
10	42,000lbs	4% (1,600lbs); 1% (400lbs)	4% harvested but not sold, 1% harvested but not sold or consumed
<b>Mean %</b>	Approximately 7.4% of total food produced is estimated to be wasted on-farm		

### 4.1.3. Causes of On-farm Food Waste

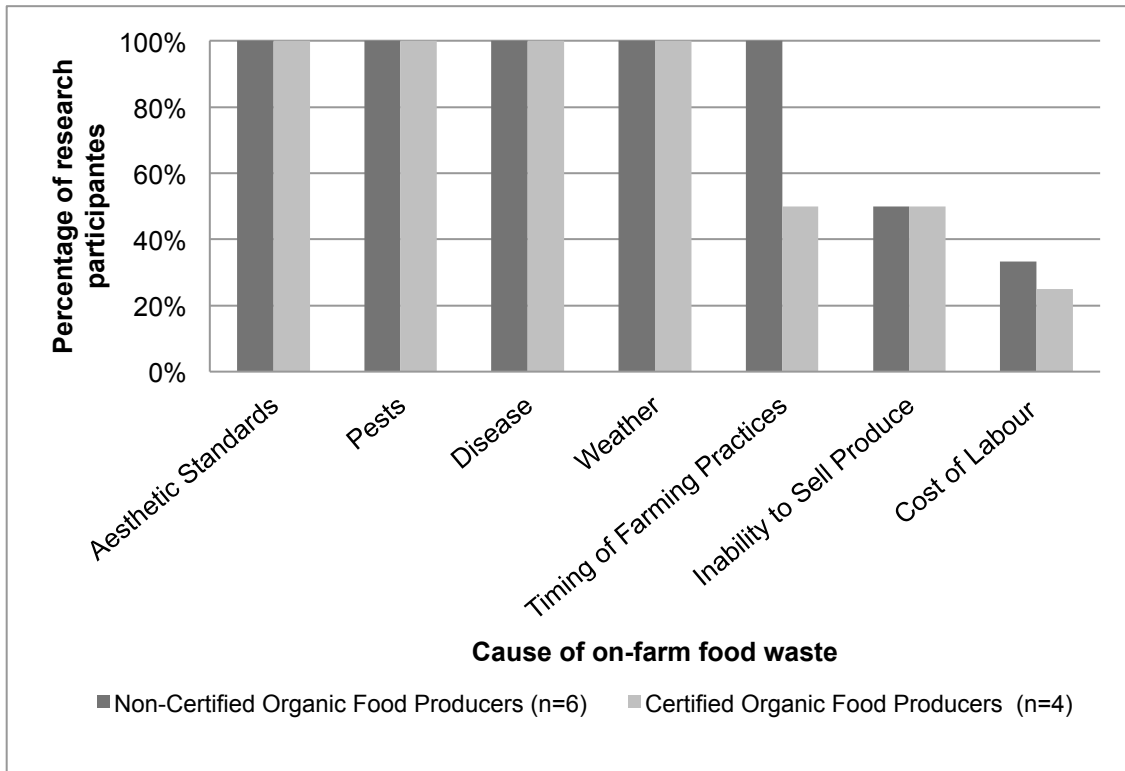
Next, I asked participants about what they consider to be the main of causes of on-farm food waste. A number of causes were discussed including aesthetic standards, pests, disease, weather, the inability to sell produce, the timing of farming practices, and the cost of labour, as depicted in Table 4. Overall, there are numerous causes of on-farm food waste and many causes are interrelated. As indicated in Figure 4, causes of on-farm food waste were similar in non-certified organic food production operations and certified organic food production operations, with the exception of the timing of farming practices. All of the non-certified organic food producers that participated in this study stated that the timing of farming practices is a cause of food waste on their farms, while only 50% of the certified organic food producers stated that the timing of farming practices is a cause of food waste on their farms.

**Table 4. Causes of On-farm Food Waste Experienced by Research Participants**

<b>Cause of On-Farm Food Waste</b>	<b>Description</b>
Aesthetic standards	Rejection of a food product based on its appearance
Pests	Rejection of a food product due to a damaging organism
Disease	Rejection of a food product due to a physical ailment
Weather	On-farm food waste caused by weather related issues such as drought
Inability to sell produce	On-farm food waste caused by a lack of access to customers for a given food product
Timing of farming	On-farm food waste caused by inappropriate timing of farming practices such

practices	as harvesting a crop at a suboptimal time
Cost of labour	On-farm food waste caused when the cost of harvesting a crop is higher than the value of the food products

**Figure 4. Causes of On-farm Food Waste Experienced by Certified Organic and Non-Certified Organic Food Producers**



All food producers interviewed stated that food products being rejected based on aesthetic standards is a cause of on-farm food waste. Aesthetically, food products may be rejected for features such as blemishes, discoloration, marks from pests, and for being misshapen or an undesirable size. Three food producers stated that food being rejected for aesthetics reasons is the largest cause of on-farm food waste on their farms. As indicated in the quotations below, it is challenging for food producers to sell aesthetically inferior produce, although it may be edible:

Potatoes don't come out of the ground perfect – so, some of them have knobs on them, some of them look like hearts, and those can't go in the bags, or in the cartons. So – and then, where do I ship those? (Participant 6)

If it doesn't look good, it doesn't sell. Really... almost regardless of what the price is. Poor looking product doesn't sell.... It's funny, because people say they don't care if it has a little blemish on it, but they do – because they don't buy it. (Participant 8)

Additionally, all food producers interviewed stated that pests, disease, and weather cause on-farm food waste to varying degrees. One food producer stated that combined, spoilage due to pests and rejection for aesthetic reasons caused almost all of the food waste on their farm. As indicated below, Participant 10 stated that pests and disease are somewhat expected to cause food waste on farms, and Participant 3 stated that pests and disease may vary from year-to-year:

We plant stuff that gets hit by pests; using organic methods that's just going to happen to a certain extent... I mean, that food that could have maybe been harvested and instead was hit by pests, yes, we end up having to waste that. (Participant 10)

With the Swiss chard, we had earwigs, so yeah, I guess we have... I don't know, maybe five to eight per cent of the leaves and that year-to-year question - that's because this year seems particularly bad for pests so sometimes we have a little bit more waste from pests. (Participant 3)

A number of research participants expressed that the relationship between weather and on-farm food waste is complex; different weather events can have a variety of impacts on crop growth. For example, warm weather can cause crops to reach maturity faster, reducing overall yield, while wet weather can cause rot, as exemplified in the following quotations:

If anything we're kind of under-par this year because it's been so hot and it's actually lowering yields in some crops.... This actually happened with a lot of our mustard green crops this year, because it's been so hot, we didn't get as many cuts off it as usual, so that means that it got too hot and the plants bolted after just one cut. Whereas normally we would get usually about two or three. (Participant 4)

Three or four years ago... we lost like 70-80% of the potato crop because of the rains, the early rains. So that's a very large, weather-related issue. (Participant 6)

Eight food producers stated that the inability to sell produce is a cause of on-farm food waste. Food producers may face difficulty in finding customers for their products due to inappropriate crop choice, poor marketing, or overproduction of food products, among other factors. Food producers stated that crop choice increases on-farm food waste if crops are in low demand, and decreases on-farm food waste if crops are in high demand. Five research participants stated that they consider overproduction of food to be a major cause of on-farm food waste. The following statements from Participants 10, 7, and 8 illustrate the relationship between food sales and on-farm food waste:

I would say that your ability to sell or not sell produce would be one of the hugest contributors – if not the biggest contributor – to food waste in my opinion. (Participant 10)

A lot of farms are facing situations where, you know, I have this crop, but I don't have a market for it right now. (Participant 7)

It's really hard to estimate what the market is demanding, especially given our state... we've only been in it now for two growing seasons. So, it's really hard to predict demand.... Yeah, so poor grasp of what the market is demanding, poor understanding of where we're at in terms of what the consumer is looking for, in terms of products. So, yeah, that would be one cause of food waste. (Participant 8)

Timing of farming practices and the cost of labour were also indicated as potential causes of on-farm food waste. Five research participants expressed that inappropriate timing of farming practices can cause on-farm food waste, particularly inappropriate harvest timing, which may result in poor product quality and unsuitable product quantity. Three research participants stated that the cost of labour can cause on-farm food waste, as described below:

There were seven or eight acres worth that we didn't even bring in from the field. We told him just to leave them out there. Because it's his labour expense to pick it, it's our labour expense to pick it up out of the bin. (Participant 6)

And then there's also the issues of the stuff that's not yet harvested and it's actually – ok, there's not a market for it, you know, how are you going to pay for the labour to harvest it? (Participant 7)

I also asked participants about a number of other potential causes of on-farm food waste that were identified in the literature including crop choice, transportation,

handling, and storage. Food producers indicated that while waste may arise from these factors, it is typically a small amount. Eight food producers stated storage practices are a minor cause of on-farm food waste; one food producer estimated that approximately 1% of stored food is wasted per month. Seven food producers stated that handling practices are a minor cause of on-farm food waste. One food producer stated that while food waste does occur due to handling practices, it is something that food producers may be able to address:

We see handling damage from the fields, from the harvesting process, and mechanical damage on our washing and packing lines. And you know, that's waste that we can see pretty quickly, and so, you know, advances in technology have made handling easier and easier on the product. So that's waste that I would say is fairly small. But it's definitely still present. (Participant 6)

While research participants identified a number of specific causes of on-farm food waste, participants also acknowledged that many causes of on-farm food waste are interrelated. Research participants indicated relationships among different causes of food waste, such as weather causing disease and aesthetic problems, as well as pests and disease causing aesthetic problems, as illustrated in the quotations below:

This year, we had too much kale at one point... and when you have too much you can run into problems with disease, and airflow isn't as good, and there are older leaves on the plants... we ended up with a glut of kale that has a bit of powdery mildew... it's not really saleable product. (Participant 7)

It kind of intersects with that aesthetics question as well.... Sometimes pests will demolish something. And it's gone, right? And there's no food there. Other times, pests will leave an aesthetic mark on there that is displeasing to consumers, and there's waste because of that, yes. (Participant 8)

## **4.2. Farm Characteristics**

This study identified four farm characteristics that may impact on on-farm food waste: volume of food produced, sales method, organizational structure, and production method. These four farm characteristics are discussed in sections 4.2.1 – 4.2.4.

### 4.2.1. Volume of Food Produced

The volume of food produced by a farm was found to be related to on-farm food waste directly in terms of the total volume of on-farm food waste, as well as indirectly by affecting food producers' options for sales, waste reduction, and waste management. I found that participants 5 and 6, representing farms producing the largest volumes of food, had a number of commonalities regarding on-farm food waste not shared by any of the other food producers in this study (Table 5). Participants 5 and 6 produce more on-farm food waste in terms of sheer volume, and participants 5 and 6 estimate that they waste from 5% - 20% of the total food they grow, a mean value of 14%. Additionally, participants 5 and 6 both sell their food products through distributors to major retailers, and generally have minimal interaction with the end consumer. Participants 5 and 6 also take part in unique food waste management techniques including owning and operating a processing facility, anaerobic digestion, selling food to livestock producers, and providing food waste to an industrial food waste processing facility. Participant 11, speaking on behalf on an industrial food waste processing facility, stated that because industrial scale processing of food waste requires a high volume of food waste, it is more easily gathered from large-scale farms that can provide large bins of food waste:

For now we're working mostly with larger processors and the more volume that a supplier produces – like, the more food waste a certain company produces – they can use a roll-off bin... A roll-off bin is basically a huge bin – 12 yards or 20 yards or 40 yards long – and the bin gets driven to our facility, the contents are dumped right on our floor, and then the bin is brought back to the facility. So it's a different way of collecting food waste, and it's very easy for us to take that food because it goes straight from the supplier to us and back to the supplier. (Participant 11)

In contrast, smaller scale farms that produce lower volumes of food were found to produce less waste in terms of sheer volume, and as a proportion of total crop grown. Smaller scale farmers estimated that they waste from 1% - 20% of total food grown, and waste a mean value of 6% of total food grown (n=7). Lower volume food producers that participated in this study were also more likely to sell food directly to consumers. Additionally, lower volume food producers do not participate in commercial-scale secondary processing initiatives, anaerobic digestion, industrial food waste processing, or selling food to livestock producers. The following quotation highlights the ability of a

food producer on a lower volume, smaller farm to minimize some aspects of on-farm food waste:

We do everything by hand. And we're pretty conscious about not overloading bins and stuff; I could see that being more of a problem with machine harvests. We're on such a small space that we're using all our square inches as effectively as we can so we're pretty conscious of what we have and when it's going to be ready and making sure we harvest it before it goes past prime. (Participant 4)

**Table 5. On-farm Food Waste Volume, Sales Methods, and Waste Management Practices of Higher Volume Food Producers and Lower Volume Food Producers**

Participant No.	Approximate Volume of Food Produced Annually	Approximate Percentage and Volume of On-farm Food Waste	Sales Methods	Waste Management Practices
<b>Higher Volume, Larger Scale Food Producers</b>				
5	738,500lbs	89,000lbs (20%)	Farm gate sales, farmers' market, retail outlets through a distributor	On-site secondary processing, donation, composting
6	12,000 – 13,000 tonnes (27-28 million pounds)	1.3 million - 2.4 million pounds (5%-10%)	Restaurants, retail outlets directly and through a distributor	Donation, sell for animal feed, industrial processing, tilling food into soil
<b>Lower Volume, Smaller Scale Food Producers</b>				
1	31,500lbs	315lbs (1%)	Farmers' market restaurants	Composting
2	56,000lbs	700lbs (1%)	CSA, farm gate sales, farmers' market, restaurants	Sell at discounted rate, donation, composting
3	8,300lbs	200lbs (2%-3%)	CSA, farm gate sales, farmers' market, restaurants	Sell at discounted rate, donation, feed animals on-farm, composting
9	18,000lbs	1,800lbs – 3,600lbs (10%-20%)	CSA, farm gate sales, farmers' market, restaurants	Donation, composting
10	42,000lbs	400lbs – 1,600lbs (1%-4%)	CSA, farmers' market, restaurants	Sell at discounted rate, donation, off-site secondary processing, composting



Food producers who did not supply an approximate volume of food produced annually were not included in Table 5.

Graphs comparing smaller scale research participants (participants 1, 2, 3, 4, 7, 8, 9, and 10) and larger scale research participants (participants 5 and 6) have been included in subsequent sections to further evaluate the potential connections between volume of food produced and on-farm food waste. While the methods used in this study are not conducive to generalizing about food waste on larger and smaller scale farms beyond what was discussed by this study's participants, potential trends identified in this research study may be expanded upon in future research.

#### **4.2.2. Sales Method**

I found that the sales methods used by food producers is related to the volume of food waste produced and to on-farm food waste management. Sales methods can be categorized as direct sales methods, where food producers interact directly with consumers, including community supported agriculture (CSA), farmers' markets, and on-farm sales, and indirect sales methods where farmers do not interact directly with consumers, including sales to restaurants and to retailers, which may be facilitated by a food distributor. All food producers interviewed except for Participant 4 used a variety of sales methods, as indicated in Table 1. Participants 5 and 6 are the only food producers interviewed in this study that sell food to major retailers through food distributors. This section outlines the sales methods used by the research participants as well as the relationship between sales method and on-farm food waste.

Nine out of ten food producers interviewed participate in direct sales methods. Six food producers interviewed participate in CSA, a direct sales method where customers pay in advance for a weekly box of produce, and seven food producers interviewed participate in farmers' markets. Participants stated that selling through CSA and farmers' markets allowed them to educate customers face to face, as expressed in the following quotations:

Another thing about the CSA and the educational part of things is the ability to show people things and say "look, this is what real vegetables look like even if there is a bit of damage to them", and,

like, I guess it goes back to your aesthetics question, like, people are quite happy to have twisted carrots, especially because we're right here to talk about it with them if there is an issue with it. (Participant 4)

We always have very knowledgeable staff at our farmers' market table that are able to communicate with the customers there.... I actually work with our sales team for our market stand to develop a list of suggestions as to how people can be using products. (Participant 10)

Participants 2 and 4 specifically stated that selling through CSA reduced waste on their farm when compared to selling through a farmers' market. Additionally, both research participants stated that they stopped selling through farmers' markets, opting to sell through CSA instead, a decision that was partially driven by the desire to reduce on-farm food waste. Farmers' markets may be prone to waste because vendors may purposely overstock their stands to give the appearance of abundance:

Farmers' markets for us have always been a huge source of waste, which is why we didn't end up doing it any more with the produce.... The thing about the market stands is that the mantra is "pile high, see it fly" which means the whole day, up until the end of the day, you're packing it up so that it looks lush and people are enticed into your stand.... Going from farmers' market to CSA – one of the deciding factors would be waste. Like not so much because it's food waste per say, but because it was – our revenues, yeah, it was a waste of food, and that's the source of our revenue. (Participant 4)

I guess we're farming direct to consumer but the ways that we do that can increase or decrease waste. And going to market increases waste, which is one of the reasons why we're not going to market anymore. I love farmers' markets, but we're doing only a CSA, and wanting to eliminate waste was a large influence for that.... I don't even think we'll have any [waste], I mean nothing I would consider waste. Which sounds really extreme, but I really think that that's the case because we're doing CSA.... People tend to take more than they can sell to a market because when the stall gets empty, people just walk by it. (Participant 2)

Participant 10, who actively participates in farmers' markets, stated that most of their on-farm food waste consists of food returned from farmers' markets, and that harvesting food for farmers' markets is not as precise as harvesting foods for other sales methods:

As I've mentioned, our food waste... probably about 90% comes back from our market returns.... So the food that we harvest for restaurants we harvest to order in exact quantities, the same as our CSA, and the – but for our markets, we're harvesting based on what we're hoping to sell. (Participant 10)

Participant 5, a high-volume organic food producer, suggested that farmers' markets might offer benefits in terms of marketing opportunities. Participant 5 stated that while they sell approximately 95% of their food products through major retailers, they find farmers' markets to be valuable for conducting outreach with consumers:

That's what we do at the farmers' market, that's the purpose of the farmers' market... [attending farmers' markets] allows us to test products... we get to grow certain things all year and say, "Hey, what do you think?", and if we see people coming back and buying it... we'll go back to the stores now do a little bit more work and talk to them about it and say, "you should carry this product, we got great reviews on and we will grow them", and stores usually say, "okay let's try it." (Participant 5)

In addition to CSA and farmers' markets, six food producers interviewed in this study participate in direct sales through on-farm sales. Participant 8 sells the majority of their products through a farm market and on-site restaurant. Selling food on-farm allows Participant 8 to offer a flexible menu at their on-site restaurant, interact directly with customers, and harvest and sell produce on the same day. Some of Participant 8's comments regarding their sales methods are expressed below:

The food that's being used in the kitchen – that's interesting when you talk about food waste. What happens is, if we have an abundance, it goes into the kitchen and they process it or they put it on the menu. So, it's not low quality food, it just means we have lots of it.... And the kitchen here is very flexible.... People come to the farm, they talk to me, they talk to my wife, they talk to other farmers... now we've got a huge connection.... [The ability to leave product in the field is] a huge advantage of having farm-direct sales.... We can sell right from the field and we don't have to over produce or over harvest. (Participant 8)

In terms of indirect sales, food producers interviewed in this study participate in two forms of indirect sales: selling to restaurants and selling to retailers through food distributors. Eight research participants sell food to restaurants, and two food producers

stated that selling to restaurants tends to create consistent food orders. Participant 1 stated that while orders from restaurants are typically consistent, if a restaurant changes its menu, it can drastically change the food order. Only Participants 5 and 6 sell food products to major retailers through food distributors, likely due to the high volume of food produced by these farms. Regarding the relationship between selling food through food distributors and on-farm food waste, Participant 6 noted that working with retailers and competing against other food producers can cause on-farm food waste. In contrast, Participant 5 stated that it is possible to work with retailers to move excess produce:

Retailers play the game too. You know, they told you to plant this but... hey, we got a better price from this guy, so good luck, have a good year kind of thing. So that happened to us with a one-acre plot that we specifically planted for a customer this year and they lost their contract.... Retailers are pretty good on their word for the most part, but sometimes they say, "Oh, we only need 80% of what we talked about." (Participant 6)

There are times when you have too much and you know, what we do is call our buyers and say and listen... I have a wack load of beans right now. So tell you what, run an ad. And I'll say okay great, I'm normally selling at \$2.35 a pound, I'll give you a \$1.90 and blow it out. So they'll bring it in and they'll say bring it in at \$1.90 and sell it for two dollars just to blow it out.... So you know they're taking it from me I'm selling it for, you know, a nickel above cost or a dime above cost just to move product. And they help us out like that a lot and the consumer loves it. (Participant 5)

#### **4.2.3. Farm Management Practices and Organizational Structure**

Decisions that food producers make regarding the management and structure of their farms may also impact on-farm food waste generation and management. Five research participants interviewed in this study stated that their farms are managed to prioritize social initiatives as well as food production. Research participants partake in a number of alternative models of farm management including farming as a social enterprise, operating a sharing farm that seeks to donate the majority of food grown to community groups, and using food production to provide employment for people who face barriers to entering the workforce through traditional means. Additionally, two food producers stated that their farms operate as teaching farms, with one food producer

actively facilitating academic research projects on their farm. Participants 3 and 4 stated that they strive to educate people about food waste issues through their teaching farms:

We have very little [waste] compared to other farms I've worked on or just had known about because, for one thing, we're a teaching institute, so we try to do things, you know, pretty holistically, so we can show other people the importance of saving food.... Yeah, I mean, yeah we make some money, but we're a social enterprise, so all the money goes back into our education programs... doing things sustainably is our number one goal. (Participant 3)

But, I mean, part of our mandate here is to educate people about what agriculture looks like. And, so, hopefully we are teaching people that ok, well, when we see a sustainable farm, we will likely see weeds, you would see chomp marks in your produce, yeah. So that's kind of our take on things. (Participant 4)

#### **4.2.4. Production Method**

As stated in Chapter 1, this study aims to investigate the differences in on-farm food waste generation and management in conventional and organic food production operations. It was more difficult than anticipated to differentiate between organic and conventional food producers. While I initially intended to only consider certified organic farms as organic food producers, I found that many non-certified food producers consider their farms to be organic. While only three food producers that participated in this study were certified organic, five food producers that participated in this study identified as organic farms but were not certified organic. Additionally, one farm was currently in the process of becoming a certified organic farm. For the purposes of this study, Participants 2, 3, 5, and 7 were classified as certified organic food producers, and Participants 1, 4, 6, 8, 9, and 10 were classified as non-certified organic food producers.

Generally, participants indicated that being certified organic had little direct impact on food waste volume and management. In terms of food waste volume, few differences were found between certified organic food producers and non-certified organic food producers. Certified organic food producers that participated in this study estimated that from 1% - 20% of total food grown is wasted on-farm, with a mean estimation of 8%. Non-certified organic food producers that participated in this study also estimated that from 1% - 20% of total food grown is wasted, with a mean estimation of

7%. In terms of on-farm food waste management, two food producers stated that the organic certification process, and growing certified organic food, has little direct impact on their on-farm food waste:

[Becoming certified organic has] no direct impact [on food waste]. Indirectly, since organic practices require crop rotation and in general result in more stable production levels – less boom or bust – there should theoretically be less food waste due to supply and demand discrepancy. (Participant 7; in certification process)

The organic certifier makes sure that we're composting things correctly and storing things correctly, but I've never been asked any – anything about what – what we're doing with the waste and how we're minimizing waste. (Participant 3; certified organic)

While being certified organic may not directly impact on-farm food waste, Participants 2 and 3 stated that producing certified organic food may indirectly impact on on-farm food waste. Participant 3 stated that certified organic food is often of a higher financial value than conventionally produced food, which may incentivize organic producers to minimize waste, and Participant 2 stated that as a certified organic food producer, they value ecologically friendly methods of farming, and minimizing food waste may play a role in farm sustainability:

[Minimizing and sustainably managing food waste] hasn't come up through the organic certification process, I don't know if – maybe just because, the product is worth more money, meaning we are more protective of it... but I don't think that's really a reason why we're doing it. (Participant 3; certified organic)

[Being certified organic] definitely [impacts] how I think about food waste, I think that goes hand-in-hand with that, those values and worldviews of more agro-ecological methods of farming.... The standards I don't think encourage or discourage food waste.... There's some thing inherent about the system that favours a closed- loop.... Yeah, it's not like super specific, but I think it does kind of have an impact as well. (Participant 2; certified organic)

### **4.3. Addressing On-Farm Food Waste**

Sections 4.3.1 – 4.3.5 describe participants' responses to the following topics: factors encouraging food waste sustainability transitions, options for reducing on-farm

food waste, options for increasing the sustainability of on-farm food waste management, barriers to reducing and sustainably managing on-farm food waste, and food waste policy options.

### 4.3.1. Factors Encouraging Food Producers to Minimize and Sustainably Manage On-farm Food Waste

Interview participants highlighted a number of factors that encourage them to minimize and sustainably manage food waste including cost savings, personal beliefs, environmental impacts, branding, public pressure, and regulatory requirements, as outlined in Table 6. All ten food producers interviewed in this study indicated that cost savings is a factor that encourages them to reduce food waste and attempt to manage food waste more sustainably. Research participants indicated that minimizing on-farm food waste may reduce landfilling fees, as well as costs associated with the labour and inputs necessary to produce food. Additionally, processing on-farm food waste into secondary products may allow food producers to make money from food that would otherwise be wasted, as stated by Participant 5 below. Additionally, Participant 8 highlights the financial importance of minimizing on-farm food waste in the following quotation:

You're making money off stuff that you would throw away... it's a great thing... Yeah, I mean if I'm going to be paying someone \$1000 for every time someone picks up a bin, you know, when that same bin has got \$10,000 in it for me. It makes no sense. (Participant 5)

Minimizing waste is hugely important for our bottom line. Overproducing hurts. Right from occupying land to caring for the crop while it's in the ground, to harvesting, to trying to remove the crop to plant a new crop. (Participant 8)

**Table 6. Factors Encouraging Food Producers to Minimize and Sustainably Manage On-Farm Food Waste**

Responses	Cost Savings		Environmental Impacts		Branding		Personal Beliefs		Public Pressure		Regulatory	
	Yes	10	Yes	6	Yes	6	Yes	5	Yes	1	Yes	0
	No	0	No	2	No	2	No	4	No	6	No	7
	N/R	0	N/R	2	N/R	2	N/R	1	N/R	3	N/R	3

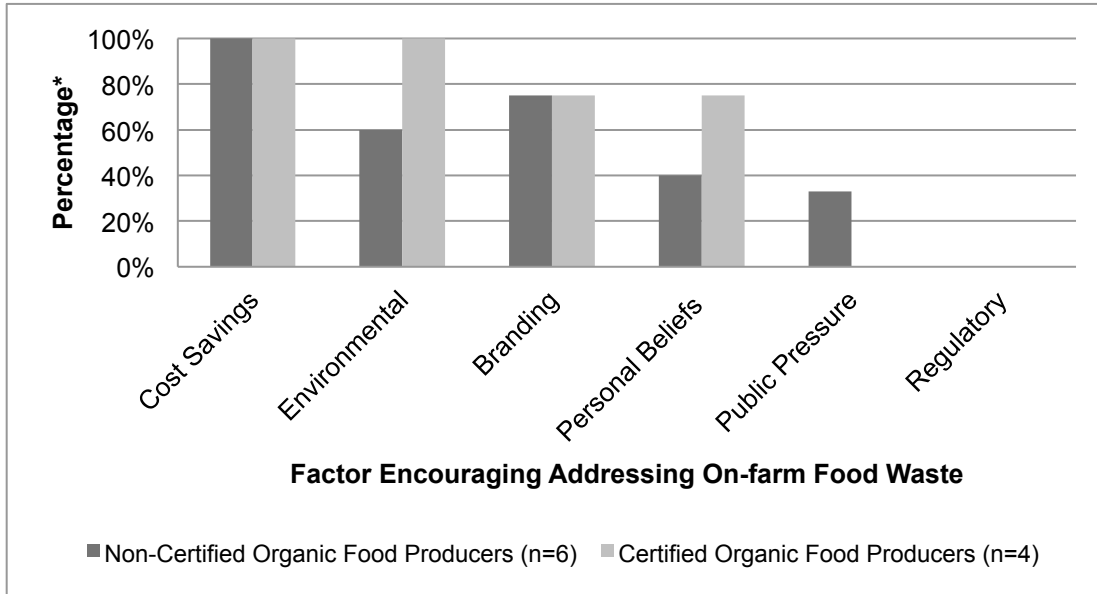
N/R indicates no response.

Six food producers interviewed in this study stated that the environmental impact of food waste encourages them to reduce and sustainably manage on-farm food waste. Additionally, six food producers stated that they are interested in reducing and sustainably managing on-farm food waste to develop an environmentally friendly brand for their food production operation. Five food producers stated that they are encouraged to minimize and sustainably manage on-farm food waste for personal reasons including food waste being unpleasant to manage, guilt felt when food is not fed to people, and wanting to address the food crisis. Only one food producer stated that they felt public pressure to reduce food waste and/or manage food waste more sustainably, and no food producers interviewed stated that they felt any regulatory pressure to reduce on-farm food waste or manage it more sustainably.

When comparing certified organic and non-certified organic food producers regarding factors that encourage them to address on-farm food waste, two key differences were found as indicated in Figure 5. First, 100% of responding certified organic producers stated that the environmental impact of food waste encourages them to address on-farm food waste compared to 60% of responding non-certified organic producers. Second, 75% of responding certified organic food producers stated that personal beliefs about food waste encourage them to address on-farm food waste compared to 40% of responding non-certified organic food producers. Furthermore, when comparing smaller scale and larger scale food producers regarding factors that encourage them to address on-farm food waste, 86% of smaller scale respondents stated that the environmental impact of food waste encourages them to address on-farm food waste compared to 0% of responding larger scale food producers (Figure 6).

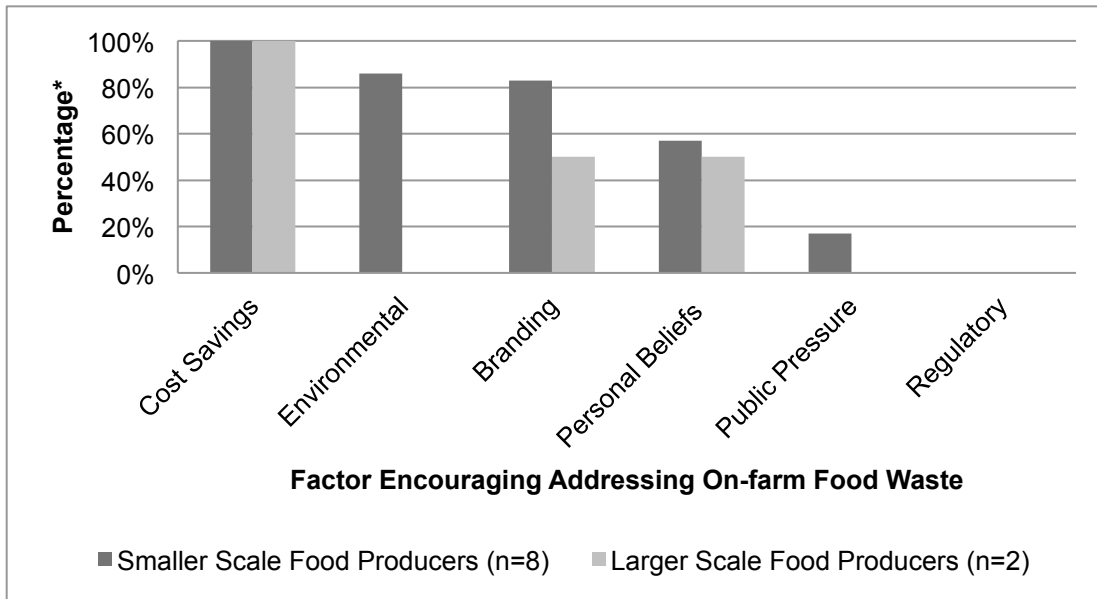


**Figure 5. Factors Encouraging Food Producers to Minimize and Sustainably Manage On-farm Food Waste: Certified Organic vs. Non-certified Organic Food Producers**



\*Percentage of participants that responded to the question.

**Figure 6. Factors Encouraging Food Producers to Minimize and Sustainably Manage On-farm Food Waste: Smaller Scale vs. Larger Scale Food Producers**



\*Percentage of participants that responded to the question.

### 4.3.2. Options for Reducing On-farm Food Waste

As indicated in the food waste hierarchy (Figure 2), source reduction is the preferred method of addressing food waste. To assess how research participants reduce on-farm food waste, I asked a series of questions about on-farm food waste reduction strategies that can be implemented at different times during the growing cycle and that address a variety of causes of on-farm food waste. I found that research participants partake in a number of strategies to reduce on-farm food waste, as indicated in Table 7.

**Table 7. On-farm Food Waste Reduction Strategies Participated in by Research Participants**

Stage in Growing Season	Waste Reduction Strategy	Examples	Waste Cause Addressed
Pre-harvest	Crop planning	<ul style="list-style-type: none"> <li>Plant in-demand crops</li> </ul>	Inappropriate crop choice, inability to sell excess produce
	Integrated pest management	<ul style="list-style-type: none"> <li>Examine crops for pests and/or disease</li> </ul>	Pests, disease, aesthetic issues
	Weather control	<ul style="list-style-type: none"> <li>Install hoop tunnels to protect small crops</li> <li>Grow crops in greenhouses</li> </ul>	Weather, aesthetic issues
	Crop maintenance	<ul style="list-style-type: none"> <li>Prune and cull plants to increase airflow</li> </ul>	Aesthetic issues, pests, disease
Harvest	Appropriate harvesting methods	<ul style="list-style-type: none"> <li>Treat each crop optimally during harvest</li> </ul>	Aesthetic issues, inappropriate handling methods
	Harvest appropriate quantities	<ul style="list-style-type: none"> <li>Participate in same-day harvest</li> </ul>	Inability to sell excess produce
Post-harvest	Appropriate storage methods	<ul style="list-style-type: none"> <li>Cool produce prior to refrigerating</li> <li>Store produce at optimal temperatures</li> <li>Remove spoiled food from storage</li> </ul>	Inappropriate storage methods, pests, disease
	Appropriate packaging methods	<ul style="list-style-type: none"> <li>Package produce in optimal packaging</li> </ul>	Inappropriate packaging methods
	Appropriate processing methods	<ul style="list-style-type: none"> <li>Minimize time between harvest and processing</li> </ul>	Inappropriate processing methods

<b>Year Round Strategies</b>	Sales practices and marketing	<ul style="list-style-type: none"> <li>• Adopt a waste minimizing sales method</li> <li>• Sell older food first</li> <li>• Discount less desirable food</li> <li>• Work with others in the food supply chain to minimize waste</li> <li>• Market atypical foods</li> <li>• Conduct market research</li> <li>• Conduct small-scale testing of new crops</li> </ul>	Inability to sell excess produce
	Diversification	<ul style="list-style-type: none"> <li>• Plant a variety of crops</li> <li>• Adopt multiple sales outlets</li> </ul>	Inability to sell excess produce
	Employee relations	<ul style="list-style-type: none"> <li>• Use experienced workers</li> <li>• Train employees about waste minimizing practices</li> </ul>	Inability to sell excess produce, generally inappropriate farming practices
	Public education	<ul style="list-style-type: none"> <li>• Discuss food waste issues with customers and members of the public</li> </ul>	Inability to sell excess produce, aesthetic issues

In terms of pre-harvest measures to reduce food waste, food producers interviewed in this research study participate in crop planning, integrated pest management, weather control practices, and crop maintenance. Crop planning includes planting specific allocations of different crop types and growing crops that are in demand by consumers. Three participants stated that they take part in integrated pest management, a strategy that considers multiple pest control strategies to find the environmentally and economically appropriate pest management approach for a given crop. Weather control strategies include using physical covers to protect crops from precipitation, as well as growing foods in greenhouses. Crop maintenance may involve culling and pruning crops to allow for optimal growth. The quotations below highlight the importance of planting appropriate crops, as well as some of the benefits of harvesting and selling food within a short time frame:

We planted a lot of daikon that we couldn't sell. And a lot of it became compost because we planted too much. So maybe that was an unsuitable crop or variety in that case, so I think that that was in the initial learning curve of what our customers wanted, but that sort of product is no longer in quantity that it is in our crop plans. So that was something that we were able to use seasonal data to manage and resolve for future seasons. (Participant 10)

I'd say that the key is that it's the same day harvest – morning harvest, and then people pick up in the afternoon with us. It's pretty clearly a good way to minimize risk. (Participant 4)

We try to pick as fresh as possible, so we harvest daily. So don't over pick, especially in the fall because in the fall, it's cool, and the product will last a lot longer in the field than it will in the cooler and that's a huge advantage of having farm-direct sales. (Participant 8)

Post-harvest, all food producers interviewed indicated that they strive to ensure optimal food treatment, including appropriate storage and processing. Study participants mentioned a wide variety of post-harvest actions that they undertake to reduce on-farm food waste including: cooling produce prior to refrigeration, storing produce at an appropriate temperature, using appropriate packaging, decreasing time between harvest and processing, and removing spoiled food from storage. Three food producers interviewed in this study stated that they had recently invested in storage facilities or were planning to do so within one year. By building a new squash storage facility, Participant 6 estimated that the shelf life of their squash would be extended by two months. The following quotations highlight post-harvest strategies undertaken by research participants, including timely food processing and appropriate storage practices:

We have on-farm cold storage, like our processing area is right next to our storage facilities, so stuff can be processed and in the cooler within ten minutes, so I mean, for us, that's pretty tight. (Participant 10)

[Food waste] can definitely be increased if you don't take rotten stuff out before you get in the barn. So, I mean, everyday, probably three times a day, I walk the barn with a flashlight and looking for any areas that are hot spots that rot is occurring, or the potatoes are trying to grow again. And trying to keep our temperature low, so yeah storage is a big factor. And, you know, we're all fighting for season extension, trying to make our crop last as long as possible. But I mean, fruits and vegetables are living, breathing things, so, they – they don't last the same way that a cardboard box would. (Participant 6)

Study participants also take part in a number of year round practices that may help to reduce on-farm food waste, including sales practices, marketing, diversification, employee training, and public education. Sales practices that may reduce on-farm food waste include adopting a sales method that reduces on-farm food waste, discounting

less desirable food products, selling older products first, and working with others in the food supply chain to minimize waste. As stated in section 4.2.2, two participating food producers switched from selling food at farmers markets to selling food through CSA, which reduced on-farm food waste. Participant 7 opened some of their berry crops to a “u-pick” style sales method later in the growing season to minimize waste and labour costs. Some study participants also indicated that marketing food products and conducting market research may reduce on-farm food waste. Specific activities participated in by research participants include marketing of atypical foods, conducting small-scale testing of new crops, building relationships with customers, forecasting market demand, and generally trying to match food supply with demand for the product. Participants 8, 6, and 10 emphasize the importance of marketing, crop planning, and relationship building in the quotations below:

People want the staple foods right? So anything out of the ordinary is a really tough sell.... Unless there's a lot of marketing that goes behind it. (Participant 8)

You can bet I'm on the phone with the marketing agency a few times every day, trying to come up with different ideas about where we can push this stuff [excess food products]. (Participant 6)

Our variation [of on-farm food waste] has definitely gone down since the beginning. I would say that the greatest influence in that has been tightening up our crop planning and building strong relationships with our customers. Both individuals and restaurants so that we have a returning base of customers that are coming back to our farmers' market, our CSA, restaurant customers that are loyal to buying from us. (Participant 10)

The concept of diversification was highlighted a number of times by research participants, including diversification of sales methods and crop choice. Research participants indicated that increased diversification may reduce on-farm food waste and increase the sustainability of food waste management. Participants 7 and 9 highlight the benefits of diverse crops and sales methods in the quotations below:

Diversity in the crops you're growing... some small farms or highly diversified farms, if you had a whole crop, a whole big field of something, a vegetable, that was a failure, well, you might have some animals that you could turn into that field to harvest – they can graze it in the field.... And also, when you have diversified cropping... you're probably a little less susceptible to, you know, feast and famine

market conductions... We have lots of different sales options. We sell at our markets, we sell through our box programs, and we sell to high-end restaurants... So if we have a glut of something, we're likely to be able to find somebody to sell it to... If we only had one sales outlet, if we only sold to restaurants, well, we'd be screwed if something, you know, if we just had a really good year with one crop, we wouldn't be able to sell it... But of course, it takes a lot of effort and a lot of management to have all those sales outlets and to do the diversified cropping. So, there's, yeah, it's generally more labour but more efficient in other ways. (Participant 7)

We don't have a big food waste challenge here because we can always move our product. But there are some farms – most farms are surviving on market sales... for example I had a farmer friend who had three acres of lettuce and then he, you know, grew it for a contract with a distributor, and it just got super hot, everything bolted – there's all kinds of reasons why – and then he had to till it all in, you know. So, that's a tremendous loss for him because it's a financial loss, but... in our case, if we had three acres of lettuce, we'd be able to get it out on time because we have lots of volunteers and folks who can get it through it. (Participant 9)

In terms of training employees about on-farm food waste reduction and management, I found that farm staff may not be directly trained to minimize and sustainably manage on-farm food waste; however, on-farm food waste may be indirectly addressed in training programs. In the quotations below, Participants 4 and 9 discuss their training of volunteers and staff, and Participant 6 highlights the value of using experienced staff:

We have volunteers working with us and part of the program is to teach them how to handle produce correctly... The program is for them to learn about sustainable farming... so we are teaching them harvesting methods, and the other end of things – the processing end of things, so, yeah, embedded in that is instructions on how to harvest things in a way that they won't go bad, or get squished. (Participant 4)

The farmer is continually training not just volunteers, but we have a number of summer students come out, so they get training on how to harvest things to extract the best quality of the vegetable... So we have an experienced farmer and then we hire... a volunteer coordinator who is experienced as well... and myself, I've been farming for 12 years. So that together is kind of the expert level and then people that, like the summer students, once they start, after a couple weeks... I wouldn't call them experts, but they know enough to show other people what to do. (Participant 9)

We try [to use experienced workers]. Most of our workers are part of the Seasonal Agricultural Worker Program from Mexico, so we have some workers that have been with us for nine or 10 years, and those guys – their knowledge is massively important... I think there's some indirect education that goes along with that, but no, we don't have education about [food waste issues]. (Participant 6)

Finally, some of the participants in this study take it upon themselves to educate their customers and the public about food waste issues, and offer strategies for food waste reduction. For example, participant 4 uses CSA as an opportunity to educate their customers about food waste and offer suggestions for minimizing waste, and participant 3 strives to educate consumers about consuming aesthetically displeasing produce as well as offering discounts for less desirable food products. Participant 3 and 4 outline their educational strategies below:

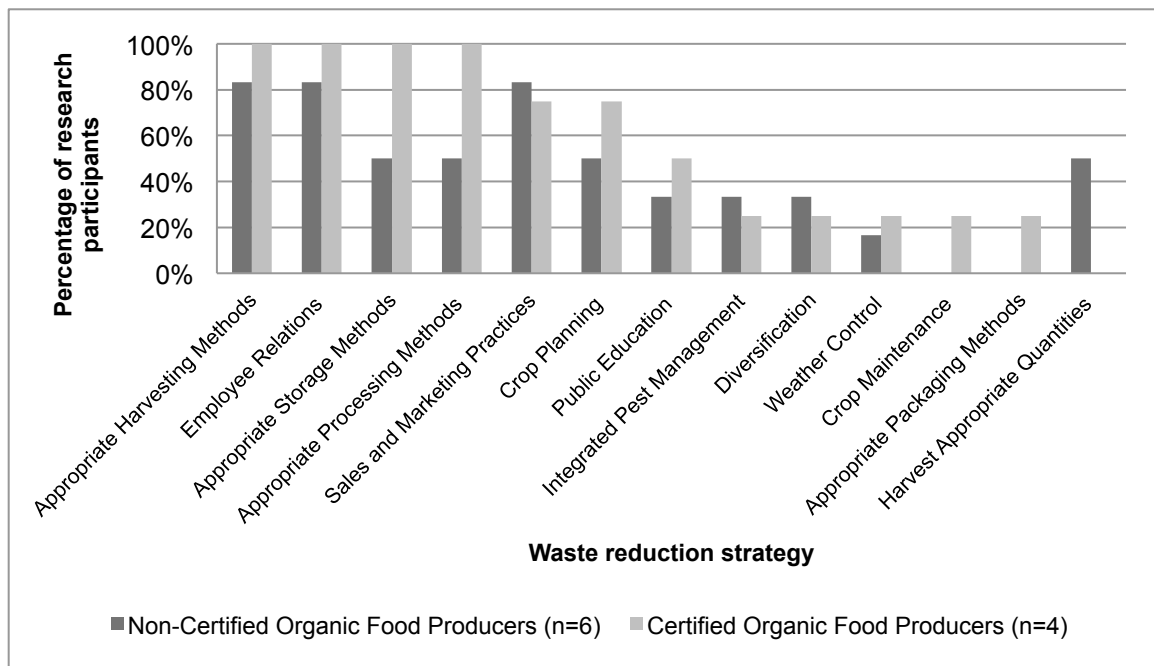
It's kind of a challenge that we put out to the CSA members, that they've signed up to get this amazing bounty of vegetables, and it's your challenge to eat them every week. Or if you can't, then store away for the winter.... So part of our mandate in educating people about food is teaching them how they can use up all that produce in a given week and what they can do with it.... The communication is done here, face to face, and also in a weekly newsletter and we're providing recipes for the produce that we supply them that week. Some things they haven't seen before, so that's something that we have to introduce them to. So yeah, like I said, recipes, and storage tips, and preservation tips. So yeah getting people away from wasting their food hopefully. (Participant 4)

We have made a concerted effort to sell ugly vegetables, sometimes at a reduced cost as – as to make money off the waste, but also to create awareness around anything that's ugly, or you know blemished, or not perfect, aesthetically, but then also, you know, educating people that sometimes aesthetically unpleasing produce is sometimes just as good. (Participant 3)

Figure 7 compares the responses of certified organic research participants to those of non-certified organic participants, and Figure 8 compares the responses of smaller scale research participants to those of larger scale research participants. When comparing participating certified organic food producers to participating non-certified organic food producers, 100% of certified organic producers stated that they attempt to implement appropriate storage and processing methods in comparison to 50% of non-certified organic food producers. Additionally, only certified organic food producers

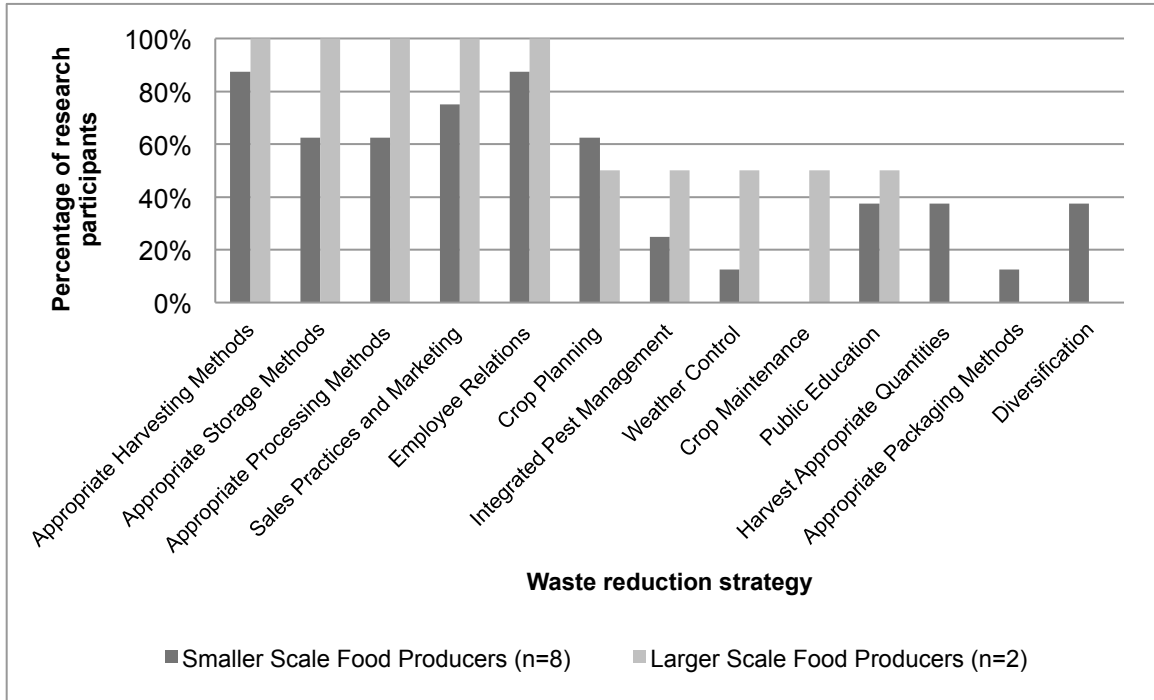
mentioned undertaking crop maintenance and appropriate packaging as on-farm food waste reduction strategies, while only non-certified organic food producers stated that they participate in harvesting appropriate quantities of food as an on-farm food waste reduction strategy. When comparing participating smaller and larger scale research participants, 100% of the larger scale participants participated in appropriate storage methods and appropriate processing methods in comparison to 63% of the smaller scale participants (Figure 8). Only smaller scale farmers mentioned participating in harvesting appropriate quantities, using appropriate packaging methods, and diversification, while only larger scale farmers mentioned participating in crop maintenance.

**Figure 7. Percentage of Food Producers Participating in Strategies to Reduce On-farm Food Waste: Certified Organic vs. Non-certified Organic Food Producers**





**Figure 8. Percentage of Food Producers Participating in Strategies to Reduce On-farm Food Waste: Smaller Scale vs. Larger Scale Food Producers**



### 4.3.3. Options for Increasing the Sustainability of On-farm Food Waste Management

While the food waste hierarchy (Figure 2) indicates that source reduction is the optimal way to address food waste, it is likely that some amount of food waste will exist across all levels of the food supply chain for the foreseeable future. It is therefore valuable to understand which on-farm food waste management strategies food producers are currently employing to assess the feasibility of sustainable options for on-farm food waste management. After source reduction, the optimal practices for managing food waste are feeding people, feeding animals, industrial uses, and composting, in that order. The participants interviewed in this study participate in a wide variety of food waste management practices, as described below (Table 8).

**Table 8. On-Farm Food Waste Management Actions Undertaken by Research Participants**

Level of food waste hierarchy	Action	Number of participants
Feeding people	On-farm secondary processing	5
	Discounting prices	5
	Donation	10
Feeding animals	Feeding on-farm animals	3
	Selling food to feed animals off-farm	1
Industrial	Anaerobic digestion	1
	Other industrial food waste processing	1
Composting	Composting	10

Research participants partake in a number of practices to feed people with food that would otherwise be wasted including processing food products into secondary products, discounting the price of food products to encourage sales, and donating food products. Three participating food producers stated that they undertake secondary processing activities including drying, canning, and cooking food products. In the following quotations, Participant 5 discusses their successful process for creating a chip product from excess and undesirable tomatoes, and Participant 10 highlights some aspects of their canning pilot project including the challenge of paying for the space needed to produce canned goods and trying to ensure product consistency and quality:

So what we did was build a kitchen... where we actually turn all of our tomatoes into tomato chips... It's a very unique product; it's a thin slice.... We have commercial dryers where it dehydrates them... and we package and retail them to the store. So basically all the tomato loss that we have coming in, we're basically turning into tomato chips.... We specialize in keeping anything from a golf ball size and up tomatoes.... So anything sized from that size up we'll put in the dryer. (Participant 5)

So the canning program, we developed that last year... it's had many successes and challenges. So to begin with it was a lot of work to even develop a pilot, and that kind of got embedded within our already existing workload... so with respect to food waste... one of the challenges is still being able to capture that food waste.... Our canning program is internalized within our organization, but the canning space that we're using is not on the farm. It's paid space.... We're trying to create a value-added product, and there has to be a certain amount of production that happens, so it's not like we can just stop what we're doing to process like ten pound of tomatoes, like you need a minimum

of 100lbs of tomatoes to make this worth our time.... And then one other final thing of that is that we're only working with a limited number of recipes. We had four last year, and we're going to try to bring on a fifth this year... but I mean, to create consistency within the product line, it's kind of necessary. So again, it's not going to capture all of the food waste. (Participant 10)

In addition to secondary processing, at least five food producers that participated in this study discount the price of less desirable and/or excess food products to encourage sales. For example, Participant 10 is able to offer food to their customers at a discounted price through direct sales, and Participant 6, who does not sell food directly to consumers, stated that they are working with a major retailer to initiate a program to sell aesthetically inferior food at a discounted price:

We sell [excess and less desirable food] as a processing grade or early harvest is kind of how we market it. Because we found that using words like "seconds"... implied a negative connotation to the product. So yeah, we'll have this on our Fresh Sheet that goes out, it's got all of the products that we're selling at a discounted rate, which is generally 30-50% discount, depending on the place in the food's lifecycle that it's in – essentially the quality... we never actually sell anything that's rotting or decomposing. (Participant 10)

We had the head root vegetable guy from [major retailer] here about a month and a half ago.... they're one of the ones leading this ugly vegetable charge in Canada.... they've done that with potatoes and apples, and now they're going to start doing it here on the west coast it sounds like. And that's product that's just ugly product.... We had them here and we said, hey, we have all this number two squash, we do a ton of business with you on squash... what can we do on the number two side of things? And so it looks like after Thanksgiving, we're going to be doing a whole bunch of ugly squash bins for him. (Participant 6)

Nine of the ten food producers interviewed in this study donate at least some of their excess produce. Some food producers donate food externally to food banks and community groups, while others donate food internally to staff members, and multiple food producers donate food both internally and externally. Some research participants, stated that they are able to donate food successfully by working with various community organizations including Farm to Food Bank, Vancouver Food Bank Angel Food Runners, and Abbotsford Connect. Community groups may assist with food donation by picking up excess food or by offering gleaning services, as indicated in the quotations below.

Alternatively, Participant 2 created an in-house donation system where CSA customers donate money to pay for CSA boxes for low-income individuals.

There's a group – Abbotsford Connect – and we've donated tonnes through them... they come and pick it up. And I have to do very little work. Like, it's easier for me to give it away than it is for me to throw it out.... There are lots of people out there who are willing to [pick up excess food from the farm]. So, initially, I didn't recognize that those channels were open and so available, but there are good people out there who do this for others. (Participant 8)

This year we have a great new service that is called Farm to Food Bank, and they'll come and they'll glean. Their purpose is to mitigate waste as well, and their point of interception is that same problem – where somebody has food in the field and they just can't get it out, and there's no market for it. And they'll come in and they'll do the labour for you and take it to the food bank. So we're so happy that some one is doing this. (Participant 2)

Following feeding people, the food hierarchy indicates that feeding animals is the next ideal way to manage food waste. Food producers participating in this study feed animals on-farm and sell food to feed animals off-farm. Three food producers interviewed in this study feed animals on-farm with food waste, including participant 8, who spoke positively about feeding animals with excess food. Participant 6, the highest volume food producer interviewed in this study, sells excess food to livestock producers at a discounted rate. Quotations from participants 8 and 6 are documented below, highlighting their practices regarding feeding animals with on-farm food waste:

We have about 100 chickens, about 100 ducks, and last year we did a bunch of pigs. And that is a very efficient use of food waste.... Food that's either sat on the shelf and is starting to look bad goes to the animals, when I over buy or we over produce... we don't actually exert the effort to harvest to feed the animals.... The solution is with animals. I really believe that. That's a great way to recycle. And, in a sense, an animal is almost like a way to preserve the food. Because they take it in, it becomes a part of their body, and they're holding onto that value, until we inevitably have to slaughter. (Participant 8)

There's a few dairy farmers and hog farmers that pick up culled potatoes every week. One farm picks up 20 ton a week.... we sell it to them for pennies on the dollar, so they get a pretty good deal. (Participant 6)

The next most preferred food waste management method is industrial processing of food waste. Participant 6 is the only research participant to partake in industrial processing of food waste, and participates in aerobic digestion and entofarming. In the following quotations, Participant 6 describes the potential for using on-farm food waste to produce methane gas, as well as the entofarming process:

I think for us, at this particular company, we see a real opportunity around food waste, and, one of our related companies in the group is an anaerobic digester, where we produce methane gas and sell it to [a utility company]. (Participant 6)

They have a whole facility, and... a flock of black soldier flies. They literally have hundreds of thousands. And they basically take pre-consumer food waste and puree it all up and create this nasty smelling slurry that they pump into trays, and the black soldier flies feed on this slurry, they lay eggs that can produce more black soldier flies, and then they poop and they get organic fertilizer out of that. So actually the eggs become fish feed and feed for other animals and the poop becomes organic fertilizer. (Participant 6)

Finally, the food waste hierarchy suggests composting as a food waste management method. Nine out of ten food producers interviewed in this study participate in some form of composting. While compost is technically defined as “a mixture that consists largely of decayed organic matter and is used for fertilizing and conditioning land”, food producers in this study participate in a wide variety of activities to return nutrients from food grown back into the soil (“Compost”, 2015). Techniques used by food producers in this study include collecting organic material and having it composted by a third-party off-side, using an on-farm three bin composting system, collecting organic material and placing it into a compost pile, tilling unharvested food back into the field, and leaving unharvested food in the field to decompose. Food that is tilled back into the field may be difficult to define and measure as food waste, as indicated in the quotations below:

If a crop is not going to sell in the field, we typically will go in there and flail it. So we use a flailer, which is basically a mower that grinds everything up into really small bits and then we grow right in that patch. So is it food waste? I see it as returning nutrients back into the soil. (Participant 8)

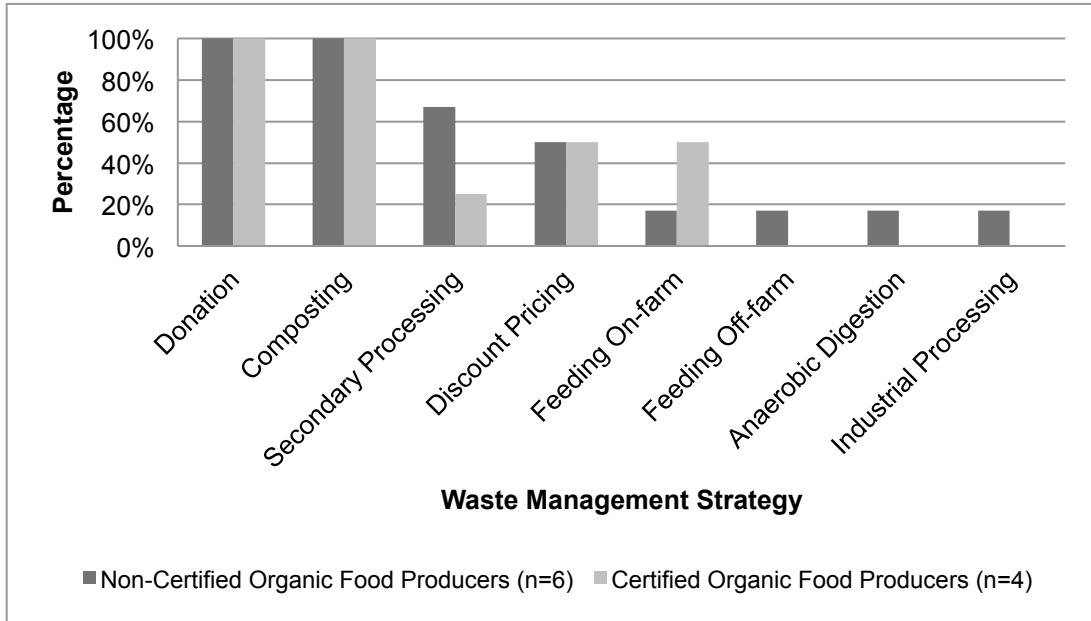
I can't even quantify the amount of things that we just didn't harvest that could have been consumed. But because we didn't harvest them,

they still served the function within our farm – a very important role actually. Because they became cover crops basically, which are monumental in terms of preventing soil erosion and returning fertility to the soil, so, that I can't quantify, nor would I consider it waste. (Participant 2)

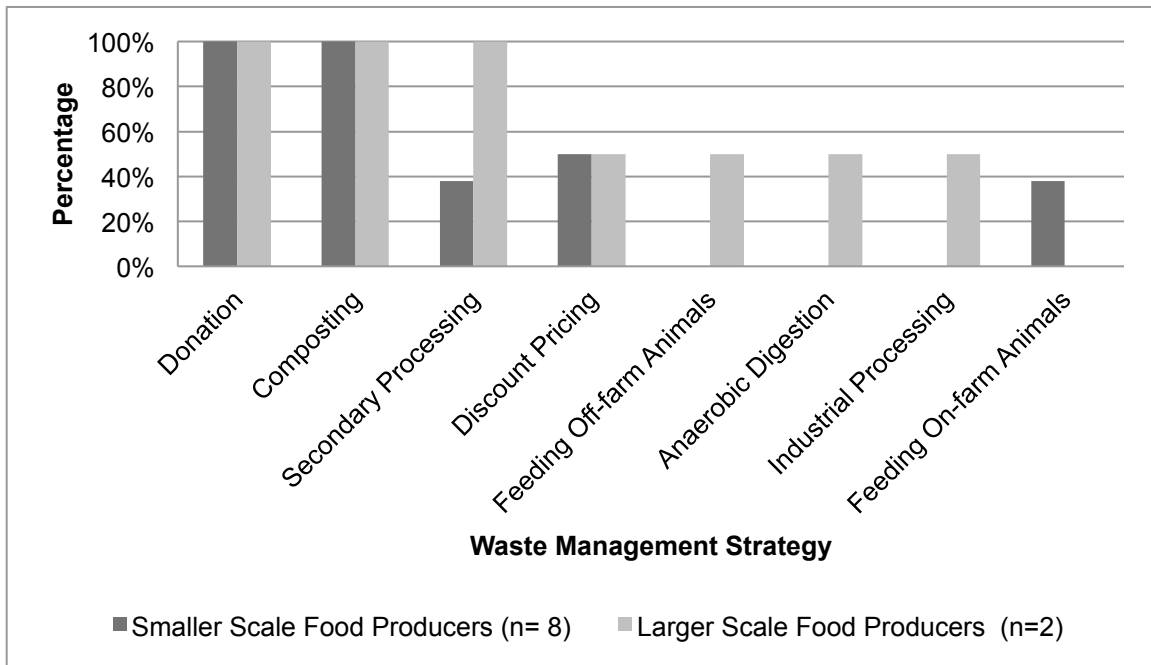
Although incineration and burial of food waste were suggested in the literature as possible food waste management strategies, no research participants interviewed in this study incinerated or buried their food waste. There was minimal landfilling of food waste by research participants, and most research participants managed food waste on-farm.

Figures 9 and 10 depict the percentage of food producer research participants participating in various strategies to manage on-farm food waste, comparing non-certified organic participants to certified organic participants (Figure 9), and smaller scale research participants to larger scale research participants (Figure 10). 67% of non-certified organic food producer participants reported participating in secondary processing compared to 25% of certified organic food producer participants. Additionally, 50% of certified organic research participants reported feeding on-farm animals with food waste, while only 17% of non-certified organic research participants reported feeding on-farm animals with food waste. In terms of smaller scale food producers compared to larger scale food producers, 100% of participating larger scale food producers reported participating in secondary processing, while only 38% of participating smaller scale food producers reported participating in secondary processing. Only a large scale, non-certified organic food producer reported being involved with selling food to feed off-farm animals, participating in anaerobic digestion, and participating in entofarming as food waste management strategies. Only smaller scale food producers reported feeding on-farm animals with food waste.

**Figure 9. Percentage of Food Producers Participating in On-farm Food Waste Reduction Strategies: Certified Organic vs. Non-Certified Organic Food Producers**



**Figure 10. Percentage of Food Producers Participating in On-farm Food Waste Reduction Strategies: Smaller Scale vs. Larger Scale Food Producers**



#### 4.3.4. Barriers to Minimizing and Sustainably Managing On-farm Food Waste

While the food producers that participated in this study are involved in a variety of on-farm food waste management strategies, participants face a number of barriers to further minimizing and sustainably managing on-farm food waste. Many interrelated themes emerged regarding barriers to adopting on-farm food waste reduction and management strategies, including financial barriers, logistical barriers, infrastructure barriers, time-based barriers, market-based barriers, food standards barriers, regulatory barriers, and barriers related to non-farmer food waste (Table 9).

**Table 9. Barriers to Minimizing and Sustainably Managing On-farm Food Waste**

Type of Barrier	Examples
<b>Financial</b>	Financial cost of donating food products and labour
	Low profit margins in agriculture industry
	Financial risk of investing in a new processing venture
	High cost of food processing equipment
<b>Logistical</b>	Small volumes of food waste; not financially viable to process or donate
	Difficult to arrange pick-up of on-farm food waste
<b>Infrastructure</b>	Lack of food processing infrastructure/organizations
<b>Time-based</b>	Other farming tasks are a higher priority
	Composting is time consuming
<b>Market-based</b>	Competing against large corporations in the food processing industry
	Challenge to find customers for processed food products
	Uncertainty regarding contracts with retailers and customers
<b>Food standards</b>	Size specifications for food products
<b>Regulatory</b>	Restricted composting on urban farms
	Restricted waste sourcing for industrial food waste management facilities
<b>Non-farmer food waste</b>	Producers have little impact on food waste after food is sold or donated
	Food waste issues are spread across multiple entities and industries

Research participants emphasized a number of financial barriers to addressing on-farm food waste, including low profit margins in the agriculture industry and the costs associated with donating and processing food products. Some participants, including Participant 11 as depicted in the quotation below, acknowledged the difficulty of



sustainably managing small volumes of on-farm food waste, as donating or processing small volumes of food may not be cost effective. Furthermore, Participants 2 and 10 made statements about the difficulty of contributing food, time, and labour to food donation initiatives, as expressed below:

If it's a smaller producer and they only need, let's say, a three yard bin at their site... you're not going to pay for the haul to bring a tiny little bin over to our place – like, it just doesn't work that way. You can only really do [entofarming] if it's a big roll-off bin.... We feel, you know, that we have the most sustainable option for food waste, but it has to make sense from a financial standpoint for our suppliers to bring that material to us. (Participant 11)

I think that just a general broken food system would be a barrier – like we don't – I probably get paid you know... based on how many hours I put in and my annual income, it'd be like \$4/hour you know what I mean? So I can't on top of a 12-hour day donate two more hours.... I'm not living above the low-income cut off, so I can't help... as much as I would like to – people in need. I kind of am a person in need as well. (Participant 2)

It's just logistically not worth the effort to try and save it. Both on our and on the end of the people who are wanting to pick up. It's just so minimal that it's not worth peoples' time.... I think that when the cost of giving [food waste] away comes out of your own already super-tight margins, it becomes really difficult.... We don't have the capacity to be able to deliver food to outside programs.... At the end of the day, it'll come down to, if I have one bin of food... does someone actually want to come pick it up? Do I have time to coordinate that because I've normally been on the farm for several hours at this point. And I just honestly don't always know when and if that food is going to exist, and being able to find someone who I can work with flexibly on that. That I can literally call up kind of last minute and be like... hey! Can you be down here in an hour, because I don't want to be waiting for you for five. (Participant 10)

Research participants also indicated that the lack of sufficient food processing infrastructure, as well as the initial investment of money and the financial risk involved with establishing a processing facility may be barriers to processing on-farm food waste. When asked if they encountered any barriers when developing their processing facility, participant 5 stated that money was a barrier to establishing a commercial scale food processing facility as the drying machines cost approximately \$30,000 USD. Similarly, participant 10 stated that there has to be a minimal amount of production to make secondary processing, in this case canning, financially efficient, and participant 6 stated

that while they would be interested in processing their own food waste, it is financially challenging to do so. Below, participants 5, 10, and 6 discuss some of the infrastructure defects and financial challenges that they have faced when attempting to process on-farm food waste:

What I'm amazed at is that there's no organic processors, I mean, the matter of the fact is that there are seldom any processors much less organic processors – literally no certified organic processors here in British Columbia, in the Lower Mainland or Fraser Valley.... That's why we went out and bought our own machines and equipment and built our own kitchen and decided to start processing ourselves.... Yeah, each one of my machines cost me 15 G's each.... But if you do it right, you can make that money back. So like I said, just the cost – the initial cost is usually a barrier. (Participant 5)

We're still looking at the bottom line. We're trying to create a value-added product, and there has to be a certain amount of production that happens, so it's not like we can just stop what we're doing to process like ten pounds of tomatoes, like you need a minimum of 100lbs of tomatoes to make this worth our time. (Participant 10)

I was also tasked with looking at the feasibility of a dehydration line, where we could put all of our culled potatoes and squash and make potato flakes and squash powder, and we think there's opportunity in both those areas, I think the issue there is our industry – you know, if I got into the potato flake business, you know who I'm competing against? I'm competing head on with some massive companies, and those companies would... just drop the price on me in this region, and I'd be out of business in two years. So that's where I think... that having a healthy food processing industry goes hand-in-hand with the agriculture industry here. And when we don't have a good food processing industry, or a strong one, that is innovative and that we have some real volume behind, then it's difficult – that's where a lot of this waste product ends up is with processors, and so we'd really like to get more into the food processing business, but the financial numbers of that, there's some real challenges in that area.... Even finding the customers for that end product would be difficult. (Participant 6)

Food producers also acknowledged that a lack of time to invest into food waste management projects is a barrier. For example, composting is a time consuming initiative; Participant 1 stated that it will take four years to create a compost product that they can use on their farm. In the quotation below, participant 5 stated that they it is challenging to find time to compost on-farm food waste; however, when the cost savings

of composting was evaluated, Participant 5 found that composting offered substantial cost savings when compared to hauling on-farm food waste:

Yeah, we started composting this year... Last year we were just having stuff hauled away and then we started doing math, and the amount of thousands of dollars that we were giving out to these people for no reason, you know, so we decided this year to start composting. [Last year] we were just too busy or too lazy – not so much too lazy but just too busy trying to do so many things, not having the time to go around and compost these things. (Participant 5)

Food producers that produce a high volume of food and sell through distributors to retailers may face additional barriers that make it difficult for them to minimize food waste, such as strict specifications for product size, competition for contracts, and uncertainty about how much food to grow. Participant 6, who produces the highest volume of food in this study, discusses these barriers below:

I have to hit eight pounds in that mesh bag, and I have to put two pieces in it... they want a 10% size variance between the pieces... theoretically, I could put a two pound and a six pound squash in there, but that would not meet spec, and that would get rejected at the door.... We calculate that about 10-15% of our entire harvest can go into this pack. So now I have a major retailer, one of our largest customers, saying that I want you to grow kabocha squash, but I only want 12% of it. So that's a big problem. Because now I have 88% that I want to find another home for.... And I have about 400-500 tones of small and large squash that go outside of the specifications.... And out of that 400-500 tones, I'm probably going to end up throwing out 100 tones of that. And that's being optimistic – it could be more than that. (Participant 6)

I mean, I don't know what my competition is putting in the ground every year.... That's really based on the contract that I can go out and get with the retailers every year.... But, I mean, retailers play the game too. You know, they told you to plant this but... hey, we got a better price from this guy, so good luck, have a good year kind of thing. So that happened to us with a one-acre plot that we specifically planted for a customer this year and they lost their contract.... Retailers are pretty good on their word for the most part, but sometimes they say, "Oh, we only need 80% of what we talked about". (Participant 6)

Participants 10 and 11 stated that they faced regulatory barriers to sustainably managing on-farm food waste, including the inability to compost on-farm food waste on

an urban farm and restrictions regarding food waste sources that can be used for industrial processing. Below, Participant 10 outlines some restrictions that they face when trying to compost food, and Participant 11 discusses the constraints that they experience when trying to source waste for their industrial food waste processing facility:

Because we're an urban farm, we have to be careful with our composting practices within the city. So we have to keep stuff in bins and we actually have to send that to composting facilities, so until bylaws in the city change we're technically not allowed to compost on site. (Participant 10)

So we're collecting only pre-consumer food waste around Metro Vancouver. And, we can only use pre-consumer food waste because of regulatory restrictions that we have. Because we're selling a feed ingredient that is going to be consumed by animals that is then going to be consumed by humans, you know, we fall under some restrictions by the Canadian Food Inspection Agency. So they need to approve our feed ingredient as an approved feed before we can sell it in Canada.... But it does make it tricky for us to get the food that we need. Because we're using it for food for our bugs so we have to make sure... that we have enough food around to feed our bugs... we have to carve out pre-consumer food waste from the whole organics waste stream. Whereas most people aren't thinking about it in different ways – they think pre-consumer and post consumer is all the same thing. (Participant 11)

Finally, research participants stated that food waste is a problem that spans across the food system, making it difficult for food producers to fully address food waste at the farm level. As participants 2, 4, and 7 state below, once food is sold or donated, it is difficult for a food producer to ensure that it will not be wasted at a different stage in the FSC. Additionally, Participant 12 highlights some of the difficulties that exist regarding addressing food waste across the FSC, including food systems issues spanning across multiple industries and jurisdictions:

That's not to say that it doesn't get wasted in the consumers' household, but that's not - I don't know, that's beyond my control if they don't eat it all. (Participant 2)

I guess another aspect of food waste in a CSA is you're hopeful that you're giving people the right amounts of things that they're taking home and using all of it. (Participant 4)

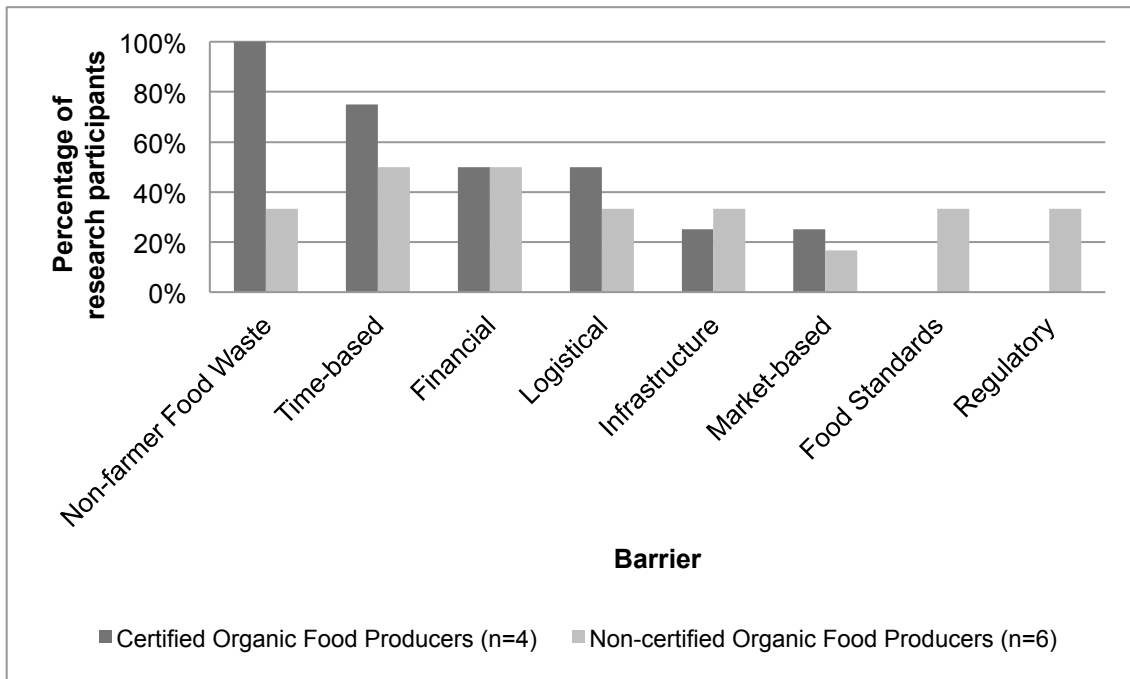
The question is there of, you know, I wonder how much of it in the end, you're selling something or donating something that's not first

quality product, you do have to wonder what's happening to it. (Participant 7)

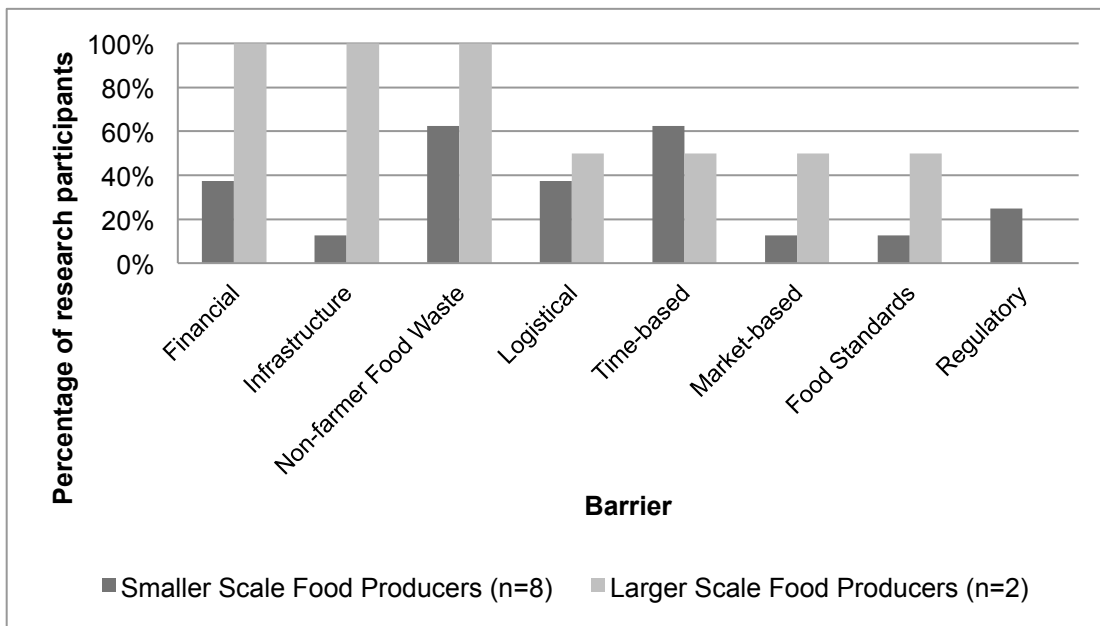
This is my answer to the biggest barrier in probably most food systems issues. It's issues of jurisdiction, and people kind of saying, "it's not my business". So much of food really doesn't have a natural, easy home... it's actually spread across the policy issues.... Right, so from a local government perspective, they're looking at it just from a waste management perspective.... But that's different than looking at it from farmers looking at it, and that more falls under the remit of the Ministry of Agriculture and what they can do about it.... The challenges and the regulatory issues and the key influencers and actors are spread across different jurisdictions. And not just governmental. Right, so it's truly multi-sectorial and multi-level, so therefore to address it.... It's often the challenge of getting full buy-in because people are like, "well, this is my issue with food waste", and it's often something different. (Participant 12)

Figures 11 and 12 compare the responses of non-certified organic food producer participants to certified organic food producer participants and smaller scale food producer participants to larger scale food producer participants regarding barriers to addressing on-farm food waste. As depicted in Figure 11, 100% of certified organic food producers stated that non-farmer food waste is a barrier to addressing food waste compared to 33% of non-certified organic food producers, and only non-certified organic food producers stated that food standards and regulations are barriers to addressing on-farm food waste. As depicted in Figure 12, 100% of larger scale food producers stated that there are financial barriers to addressing on-farm food waste compared to 38% of smaller scale food producers. Additionally, 100% of larger scale food producers stated that there are infrastructure barriers to addressing on-farm food waste compared to 13% of smaller scale food producers, and 100% of larger scale food producers stated that there are non-farmer food waste barriers to addressing food waste compared to 63% of smaller scale food producers. Only smaller scale food producers stated that there are regulatory barriers to addressing on-farm food waste.

**Figure 11. Barriers to Addressing On-farm Food Waste: Certified Organic vs. Non-certified Organic Food Producers**



**Figure 12. Barriers to Addressing On-farm Food Waste: Smaller Scale vs. Larger Scale Food Producers**



#### 4.3.5. Policy Options

Finally, I asked food producers if they would support or oppose various regulatory options for addressing on-farm food waste. Multiple research participants stated that they would need to know the specific parameters of any policy option prior to supporting or opposing it in a real-world setting. As indicated in Table 10, research participants would generally support policy options that require minimal mandatory action by food producers, with the potential exception of incentivizing the reduction and sustainable management of on-farm food waste. Out of nine food producers that provided feedback on policy options to address on-farm food waste, eight participants would support funding research, eight participants would support providing food producers with incentives, seven participants would support industry-developed voluntary regulations, and six participants would support funding educational campaigns. Voluntary guidelines were generally preferred to regulatory guidelines, as indicated in the quotation below:

Voluntary guidelines yeah I mean anything that helps people do what they wanted do but if it's regulatory, this is what you got to do, you got to register this and fill paperwork out for that... no. I'm not a fan of paperwork. (Participant 5)

In contrast, only three participants would support stricter mandatory regulations for reducing and managing on-farm food waste, and only two participants would support taxing food producers for producing on-farm food waste and/or for managing on-farm food waste unsustainably. In addition to stating their opposition to regulatory measures, Participants 4 and 6 stated that stated that top-down regulations regarding on-farm food waste may not be feasible at this time, as expressed in the quotations below:

I think that farmers are really quite over-burdened with the formalities of the food system.... I don't know if I would be keen to burden them even more with stricter regulations and penalties and stuff like that.... I don't think that's something that the BC Ministry of Agriculture – like they just don't tend to... like they don't come down hard, like, they're trying to do more educational stuff. I think that's probably better. (Participant 4)

Yeah, it's pretty hard to say, "reduce food waste" – it's so market driven, that's the thing. For the government to come in and say, "you need to cut food waste by 30% over 10 years", or some arbitrary

number like that... whether they're Liberal, NDP, or Conservative... they'll all have opposition. (Participant 6)

**Table 10. Policy Options to Encourage the Reduction and Sustainable Management of On-farm Food Waste**

Policy Option	Support	Oppose	Do Not Know*
Funding research to develop on-farm food waste reduction and management strategies	7	1	1
Providing food producers with incentives to reduce on-farm food waste/manage on-farm food waste more sustainably	8	1	-
Industry-developed voluntary regulations for reducing and managing on-farm food waste	7	-	2
Funding educational campaigns to encourage food producers to reduce on-farm food waste/manage on-farm food waste sustainably	7	1	1
Stricter mandatory regulations for reducing and managing on-farm food waste	3	4	2
Taxing food producers for producing on-farm food waste and/or for managing on-farm food waste unsustainably	2	7	-

One food producer did not respond to this section. \*\*"Do not know" includes answers "maybe" and "indifferent".

In addition to the policy options listed in Table 10, research participants posed a number of other suggestions for regulatory measures, including government support for local food campaigns, funding for programs that assist in harvesting and picking up excess food, and increased information sharing and collaboration between stakeholders at different stages of the food system. Some of these suggestions are highlighted in the quotations below:

That's what they should be doing, helping the farmers, you know, trying to promote their product and find means for the farmer to sell more of his product more than anything else.... "Buy Local", that was a great idea, you know?... It was a local farmer campaign, and it was a great thing. It did a great thing for us as farmers... that's what they should be doing to promote us rather than worrying about all that other bureaucratic garbage. No need to tax things. (Participant 5)

Yeah, I mean, in terms of policy wise, or programs... a lot of farms are facing situations where... I have this crop, but I don't have a market for it right now, or I even have it harvested, but there's no one to



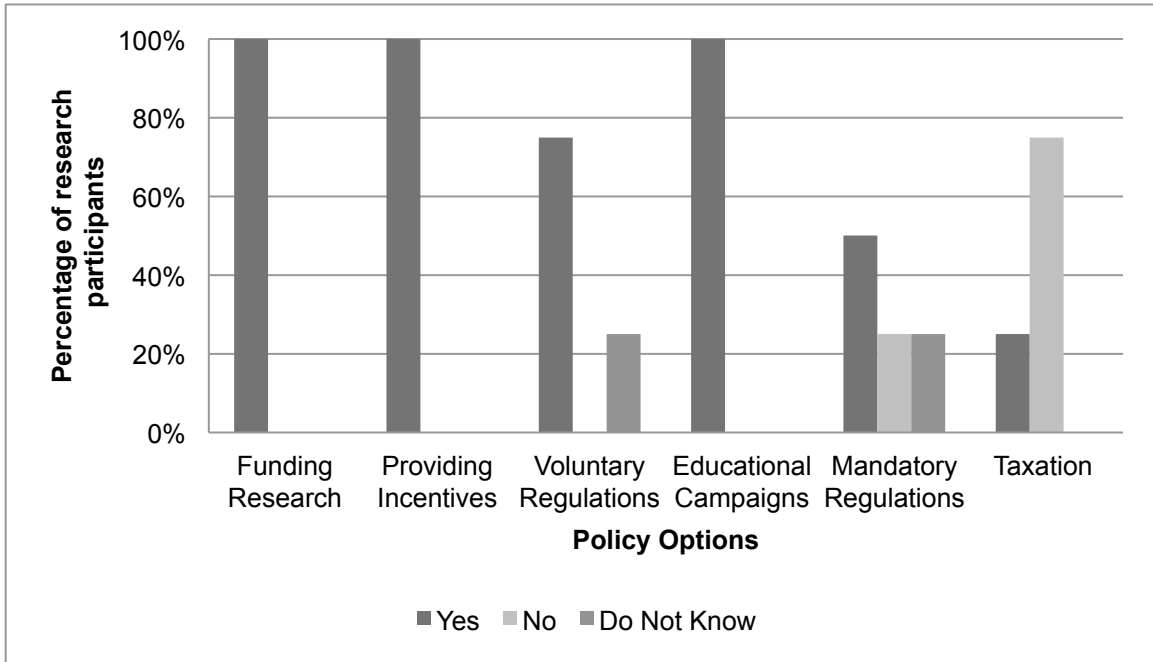
transport it. So you know, something that would... offer some subsidies to enable that to happen better – tax credit for donated food. (Participant 7)

I think there's definite ways all industries could work together to ensure best practices. Farmers can be both very open with each other and very closed with each other. (Participant 6)

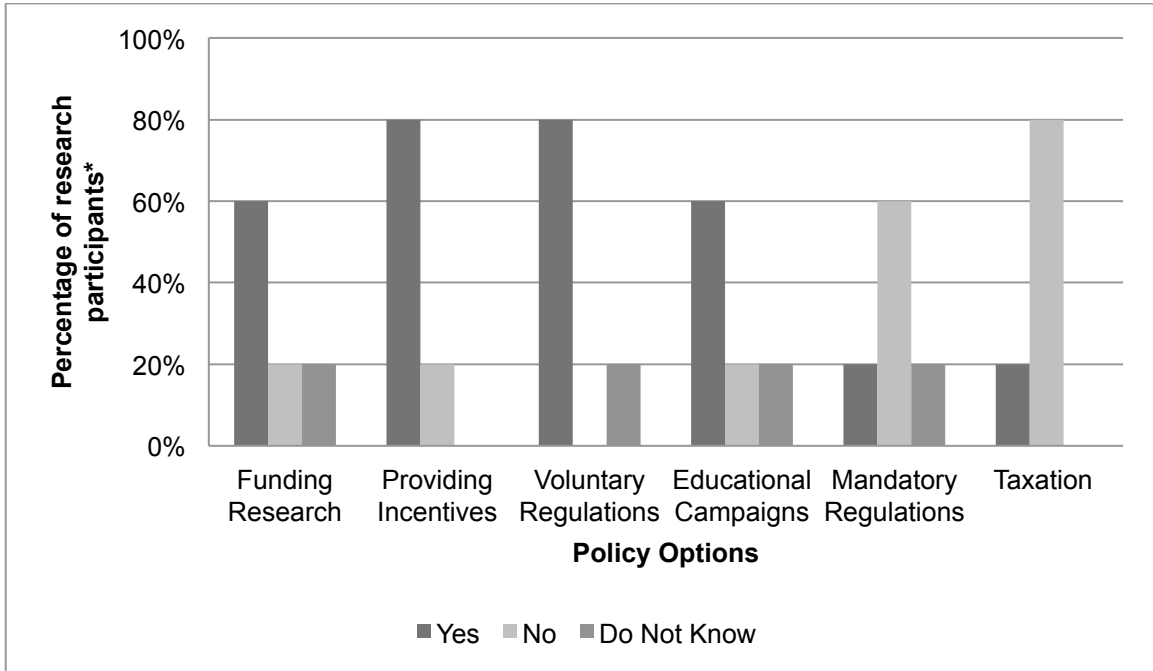
There's definitely time in this work where some of the solutions just need to be identified at the farm level – like there are issues that can be addressed at specific level. But unless we pull out and take a bigger view of it and bring different people together... You can't solve a problem by creating another one, right? And I think a lot of solutions to food waste – they might solve it at one level, but they might create a problem at another level. (Participant 12)

Figures 13 – 16 depict research participants' responses to various policy options for addressing on-farm food waste, categorized by certified organic, non-certified organic, larger scale and smaller scale food producers. As depicted in Figure 13, 100% of participating certified organic food producers support funding research, providing incentives, and funding educational campaigns to address on-farm food waste. In comparison, 80% of responding non-certified organic food producers support incentives, and 60% support funding research and educational campaigns. Additionally, 60% of responding non-certified organic food producers oppose mandatory regulations, while 25% of responding certified organic food producers oppose mandatory regulations (Figure 14). Larger scale food producer participants had the same responses to all policy options: 100% support for funding research, providing incentives, voluntary regulations, and educational campaigns, and 100% opposition to mandatory regulations and taxation (Figure 15). The responses of the smaller scale participants were less polarized, although the majority of smaller scale participants support funding research, providing incentives, voluntary regulations, and educational campaigns, and oppose taxation. 43% of smaller scale research participants stated that they support mandatory regulations, compared to 0% of larger scale research participants (Figure 16).

**Figure 13. Policy Options: Certified Organic Food Producers (n=4)**

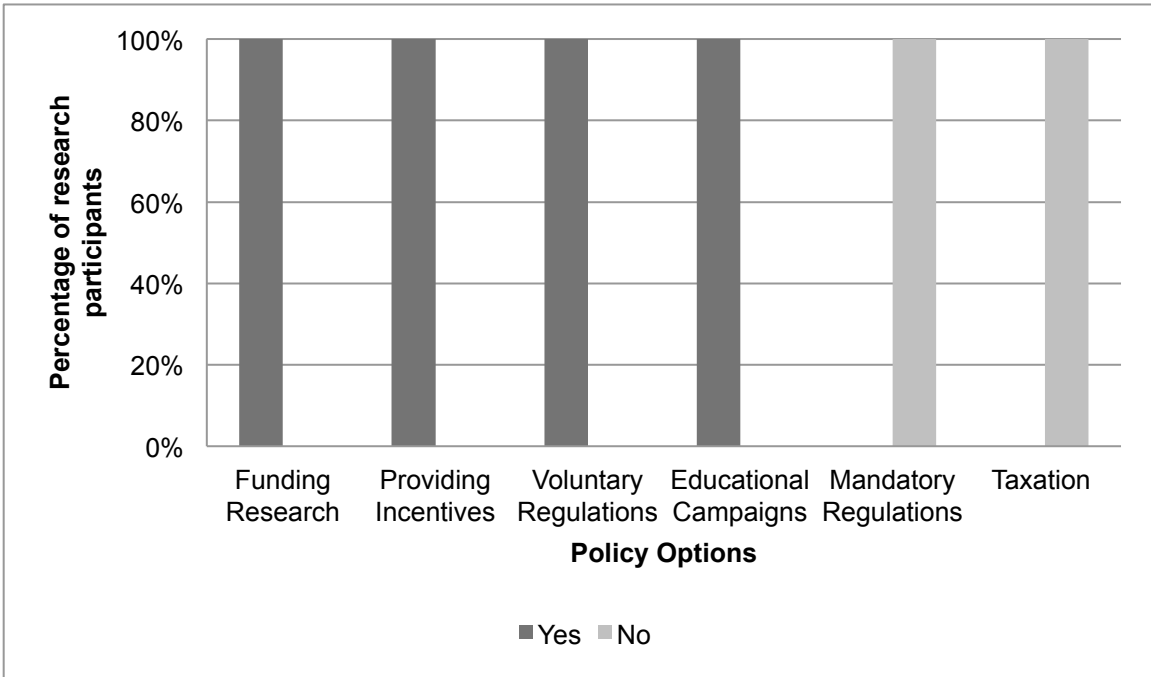


**Figure 14. Policy Options: Non-certified Organic Food Producers (n=5)**

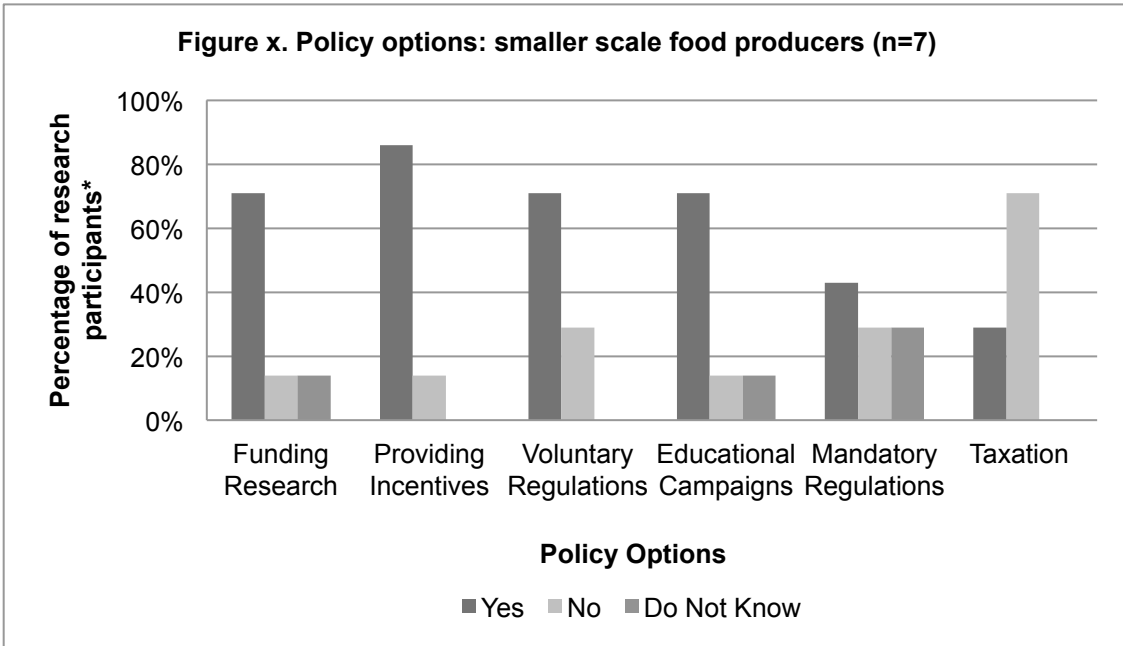


\*Percentage of participants that responded to the question

**Figure 15. Policy Options: Larger Scale Food Producers (n=2)**



**Figure 16. Policy Options: Smaller Scale Food Producers (n=7)**



\*Percentage of participants that responded to the question

## **Chapter 5.**

### **Discussion**

The results from this study provide insights about on-farm food waste, and these results will now be discussed in the broader context of food waste, sustainability transitions, the food system, and sustainable development. This study gathered valuable information regarding how food producers conceptualize on-farm food waste, as well as an understanding of the causes of on-farm food waste, how farm characteristics may impact on-farm food waste, and options for reducing and sustainably managing on-farm food waste. This chapter discusses the findings as they relate to the following research questions:

- Do organic food producers produce more or less waste than conventional food producers?
- Do food waste management practices differ between organic and conventional food producers?
- What role do producer food waste practices play in agricultural sustainability?

Additionally, the recommendations section of this chapter outlines the implications of the findings for food producers and policy makers attempting to encourage the minimization and sustainable management of on-farm food waste. The limitations of this study as well as possibilities for future research are outlined at the end of this chapter.

#### **5.1. On-farm Food Waste in Certified Organic and Non-certified Organic Food Production Systems**

This section discusses the first and second research questions posed in this study:

- Do organic food producers produce more or less waste than conventional food producers?
- Do food waste management practices differ between organic and conventional food producers?

In terms of on-farm food waste volume and management methods, few differences were found between the certified organic food producers and the non-certified organic food producers interviewed in this study. Specifically regarding estimated volumes of on-farm food waste, the food producers interviewed in this study estimated that from 1% to 20% of total food grown is wasted on-farm, with a mean estimation of 7.4%. The certified organic food producers that participated in this study estimated that from 1% - 20% of total food grown is wasted on-farm, with a mean estimation of 7.8%. The non-certified organic food producers that participated in this study also estimated that from 1% - 20% of total food grown is wasted, with a mean estimation of 7.3%. The estimations reported by research participants in this study are consistent with Gunders (2012), who reported that food producers waste approximately 2% - 20% of the food that they grow. While these calculations are based on self-reported estimations of on-farm food waste and quantitative, measured on-farm food waste data is necessary to supplement the information gathered in this study, differences were not found between the estimated volume of food waste produced on participating certified organic farms when compared to the estimated volume of food waste produced on participating non-organic farms.

Practices to address on-farm food waste were divided into two main categories: actions taken to reduce on-farm food waste (food waste reduction strategies), and actions taken to manage existing on-farm food waste (food waste management strategies). Regarding actions taken to reduce on-farm food waste, 100% of participating certified organic producers stated that they tried to implement appropriate storage and processing methods compared to 50% of non-certified organic food producers. Additionally, only certified organic food producers mentioned undertaking crop maintenance and appropriate packaging as on-farm food waste reduction strategies, while only non-certified organic food producers stated that they participate in harvesting appropriate quantities of food as an on-farm food waste reduction strategy. The majority of both certified organic and non-certified organic food producers reported participating

in appropriate harvesting, storage, and processing methods, engaging with employees about food waste issues, and adopting sales and marketing practices to reduce on-farm food waste. It is possible that participating food producers participate in other food waste reduction strategies that were not discussed in the interviews.

Regarding strategies to manage existing on-farm food waste, 67% of non-certified organic food producer participants reported participating in secondary processing compared to 25% of certified organic food producer participants. There is limited research on food processing in organic and non-organic food systems; however, Post, Shanahan, & Jonsson, (2008) found that small organic farms may benefit from the implementation of simple processing methods, assisting small organic producers to capitalize on the increasing demand for processed food alternatives. Processing in certified organic food systems may be more complex than processing in non-organic food systems, as Post, Shanahan, & Jonsson, (2008) also found that consumers perceived that organic foods should largely be unprocessed, and that the additional environmental impacts associated with processing organic foods may undermine the sustainability of organic food products. Additionally, 50% of certified organic research participants reported feeding on-farm animals with food waste, while only 17% of non-certified organic research participants reported feeding on-farm animals with food waste. Generally, the food producers who fed on-farm animals with food waste spoke positively about the ability to use food waste to feed animals. In a recent study, Salemdeeb, zu Ermgassen, Kim, Balmford, & Al-Tabbaa (2016) found that there is growing interest in removing barriers to using food waste as animal feed in the EU, and that using food waste to feed pigs had a lower environmental impact than anaerobic digestion or composting, which is consistent with the preferences for food waste management indicated in the food waste hierarchy (Figure 2).

Overall, while organic certification may have numerous indirect impacts on on-farm food waste, there are three direct impacts of organic certification on the management of on-farm food waste. First, organic standards impact how certified organic food producers can manage pests, which in turn impacts how organic producers can attempt to reduce pest-induced food waste. Second, organic standards impact what can be composted and fed to animals on organic farms (Organic Production Systems:

General Principles and Management Standards, 2015; Organic Products Regulations, 2009; Organic Production Systems Permitted Substances List, 2006). Third, organic standards must be adhered to when conducting secondary processing as a certified organic food producer, which may complicate the ability of organic food producers to process food waste into secondary products (Organic Production Systems: General Principles and Management Standards, 2015). It is also possible that some characteristics of certified organic farms may be pertinent to reducing and sustainably managing on-farm food waste. As MacRae et al. (2007) found, organic farms outperformed conventional farms economically due to reduced input costs, diversified production and marketing channels, increased resilience to market conditions, increased price premiums on food products, and an increased ability to adapt to weather extremes. Farm attributes such as having multiple channels through which to sell food products may assist in managing food waste more sustainably.

Through this research, I found that there are numerous farm characteristics in addition to organic certification that may impact on-farm food waste including volume of food produced, sales methods, and organizational structure. Larger scale farms that produce higher volumes of food were found to produce more waste in terms of total volume. Participants 5 and 6, the larger scale food producers interviewed in this study based on volume of food produced, estimated that they waste from 5% - 20% of total food grown, with a mean estimation of 14%. Smaller scale farms that produce lower volumes of food were found to produce less waste in terms of absolute volume, and smaller scale farmers estimated that they waste from 1% - 20% of total food grown, with a mean estimation of 6%. Further research on the ratio of food produced to food wasted in different food production systems would be useful in providing additional insights on these findings, as indicated in section 5.5.

In terms of managing on-farm food waste, differences regarding secondary processing, industrial food waste management, and feeding on-farm animals were found between the larger and smaller scale food producers interviewed in this study. 100% of participating larger scale food producers reported participating in secondary processing, while only 38% of participating smaller scale food producers reported participating in secondary processing. Only Participant 6, the largest-scale, highest volume food

producer involved in this study reported selling food to feed off-farm animals, and participating in industrial processing as food waste management strategies. Interestingly, no smaller scale or certified organic research participants were involved in industrial food waste management strategies, and Participant 11, who represents an industrial food waste management facility, stated that it is financially challenging to accept small volumes of food waste for industrial processing purposes. Based on the research participant responses, it appears that it is challenging for smaller scale food producers to participate in industrial processing of food waste.

In addition to waste reduction and waste management trends, larger scale participants were found to be more likely to sell food indirectly, have less interaction with consumers, have less opportunities to educate consumers directly, and sell food through a longer supply chain across a wider geographical area. In contrast, smaller scale, lower volume food producer participants were found to be more likely to sell directly to consumers, more likely to interact face-to-face with consumers, and have more control over discounting food prices. Researchers such as Canfora (2016) and Kawecka & Gębarowski (2015) found environmental benefits of shorter food supply chains as well as financial and social benefits inducing higher profit margins and increased insights into consumer demand through face-to-face interactions. However, specific research regarding supply chain length and on-farm food waste is necessary. Interestingly, two smaller scale food producers stated that selling food through a CSA reduced on-farm food waste compared to selling food through a farmers' market, a finding that could be adopted by other smaller scale food producers seeking to reduce on-farm food waste.

The research methods used in this study make it inappropriate to generalize beyond the food producers interviewed in this study; however, further research on the impact of different farm characteristics, including the scale of farming, on on-farm food waste would be useful. There are likely different options for transitioning towards on-farm food waste reduction and sustainable management depending on the volume of food produced, sales method, production method, and organizational structure, among other farm characteristics not addressed in this research study. It is unlikely that there is one defining farm feature, such as organic certification, that completely determines on-farm food waste practices.



## **5.2. On-farm Food Waste and Agricultural Sustainability**

This section addresses research question three: what role do producer food waste practices play in agricultural sustainability? By answering this research question, I aim to offer insights about how agriculture can become more sustainable through minimizing and appropriately managing on-farm food waste. By using the sustainability transitions perspective to address research question three, I aim to relate this research study to the broader goal of increasing food system sustainability, and answer questions such as, “when and why do farmers develop and use more sustainable farming practices?” posed by Hinrichs (2014, p. 143). I found that the food producers interviewed in this study actively participate in actions to minimize and sustainably manage on-farm food waste, and are interested in further addressing on-farm food waste, particularly due to the negative financial consequences of on-farm food waste. That being said, there is room for improvement regarding how food producers address on-farm food waste. This section outlines underlying causes of on-farm food waste, factors that encourage research participants to address on-farm food waste, and options for minimizing and sustainably managing on-farm food waste as related to participants’ responses and the literature.

To understand how to feasibly reduce and sustainably manage on-farm food waste, I gathered information about the underlying causes of on-farm food waste. There are a wide variety of factors that can cause on-farm food waste including rejection of food products based on aesthetic and quality standards, spoilage due to pests, spoilage due to disease, poor weather conditions, selection of unsuitable crops or crop varieties, inappropriate harvesting methods, unsuitable storage methods, and damage arising during transportation (Buyukbay et al., 2011; Gunders 2012; Hodges et al. 2011; Prusky, 2011; Shahzad et al. 2013, Shukla & Jharkharia, 2013). In this study, research participants expressed that rejection of food based on aesthetic standards, spoilage due to pests, disease and weather, and inability to sell produce are responsible for large proportions of on-farm food waste. In contrast, research participants estimated that inappropriate crop choice, inappropriate harvesting, unsuitable transportation methods, and unsuitable storage methods caused minimal amounts of on-farm food waste. Research participants indicated that causes of on-farm food waste are interrelated, for

example hot weather causing discoloration, leading to food products being rejected based on aesthetics. The interrelated nature of on-farm food waste causes may increase the complexity of addressing on-farm food waste. Additionally, many causes of on-farm food waste extend beyond the ability of food producers to address fully, such as the inability to find a market for excess food products, which relates more broadly to market forces and the food system as a whole. While it is important to address all causes of on-farm food waste, I suggest prioritizing solutions for rejection based on aesthetic standards, the inability to sell produce, and spoilage due to pests, disease, and weather as these causes of on-farm food waste were experienced by the highest number of research participants.

In addition to assessing the underlying causes of on-farm food waste, I assessed factors that could potentially encourage farmers to address on-farm food waste, and multiple factors were found to encourage food producers to address on-farm food waste. Overall, I found that the most important factor for encouraging food producers to minimize on-farm food waste and adopt sustainable on-farm food waste management strategies is cost savings. All food producer participants, regardless of production method or volume of food produced, stated that cost savings encourages them to minimize and manage on-farm food waste. An FAO report highlights the importance of incentives to encourage farmers to address waste, as well as the need to find FSC-wide solutions, stating: “farmers are likely to adopt technologies only if there are sound incentives to do so.... The same applies to the reduction of wastage and post-harvest losses, which require better-functioning supply chains” (Food and Agriculture Organization of the United Nations, 2013). Fortunately, many food producers and researchers understand that minimizing and addressing on-farm food waste in a sustainable manner can have financial benefits. As stated in a recent Canadian study, “through reducing food waste, businesses can reduce operating costs by 15 to 20 percent and increase profitability by the equivalent of 5 to 11 percent.” (Gooch & Felfel, 2014, p. 29). Overall, minimizing and sustainably managing on-farm food waste provides opportunities to not only increase sustainability but also to increase profitability.

While cost savings appears to be the factor most likely to encourage food producers to address food waste, other factors, including environmental impacts and

personal attitudes were also reported to be influential. Responding certified organic participants were more likely than responding non-certified organic participants to state that they are encouraged to address on-farm food waste based on environmental impacts and their personal attitudes towards on-farm food waste. These results may reflect a higher concern for the environmental impacts of farming among organic food producers, which has been found in other research. For example, Storstad & Bjørkhaug (2003) state that organic farmers are more likely to be concerned about environmental issues associated with farming than conventional farmers and Mzoughi (2011) found that while economic concerns play a strong role in the adoption of organic farming practices, social and moral concerns also influence the decision to adopt organic farming practices. Interestingly, I found that responding smaller scale participants were more likely than responding larger scale participants to state that they are encouraged to address on-farm food waste due to the environmental impacts of food waste; this topic has not been thoroughly studied in current literature and may be a useful area of future research.

All participating food producers indicated that their farming operations produce at least some food waste, and all food producers take some actions to minimize on-farm food waste. The literature acknowledges multiple on-farm food waste reduction strategies including: educating consumers about food waste issues, increasing the shelf life of products, collaboration between food producers and food marketers, establishing optimal treatment practices for each food product, reducing the inefficient use of fertilizers, irrigation water, and pesticides, more closely matching food production to actual food needs, harvesting at optimal times, creating product-appropriate storage and processing facilities, using experienced workers, and using appropriate harvesting methods (Buzby et al., 2011; Buzby & Hyman, 2012; Hickey & Ozbay, 2014; Kader, 2005; Kantor et al., 1997; Prusky, 2011; Shahzad et al., 2013; Smil, 2004). Food producers interviewed in this study participated in educating customers on food waste issues, increasing the shelf life of their products, working with others in the food industry, striving to treat each product optimally, and striving to match supply with demand. Research participants also participated in a number of other waste reduction strategies including crop planning, crop maintenance, crop diversification, integrated pest management, weather control, marketing, sales method diversification, and employee education. To minimize on-farm food waste to the fullest extent possible, it is likely that

food producers will need to adopt best practices regarding both farming practices and business practices. The responses of the research participants indicate that there is no one solution to minimizing on-farm food waste; to successfully minimize on-farm food waste, it is necessary to combine a number of waste minimizing actions.

Food producers must manage any on-farm food waste that cannot be minimized; the literature suggests using surplus crops as fertilizer or animal feed, and practicing farm-level food recovery (Gunders, 2012; Kantor et al., 1997). The food waste hierarchy (Figure 2) provides guidance on food waste management options by ranking options according to sustainability. Research participants take part in a variety of waste management strategies including: donation, secondary processing, discount pricing, feeding animals on-farm, feeding animals off-farm, industrial processing, and composting. All research participants take part in more than one waste management strategy, and all participants donate and compost food products to varying degrees. According to the food waste hierarchy, donation of food waste to for human consumption is a preferred waste management option, therefore the fact that all food producers interviewed participate in donation of food products can be seen as positive. In contrast, composting, while it may play an important role in returning nutrients to the soil, is not considered to be a preferred food waste management strategy according to the food waste hierarchy. There may be potential to encourage food producers to shift food from composting to more optimal management strategies. It may be difficult for smaller farms to move away from composting as they often have small volumes of food waste that can be difficult to donate or process due to the time and labour necessary to facilitate donation and processing. Although composting food waste is not ideal according to the food waste hierarchy, it is preferred to landfilling and incinerating food waste. Fortunately, no research participants were found to incinerate their food waste, and only one research participant mentioned landfilling food waste when crops were diseased.

While the food waste hierarchy (Figure 2) is a useful tool to rank the sustainability of different food waste management options, not all of the food waste management options highlighted in the food waste hierarchy may be feasible for all food producers. However, the food waste hierarchy may provide a useful guideline for food producers who are trying to increase the sustainability of their on-farm food waste management,

although adjustments specific to each farming operation as well as more detailed waste management plans may be necessary. On-farm food waste may be particularly important to manage appropriately as the food wasted at this stage of the supply chain is often still in edible condition, and food that is in edible condition can be prioritized for human consumption (Kantor et al., 1997). For food that is not in edible condition, waste management options may be more limited.

Regarding the overall transition towards agricultural sustainability, and particularly the questions of when and how farmers develop more sustainable farming practices, this research project provides some insight. When it comes to addressing on-farm food waste, farmers appear much more likely to develop sustainable practices when there is a financial incentive to do so; however, there are many ways that the adoption of sustainable waste management is manifested across farming operations, and many factors in addition to cost savings, such as farm size, production method, and farmer attitude, that combine to make it more or less likely for a food producer to adopt sustainable waste practices. As Hinrichs (2014) states, there is no one easy, obvious, or uncontested pathway on which to transition to sustainability, an opinion that was echoed by the food producers that participated in this study. The responses of the research participants indicate that there is no one solution to addressing on-farm food waste; to successfully address on-farm food waste, it is necessary to combine a number of waste minimizing actions and sustainable management strategies.

### **5.3. Farm Scale and On-farm Food Waste**

While this research project initially intended to focus on comparing certified organic farms to non certified organic farms on the topic of on-farm food waste, a number of other farm characteristics were found to influence on-farm food waste including farm scale and volume of food produced. The two larger scale food producers that participated in this study, one of which was a conventional farm and one of which was an organic farm, had a number of commonalities that were not shared by smaller scale food producer participants. The larger scale food producers participated in a wider variety of waste management strategies than smaller scale food producers, sold food through distributors to major retailers, and shared similar opinions on regulatory action

around food waste policy. Based on the findings of this research, farm scale appears to have more of an impact on on-farm food waste than whether a farm is certified organic or non-certified organic.

The relationship between farm scale and on-farm food waste appears to be complex. Based on the findings from this research, there are some aspects of smaller scale farming that may be conducive to addressing on-farm food waste including more concern for the environmental impacts of food waste, more support for mandatory policy regulations to address on-farm food waste, and an increased ability to educate consumers on food waste issues. Large scale farming, however, also appears to have some features that may be beneficial to addressing on farm food waste, such as increased options in terms of food waste management particularly due to higher volumes of food waste being gathered in one place making it easier to undertake processing and industrial activities. Larger scale food producers may also be able to work with major retailers on campaigns and marketing initiatives to reduce food waste, and may have an increased ability to invest in equipment that can be used to minimize and process on farm food waste. That being said, the larger scale farmers that participated in this study estimated that they wasted slightly more food than smaller scale participants as a proportion of total food produced, which may undermine sustainable actions taken by larger scale farmers. It appears that different options for addressing on-farm food waste may be necessary for farms operating at different scales as they may face different challenges. Overall, on-farm food waste is an important dimension of agricultural sustainability that needs to be included when assessing the sustainability of farming at different scales. More research on the relationship between on-farm food waste and farm scale is necessary to provide a better understanding of the ultimate impact on farm sustainability.

#### **5.4. On-farm Food Waste and the Food System**

Currently, the global food system is facing numerous complex issues, and addressing food waste is one of many important actions that will assist in transitioning the food system towards increased sustainability. While this research study focuses on on-farm food waste and the experiences of primary food producers, this section aims to

place the discussion of on-farm food waste into the broader dialogue of sustainable agriculture and the food system as a whole. This section addresses topics that arose in the interviews regarding on-farm food waste and its relationship to the food system, including the role of food producers and other FSC actors in addressing food waste, ethical issues regarding food waste donation, and the challenges associated with characterizing food as a commodity.

Although addressing food waste at the primary production stage of the food system is critical, it is also important to consider the implications of addressing on-farm food waste at other stages of the FSC, as well as the need for collaboration between different actors in the FSC to completely address the issue of food waste. As stated by Participant 12, it is important that actions taken to reduce on-farm food waste do not simply shift food waste from one stage of the FSC to another:

I think a lot of solutions to food waste – they might solve it at one level, but they might create a problem at another level. But, when we have issues around split jurisdiction, it's like, "well, that's your problem now, you can deal with that now." (Participant 12)

While food producers have a critical role to play in increasing the sustainability of agriculture and the FSC by addressing on-farm food waste, the issue of food waste is prevalent across all stages of the FSC (Figure 1). Actions of food producers alone cannot address the full extent of food waste. Research participants expressed the need for other actors in the FSC to address waste, discussing "non-farmer food waste" – food waste caused by non-farmer FSC actors – as a barrier to addressing food waste. There appears to be opportunities to increase collaboration and communication across the FSC, allowing the industry as a whole to address food waste issues that cannot be addressed at individual FSC stages, and helping to avoid food waste due to a lack of communication between different actors in the FSC, identified as an issue by Shukla & Jharkharia (2013). A whole chain approach to addressing food waste may be financially beneficial to all actors across the FSC, and possibly even more so than by attempting to address food waste at each individual stage of the FSC. The Food Chain Centre found that by using a whole chain waste reduction approach in the fresh produce industry, there is a potential for approximately 20% cost savings across the food chain (Waste & Resources Action Program, n.d.).

I suggest further examination of on-farm food waste from a sustainability transitions perspective, particularly when attempting to develop solutions that can be implemented on farms with the goal of increasing the sustainability of the food system as a whole. As Markard (2012) states, broad scale socio-technical systems, such as the food system, consist of actors, institutions, material artifacts and knowledge, and that these networks interact to provide services. By conceptualizing farming and food waste as one part of the larger food system, we can better understand the broader implications of shifting farming practices, as well as which aspects of food waste can realistically be addressed on-farm, and which aspects of food waste will need to occur in conjunction with others in the food system.

According to the food waste hierarchy (Figure 2), feeding people through methods such as donation is a preferred way to manage food waste; however, some research participants raised concerns about the ethics of idealizing food donation as waste management strategy. Specifically, some research participants stated that they are concerned about donating inferior quality food products to people who rely on donated food, as this may contribute to what can be described as a “two-tier food system”. According to Citizens for Public Justice (n.d.), the primary food system is a sector in the formal economy, allowing users to purchase the food that they desire in exchange for money. In contrast the secondary food system “is largely volunteer run, based on donations and provides users with what is available”, and “more than 800,000 Canadians rely on the secondary system in any given month” (Citizens for Public Justice, n.d.). Those who are able to access the primary food system may have access to more nutritious, higher quality food compared to those who rely on donations. While donation is currently a well-received option for food waste management, it is unlikely to address the underlying food access issues of poverty and ongoing reliance on food banks. Additionally, research participants often described donating on-farm food waste as a financial burden. The BC Food Systems Network states that a whole chain approach to addressing food waste is necessary, and that tax incentives for donating food waste may create a perverse incentive by rewarding businesses for generating food waste rather than offering incentives for waste reduction (Mansfield et al., 2015). By striving to move our socioeconomic system towards one where all people are economically secure and do not need to rely on donated food, it is more likely that all



people will be able to access nutritious food of their choosing, and that food producers will be able to use food that would otherwise be donated for a more economically beneficial purpose.

In the current global economic system, food, despite being a necessary component of human survival, is conceptualized as a commodity that is produced, sold, bought, and consumed in supply chains consisting of numerous profit-oriented businesses. Some researchers, including Rundgren (2016) argue that the food system in its current existence, managed by free trade and unlimited competition, is not compatible with sustainability goals. In this system, food producers may only be able adopt food waste minimization and management strategies if they are proven to be financially beneficial, as stated by Participant 10 below:

I think that it's just a little more complex than whether food waste is important or not – I definitely think it is – it's just that with food, and the way that it's currently conceived within our societal and even global structure in that it's a commodity from which people earn their living, and salvaging food is always going to have a cost associated with it, and when that cost is cutting into peoples' livelihoods and their capacity – whether that's a time capacity or money or whatever resources, there's always going to be a struggle with that. (Participant 10)

In terms of increasing the sustainability of the global food system, I agree with Shukla & Jharkharia (2013) who suggest that fresh produce supply chain management should shift its focus from profit maximization to waste minimization. However, I do not believe that a food system oriented towards waste minimization is feasible without large scale shifts in the global economic system as fresh produce supply chains, and other food supply chains, are part of a larger economic system that is focused on profit maximization. At the present time, focusing on the cost savings offered by waste minimization and some sustainable waste management strategies may assist farmers to transition towards environmentally sound food waste practices. Effectively managing food waste may offer a way to increase both agricultural sustainability and agricultural profitability; as stated by Gooch & Felfel (2014, p. 5), “addressing food waste is a clear opportunity for businesses to be more profitable and to actively contribute to a more environmentally and socially responsible world.” That being stated, working towards a

higher-level food system shift from profit-orientation to waste-orientation may be necessary to fully address food waste across all stages of the food supply chain.

## **5.5. Recommendations**

Overall, improvements in the management of on-farm food waste can increase agricultural sustainability. This section outlines five recommendations for addressing on-farm food waste and food waste in general based on data collected during this study.

### **1. Conceptualize food waste as a resource with cost saving and/or profit producing potential**

Table 11 outlines the potential revenue sources of food waste management strategies that were discussed by participants in this study. In addition to the cost saving and revenue generating factors listed below, all waste management options listed in Table 11 eliminate, or partially eliminate, the need to pay for hauling landfill-tipping fees. Food producers may need to conduct cost benefit analyses regarding the initial and ongoing investments of money, time, and labour that would be required to adopt these management strategies. By conceptualizing food waste as a revenue generating resource and seeking to maximize the value of food waste management, food producers, and those in the food industry in general, may be able to innovate creative solutions that will increase both food system sustainability and revenue. There appears to be increasing interest in finding value in food waste across the food supply chain (Abderrahim, Clark, & Luque, 2013).

**Table 11. Potential Source of Revenue From Various Food Waste Management Techniques**

Action	Potential Revenue Source
Feeding people (secondary processing, discounting prices, donation)	<ul style="list-style-type: none"> <li>• Selling value-added food products</li> <li>• Charging a fee to process food products for other food producers</li> <li>• Renting out food processing space/equipment</li> <li>• Reducing prices allowing food products to be sold through regular means of retail</li> <li>• Tax credits* for donating food products</li> </ul>
Feeding animals (on-farm and off-farm)	<ul style="list-style-type: none"> <li>• Reducing or eliminating the cost of animal feed</li> <li>• Reducing the cost of fertilizer by collecting animal manure</li> <li>• Selling meat, dairy, and/or egg products</li> <li>• Selling food products to livestock producers</li> </ul>
Industrial processing	<ul style="list-style-type: none"> <li>• Selling secondary products produced at an industrial scale, such as natural gas produced through anaerobic digestion</li> </ul>
Composting	<ul style="list-style-type: none"> <li>• Reducing or eliminating the cost of compost</li> <li>• Charging a fee to compost food products for other food producers</li> <li>• Selling excess compost</li> </ul>

\*Such as the recently initiated B.C. Farmers' Food Donation Tax Credit (Government of British Columbia, n.d.).

## **2. Improve opportunities for processing excess food**

Secondary processing can provide a way to create value-added products from food that would otherwise be wasted, as indicated by Participant 5 who was able to successfully establish a commercial scale food processing facility. While processing may be a preferred option for food waste as it allows food waste to be used to feed people while generating revenue and creating jobs in the processing industry, participants in this study acknowledged a number of barriers to effectively processing food products including financial barriers, lack of processors, and competition. While there may be a trade off between food waste and packaging waste when food is processed (Uzea, Gooch, & Sparling, 2014), “the absence of large and medium-sized processing plants in areas of significant food production is often a source of high food losses” (FAO, 2015, p. 20). Additionally, increasing processing at the farm level may assist to diversify the income and skills of farmers, as well as extending the shelf life of agricultural products (FAO, 2015). Post et al. (2008) state that a well functioning processing industry may increase the consumption of organic products, and that there is a general increase in

demand for processed foods. Furthermore Kantor et al. (1997) states that processing advances have created new uses for food products that would have been wasted in the past. While opportunities for increased processing may be beneficial, Gunders (2012) cautions that it is necessary to follow best practices regarding establishing processing facilities as, “even if a processing facility is willing to accept products that might otherwise be discarded, the location must be close enough to justify transport costs, and the facility must have the capacity to process the product” (p. 8).

### **3. Assess food waste on a farm-by-farm basis**

As demonstrated by the food producers that participated in this research study, there are numerous individual actions that can be combined in a myriad of ways to address on-farm food waste. Additionally, there are many different types of farms with unique operational goals, management styles, production methods, and sales methods, among other characteristics. It is necessary for individual food producers to minimize and manage on-farm food waste by taking actions that are most suitable for their organization. Therefore, based on this research, I am not able to prescribe an all-encompassing method suitable for all food producers attempting to address food waste on their farms. At this time, I suggest that food producers identify a definition of food waste that is appropriate for their organization and develop a measurement and/or estimation strategy for on-farm food waste. Additionally, I suggest that food producers outline their current methods of minimizing and addressing on-farm food waste, and identify opportunities to implement strategies, such as those listed in Table 11. By formally addressing on-farm food waste and taking steps to minimize and manage it effectively, food producers may be able to identify options that are both environmentally sustainable and economically beneficial. Overall, I suggest that food producers focus on consistently implementing waste management strategies that are tailored to their organization; to effectively address on-farm food waste it is likely that food producers will need to create a network of interconnected actions over an extended period of time.

### **4. Increase collaboration and communication among all actors in the food system**

Increased collaboration and communication among all actors in the food system is important because food waste is an issue that spans across all stages of the food supply chain. Food waste issues, such as the rejection of food products based on

aesthetics, go beyond any single stage of the food supply chain, and therefore must be addressed collaboratively. Additionally, addressing food waste at one stage of the FSC may have widespread implications across the FSC that should be considered. Collaboration may also help to address difficulties associated with food waste issues including the fragmentation and separation of information about food waste across multiple disciplines (Shukla & Jharkharia, 2013). Gunders (2012) suggests the initiation of collaborative regional food networks to specifically address food waste through reduced transportation and reduced waste of products with short shelf lives. Examples of initiatives striving to facilitate collaborative projects in the food industry include the Ontario Tender Fruit Lab, the Waste & Resources Action Program, and the Metro Vancouver Regional Food Systems Strategy, which strives to provide regional government support for food recovery programs (Metro Vancouver, 2011; Tjornbo, Chung, Laban, & Buré, 2014; Waste & Resources Action Programme, n.d.). The BC Food Systems Network also promotes collaborative approaches to reduce food waste, stating that it is necessary to take a whole chain approach to food waste and to “promote value chains that enhance relationships between producers, processors, distributors, foodservice providers, retailers and others to have the greatest financial and environmental benefits for businesses” (Mansfield et al., 2015, p. 6).

##### **5. Shift policy incrementally and consistently to promote waste minimization and sustainable waste management across the FSC**

In terms of policy recommendations, it is likely that a network of policies are necessary to address an issue as complex as food waste, ranging from regulating individual aspects of the FSC to policies that address the food system as a whole. As stated by research Participant 12, while there are aspects of food waste that need to be addressed at each stage of the FSC, collaborative policy approaches with the cohesive overarching goal of minimizing waste across the FSC are critical to overall food system success on this issue. Based on my findings, it is unlikely that food producers would support strict top-down policies regarding food waste, therefore governmental agencies may instead aim to focus on motivating and enabling change, as well as potentially providing support for research, education, and incentives that address food waste, approaches that are consistent with findings from Uzea, Gooch, & Sparling (2014) and Shahzad et al. (2013). Uzea, Gooch, & Sparling (2014) state that based on international

efforts to address food waste, they recommend adopting a collaborative approach to food waste in Canada, with governmental organizations acting as potential facilitators of initiatives to address food waste.

In terms of policy regarding on-farm food waste specifically, I would recommend starting with voluntary guidelines and incentives, as well as research and education. At this time, based on the lack of policies regarding food waste, there does not appear to be political will or governmental resources to create strict policies regarding food waste. Additionally, based on the data gathered in this research, it is likely that food producers will be more supportive of food waste policies that are voluntary or provide them with incentives for minimizing or sustainably managing food waste. The government of British Columbia has recently introduced the Farmer's Food Donation Tax Credit to encourage food producers to donate food to registered charities, which aligns with suggestions made in the literature to provide incentives to alter food waste practices by enacting regulatory measures that incentivize complete harvest, and providing funding to food producers who redirect waste to charitable organizations (Buzby & Hyman, 2012; Government of British Columbia, 2015; Gunders, 2012; Hodges et al., 2011). Most research participants in this study also supported research and educational initiatives, and Uzea, Gooch, & Sparling (2014) similarly found that research participants would support provincial agencies and ministries developing a common set of definitions regarding food waste as well as a common set of food waste management routes.

Because certified organic food producers are already held to a higher level of regulation than non-certified organic food producers, it may be possible to implement food waste regulations more easily for certified organic farmers through organic standards. Currently, some aspects of organic guidelines may be interpreted to apply to food waste issues, such as "the principal goal of organic production is to develop operations that are sustainable and harmonious with the environment", however little regulation specifically refers to on-farm food waste (Organic Production Systems: General Principles and Management Standards, 2015, p. 7). By integrating steps to address on-farm food waste in organic standards, organic producers may be able to further increase the sustainability of organic agriculture and become leaders in addressing on-farm food waste. The certified organic food producers that participated in

this study stated that they are more likely to address on-farm food waste for environmental and personal reasons, indicating that organic producers may potentially be open to increased action on food waste. However, one research participant stated that organic food producers are already burdened with extensive regulation, indicating that adding additional regulation may be poorly received. More research to understand if organic food producers would be supportive of amending organic standards to include more specific regulation on food waste is necessary.

## **5.6. Limitations and Future Research**

While this research project was designed using commonly accepted qualitative methods, it is subject to limitations including estimation errors and inconsistencies as well as general limitations of interviews as a research method. There are many potential sources of error associated with measuring and estimating on-farm food waste, and because this research project depended upon self-reporting, estimations of food waste volumes may be particularly subject to error. Prusky (2011) found that estimating food waste may be problematic, stating that “a study in which the directly measured losses were compared with estimates obtained by interviews revealed significant differences among the evaluations at the farm, wholesale and retail levels” (p. 464). Directly measured losses were found to be up to 20% more than estimated losses, indicating a tendency for underestimation regarding self-reported food waste. Additionally undermining the ability to accurately estimate volumes of on-farm food waste is the general lack of inclusion of unharvested food in estimations of food waste. Finally, the food producers I interviewed did not have consistent definitions of food waste or consistent measurement or estimation techniques, making it difficult to meaningfully compare estimations among different food producers. While it is clear that food is wasted on-farm, more research is needed to determine precise volumes of on-farm food waste.

As with all research methods, the methods used in this study have limitations. This study relies on qualitative data collected in primary interviews, which, while useful for providing in-depth information about the participants that were involved in this particular study, cannot be used for statistical generalization due to the small and non-

representative sample of research participants (Kvale, & Sage, 2007). This study would benefit from the collection of statistically generalizable quantitative data to supplement its findings. Additionally, Taylor, Bogdan, & DeVault (2016) state that interviews are limited by the fact that people may say and do different things in different situations, and that interviews do not allow for observation of participants within the context of their environment. Case studies and participant observation research may also be useful to supplement this study.

One of the most valuable aspects of using interviews as a research method is the ability to gather detailed information and generate new research topics. This study is no exception, and a number of research topics were generated including:

- 1. Conduct quantitative assessments of food waste.** Although labour intensive and time consuming, it would be valuable to implement a standardized definition and measurement strategy to assess food waste on farms and across the food system. It would also be useful to conduct this quantitative analysis among comparable farms, as well as analysing different types of farms in different geographic areas to allow for comparison.
- 2. Implement and assess on-farm food waste reduction strategies.** A number of food waste reduction strategies were highlighted in this research project, and further research assessing the benefits and challenges of various food waste reduction strategies would provide food producers with additional information about which practices they may want to adopt on their farms.
- 3. Implement and assess food waste management strategies.** Similarly, this study identified a number of food waste management strategies, and further research assessing the benefits and challenges of various food waste management strategies would be useful.
- 4. Implement and assess policies that address food waste.** An assessment of existing policies designed to address food waste would assist institutions seeking to develop effective policies to further address food waste. Additionally, trial policies could be implemented and assessed.
- 5. Conduct research that evaluates the food supply chain as a whole.** Research on food waste from a food system and/or supply chain viewpoint would provide insights on how to transition the whole food system towards waste minimization and sustainable waste management. Additionally, conducting research from a FSC perspective may allow greater profitability across the FSC; as Gooch & Felfel (2014) state, “adopting a whole of chain approach will unequivocally produce greater opportunities and benefits than if focusing on an individual business or department within a business. Achieving a 20 percent reduction in costs and the equivalent of a 5 to 12 percent increase in profitability is entirely feasible, particularly in highly perishable segments such as produce” (p. 26).



**6. Research on the relationship between different farm characteristics and sustainability.** This research revealed that there are numerous farm characteristics, including volume of food produced, production method, management style, sales method, and organizational structure, that can intersect in different ways to affect the sustainability of a farm. More research holistically comparing different types of farms on a variety of indicators of agricultural sustainability such as resource use, energy use, yield, and land use, as well as on-farm food waste, may reveal which combinations of farming characteristics are ideal for fostering sustainable food production.

## Chapter 6.

### Conclusions

To conclude this study, Chapter 6 highlights key findings and provides concluding remarks placing food waste in the larger discussion about sustainable development. Four key findings from this study are outlined below:

1. No conclusive differences were found between certified organic and non-certified organic food producers regarding volume and management of on-farm food waste.
2. Research participants from all types of farms indicated that the factor most likely to encourage them to address on-farm food waste is cost savings.
3. Different farm characteristics including volume of food produced, production method, sales methods, organizational structure, and management style intersect in numerous ways, resulting in a variety of impacts on-farm food waste reduction strategies and on-farm food waste management strategies.
4. Food waste is an issue facing all aspects of the large and complex global food system. To fully address food waste, actions oriented towards minimizing and sustainably managing food waste must be undertaken in a collaborative manner at all stages of the FSC.

While more research regarding the relationship between on-farm food waste and sustainability is necessary, this study has provided information about how food producers conceptualize on-farm food waste, different actions that food producers can take to address on-farm food waste and increase agricultural sustainability, and how on-farm food waste fits into the broader context of food waste across the FSC. As indicated by the diversity of food waste reduction and management strategies participated in by the food producers interviewed in this study, there does not appear to be a single pathway towards food waste minimization and sustainable food waste management. Additionally, it is likely that transitioning towards an agricultural system that minimizes and sustainably manages on-farm food waste will require numerous actions over an extended period of time. Furthermore, as food waste is an issue that spans across the

food supply chain, food producer collaboration with others in the food industry is necessary to address food waste at a food system level. While food waste is one of many aspects of food production that impacts agricultural sustainability, it is clear that food is currently wasted on farms, and that food waste should be included in assessments of agricultural sustainability.

To enable the minimization and sustainable management of on-farm food waste to increase agricultural sustainability, I propose a two-phase approach. To immediately garner food producer interest in addressing on-farm food waste, I suggest first focusing on the economic benefits that minimizing and sustainably managing on-farm food waste can provide. Optimal farming and business practices can lead to reduction in wasted products, and potential revenue generation through secondary processing and tax returns may increase the profitability of farming operations. Second, a larger-scale, system-wide approach should be taken to minimize waste in an ethical and collaborative manner across the FSC. This will likely require voluntary action from actors the FSC as well as increased regulation regarding food waste.

Minimizing and sustainably managing food waste will contribute to creating a sustainable food system, which is necessary to meet sustainable development goals of for a number of reasons. First, the food system uses a great deal of resources, and minimizing food waste reduces the amount of resources that are wasted (Freibauer et al. 2011). Additionally, finding ways to sustainably manage food waste that cannot be minimized may assist in retaining some of the economic, caloric, and/or nutritional value of food products. Second, the food system is necessary for human survival, and addressing food waste across the FSC is critical to ensuring that our food system is functional for future generations (Buzby & Hyman 2012). Third, food waste has widespread economic, social, and environmental impacts, and addressing food waste can provide food while reducing the need for additional inputs (Hodges et al., 2011). As stated by Roseland (2012), sustainable development requires changing current economic, social, and environmental practices, including practices related to food production, to establish systems that are optimal to sustaining human existence on earth.

As outlined in the literature review, sustainable development is necessary for a variety of economic, social, and environmental reasons including economic disparity, population growth, biodiversity loss, climate change, and ocean acidification (Buzby & Hyman, 2012; Kareiva & Marvier, 2011; Roseland, 2012). Sustainable development is a goal agreed upon by many local, national and international entities. For example, the United Nations has recently designated a sustainable development goal regarding sustainable food systems, stating that the establishment of sustainable food production systems is a global goal to be reached by 2030 (United Nations, n.d.). Thankfully, while humans continue to face a multitude of complex sustainability related issues, public awareness and concern for sustainability issues and support for sustainability policies is increasing (Field & Olewiler, 2011).

While there is still a great deal of improvement and further research necessary to fully address the issue of food waste both on the farm and across the food system, the topic of food waste appears to be of more interest in recent years than it has been in the past. Fortunately, from industry reports, to academic research, to government initiatives to media coverage, food waste has become increasingly discussed as of late. This momentum must be harnessed to ensure that food waste is addressed to its full potential and conceptualized as a resource that has the ability to feed people, increase food system sustainability, create jobs, and increase food industry profitability. Transitioning towards sustainability regarding all aspects of food waste will create environmental, social, and economic benefits, and assist in creating a more sustainable food system.

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# Appendix A.

## Interview Schedule

### Information about Farm Facility

What is your job title?

What are the responsibilities of your role?

Is your farm certified organic?

Has your farm participated in the BC Environmental Farm Plan Program?

What types of food are produced on your farm?

How large is your farm?

What is the total volume of food your farm produces per year?

Where is the food produced on your farm distributed/sold?

How is the food produced on your farm distributed/sold?

### Food Waste

Definition: wholesome edible material intended for human consumption, arising at any point in the FSC that is instead discarded, lost, degraded, or consumed by pests (FAO 1981)

What is the total volume of food waste that your farm generates?

What are the causes of food waste on your farm? (Give % for each if possible)

Produced too much (discrepancies between supply and demand)

Food products did not meet standards (aesthetic/quality)

Spoilage due to pests

Spoilage due to weather

Damage from handling practices

Damage from storage conditions

Damage from transportation practices

Unsuitable crop/crop variety choice

Other – please describe

Does the amount of food waste on your farm vary from year to year?

If yes, could you describe why this variation occurs?

Do you think that your farm produces: too much food waste, an appropriate amount of food waste, or not enough food waste (perhaps if used for compost)?

Do you think that food waste is an important issue for food producers?

If yes, why? If no, why not?

(If farm is organic) does your organic certification have any impact on your farm's generation and/or management of food waste?

### **Food Waste Management**

What does your farm do with food waste? Please indicate all practices that you use (Give % of food waste managed under each practice if possible)

Feed people – sell (if yes, where is it sold?)

Feed people – donate (if yes, where is it donated?)

Feed animals – on farm

Feed animals – sell (if yes, where is it sold?)

Feed animals – donate (if yes, where is it donated?)

Compost – use on farm

Compost – sell (if yes, where is it sold?)

Anaerobic digestion

Burial

Landfill

Incinerate

Other – please describe

Do you participate in any of the following waste-reduction strategies?

Educate employees about food waste issues

Communicate with others in the food industry about how to best match food supply with food demand

Increase shelf life of products

Establish optimal treatment practices for each food product

Create product-appropriate storage facilities

Create product-appropriate processing facilities

Use experienced workers

Use appropriate harvesting methods

Plant specific crops

Other – please describe

Does your farm store food waste on-site?

If yes, is it stored under cover?

If yes, is it stored on a concrete pad?

If food waste is composted, how is the compost used on-farm?

Has the Metro Vancouver Organics Ban affected how you manage food waste?

### **Policy**

If government agencies were to change policies/adopt new policies regarding food waste produced by farms, how strongly would you support the following? (Don't know/strongly support/support/indifferent/oppose/strongly oppose)

Creating stricter mandatory regulations for managing on-farm food waste

Creating stricter mandatory regulations for reducing on-farm food waste

Allowing the agriculture industry to develop more stringent voluntary guidelines regarding food waste reduction and management

Taxing farmers/food producers for producing large amounts of food waste

Taxing farmers/food producers for disposing of food waste in an unsustainable manner

Funding research to develop more sustainable food waste management technologies and practices

Funding research that assists in reducing food waste

Funding campaigns to encourage farmers/food producers to reduce on-site food waste

Providing incentives (ex. tax credits) to farmers/food producers to reduce food waste (ex. incentivize complete harvest)

Providing incentives (ex. tax credits) to farmers/food producers to adopt more sustainable food waste management practices (ex. funding to farmers who donate to charitable organizations)

## Transitions

Has your company ever adopted a practice to help reduce the amount of food waste produced?

If yes, please describe what this practice is and why it was adopted

Did you encounter any barriers during this transition?

Has your company ever adopted a technology or practice to help reduce the impact of food waste on the environment?

If yes, please describe what this practice/technology is and why it was adopted

Did you encounter any barriers during this transition?

Has your farm changed food waste management practices over the past 5 years?

If yes, please describe the change and why it occurred

If no, please describe why not (barriers to transition)

Which factors have encouraged your farm to transition towards sustainable food waste management in the past? (Or, if no efforts have been made, which are reasons that would be likely to encourage your farm to transition towards sustainable food waste management in the future?)

Organizational concern about environmental impacts

Desire to have an environmentally friendly image/brand

Public pressure

Anticipation of more stringent environmental regulations in the near future

Cost savings

Other – please describe