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Can On-Farm Food Loss Prevent Waste? Insights from California Produce Growers

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Abstract

Significant quantities of edible produce are lost at the farm level. Amidst growing concern about the environmental impacts of food loss and waste, policymakers and advocates have invested in exploring farm-level interventions that might reduce the environmental footprint of food. Farmers are obvious stakeholders in such efforts, yet their voices are often missing from the discussion. Drawing on interviews with 25 growers in California, we show how on-farm losses are driven by efforts to mitigate economic risk within food supply chains. Buyers minimize risk by demanding consistent volumes of perfect produce to offer to consumers, and growers in turn minimize their financial risks by holding back “imperfect” and surplus food. If food is likely to be rejected further down the supply chain, growers abandon it on the farm. Using the EPA food recovery hierarchy and the tools of life cycle analysis (LCA), we then compare the environmental impact of farm-level loss to downstream alternatives. While landfill disposal is common at the retail and consumer levels, food lost at the farm level is tilled back into the soil or sold as animal feed. We conclude that some on-farm losses may prevent more environmentally harmful “waste,” defined here as landfilled

food, further down the supply chain. Our analysis argues for a cautious approach to remedying on-farm food loss—one that recognizes its structural causes and considers the comparative environmental impact of loss and waste at different stages of the supply chain.

1. Introduction

As the topic of food loss and waste (FLW) has garnered increasing attention in policymaking and advocacy circles, interest has turned to farms as sites of food loss and potential locations for targeting solutions. Particularly in the arena of fresh produce, studies suggest that significant quantities of edible crop are abandoned at the farm level (Alexander et al., 2017; Johnson et al., 2018; Neff, Dean, Spiker, & Snow, 2018). In light of this information, civil society groups, foundations, government agencies, and other actors have invested in exploring the role of farms in reducing FLW. Among other objectives, a key goal of such efforts is to reduce the environmental footprint of food.

While farmers are obvious stakeholders in solutions involving farms, we know little about their experiences and perspectives related to food loss and waste. Numerous quantitative studies have investigated on-farm losses. Yet we are aware of only one peer-reviewed qualitative study documenting grower views in Scotland (Beausang, Hall, & Toma, 2017) and two other reports on farmer views within the United States (Berkencamp & Nennich, 2015; Milepost Consulting, 2012). These works emphasize farmers' unique understanding of the complex factors driving loss and their important roles in crafting effective solutions, highlighting the need for further investigation. Our research helps to fill the existing gap in the literature by sharing the perspectives of fresh produce growers in California, drawing primarily on 25 semi-structured interviews with growers of leafy greens, tomatoes, and peaches.

Based on insights from these farmers, we contribute to policy conversations by thinking holistically about the drivers of on-farm losses and the role that such losses play in the overall environmental impact of FLW. We use the term "waste" here to specifically refer to food sent to landfills (Bellemare, Çakir, Hikaru, Novak, & Rudi, 2017), as distinct from the broader category of "loss." This definition distinguishes the highest cost pathway of landfill disposal (which includes such costs as tipping fees, reduced landfill capacity, and emissions of greenhouse gases, GHGs) from other pathways that recover at least some value from food that is not consumed by humans (e.g. animal feed, anaerobic digestion, composting, and land application). Given finite resources, advocates and policymakers must determine which FLW interventions will be most efficient and where along the food supply chain (FSC) to invest the greatest energy. Thus, we ask: How do practices at the farm level impact the production of waste? To what degree would reducing on-farm food loss mitigate problematic environmental impacts? What kinds of changes could or should occur at the farm level?

To address these questions, we begin by reviewing the current interest in on-farm losses, noting the need for greater farmer input in the discussion and explaining the methods we used to capture their views. The second two sections of the article discuss key findings from interviews. First, we explain on-farm losses from a political economy perspective, contextualizing farm-level decisions to abandon edible produce within an agricultural system in which economic risk has shifted toward producers. We then reference the Environmental Protection Agency (EPA) food waste hierarchy and the tools of life cycle analysis (LCA) to evaluate the comparative environmental impact of different loss and waste scenarios in light of what is actually done with food left on farms. The concluding section considers implications for both research and practice, proposing new areas of investigation.

2. Farms and Food Waste: Inserting Growers’ Views into the Conversation

In the U.S. and other developed countries, most of the attention on food loss and waste has focused on the processing, retail, and consumer levels rather than on the farm (Alexander et al., 2017; Buzby, Wells, & Hyman, 2014; Dou et al., 2016; van der Werf & Gilliland, 2017; Xue et al., 2017). Yet numerous studies indicate that significant quantities of food are discarded or diverted at the farm level, particularly in the arena of fresh produce (WRAP, 2011; Gunders, 2012; Brautigam et al., 2014; Berkenkamp

& Nennich, 2016; Alexander et al. 2017; WRAP, 2017). The United Nations Food and Agriculture Organization (FAO) estimates 20% loss in fruits and vegetables in North America at the agricultural level (Gustavsson et al., 2011, p. 7). A study based on grower reports in four Nordic countries suggests similar levels of loss, with 10% to 26% of fruits and vegetables originally intended for human consumption diverted from the food supply chain (Hartikainen, Mogensen, Svanes, & Franke, 2018, p. 508). Based on in-field measurements on North Carolina farms, Lisa Johnson found significantly higher levels of edible food left in the field, averaging approximately 40% loss across eight different fresh vegetables and fruits (Johnson et al., 2018). Beyond such statistics, images of seemingly perfect produce abandoned in fields or dumped into disposal bins make a compelling case for intervention.

In response, foundations, non-profit organizations, government agencies, and others are investing in research and projects that explore on-farm food loss prevention and recovery options (Berkenkamp & Nennich, 2016; Harwood and Baker, 2015). For example, the United States Department of Agriculture (USDA) recently funded a project to synthesize research on quantities and drivers of on-farm losses across various crops. Our own qualitative work and associated quantitative field-based studies in Florida, California, Vermont, Idaho, and New Jersey is part of a $1.3 million funded by the Foundation for Food and Agriculture Research (FFAR) and the Walmart Foundation, with the goal of investigating on-farm loss and recovery potential. A key goal driving this agenda is reducing the environmental footprint of agriculture—improved food recovery promises more efficient use of land and resources to feed a growing population, as well as reductions in organic waste disposal linked to GHG emissions.

In tackling this issue, applying consistent terminology remains a challenge. Researchers, advocacy groups, government agencies, and international bodies have adopted significantly different definitions of “food loss” and “food waste.” For example, the FUSIONS consortium provides a comprehensive definitional framework for waste, understood as all food and inedible parts removed from the supply chain (FUSIONS, n.d.). The FAO links loss and waste to different points in the supply chain; “loss” is taken to mean decrease in edible food mass at the production, postharvest and processing stages, while “waste” occurs at the end of the chain as a result of retailer and consumer behavior (Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011, p. 2). The USDA defines both loss and waste as occurring post-harvest, distinguished by the degree of human agency involved; food waste is a “component of food loss [that] occurs when an edible item goes unconsumed, such as food discarded by retailers due to undesirable color or blemishes and plate waste discarded by consumers” (Buzby et al., 2014, p. iii). Finally, the EPA distinguishes between “wasted food,” which is food not used for its intended purposes, and “food waste,” which is food that has lost its value and has to be managed (US EPA, 2015).

In light of competing definitions, Marc Bellemare and coauthors advocate distinguishing “food actually wasted” (2017, p. 2) from that merely removed from the supply chain, asserting, “As long as food does not end up in a landfill, it is not wasted” (2013, p. 5). Given our focus on comparative environmental outcomes, we follow this approach and use the term “waste” to specifically refer to food sent to a landfill at any point along the supply chain. As elaborated further below, the disproportionate environmental impact of landfill disposal justifies distinguishing it from other potential pathways (Scherhaufer et al., 2015). Moreover, our interviews alerted us to the very different connotations of “losing” versus “wasting” food, with the latter implying a need for behavioral change that overestimates the agency growers actually exercise within the broader political economy of food.

To assess the relationship between on-farm food loss and environmental impact, our approach has been to listen carefully to the people most directly engaged: farmers. A richer qualitative understanding of the processes that drive on-farm losses can support a more realistic evaluation of the likely consequences (intended and unintended) of proposed solutions.

3. Methodology: Collecting Grower Views

California has the highest agricultural output of any US state, along with the largest and most diverse fresh produce sector. Many parts of this sector are tightly integrated into the global supply chain system; others are part of local and regional food systems that emphasize direct marketing, or hybrids doing both. We explored on-farm food loss and recovery possibilities in three key California crops: leafy greens, tomatoes, and peaches. The first two were chosen because of the size and scale of their presence in California, their importance in national and global markets (e.g. as common ingredients for fast food and retail food outlets), and thus their potential for major environmental and social gains or losses. Peaches were selected to determine if the trends observed in annual leafy greens and tomatoes were similar in a perennial tree crop, and more specifically, an orchard crop that is highly perishable.

Table 1. Economic and Physical Scale of Peach, Tomato, and Lettuce Production in California

Crop Type	**CA Share of US Receipts**	**Acreage Harvested (1,000 Acres)**	**Production (1,000 Tons)**	**Total Value ($1,000)**
Peaches (Freestone)	NA	20	244	NA
Fresh Tomatoes	27.1	NA	330.8	206,413
Lettuce (Heads)	63.7	83.5	1,523.9	993,567

Source: (California Department of Food and Agriculture, 2018)

We used semi-structured interviews to capture grower perspectives on how much food is lost on their farms, the causes and effects of these losses, and potential solutions. Open-ended interviews are a methodology well-suited to exploring complex processes and generating propositions about causal relationships. Semi-structured interviews are oriented around a series of broad questions, but allow the respondent to help guide the discussion by raising new issues in spontaneous conversation (Hammer & Wildavsky, 1993). This approach is ideal for respondents who might feel reticent about being interviewed, as well as for preliminary research in which the goal is to explore the range of views within a given group.

We recruited initial interviewees through contacts established through the University of California Cooperative Extension system (UCCE), the California Food Waste Roundtable, and the researchers’ professional networks. We then used a process of “snowballing,” where each respondent indicates potential interviewees. Initial recruitment efforts were challenging—some growers were distrustful of researchers who might portray them as wasteful and wary of the potentially burdensome new regulations. Responding to grower sensitivities, and in light of conflicting definitions discussed above, we eliminated the terms “waste” or “loss” from our interviews, instead asking growers to comment on “crops that do not make it to primary markets.”

In total, we interviewed 25 growers of leafy greens, fresh peaches, and fresh tomatoes, roughly split between the three crops. Farms ranged in size and reflected the organizational diversity of California agriculture, in which “no single structure can be considered a prototype” (Carman, Cook, & Sexton, 2003, p. 99); they varied in degree of vertical integration, reliance on contracts versus spot markets, and type of contractual arrangements, among other factors. The category “grower” included people holding different roles on the farm, such as harvest manager, owner, sales representative, and other positions. Interviews lasted approximately one hour and were mostly conducted on farms, unless farmers requested a phone interview. We recorded all in-person interviews except for one case in which a grower requested not to be recorded. For phone interviews, we took detailed notes throughout the conversation to generate close transcriptions. We guaranteed the confidentiality of participants and their businesses.

Our sample was small relative to the number of farmers growing these crops in California, was based on convenience and previous researcher connections, and—given the resistance we initially encountered—was likely biased in favor of growers more open to the idea of addressing food loss. Thus, our findings cannot be interpreted as a general representation of grower views. They offer instead an important initial look into the range of opinions growers might have, generating insights that can inform subsequent research and policy.

Table 2. Distribution of interviews and farm visits among the 3 crops.

	Farmers interviewed	**On-farm site visits**
Leafy greens	9	5
Fresh peaches	7	5
Fresh tomatoes	5	4
Combination of these products	4	4
Total:	**25**	**18**

All interviews were professionally transcribed and uploaded to a qualitative data analysis software program. Multiple readings of the transcripts generated codes for both manifest and latent themes, as we sought to capture both visible content and underlying meanings (Babbie, 2015) and refined these through iterative discussions. Organizing interview excerpts by code, we then generated a comprehensive report summarizing key findings.

Our qualitative work generated two core insights for designing FLW solutions involving farms. The first is the need to understand how on-farm losses are structured by the way economic risk is borne within the current agricultural system. The second is the need to assess the relative environmental impact of food lost at the farm as compared to other points along the supply chain. The next two sections explore these findings in greater detail.

4. Risk Mitigation and On-Farm Loss: Farmer practices amidst integrated supply chains

Growers are faced with the challenge of optimizing their farm performance in the context of broader economic, political, and environmental conditions. Further, these conditions are changing. The past few decades have featured dramatic structural changes in the political economy of food and agriculture, including the increasing concentration of power in fewer corporate firms (Hendrickson, Wilkinson, Heffernan, & Gronski, 2008; Howard, 2016) and the “transition from independent economic stages coordinated primarily by markets to much more tightly aligned food supply or value chains coordinated by various forms of negotiated linkages” (Boehlje, 1999, p. 1040). The majority of US fresh produce production is governed by these structural arrangements; while a small percentage of fresh fruits and vegetables are distributed through direct marketing channels, most growers today rely on others to sell their product (Cook, Roberta L, 2011). The perishability of fresh produce has always limited the bargaining power of producers as compared to buyers, but recent structural shifts have deepened these power imbalances (Carman et al., 2003, p. 101). Growers now compete with each other for a limited number of increasingly demanding buyers (Boehlje, 1999, p. 1040). As evidence of growers’ relative weakness within this system, the farmer share of the food dollar has been steadily shrinking over time (Economic Research Service, USDA, 2018).

Within this context, sociologist Zsuzsa Gille (2012) advocates for placing the question of risk at the foreground of food loss analysis. Using the term “waste” in a general sense, she asserts, “Economic risks are a key aspect of the production of waste…efforts to shield oneself from economic uncertainties generate waste in different stages of production and consumption” (Gille, 2012, p. 32). The production and sale of fresh produce are inherently risky endeavors, as both Mother Nature and consumer markets are fickle, and the perishability of the product means short timelines for turning a sale (Carman et al., 2003, p. 101; Minor et al., 2019, p. 3). As Gille notes, one exercise of power is the ability to transfer risk to other actors. In today’s agricultural system, retailers can shield themselves from financial uncertainty by demanding consistent volumes of perfect produce to offer to consumers; to obtain and retain a buyer, growers must ensure reliable quantities and meet rigid quality standards. Power imbalances manifest in the form of unsold food on farms, as growers must plant sufficient quantities to allow for fluctuations in yield and quality and then leave unharvested or cull unwanted product (Gille, 2012, p. 35).

Interviews with California produce growers reveal two broad categories of food abandoned at the farm-level as a result of economic risk management within this structure: edible food that does not meet quality standards, often termed “imperfect produce,” and perfect produce for which there may not be a buyer, termed “surplus produce.” Growers gave broad estimates of quantities of edible food lost and, as in other qualitative studies, discounted their accuracy by emphasizing significant variance by year and within a given season (Beausang et al., 2017, p. 181). Tomato and peach growers reported losing approximately a quarter of fruit, with tomato losses primarily occurring in the field and peach losses occurring at the packing shed. Leafy greens growers’ estimates varied by crop but ranged from less than 5% to close to a quarter. The economic risks that drive the loss of imperfect and surplus produce are discussed in turn.

Edible food is often discarded because it fails to meet established quality specifications for size, ripeness, or cosmetic features. In the case of peaches, growers described marks from hail pellets or rubbing branches. Fresh tomatoes with sunburn or “catfacing”—an abnormal cracking and dimpling of the skin–are discarded. Leafy greens growers noted that romaine with a bit of tip damage from wind, or iceberg heads with a “football” rather than spherical shape might get left behind during harvest. Standards may be set by retail firms, government agencies or industry associations, and can vary for specific markets or grades. In the case of fresh peaches, for example, some growers pack a smaller sized peach in parallel to their “number ones.” In contrast, a lettuce grower described rigid size requirements for romaine lettuce: “If you need a 10-inch head of romaine, and there’s a 7-inch head of romaine, [the pickers] are just going to walk right by it… There’s not like, medium romaine, large romaine. So, if it doesn’t meet that minimum criterion, it just gets left behind” (Interview 26).

Growers described two underlying justifications for disposing of “imperfect” food. The first is the risk that produce would become inedible by the time it reaches consumers. In researchers’ analysis of food lost on farms, it is often unclear whether they are considering edibility on the day of the assessment or in the context of the required transport/storage/handling for successful passage through the supply chain (Johnson et al., 2018; Neff et al., 2018). In contrast, growers explained culling for quality based on what produce would look like when it reaches an end destination. As one peach farmer commented, “Very few of them [the culls] are not edible. Even the soft is edible. It's just too soft to handle to get it to anybody... That's what I take home to eat, to my grandkids. But it doesn't have to ride on a machine or go on a five-day truck ride to the East Coast, you know? It just won't make it” (Interview 15). Culling for size has practical as well as aesthetic importance, as a precisely packed box can prevent damage in transport. A lettuce harvest manager explained that small heads get left behind “because we need that full box. If you got lettuce rolling around the box it'll get rejected" (Interview 2). Relatively small cosmetic blemishes could develop into decay over time, as another grower explained: "If it's imperfect because it's got a flaw, it might be minor at the field level when they're looking at it, but it might be a ball of mush by the time it gets to the consumer level" (Interview 32). Another farmer elaborated:

> The biggest thing is that when you have these different products and you start trying to extend their marketing ability, if there's imperfections, that can lead to breakdown…A lot of times if it's product that's either past what we call its bloom, it's not going to have the shelf life. And if you start trying to push that into regular channels or into other channels, it may lead to food safety issues… (Interview 5).

As he concluded, the possibility that imperfect produce might decay further down the supply chain drives heavy culling at the field level.

The second justification for abandoning imperfect produce is the risk that the product will be undesirable to consumers. As a leafy greens farmer commented, "Customers, they eat with their eyes. So if the product doesn't look good on the shelf, if there's any discoloration, or any little thing, customers won't eat it, or buy it" (Interview 2). He went on to explain how such consumer preferences drive losses. "So sometimes, with romaine there could be a little bit of wind damage just on the very tip—the little tip burned—and a bad market, we'll walk away from that" (Interview 2). Asked what portion of his tomato culls is edible, one farmer summarized, "Whatever the culls, if it's just the color, or the catfacing, all of that is edible. It's just the view of it" (Interview 11). A peach farmer commented, "I could take you to a packing shed and you'd watch the cull line and you'd go, why are you throwing that away? But that’s how particular the market is” (Interview 21). Though growers talked about consumer preferences, quality specifications reflect buyer interpretation of such preferences. A leafy greens farmer commented, “What we think there’s a market for, and the retailers we sell for think that there’s a market for, it’s a different story. We are doing what the retailer wants to do. We don’t know the consumers” (Interview 1).

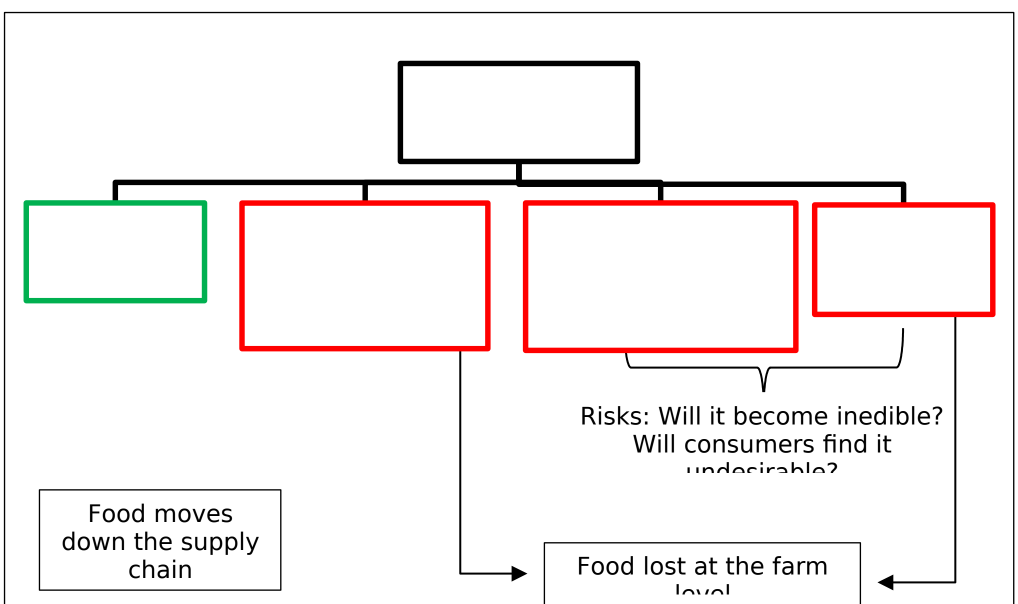
Ultimately, a more immediate risk to growers compels them to abandon imperfect produce—the risk that the product will be rejected further down the supply chain. In cases of rejection, suppliers not only risk losing a buyer, they are also responsible for disposal of the rejected product, which may involve additional financial costs. Even small percentages of borderline produce can spur retailers to reject an entire load, prompting growers to err on the side of caution in meeting quality specifications. As one grower summarized, “If you’re going to have waste, better to have it here at this level, rather than ship something of questionable quality.” In her study of six vegetable crops on a North Carolina farm, Lisa Johnson (2018) found that, even when significant portions of a field are top quality, farmers might discontinue harvesting to avoid inadvertently including imperfect product in a shipment— potentially prompting rejection and tarnishing the farmer’s reputation (248).

What constitutes “questionable quality” varies based on market conditions. Weak markets can effectively narrow quality specifications. A tomato farmer described what would currently be considered “overripe,” commenting, “And now the market is so low, any pink [on the tomato], they [the pickers] will throw it away” (Interview 11). A peach grower explained:

> If there's too much fruit, nobody wants these bottom sizes. Two years ago, there was no market basically for medium to small fruit because there was so much fruit and there was plenty of big. So the packers were telling guys, just leave those small ones on the tree—don't bring them into us because it wouldn't pay for the picking and the packing… (Interview 16)

The risk of retailer rejection also expands in cases of oversupply, making growers more cautious in assessing imperfections. As a leafy greens grower commented, “When the market is bad, that is when you’re most likely to step over something, or really get picky. So maybe you don’t take a chance putting a short head of lettuce in, or something ugly” (Interview 25). Buyers have relatively unchecked power to determine when rejection is justified—although suppliers have the legal right to demand external inspections, their position in relation to buyers can make this impractical—meaning that quality complaints may be used to mask rejections based on decreased demand (Eriksson, Ghosh, Mattsson, & Ismatov, 2017). A study from Sweden showed how retailer power to make suppliers absorb costs of quality and quantity fluctuations— through unchecked reclamations and, in some cases, “buy-back” agreements for unsold food—both expands overall levels of food loss and shifts loss toward suppliers (Eriksson et al., 2017)

Relatedly, growers also incur loss in the form of surplus perfect food. In weak markets, they may leave superior quality produce unharvested for risk of failing to recover additional variable costs. A lettuce harvest manager explained that, when sales are unsure, “we won’t even harvest it, because then we pay for it twice.” He elaborated, “We pay for it to be harvested and cooled, and then it just sits there, and then we have to pay for it to get disposed of, so it’s cheaper to just cut your losses with the growing costs” (Interview 2). While most US fresh fruits and vegetables are sold in spot markets, a significant portion is produced under contract (MacDonald & Korb, 2011, p. 5). Some growers commented on how contractual arrangements might impact loss due to surplus—one lettuce grower explained how the expansion of contracting has helped growers fine-tune planting and harvesting schedules with more predictable sales (Interview 6). On the other hand, to fulfill contracted volumes and maintain buyers, growers must plant sufficient quantities to account for fluctuations in yield (Minor et al., 2019, p. 4). Thus advantageous as much as adverse weather may provoke loss, as bumper crops can mean that food sits in the field (Gille, 2012, p. 34). One grower described high levels of loss “when it was just a great year for tomatoes and we have more than we have markets committed” (Interview 11).



In sum, growers abandon or discard food due to the exigencies of an increasingly competitive market and their desire to minimize financial loss. Fluctuations in yield and quality are endemic to farming fresh fruits and vegetables, and buyers have the power to shield themselves from economic risk by demanding consistent supplies of perfect produce, pushing losses back to the farm level. As one farmer commented, “They [retailers] are the big players in the game. They make the rules and they make the calls. I’d like to say we’re in control, but they’re the giants” (Interview 3).

5. Lost But Not Wasted: The comparative environmental impact of food loss on farms

When assessing environmental impact, not all food loss is equal—*where* and *how* loss occurs along the food supply chain dictates its effects. Thus, a second step in assessing the role farms and farmers can and should play in food waste reduction is to consider the comparative environmental impact of on-farm food loss. Life-cycle assessment (LCA) methods are one means of measuring the comparative environmental impact of loss and waste at different stages of the food supply chain, where the resource inputs and waste emissions are analyzed across a product life-cycle, from “cradle to grave” (i.e. production to disposal). Existing studies that apply LCA methodology to the food supply chain have highlighted the cumulative increase of embedded resource use (e.g. water, energy, and other material inputs) as food items pass through the value chain (Bernstad, Cánovas, & Valle, 2017). For example, one can consider energy as an input at each stage of the supply chain from producer to consumer, along with transportation energy to convey the products between stages (Canning, Charles, Huang, Polenske, & Waters, 2010; Pelletier et al., 2011). The further down the supply chain that food is either lost or wasted, the greater the embedded energy costs of the forfeited food item; in comparative terms, pushing loss “upstream” toward producers represents reduced environmental impact.

In assessing environmental impact, we also need to consider what happens to lost food. The EPA has developed the food recovery hierarchy as a heuristic model for prioritizing food loss and waste solutions based on total environmental, social, and economic benefits (US EPA, 2017). In order of preference, the EPA suggests reducing the volume of food loss and waste at the source; feeding hungry people with surplus food; diverting food scraps to animals; industrial valorization of food waste through recovery of biochemicals, fuels, and energy; composting for nutrient recovery; and finally, landfill and incineration as a last resort. The significant difference in environmental outcomes justifies distinguishing food truly “wasted” in landfills from that lost or diverted in other ways. Not only is the potential to recover valuable nutrients lost via landfill disposal, the decay of the organic food material in anaerobic landfill conditions produces methane, a GHG that is 25 times more potent than carbon dioxide (CO_2). In the United States, it is estimated that methane emissions from food disposed in landfills represents 26% of the total GHG emissions of food loss, which in turn is estimated to be 1.8 kilograms (kg) of carbon dioxide-equivalents (CO_2-eq) per person per day (Heller & Keoleian, 2015). Unfortunately, the EPA estimates that only 5.1% of the food waste portion of all municipal solid waste (MSW) in 2014 was diverted from landfills and incinerators for composting (US EPA, 2016b).

Location and mode of food loss are interrelated; as food moves down the supply chain, the odds of it being diverted to a landfill increase significantly (Hoover & Moreno, 2017; Thyberg et al., 2015; Scherhaufer et al. 2015). While on-farm loss is common and significant, actual "waste" in the sense of landfill disposal is a rarity on farms. One grower summarized, "We are effectively a zero landfill farm" (Interview 25). As growers explained, the easiest and most cost-effective ways to dispose of imperfect or surplus product is to till it back into the soil. Leafy greens are packed in the field, so anything that does not meet standards will simply be left behind by pickers and disked under when the field is prepared for the next planting. Similarly, with fresh tomatoes, pickers toss imperfect fruit on the ground. Beyond economic efficiencies, growers saw this practice as environmentally beneficial, or at least neutral. As one greens grower commented, "Well it's good for the field because we are returning, essentially, all the nutrients or at least part of them down to the organic matter, and back to the soil" (Interview 1). An organic tomato grower explained, "So when people say that food is being wasted, maybe it’s just not going through the traditional distribution system. Everything that we grow in some way makes it back into the natural system of recycling nutrients” (Interview 12).

Growers also reported diverting unused produce to animals—an option which ranks relatively high in EPA’s food waste recovery hierarchy. In the case of peaches, fruit left on trees or in the orchard can be an attraction for pests, therefore most growers reported harvesting virtually all produce in multiple picks, leaving most culling for on-site packing houses. Post-harvest culls were then sold as animal feed at a minimal price. A peach farmer explained: “These extra softs, those go to the cows. They volume-fill trucks, and they haul them out and dump them in these vats that they grind them up with straw, so they make the straw real palatable for the cows” (Interview 15). As found in other qualitative work, growers often highlighted the relatively productive uses of food lost at the farm level (2017, p. 180).

Figure 3 illustrates the comparative environmental impact of typical on-farm losses as compared to loss further down the supply chain, showing the total estimated GHG emissions (or global warming potential, GWP) for two example scenarios for fresh tomato losses. Estimates of GHG emissions are presented for losses by stage of the food supply chain as well as the most likely food waste disposal option for each scenario. The first scenario represents losses in the field that are ultimately ploughed back into the soil; the second scenario represents food waste at the point of consumption that ends up being landfilled. The data presented were consolidated from a report by the European Union (EU) FUSIONS project, and thus are biased towards European production and waste management systems (Scherhaufer et al. 2015). Further, while the report specifies GWP specifically for tomato production, the GWP estimate for disposal is limited to the broader category of organic waste (specific estimates for fresh tomato disposal were unavailable).

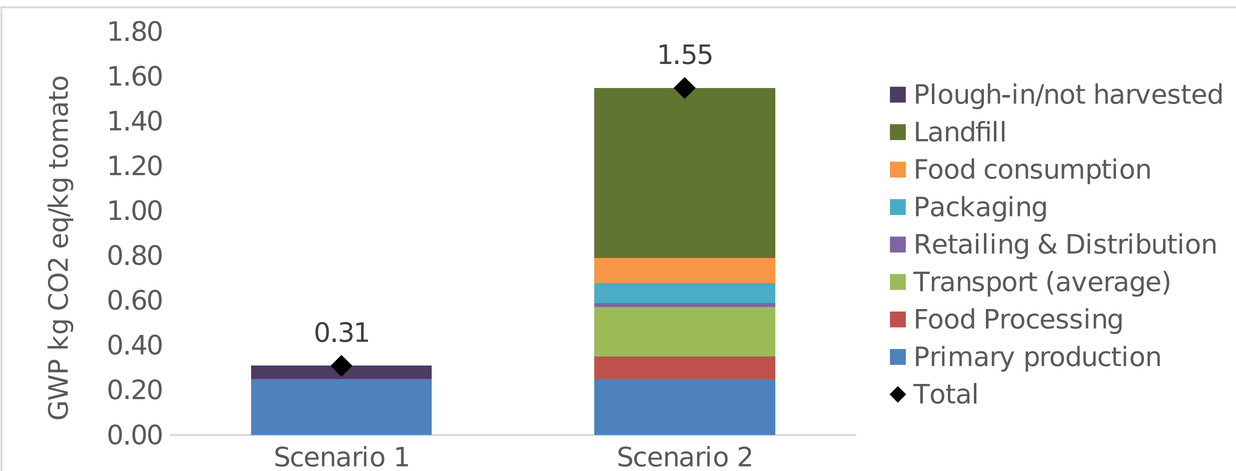


Figure 3. Comparison of global warming potential (GWP) for two illustrative scenarios of tomato loss pathways, incorporating the impact of the food supply chain and organic matter disposal options (data consolidated from Scherhaufer et al. 2015)

For Scenario 1, the total GHG emissions factor is estimated to be 0.31 kg CO_2-eq per kg tomato, based on emissions factors of 0.25 kg CO_2-eq/kg for tomato cultivation and 0.06 kg CO_2-eq per kg of organic material that decomposes in the field. The estimated GWP for Scenario 2 (1.55 kg CO_2-eq per kg tomato) is five times greater than Scenario 1, since it incorporates GHG emissions factors for each stage of the tomato supply chain (0.10 for processing, 0.22 for transportation, 0.02 for retailing and distribution, 0.09 for packaging, and 0.11 kg CO_2-eq per kg tomato for food consumption) as well as the much higher emissions factor for landfill disposal (0.76 kg CO_2-eq/kg organic material).[1]

Not only are downstream losses far more environmentally costly than on-farm losses, we might also conclude based on the previous section's discussion of risk that Scenario 1 may help prevent Scenario 2. First, growers did report sending food to landfills in rare cases where they made the wrong call on harvesting and packing surplus or imperfect food. One grower observed how this might play out in the case of product lacking a buyer: "Maybe a grower who has nowhere to put something, packed a lot of bad stuff, maybe that's where they would take it…" (Interview 12). A leafy greens grower also related sending food to a landfill in cases where a retailer had rejected a load and he was unable to find other outlets for sale or donation. As he explained, "Yes, it [sending food to a landfill] could happen, but very rarely. You realize that if you already packed something, for that product to hit the landfill, something really bad needs to happen. It would have to be a recall" (Interview 1). Landfill disposal after picking and packing a product–and particularly after sending it to a retailer only to face rejection and incur

[1] GHG emissions for "food consumption" in the original study reflects consumer travel for purchasing as well as home refrigeration.

additional costs for disposal—is a worst-case financial scenario for farmers. Thus, grower's efforts to mitigate financial risk by erring on the side of caution when deciding what to leave behind or discard may also mitigate environmental impact. While it expands levels of on-farm food loss, holding back borderline product may reduce actual waste in the form of landfill disposal.

Much of the food that growers abandon is not borderline but rather clearly fails to meet quality standards—standards that, as growers explained, address underlying risks that produce might become inedible in transit or might be unacceptable to consumers. More broadly then, to the extent that on-farm culling prevents potentially unstable or undesirable product from moving further down the supply chain, economic risk mitigation strategies may also mitigate environmental impact. Buyers' efforts to shield themselves from potential financial loss drive on-farm losses. But they may also inadvertently lessen environmental risks, including additional resource inputs and increased likelihood of food ultimately ending up in a landfill. As growers often commented, if loss is to occur, the farm is the best place for it. Put succinctly, and somewhat counterintuitively, some on-farm food loss may help prevent actual waste.

6. Conclusions

We have drawn on qualitative data captured through interviews with California fresh produce farmers to consider the role of farms and farmers in reducing food waste. Our analysis focused specifically on the environmental benefits of waste reduction, thus distinguishing the most ecologically costly "waste," in the sense of landfill disposal that contributes to greenhouse gas emissions, from food diverted from supply chains in other ways. While the ideal is to prevent any form of food loss along the supply chain, we take a pragmatic approach that seeks to identify the least bad option in environmental terms.

Our research contextualizes on-farm food loss within the broader political economy of food production. We show farm-level losses as the result of a system in which buyers shield themselves from financial risk by demanding consistent volumes of perfect produce, and in which growers bear this risk by absorbing fluctuations in yield and quality in the form of unsold food. Disposing of "imperfect" food on the farm mitigates two underlying forms of risk. The first is that produce will not be desirable to consumers, falling beyond standards of what constitutes marketable food. The second is that relatively minor imperfections at the field level might, over the course of the trip to the end user, worsen and render the food inedible. For growers, the immediate risk is investing additional resources in food that may either be rejected on quality grounds further down the supply chain—jeopardizing a relationship with a buyer and resulting in potential disposal costs— or, in cases of oversupply, may never find a buyer at all. "Your first lost is your best loss" is the governing logic for growers competing in an agricultural system in which they have diminishing power.

This logic also applies, however, to the environmental costs of lost food. Embracing a food systems perspective, and using the EPA's food waste and recovery hierarchy to prioritize different potential pathways for food, we show the farm as the best place for loss to occur. Environmental resources accrue as food moves along the supply chain, thus upstream loss is by definition preferable. Growers we interviewed almost never sent surplus or imperfect produce to landfills. Virtually all such food is either tilled back into the soil or sold as animal feed, both of which rank as preferable options within the EPA hierarchy. In contrast, food lost further down the supply chain is far more likely to be landfilled, causing disproportionately greater environmental harm and contributing to GHG emissions. Grower financial risk mitigation strategies that cause food to be lost on farms rather than further down the supply chain may help mitigate environmental harm as well.

Claiming that some on-farm food losses may prevent food waste within the current agricultural system is certainly not to advocate for the status quo. First, our analysis does not address the potential social impact of recovering food from farms. Emphasizing humanitarian rather than environmental considerations alters the calculation of when it is worth recovering underutilized food from farms, even if some of it may ultimately end up in a landfill. More importantly, "win-win" solutions with both social and environmental benefits are possible—and, in some cases, underway. We intend with this analysis to help clarify parameters for thinking about such solutions. Markets with more flexible quality and quantity requirements can move more food off of farms. But to avoid the unintended consequence of turning on-farm loss into downstream waste, efforts to recover imperfect or surplus product should carefully address two key questions: What is the likelihood that this food will ultimately make it to a consumer? And what will happen to it otherwise?

We need more rigorous research on the comparative environmental impact of food loss along the supply chain and related calculations of the probability that food retained at the farm level would become waste further downstream. A number of LCA studies exist that compare the environmental impact of recycling options (e.g. composting and anaerobic digestion) for food loss and waste relative to the landfill (Edwards, Othman, Crossin, & Burn, 2018; Gao, Tian, Wang, Wennersten, & Sun, 2017; Mata-Alvarez, Macé, & Llabrés, 2000; Takata et al., 2012). This work could be extended to make more direct comparisons between these downstream recycling options relative to tilling produce back into the field (or collection for animal feed) at the production stage. Further, and significantly more challenging, would be to quantify the risk of produce being lost/wasted at each stage of the supply chain based on quality parameters determined at harvest. However, with advancements in traceability and transparency of food products through the supply chain (Bosona & Gebresenbet, 2013), models could be developed to optimize the selection of produce to maximize the probability of reaching the consumer, while minimizing economic and environmental costs form a life-cycle perspective. Building on European case studies, further work might also explore how the technical terms of contractual arrangements, marketing standards, and other details of producer-buyer relationships influence farm-level losses (Eriksson et al., 2017; Hornibrook, Fearne, & Duffy, 2003; Mena, Adenso-Diaz, & Yurt, 2011), as well as the ways that different organizational structures and distribution channels (e.g. grower cooperatives, farmers markets) shift risk calculus and thus loss.

From a practitioner viewpoint, our findings suggest the need to adopt a broad perspective in analyzing the problem of on-farm loss and potential solutions, reassessing the role that farmers could and should play in waste reduction. We do not see the current scenario, where large quantities of potentially edible produce are never consumed as food, as inevitable or acceptable; nor do the growers we interviewed. Addressing this problem, however, requires recognizing “waste as a function of social relations” and avoiding the tendency “to assume that the causes of food waste reside within the stages within which they appear” (Gille, 2012, p. 38). Growers repeatedly insisted they are doing their best to maximize efficiency and minimize loss—of food, but also of revenue—within a market-based system controlled by more powerful actors. They are constantly striving to reduce loss levels by improving the quality of what is produced, thus allowing them to sell greater portions of what they grow. Growers would certainly welcome changes down the supply chain that would alter the decision-making scenarios they face when determining what to leave behind. As one lettuce farmer put it, “You may not be talking to the right people. We are just the executors” (Interview 1). Without addressing larger market structures that perpetuate oversupply and cause "imperfects" to be rejected by retailers and consumers, growers may be doing the best they can by absorbing significant levels of loss.

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Interview 22, August 2, 2017

Interview 24, July 8, 2017

Interview 25, August 2, 2017

Interview 26, July 26, 2017

Interview 32, August 17, 2017

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