An Analysis of the Environmental Impact of Food Loss on Farms in Vermont

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Executive Summary

A surplus of food exists in Vermont food systems, much of which is never used or is "lost". Food loss is edible but unutilized crops that are left in farm fields to be tilled, thrown out into landfills, or harvested but neither sold nor donated. Despite the ubiquity of food loss, the environmental costs associated with it are largely unknown. The goal of this project is to understand how salvaging crops can benefit farmers, communities, and the environment by calculating the sunk costs of resources utilized in producing edible crops that currently stay on farms. Our objectives are to quantify the sunk costs of water and fuel when edible crops are lost on farms and to communicate with stakeholders, including local farmers and partners at Salvation Farms, about the benefits and costs of reducing food loss. For the purposes of the final report and infographic, we used the most efficient and straightforward models and calculations given the scope of our project and the data available. However, there are several methods that can be used to validate these estimates, some of which future teams may be recommended to use.

Introduction

An estimated surplus of over 14.3 million pounds of fruits and vegetables exist in Vermont food systems, and the environmental costs associated with those lost crops are largely unknown (Snow 2016). Salvation Farms is a nonprofit dedicated to strengthening resilience in Vermont's food system through agricultural surplus management which is the movement of excess produce to organizations and community members that can use the food. The organization evaluates benefits of agricultural surplus management, from the economic value of salvaging crops to the amount of volunteer hours they receive. However, there are still other benefits to agricultural surplus management that they hope to understand, such as sunk costs of resources when crops are not salvaged and potential environmental impacts. Sunk costs are any costs that have already been made and cannot be recovered, such as the cost of irrigating crops after they have already been grown.

Knowing this quantitative loss of input resources can help stakeholders in the food system better understand the sunk costs that they are unable to capture by letting healthy, edible crops go unutilized. Likewise, this can help Vermont institutions understand the benefits that may result from salvaging food and working in partnership with Salvation Farms. Creating relationships between farmers and the community is an essential part of establishing a strong and resilient food system. The valuation of their sunk costs can lead to a better understanding of how the inputs a farmer uses directly benefits people when their surplus is managed to feed the community (McAfee 2010).

Managing agricultural surplus is one way that local food can be supplied to underprivileged members of the community. Food that is deemed unmarketable by the farmer due to aesthetic reasons but is still edible can be reaped after the harvest and redistributed to people outside of farmer's market and other traditional markets (Hinrichs 2000). Agricultural surplus could also be distributed to institutions throughout Vermont such a schools or prisons to provide fresh produce for these people. Using locally grown produce in these institutions means that food does not need to be imported from outside of the state, which fosters a stronger local food system and reduces reliance on the global market. This means that the inputs the farmer invested into the crops are directly advantageous to the local food system and the community, which in turn benefits the farmer (Anderson 2008).

The goal of this project is to create a quantified understanding of selected, sunk environmental resource costs from food loss in farms to help build partnerships between agricultural surplus managers and farmers to strengthen Vermont's food system.

Our objectives are to:

1. Quantify the sunk costs of water and fuel when farmers do not manage their crop surplus.
2. Communicate with stakeholders including local farmers and partners at Salvation Farms about the benefits and costs of reducing food loss.

Background

Food loss causes a stress on the food supply chain. Farmers have to shoulder the sunk costs of the resources they use and communities are unable to gain from the unsalvaged crops. Food loss for the purposes of this project is defined as the edible but unutilized crops that are simply left in farm fields to be tilled, thrown out into landfills or harvested but neither sold nor donated. In Vermont's food system, 32% of the 14.3 million pounds that is lost is left unpicked and the other 68% is unsold or not donated (Snow 2016).

The causes of food loss in medium and high-income countries such as the United States are consumer behavior and the failure of communication between members in the food supply chain. Consumers have high quality standard for what they pay for. For this reason, markets generally turn down farm produce that do not meet aesthetic standards, whether it relates to weight, size, or appearance. If the blemished crops cannot be sold, many farmers leave them on site. Due to inadequate coordination between stakeholders in the food system, there is often a surplus of food being produced in farms that goes unutilized (Otterdijk 2012). This lack of coordination also contributes to the uneconomical and inefficient construction of the modern food supply chain. For Salvation Farms' 2016 report on Vermont's food loss, the organization surveyed a number of farms in the state to identify the reasons as to why crops are not being utilized. Shown below are tables from their findings.

Table 1: Farmers' stated reasons for not picking produce.

Reason for not picking produce	Number of Farms	Percent of Farms
Blemished produce (albeit edible)	28	48%
Not confident would be able to sell	24	41%
Lack of available labor	18	31%
Lack of affordable labor	6	10%
Other	12	21%

Table 2: Farmers' stated reasons for not selling produce

Reason for not selling produce	Number of Farms	Percent of Farms
General lack of demand for the item	27	47%
Oversaturation of the market with the item	25	43%
The produce- while completely edible- had blemishes	20	34%
The produce was only partially edible	6	10%
Other	10	17%

Note: Retrieved from *Food Loss in Vermont Estimating Annual Vegetable & Berry Loss* (2016).

Based on their results, imperfection of fruits and vegetables is the main reason why farmers do not harvest them. This reason also makes up a relatively large percentage of why the crops are not sold in the market. However, the two main reasons for why they are not sold are from the lack of demand for food which does not meet market specifications and oversaturation. This suggests that there is a lack of coordination between participants in the food supply chain. Because of this, it is important that farmers, markets, and members of the community have a strong relationship with one another to reduce the excess supply and prevent edible crops from going to waste.

Methods

Sunk costs are costs that have already been made but cannot be recovered. For our project we decided to quantify the sunk costs of water and fuel to understand what farmers can gain from utilizing agricultural surplus management, and salvage the blemished but edible crops they grow instead of letting them turn into food loss.

To determine the sunk cost of gallons of water on vegetables and berries not used for human consumption, we first searched for data on water usage on Vermont farms. We compiled data on water usage for farms in Vermont using the 2013 Vermont Census from the USDA National Agriculture Statistics Service. The data from the census gave the amount of water used for both vegetables and berries in acre feet/acre[1]. This was separated into categories based on irrigation types. We averaged

[1] Acre ft/acre refers to the volume of one acre of surface area to a depth of one foot.

the acre feet/acre of water used for all irrigation types for this analysis. The average acre feet/acre of water used for vegetables and berries were then converted into gallons/acre. Data from Salvation Farms' Food Loss study were used to find the acreage of both vegetables and berries lost on Vermont farms by taking the percentage of food lost from the total acreage of vegetables and berries grown (Snow 2016). We multiplied the gallons/acre of water used for each crop type by the acres lost to determine the total sunk cost of gallons of water from unused vegetables and berries.

To determine the sunk cost of gallons of fuel when vegetables and berries in Vermont were not consumed, we compiled fuel usage data from crop budgets from a variety of sources, the majority of which were listed in a University of Vermont Extension Page on Crop Budgets (Cornell University 2014, Manitoba 2016, New Jersey 1996, University of Vermont n.d., and University of Wisconsin 2014). The fuel usage data was compiled for the top fruits (strawberries, blueberries, and raspberries) and vegetables (tomatoes, potatoes, sweet corn, pumpkins, and summer and winter squash) grown in Vermont. The fuel consumption per acre was then independently averaged for vegetables and fruits, then multiplied by the acreage of vegetables and fruits produced in Vermont (3,987 and 601 acres respectively) and the percent of vegetables and berries that go unsold (16% and 15% respectively) (Snow 2016). The gallons of diesel and gasoline were then summed and multiplied by the respective average diesel and gasoline price for the first four months of 2017 (VT Agency of Transportation 2017). The sunk cost of diesel and gasoline were then summed to get a lump figure of the monetary loss of fossil fuels in unused produce.

Findings

Overall, the total sunk cost of water on unused vegetables is 6.25% of the total water used, or approximately 116 million gallons, per year. For berries, 6.67% of the total water is "lost" on unused berries which amounts to 24 million gallons of water (Figure 1). This water loss represents resources that farms are using which are never used for human consumption.

Table 3: Vermont Vegetable and Berry Water Usage, USDA 2013 Census Data

	Water Usage (acre ft/acre)	**gal/acre**
Vegetable Average	0.575	187364.325
Berry Average	0.825	268827.075

Table 4: Acres of crops and gallons of water "lost" on Vermont Farms

	Vegetables	**Berries**
Acres lost	623.52	90.15
Water lost (gal)	116,825,403.9	24,234,760.81

Table 3 shows the water usage data used from the Vermont 2013 Census, along with the conversion into gallons/acre. The averages were used across irrigation types to account for all Vermont farms in the analysis. Table 4 shows the acres of vegetables and berries “lost” on Vermont farms and the corresponding gallons of water used to grow those crops that are “lost”.

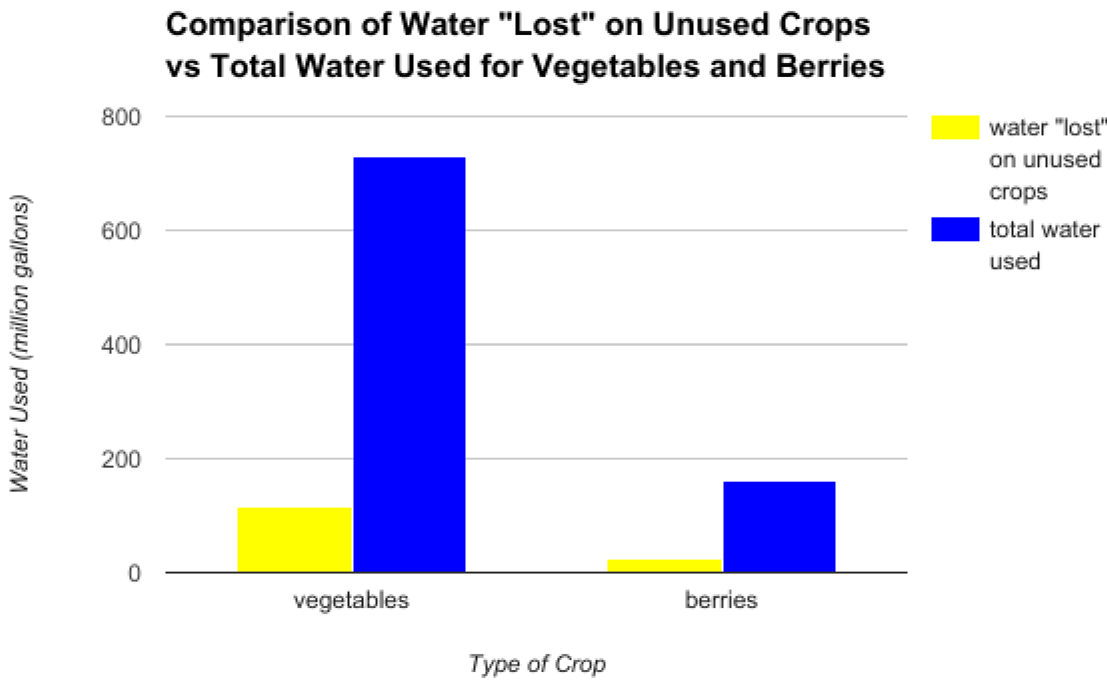

Figure 1: The yellow columns show the millions of gallons of water that are used to grow vegetables and berries which then go unused. The blue columns show the millions of gallons used to grow vegetables and berries in total, including both crops used and unused for people.

For fuels, the total sunk cost of unused vegetables is 16% of the total diesel used and 16% of the total gasoline used, or approximately 2,761 and 2,676 gallons respectively. For berries, 15% of the total fuel is “lost” on unused berries which total 2,656 gallons of diesel (Figure 2). Combined, this equated to $20,504 of fuel lost per year (Table 6). This fuel loss is another example of an environmental cost that is incurred when produce goes unused.

Table 5: Crop Production Fuel Usage by Crop for the Most Common Vermont Crops

Crop	Gallons diesel used per acre	Gallons gasoline used per acre	Source
Tomatoes	2.06	12.96	University of Wisconsin, 2014
Potatoes	81	No data	Manitoba, 2016
Sweet corn	10.33	No data	New Jersey, 1996
Pumpkins	2.06	4.89	University of Wisconsin, 2014
Summer squash	2.06	5.15	University of Wisconsin, 2014
Winter squash	2.06	2.73	University of Wisconsin, 2014
Strawberries	53 [1,2]	No data	Cornell University, 2014
Blueberries	12.31 [2]	No data	New Jersey, 1996
Raspberries	23 [1,2]	No data	Cornell University, 2014
[1] Value obtained by multiplying machine hours by fuel usage rate given in source			
[2] Production year with mature plants assumed for this value			

Table 6: Total Fuel Loss Calculations for Vermont Farms

	Gallons diesel used per acre	Gallons gasoline used per acre
Average gallons of fuel per acre (Vegetable)	4.43	4.29
Total gallons of fuel used in Vermont vegetable production	17,257.22	16,724.63
Total gallons of fuel lost in Vermont vegetable production	2,761.15	2,675.63
Average gallons of fuel per acre (Berries)	29.44	0
Total gallons of fuel used in Vermont berry production	17,691.44	0
Total gallons of fuel lost in Vermont berry production	2,653.72	0
Total fuel lost per year	5,414.87	2,675.94
Price per gallon of fuel in Vermont (April 2017)	$2.65	$2.30
Dollars lost in vegetable/berry production in Vermont, per year	$14,349.41	$6,154.66
Total dollars lost	$20,504.07	

Table 5 shows the fuel usage per acre of producing the most common crops in Vermont as listed in the Snow 2016 report. The fuel consumption data was compiled from data found in crop budgets from a variety of sources. It is important to note that these figures give an approximate value but will vary depending on the equipment and management practices used as well as the size of the farm.

Table 6 shows the steps taken to calculate the total amount of fuel lost via unused crops in Vermont in terms of both gallons and dollars. The calculations are based on the estimate of 3,897 acres of vegetable harvested and 601 acres of berries harvested and a 16% loss of vegetables and 15% loss of berries in Vermont (Snow 2016). Additionally, the fuel prices are based on an average of the fuel prices in Vermont for January-April 2017 as listed on the VTRANS website.

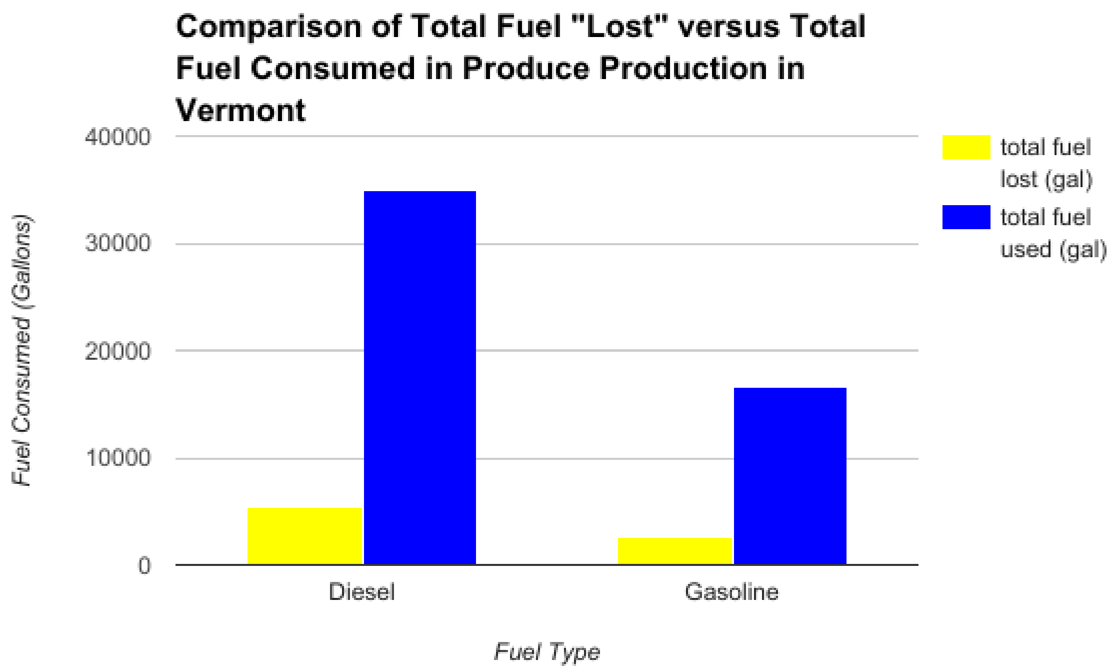

Figure 2: The yellow columns show the gallons of fuel that are used to grow vegetables and berries which then go unused. The blue columns show the gallons of fuel used to grow vegetables and berries in total, including both crops used and unused for people.

Recommendations

The estimates for this analysis were obtained using census data from the USDA 2013 Census and data found from the University of Vermont Extension Page on Crop Budgets. Given the scope of our project, we conducted our analysis using the data and information we found from our own research and what was provided by Salvation Farms. However, there are several models that can be used to validate these estimates. Many of these models were outside the expertise of the project team members, or were too complex to use within the timescale of the project. It is recommended that future teams working on this issue use one of the below models to compute the resources lost as a result of food loss on Vermont farms more accurately. There are three fossil fuel models and two water use models.

Fossil Fuel Models

Acker, Atwater, French, Glauth, & Smith (2010)- Northern Arizona University

This paper by Acker et al. (2010) provides the equation:

Gallons of diesel/acre = (Machine hours/acre) * Number of occurrences * (Diesel/hour)

Using data from budget sheets obtained from an agriculture operation in Arizona, the authors were able to calculate the approximate amount of fuel consumed in various field activities on farms. The paper contains a table that compiles these estimates, which can then be used for the “diesel/hour” variable in the equation.

We recommend that future teams either use the numbers already provided for the “diesel/hour” variable in the paper, and then obtain the other two variables (“Machine hours/acre” and “Number of occurrences”) from Vermont agricultural operations, or that “Diesel/hour” estimates specific to Vermont are calculated and used in lieu of those obtained from the Arizona operation. Ultimately the most accurate method to determine fuel consumption would be a survey presented to farms asking for gallons of gasoline and diesel fuel consumed in a growing season, acres of given crops, and machine hours per acre for both diesel and gasoline burning farm implements. This would likely be the most accurate method as fuel consumption can vary greatly based on equipment and management practices as well as the size of the farm and operator efficiency.

The benefits of using the information provided in this paper for calculating fossil fuel use would be the simplicity of the equation given, and the data given for fossil fuel consumption during specific activities. Groups should also consider the different agricultural methods used in Arizona versus Vermont. One caveat to this model is that the provided data from the Arizona agricultural operation results may not be accurate for the growing conditions seen in Vermont.

Downs & Hansen (1996)- Colorado State University

Researchers compiled a datasheet that gives the average energy use and fuel consumption of various agricultural activities. The consumption rate is given in “gallons/acre”, and thus can be easily adapted for a variety of crop types.

Since we know which crops are most widely grown in the state of Vermont, we recommend that future teams interview farmers familiar with the field work needed to produce that specific crop. Once a list of activities has been compiled, the group can divide the total agricultural land area in Vermont into its respective crop types, and then find fuel consumption for each respective crop using the data provided in the paper. For example, if we know that a certain crop needs to use a rolling cultivator and rotary hoe, the group can find the total acreage of farmland used to grow that crop, and multiply it by the consumption rate of a rolling cultivator and a rotary hoe, which is provided in the paper. The total consumption for all crops can then be summed up, providing future groups with an estimate of the total diesel fuel use in Vermont agricultural operations.

This model is beneficial because of its relative ease of use. Groups will only need to find the acreage of crops grown, and the fuel-consuming field activities associated with each crop type. Once these two variables are known, an estimate of total fuel consumption can be calculated.

When using this model, groups should consider the fact that fuel consumption rates given for each field activity were calculated as an average across multiple states. This means that environmental factors, like density and soil moisture content, may not be accurate with those seen in Vermont. This model will provide a number that is consistent with average fuel consumption rates in the United States, but not necessarily Vermont.

Hanna, Sawyer, & Petersen (2012)- Iowa State University

A document published by the Iowa State University Extension Program gives a method for calculating fossil fuel use with two layers of complexity. The simpler method involves calculating a range of fossil fuel use dependent on the acreage of farmland being cultivated. The document states that between 4-6 gallons of diesel are used per acre in agricultural operations. The second, more complex method is like the above Colorado State University (CSU) model, where a table is provided with the fuel consumption rates of a variety of field activities. If it is known which farming methodologies are used, a more accurate estimate of total fuel consumption can be calculated.

Future groups can take advantage of the less complex method given in the paper. The total amount of agricultural land in the state of Vermont is well documented, so a rough range of fossil fuel consumption can be easily calculated.

When it comes to using the more complex method, we recommend that groups refer to the CSU document rather than the table provided by Iowa State University. Whereas the CSU researchers obtained average fuel consumption rates across state lines, the Iowa State numbers were only calculated with the loamy soil types that are typical of Iowa. Thus, the results obtained from using the provided numbers may not be accurate when it comes to environmental and soil conditions found on Vermont farms.

<u>Water Use Models</u>:

Acker, Atwater, French, Glauth, & Smith (2010)- Northern Arizona University

A table with the average acre feet of water usage is included in the paper published by Northern Arizona University. There are 13 crops that have data, which can be used to calculate the total acre feet or gallons of water used in agricultural operations.

Future groups can use the information in this table to calculate gallons used for each crop type, which can provide an estimate of water used on Vermont farms. Groups should be mindful that the table was compiled using data from farms in Arizona, meaning that the amount of water needed for the same crops may be different on Vermont farms.

Jarvis (1989)- Journal of Hydrology Root Water Uptake Model

An article published in the Journal of Hydrology contains an equation and the variables needed to calculate the root water uptake of agricultural crops. This is a very powerful tool, and can be used to calculate the total amount of water actually used by the crops growing on Vermont farms. However, much information needs to be known before the model can be used, such as the layering structure and patterns of the soil that the crop is being grown in, the growth rate of the plants, the maximum root depth, and others.

This model is perhaps the most complex of the ones that would be recommended to future groups. However, it can be useful in compiling data for future reports. An example of this knowledge in use would be including the amount of water that it takes to grow a single potato on Vermont farms, or the amount of water that will effectively be "put to use" by an institution that buys a bag of food that has been reclaimed.

Conclusions

Utilizing limited resources effectively is an important aspect of promoting a healthy environment. When millions of gallons of water and fossil fuels are used to produce crops which are not consumed, those resources cannot be used to support the people and places that need food. The farmer's investments are "lost" on crops that never make it off their farms. This includes the environmental costs of not utilizing finite resources to their best potential and the costs to the community which would benefit from the fresh local foods that farmers supply. Rather than allowing these resources to be lost in the form of unused food, using edible but unmarketable surplus to feed people is an important alternative. Thus, surplus food makes it to the places that need it, such as schools and charitable food organizations.

Organizations like Salvation Farms are vital in reducing food loss and using the resources farmers invest for their intended purpose of feeding the community. Salvation Farms manages surplus food on Vermont farms through programs which move unmarketable food from farms to places which need them. Through demonstrating the environmental impacts of water and fuel usage, we recommend that these factors be considered when advocating for surplus food management. Understanding the sunk costs of resources and leaving food on farms rather than managing the surplus availability could provide a potential incentive for stakeholders to support organizations like Salvation Farms to aid in creating supply chain management practices for farm surplus.

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