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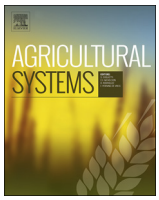

Farmer harvest decisions and vegetable loss in primary production

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ABSTRACT

The topic of food loss and waste has risen in importance since the revelation that an estimated 40% of food in America is never consumed. Losses at the field level, however, are not well understood, and economic and growing conditions that dictate decisions made by fruit and vegetable growers can determine how much food is left unharvested. Many strategies have been suggested to reduce food loss and waste, but their development has been informed by concerns at the consumer level, and may not motivate growers to reduce losses. This study sought to understand how growers make decisions regarding when to end the harvest, and explores growers' perceptions of strategies that would incentivize them to reduce losses. The authors conducted seventeen semi-structured interviews with mid-sized to large commercial vegetable growers in North Carolina. The resulting findings clarify the primary decision-making drivers affecting food loss in the field, including whether growers have an interested buyer, the quality of the produce, the available price, the financial risk of product rejection, and the priority of another field becoming mature and ready to harvest. Growers did not perceive losses to be of high enough volume or value to measure crops that were left unharvested in the field, though research indicates that the volume is actually significant. We also asked growers about their perceptions of strategies for reducing farm level losses that have been promoted in industry reports on the subject. These strategies include facilitating donation and supporting emerging markets that focus on imperfect produce. Neither of these aligned well with strategies that growers perceived as important, such as increasing demand, providing processing infrastructure, and facilitating a consistent market and prices. While some growers donate produce or participate in gleaning, these activities can be limited by continued negative perceptions. Findings from this research suggest that, in order to effectively reduce the loss of edible food at the farm level, growers must be included in the development of strategies, and those strategies must incentivize their participation in order to be effective.

1. Introduction

In North America, the fresh fruit and vegetable crops that are critical to improving public health are lost from the supply chain at higher rates (50–60%) than other foods, such as meat, dairy, and cereal crops (20–25%, 20%, and 35%, respectively; Gustavsson et al., 2011). Each of these types of food are lost or wasted from production through distribution, processing, retail and food service, and at the consumer level. The Food and Agriculture Organization of the United Nations estimates that the equivalent of 20% of the fruit, vegetables, roots, and tubers sold by farms are lost during production in North America, typically either left in the field or graded out in packing (Gustavsson et al., 2011).

Popular press descriptions of "food waste" often conflate both food "loss" and "waste" into a singular term, yet there are key differences, and there is no clear consensus on definitions. "Food waste" is generally related to individual behavior and occurs within the retail, restaurant, and household levels of the supply chain (Gustavsson et al., 2011; Parfitt et al., 2010). "Food loss," conversely, refers to the "unintended result of agricultural processes or technical limitations in storage, infrastructure, packaging, and/or marketing" (Lipinski et al., 2016). This includes the loss of mature produce crops that are ripe for harvest and intended for human consumption, but that are left unharvested during primary production due to constraints outside the control of the grower, such as weather and market demand. This description of food loss in production accurately captures the subject of this research.

Government and industry groups have recently produced guides detailing measurement and reduction of food waste at the distribution,

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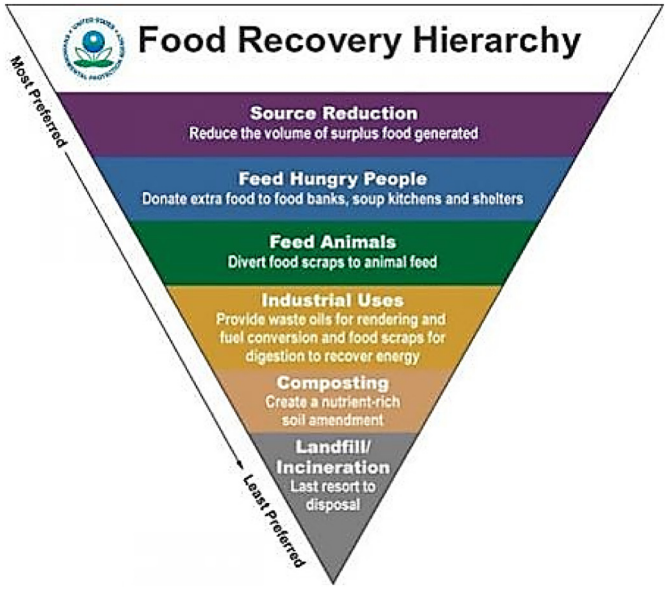

Fig. 1. EPA food recovery hierarchy (EPA, 2015).

retail, restaurant, and foodservice sections of the supply chain (EPA, n.d., 2014, 2017; FWRA, 2015; ReFED, 2018). At the consumer level, awareness and behavior change are the targets of the national "Save the Food" campaign (savethefood.com) by the Natural Resources Defense Council and Ad Council. Popular books target consumers as well, such as *American Wasteland* (Bloom, 2010) and *Waste Free Kitchen Handbook* (Gunders, 2015). Food loss on farms, in contrast, has been relatively neglected, leaving gaps in our knowledge of the extent of losses at the agricultural level, as well as gaps in our understanding about the drivers of these losses. This is due, in part, to the logistical and budget-related challenges of studying food loss quantitatively, such as through field sampling, at the farm level. While government agencies, non-profits, activists and entrepreneurs have proposed strategies to reduce food loss and waste, including EPA's well-known Food Reduction Hierarchy (Fig. 1; EPA, 2015), our work with farmers suggests that these strategies were developed without sufficient input from growers themselves, are therefore not tailored to account for the complexity of managing agricultural production, and as a result might not be viable or adopted. Additional research is needed to more thoroughly understand growers' decision-making process related to when to stop harvesting their crops, which leads to the loss of edible produce left in the field. This paper addresses this gap in our knowledge and provides a framework for understanding farmers' decision-making and perceptions of the issue of food loss, through interview analysis. This understanding can support the development of more effective strategies for preventing, rescuing, and diverting produce that would otherwise be left in the field.

1.1. Prior research on food loss

As noted above, a focus on consumer-level waste has shaped how governments and major institutions conceptualize the issue of food loss and waste, and driven the types of innovations and interventions that have emerged as strategies (Griffin et al., 2009; Gustavsson et al., 2011; Hall et al., 2009; Kummu et al., 2012), often based on recommendations from the EPA's Food Recovery Hierarchy. Closer scrutiny of the reporting available on food loss throughout the global supply chain reveals significant knowledge gaps at the farm level in the US, and in developed countries overall (Schnieder, 2013; Van der Werf and Gilliland, 2017). A limited number of qualitative studies have reported that two factors are the primary drivers of losses at the farm level. First, these studies suggest that stringent quality standards required by buyers force growers to leave product unharvested (Beausang et al., 2017; Beretta et al., 2013; Garrone et al., 2014; Ghosh et al., 2016; Gunders, 2012; Gustavsson et al., 2011; Hodges et al., 2011; Kantor et al., 1997; Milepost Consulting, 2012; Parfitt et al., 2010; Priefer et al., 2016). Second, it has been asserted that losses occur when purchase prices are insufficient to pay for the cost of harvest (Gunders, 2012; Gunders et al., 2017; Milepost, 2012). While these factors are relevant, standards and pricing may be only part of the complex decision-making process that farm owners engage in when considering when to stop harvesting a field.

To date, the data that have been used to inform strategies aiming to reduce on-farm food loss have been restricted to two studies of small farms (most farms produced on < 25 acres) located in Minnesota and Vermont (Berkenkamp and Nennich, 2015; Neff et al., 2018). We argue that small farms have the agility to market directly to consumers, or use unmarketable produce for animal feed or compost, making their situation unique. Mid-scale growers, in contrast, have constraints on both sides of the marketing spectrum: they are less suited to sell excess or off-spec product through direct-to-consumer channels such as farmers markets, but also too small to support private processing infrastructure like a dehydration or freezing facility. Therefore, research is needed to understand how food loss operates on mid to large-scale farms.

Despite the restrictions on the generalizability of these two studies to farms of larger scales, the Minnesota study was used as a data source for a recent national estimate of farm-level fruit and vegetable loss (20.2 billion pounds per year; ReFED, 2016). This estimate was cited in the same report that provides the most comprehensive analysis of strategies that aim to reduce losses and waste, which was developed by a collaboration of organizations in the US– Rethinking Food Waste through Economics and Data (ReFED;, 2016).

ReFED's options for food recovery from the agricultural level include development of emerging markets for produce that has a compromised appearance (eg. "ugly" produce), improvement of processing opportunities for growers, and facilitating donation through improving infrastructure and tax policy (ReFED, 2016). The economic analysis in the ReFED report indicates that suggested strategies promoting food donation are cost-effective, provide high relative net economic value, and can divert high relative volumes of food, making them attractive ideas to shepherd forward, possibly through policy (ReFED, 2016). With little input from producers themselves, and a reliance on data that overlooks the experiences of mid- to large-scale farms, it may be that these strategies lack financial incentives for growers, or for other reasons may be seen as unfeasible from a grower point of view.

Other research and reports on the topic of food loss have also proposed market-based and policy strategies. One California study by Milepost Consulting (2012), which informed strategies suggested in the landmark Natural Resources Defense Council paper 'Wasted' (Gunders, 2012), discussed similar strategies to reduce food losses as the ReFED report, including: tax credits for donations, transportation and storage improvements for donations, marketing imperfect produce, and gleaning. However, information on whether the growers and other stakeholders that were interviewed for the Milepost study supported this selection of strategies was not included in the report. Most recently, researchers interviewed representatives from 12 specialty crop farms in California ranging in size from seven to 30,000 acres (median size 6000 ac) for insight into grower-friendly strategies to reduce food loss (Campbell and Munden-Dixon, 2018). The authors reported that participants were most interested in seeing more advantageous marketing contracts and more opportunities for processing (Campbell and Munden-Dixon, 2018). While providing insight into grower views on outlets for on-farm loss, exploration of growers' decision-making factors related to the timing of harvest and the processes that influence the choices they make that may lead to food loss were not a part of this study.

Prior research of on-farm loss neglects to take into account the complexity of managing mid- and large-scale produce farms, and the

decision-making process that growers rely on when determining whether to stop harvesting certain fields, which in turn affects the amount of edible product that is lost. Fruit and vegetable crops vary widely in physiology and management, and are often harvested multiple times. The decision to continue the harvest, or stop harvesting, directly influences how much fresh produce is available in the marketplace, and how much is left unharvested in the field. Understanding the multiple factors that contribute to growers' harvest decisions is crucial to constructing viable means to reduce loss at the farm level. For example, the decision to harvest is based on quality standards, yet these standards are variably enforced; when market supply is low and a produce item is more difficult to source, buyers often relax standards for appearance and size quality, and raise them again when the supply increases (BSR, 2013). Thus the decision to harvest is reliant on a fluctuating standard for quality. Decision-making in supply chains is often determined by regulations, such as quality standards, but can also be subjective and based on qualitative factors, including supply chain actors' perceptions (Bloom and Hinrichs, 2011; Hatanaka and Busch, 2008). In combination with the perishable nature of many specialty crops, the need to manage hours requirements for labor, fluctuating prices, and the lack of consistent quality standards, the decisions made on the farm that lead to or prevent losses in the field are made under highly variable conditions. Because the industry is fragmented, there is often little funding for research, and there are few operations research and management science models available to support decision-making in this sector (Zhang and Wilhelm, 2011). Simple tools such as decision trees are often used to develop these models.

Research discussed in this paper explores harvest decision-making through qualitative inquiry with mid-size to large vegetable growers in North Carolina. When mature crops are ready for harvest in the field, what influences growers' decisions to end the harvest? How do they perceive the volumes of produce lost in the field? What potential strategies to reduce field losses are seen favorably by producers themselves, and why? An overview of the methods used and description of the participants is presented below, followed by the key findings and discussion of the application of these findings to the development of strategies that reduce farm level food loss.

2. Methods

2.1. Participant selection and recruitment

The focus of this research is commercial fruit and vegetable producers who sell the majority of their crops through wholesale market channels which require meeting specifications for quality, rather than direct marketing, in which products of a wide range of appearance quality may be marketed and sold. Recruitment of growers willing to be interviewed took more than twelve months. Participants agreed to be recorded when assured of confidentiality. Discussion of food waste is now common in media and among consumers. However, growers perceive losses differently than the general public, and it was determined prior to participant recruitment to be a sensitive topic for growers, especially as they may feel that the focus on food waste places blame on them and their operations. The term “food waste” was avoided during recruitment and interviews to reduce the growers' perception of blame or judgement. The term “loss” was used often, however, generally without the “food” qualifier.

Participants were recruited from North Carolina at regional vegetable growers' association and commodity meetings in the Carolinas throughout 2015 and 2016, with a survey distributed to interested growers. This survey was designed to elicit information about growers' perceptions of losses on their farms, including questions such as: how much of their crop is left unharvested, how the decision to stop harvesting is made, their unique market network, which USDA grades they are marketing, and the most common destination for losses. The final question on the survey asked growers if they were willing to further discuss production losses in an in-person interview. When funding allowed, an incentive was offered for survey responses that were completed and returned. While the number of survey responses did not result in data of statistical significance (and therefore are not reported here), this method allowed for identification of growers who were willing to participate in qualitative, semi-structured interviews. In addition, one grower was recruited through contacts within North Carolina Cooperative Extension, and subsequent growers were identified through snowball sampling wherein study participants provided the names of other growers who they thought might be interested in participating in the study. Sample size was determined through theoretical saturation, the point at which no new information is gained from adding more sources (Fusch and Ness, 2015; Riley, 1996).

2.2. Interview guide development and procedure

A semi-structured interview format was chosen, as it allows for standardized questions to be asked, as well as deviation from a predetermined set of questions as unanticipated themes emerge (Jamshed, 2014). The interview guide and accompanying documents were developed, then reviewed and approved by the Institutional Review Board at North Carolina State University (Protocol Number 6388). Open-ended questions covered how growers make the decision to stop harvesting, what strategies growers thought would benefit them, their perceptions of current proposed strategies to the issue of food loss, such as “ugly” produce programs, and common donation and field gleaning practices. North Carolina growers were also asked about the volumes of produce lost on the farm, and how that is estimated. Farm profile information, such as farm size and primary markets, was collected, as well as limited production details, such as which crops are grown and how crops are destroyed prior to replanting. Interviews were conducted between March and June of 2016, and January to May of 2017. The majority of interviews lasted 30 to 60 min. Interviews were audio recorded and transcribed verbatim.

2.3. Participants

A total of seventeen interviews were completed for this research. Most interview participants were located in eastern North Carolina, a major production region in the state. The participants' acreage was primarily dedicated to vegetable production (see Table 1 for crops grown and primary markets). Interview participants produced vegetables on acreage ranging from 30 acres to over five thousand acres. The average farm size in North Carolina is 170 acres, which is about half the average farm size in the US (USDA-NASS, 2017a, 2017b). Just over 82% of the interviewees produced vegetable crops on acreage larger than the NC farm size average, and would be considered mid-size to large operations for North Carolina. Taken together, the participants operate 19.6% of the land area devoted to vegetables in the state. Interviewees were farmers or part of the farmer's family and actively participating in farming, with the exception of two (Growers O and Q), whose work focuses on marketing the production from their farms. Agriculture represents North Carolina's most economically important industry at $84 billion, and employs 686,000 people (USDA-NASS and NCDA&CS, 2017). North Carolina has recently ranked in the top 10 states for US production of a variety of vegetable crops including cucumber, bell pepper, watermelon, squash, and cabbage, and is ranked #1 for sweet potato production (USDA-NASS and NCDA and CS, 2017).

2.4. Thematic analysis

Interviews were reviewed independently to determine the best approach to thematic issue-based analysis, which is a type of pattern recognition using familiarity with the data to identify groups of ideas that converge into a topic, or theme (Rice and Ezzy, 2000). The approach used here is well described by Weiss (1994), and includes the following

Table 1
Acreage devoted to vegetable production, major crops grown, and primary markets for seventeen interview participants in a North Carolina study of farmer decision-making surrounding harvest.

Grower	Vegetable acreage	Crops grown	Primary market
A	< 100	sweet corn, melons, mixed vegetables	retail, restaurant distributor
B	100–500	sweetpotato, mixed vegetables	retail, restaurant distributor
C	100–500	mixed vegetables	retail, restaurant distributor, terminal markets
D	100–500	sweetpotato, mixed vegetables	retail, restaurant distributor
E	100–500	mixed vegetables, sweetpotato	retail, restaurant distributor
F	100–500	melons, mixed vegetables	retail, restaurant distributor
G	100–500	sweet corn, mixed vegetables	retail, restaurant distributor
H	500–1000	mixed vegetables, melons	retail, restaurant distributor, processing
I	500–1000	mixed vegetables	retail, restaurant distributor
J	500–1000	sweetpotato, melons, mixed vegetables	retail, restaurant distributor
K	500–1000	sweetpotato, mixed vegetables	retail, restaurant distributor, processing
L	500–1000	mixed vegetables	terminal markets, restaurant distributor
M	1000–2000	sweetpotato, melons	retail, restaurant distributor, processing
N	1000–2000	sweetpotato, melons	retail, restaurant distributor, processing
O	1000–2000	sweetpotato	retail, restaurant distributor, processing
P	> 2000	sweetpotato	retail, restaurant distributor, processing
Q	> 2000	sweetpotato	retail, restaurant distributor, processing

steps: familiarization with the dataset, generation of codes, sorting the codes into themes, reviewing, defining and finally naming themes. Based on familiarity with related literature, topics of interest and themes were chosen for a coding framework that aligned with the research questions. However, unanticipated themes emerged and were included using open coding. The primary author coded the interview transcripts according to the identified themes, and used NVivo 10 qualitative data software to make comparisons between and across themes. Some of the codes generated to analyze data included: when to stop harvesting, percentage estimate, can't afford to harvest, big picture goals, donation tax benefits, quality, weather, and labor.

Given the sensitive and complex nature of on-farm food loss, qualitative methods were chosen to explore growers' perceptions, to allow for unexpected themes to emerge, and to provide explanations of how different factors interact. Using a semi-structured interview style allowed enough latitude in questioning to capture rich data, and performing the interviews in-person (in addition to several interactions prior to the interview) encouraged trust from the research participants. The transcripts and many of the quotes shared in the findings section contain facts, feelings, and bring up larger themes, indicating the richness of the dataset. Issues of reliability and validity have been addressed in this study by providing detailed information about research methods, transcribing interviews verbatim, and providing rich detail in the analysis so that readers can evaluate the plausibility of interpretations (Creswell, 2007; Stake, 2000). Finally, the small sample size in this study precludes generalization to the broader population. However, by identifying key patterns and themes, and identifying negative cases that challenge current assumptions, this study can contribute to our understanding of the causes of on-farm food loss, and help to refine theories and strategies on the subject while also suggesting areas for further research.

3. Results and discussion

This study provides insights into how growers determine when to end the harvest, how growers perceive the volume of losses in their fields, and what food-loss reduction strategies they feel will best benefit their operations. As mentioned earlier, sensitive use of terminology was emphasized throughout this study, as this negative reaction to the term "food waste" from Grower I illustrates: "food waste is a sore subject with a lot of these farmers. Because, believe me, the farmers would sell everything that they had if they could make something. But, they can't give it away. I mean, we wouldn't be in business if we did."

The discussion will follow the outline provided by Table 2, which summarizes the participants' response rates favoring key topics. The results shown first highlight the variety of causes of losses that influence growers' decision-making, and how many of the participants consider each to be significant, revealing agreement on several major factors among the majority. Second, the growers show that the volumes remaining in the field are not considered a source for further opportunity to grow yield, as the majority did not actively measure or estimate losses once the harvest ended. Third, growers provided strategies that have the potential to financially benefit their operations, with strong support for increasing demand and prices, and mixed support for donation-based strategies and development of alternative markets.

3.1. Growers balance interacting factors in harvest decision-making

Many horticultural crops, such as cucumber or bell pepper, are harvested several times before the grower makes the decision to stop. The number of harvests completed during peak maturity varies among crops and farms, after which the crop is typically abandoned or destroyed, leading to high volumes of edible food loss in the field (Johnson et al., 2018b). Other crops, for example, cabbage, produce one salable unit per plant. In that case, harvest may still occur several times in the same field because the heads mature at different rates due to irregular field conditions, and then the decision is made to discontinue the harvest. Because weather conditions vary, market demand and price fluctuate, and produce crops have high perishability, growers cite urgent decision-making conditions. Grower F said, "It would be nice to plan it out … [but] this is all day-to-day. It's based on what you dealt with that day."

Vegetable growers were asked how they determine when it is time to stop harvesting a given crop. This line of questioning revealed complex interactions between several factors thought to contribute to food loss in production. For example, Grower I described the high degree of variability and complex nature of the decision to stop harvesting: "Every field would be different and it'd have a different reason. I mean, it would be the weather, it would be the price. It would be labor." Analyzing growers' responses allows us to categorize the causes of food loss into several themes. These themes were arranged into a decision tree representing the practical way in which growers determine whether or not to continue the harvest (Fig. 2). Findings from this research suggest that when evaluating whether or not to continue the harvest, a grower weighs these interacting drivers, ultimately determining whether to harvest the field. As many of these factors need to coalesce in order to motivate a grower to continue the harvest, the chance of avoiding significant losses in the field by continuing to harvest are slim. This decision tree also allows us to identify key areas for intervention to reduce on-farm losses. For example, addressing the

Table 2
Participant response rates for discussion topics in a North Carolina study of farmer decision-making surrounding field losses in vegetable production (n = 17).

Growers' reported causes of food loss in production	% of participants considering this factor in harvest decision-making
Insufficient market price that does not cover cost of production	82.4
Produce quality determined by weather, infestation, management	76.5
Availability of buyers interested in the crop	70.6
Financial risk of rejection	58.8
Field priority and labor scheduling needs	47.1
Growers' perception of volume or value of losses	**% of participants**
Rely on field sampling to estimate losses in the field	0
Report field loss of 0–20% by their own estimation	35.3
Allowed subsequent field sampling to measure losses	41.2
Growers' suggestions for food loss reduction strategies	**% of participants considering this solution beneficial to their operations**
Facilitating market consistency and high prices	76.5
Improving access to processing facilities	70.6
Increasing demand for fresh produce	64.7
Incentivizing and facilitating donation	47.1
Marketing "ugly" but mature and safe produce	41.2
Current donation and gleaning operations	41.2
Modifying consumer expectations for appearance quality	35.3

leverage point at the beginning of the growers' decision tree will influence the rest of the drivers. This suggests that expanding the array of buyers for various quality grades, or increasing overall demand, are effective means to reduce the volume of losses in the field. In the following sections, we will provide additional detail about the decisions growers make at each step of the decision tree.

3.1.1. The availability of buyers influences food loss via impacts on price and accepted quality

The leverage point with the most weight in harvest decisions is the determination of whether a buyer is available who is interested in purchasing the crop. Grower M characterized his network of buyers as small and risky: "basically we only have two customers … so if either one of those didn't need us anymore, that would hurt." The availability of a buyer is directly connected to market price, with growers describing market price as the most critical factor influencing the harvest decision (Table 2). The question of having a ready buyer can mean the difference between high rates of food loss in the field or a reduction in food loss through better utility of the crop. Buyer availability affects the sale of the entire crop, not only the amount left after the primary harvest.

Buyers that are in search of a particular vegetable commodity may take advantage of the seasonal nature of vegetable production and contact growers in areas of decreasing distance to population centers, both to reduce transportation costs and increase shelf life. This presents a challenge for growers if crops are mature in the field at the same time buyers are sourcing in another geographic area. Grower J discussed the timing of the watermelon market: "it all depends on, you know, Georgia and South Carolina. From where we're at, it all depends on when they finish, or when they start. We're in that window and if they keep on later on and still have good quality, we're in bad trouble right here." This can result in a surplus crop as prices fall and connections to the supply chain drop off, resulting in growers being stuck with a product that is rapidly losing shelf life. Grower C described his lack of a secondary market for one crop: "Cucumbers have no salvageable value once you leave fresh market. There's not a place that will process them and there's really no place that will take them and utilize them any other way except for fresh market. So, once that's over with, it's gone.

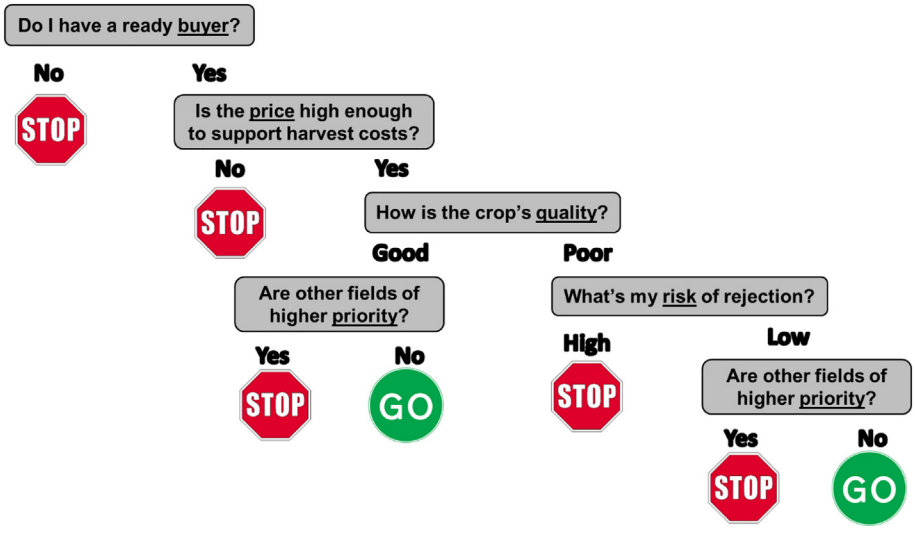

Fig. 2. Decision tree illustrating the questions growers use to determine whether or not to continue the harvest in vegetable crop production, as summarized by seventeen commercial growers in a North Carolina study.

It's just like cutting off a spigot." The lack of a ready buyer makes the decision to end the harvest straightforward, even though high quality, mature crops may still be available in the field. Processing the surplus may seem like a viable alternative. However, the processed vegetable industry is more vertically integrated, and includes contract terms that dictate the cultivars used, management, and harvest.

Crops produced that fall outside the range of traditional appearance quality are often lost unless a grower can identify an alternative buyer, which can present a challenge due to the need to develop a new business relationship. Grower E did not know of alternative buyers in the area: "if anybody comes up and wants to buy up what I'm throwing away, I'll be more than glad to harvest it and sell it to them." Marketing a crop, or several crops, can require branding, different types of packaging, and meeting a different set of food safety certifications for each buyer, in addition to other hurdles. A marketing specialist representing Grower O, who estimated very low rates of loss in the field, advised, "it takes creativity, it takes making phone calls every day to buyers you never talk to, to say, I'll send you free samples, I'll send you a free pallet." These strategies may not be economically feasible for medium-sized growers without dedicated marketing staff. Interventions to address relationship development between growers and buyers include networking and workshop panels facilitated by an intermediary partner; these panels help match growers and buyers, ensuring that growers can meet a buyer's minimum requirements for acreage, packing, food safety and transportation (Dunning, 2015).

3.1.2. Growers agree price causes loss, but interactions with other factors complicate decision-making

The majority of growers cited price as the most important factor that influences harvest decision-making (Table 2), although having a reliable buyer is a precursor to receiving a suitable price, as discussed above. When a grower has an interested buyer, the offered price may or may not support covering the costs required for the continued harvest of the crop. The cost of labor and packing required to remove produce from the field, referred to as "pick and pack" costs, can total 60% or more of total production costs for any single crop (Berkenkamp and Nennich, 2015). Prices are variable depending on a confluence of factors: the market price fluctuates with demand, buyers source from different regions throughout the season, and the grower may not have a relationship with all available buyers. In addition, the prices offered vary with produce quality (Dunning et al., 2019) and volume of product shipped (USDA-ERS, 2003). Grower E summarized his decision-making related to prices and buyers this way: "If I'm not going to make enough per bushel to harvest it, I just leave it in the field. … If I harvest it, put it in a bin, and then it's not usable, or it's usable at a price less than my harvest and storage cost, I'm losing money. I try just to harvest the product in market." Grower N discussed the interaction of price and quality when sweet potatoes of marketable quality are left in the field: "the thing about that potato, that good one, all that cost you was to raise it, 'cause they [farm labor] don't get paid for picking it up. But when it gets put in that box, that's the extra two dollars." As these quotes indicate, if the price doesn't support the pick n'pack costs, growers will make the decision to leave produce in the field, regardless of the quality.

Grower N revealed more challenges in the interaction between price, quality and the risk of rejection, as transactions rely on relationships and communication. According to Grower N, the harvest is stopped "when the labor costs more than what you can get out of the watermelons. Most of the time you don't know that until you go and ship four or five loads too many." This quote illustrates that as communication lags between grower and buyer, continuing to ship poor quality can result in price adjustments that penalize the grower. Grower F summarized the interaction of price and quality this way, "once you get that product picked and brought up here, [to the packing house] that's the most expensive produce you've got because you've got your labor in it. If you take it up here and then you got to carry it right back to the woods and dump it out, then you're better off leaving it in the fields and not even harvesting that. We run across that quite a bit." If the harvest coming into the packinghouse displays overall poor appearance quality as it comes out of the field, either because of irregular field conditions or inexperienced harvesters collecting produce that does not meet quality standards, additional labor is then needed to sort out that poor quality and dispose of the unmarketable produce. Growers seek to balance the price offered by sometimes just a single buyer with the available quality determined by unpredictable growing conditions. This equation is continually evaluated by growers, and when the offered price does not meet a threshold, unique to their operation for a specific crop, the harvest may be abandoned, leading to crops lost in the field. These crops may be of high nutritional quality, have perfect appearance quality, and be at optimum maturity. Grower P said, "Just to give you an example, cabbage pricing got ridiculously low, and we disked the field up. Just straight disked it up, because we would have lost money. Beautiful cabbage, too." Without a price supporting their harvest, and a buyer interested in the crop, the quality is a secondary consideration, even though producing top quality is a growers' primary focus.

3.1.3. Quality is a driver of losses

As noted above, crop quality interacts with multiple other factors to create loss, making it of critical importance in the decision-making process. Growers monitor quality throughout the season. Grower H noted how this influences harvest decision-making, "We actually take random samples out of the field, and if we start to see issues, then we are able to make a financial decision at that time, whether it's worth continuing to harvest or not." Buyers that inspect produce upon receipt may put similar weight on appearance *quality* and *condition*, when only condition affects shelf-life. Produce inspection training materials provided by the USDA-AMS (2017) define quality indicators as being permanent and unchanging over the time period spent in the supply chain, and not affecting shelf life. Quality indicators can include maturity level, size, shape, color, or other permanent factors such as scarring or cracks; while important to buyers, these indicators do not affect the edible nature of the crop. Condition, however, can be characterized by being progressive in nature. A vegetable in poor condition may be bruised, decayed, or shriveled, which would only worsen with time (USDA-AMS, 2017). Grower N discussed watermelon left in the field in good condition, but that did not meet the quality indicator of size: "there'll be a world of them out there. Yes, they are watermelons, and yes, they are just as sweet and good as a big one. They're just not marketable." Many melon growers discussed surplus 8–12 pound watermelons, often found when vines age and daylength gets shorter at the end of the summer, as unmarketable, even though the sugar content and other quality indicators are still strong.

On the other hand, some produce is lost due to unavoidable factors that reduce quality to the point of being unmarketable. Produce growers who are operating hundreds of acres are often leaning on generations of experience, and have access to the latest in industry advancements such as customized fertility programs, targeted irrigation equipment, high-performing cultivars and effective pest and disease control. However, even when a field is properly managed, produce quality can be negatively affected by irregular soil conditions, insect infestation, disease pressure, and weather, factors that are outside of the growers' control.

3.1.4. The financial risk of rejection for poor quality can influence harvest decision-making

Almost 60% of grower participants cited the financial risk of a buyer rejecting the harvest at the point of purchase as a very real cause of food loss in the field. When a grower has an interested buyer and the price will cover the harvest, but the quality of the crop is not optimal, the risk of rejection by the buyer comes into play. Responding to the question of when the harvest is stopped, Grower J said "When you have a load or

two rejected. Most times, late in the season like that, it's because they're overripe. The best thing you can do is just walk away from it." This quote reveals an interaction between produce quality and the risk of rejection. As the grower is investing not only in the crop's production, but its harvest, sorting, packaging, and transportation, the risk of rejection is a very real financial consideration. Grower N detailed the rejection of a load, saying, "We're only trying to make a small amount of profit, and one hiccup could be a $12,000 back step." After investing in producing and packing the crop, rejection or cancellation may mean additional costs such as transportation back to the farm to be repacked, or to an alternate buyer, a food bank, or a landfill.

3.1.5. Field priority and farm scheduling contributes to losses and factors into decisions

Finally, the grower must decide which field has the highest priority for the available harvest crew's focus, often because of the difficulty associated with predicting peak maturity. Just under half of grower participants discussed the scheduling of harvest and labor relative to their decision to leave crops unharvested. Grower G said, "You'll have another planting that you planted that'll come in behind that. We try to plant every three to four weeks, so that when that crop's done, we start on a new crop." Vegetable crops are often produced in rapid succession, not only to guarantee regular income over the farm's production season, but to ensure tasks are available for the contracted work crew to complete. Similarly, Grower A said, "you basically start the next crop as soon as you finish the one that's currently being harvested." Farms in North Carolina often hire workers through the federal H-2A program, which has hourly requirements for each week (Arcury et al., 1999; US Department of Labor, 2010). As the maturity and size desired by buyers declines in a given field, crews may be moved to another field with some urgency, and a field may be abandoned prematurely if another field is displaying high volume or high quality.

3.2. Grower participants did not intentionally plant more than they expected to sell

There is an assumption in the literature about food waste and losses that growers overplant as a way to mitigate risk, and that this is a factor that contributes to food loss and waste (Gille, 2013; Gunders, 2012; Gunders et al., 2017; Gustavsson et al., 2011; Mena et al., 2011; Midgley, 2014; Milepost Consulting, 2012; WRAP, 2017). One participant that previously worked for a large farm with many contract-based sales recalled being required to calculate how much was needed to fulfill contracts, then add a variable percentage on top of that in order to supply spot markets. This would not be considered overplanting, however. It is planned planting with the anticipation of and desire for selling in a spot market. When asked about their planting strategy and how they determined how much to plant, none of the growers in this study identified overplanting as a common practice. Instead, the growers, mostly working without contracts, planted based on what they sold the previous year, or what was projected to sell in the current year. None of the growers interviewed calculated what would be needed for their markets, then added a percentage above that to account for market growth or weather-related damages. Rather, growers were keen to plant only what they knew they could sell, both to minimize production costs and keep excess product out of the market. As Grower F put it: "I don't try to overplant. … If you can't sell it and then you go to the market place and cut the price, well, all you've hurt is yourself and your neighbors too. So you're not helping yourself is the way I look at it." Since a variety of complications like this can arise as a result of utilizing the entire crop, growers appear comfortable with a certain amount of loss, which contributes to the perceived value of the surplus. This finding directly contradicts common assumptions about the causes of on-farm food loss, and therefore should be explored in further studies and considered in any policy recommendations that are designed to address this issue.

3.3. Growers perceive field losses to be of low volume or low value

Another issue related to designing strategies to reduce on-farm food losses is the lack of reliable data about the volume of unharvested, edible crops. As mentioned earlier, most studies on this topic rely on grower self-estimates (Berkenkamp and Nennich, 2015; Milepost Consulting, 2012; Neff et al., 2018). In order to assess the validity of this method, growers were asked if they could estimate how much of their main crop was unmarketable due to quality issues, what methods they use to estimate field losses, and whether or not they have measured how much is left in the field after the final harvest of each field. This line of questioning seemed to be difficult for growers, and out of seventeen interview participants, eleven did not provide an estimate. Responses from the six growers that felt comfortable reporting an estimate ranged from 1 to 20% of the marketed crop (Table 2), with three of the six estimating 20%. Enterprise budgets for specialty crops often base calculations on the assumption that 80% of the yield is marketable, or a median yield rate, rather than reported yield rates (Bullen, 2012; Fonsah and Shealey, 2018; Sydorovych et al., 2012; USDA-NASS, 2017a), so growers may be familiar with automatically considering 20% of the crop unmarketable during planning. Considering that this 20% represents a loss of edible food, but may not represent a loss of marketable product to growers, this portion may fall into some definitions of overplanting, but was not recognized as such by participants.

As commercial farms must provide products to their buyers that display uniform appearance quality, which is associated with economic value, the nutritional value of the produce can be overlooked. Grower C characterized this phenomenon: "in the industry, whenever it is not marketable, it is not classified as food, really … it is a product. … and it is wasted foodstuffs, is what it is." This popular perception can explain why a grower would give more weight in harvest decision-making to buyer and price over produce quality, and contribute to the perceived low value of the produce remaining in the field postharvest. Additionally, many growers described the remaining crop as having little to no value in comparison with the costs required to harvest and market it. Therefore, for them, the remaining crop was not worth measuring, estimating, or considering in general. Grower H put the volume remaining in the field into context: "No, we never estimate it. Once we get to a point where the quality, the risk of the harvest labor and the packaging and freight, once the quality is poor enough or our risk is so high to do that, it could cost a lot of money. At that point we stop. Just stop." This illustrates again how the quality, price relative to the harvest costs, and the financial risk of rejection are considered in combination to determine when to stop harvesting, without consideration of the volume remaining in the field. The overall consensus among the grower participants was that the produce left in the field, whether or not it would be considered marketable or edible, was either of low quantity or quality, or was abandoned due to a series of market conditions congruent with the decision-making process above, or both. Grower C summarized, "If the time's right, and it's time to walk away from it, we just say, 'okay, it's time to walk away from it.'" No growers participating in this study used field sampling to determine an accurate estimate of product remaining in the field, although a recent study indicates an average of 42% of the marketed crop has been left unharvested (Johnson et al., 2018b).

The quality of the six estimates provided by the study participants was not considered reliable enough to report an overall percentage of potential yield loss in this study. An answer from Grower K illustrates this: "We know you leave a lot of potatoes in the field. At what percent? If I told you a number, it would just be something I'm pulling out of the air." The limited studies that cite figures or ranges of produce lost relative to yield often do not provide this needed context that describes the confidence growers have in their own estimate. For example, Grower F said, "if you need a percentage, probably 10%, something like that. 15% maybe. And there again, it's just a lot of what's going on in the marketplace. It's hard to figure." Those that answered with a figure

couched the estimate in similar context, citing the variability by field, by crop, and by year, contingent on fluctuating factors outside of their control. If a number was provided, growers were asked what method they used to determine the estimate, and the consensus was either a visual estimate or no given method that they could describe. Studies comparing interview estimates with field-based data in the UK and Scandinavia have concluded that growers underestimate losses from the farm (Hartikainen et al., 2018; WRAP, 2017). Other methods to determine remaining volumes quantitatively, including field measurement, may be preferable and are available (Chaboud and Daviron, 2017; Johnson et al., 2018a; Muriana, 2017; Reutter et al., 2017). The current estimated volume left at the farm level in the US is 20% of production, but a recent estimate of crops left unharvested revealed this estimate is in need of reevaluation as it could be inaccurate (Johnson et al., 2018b).

3.4. Growers suggest alternate strategies to reduce food loss in the field

The focus surrounding the national food loss and waste discussion has now shifted to the search for strategies. Hence, this project sought strategies sourced from vegetable growers themselves, in an effort to determine whether they align with those proposed by the ReFED consortium, EPA, and the NRDC, and to determine which strategies may benefit growers' operations from their perspective. Comparisons can be made between strategies discussed by vegetable growers participating in this study and a handful of prevention- and recovery-based strategies suggested (ReFED, 2016). The suggestions that focus on reducing on-farm food loss include altering produce specifications for appearance quality, and facilitating produce donation by standardizing regulations, promoting tax incentives, and using software to match donors with organizations in need of produce (ReFED, 2016). The EPA's Food Recovery Hierarchy suggests reducing overproduction and donation as strategies to reduce food loss throughout the supply chain (EPA, 2015).

Based on the responses of growers in this study, a new hierarchy for food recovery is proposed that incorporates the needs of specialty crop producers, and can be considered a starting point for the development of programs or toolkits that aim to reduce agricultural losses (Fig. 3). Development of emerging markets for blemished or misshapen crops, modifying consumer expectations for quality, and facilitating donation are included. However, the most desirable option for preventing food loss in production from the growers' perspective is facilitating consistent markets and high prices. The most preferable to least preferable approaches to food recovery from fruit and vegetable production operations are shown, which represent strategies supported by growers participating in this study (Table 2). In the following sections, we will explore growers' perceptions of each of these strategies.

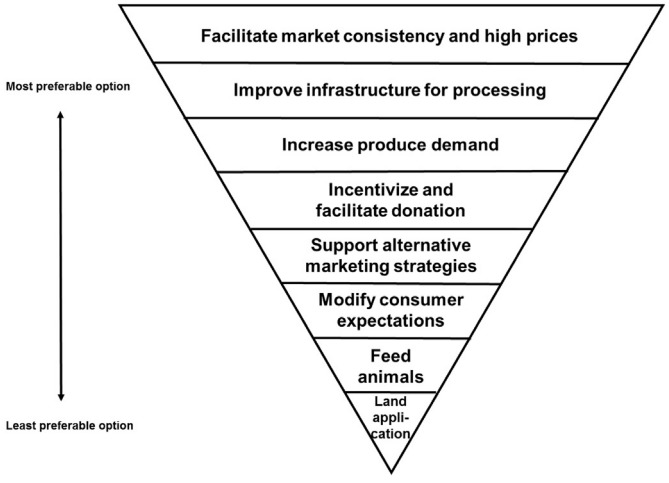

Fig. 3. Proposed hierarchy indicating the most and least preferable strategies for recovery of food from agricultural operations specializing in fruit and vegetable production. Strategies are based on qualitative analysis surrounding current approaches to reducing losses and those described by seventeen growers participating in a North Carolina study.

3.4.1. Market and Price Consistency

The majority of growers interviewed reported needing a more consistent market, flexible buyers, and high prices, aligning with the main leverage points identified by the decision tree (Fig. 2). Several expressed that food loss in the field is often considered a cost of doing business, saying it was impossible to sell the entire crop. A few growers did not have strategies to offer, like Grower J, who said “well, I don't know what can cover our cost, but it'll be better than leaving it in the field. But covering your cost can be expensive: packaging, trucking, labor.” To control market price and consistency, retailer market power may need to be addressed, as retailers have the ability to hold prices below competitive rates (USDA-ERS, 2003). Grower J described the inability to negotiate with large retailers during the rejection of a load of produce, saying, “I've already had PO's [purchase orders] – hundreds of them – over the years, and they [the retailer] cancel, and they already sent you the PO. You've already got the truck lined up and they cancel. What are you going to do? What else you going to do with them [the product]? And, you can't fight Walmart and Food Lion and Kroger.” When retailers control industry prices and have the ability to reject orders at will, financial instability for growers results, in addition to food loss.

3.4.2. Processing

The need for opportunities in processing was mentioned by many growers. Working to attract companies to the region that process available vegetables with a wide range of appearance quality is an idea that has the support of growers in this study. Grower J reported recent success in this area: “French fry business has helped the sweet potato business tremendously. Tremendously. They're a little on the cheap side, but it's better than leaving them in the field. Five years ago, we left them all in the field. We just left them.” The price offered by processors must support the harvest costs of the crop, which may still need improvement. Grower E did not have a relationship with a processor as a secondary market for his sweet potatoes, and asserted, “Processors won't pay. They're used to paying for seconds and unusable for the fresh market, so the prices are pretty low. I'm not all over looking for process business.” The potential for the processing industry to accept and utilize surplus crops aligns with the suggestions from growers in the California study (Campbell and Munden-Dixon, 2018). Suitability of processing as a solution to food loss will depend on the perishability of the crop, size of farm (volume available), produce variety, and other factors. Processors may source from a few growers in a variety of regions, contracting volumes and prices in advance to ensure a consistent supply to their facility. In addition to requiring certain quality indicators, such as size or color, the cultivars used can be dictated by the processor. Utilizing another cultivar may result in a final product with quality or flavor that varies from what the customer expects, making it difficult to utilize surplus produce. For example, fresh market cucumbers are not the same variety as required for use in making pickles.

3.4.3. Demand

One overall theme that growers perceive must be addressed in order to reduce losses is demand, which 65% of growers mentioned. Grower P theorized about future developments in agricultural production, saying, “as we evolve over time, what you're going to see is that the ugly vegetable campaign is going to eventually be a non-issue because the demand for the product, worldwide, in years to come is going to be such that, there ain't nobody going to pay it no mind. I think you're going to see that demand ... is going to be what dictates.” This grower is basing his assessment of the growing market for produce based on calculations of how much the population is projected to grow. Another strategy is to

increase the consumption of fruits and vegetables in the existing population. Increasing consumption in current consumers may be a strategy to increase demand, as 22.6% of US consumers report eating vegetables less than once per day (CDC, 2013). In order to meet US dietary recommendations, the current supply of vegetables available to consumers should be increased by 70% (Krebs-Smith et al., 2010). Although challenged by current appearance quality standards, growers may be closer to meeting the need for that kind of increase in supply than previously thought, based on data from in-field measurements of loss (Johnson et al., 2018b).

3.4.4. Alternatives

Developing alternative markets for produce that does not meet current appearance quality standards has been suggested as a way to decrease losses at the farm level (Gunders, 2012; ReFED, 2016). Several produce programs and companies have emerged with this focus, such as national retail programs, regional foodservice distribution, and subscription boxes for home delivery, many of which offer a cost savings to customers which may then impact the price offered to growers. However, this analysis has revealed that growers may not be connected to alternative markets as they emerge. Additionally, growers in this study were concerned about the effect marketing lower produce quality would have on the price of their main crop, echoing the earlier study from smaller farms which discussed cannibalization of the market for higher quality (Berkenkamp and Nennich, 2015). Grower responses to the emergence of the "ugly" produce trend varied from concern to excitement, and less than half of the participants viewed the trend favorably. A benefit of the emerging market for imperfect produce may be that lowered prices will allow more consumers to buy fresh produce, creating new demand. However, growers have concerns about this, since increased supply can also drive down prices. Grower K summarized it this way, "I don't know where this ugly food deal is going to go other than I think it's going to hurt the grower more than anything else. It's going to lower the price of a good product." As these programs emerge and gain popularity, growers appear tentative in their participation, but are interested to see how the addition of these markets will affect their operations.

3.4.5. Donation

Growers were asked about their experiences with donating and field gleaning, and responses were mixed, with less than half seeing current practices as favorable. Some growers donate when possible, mostly produce that is sorted out in the packinghouse, rather than specifically harvesting produce from the field for donation. Donation of loads that have been rejected at their destination is more common than donation directly from the farm, and allows the grower to avoid paying for freight back to the farm. Grower Q only donates rejected loads, "We do that [donate] if we have a certain rejection in an area that has a food bank. That's the only time we do it. We don't work directly with food banks."

Two organizations are actively gleaning in eastern North Carolina, the Society of St. Andrew, a national charity, and a regional organization. Growers indicated local churches and civic organizations also participate in gleaning. Knowledge about and perceptions of gleaning were mixed, with Grower Q noting "I don't even know what that is." Liability was also a concern related to gleaning practices. As Grower N mentioned: "some of the farms are not owned by me, and the landowner may not want people out there." Growers can perceive gleaners as a challenge to maintaining their food safety certifications, as Grower E suggested: "I don't do that anymore. If they don't work for me, they're not in my field. I'm not supposed to, so I won't do it." According to Good Agricultural Practices certification, visitors to fields are required to follow sanitation and personal hygiene practices in accordance with strategies that can prevent microbial contamination of produce (Maughan et al., 2016). The certification requirements can vary by buyer, however, and may require training for personnel in the field. Food safety recommendations have not yet emerged for gleaning crops after the main harvest season. In order to avoid a produce recall that can bankrupt a farm, growers may simply avoid activity that could potentially lead to contamination.

Alongside the traditional definition of gleaning that includes providing access to fields so that a charitable organization can harvest crops, growers also consider individuals who enter the field with or without permission as gleaners. Grower K compared and contrasted these two gleaning types as negative and positive:

> The negatives of gleaning [are] that the people that are doing the gleaning will mess up your fields…. They'll get in front of your truck. Your truck can't get out on the field. What most of the growers are doing, is when they finish a field, they cut it up that day…. It's sad, there's a lot of good food wasted, but it's really aggravating. … We [arrange for a group to] glean the lettuce. But, they're told where to go. It's one of the church groups comes out with the people and tells them what to do. It's supervised. That works good because all we are going to do with it is cut it up with a machine. Those people will get it, and we get a tax credit for it. I don't know how much money it amounts to, but it's something. It makes somebody eat a little better, or have something to eat.

This grower's perspective suggests that individuals removing crops from the farm without permission are considered "gleaners," which may negatively influence the access that organized gleaning groups have on farms. Also, it shows that organized gleaning can result in a positive outcome for growers.

The EPA hierarchy (Fig. 1; EPA, 2015) indicates that donation is a preferred method to increase food recovery. Food donation tax benefits were made permanent in the U.S. in 2015 through the PATH Act, and some states offer tax incentives for donation (Gunders et al., 2017), yet the growers interviewed did not note tax incentives from donation as an important driver for harvesting decisions. Several growers echoed the thoughts of Grower H, who was discussing the tax benefits available for donations: "To be clear on the taxes, they're claiming that we've already expensed the labor and we've already expensed the boxes. So we're really not going to get an extra tax break. But, yes, if there was an incentive there, we definitely would do more of it." Providing growers a tax credit that incentivizes donation, rather than a tax deduction, has been suggested as a solution to reducing losses (Gunders et al., 2017). As many farms operate with low margins, the available tax deductions may lack impact as an incentive since they reduce taxable income, whereas a tax credit directly reduces tax liability (Harvard and NRDC, 2017). Some states provide additional incentives for donation. For example, a tax credit for gleaning was once available in North Carolina; however, it was repealed in 2014 (NCDOR, 2014).

Additionally, donation and gleaning can present logistical challenges for many growers during a busy season. Increasing the efficiency of gleaning operations, as shown in the stochastic optimization model developed by Lee et al. (2017), may alleviate growers' concerns surrounding the ability to quickly get back into the field, as well as maximize the volume of produce collected. An increase in grower participation would improve the volume of produce available (Lee et al., 2017). Further education on the available tax incentives and donation liability was not requested by growers at the time of interview, but subsequent discussions indicate that additional information clarification of the process to growers could be useful.

A middle ground between donating product and developing alternative markets is evidenced in the North Carolina Farm to Food Bank program, an example of similar programs around the country. These programs offer to cover the harvest costs for growers, enabling them to more fully utilize their production, and ensure wider distribution of fresh produce. In Kentucky and Indiana, Farm to Food Bank programs list prices available to growers online, and are typically 95% of the market price for Number 2 quality produce (ISAFB, 2018; KAFB, 2018).

4. Conclusion

As the food loss and waste discussion turns toward suggesting strategies for stakeholders along the US supply chain, the primary production level requires tailored strategies that will ensure economic sustainability of these operations. This paper contributes to the body of research that attempts to more fully characterize and understand the factors that contribute to on-farm food loss by examining the experiences and perspectives of mid to large-scale growers, who have been largely overlooked in previous studies. This investigation of harvest decision-making by mid-size to large specialty crop growers in North Carolina was used to create a decision-tree detailing the primary drivers of farmer decision-making that influence on-farm loss in order to identify key leverage points that can contribute to effective reduction strategies. Findings suggest that the availability of buyers, sufficient price, appearance quality, risk of rejection and priority of other work on the farm must be balanced in order to successfully move a crop from the field into the marketplace. Growers in this study perceive crops left in the field as low value, or occurring in a low volume that may not affect their profitability. Donation and gleaning did not offer growers enough incentive to continue the harvest, and can present barriers to farm efficiency. Growers are the key to reducing food loss on the farm, and these nuanced factors important to their operations must be incorporated into the development of strategies.

This study also drew into some common assumptions and methods related to on-farm food loss. First, contrary to what is cited in the literature (Gille, 2013; Gunders, 2012; Gunders et al., 2017; Gustavsson et al., 2011; Mena et al., 2011; Midgley, 2014; Milepost Consulting, 2012; WRAP, 2017), growers in this study did not overplant as a way to mitigate their risk. Therefore, the EPA's food recovery hierarchy that promotes reducing the volume of surplus food produced as the first step to reducing losses is not well-suited to the reality of agricultural operations. Second, growers' uncertainty and lack of confidence about reporting estimates of losses draws into question one of the most common methods for estimating on-farm food loss nationally. This finding supports the need for field measurement in order to more accurately quantify the potential amount of edible produce that is left unharvested, which in turn will affect the strategies that should be used to rescue these products. Finally, the strategies suggested for reducing food losses at the agricultural level that may be promoted because of high economic value or high projected diversion, such as facilitating an increase in donation and developing alternative markets, may not incentivize growers, who see strategies directly benefiting their operations as more critical. Growers representing almost 20% of the specialty crop acreage in North Carolina expressed interest in realizing better connections to a variety of flexible and consistent buyers, more processing facilities, and increased overall demand for produce. Opinions of donation and gleaning are negatively impacted by perceived problems. However, findings suggest that these options could be perceived more favorably with clear information on tax benefits, liability considerations, and, particularly, financial remuneration.

This research described qualitative analysis of key decision-making variables on commercial vegetable farms in the US that impact the level of agricultural losses, detailed how growers perceive the volumes of produce lost in the field, and suggested strategies supported by growers that can reduce on-farm losses. Further study in the US will be required to understand differences based on crop, farm size, region, and other factors.

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Appendix A. Supplementary data

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