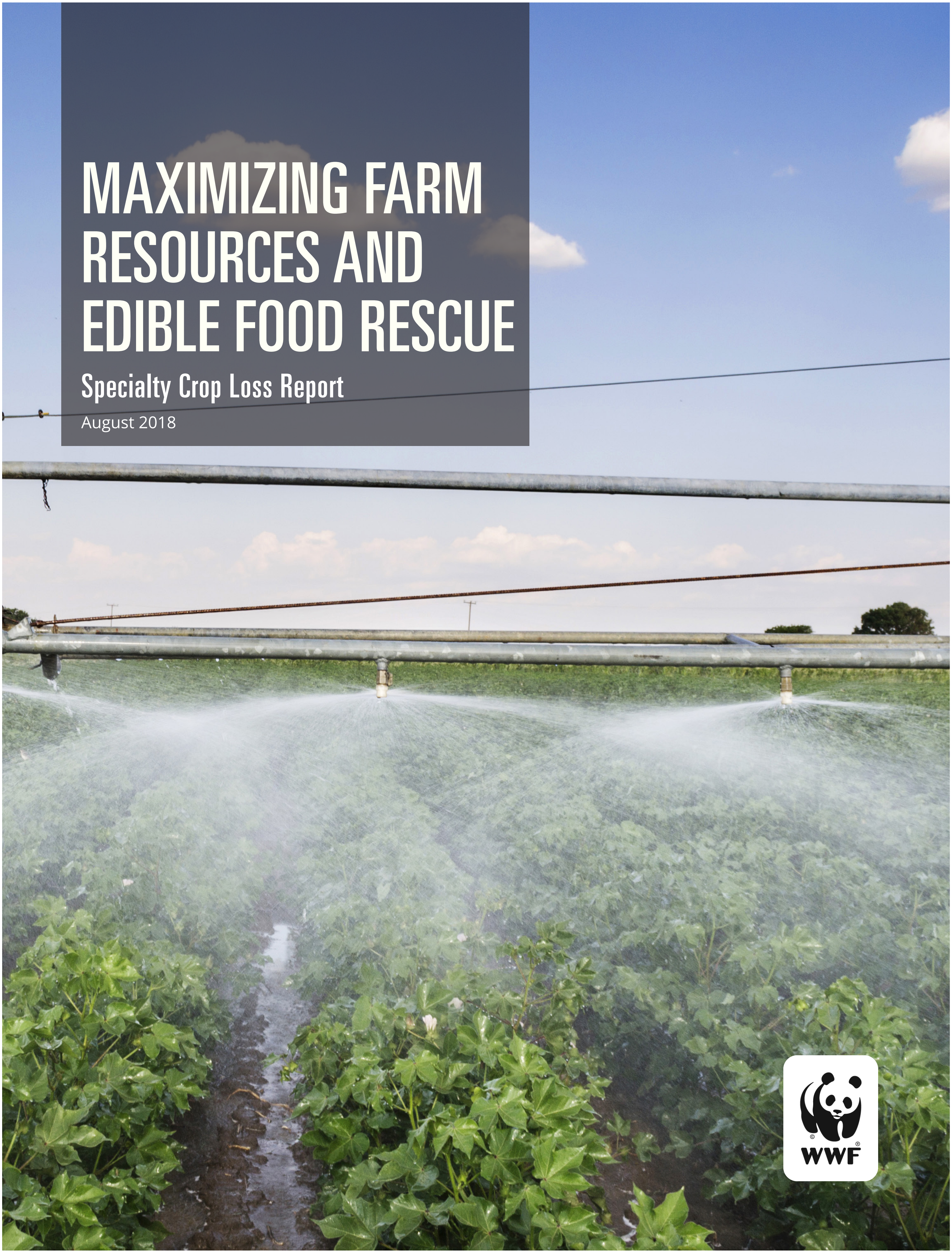
MAXIMIZING FARM RESOURCES AND EDIBLE FOOD RESCUE

Specialty Crop Loss Report

August 2018



ACKNOWLEDGEMENTS

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BACKGROUND

The business of food production globally has the largest environmental impact of any human activity. Food production accounts for 70% of biodiversity loss,[1] 70% of freshwater use,[2] 25-35% of greenhouse gas emissions (GHGs),[3] and 50% of soil erosion.[4] We produce more than enough food to feed all people currently on the planet, but it's estimated we waste one third of all calories produced globally. North America wastes more food than any other region, while in the United States more than 41 million people (including 13 million children) are food insecure.[5,6] In the US, one estimate indicates that 16% of food waste occurs at the farm level, which is about 19 million tons; however, this number is based on limited field studies and estimates vary considerably by region as well as quantification scope and method.[7] Recovering or rescuing safe and wholesome food from farms represents opportunities to support Americans living in food insecure households and create additional revenue streams for farmers and downstream food handlers by sending produce to alternative markets for value-added products. Ironically, farms also represent a point in the supply chain where unavoidable food loss may be most efficient, rather than later in the chain, when additional labor, refrigeration and transportation inputs and resources are embedded in wasted food products.

According to ReFED, accepting and integrating the sale of off-grade or imperfect produce—including produce with a short shelf life and produce of different sizes, shapes, and colors—could divert 266,000 tons of waste by 2030, potentially valued at more than $275 million ($1,039 per ton).[8] Utilizing this waste represents potential financial opportunity for stakeholders in the agricultural supply chain, but redirecting this off-grade produce to new markets has its own challenges. There are many factors that make it uneconomical for growers to harvest all that they produce, including low market prices, high labor costs, and strict cosmetic standards that result in insufficient demand for imperfect produce (e.g. oversized zucchinis or bent carrots). During pre-production it is common for growers to overplant to ensure contract fulfillment for buyers. Once a contract is filled, the rest of the crop is left in the field which is often referred to as a "walk-by" field. Despite gleaning and farm-to-food-bank efforts to recover this unharvested food, a significant portion of edible food is often left in the fields to be tilled under. Several studies show that changing produce specifications to expand the sale of imperfect farm products could lead to the use of an estimated 10 million tons of crops that would otherwise result in loss at the farm level.[8]

In addition to the financial benefits of rescuing food, there are also potential environmental benefits to diverting food from landfills, if that is where it is ultimately going at the end of its life-cycle. For multiple spots along the supply chain including at a consumer's home, this can be a significant greenhouse gas (GHG) savings. However, at the farm, food loss rarely is sent to landfill and ends up in alternative surplus streams such as animal feed, biogas generation, composted as a soil amendment, or tilled under. Prioritizing the range of solutions is part of the challenge.

Although it represents a significant economic and environmental issue, farm level food loss and under-utilization of specialty and commodity crop production in the U.S. is not well understood and is largely unmeasured. Given the data gap and lack of information, measuring and understanding farm-level losses is a first step towards taking corrective actions to recover and fully utilize what could be eaten by people. For the purpose of this report, food loss includes the entire crop destined for market, which by its very nature includes the part intended for people to eat (i.e. food) along with what's often referred to as inedible parts (e.g. pits/stones, stems).[9]

1 Secretariat of the Convention on Biological Diversity (2014) Global Biodiversity Outlook 4. Montréal, 155 pages.
2 FAO (2016). AQUASTAT Main Database - Food and Agriculture Organization of the United Nations (FAO). Accessed on 03/21/2018.
3 Tubiello, F. N. et al (2014). Agriculture, Forestry and Other Land Use Emissions by Sources and Removals by Sinks. Food and Agriculture Organization of the United Nations. Rome, Italy.
4 Yadav, S.K. and S. Kumar (2007). Soil Ecology. APH Publishing Corporation. 194 pp.
5 FAO (2016). FAOSTAT Database. Food and Agriculture Organization of the United Nations (FAO). Accessed at <http://www.fao.org/faostat/en/#data/EL>.
6 https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics.aspx
7 Xue, L., Liu, G., Parfitt, J., Liu, X., Van Herpen, E., Stenmarck, Å., ... & Cheng, S. (2017). Missing food, missing data? A critical review of global food losses and food waste data. Environmental Science & Technology, 51(12), 6618-6633.
8 http://www.refed.com/analysis?sort=economic-value-per-ton
9 For definitions of "food" and "inedible parts" see the Food Loss and Waste Accounting and Reporting Standard at www.flwprotocol.org

INTRODUCTION

World Wildlife Fund's (WWF) mission is to conserve nature and reduce the most pressing threats to the diversity of life on Earth - and to build a future in which humans live in harmony with nature. Given the environmental impacts of food production, reducing food loss and waste[10] is a critical strategy to fulfill this mission. We need to freeze the footprint of food and improve the resource use efficiency of our global food system. Currently, commodity crops make up most of the land under production in the US, with 215,754,000 acres under cultivation for crops such as corn, wheat, and soy. In contrast, specialty crops (i.e., vegetables, fruits, and tree nuts), which are the focus of this study, make up approximately 7,078,160 acres.[11] As we contemplate the impact that reducing specialty crop losses can have on preserving wildlife habitat, it is important to both understand how the current specialty crop footprint compares to commodity crops and how a move towards more sustainable diets will shift these dynamics.

In October 2016, WWF, the Global Cold Chain Alliance (GCCA), and the University of California at Davis (UC-Davis) initiated a multi-year study to measure underutilization of four specialty crops: fresh and processing tomatoes[12], fresh and processing peaches, processing potatoes, and leafy greens. These four crops were selected based on their land impact, distinctive growing and harvest characteristics, and consumer popularity and demand within the US food system. Additionally, the findings of a separate study started by Santa Clara University (SCU) that analyzed 10 specialty crops in California in 2016 are also included in this report. WWF is supporting additional field studies conducted by Santa Clara University in 2018. All three research teams gathered both quantitative and qualitative data on the amount of loss occurring and reasons for that loss. UC-Davis used a qualitative approach to collect data and primarily met with growers and farm managers in California. GCCA used a methodology that produced both quantitative and qualitative results and met with growers in New Jersey, Florida, Idaho and Arizona.

This project set out to further inform baseline measurements for specialty crop loss by measuring and reporting in-field data using the Food Loss and Waste (FLW) Accounting and Reporting Standard (Appendix 1).[13] Additional objectives for the project included:

- understanding current information flow challenges within our food production systems from farm to retail,
- inventorying solutions for underutilized farm products that have the potential to increase revenue for growers, and
- seeding small scale pilot projects that address some of the causes of loss that emerged.

To ensure multiple perspectives were incorporated into this research and final report, WWF formed an advisory committee comprised of farmers, non-government organizations, the private-sector, academic institutions, as well as technology innovators, to better guide and inform in-field research and strategize future paths including possible solutions to prototype. The advisory committee helped the research teams and WWF make necessary connections to appropriate stakeholders to scale efforts beyond the research stage; reviewed and provided comments on preliminary results from qualitative and quantitative surveys and data; and assisted in the selection of pilot projects.

The findings from this research showcase the uniqueness between qualitative and quantitative data results and the importance of both to tell a more complete story about what is happening with food loss and waste from the field to the farm-gate. Quantitative results show the raw potential for recovery given the unique context and market conditions of the timeframe being measured. *Qualitative* results show the economic losses that farmers are faced with when deciding whether or not to rescue seconds as well as market and labor dynamics, and strict cosmetic and quality standards that make it difficult to harvest everything in-field. The *qualitative* results provide essential insights into what solutions are (and are not) practical.

10 For the purpose of this report we will describe any form of loss to be that of food meant for human consumption. This work builds upon studies including, but not limited to, Beyond Beauty: The Opportunities and Challenges of Cosmetically Imperfect Produce, Food Loss in Vermont, WRAPs studies on food loss and waste within supply chains, and Feedback Global's research and investigations into supply chain loss.
11 https://www.nass.usda.gov/Statistics_by_Subject
12 Botanically a fruit, but declared a vegetable in the Supreme Court case, Nix vs. Hedden
13 Details on the Food Loss and Waste Accounting and Reporting Standard can be found at www.flwprotocol.org

Finally, *life-cycle assessments* (LCAs) of the crops performed by UC-Davis quantify the resources that are lost when a crop does not make it to market, including water use, chemical inputs, GHGs, and energy use.[14]

The following report outlines the research methodologies used to capture both the quantitative and qualitative data followed by a discussion of the results from both research methods including voices from the field and a quantification of the environmental impacts of loss. Finally, initial paths forward and possible solutions to prototype are outlined based on the outputs of a convening WWF co-hosted with SCU on March 2nd, 2018.

14 The scope of the LCA included upstream raw material extraction and processing of farm inputs, transportation of materials from manufacturer to farm, and all inputs (i.e. energy, fuel, water, etc.) required for planting to harvest.

METHODS

The project utilized two different methodologies for in-field data collection, one quantitative and one qualitative. The results from the quantitative method have been summarized using the FLW Standard for final reporting (Appendix 1). This reporting standard was developed by the World Resources Institute (WRI) and six other organizations with support from a multi-stakeholder advisory group with the purpose of summarizing clearly and consistently studies that quantify food and/or associated inedible parts removed from the food supply chain. Data was collected verbally, by way of questionnaires and discussions with farmers, physically by direct measurement in the field at the time of harvest, and indirectly by observing sorting, packaging and handling practices. Life-cycle inventories were also developed to conduct LCAs for peaches, leafy greens, and tomatoes. The following sections outline the methodologies used in the study.

Commodity System Assessment Methodology

The Commodity System Assessment Methodology (CSAM), used by research teams at GCCA, is a step-by-step method for describing and evaluating the planning, production, harvest, postharvest handling, and marketing of agricultural commodities (refer to **Figure 1**).[15] A typical commodity system under CSAM is made up of 27 components that account for the steps associated with the pre-production, production, and post-harvest handling and marketing of a product. For the purpose of WWF's project goals, only the pre-production, production, and post-harvest modules were used to gather data on the four specialty crops of interest. Data collected included farm planning and seed quality (pre-production), pests and cultural practices (production), harvest practices, handling, packing practices, access to cooling and/or storage, and options available for processing or creating value added products (post-harvest). Researchers had to be opportunistic with farm selection relying on local cooperative agriculture extension offices and commodity groups to recruit farmers.

To gather data on crop production that did not make it to the end consumer, the field research teams collected two data forms for every farm, one in the field and one in the packinghouse. The on-farm data collection form consisted of crop logistic questions and specific crop measurements. To measure crop specifics, field teams went into the fields directly after a harvest and randomly sectioned off 3, 10 feet by 10 feet, squares around each plant's base or in the field rows (e.g. around the base of a peach tree or in the middle of a potato field). The 3 randomly selected plots were all selected from the same field. The teams then gathered all the produce remaining post-harvest within the quadrant. This remaining produce was then analyzed and grouped into categories such as mechanical damage, pest damage or decay to determine why the produce was not harvested and to quantify roughly how much was not harvested due to that factor. Pulp temperature, relative humidity, sugar content (brix), and firmness were also measured to provide a more accurate picture of ripeness. To determine total seasonal production of the sampled farms which was used to determine loss rates, one of the following two numbers was used: 1) total production based on state yield averages (this was used for farms that reported yields that seemed higher than normal) or; 2) total production based on reported data from growers. The variance between these two approaches is equal to or less than 10%.

For packinghouse data, loss estimates were provided by managers, with a wide range of estimated sorting losses based on weather, variety and market demands. Sample packinghouses did not have records or measurements for produce that was sorted out and discarded. With standard packaging rates for tomatoes and peaches (25 lb. capacity), losses were calculated per packinghouse per day, and per season (80 days of operation over 6 months for tomatoes; and 85 days over 3 months for peaches). Lastly, farm logistics were also gathered such as farm size, growing season, markets, size and grading criteria. To see the detailed data collection sheets, please view the CSAM worksheets in Appendix 2. The following details the specific methods for each of the four crops studied.

15 The CSAM was initiated by Harvey Neese, Director of the Postharvest Institute for Perishables (PIP) and developed as a joint effort with the Inter-American Institute for Cooperation on Agriculture (IICA; primary author is Jerry LaGra, IICA Rural Development and Marketing Specialist) and the ASEAN Food Handling Bureau. CSAM was initially used in USAID-funded projects in Egypt, Lebanon and Indonesia to gather data on postharvest loss and to document the constraints and opportunities for agriculture development.

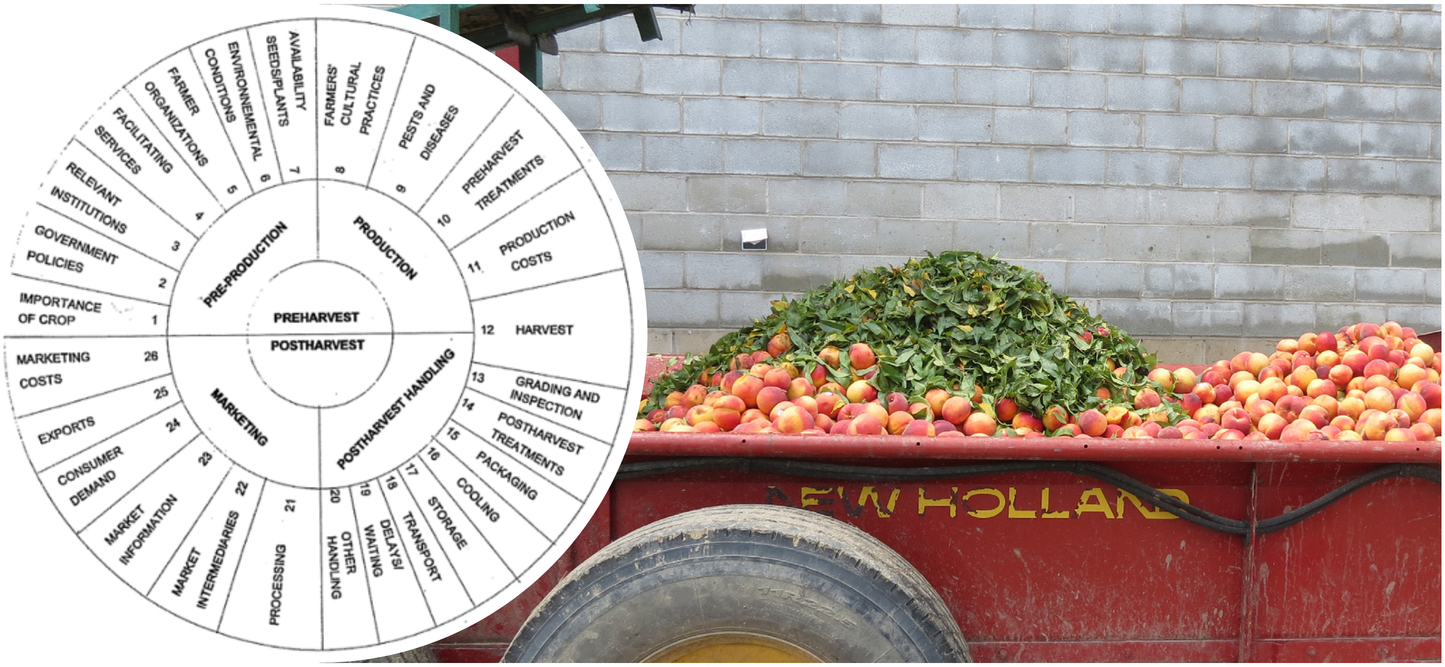


Figure 1 Commodity System Assessment Methodology components for measuring losses during pre-harvest, production, post-harvest and marketing period

Qualitative Data Collection

To complement the quantitative on-farm measurements performed by GCCA, researchers from UC-Davis performed qualitative interviews to collect growers' estimates of the portion of crop left in the field, their assessments of the key drivers of loss, their experiences in diverting "seconds" or "culls" to other markets or recipients, and their opinions of what, if any, interventions could help reduce on-farm loss. Obtaining the growers' perspectives and voice was crucial to telling a more complete story of specialty crop loss in this study. By collecting data with a qualitative methodology, we are able to get a glimpse into decision-making issues that growers face in determining what to leave in the field; the kinds of networks they engage in to distribute crops beyond primary markets; their attitudes toward the idea of capturing "food loss"; and how these attitudes may be grounded in broader world views and value systems.

Similar to the quantitative methodology, researchers began by networking internally, connecting with individuals within the UC Cooperative Extension (UCCE) system. UCCE advisors then connected researchers with other intermediaries—for example, leaders of crop-specific research institutions or grower associations. Phone interviews with intermediaries were conducted to explain the intent of the research and to establish common goals for capturing perspectives of crop-loss issues. UCCE specialists were able to provide critical insight as to what growers would think of researchers coming into the field, which in turn assisted researchers in tailoring and developing their interview questions and data collection techniques, as well as their outreach strategy. UCCE advisors and intermediaries cautioned the research team about using the phrase "food waste" when explaining the project as it would likely be received poorly since growers do not consider product left in-field to be waste as it is incorporated back into the soil and not a result of any poor practices on farm, but rather the result of complicated market dynamics. Preliminary data collection consisted of interviewee/farm/crop background, food loss estimates, factors driving food loss, food recovery and recycling practices, and the key opportunities available moving forward. Please view the full interview protocol in Appendix 3. Lastly, researchers conducted in-depth, semi-structured interviews with growers. These interviews contained questions around the extent of loss in the grower's operation, drivers for loss, and potential opportunities for minimizing loss. The interviews were semi-structured to allow them to have a natural flow and for growers to talk freely and openly. The interview results were fully transcribed and coded using qualitative analysis software to identify key themes and recurring ideas.

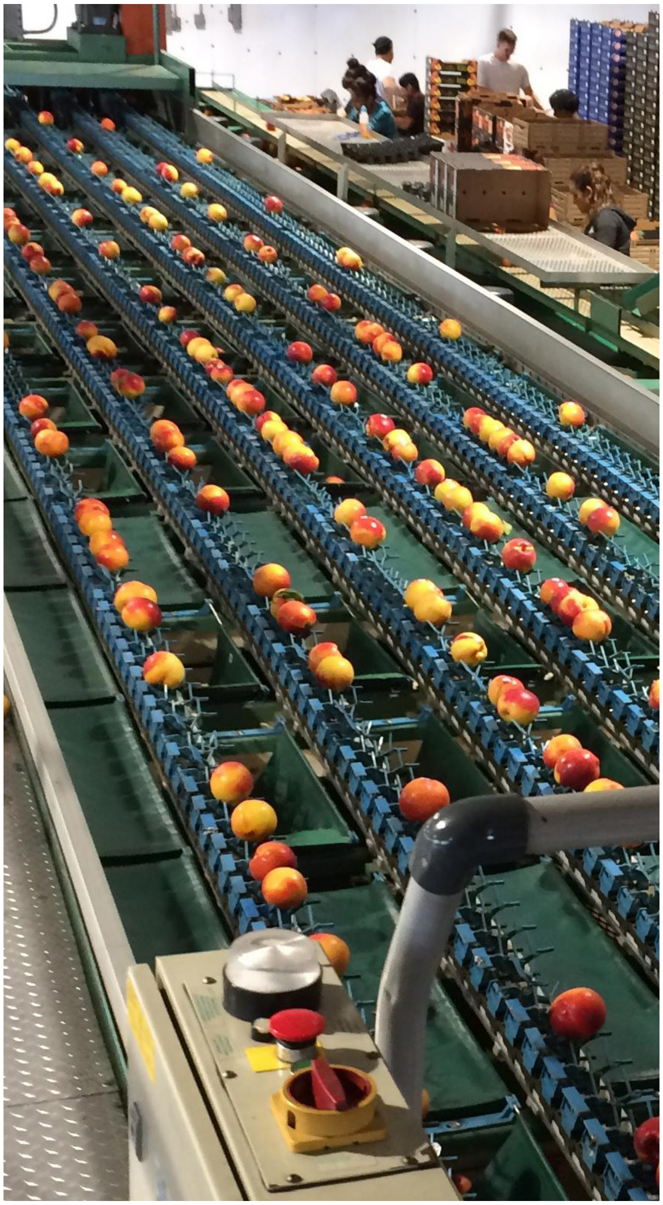
Life-Cycle Assessment

A Life-Cycle Assessment (LCA) is a comprehensive tool used for assessing the total resources used throughout the full life-cycle of a product and their associated environmental impacts. LCA's are a tool commonly used to identify environmental opportunities or "hotspots" along the pre- or post- production chain to mitigate energy consumption, water quality impacts, ecotoxicity, and GHG emissions.[16] Sample outputs of an LCA include estimates for embedded energy, greenhouse gas (GHG) emissions,

16 http://asi.ucdavis.edu/programs/sarep/publications/ag-resources-enviro/life-cycle-assessment-fact-sheet-2015

levels of ecotoxicity, and impacts to water quality for a given product.[17] For the purpose of this work, UC-Davis performed an LCA on each of the following: processing tomatoes, fresh tomatoes, processing peaches, and romaine lettuce. The LCAs' boundaries covered all inputs from field to farm-gate including: water, fertilizers, soil amendments, energy required for irrigation water, and machinery fuel production and combustion, and transport of materials to field. Please refer to Appendix 4 for the detailed system boundaries as required by the LCA guidelines.[18]

To perform the LCA's, preliminary data was collected from the Cost and Return studies conducted by the UC Davis Department of Agriculture and Resource Economics (ARE). These studies describe the material inputs to a production system and associated costs, as well as machinery use, etc. for a range of fruit, vegetable, field, tree and vine crops, as well as animal commodities. Pesticide data is based on the California pesticide use reporting (PUR) data. Diesel consumption for on-farm tractor use is estimated from farm equipment use hours from the costs and return studies combined with tractor engine testing. Crop yield data comes from the USDA National Agricultural Statistics Service data. The IPCC 2006 guidelines are used to estimate direct and indirect emissions associated with N fertilizer application. For all relevant input materials (e.g. raw materials, water, electricity, fuels), the one-way transport distances are estimated from the manufacturer to the nearest distribution point to the field using georeferenced Google map road mile data between manufacturer and consumer (at the field). The primary data is linked with the secondary data, i.e. life-cycle inventories (LCI) or life cycle data, accounting for inputs and the outputs for all materials for the select crops. The LCI helps to develop attributional LCA's to estimate energy use, greenhouse gas emissions, and other environmental impacts associated with the materials input to the system, based on the defined system boundary (Appendix 4). Please see Appendix 5 for detailed life-cycle inventories.



17 http://asi.ucdavis.edu/programs/sarep/publications/ag-resources-enviro/life-cycle-assessment-fact-sheet-2015

18 Organización Internacional de Normalización [ISO] (2006). ISO 14040: Environmental management–life cycle assessment–principles and framework. London: British Standards Institution. Organización Internacional de Normalización [ISO] (2006). ISO 14044: Environmental Management, Life Cycle Assessment, Requirements and Guidelines. London: British Standards Institution.

RESULTS

Quantitative

Tomato

A total of 6 farms were interviewed with 4 farms allowing for in-field measurements in two counties in Florida, Manatee and Hillsborough counties (please refer to sector profiles in Appendix 6 for more details on production models) during the month of May 2017. Interviews were conducted with company owners, growers, packinghouse managers and university professors to get a complete perspective of postharvest practices. Market prices had significantly increased in Manatee and Hillsborough counties the year measurement occurred due to high white fly pressure and low rainfall in southern Florida causing growers to harvest a small, immature green crop. This led to minimal field data collection opportunities due to growers' lack of time, insurance and liability concerns, and food safety standard concerns. The peak in market price was higher than it was in the past five years, $20.00 per 25 pounds, causing growers to work exceedingly longer days with limited time for interviews.

In-Field Losses

Grower Estimated Losses

Across all 6 farms assessed, growers estimated on average 25% was lost in the field with a range of 20% - 60% based on weather, variety and market demands (quality and size standards).

Measured and Calculated Losses

Only four of the six farms allowed for in-field measurement. Based on the 4 harvests and in-field sample measurements of yield per acre, the range of loss is calculated to be between 29% - 72% with an average loss of 40%, which was calculated by dividing the total calculated losses by the total potential production. Measured postharvest loss was much higher than estimated postharvest loss when researchers were able to obtain measurements. Average losses measured during this one harvest were 4,848 pounds per acre, and during four harvests per season totaled 19,392 pounds, which translates to a total loss of 20.9 million pounds of tomatoes across the 6 farms (see **Table 1** for detailed results). Culled fruit in-field were either too small, too ripe for the intended market, or damaged. Based off the standards in the CSAM protocol, 39% of the culls assessed for damage, decay and defects, had no visible quality problems.

Packinghouse Losses

A total of six tomato packinghouses were assessed for losses. The daily packing capacity of these packinghouses ranged from 8,000 – 1.1 million pounds since some were smaller on-farm operations compared to larger operations that may have pulled from multiple farms. Packinghouse managers estimated loss at the packinghouse to be between 2% and 62% with an average of 39%, which equated to a measured loss of 503,900 pounds per day (refer to **Table 2** for more detailed data). Culled fruit was either too ripe, too small, or too large for the market. About 23% of the culls assessed for defects, decay, and damage at the packinghouses had no visible quality problems. Culled fruit in the packinghouse totaled a minimum of 40.2 million pounds, or 14.8%, over the course of the harvest season and was sent for cattle feed processing.

Table 1 Summary of measured and estimated tomato losses in-field (2017)

Farm	Acres	Grower estimated sorting losses (%)	Average measured losses in 3 sample plots (9x10ft) (pounds)	Average measured losses scaled to lbs/acre (pounds)	Calculated total losses/acre at the end of the season (pounds)	Total calculated loss per farm (pounds)	Total potential production (pounds)*	% Measured Loss
1	200	25	6.87	3323	13293	3,878,400	9,546,400	
2	40	25	9.27	4485	17940	775,680	1,909,280	
3	100	25	8.07	3904	15617	1,939,200	4,773,200	
4	40	20	15.87	7679	30717	775,680	1,909,200	
5	300	0				5,877,600	14,319,600	
6	400	38-60				7,756,800	19,092,800	
AVG	180	25%	10	4848	19,392		47,732	
TOTAL	1080					20,900,000	51,550,000	40%

Table 2 Summary of measured and estimated tomato losses at the packinghouse (2017)

Packinghouse	Daily packing capacity (pounds)	Estimated loss per day (%)	Measured average loss per day (pounds)	Calculation of total losses per season (pounds)	Total potential production (pounds)	% Measured Loss
1	12,500	10	1,250	100,000		
2	125,000	62	77,500	6,100,000		
3	1,125,000	2-5, 40-60	56,250	4,500,000		
4	625,000	50	312,500	25,000,000		
5	8,000	30-60	2,400	192,000		
6	300,000	18-50	54,000	4,320,000		
RANGE		2-62				
AVG		39	83,983			
TOTAL			503,900	40,200,000	272,000,000	14.8%

Peach

A total sample of ten farms and ten packinghouses in Cumberland, Salem and Gloucester counties in New Jersey were assessed in August 2017 for peach losses, covering 2,907 acres of production (refer to **Table 3** for detailed data). Interviews were conducted with company owners, growers, packinghouse managers and extension agents to get a complete perspective of postharvest practices. Peaches are harvested by trained crews who pick peaches considered "ripe" for shipment, returning to the same tree 3 – 5 times per season.

In-Field Losses

Grower Estimated Losses

Across the 10 farms assessed, growers estimated on average 16% of peaches are lost in the field with a range of 3% - 60% based on weather, variety and market demands (quality and size standards).

Measured and Calculated Losses

Measurements were taken by sampling losses under three trees per farm and then calculating losses per tree over the season (3-5 harvests) and average losses per acre (150 ft2/tree, 120 trees/acre). Average measured loss was 4,976 pounds per acre, or 37%, due to weather, variety and market demands (quality and size standards). Total loss for the ten measured farms was 14.9 million pounds (see **Table 3** for more details). Peaches were culled in-field because they were either over-ripe or too small. About 30% of culls in-field assessed for defects, damage and decay, had no visible quality problems.

Packinghouse Losses

Total loss for the ten packinghouses was 9.2 million pounds or about 14%. Estimated losses averaged 13% with a range of 2%-33% (see **Table 4** for more details). About 7% of culls in the packinghouse were either over-ripe or too small. Peach culls were often dumped onto unused fields, fields with younger trees, or in the woods near the farm or packinghouse. One large cooperative packinghouse was found to donate 1.5 million pounds of off-grade peaches to local food banks. More information on the peach industry can be found in Appendix 6. WWF field notes from field visits with the research team can be found in Appendix 7.

Table 3 Summary of measured and estimated peach losses in-field (2017)

Farm	Acres	Grower estimated sorting losses (%)	Average measured losses in 3 sample plots (10x10ft) (pounds)	Average measured losses scaled to lbs/acre	Total calculated loss per farm, after 3 harvests (pounds)	Total potential production (pounds)	% Measured Loss
1	72	8	4.8	864	186,624	1,004,112	
2	30	12	11.5	2,070	186,300	418,380	
3	35	20	7.5	1,350	141,750	488,110	
4	30	3	8.9	1,602	144,180	418,380	
5	400	60	12.7	2,286	2,743,200	5,578,400	
6	950	15	10.5	1,890	5,386,500	13,248,700	
7	240	15	9.5	1,710	1,231,200	3,347,040	
8	500	13	6.8	1,224	1,836,000	6,973,000	
9	500	2	7.8	1,404	2,106,000	6,973,000	
10	150	18	12.1	2,178	980,100	2,091,900	
AVG	291	16.6	9.2	1,656	1,494,185		
TOTAL	2907				14,900,000	40,541,022	36.9%

Table 4 Summary of measured and estimated peach losses at the packinghouse (2017)

Packing-house	Estimated daily packing capacity (pounds)	Estimated daily sorting loss (%)	Average measured loss per day (pounds)	Calculated loss per season (pounds)	Total potential production (pounds)	% Measured loss
1	1,100	11	110	9,350		
2	250,000	10	25,000	2,125,000		
3	2,100	3	63	5,335		
4	100,000	10	10,000	850,000		
5	3,100	2	62	52,720		
6	125,000	33	427,250	4,016,250		
7	20,000	2	400	34,000		
8	10,000	10	1,000	85,000		
9	125,000		23,800	1,995,570		
10	2,100	15	315	26,775		
AVG		13%				
TOTAL			108,000	9,200,000	65,000,000	14.2%

Potato

Nine farms ranging in size from 140 to 80,000 acres were assessed in Canyon, Ada, Owyhee, Power, Bingham, and Bonneville counties in Idaho in September of 2017. Potatoes are harvested only once per season since is does not make economic sense to make a second pass through the fields to pick up the smaller potatoes while also compacting the soil. Idaho potatoes are mechanically harvested by large machines that lift the potato plants and shake off the crop (hanging at the roots). Harvest chains are set at 2 inches meaning anything smaller than that, falls between the chains. Processing potatoes are handled after harvest by transloaders that sort the crop again to remove additional debris. More information on the potato industry can be found in Appendix 6.

In-Field Losses

Grower Estimated Losses

Across the 9 farms assessed, researchers were only able to gather 2 estimates for average in-field loss which ranged from less than 5% to as much as 15%.

Measured and Calculated Losses

Similar to grower estimates, in-field measured loss was 2% (refer to **Table 5** for detailed data) for a total of 103 million pounds across the 9 farms. Of the culls assessed for damage, decay, and defects, 80% had no visible, quality issues. Potatoes that were left in the field either fell between harvest chains because they were too small or were left because they had no market value due to mechanical damage or size. Gleaning was reported at fields that were close to city, urban centers. Loss in-field was usually tilled in, while loss in transloaders was dumped onto fields to overwinter, decompose, and then be tilled under.

Transloading Site Loss

A total of four transloaders were assessed. Three of the four transloader operations were estimated by onsite managers, while the fourth, site 2, was measured during active transloader operations for a period of 60 seconds. Culls were estimated between 1.3% and under 5% with the measured value at 1.4% (see **Table 6** for detailed data). Therefore, the lowest possible loss rate was calculated to be 1.4% while the average loss rate utilized the 3% average and was found to be 2.6% when using the higher end production volumes. Growers all over the state reported composting foreign material and plant matter (i.e. unsellable potatoes) coming out of the transloading areas and tilling it back into the fields. Therefore, unsellable potatoes were not viewed as a "loss" to growers, but rather providing nutrients to the soil for the next crop (usually sugar beets). However, potatoes contain about 8% water and only a small amount of nitrogen (2.1% on a dry weight basis) so their value as fertilizer is low. According to Olsen et al (2001)[19], it would require the application of 10 tons of potato culls per acre to supply about $11 worth of nitrogen fertilizer. Stark et al (2004)[20] recommends 200 to 220 lbs. of N fertilizer per acre to produce 400 to 500 CWT of potatoes (at a price of $0.13 per lb., the cost per acre would be $28.60).

19 Olsen, N., Nolte, P., Harding, G. and Ohlensehlen, B. (2001) Cull and waste potato management. University of Idaho, College of Agriculture, Cooperative Extension System CIS Bulletin #814.
20 Stark, J., Westermann, D. and Hopkins, B. (2004) Nutrient Management Guidelines for Russet Burbank Potatoes. University of Idaho, College of Agriculture, Cooperative Extension System CIS Bulletin #840.

Table 5 Summary of measured and estimated processing potato losses in-field (2017)

Farm	Acres	Average measured losses in 3 sample plots (9x10ft) (pounds)	Average measured losses scaled to lbs/acre	Total calculated loss per farm (pounds)	Total potential production (pounds)	% Measured loss
1	650	1.60	790	513,760	33,676,500	
2	240	2.60	1284	308,256	12,434,400	
3	80,000	2.27	1119	89,578,400	4,144,800,000	
4	140	2.53	1251	175,205	7,253,000	
5	6000	1.47	724	4,347,200	310,860,000	
6	350	1.87	922	322,746	18,133,500	
7	500	5.33	2634	1,317,335	25,905,000	
8	3500	3.40	1679	5,878,600	181,335,000	
9	1000	2.80	1383	1,383,200	51,810,000	
AVG		2.65	1310			
TOTAL	92,380			103,824,000	4,786,207,000	2%

Table 6 Summary of measured and estimated processing potato losses at transloading site (2017)

Transloading sites	Daily packing capacity (pounds)	Estimated & measured* loss per day (%)	Calculated loss per day (pounds)	Estimated loss per season (pounds)	Total potential production (pounds)	% Measured Loss
1	7,000,000	< 5%	210,000	6,300,000		
2	1,690,000	1.4%**	23,660	709,800		
3	1,500,000	n/a	45,000	1,350,000		
4	910,000	2.2%	20,000	600,000		
TOTAL	11,100,000		298,660	8,959,800		
PHLs at Lowest %		1.4%		4,700,000	338,000,000	1.4%
PHLs at AVG %		3% *		8,900,000	342,000,000	2.6%

* estimates based on a very small amount of data

Romaine Lettuce

A total of ten farms were assessed in Yuma county, Arizona in January 2018 (refer to **Table 7**).

Since romaine is cut, trimmed and packed in-field as hearts or heads, packinghouses are not part of the supply chain and were not assessed. After being picked and packed, romaine is cooled at nearby vacuum cooling units and shipped to market within just a few hours. Currently, the romaine market is driven by the heads and hearts and the outer leaves function as a protective shield for these marketable parts. More information on the romaine lettuce industry can be found in Appendix 6.

In-Field Losses

Grower Estimated Losses

No estimations were given by growers for the amount of loss that occurs in-field.

Measured and Calculated Losses

Calculated in-field loss for romaine lettuce was an average of 56% (417 million pounds) with a range of 49% to 64%. Reasons for culls included strict market standards and occasional weather events that left leaves with ice damage or sunburn (see **Table 7** for more details). About 69% of culls assessed for defects, damage and decay on-farm, had no visible quality problems. This percentage includes the outer leaves that are left in the field as a result of harvesting hearts and heads. There was a minimum of 292 million pounds of trimmed leaves left behind, out of the 417 million pounds left as culls, which is about 70%.

To recover some of the resources used to produce the 56% of culls left in the field, farmers either allow additional packers into their fields or till the biomass back into the land. Seven of the ten farms allowed bulk packing operations in their fields directly after the harvest, with an estimated recovery range of 2%-10% per farm, totaling 4.5 million pounds of produce (1% of the total wasted).

Table 7 Summary of measured romaine lettuce losses in-field (2018)

Farm	Acres	Average measured losses in 3 sample plots (9x10ft) (pounds)	Average measured losses scaled to lbs/acre	Total calculated loss per farm (pounds)	Total potential production (pounds)	% Measured loss
1	3030	63.9	30,927	93,710,628	190,610,628	
2	115.8	64.3	31,121	3,603,835	7,303,835	
3	270	81.9	39,639	10,702,692	91,302,692	
4	1060	99.4	48,109	50,996,176	84,896,176	
5	800	88	42,592	34,073,600	59,673,600	
6	700	76.7	37,122	25,985,960	48,385,960	
7	1698	80.8	39,107	66,404,026	120,704,026	
8	938	91.6	44,334	41,585,667	71,585,667	
9	800	117	56,628	45,302,400	70,902,400	
10	950	98	47,432	45,060,400	75,460,400	
AVG	1036	86.2	41,701			
TOTAL	10,362			417,425,384	749,025,384	55.7%

Qualitative

A total of 33 growers (9 leafy greens, 7 fresh peaches, 3 processing peaches, 5 fresh tomatoes, 5 processing tomatoes, 3 greens and fresh tomatoes, 1 multi-crop farm), nine grower intermediaries, and 23 UC Cooperative Extension agents were interviewed to gather data on post-harvest losses. Potatoes were not included in the qualitative data collection since they are not grown in California. Of the total interviews, 21 were conducted on-farm (5 leafy greens, 5 fresh peaches, 4 fresh tomatoes, 3 processing tomatoes, 3 greens and fresh tomatoes, 1 multi-crop farm) and the rest over the phone. Only the grower interviews were coded and analyzed for trends and themes.

When growers were asked why loss occurs, they explained that edible food is lost (i.e., either left in the field or culled postharvest) due to a lack of markets that will cover the variable cost of moving it down the supply chain. This was attributed to two main reasons:

1 The produce is imperfect in some way often failing to meet quality standards—these quality standards can vary based on market and crop (e.g., if there is lower supply, retailers will accept minor defects, but when there is plenty of produce they will be pickier) leading to high variability in loss levels among crops, from year to year, and even from field to field.

2 Although the product is perfect, there is insufficient demand for the amount produced—contracts have already been filled, or the market price is below the cost of harvesting. When the price for the crop drops below a certain price, it simply may not be worth it to run a crew through the field to harvest, pack, and cool the product. The job of forecasting the market while mitigating risk is a tricky one, particularly when considering environmental factors such as weather. Adding to this economics challenge is the tight labor supply in California that also leads to a high price for labor.

Table 8 highlights the average estimated losses growers provided during the interview process for all stages of production. Pre-harvest culls were estimated to be a large source of loss for fresh tomatoes, leafy greens, and occasionally processing tomatoes, while post-harvest culls were often unknown. For the purposes of this study, the post-harvest cull and walk-by field numbers are most relevant, but the pre-harvest culls are included in the table below to show their relative size and impact compared to the losses of interest.

In addition to the two main reasons for loss, agreeing on a definition of food and loss also proved challenging. Food and therefore food loss can mean different things to different people along the value chain creating confusion and a lack of understanding for what number the researchers were trying to obtain. The common definition for food included in the FLW Standard is anything "intended for human consumption", and therefore loss is anything that did not make it to humans for consumption, however, this can still mean different things to different people. As demonstrated from the quantitative data, romaine hearts have high levels of loss, mostly in the form of discarded outer leaves from harvesting the hearts. Growers calculate loss based on the number of units harvested rather than total mass, not considering discarded outer leaves as part of the product, and therefore estimate romaine hearts as being a low loss crop.

While loss may be hard to define, there is consensus that some percentage of produce that could still be consumed by humans is often left in the field after harvest or left in a field that was never harvested. Many growers recognize this as a problem and an inefficiency in the system, and some donate excess produce through the food bank system or use volunteer labor to glean the fields. However, food banks also face challenges receiving large donations of fresh product as they often have limited storage capacity and demands that may not directly line up with their supply. Therefore, they would often prefer to receive a combination of fresh and shelf-stable items. Some growers have also investigated alternative markets such as sending seconds to be processed. However, growers reported some programs as being another additional cost or burden that's absorbed into their operations. Some felt that gleaning programs, which take a relatively small amount of the product from the field, were not worth the potential liability or organizing hassle. In the case of fresh peaches, some growers were able to divert their seconds to juicing, drying, or freezing facilities. Growers repeatedly named off the USDA Farm to School Program, established under the Healthy, Hunger-Free Kids Act of 2010, which supported frozen peaches for school lunches as being very effective and beneficial to both supplier and consumer. Unfortunately, programs like these have been discontinued and several are also at risk of being discontinued in the next Farm Bill. For more excerpts from the qualitative interviews, see Appendix 8.

Table 8 Range losses estimated for fresh and processed tomatoes, fresh and processed peaches, and leafy greens based on grower interviews

	Walk-by Fields	Pre-Harvest Culls	Post-Harvest Culls
Fresh Tomatoes	Rare	15% - 40%	2%
Processing Tomatoes	Anecdotal responses; e.g. lost 2,000 tons one year	2% - 6%; 20% in case of "split set" (uneven ripening)	Occurs at processing plant
Leafy Greens	5-15%	0-25%, dependent on variety and quality of field	Minimal and infrequent
Fresh Peaches	Did not offer averages	2-3%	10-50%
Processing Peaches	Did not offer averages	2-5%	Occurs at processing plant

Life Cycle Assessment

The following list details the main data included in each LCA and the primary data source. These data pieces detail the Life-Cycle Inventory (LCI) and are required to determine the environmental impact categories that will be included in the LCA.

- Fertilizer use data – based on estimated application rates from UC Davis cost and return studies;
- Pesticide data – based on the California pesticide use reporting (PUR) data and sometimes compared with grower application rates when reported;
- Diesel usage for on-farm tractor use - farm equipment-use hours from the cost and return studies;
- Crop yield data - United States Department for Agriculture (USDA) National Agriculture Statistics Survey (NASS); and
- One-way transport distances - estimated from the manufacturer to the nearest distribution point to field using Google map road mile data.

UC-Davis performed life cycle assessments of four crops, processing tomatoes, fresh tomatoes, romaine lettuce, and processing peaches, to understand the resource use implications for the quantified and estimated losses on-farm. UC-Davis used the Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI) methodology to perform the impact analyses on each crop, which included GHG emissions, primary energy use, water use, ecotoxicity, acidification, and eutrophication to name a few. The full impact assessment results will be published in a journal by the end of 2018. Overall, results showed that the environmental burdens associated with processed peach production were higher than the annual crops assessed. Installation of irrigation systems, pesticides, and biomass combustion as an energy feedstock as well as in-field burning, contribute significantly to impact categories such as ozone depletion, human toxicity, particulate matter in the air, and eutrophication of water bodies. The detailed results for each crop are included in the sections below. The full LCA results and tables will be published in the coming year in a peer reviewed journal.

Processing Tomato

Overall, on-farm fuel (diesel) use, irrigation water (diesel), and irrigation water (electricity) are the top contributors to the impacts associated with processing tomato production. Diesel production and combustion contribute to carbon dioxide (CO2) and methane (CH4) emissions and hence GWP100 impacts by 26% and to 23% for tractor and irrigation, respectively. Crude oil, hard coal, and natural gas inputs are the main contributors to on-farm fuel (diesel) production (37%) and irrigation water (diesel) (32%), leading to the total primary energy impacts. Direct water (79%) and irrigation water (electricity) (19%) are the main contributors to freshwater use. The main contributors to the TRACI impacts are on-farm fuel (diesel) use (26-50%) and irrigation diesel (23-45%). Nitrogen and carbon monoxides emitted from diesel production and combustion are the top contributors to TRACI impact categories like smog air.

Fresh Tomato

Like processing tomatoes, on-farm fuel (diesel) use, irrigation water (diesel), and irrigation water (electricity) are the main contributors to the impacts associated with fresh tomato production. Compared to processing tomatoes, fresh tomatoes have slightly higher GWP impacts from on-farm fuel (diesel) (28%) and irrigation water (diesel) (25%) use due to lower fresh tomato yields. In other words, if the inputs (e.g., gallons of diesel) to the production system are the same, a lower yielding crop like fresh tomato will appear to have higher impacts compared to a higher yielding crop like processing tomato for the same amount of input to the production system, because the total yield (or kg of product, i.e. the functional unit) is divided by the inputs to the production system.

Direct water (82%) and irrigation water (electricity) (17%) are the main contributors to freshwater use. The main contributors to the TRACI impacts are on-farm fuel (diesel) use (22-50%) and irrigation water (diesel) (19-44%).

Romaine Lettuce

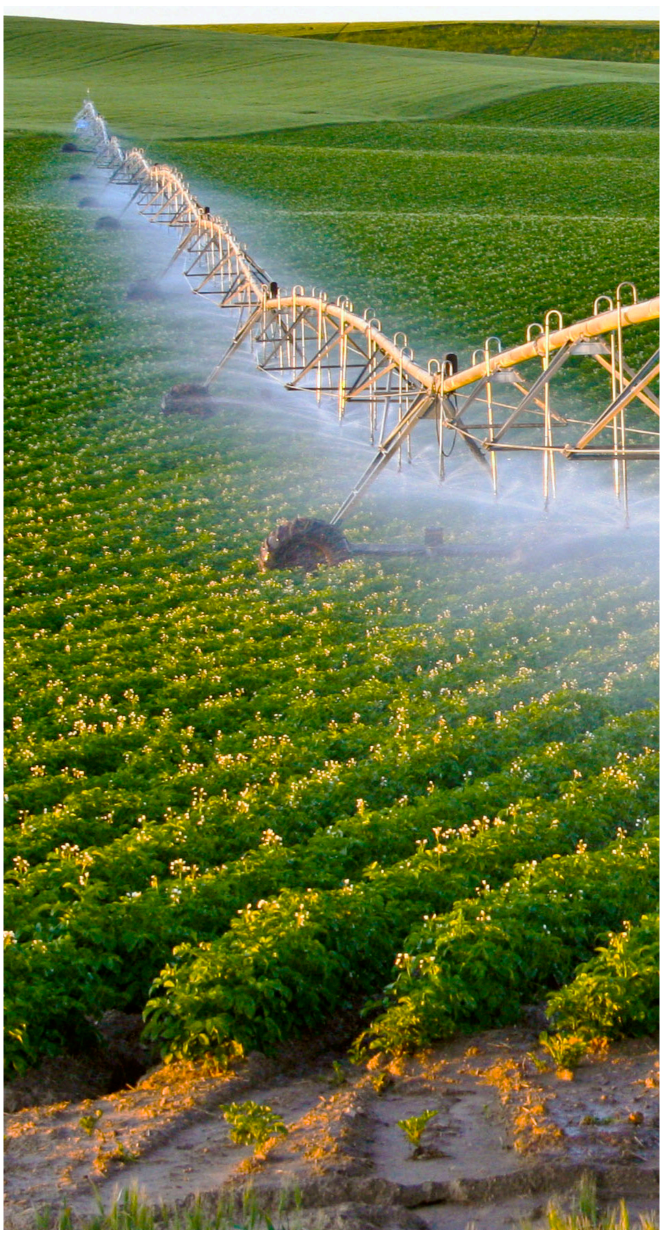
Overall, on-farm fuel (diesel) use, irrigation water (diesel), and irrigation water (electricity) are the main contributors to the impacts associated with romaine lettuce production. On-farm (diesel) fuel use and in field N2O emissions contribute to 65% and 17% of the total GWP. As mentioned above, CO2 and CH4 emissions from on-farm fuel (diesel) use are the primary contributors to the GWP impacts. The N2O emissions from nitrogen fertilizer appear to be higher for romaine lettuce compared to processing and fresh tomato on a per kg of material input to kg of cultivated product basis. However, the actual, total N2O emissions are higher for processing tomato (2.76 lbs/ac) compared to romaine lettuce (2.15 lbs/ac), yet the romaine lettuce yields are lower than the processing tomato yields and therefore on a per kg of cultivated product basis the impacts from N2O appear to be higher for romaine lettuce.

On-farm fuel (diesel) use (81%) and irrigation water (diesel) (8%) are the primary contributors to total primary energy impacts. The main impact to freshwater use is direct water (87%) and electricity use for irrigation (10%). The main contributors to the TRACI impacts are on-farm fuel (diesel) use (22-50%) and irrigation water (diesel) (19-44%).

Processing Peach

As with the annual crops assessed in this study, on-farm fuel (diesel) use, irrigation water (diesel), and irrigation water (electricity) are the main contributors to the impacts associated with processing peach production, with the addition of irrigation system installation and biomass combustion (as energy feedstock as well as in-field burning). On-farm fuel use and irrigation pumping (diesel and electricity) contribute some 12% and 67% of the total GWP, respectively, whereas biomass combustion and irrigation system component production respectively contribute 6% and 3% of GWP. N2O emissions from nitrogen fertilizer are lower than those of the annual crops assessed (0.85 lbs/ac annual mean and 0.00003 kg N2O/kg yield). Soil N2O emission contributes about 2.7% of total GWP in peach production.

On-farm fuel use (19%) and irrigation water pumping (78%) are the main contributors to total primary energy use. Freshwater consumption is dominated by direct water application for irrigation (99%). On-farm fuel use is a significant contributor to TRACI impacts, at 34% of acidification, 20% of ecotoxicity, 19% of eutrophication, 69% of non-cancer human toxicity, 18% of fossil fuel use, and 53% of smog formation potential. Credits for avoided fossil fuel use from biomass energy generation offset some 11% of total GWP impacts of peach production.



Results Summary

The results of the field studies and qualitative interviews highlight potential opportunities for improving utilization that could lead to economic benefits for growers, buyers, and consumers while also minimizing the environmental impacts of fresh fruit and vegetable production per unit, but further research is still needed to explore specific opportunities. Moreover, every food crop is different, and therefore opportunities will need to be highly tailored to the planting schedules, growing regions, harvest methods, and overall demand patterns. For example, loss reduction solutions for highly perishable foods like leafy greens and peaches may require more regional production or value-added processing to avoid longer journeys. On the other hand, a hardier and more efficient crop in terms of loss rates, like potatoes, may need to focus on genetics that can make those 1-2% of potatoes left in-field larger and therefore more economically worthwhile to harvest. Field studies on all perishable products share similar themes for why the crop is rejected or culled out. These similarities include:

¤ Decay: if product is too ripe when it begins the journey there is a risk that retailers may reject it when it reaches their distribution center.

¤ Damage: from pest issues, unpredictable weather events, and over-ripeness. Markets do not accept produce that cannot handle long transportation hauls or have cosmetic defects.

¤ Size: fruits and vegetables that are too small, too large, or misshapen, may not meet retailer standards or quality grades for sale to consumers as intact, whole fruits and vegetables.

Table 9 summarizes the extent of the loss due to the afore-mentioned loss reasons across the four crops studied. Crop loss was highest in romaine lettuce (research included both hearts and heads) due to culling of outer leaves, while the potato production system was found to be extremely efficient in planting and harvesting practices. Fresh tomatoes and peaches have strict cosmetic standards to ensure they can survive the long transportation distances and meet the end consumers' cosmetic standards. All crops investigated for this study except romaine lettuce, were transferred from farm to packinghouse for sorting and packaging, where additional culling occurred with tomatoes and peaches experiencing about the same cull rates (~14%). There was no loss associated with the transport between field and packinghouse except for potatoes. Potato losses occurred in-field, during the transloader process, and in transport to storage sheds. The vast majority of the culls from the four crops were tilled back into the field, left to decompose, or dumped onto other fields with little to no food loss sent to landfill. The methane effects of large scale dumping into single areas is unknown and was not measured as part of this study. These results have also been summarized in Appendix 1 using the FLW Standard reporting framework.

Table 9 Summary of losses in-field and at the packinghouse

Crop and Expected Yield/ Acre[1]	Grower estimated in-field loss ranges (%)	In-field measured loss (%)	Manager estimated packing-house loss ranges (%)	Packinghouse measured loss (%)
Fresh market tomatoes in FL. **28,000 lbs./acre**	2-60% Average 25%	40.6%	2-62% Average 39%	14.8%
Fresh market peaches in NJ. **8,500 lbs./acre**	3-60% Average 16.6%	36.9%	2-33% Average 13%	14.2%
Processing potatoes in ID. 50,500 lbs./acre	1-15% Average 2.6%	2.5%	1.4-5% Average 3%	1.4-2.6%
Romaine lettuce in AZ. **32,000 lbs./acre**	No estimates made by growers	56%	No packinghouse operations	

[1] National Agricultural Statistical Service data (2015-2016)

Food recovery or donation was not a regular procedure implemented by any of the farms studied but did happen occasionally when conditions were right. All growers discussed the logistical and economic issues with having food rescue organizations and gleaners come on-farm. The Food Safety Modernization Act (FSMA) severely limits the ability of allowing gleaning to occur in fields, particularly by persons not trained in food safety.[21] Many growers view the presence of gleaners as another economic loss and a litigation concern. Food rescue organizations and gleaners may unknowingly disturb operations, costing the growers time that they do not have. Yet growers did not hesitate to offer advice on how to improve existing recovery systems, in some cases referencing effective programs that have since been discontinued (e.g. a USDA program that subsidized frozen peaches for school lunches). Growers agreed that the key to improving recovery options is to develop secondary markets, or raise awareness of them to growers, and to cover variable costs and improve logistics for donation.

Uncommon to previous LCA work, the LCAs for the four crops begin to show the resource use implications when loss in factored in to the impact analysis. For example, if losses are included in the estimated water consumed (direct water use in field), the amount of water consumed by a fresh tomato increases by more than a quarter, due to quantity of yield of fresh tomatoes produced per unit of water and estimated loss (28%) (**Figure 2**). This same trend can be seen across all indicators including primary energy use (**Figure 3**) and GHG emissions (**Figure 4**) per unit of tomatoes produced.

To further put the impact of these losses into perspective, the estimated loss of each crop was extrapolated across the California production landscape (i.e., the losses found during the study were applied to the total amount of a crop produced in the state using a 5-year average yield). The amount of estimated water loss that occurs from producing fresh tomatoes that never make it off the farm and thus are considered food loss is equal to the estimated amount of water used by 38,000 households per year in California. The total primary energy that is lost from processing tomatoes that never make it off the farm is equivalent to the annual emissions from approximately 7,000 cars in California. The amount of CO2 emitted from the production of romaine lettuce that never makes it off farm is equivalent to the annual emissions of 1,647 vehicles. As the larger research and environmental community considers how to address this issue, it is important to always put the problem into context to help prioritize future actions.

Yet, while this may imply that resource use will be more efficient if food does not become loss in field, there is potential for these losses to transfer further along the supply chain, accumulating more resource use the further the product goes. This demonstrates that the best place for loss may be in the field.

21 https://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm334114.htm

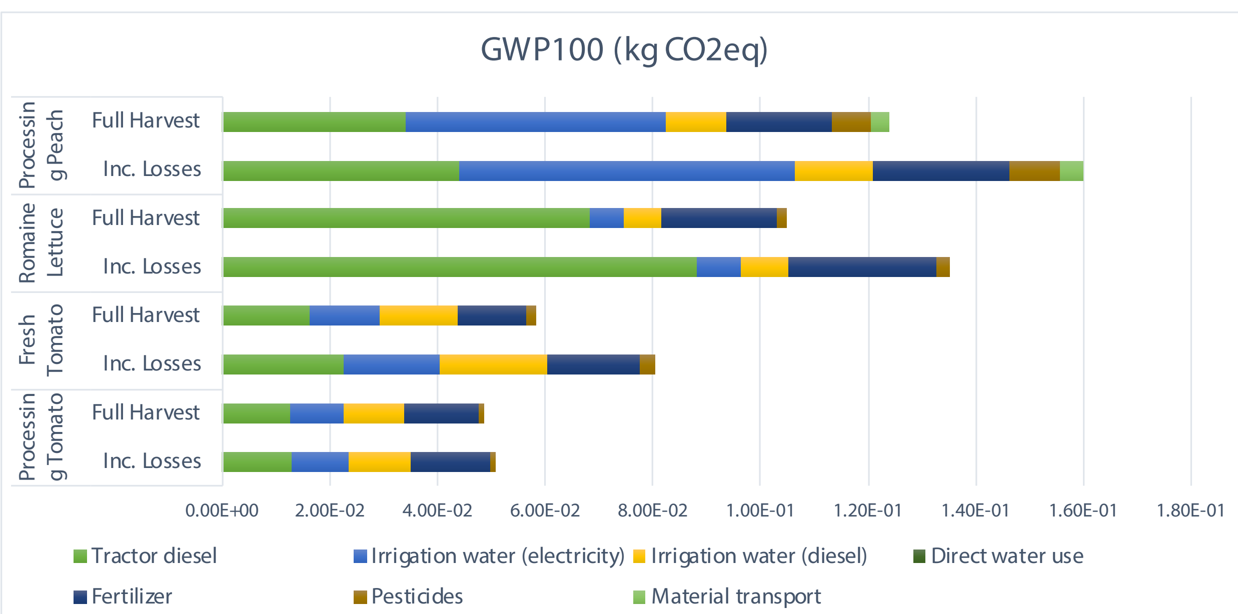


Figure 2 Life-cycle total freshwater use (in gallons (gal)) impacts for full harvest (assuming 100% of the product consumed) and including losses. Freshwater use includes all water used (e.g., including in turbines for electricity generation, a percentage of which returns to the watershed and is not consumed). Direct water use is the irrigation water applied per crop.

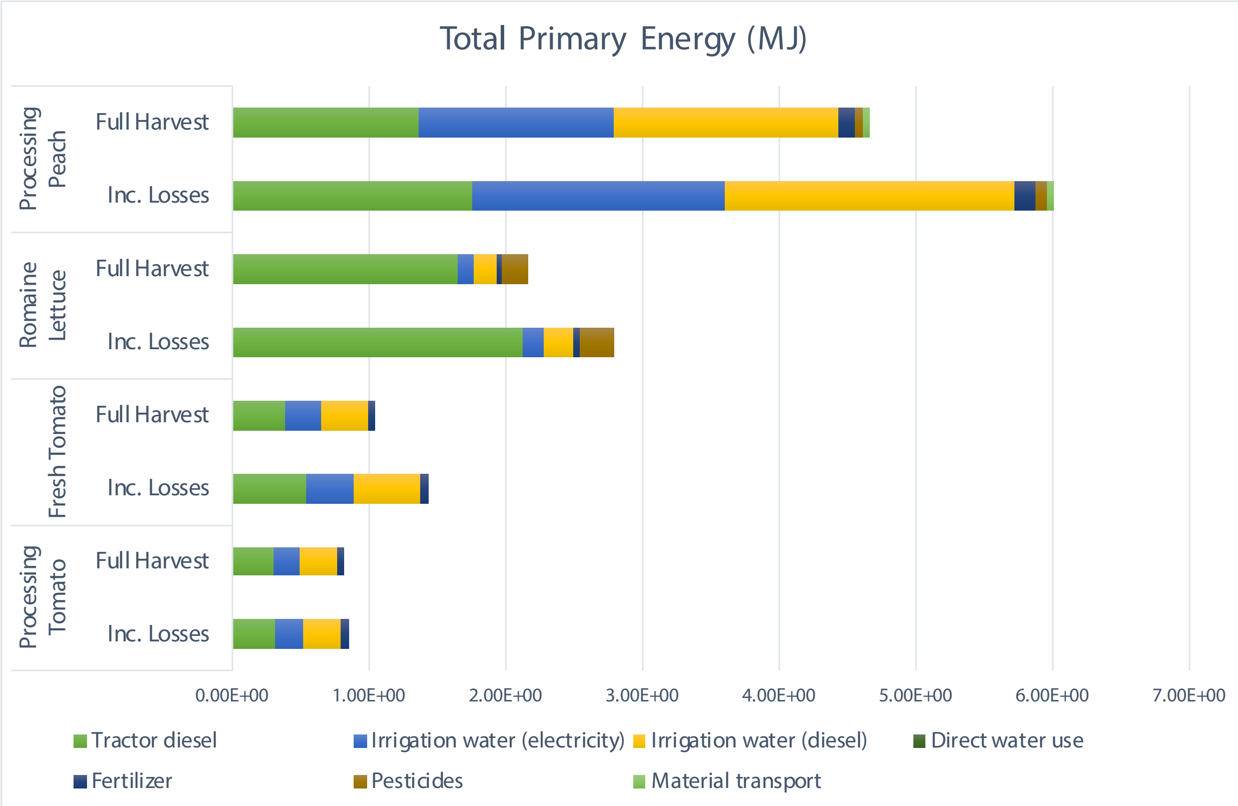


Figure 3 Life-cycle total primary energy use (in megajoules (MJ)) impacts for full harvest (assuming 100% of the product consumed) and including losses.

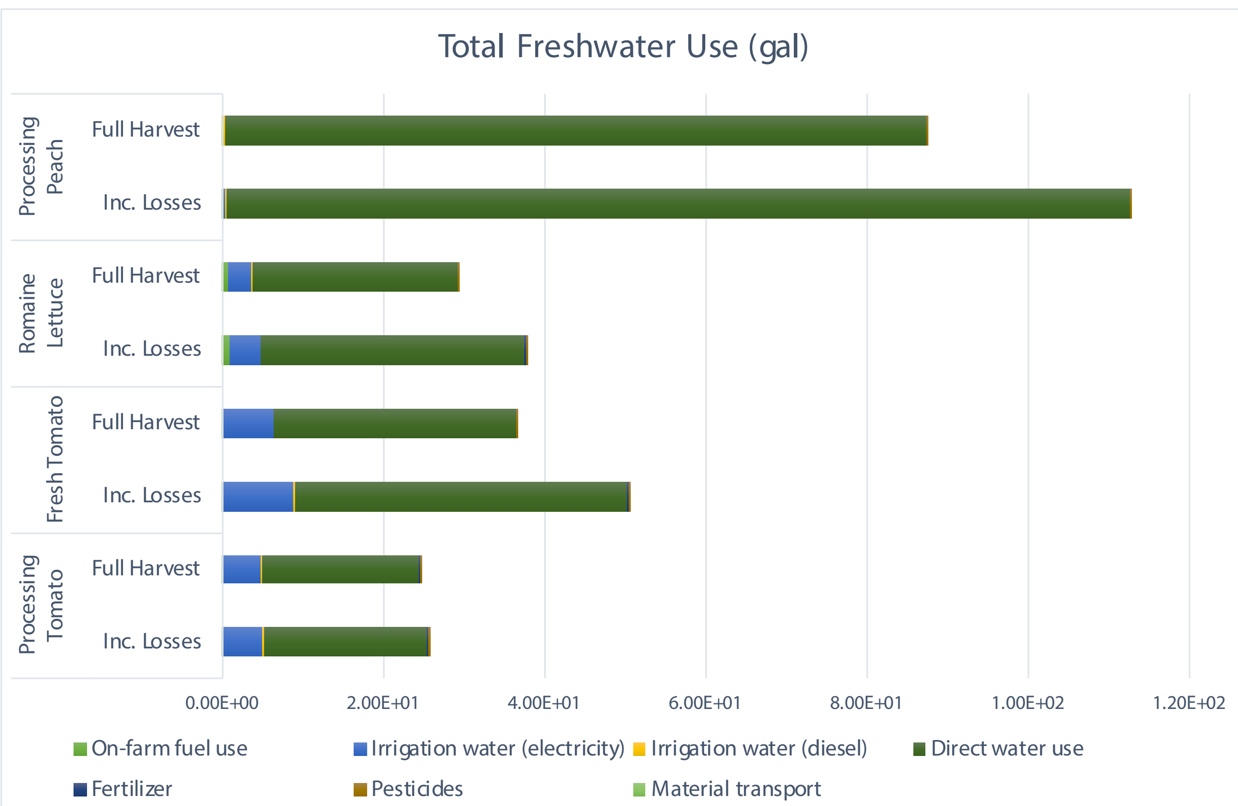


Figure 4 Life-cycle total global warming potential (in kg CO_2eq) impacts for full harvest (assuming 100% of the product consumed) and including losses.

DISCUSSION

The current, fresh produce production system in the United States has evolved to deliver cosmetically perfect and high-quality products to retailers, buyers and food service outlets at ideal ripeness, in some instances requiring food to travel hundreds, even thousands of miles with minimal damage. Currently this system is not fully utilizing the total production of many crops, which suggests the inefficient use of the precious resources that went into their making. Players along the supply chain do not consider the product sold to product grown ratio (market potential) to be a metric for success since operations are often still profitable and economically sustainable with upwards of 25% loss or underutilization. As one tomato grower stated, "When people say that food is being wasted [on the farm], 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." While this may be true, additional research is recommended to investigate higher soil nutrient return rates, comparing tillage of crop residues back into the soil to using the residue for composting and then returning the compost to the soil.

Comparing the fresh produce studies, to the processing potatoes highlights key differences between the production models that could help inform improved production systems for fresh produce. Processing crops were found to be more efficient, from their grower-buyer practices upstream to the sorting and processing facilities. It is imperative to explore the models used for processing crops and their applicability to the fresh market. This also provides a case for exploring an increased production of frozen and processed produce items to limit loss and maximize efficiency.

The results from the field studies illustrate an immense opportunity for full-product utilization that could improve economic conditions for both growers and buyers while minimizing the effects that expansive agriculture and fresh water withdrawal are having on our world's natural resources. Since food recovery, oftentimes, is highly dependent on the local costs (labor, transport costs, processing, packing, marketing) and economic benefits, there is a need to think deeper about the contracts dictating the buyer, grower relationship, as well as more broadly about opportunities across the supply chain. This study illustrates the need to create a food loss portfolio for all specialty crops, considering the large range in loss quantities across crops.

Below is a list of possible future outcomes from this work, associated pathways and next steps needed along the agricultural value chain to improve product utilization from farm to folk in an effort to decrease loss rates and increase growers' profits. This list was generated from a collaborative convening held March 2nd, 2018 in Santa Clara, California, that included produce supply chain actors, food rescue organizations, growers, technology industry representatives and nonprofit actors. For additional information on how some of these next steps directly address the reasons for loss found during our research and current efforts underway to pilot test these solutions see **Table 10** and for more detail see Appendix 9.

Table 10 Solutions based on reasons for loss

Reasons for Loss	Possible Solutions	Solutions in Prototype
Does not meet quality or retail standards	¤ Omnichannel (e.g., retail, food service, value-added processing, donation, secondary surplus markets) solutions to deal w/varying ripeness and size issues ¤ Behavior change: consumer awareness/ campaign for "bronzed" items ¤ Retail merchandising prototypes ¤ New products, i.e. canned soup for romaine leaves	¤ ***Imperfect Can Work Perfectly:*** Several companies in the US are capturing food that is out of grade and rejected at the farm or distribution center by buyers and selling the product at lower prices to food service operators who do not need perfect produce. Food banks are also acting as secondary beneficiaries in this process, when the out of grade produce cannot be sold but can be donated safely.
Too ripe	¤ Send to local food banks ¤ Send to regional retail outlets ¤ Diverting to the frozen, value-added, or canned supply chain	¤ ***Extending Shelf-Life:*** Innovative companies are developing food-grade coatings, to cover produce items, locking water in and oxygen out, slowing the ripening cycle and doubling the lifespan of fruits and vegetables without refrigeration or a controlled atmosphere.
Labor shortages and cost of labor leading to unharvested fields	¤ Mechanization ¤ Increase availability of reliable labor force to harvest fruits and vegetables	¤ ***Supplemental Labor:*** Innovative companies are working on both technology and improved business models to address this challenge. Tech companies are developing highly efficient mechanical harvesters to enhance the labor force and start-ups are prototyping improved business models that professionalize in-field food rescue currently done by volunteers.
Market dynamics & the Grower/ Buyer relationship	¤ Cooperative competition to improve supply/demand dynamics that reduce prices ¤ Financially viable alternative markets including value-added processing & food banks ¤ Whole field/farm purchasing ¤ Using stranded assets to grow greens closer to population centers ¤ Genetic enhancements to improve edibility of outer leaves	¤ ***Optimizing Food Recovery:*** Many companies, and even food banks are developing technologies to improve gleaning, delivery efficiency, and payments to farmers ¤ ***Improving Transparency:*** Many innovators are developing online platforms to market & distribute excess produce, increasing transparency of what is available and allowing markets to react

FUTURE 1

Food Full-Cost Accounting

Imagine a future in which food is priced to incorporate all externalities, full costs of production, and is subsidized based on health benefits.

Pathways & Actions

PATHWAY 1

All inputs, including the true cost of water, a living wage for farm workers, ecosystem service benefits provided by natural habitats on farm land, proper land stewardship, and environmental degradation caused by food production (i.e., soil erosion) are built into the price of our food using the principles of full cost accounting.

ACTION 1 **Develop methodologies that put a price on ecosystem service benefits, similar to a carbon credit, giving grocers and retailers the opportunity to purchase low ecosystem impact products with associated credits, potentially offering them a tax incentive for those purchases.**

ACTION 2 **Standardize farm reporting of full-utilization percentages and encourage growers to make under-utilized produce more visible. Measurement and transparency can support the shift to full product utilization.**

PATHWAY 2

Reduce input costs and contain the potential increase in prices caused by full cost accounting by having legislation around mandated landfill bans, wide-scale composting and a system to streamline the use of the resulting compost on regional farm land to replace synthetic fertilizer use.

ACTION 1 **Develop sample legislation that could be used at a state or municipal level to legislate landfill bans for organics and then actively work with those states to pass the legislation.**

ACTION 2 **Develop tax incentives or other mechanisms to encourage use of compost over fertilizer to develop a demand market for large composting facilities needed under new legislation.**

FUTURE 2

Healthy Food for All

Imagine a future in which consumers are changing demand by eating their daily recommended servings of fruits and vegetables based on health professional recommendations, and access to this produce is ubiquitous, improving the overall population's health

Pathways & Actions

PATHWAY 1

Fruits and veggies are more affordable than processed foods, thanks to programs that allocate funds to specialty crops based on the My Plate requirements, while low-nutritional items are no longer subsidized or prioritized.

ACTION 1 **Work to understand the required process for lobbying for this change.**

ACTION 2 **Develop a training specifically for logistics companies and supply chain actors on how to adopt the Sustainable Development Goals made by the United Nations and the GSM Association.**

PATHWAY 2

Government has created one form of alternative markets to purchase excess produce and distribute to those in need and in food deserts.

ACTION 1 **USDA uses SNAP funding to purchase surpluses.**

ACTION 2 **SNAP funding and other government and organizational funding exists for food delivery and access in food deserts.**

PATHWAY 3

The public is well educated on their nutritional needs.

ACTION 1 **Work with celebrities who are already in the nutrition space to tie their websites and blogs to agriculture and the issue of loss.**

ACTION 2 **Work with health coaches in food banks.**

ACTION 3 **Change perceptions of fresh and frozen and encourage more consumption of frozen and value-add processed produce.**

FUTURE 3

Supporting growers large and small and scaling urban agriculture where appropriate

Imagine a future in which the large-scale industrial agriculture system co-exists with regional food systems, reshaping the way cities and regions are supplied with fresh fruits and vegetables.

Pathways & Actions

PATHWAY 1

Small to medium sized regional farms produce the lion's share of specialty crops during optimal growing seasons and are fully integrated with supply chains to feed regional markets.

ACTION 1 **Pilot fruit and vegetable subscription services or weekly consumer preferences across retail platforms to provide better data and upfront seasonal forecasting which can be used by buyers to better anticipate demand.**

ACTION 2 **Work with states to encourage regionally-focused sourcing of fruits and vegetables when in season and growing urban agriculture to provide off-season items.**

ACTION 3 **Investigate the opportunity to use stranded assets for more regional food production with vertical and aquaponic farms for items such as greens that have high levels of loss in-field and across the value chain due to their fragility.**

PATHWAY 2

Industrial, large-scale growers meet commodity and unmet regional specialty crop demands to fully utilize all of their resources.

ACTION 1 **Improve grower and buyer communication platforms that enable highly-coordinated supply chains.**

ACTION 2 **Expand marketing campaigns for all produce grades and continue to promote innovations around shelf life extension.**

ACTION 3 **Conduct economic and environmental analyses around concurrent harvesting which allows for off-grade produce to be harvested in tandem with market standard grade crops.**

FUTURE 4

Food Safe and Donation Sound

Imagine a future in which all food donation barriers are eliminated.

Pathways & Actions

PATHWAY 1

All agricultural and supply chain activities are transparent, collaborative, traceable and highly coordinated, allowing for improved decision making, streamlined food safety protocols and efficient donation systems. Brand liability concerns are eliminated.

ACTION 1 **Conduct research and development through public/private partnership funding models at various universities across the country.**

ACTION 2 **Investigate technologies that could contribute to this future such as: embedded granular microbial testing that provides alerts on food packaging and cartons when their presence is detected, allowing contaminated supplies to be removed immediately and chain of custody to be quickly determined.**

PATHWAY 2

Government organizations have provided very specific, clear, and coordinated universal guidance for donation of surplus produce to people or animals, including easy to understand food safety laws.

ACTION 1 **Developing a working group with representation from all necessary agencies – state and federal – to reach consensus on universal food donation standards to minimize confusion and to develop a large education and communication strategy to spread the word.**

Since the development of these actions and next steps, the USDA, Agriculture Marketing Service funded a study, “Relationship between food waste, diet quality, and environmental sustainability”, that focuses on the relationship between food waste, diet quality, nutrient waste and measures of sustainability including: use of cropland, irrigation water, pesticides and fertilizers. The results showed that there was an inverse relationship between a healthy diet and increased levels of food waste meaning that the fresher produce that is consumed, the more waste that accumulates.[22] This study suggests the critical need for continued promotion of both improving diet quality and minimizing food waste. Lower waste rates may also be possible by increasing value added processing and changing perceptions around frozen fruit and vegetable consumption. A current example of the recommendations made in the USDA study include the Save the Food campaign done by the Natural Resources Defense Council (NRDC) and the National Ad Council. Save the Food offers campaign assets that include videos, print materials, and digital media. Their website offers tips on how to decrease food waste at home through cooking and food preparation techniques, and proper storage directions for a large variety of fruits and vegetables as well as meat, poultry, seafood, dairy, eggs, beans, legumes and eggs. Other studies which build upon this work include Beyond Beauty: The Opportunities and Challenges of Cosmetically Imperfect Produce, Food Loss in Vermont, WRAP’s studies on food loss and waste within supply chains, and Feedback Global’s research and investigations into supply chain loss.

22 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0195405

CONCLUSION

In the fresh production system, food loss is a symptom of underlying structural issues in the supply chain that are often caused by lack of information and imbalances in power and cooperation between growers and buyers. Generally, the harvest is planned according to what the market demand is anticipated to be. This makes a harvest hard to fully predict since dynamics outside of a grower's control such as weather, labor, and future demand from retailers can significantly impact that amount that is actually harvested come time for harvest. These factors during the 2017/2018 growing season lead to upwards of 2% - 56% loss for the specialty crops studied. While this may not be considered a significant financial loss to the growers, it represents a significant opportunity to help close the meal gap. In 2017, only 1 in 10 American adults consumed the recommended amount of fruits and vegetables. If more Americans met those dietary recommendations, there would be a significant impact on the domestic specialty crop market.

As stated by ReFED, 52 million tons of food is sent to landfill every year while another 10 million is discarded or never harvested, while 1 in 7 Americans is food insecure. If the US is to become a model of efficiency for the developing world who must leapfrog our current paradigm, a higher priority must be put on improving information flows, predictive analysis, shifts in "marketability," consumer acceptance of off-grade produce, and scaling profitable urban solutions for highly perishable produce. From this final analysis, we have seen how much is possible by reporting specialty crop underutilization that occurs on farms. Now it's a matter of determining the simplest and most effective ways for growers to partake in, or continue, measurement on their own. There is a tremendous need for fresh, frozen and value-add fruits and vegetables. The challenge is being both predictive and responsive where and when the opportunities arise and creating market-based systems that can facilitate better information flows to match consumption with production. All of this must be done with the understanding that the current footprint of food production cannot expand if we accept that further habitat and biodiversity loss are detrimental to all life on Earth. With the ecological limits of our planet being pushed to extreme levels due of food production, striving for a food system that eliminates loss and waste is absolutely imperative if humans are to reverse current resource consumption imbalances and establish regenerative food systems.

APPENDIX 1

Specialty crop loss results reported using the FLW Accounting and Reporting Standard (FLWS)

Timeframe

Fresh market tomatoes in Florida: May 18 through August 16, 2017

Fresh market peaches in New Jersey: August 1 to 7, 2017

Processing potatoes in Idaho: September 19 to 26, 2017

Romaine lettuce in Arizona: January 9 to 19, 2018

Material Type

Fresh market tomatoes in Florida: food and associated inedible parts

Fresh market peaches in New Jersey: food and associated inedible parts

Processing potatoes in Idaho: food and associated inedible parts

Romaine lettuce in Arizona: food and associated inedible parts

Quantity and Destination of Losses

Crop/location	Farms	Packinghouses
Fresh market tomatoes in Florida	11.8 million lbs. FLWS Destination: Not harvested/plowed in	40.3 million lbs. FLWS Destinations: Animal feed
Fresh market peaches in New Jersey	14.9 million lbs. FLWS Destination: Not harvested	9.2 million lbs. FLWS Destinations: Refuse/discards/litter
Processing potatoes in Idaho	104 million lbs. FLWS Destination: Not harvested/plowed in	4.7 to 8.9 million lbs. FLWS Destinations: Animal feed, Biomaterial/processing, Co/anaerobic digestion, Compost/aerobic
Romaine lettuce in Arizona	417 million lbs. FLWS Destination: Not harvested/plowed in	Not applicable (all produce is field packed)

Boundary (view the images below for more detail)

Fresh market tomatoes in central Florida at 6 farms and 6 packinghouses

Fresh market peaches in southern New Jersey at 10 farms and 9 packinghouses

Processing potatoes in Idaho at 9 farms and 4 transloaders

Romaine lettuce in Yuma, Arizona at 10 farms

Data Collection Methodology

CSAM studies were conducted by the WFLO/GCCA team for each target crop and included:

- Literature reviews
- Interviews with key informants on the full commodity system from production through marketing
- Observations of harvesting, postharvest handling, and packing (with photos)
- Field visits to farms and packinghouses for data collection on quality and quantity of losses/discards

In addition, for this study, randomly selected samples of the rejected/discarded or unharvested produce were taken to determine the weight of losses per acre and the quality characteristics of those losses. For row planted crops, three randomly selected plots of 9 x 10 ft in size (90 sq. ft.) were marked and all the rejected produce inside was gathered and weighed. The average weight was multiplied by 484[23] to calculate average losses per acre. For peaches, the team used a slightly different metric, measuring losses under 3 randomly selected trees per farm and multiplying by 150 (the average number of trees planted per acre).

Quality characteristics for 3 randomly selected samples of 20 units were rated via 5-point scales where:

Overall quality of each unit: Excellent = 5; Moderate = 3; Poor = 1

Damage to each unit: Extreme = 5; Moderate = 3; None = 1

Decay on each unit: Extreme = 5; Moderate = 3; None = 1

Defects for each unit: Extreme = 5; Moderate = 3; None = 1

For each sample, the % excellent quality, % damage, % decay and % defects were calculated based on these 20 units.

Scaling of sample data (based on averages of 3 random samples per site)

Farms: measured losses per acre were multiplied by acres at each site.

Sum of sites = total losses per season

Packinghouses: estimated losses per day were multiplied by days of operation at each site.

Sum of sites = total losses per season

Accuracy, Completeness, and Uncertainty

Data is based on sites randomly selected during a few harvesting days of the season for each crop. It is a representative snapshot from one point in time and therefore is difficult to determine how well it represents the whole growing season and specific crop across the U.S.

Drivers for Loss

Fresh market tomatoes in Florida: market standards (quality standards for size, color, shape)

Fresh market peaches in New Jersey: market standards (quality standards for size, color, shape)

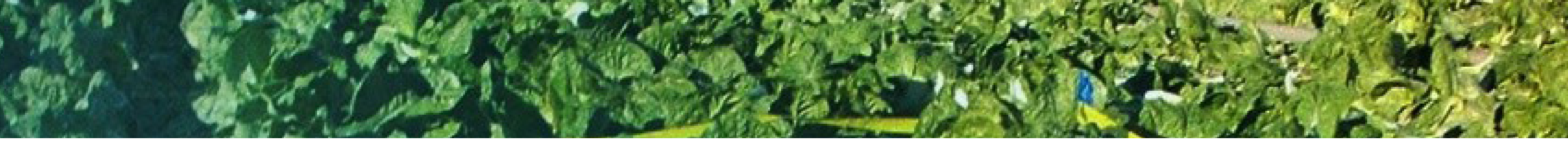
Processing potatoes in Idaho: market standards (quality standards for size, shape), rejects are smaller than 2 inches in diameter

Romaine lettuce in Arizona: market standards (quality standards for size), lots of trimmings of tops, tails, outer leaves for packing of inner hearts.

Were measurements done separately for loss amounts and drivers?

No.

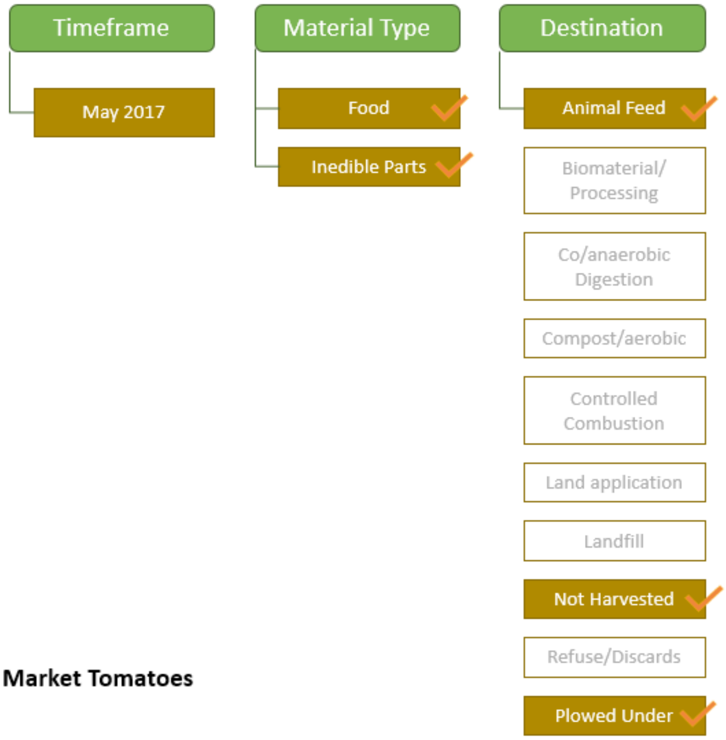
23 The 484 number was used to scale up the loss results since the sample was taken from a 10 sq. yard area which when divided the total square yards in an acre (4,840 sq. yardsresults in a multiplier of 484.



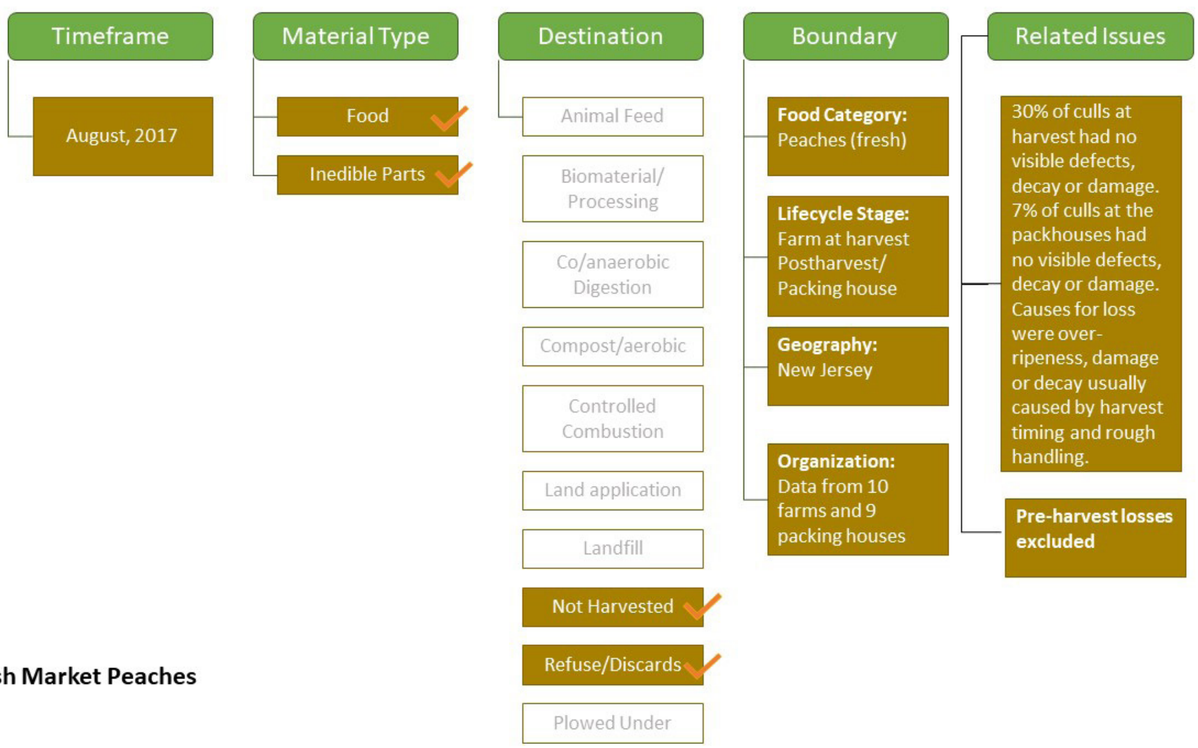
Summary Scope for Inventory of Peaches, Potatoes, Romaine Lettuce and Tomatoes

The following visuals show the scope of the food loss inventories discussed in this report.

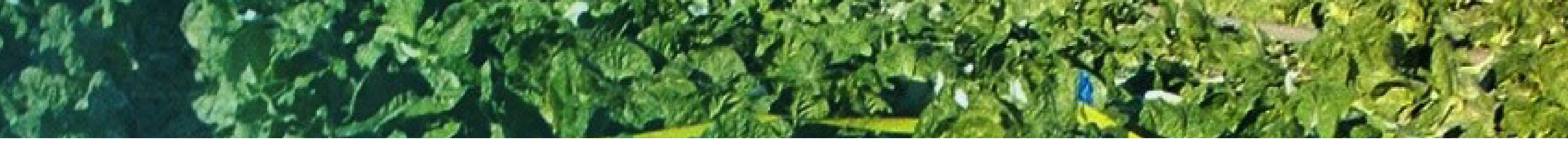
Note: All the destinations listed in these visuals were in scope for the studies conducted but product only went to those that are marked with a check in the images below.

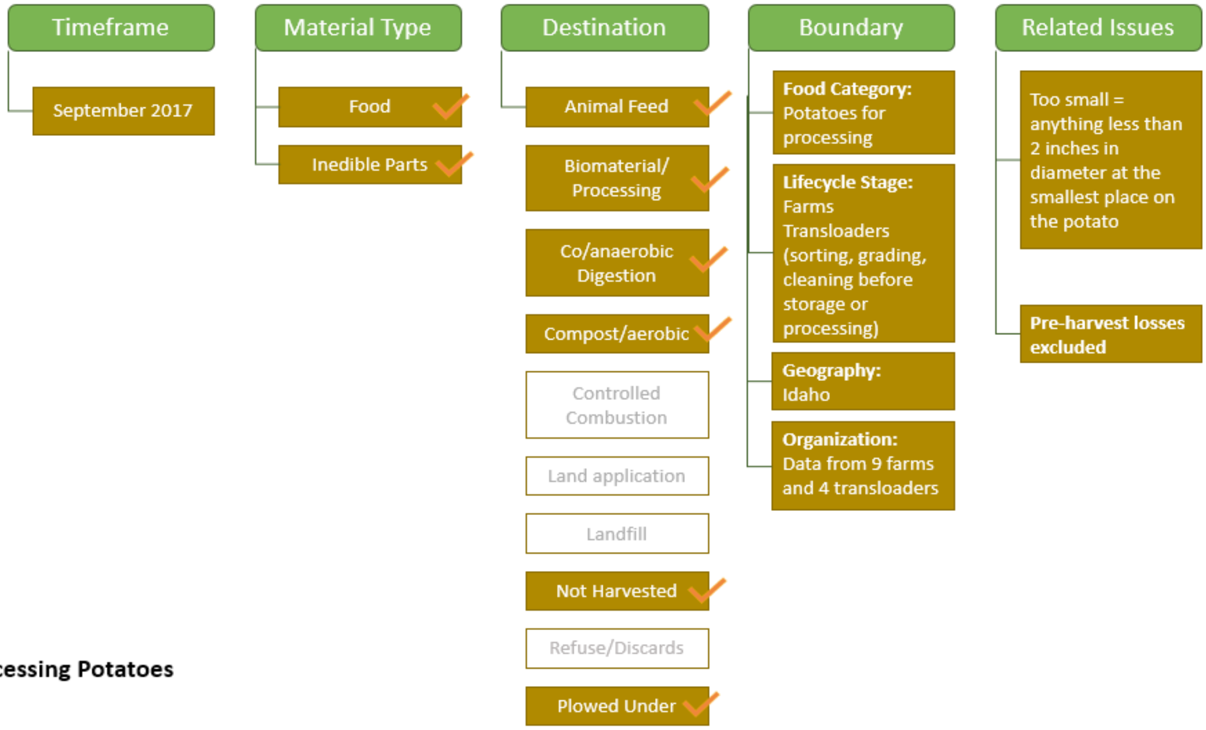


Fresh Market Tomatoes

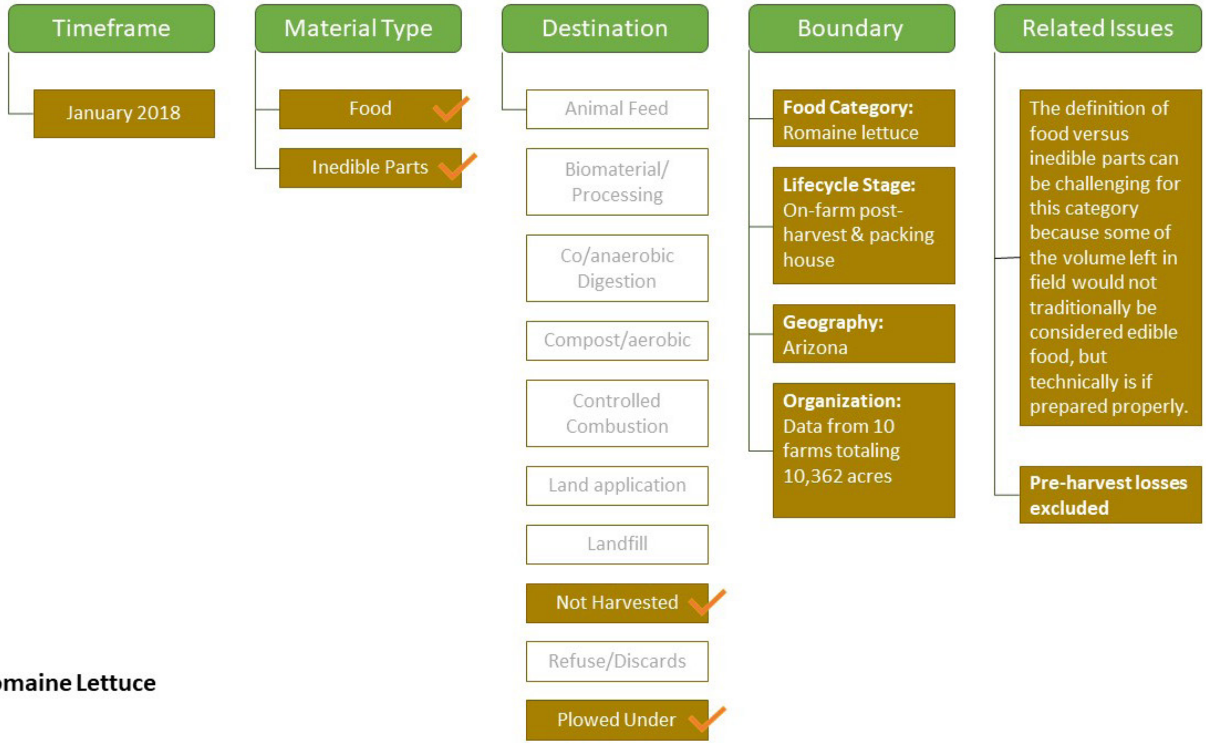


Fresh Market Peaches





Processing Potatoes



Romaine Lettuce

APPENDIX 2

Commodity System Assessment Field and Packinghouse Survey Sheets

WWF/WFLO Project 2017

Sampling (select 3 random samples of 20 discards/rejects)	weight of sample =	weight of sample =	weight of sample =	
SSC % (Brix) (measure 3 randomly selected fruits with refractometer)				Avg brix
Firmness (measure 3 randomly selected fruits)				Avg lbf
Pulp temperature in °F (in 3 randomly selected fruits per sample)				Avg temp
Quality sort for defects, decay, damage (# out of count of 20) Ratings from 5= Extreme defects, decay or damage; 3 = moderate; 1 = none	# with rating 5 _____ # with rating 3_____ # with rating 1 ______	# with rating 5 _____ # with rating 3_____ # with rating 1 ______	# with rating 5 _____ # with rating 3_____ # with rating 1 ______	
number with **obvious defects** ie: cracks, sunburn, misshapen, etc	# ______ (describe)	# ______ (describe)	# ______ (describe)	Avg #
number with **decay** symptoms ie: fungus, bacterial rots, etc	# ______ (describe)	# ______ (describe)	# ______ (describe)	Avg #
number **damaged** ie: bruises, cuts, mechanical injury, insect damage	# ______ (describe)	# ______ (describe)	# ______ (describe)	Avg #
Ripeness rating: 6=red 5= light red 4= pink 3=turning 2=breaker 1=MG	# red____, # light red_____, # pink_____, # turning______, # breaker______, # MG_____	# red____, # light red_____, # pink_____, # turning______, # breaker______, # MG_____	# red____, # light red_____, # pink_____, # turning______, # breaker______, # MG_____	
Rate package protection (mark one with an X) example: plastic crates = 5	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no protection	take a photo of the container or package		
Describe package or container: **Type, material, dimensions, cooling efficiency**		Size and/ or weight of package or container: ______		
% are calculated by #/20 or weight/total weight of sample or count/total count of sample				

1 acre = 4840 sq yards ; 10 sq yards = 90 sq ft

weight loss in 90 sq ft x 484 = weight loss per acre

ON FARM DATA COLLECTION WORKSHEET Name of Data Collector:

TOMATOES Variety (_____________) or describe color, shape, etc

Code: Farm____

Questions and observations	At Harvest			
Date				
Location of farm				
Size of farm				
Crops produced				
Season for tomatoes	Range of harvesting dates for this farm:			
Name of destination market (if known)				
Distance to packinghouse	_______miles		Expected journey time _____hours	
Harvesting --	# of times per plant = ________		in a typical year ____ or actual _____	
Harvesting --	Is this the 1st harvest? YES/NO		If no, what number is it? _________	
Sorting - selecting out of that produce which will not be sent to the packhouse	Was pre-sorting done at harvest? Yes/No	If Yes, estimate waste (discarded) _______% or left on the vine ______% Reason for sorting out:	Was sorting done again before farm gate sale or transport? Yes/No	If Yes, estimate waste (discarded):_______% Reason for sorting out:
What happens to culls/rejects?	If discarded/removed from field: describe destination (gleaned, donated, animal feed, landfill, etc)		If left in field, describe what happens (tilled into soil, composted, other)	
Size Grading : is there any grading into different sizes **on the farm**?	If Yes, estimate % in each category: Large ____% ; Medium ____% ; Small ____%		If Yes, estimate % in each category: Large _____% ; Medium ____% ; Small ____%	
Does price offered vary by quality grade?	Describe grading criteria:		If Yes, what is the price offered for each quality grade? Highest _____ ; Middle _____ ; Lowest _____	
Expected farm gate price:	Contracted price __________ or negotiated price ________		Price offered _______ (by weight? By Volume? By Number of containers?) Price per lb: _______	
MEASUREMENTS	**At Harvest or before transport from farm to packinghouse**			
Yield per acre (inquire from farmer)	Measured (actual weight) ____________ or estimated _______________			
Time from harvest	harvest = 0 hours			
Time of day				
Air temperature				
Relative humidity %				
Field losses in 90 sq ft	Mark a 9 foot x 10 ft section with tape and stakes. Do this in 3 locations in the field after the harvest (random selection)			
Collect and Weigh the discards or rejected produce (lbs)	total weight= _______	total weight = ______	total weight = _______	

PACKHOUSE DATA COLLECTION WORKSHEET   Name of Data Collector:

TOMATOES   Variety (_____________) or describe color, shape, etc

Code: PACKHOUSE____

Questions and observations	During packing			
Date				
Location of packinghouse				
Size of operation (volume packed/day)				
Crops packed				
Season for tomatoes (range of packing dates)				
Name of destination market (if known)				
Distance to market if known	________miles		Expected journey time _____hours	
Arrivals	# of truckloads per day = ________		in a typical year ____ or actual _____	
Sorting - selecting out of that produce which will not be sent to the market	Was pre-sorting done before entry to the facility? Yes/No	If Yes, estimate waste (discarded) _______% Reason for sorting out:	Was sorting done again during packinghouse operations? Yes/No	If Yes, estimate waste (discarded):_______% Reason for sorting out:
What happens to culls/rejects?	If discarded: describe destination (gleaned, donated, animal feed, landfill, etc)		If returned to the field, describe what happens (tilled into soil, composted, other)	
Size Grading : is there any grading into different sizes?	If Yes, estimate % in each category: Large ____% ; Medium ____% ; Small ____%		If Yes, estimate % in each category: Large _____% ; Medium ____% ; Small ____%	
Does price offered vary by quality grade?	Describe grading criteria:		If Yes, what is the price offered for each quality grade? Highest _____ ; Middle _____ ; Lowest _____	
Expected price:	Contracted price __________ or negotiated price ________		Price offered _______ (by weight? By Volume? By Number of containers?) Price per lb: _______	
MEASUREMENTS	**At the packinghouse**			
Volume packed per day (inquire from manager)	Measured (actual weight) ____________ or estimated _______________			
Time from harvest	harvest = 0 hours (actual________ or estimated_________)			
Time of day				
Air temperature				
Relative humidity %				

WWF/WFLO Project 2017

Packinghouse losses (per day)	Iniquire regarding records ___ or estimates __ of the weight of culls (__________) and/or the weight of seconds (_____________)			
Does anyone collect and Weigh the discards or rejected produce (lbs)?	Yes/No	If yes: Total weight of discards: _______		
Sampling (select 3 random samples of 20 discards/rejects)	weight of sample =	weight of sample =	weight of sample =	
SSC % (Brix) (measure 3 randomly selected fruits with refractometer)				Avg brix
Firmness (measure 3 randomly selected fruits)				Avg lbf
Pulp temperature in °F (in 3 randomly selected fruits per sample)				Avg temp
Quality sort for defects, decay, damage (# out of count of 20) Ratings from 5= Extreme defects, decay or damage; 3 = moderate; 1 = none	# with rating 5 _____ # with rating 3_____ # with rating 1 ______	# with rating 5 _____ # with rating 3_____ # with rating 1 ______	# with rating 5 _____ # with rating 3_____ with rating 1 ______	#
number with **obvious defects** ie: cracks, sunburn, misshapen, etc	# ______ (describe)	# ______ (describe)	# ______ (describe)	Avg #
number with **decay** symptoms ie: fungus, bacterial rots, etc	# ______ (describe)	# ______ (describe)	# ______ (describe)	Avg #
number **damaged** ie: bruises, cuts, mechanical injury, insect damage	# ______ (describe)	# ______ (describe)	# ______ (describe)	Avg #
Ripeness rating: 6=red 5= light red 4= pink 3=turning 2=breaker 1=MG	# red____, # light red_____, # pink_____, # turning______, # breaker______, # MG_____	# red____, # light red_____, # pink_____, # turning______, # breaker______, # MG_____	# red____, # light red_____, # pink_____, # turning______, # breaker______, # MG_____	
Rate package protection (mark one with an X) example: plastic crates = 5	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no protection	take a photo of the container or package		
Describe package or container: **Type, material, dimensions, cooling efficiency**		Size and/ or weight of package or container: ______		
% are calculated by #/20 or weight/total weight of sample or count/total count of sample				

APPENDIX 3

On-Farm Food Loss: Interview Protocol

Goals:

1. Produce quantitative estimate of on-farm losses by crop type
2. Better understand grower perspective on the multiple factors that drive on-farm food loss, and
3. Examine the practices, opportunities, and constraints surrounding current food recovery or recycling practices by these growers

Background on interviewee/farm/crop

- Title/role/time with farm
- Total acreage/variety of crops grown
- Acreage of specific crops (lettuce, tomatoes, peaches)
- Harvesting methods/packing and/or processing arrangements

Factors driving on-farm food loss

- Share a few typical scenarios/stories
- In their view what are the top 3 or so drivers

Estimates of food loss (in percent)

- For the crop in question:
  - Low loss year
  - High loss year
  - Avg. year
- Higher or lower in comparison to other crops they grow
- What distinguishes high from low loss years?
- Degree of confidence in these estimates
- How significant are these numbers? (is this a big deal or not?)

Recycling/food recovery practices

- What currently happens to lost food?
  - Tilling for soil improvement
  - Animal feeds
  - Gleaning
  - Food banks
  - Other
- What is working well, not so well, and would they prefer other alternatives?

Key opportunities they see moving forward

- What changes are needed, if any, to reduce on-farm food loss? (probe for)
  - Policy/regulatory changes
  - Marketing standards
  - Community partnerships
  - Other
- Their overall read on this issue
  - The potential for food loss recovery to improve the efficiency of the current system
  - Secondary market options- what can this look like?
  - What it would take to make food recovery efforts pencil out

On-Farm Food Loss: Survey Protocol

Goals:

1. Produce quantitative estimate of on-farm losses by crop type
2. Better understand current food recovery or recycling practices by these growers

Background on interviewee/farm/crop(s)

- Title/role/time with farm
- Total farm acreage/acreage of specific crops (lettuce, tomatoes, peaches)
- Harvesting methods/packing and/or processing arrangements

Factors driving on-farm food loss

- In their view what are the top 3 or so drivers of on-farm food loss (pick up to 3)
  - Weather
  - Pest damage/disease
  - Imperfections that don't meet cosmetic standards
  - Economics (cost of harvesting doesn't pencil out given market prices)
  - Labor shortages
  - Difficulties with storage or handling
  - Deliberate overplanting to compensate for unexpected loss
  - Food safety regulations
  - Others not listed___________

Estimates of food loss (in percent)

- For the crop in question:
  - Low loss year
  - High loss year
  - Avg. year
  - Higher or lower in comparison to other crops they grow
- Degree of confidence in these estimates

Recycling/food recovery practices

- Of total % lost in avg. year, what % ends up as the following:
  - Tilled into the ground
  - Used for animal feed
  - Informally gleaned by workers, neighbors, etc.
  - Made available to food bank or other free food outlet
  - All other

APPENDIX 4

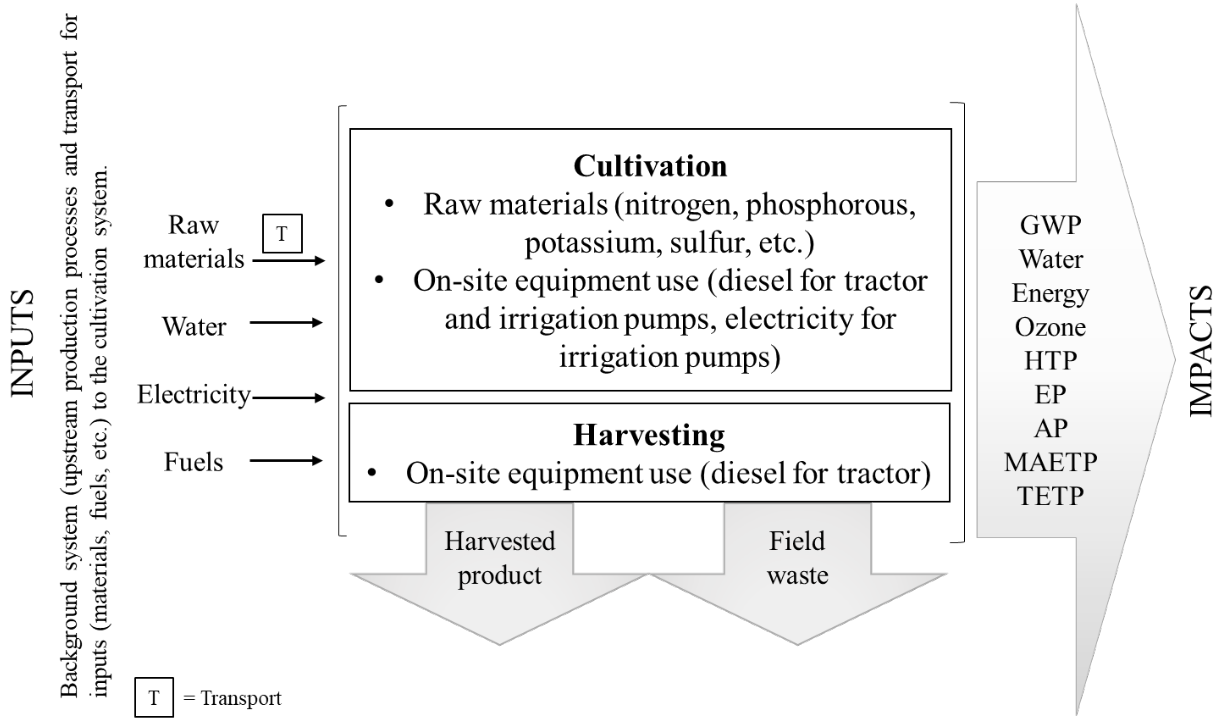


Figure 5 Life-cycle assessment flow

APPENDIX 5

Table 11 Life cycle inventory datasets (secondary data) for cultivated processing tomato

Material or Process	LCI Name [Location, e.g., at refinery]	Region[1]	Database	Year
Diesel	1 kg Diesel [Refinery products]; 1 m3 US: Diesel, combusted [Interme-diates]	USA	GaBi	2015-2018
Water for irrigation	Electricity grid mix – California Mix (CAMX)	USA-CA	GaBi	2015-2018
Water for irrigation	1 kg Diesel [Refinery products]; 1 m3 US: Diesel, combusted [Interme-diates]	USA	GaBi	2015-2018
Zinc	market for zinc	GLO	EcoInvent	2015-0
Gypsum	market for gypsum, mineral	GLO	EcoInvent	2015-0
CAN17	market for calcium nitrate	GLO	EcoInvent	2015-0
CAN17	Urea (agrarian)	USA	GaBi	2015-2018
CAN17	ammonium nitrate (AN, solution) 52% N	USA-CA	GaBi	2015-2018
UN-32	Urea (agrarian)	USA	GaBi	2015-2018
UN-32	ammonium nitrate (AN, solution) 52% N	USA-CA	GaBi	2015-2018
N: 8-24-6	Urea (agrarian)	USA	GaBi	2015-2018
N: 8-24-6	Ammonia	USA	GaBi	2015-2018
P: 8-24-6	phosphoric acid (75%)	USA	GaBi	2015-2018
K: 8-24-6	potassium nitrate	GLO	GaBi	2015-0
[Thiolux] Sulfur	Sulphur (elemental) at refinery	USA	GaBi	2012-2018
[Trifluralin 4 E.C.] Trifluralin	market for dinitroaniline-compound	GLO	EcoInvent	2015-0
[Warrior] Lambda cyhalothrin	market for pyrethroid-compound	GLO	EcoInvent	2015-0
[Round Up] Glyphosate	glyphosate production	GLO	EcoInvent	2015-0
[BRAVO] Chlorothalonil	market for chlorothalonil	GLO	EcoInvent	2015-0
[Matrix] Rimsulfuron	market for [sulfonyl]urea-compound	GLO	EcoInvent	2015-0
[Ethrel] Ethephon	Phosphoric acid (75%)	USA	GaBi	2015-2018
[Ethrel] Ethephon	market for dichloromethane	GLO	EcoInvent	2015-0
Kocide 3000	copper production, primary	RNA	EcoInvent	2015-2018
Kocide 3000	Hydrogen at refinery	USA	GaBi	2012-2018
[Dual Magnum] Metolachlor	market for metolachlor	GLO	EcoInvent	2015-0
Oxyfluorfen	diphenyl ether	GLO	EcoInvent	2015-0
Adjuvant	market for paraffin	GLO	EcoInvent	2015-0
Average Material Transport	US: Transport, combination truck, average fuel mix [Products and Intermediates]	USA	GaBi	2009-2016

[1]RoW=Rest of World, RER=Europe, GLO=Global, DE=Germany, USA=North America, EU-28=Europe, CA-QC = Canada-Quebec, FR=France, RNA=North America

Table 12 Life cycle inventory datasets (secondary data) for cultivated fresh tomato

Material or Process	LCI Name [Location, e.g., at refinery]	Region[1]	Database	Year
Diesel	1 kg Diesel [Refinery products]; 1 m3 US: Diesel, combusted [Intermediates]	USA	GaBi	2015-2018
Water for irrigation	Electricity grid mix – California Mix (CAMX)	USA-CA	GaBi	2015-2018
Water for irrigation	1 kg Diesel [Refinery products]; 1 m3 US: Diesel, combusted [Intermediates]	USA	GaBi	2015-2018
Zinc	market for zinc	GLO	EcoInvent	2015-0
Gypsum	market for gypsum, mineral	GLO	EcoInvent	2015-0
CAN17	market for calcium nitrate	GLO	EcoInvent	2015-0
CAN17	Urea (agrarian)	USA	GaBi	2015-2018
CAN17	ammonium nitrate (AN, solution) 52% N	USA-CA	GaBi	2015-2018
UN-32	Urea (agrarian)	USA	GaBi	2015-2018
UN-32	ammonium nitrate (AN, solution) 52% N	USA-CA	GaBi	2015-2018
N: 8-8-8; 10-34-0	Urea (agrarian)	USA	GaBi	2015-2018
N: 8-8-8; 10-34-0	Ammonia	USA	GaBi	2015-2018
P: 8-8-8; 10-34-0	phosphoric acid (75%)	USA	GaBi	2015-2018
K: 8-8-8	potassium nitrate	GLO	GaBi	2015-0
N_2O (direct and indirect) from field soil	-	-	-	-
[Thiolux] Sulfur	Sulphur (elemental) at refinery	USA	GaBi	2012-2018
[Trifluralin 4 E.C.] Trifluralin	market for dinitroaniline-compound	GLO	EcoInvent	2015-0
[Warrior] Lambda cyhalothrin	market for pyrethroid-compound	GLO	EcoInvent	2015-0
[Round Up] Glyphosate	glyphosate production	GLO	EcoInvent	2015-0
[BRAVO] Chlorothalonil	market for chlorothalonil	GLO	EcoInvent	2015-0
[Ethrel] Ethephon	Phosphoric acid (75%)	USA	GaBi	2015-2018
[Ethrel] Ethephon	market for dichloromethane	GLO	EcoInvent	2015-0
Kocide 3000	copper production, primary	RNA	EcoInvent	2015-2018
Kocide 3000	Hydrogen at refinery	USA	GaBi	2012-2018
[Asana] Esfenvalerate	combined phenyl acetic acid, hydrogen 5.28%, Chlorine 8.4%, and Nitrogen 3.3%	USA	GaBi	2012-2018
[Agrimek] Abamectin	Lactic acid	USA	GaBi	2012-2018
[Mancozeb] Dithane	market for mancozeb	GLO	EcoInvent	2015-0
Adjuvant		GLO	EcoInvent	2015-0
Average Material Transport	US: Transport, combination truck, average fuel mix [Products and Intermediates]	USA	GaBi	2009-2016

[1]RoW=Rest of World, RER=Europe, GLO=Global, DE=Germany, USA=North America, EU-28=Europe, CA-QC = Canada-Quebec, FR=France, RNA=North America

Table 13 Life cycle inventory datasets (secondary data) for cultivated romaine lettuce

Material or Process	LCI Name [Location, e.g., at refinery]	Region[1]	Database	Year
Diesel	1 kg Diesel [Refinery products]; 1 m3 US: Diesel, combusted [Intermediates]	USA	GaBi	2015-2018
Water for irrigation	Electricity grid mix – California Mix (CAMX)	USA-CA	GaBi	2015-2018
Water for irrigation	1 kg Diesel [Refinery products]; 1 m3 US: Diesel, combusted [Intermediates]	USA	GaBi	2015-2018
Blends (N)	urea (agrarian)	USA-CA	GaBi	2015-2018
Blends (N)	ammonium nitrate (AN, solution) 52% N	USA-CA	GaBi	2015-2018
Blends (P)	Phosphoric acid (75%)	USA	GaBi	2015-2018
Potassium sulfate	market for potassium fertilizer	GLO	EcoInvent	2015-0
N2O (direct and indirect) from field soil	-	-	-	-
[Thiolux] Sulfur	Sulphur (elemental) at refinery	USA	GaBi	2012-2018
[Warrior] Lambda cyhalothrin	market for pyrethroid-compound	GLO	EcoInvent	2015-0
Kocide 3000	copper production, primary	RNA	EcoInvent	2015-2018
Kocide 3000	hydrogen at refinery	USA	GaBi	2012-2018
[Agrimek] Abamectin	lactic acid	USA	GaBi	2012-2018
[Mancozeb] Dithane	market for mancozeb	GLO	EcoInvent	2015-0
Average Material Transport	US: Transport, combination truck, average fuel mix [Products and Intermediates]	USA	GaBi	2009-2016

[1]RoW=Rest of World, RER=Europe, GLO=Global, DE=Germany, USA=North America, EU-28=Europe, CA-QC = Canada-Quebec, FR=France, RNA=North America

Table 14 Life cycle inventory datasets (secondary data) for cultivated processing peaches

Material or Process	Location	Region[1]	Database	Year
Gasoline mix (regular)	at refinery	USA	Professional	2013–2019
Urea - Ammonium Nitrate (UAN)	at plant	USA	Professional	2016–2019
Urea (agrarian)	at plant	USA	Professional	2016–2019
Lactic acid (fermentative)	at plant	USA	Professional	2016–2019
White mineral oil, at plant	at plant	USA	Professional	2009–2016
market for chemical, organic	NA	GLO	EcoInvent	2015–0
alkylbenzene production, linear	NA	RoW	EcoInvent	2015–0
cumene production	NA	RoW	EcoInvent	2015–0
expanded clay production	NA	RoW	EcoInvent	2015–0
Solar PV [estimated based on Unit process raw data for 1 m2 of PV panel]	NA	California Central Valley	NA	NA
Ammonia	NA	RoW	EcoInvent	2015–0
Calcium ammonium nitrate (CAN, solid)	at plant	USA	Professional	2016–2019
Magnesium sulfate (agrarian)	at plant	CA	Professional	2016–2019
Potassium chloride (agrarian)	at plant	USA	Professional	2016–2019
market for glycerine	NA	GLO	EcoInvent	2015–0
Potassium Hydroxide	at plant	USA	Professional	2016–2019
naphthalene sulfonic acid production	NA	RoW	EcoInvent	2015–0
water production, ultrapure	NA	CA-QC	EcoInvent	2015–0
phosphoric acid production, dihydrate process	NA	RoW	EcoInvent	2015–0
Beet sugar production	NA	RoW	EcoInvent	2015–0
Citric acid	NA	RoW	EcoInvent	2015–0
Fresh poultry manure, market	NA	GLO	EcoInvent	2015–0
Manganese sulfate production	NA	GLO	EcoInvent	2015–0
Monoammonium phosphate (MAP)	at plant	USA	Professional	2016–2019
lime production, algae	NA	FR	EcoInvent	2015–0
market for formaldehyde	NA	GLO	EcoInvent	2015–0
Propane at refinery	at refinery	USA	Professional	2013–2019
EDTA production	NA	RoW	EcoInvent	2015–0
market for sulfur	NA	GLO	EcoInvent	2015–0
Sodium phosphate production	NA	RoW	EcoInvent	2015–0
Sodium hydroxide (from chlorine-alkali electrolysis, diaphragm)	at plant	USA	Professional	2016–2019
Polyvinyl chloride film (PVC)	at producer	USA	PlasticsEurope	2005–2012
Cottonwood lumber, 1 inch (449 kg/m3), kiln-dried	at plant	USA	Professional	2016–2019
Water based paint white (EN15804 A1-A3)	at plant	EU-28	Professional	2016–2019
Natural gas mix	at consumer	USA	Professional	2013–2019
imidazole production	NA	RoW	Professional	2015-0
Phosphoric acid (100%) wet process	at plant	USA	Professional	2016–2019
Ferrous sulfate	at plant	USA	Professional	2016–2019
Waxes/ paraffins	at refinery	USA	Professional	2013–2019
Naphtha	at refinery	USA	Professional	2013–2019
Potassium sulfate as K_2O	at plant	RER	EcoInvent	2015-0
Zinc monosulfate	at plant	RER	EcoInvent	2015-0
Phosphoric acid (54% P_2O_5, agrarian)	at plant	USA	Professional	2016-2019
Boric acid, anhydrous	at plant	RER	EcoInvent	2015-0
Chemical, inorganic	at market	GLO	EcoInvent	2015-0
Potassium carbonate production, from potassium hydroxide	at plant	GLO	EcoInvent	2015-0

Table 15 Life cycle inventory datasets (secondary data) for cultivated processing peaches (cont'd)

Material or Process	Location	Region	Database	Year
Potassium sulfate	at plant	RER	EcoInvent	2015−0
Potassium nitrate	at plant	RER	EcoInvent	2015−0
Pesticide (unspecified)	at plant	RER	EcoInvent	2015−0
Pyrethroid-compound	at plant	RER	EcoInvent	2015−0
Benzimidazole-compound	at plant	RER	EcoInvent	2015−0
Benzoic-compounds	at plant	RER	EcoInvent	2015−0
Dichloropropene, pesticide, unspecified	at market	GLO	EcoInvent	2015−0
Glyphosate	at plant	RER	EcoInvent	2015−0
Dinitroaniline compounds	at plant	RER	EcoInvent	2015−0
Bipyridylium compounds (from diquat production)	at plant	RER	EcoInvent	2015−0
Thiocarbamate compounds	at plant	RER	EcoInvent	2015−0
Organophosphorous compounds	at plant	RER	EcoInvent	2015−0
Copper oxide	at plant	RER	EcoInvent	2015−0
propylene glycol production, liquid	NA	RoW	EcoInvent	2015−0
Silica sand (flour)	at plant	USA	Professional	2016−2019
Dithiocarbamate compounds	at plant	RER	EcoInvent	2015−0
Polyethylene pipe (PE-HD)	at plant	RER	Professional	2005−2012
Polypropylene GMT part	at plant	DE	Professional	2016−2019
Polyvinylchloride pipe (PVC)	at plant	RER	Professional	2005−2012
Electricity grid mix – California Mix (CAMX)	n/a	USA	Professional	2012−2019

[1]RoW=Rest of World, RER=Europe, GLO=Global, DE=Germany, USA=North America, EU-28=Europe, CA-QC = Canada-Quebec, FR=France, RNA=North America

APPENDIX 6

Sector Profiles

The following subsections describe the agricultural landscape for fresh tomato, fresh peach, leafy greens (romaine lettuce), and potato. This includes their overall acreage in production, harvest, yield, and other subsequent factors that assisted WWF and partnering research teams to select these specific crops for measurement. Potato, lettuce, and tomato are three of the four most popular fresh market vegetables in the U.S.

Fresh Tomato

Tomatoes are a climacteric fruit with about 7,500 different varieties bred for specific growing conditions, fruit types and geographic regions. Climacteric means there is a series of biochemical changes initiated by the autocatalytic production of ethylene which marks the change from growth to deterioration, increasing respiration and therefore ripeness.[24] This is when postharvest fungus and disease is likely to set in.

After China, the U.S. produces more tomatoes than any other country in the world. Fresh and processed tomatoes account for over $2 billion in annual farm earnings.[25] Fresh tomatoes are the fourth most popular vegetable in the U.S. after potatoes, lettuce and onions. Some estimates suggest that the U.S. fresh-tomato market is about equally divided between foodservice and retail consumer sales. Yet, in terms of total consumption from all sources, 70% is consumed at home with about 30% consumed outside the home.[26] Unique to the United States, specific tomato varieties are grown to fill certain markets, for example processing tomatoes must be able to produce paste so a specific variety is grown so that the processing is as efficient as possible. Processed tomatoes in the U.S. are harvested mechanically and delivered under contract between growers and processors. Fresh tomatoes are harvested by hand and are often priced at higher rates and sold on the open market.

The largest fresh tomato producing states are California and Florida which both offer the largest commercial acreage for fresh tomatoes and the largest production by volume. At about 30,000-40,000 acres, California and Florida account for two-thirds of the total acreage in the U.S. used for fresh tomatoes and two-thirds to three-fourths of total production.[27] The volume for California and Florida tomatoes is highest in spring, when shipments peak, but in summer they are the lowest because local markets begin selling their tomatoes during that time. Florida's winter production is often delivered to eastern states, while western states are receiving tomatoes from Mexico. As a warm season crop that is intolerant to frost, imported tomatoes account for about one-third of total consumption in the U.S. and are steadily increasing while exports have remained minimal. Alternative markets have also emerged in the past 10-20 years. Hydroponic tomatoes have gained momentum while Canada's hothouse imports peaked in 2005 and Mexico's greenhouse tomatoes account for 71% of their exports to the U.S. Although the fresh tomato market is about evenly split between retail and food service, the price for tomatoes is linked to shipping-point price which directly alters retail prices month-to-month.

Fresh market tomatoes in Florida are planted so that a steady, weekly supply is harvested over a 6-8 month season. Tomato plants are harvested 4 – 7 times per season. The Florida tomato commission sets marketing standards and negotiates the new price every year, per carton. Extension key informants estimate the cost of production in Florida to be around $11,000 per acre. In 2015, about 95,000 acres of fresh market tomatoes were planted and 92,000 acres were harvested producing approximately 1.35 million tons of fresh tomatoes. This is about a 2.8% decrease from what was harvested in 2014 and a 3.4% decrease from what was planted in 2014 (refer to **Table 16**). Although there is a minor yet steady decrease occurring in tomato acreage, the number of farms growing tomatoes has increased. With a growing demand for fresh tomatoes, it is now common practice to grow tomatoes in open fields and under cover in a protected production system to provide a year-round supply.

Table 16 Fresh market tomato yield, total production, and total value of production by state for 2013-2015

Tomatoes for fresh market area and yield (2013-2015)						
	Yield/acre (cwt)			Total Production (1,000 cwt)		
State	2013	2014	2015	2013	2014	2015
Florida	265	280	295	9,010	9,240	9,499
California	300	315	310	10,200	10,175	9,424
Tomatoes for fresh market price and value (2013-2015)						
	Price ($) / (cwt)			Total value of production ($1,000)		
State	2013	2014	2015	2013	2014	2015
Florida	50.60	47.30	47.70	455,906	437,052	453,102
California	36.20	34.80	34.90	369,240	354,090	328,898

24 https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/climacteric-botany
25 https://www.ers.usda.gov/topics/crops/vegetables-pulses/tomatoes.aspx
26 https://www.ers.usda.gov/topics/crops/vegetables-pulses/tomatoes/
27 https://www.ers.usda.gov/topics/crops/vegetables-pulses/tomatoes.aspx

Fresh Peach

Original measurement of peaches, completed by the GCCA was initially scheduled to take place in the state of South Carolina, which produces 8% of the total U.S. production. Due to a spike in temperatures early in spring, followed by a late frost, the majority of peach tree flowers died causing a peach production loss of 90%. After conducting literature reviews and researching the sector profile for peaches, the research team moved their data collection to the state of New Jersey.

The U.S. is the third largest peach producer in the world, with China being the lead peach/nectarine producer. As of 2014, peaches are commercially produced in 23 states which is a decline since 2006 when 29 states were producing peaches. There are two basic types of peaches that are grown in the U.S., freestone and clingstone. Clingstone peaches are more suitable for processing because the meat of the peach "clings" to the "stone" whereas freestone peach pits release more "freely" from the pit.[28] The top peach producing states are California, South Carolina, Georgia and New Jersey. While Georgia, South Carolina and New Jersey have both peach varieties available from July to September, clingstone and freestone harvests vary in California. Clingstone peaches are available from the beginning of July to mid-September and freestone peaches are available mid-April to the beginning of October.

In California, peach trees typically begin yielding fruit around the third year. When trees are in low yield, they are harvested by hand, but by year five or six, they are harvested mechanically. The production life-span of a peach orchard is about 15-20 years. Orchard removal entails large quantities of biomass material being removed from the orchard and sent for biomass energy generation, in-field burning, or chipping and mulching for orchard ground cover. Peach trees require thinning to encourage larger peaches with lower yields as opposed to very high yields resulting from smaller fruit.

About half of all peach production in the U.S. is for the fresh market. The other half is for the processing market of which 75% is canned, 21% is frozen and the rest is dehydrated. In 2016, 99,790 acres were in peach production yielding 795,630 tons of peaches, compared to almost 100,000 acres in 2015 yielding 847,210 tons of peaches and 102,500 acres in 2014 which yielded about 853,000 tons of peaches.[29] Similar to tomatoes, peach production acreage has been gradually decreasing, although the value has been gradually increasing.

Potatoes

As the leading crop in the United States, potatoes contribute about 15% to all farm sale receipts for vegetables.[30] The majority of potatoes grown are for the processed market, which most commonly include products like french fries, chips and dehydrated potatoes (refer to **Table 17**) with the remainder left for fresh market. Primary potato production occurs in the fall, although they can grow year-round. Western states produce almost two-thirds of fall potatoes with Idaho and Washington accounting for over half of the total. Idaho is the leading potato producing state, with 325,000 acres, or 31.4% of US acreage planted in 2016.[31] The market value for potatoes in 2015 was $7/ hundredweight (cwt).

Historically known for its storage and travel advantages, major fall-season potato varieties can be sold in both fresh and processing markets through September of the following year. A shipper's ability to store potatoes allows them greater flexibility when marketing them on the open market, meanwhile processed potatoes are sold under production contracts. These contracts are usually negotiated before spring production time and include volume, price and variety, allowing growers to effectively broadcast planting to meet the contract requirements. Due to the low production of winter potatoes (~10%), potatoes market value is highest in the winter and lowest in the fall. Based off observations in field, the harvest window in Idaho potatoes is from mid-August to the end of October. The harvest for storage potatoes is from mid-September to the end of October.

Table 17 Quantity of processing potatoes by item for 2014-2016

Processing – United States: 2014-2016

Utilization items	Crop year		
	2014	2015	2016
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Processing			
Chips and shoestrings	73,960	56,807	60,266
All Dehydrated (including starch and flour)	48,707	48,016	48,015
Frozen french fries	152,832	152,329	156,985
Other frozen products	9,208	13,573	12,695
Canned products	435	985	1,234
Other canned products (hash, stews, soups)	886	730	698
Other (including fresh pack, potato salad, vodka, etc)	6,907	6,420	6,000
Total	292,935	278,860	285,893

Fields are tended to for about twelve hours each day. Potatoes are mechanically harvested with a windrower which takes two passes through the field or harvested with multiple harvesters in the field. The first pass places two to four rows of crop in the furrow between two unharvested rows. The second pass takes unharvested rows and digs with a conventional harvester while the windrowed rows are picked up simultaneously. Adjustable chains are set on the harvesters (45 mm or 1.75") to allow unsellable small material to fall through. The harvested crop is removed from the field in ten-ton trucks and transported to a nearby transloading area or storage shed. Potatoes are removed from the harvest truck via a conveyor belt to a grading table where dirt clods, rocks and plant debris, and other materials are removed. Non-potato material is removed by falling through finger rollers, knocked off by a clod

28 https://www.agmrc.org/commodities-products/fruits/peaches/
29 http://usda.mannlib.cornell.edu/usda/current/NoncFruiNu/NoncFruiNu-06-27-2017.pdf
30 https://www.ers.usda.gov/topics/crops/vegetables-pulses/potatoes.aspx
31 http://usda.mannlib.cornell.edu/usda/current/Pota/Pota-09-14-2017.pdf

hopper, shot out by air knife, and picked out by human selection. The potatoes are then transferred into a semi-truck or put into storage using a system of conveyors and a potato piler.

Potatoes destined for frozen/ fry market must meet requirements of 2” in diameter (at narrowest), while potatoes for chip processing are required at 1.75” in diameter. Growers on the west side and east side of Idaho were found to grow different potato varieties. Growers on the western side of Idaho reported growing Russet varieties (Burbank, Norkotah and Shepody) and selling directly to frozen/ french fry processors. Growers on the eastern side of the state reported growing a wider variety of potatoes (Russets, Waneta, Umpatilla and patented varietals such as Lamoca), selling both to fresh, processing fries, chippers and dehydration markets. Growers in the south of Idaho oftentimes operated their own storage facilities allowing them to sell in weekly loads to packinghouses or processors.

Potatoes typically have three major markets: fries, chips, or fresh. Most of the fry and chip production is driven by contracts with growers while the fresh market can be a mix of contracts and open market. Contracts for frozen/fry processors dictate the weight of the product (in cwt sacks) with benchmark incentives for larger sizes (at least two inches) and cleaner product (no foreign material). Contracts for chip processors typically offer a fixed price for an amount of product. The weight of foreign material is tarred out of the product load and subtracted from the growers’ payment. If the growers do not meet the specified conditions in the contract, then the potatoes are rejected. If the potatoes are under two inches, they are paid at a reduced rate.

Different from many other specialty crops, and since most potatoes are for the processing market, even if weather conditions render a field, or portions of a harvest, as low-quality, buyers often still purchase the product (at a lower cost) for alternative products. Also, unique to processing potatoes is the full utilization of all planted fields., since the contracting practices are tied to the processors’ own demand and supply forecasts. Buyers purchase whole fields, and therefore will rarely deem a field as a “walk-by” as cosmetic deficiencies and other appearance issues is not a criterion. Potato fields are purchased, and the harvest is sorted through, for solids and sugars, as opposed to appearance.

Large storage facilities can hold Russet varieties for up to 12 months if kept at proper relative humidity and temperature. Potatoes intended for longer-term storage are also gassed with an anti-sprouting applicant (approximately 2 weeks after the storage shed is loaded). Potatoes are mechanically loaded into the shed via the Spudnik belt, with an operator at the top of the pile rotating the tail of the loader to prevent potatoes from rolling off. Metal air vents are positioned horizontally on the ground every 6-9 feet, with holes to allow air circulation from an evaporative cooling wall inside the building. Temperature can be controlled by opening or closing off walls to the building. The storage room walls are either curved or tilted inward to prevent the weight of produce from collapsing the building outward.

As reported by NASS nearly six percent of the 2016 U.S. potato production went un-sold.[32] This is notably unchanged from shrink and loss in 2014 and 2015. The “shrinkage and loss” category accounts for the normal water weight loss and loss due to respiration during storage. It also accounts for the potatoes that do not meet market quality standards due to decay, bruising, greening, sprouting, disease and other factors.

Leafy Greens

Leafy lettuces include romaine, butterhead, and loose-leaf types. This is different from iceberg lettuce which is a head lettuce. Combining head and leaf lettuce, it is the third most consumed fresh vegetable in the U.S., behind tomatoes and potatoes. In 2015, consumption of leafy greens was about 11 pounds per person, and 13.5 pounds per person for head lettuce.[33] Leaf and romaine consumption was slightly lower in 2015 than the previous five years.

The primary lettuce producing states are California and Arizona, although it is also grown in many other states. Comprising 98% of the total loose-leaf lettuces in 2013, California also covered about 71% of the head lettuce produced and Arizona produced about 23%.[34] In 2016, 59,500 acres of leafy greens were planted, and 59,200 acres were harvested producing 13,264,000 cwt. In the same year, 97,300 acres of romaine were planted and 96,200 were harvested. This represents a steady decline from the 166,800 acres total between romaine and leafy greens in 2015 which may be attributed to the severe drought in California (refer to **Table 18**).[35] Although acreage of large farms has decreased, there has been a significant increase of farms producing lettuces on 5 acres or less. Between 2007 and 2012, there has been a 38% increase of lettuces grown on small-scale farms.

32 http://usda.mannlib.cornell.edu/usda/current/Pota/Pota-09-14-2017.pdf
33 https://www.ers.usda.gov/webdocs/DataFiles/83086/Section%202_SandU%20Fresh.pdf?v=42831
34 https://www.agmrc.org/commodities-products/vegetables/lettuce/
35 https://www.agmrc.org/commodities-products/vegetables/lettuce/

Table 18 Planted acreage, harvested acreage and yield of specialty crops from 2014-2016

Crop	Planted Acreage	Harvested Acreage	Yield (cwt/ acre)	Planted Acreage	Harvested Acreage	Yield (cwt/ acre)	Planted Acreage	Harvested Acreage	Yield (cwt/ acre)
	2014			**2015**			**2016**		
Fresh Tomato	101,900	97,600	280	95,200	92,200	286			
Potato	1,062,600	1,051,100	421	1,066,100	1,054,400	418	1,037,000	1,018,300	433
Romaine lettuce							97,300	96,200	301
	Production (tons)	**Not Harvested (tons)**	**Production (tons)**	**Not Harvested (tons)**	**Production (tons)**	**Not Harvest-ed (tons)**			
	2014		**2015**		**2016**				
Fresh Peach	393,320	6,540	357,735	N/A	337,040	N/A			
	Production (tons)	**Acres Bearing**	**Production (tons)**	**Acres Bearing**	**Production (tons)**	**Acres Bear-ing**			
	2014		**2015**		**2016**				
Processing Peach	852,939	102,540	847,210	99,790	795,630	94,070			

APPENDIX 7

Notes from the field: WWF in field with GCCA to report out grower and research observations, 8/3/2017

GCCA had a two-person research team to conduct quantitative and qualitative research and data collection on peaches. Researchers were originally planning to collect data in South Carolina, but after a massive freeze in late March, South Carolina lost about 90% of their crop. With New Jersey being the second largest peach growing state on the east coast, the research team quickly shifted their schedule and location. The research team completed a pre-departure literature review that followed the CSAM protocol to provide background on the fresh peach industry and specific information on crop production, postharvest practices, and product marketing. Interviews with postharvest experts were also conducted as part of the preparation. Through this process, specific counties were identified as target areas in the garden state, since they produced the most fresh market peaches in New Jersey. Interviews began July 31st and continued through August 8th. Interviews were conducted with company owners, growers, packinghouse managers, and cooperative extension agents to gain better insights into the industry and the nature of postharvest practices and loss. Additionally, field data was collected by measuring off 3, 10ft. x 10ft. squares around peach trees to analyze the fruit for mechanical damage, pest damage and decay.

Observations

Despite the busy harvesting season and much higher demand due to South Carolina's late frost, and California's drought, growers and extension agents provided a considerable amount of their time to the research team for them to ask questions, tour facilities and measure peaches in the field. A representative at Rutgers Experimental Farm warned the team to be cautious of growers' time during peak harvest season, and that there was a very short window for them to maximize on their peach yield. He explained the loss of family farms since children and grandchildren have no interest in farming. Only a few large peach growers are left in the region.

"There is a reason there are only a few growers left, besides the fact that children don't take over their family farm, these guys are smart and savvy! Things take time. It's hard to make change, but it's not impossible." - Peach grower

Farm 1

The first farm visited was the largest peach farm in New Jersey with 950 acres of trees. The trees stay in the ground about 12-15 years and in one harvesting season are passed through about 4 times until they completely strip them. They have a packinghouse on their facility with about 200 workers. About 30,000 gallons of water are used every other day to cool the peaches when they are received from the field. Peaches are then sent down lines where workers separate them according to grading requirements and package them according to supplier standards (Costco and Walmart have specific packaging). About 10% of their peaches are unclassified primarily due to pest damage, mechanical damage and bacterial spot. About 600,000 boxes of peaches were produced that particular season and the facility can pack about 14,000 boxes a day. Workers can fill 5 bins of peaches in 20 minutes. The research team interviewed the packinghouse manager who was very open and willing to take some time to fully answer the questions.

After touring the packinghouse, the team went into the field with the farm manager to collect the quantitative data. There were many peaches left on the ground around trees, some in perfect condition and others with serious pest or mechanical damage. The field manager commented that the workers drop soft and blemished peaches. Researchers also measured the sugar content, firmness, and pulp temperature of the fruit. The research team took about 30-45 minutes on farm to collect data, and about an hour in the packinghouse. Completion of qualitative and quantitative data collection took about two hours total.

Farm 2

Farm two covered about 250 acres. Harvesting began 4th of July and went until Labor Day weekend. At 143 trees per acre, farm 2 had about 18 employees (all Puerto Rican) to harvest the fields. Farm 2 did not have a packinghouse on site, but instead took the harvest to ProPack about 10 miles away. 98% of peaches grown are for wholesale while the rest are sold at their farm for locals. The farm manager's opinion on ProPack was that they grade too hard, which is hard for growers. His biggest worry as a peach grower, along with most other growers the researcher team interviewed, was hail. Hail damage was particularly bad and unpredictable. Workers drop about 15% of the crop to the ground for similar reasons as farm 1. Interviews were very casual, and the grower was such a pleasure to speak with. Researchers sat in the growers' tractor barn to go over the qualitative worksheet together and then went to the fields, with no supervision, to conduct the quantitative assessment. From first appearance, farm 2 has significantly less peaches left on the ground around the trees than farm 1.

Other thoughts and observations of research teams

Field researchers were extremely prepared and knowledgeable on CSAM, crop production and the overall landscape of peach farming. Their approach with growers was very candid and unassuming, and growers seemed to really enjoy talking to them and sharing information about their farms and production levels. From the full day we spent visiting two peach farms, we encountered no obstacles in approaching growers and walking around their fields and operation centers. One of the field researchers has her master's degree in international agricultural development from the University of California Davis and the other has one master's degree in Geographic Information Systems (GIS) and is working on his second degree in project management. They completed their CSAM training with Dr. Lisa Kitinoja in February 2017.

APPENDIX 8

Voices from the Field –

Excerpts from the Qualitative Interviews

1. What is considered edible?

Growers generally estimate that a high percentage of what is lost is edible, but not marketable. Growers were all equally skeptical of using one definition for edible and had many questions about how one would define this term. For example, although a crop might be "edible", could it be sold as food for humans? Would anyone want it? Also, the concept of edible now versus edible when it reaches the consumer was brought up by a few growers.

"It has just a little bit of scarring, no condition issues. So, it's absolutely as good as the number one, but it's got maybe a tiny hail mark on it. And I could show you some of the boxes, you would go, I would buy that any day. And it's sold at quite a steep discount…"

-Peach grower

"But whatever the culls, if it's just the color, or the cathead [type of deformation], all of that is edible. It's just the view of it. Just like clothes. Old variety of clothes, you can still wear them, but you can't get rid of them."

-Fresh tomato grower

"Every single one of [the culls] is edible—well let's say 99 percent. I mean there'll be a few that will be overripe. But those probably will be the most delicious."

-Fresh peach grower

"The outer leaves left behind, that is the workhorse of this plant, not waste…You wouldn't go out into a tomato field and see all of those vines and go, "Oh, what a waste!" It's not waste. It's what we needed to grow the vegetable."

-Leafy greens grower

You could eat that peach right now (referring to a cull), but I don't think you could eat that if it traveled for a day or something.

-Peach grower

But 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.

-Leafy greens grower

Is it really "loss"?

Virtually all produce loss on farm is tilled back into the soil, dumped on farm (e.g. for use as a soil amendment), or used as animal feed. Therefore, growers reported rarely sending food to landfill or other destinations where there is less opportunity for some value to be captured.

"The idea is I think if you're going to have waste, better to have it here at this level. Rather than ship something of questionable quality."

-Leafy greens grower

"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."

-Organic tomato grower

What drives loss?

Food loss on farms is primarily driven by weather and the markets. Market prices and retailers' views of consumer preferences guide quality standards and influence how much a producer will harvest or leave in the field. The market price determines how cost effective it is to use labor to harvest a crop with questionable value in the field.

Consumer Preferences

Growers also commented that consumer preferences and thus retail specifications lead to significant waste.

"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. So that's why [we leave things behind], our customer base is just so picky."

-Harvest manager for leafy greens

"We throw away, daily, a quarter of a million pounds…Maybe it's overripe, maybe it's misshapen, maybe it's a split pit…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."

-Fresh peach grower

Markets

"And that's probably one of the worse things, is that when the market is bad, that is when you're most likely to step over something, or really get picky. If you can't sell it, then it's cheaper to leave it in the field than it is to pick it, pack it, and cool it."

-Leafy greens grower

"We've had that where, the market for peaches last year was pretty suppressed, and the last few picks were small. And they just walked away from what was left out in the field…Whatever's left that's small there's no market for it, because there's a glut for that size you might just leave those out there."

-Peach grower

"It costs us the same amount of labor to bring it out of the field, a number one piece of fruit as a number two piece of whatever it is. So, generally, if the thing isn't really at par, we just leave it in the field, and be done with it."

-Fresh tomato grower

"[Loss] varies based on what the marketplace is, and it's all about oversupply. So last winter, we left like 200 acres of lettuce through the course of the whole season…. And there were other seasons that we didn't leave any walk-byes at all…. We track that very closely because it impacts the bottom line. It's really hard to predict what that's going to be."

-Leafy greens grower

"So that's where farming is a big gamble. So, you want to plant enough that you have enough to meet your contracts, but not overplant to where you just can't sell what you got."

-Processing tomato grower

Weather

A less obvious issue is that weather also changes consumption patterns. Ask any grocery merchandising team and they know weather has a direct impact on the food people buy. Abnormal weather patterns can have big impacts on growing regions. In the extreme, preparations for a storm in the Northeast can leave grocery store shelves barren one day and lack of distribution and demand in the subsequent weeks can leave fresh produce stockpiled and lost on farm. In these situations, improving information flows so that food could potentially be rescued or gleaned by food-rescue organizations will be critical if we are to reduce food loss.

"So, there is a lot of effort that goes into figuring out the right variety for the right time of the year for climates and soil. And anyone will tell you, it's an art. I will never forget having this really humid storm in September. And all of the lettuce right after the storm didn't have any life to it... When it got the East Coast, it was all blotchy and looked terrible. It was all because of this environmental event that occurred."

-Leafy greens grower

"I mean, you figure it's 2% of your acreage on average. So, some years it's 20% [loss], some years it's not, most years it's nothing. Hail as a phenomenon is usually isolated to very small patches. And some growers could be widely affected in devastating amounts, a 100% loss. And our neighbor 300 yards away will be zero damage."

-Peach grower

"If we have good weather, the trees will set better. Then we'll have more of a crop. If the weather is kind of junky, then your crop won't set, and then your things reduce. Your numbers reduce."

-Peach grower

"We had a hot spell, about two weeks ago. Well when it gets that hot, our plants, it just kind of stops them...On fresh market, we are supposed to have a certain amount per week. But two weeks are combined now. Because it slowed down our tomatoes. But now they are growing again, but the younger ones caught up. Some people even had to disk under, because there is too much maturity at the same time."

-Fresh tomato grower

Labor

"But, yeah, just domestic labor around here, it's really tough. But I'd say for me, right now, I got my five crews. They're all H2A...We're not having issues as far as our products go, just because we have that secured labor. But the overhead for them is just outrageous, but that's what we have to do... "

-Leafy greens grower

"It's getting harder. And, of course, with minimum wage going up it's getting more expensive, so we're getting priced out of a lot of the fresh market business in California... We're paying $11 an hour and in Mexico they're paying $10 a day."

-Processing tomato grower

"Go ahead and raise the minimum wage. No one is paying minimum wage in the industry anymore. It's that we don't have the labor."

-Processing peach grower

How is food recovered?

Growers reported two ways in which food is generally recovered, 1) diversion of fresh produce culls into processing options such as juicing, drying, freezing, or some other value-added product; 2) donation of product to food banks, oftentimes absorbing the cost of donation efforts and receiving any tax credits.

"One [outlet for culls] would be Fresno food bank or Visalia food bank. We probably send them, of multiple fruit, not just peaches, 30 or 40 truckloads, 25-ton truckload lots, a year. So, we will give them off size, off grades."

-Fresh peach grower

"Of that two percent (of post-harvest culls), probably at least one to one and a half percent goes to food banks. It's mostly a matter of what they can receive and take and distribute within shelf life of that particular product."

-Fresh tomato grower

"Here with leafy greens, like I said, [food bank donations] is really stuff that – it's a local rejection and it comes back to our cooler and we don't think we can ship it out because of age. So, again – perfectly edible, but is it going to make a trip to Denver? So that's probably, leafy green-wise, we're looking at rejected product and out-of-rotation product."

-Leafy greens grower

"There's no better way to reward a farmer than tax incentives. That helped us greatly. If we could get some sort of a write off for donating, that will offset the cost of our box and our labor and our pallet in the handling. In their heart, every farmer would like to help."

-Fresh peach grower

"You need someone to cover that variable cost, or why else would you capture it in the first place? But the other point is that there is a channel of commerce that it can go into. So, you need an organization that wants that product, that will pay for the marginal cost of harvest and then have the logistics to handle it. To get it to whoever the end users are going be."

-Leafy greens grower

"If a food bank or a glean association were to have some kind of an intimate relationship with the grower... I mean a relationship where they could work with the grower more closely...You know, without bugging me, but somehow or another getting a hold of the small grower on a weekly basis, saying, you know, "Hey, you go anything that we might be interested in?" And I might say, "Gee, come to think of it, yeah, I got some lettuce out there. Why don't you come out and get it?""

-Tomato and leafy greens grower

"So, to have less product left behind, it would be to just find lower level customers. So, if you could find those discount markets, so at least you're making some type of margin. Or if food banks, or whatever, have their own harvest crews and impose the costs on themselves, you know, and took the liability for it."

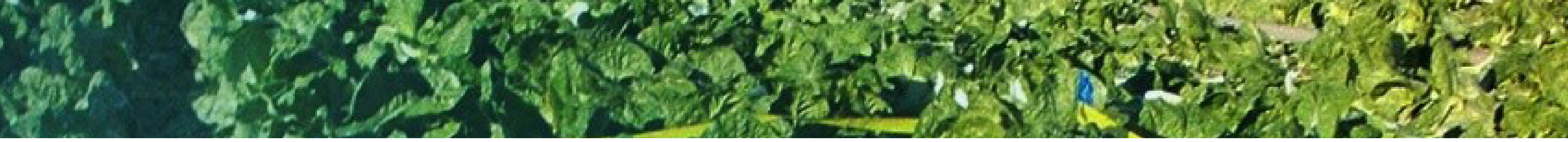
-Leafy greens grower

"In the past, the best secondary market that has actually paid something to the growers has been the frozen market. Where that's been a hit is where the government has put frozen peaches into school lunch programs."

-Fresh peach grower

What are the biggest challenges for reducing loss?

Growers elucidated that the system in place is meant to deliver cosmetically perfect produce at the lowest cost to consumers. Growers attributed most loss to unpredictable events, which happen at low frequency, but with high volume impact. Creating a system that can react to such unpredictability would require a heightened level of transparency and information sharing, while avoiding incentives for additional over-production.



"But in the best conditions, your investment [on a recovery system] is going to get a zero return…. There's just nothing to be recovered. So, in the conditions that are ideal, there's no use for it. It's only when things are less than ideal that there's a use for it. But there's no reason to set up something for less than ideal conditions, because that's not the condition that's normal, you understand."

-Processing tomato grower

"If I had other ways to go with those really small heads [of lettuce] – but the problem is, there just isn't the volume. I mean, we are just not losing that much, really. I mean, we always try to dial in and get everything out of it… You may get a little bit more, but the problem – really, at the end of the day, it's an economic deal. Unless you have fields that are really uneven, we just don't get that kind of variability to justify spending that much more to get it out of the fields. And that's the problem with off quality product: it all boils down to economics."

-Leafy greens grower

"So, there's other stuff where you know you're going to have X amount of waste. Where us, we're very—we're extremely variable. That's the difficult part, the variability along with perishability make it very tough. So—that's the challenge for this industry."

-Fresh peach grower

"We need to break even, and it has to be easy too [to donate]. Like I was telling you before it's more effort for me to give away stuff than it is to sell it. I spend more time giving away free tomatoes than I do with someone that pays more. It's more trouble for me to donate stuff."

-Fresh tomato grower

"People think of gleaners and they think like, it's free to the farmer, like oh, the farmer doesn't have to do anything. But that's like it couldn't be further from the truth."

-Greens and tomatoes grower

"Basically, we operate like a house of fire during the season. It's pretty crazy. So, anything complicated with [recovery]—I mean it's just not manageable."

-Peach grower

"So, to ask [growers] to slow down their production or to donate anything – palettes, totes, any – you know, just their labor, is really hard to do, because every morning they're waking up knowing they're going to lose x amount of money that day. And to go, you know, "You can help some people if you just lost a little bit more money?" It's a really hard pill to swallow for growers."

-Leafy greens grower

"So, it's hard to have a market for those kinds of seconds. There was an ugly fruit movement that was going on…. But the challenge is, is it still going to cost the farmer the same amount to get it to market or not. And one would think that they're going to get a discounted price because it's not the highest quality. So, there is the economics of it."

-Tomatoes and leafy greens growers

"What always drives me crazy is that these got grown. They got picked. They got taken all the way down, and then we're going to throw it out. We paid to grow it. We paid to harvest it. We paid to sort it, and then now the chickens aren't going to pay us. So, you're asking, is there a market for that? For right now, these go to the chickens. So, I guess there's a market – chickens."

-Organic tomato grower

What do growers think about the food waste movement?

Many growers are hesitant to talk to activists about loss, fearful that their situation will be misrepresented, and the agricultural community will get a bad reputation. Also, some growers are resistant to organizations and researchers trying to fix problems that either may not exist, or that they do not fully understand. As growers see unpredictable weather events and market forces as the main causes of loss—factors which they have been trying to mitigate for years—they are skeptical of outsider-driven interventions and simple solutions. At the same time, many growers consider themselves to be natural stewards of the land and expressed an on-going desire to reduce food loss and improve recovery options.

"We work with land and are forced to accept that our crop will be this standard. This is what we've been working for three or four months, so imagine this is the fruit of our labor. So, if we could change that situation, if we were not tied to that vicious circle of economics with the people we are working with. We try to be generous…You will find some willingness on the part of growers as a whole to help…. But you might not be looking at the right people here. We are the executors."

-Leafy greens grower

"We have people come through from all over the world and they go, "Wow, why are you throwing this away or why are you throwing that away?" We're like, "We wish the hell we weren't." And they're going, "We're going to figure this out," and we go, "Okay, get back to us, yeah.""

-Peach grower

APPENDIX 9

Table 19 Detailed crop loss rates and solutions by crop (Sources: WWF study and Santa Clara University Study)

Crop	% Loss	Reasons for Loss	Possible Solutions
Peaches (NJ)	23 – 38%	¤ Too soft ¤ Too small ¤ Within grade ¤ Hot weather ¤ Cosmetic defects ¤ Market dynamics ¤ Labor shortages & cost	¤ Omnichannel solutions to deal w/varying ripeness ¤ Cooperative competition to improve supply/demand dynamics that reduce prices ¤ Financially viable alternative markets including value added processing & food banks ¤ Hyper-local distribution and information flows during peak harvest and ripeness.
Tomatoes (FL - fresh)	40-50%	¤ Too small ¤ Within grade ¤ Cosmetic defects ¤ Weather late in the season ¤ Market dynamics ¤ Labor shortages & cost	¤ Omnichannel solutions to deal w/varying ripeness ¤ Cooperative competition to improve supply/demand dynamics that reduce prices ¤ Financially viable alternative markets including value added processing & food banks
Romaine Lettuce & Romaine Hearts (CA & AZ)	56 – 107%	¤ Too big ¤ Misshapen ¤ Trimming of outer leaves for hearts ¤ Market dynamics ¤ Labor shortages & cost	¤ Financially viable alternative markets including value added processing & food banks ¤ Using stranded assets to grow greens closer to population centers ¤ Genetic improvements to improve edibility of outer leaves ¤ New soup products with giants like Campbell's and other startup value add processors.
Watermelon	27%	¤ Cosmetic defect/color ¤ Too small	¤ Promotion of local market expansion ¤ Competitive coordination on growing / sales cycles between growers ¤ New Marketing campaign: Sell pollinator watermelons with seeds
Green/Red & Napa Cabbage	22-37%	¤ Outer leaf discard ¤ Too small ¤ Cosmetic defect/color	¤ Genetic improvements to improve edibility of outer leaves ¤ Using stranded assets to grow greens closer to population centers
Celery	25%	¤ Outer leaf discard ¤ Too small	¤ Financially viable alternative markets including value added processing & food banks
Iceberg Lettuce	50%	¤ Outer leaf discard ¤ Too small ¤ Too large	¤ Genetic improvements to improve edibility of outer leaves ¤ Using stranded assets to grow greens closer to population centers ¤ Promoting roof top and urban production centers
Kale	36%	¤ Outer leaf discard ¤ Cosmetic defect/color	
Cauliflower	36% (Harvested multiple times)	¤ Cosmetic defect/color ¤ Too small ¤ Too large	¤ Financially viable alternative markets including value added processing & food banks ¤ Behavior change: consumer awareness campaign for "bronzed" items
Green Leaf Lettuce	25%	¤ Outer leaf discard	¤ Using stranded assets to grow greens closer to population centers ¤ Promoting roof top and urban production centers
Bunch Spinach	18%		¤ Promoting roof top and urban production centers
Round Tomatoes (fresh)	7%	¤ Too small ¤ Within grade ¤ Cosmetic defect/color	¤ Omnichannel solutions to deal w/varying ripeness ¤ Financially viable alternative markets including value added processing & food banks ¤ Promotion of local market expansion
Roma Tomatoes (processing)	6%		¤ Genetic improvements to promote more synchronized ripening

Broccoli	22% (Harvested multiple times)	¤ Too small ¤ Too large ¤ Cosmetic defect/color	¤ Financially viable alternative markets including value added processing & food banks ¤ Behavior change: consumer awareness campaign for "bronzed" items
Brussels Sprouts	17%	¤ Within grade ¤ Cosmetic defect/color	¤ Behavior change: consumer awareness campaign for "bronzed" items
Green Beans	26%	¤ Cosmetic defect/color	¤ Financially viable alternative markets including value added processing & food banks ¤ Hyper-local distribution and information flows during peak harvest and ripeness.
Cantaloupe	7% (Harvested multiple times)	¤ Too small ¤ Within grade ¤ Cosmetic defect/color	¤ Omnichannel solutions to deal w/varying ripeness ¤ Competitive coordination on growing / sales cycles between growers ¤ Financially viable alternative markets including value added processing & food banks ¤ Promotion of local market expansion
Sweet Corn	13%	¤ Too small ¤ Within grade ¤ Cosmetic defect/color	¤ Behavior change: consumer awareness campaign for "bronzed" items ¤ Financially viable alternative markets including value added processing & food banks ¤ Damaged "bird-peck" corn is sweeter and more delicious, less shelf life, local distribution ¤ Eliminate pesticide use for cosmetic leaf treatment (ugly corn husky = less chemical input)
Strawberries	25%	¤ Too small ¤ Within grade ¤ Cosmetic defect/color	¤ Omnichannel solutions to deal w/varying ripeness ¤ Financially viable alternative markets including value added processing & food banks ¤ Promotion of local market expansion
Artichokes	5% (Harvested multiple times)	¤ Too small ¤ Within grade ¤ Cosmetic defect/color	¤ Behavior change: consumer awareness campaign for "bronzed" items ¤ Marketing: Understand that smaller "chokes" are amazing and a culinary delicacy ¤ Develop new recipes for underutilized food types.
Potatoes (processing)	2.6%	¤ Too small and sorted out ¤ Damaged	¤ Limited opportunities on farm – system already very efficient; more opportunity in fresh market with improved buyer/grower relationships