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Estimating on-farm food loss at the field level: A methodology and applied case study on a North Carolina farm

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ABSTRACT

Current estimates of food loss at the farm level are either carried forward from decades-old estimates that rely on data from small farms using alternative agricultural practices, or they are based on grower estimates reported during interviews. A straightforward protocol adaptable to many crops is necessary to provide comparable data that can begin to fill gaps in knowledge on food loss in the US. Accurate estimation of on-farm losses for fruits and vegetables can inform ongoing national food loss and waste discussions and farm-level business decisions that hold potentially positive impacts for farm viability and resource-use efficiency. This paper describes a straightforward methodology for field-level measurement and demonstrates its utility on six vegetable crops harvested in 13 fields of a 121-hectare North Carolina vegetable farm.

In this case, results showed that on average, approximately 65% of the unharvested crop that remained in the field was of wholesome, edible quality, although the appearance may not meet buyers' specifications for certain markets. The overall estimated average of vegetable crops that remained unharvested, yet were wholesome and available for recovery, was 8840 kg per hectare on the case study farm. The portion of the grower's reported total marketed yield that remained unutilized in the field averaged 57%, a figure greatly exceeding current estimates of farm level loss. Developing strategies to utilize these losses could enable growers to increase the amount of fresh produce moving into the supply chain, and represent a path towards sustainable intensification of vegetable crop production.

1. Introduction

As worldwide interest in the problem of food waste has soared, an important part of the supply chain is often overlooked: food loss that occurs at the farm level, sometimes referred to as primary production. In the US, a report by the Natural Resource Defense Council in 2012 sparked renewed discussion by estimating that food intended for human consumption is lost or wasted along the supply chain from the producer to the consumer at a rate of 40% (Gunders, 2012; Gunders et al., 2017; Hall et al., 2009). However, this calculation does not include food that never reaches the supply chain, such as unharvested crops or crops that remain in the field after the primary harvest (Hall et al., 2009). Food loss during production contributes to significant losses of freshwater, cropland and fertilizer (Kummu et al., 2012), in addition to capital investments in labor and equipment. Since the crop's use is not maximized, these resources are not used efficiently. Utilizing the entire crop produced could increase yield without increasing land or chemical input usage. This means that reducing farm level losses may be a path towards sustainable intensification, defined as producing more food without increasing negative environmental impacts (Garnett and Godfray, 2012; Pretty and Bharucha, 2014). As the global population continues to increase, debates continue over whether the US needs to increase yield in commodity and other crops. An increased need for food and high rates of food insecurity have historically translated to a push for increasing crop yield, and vegetable growers continually seek to maximize their production with improved varieties, custom fertility, targeted irrigation, and complex pest and disease management strategies. An alternate way to increase the amount of food coming from farms would be to reduce losses, improving sustainability while increasing food availability (Beddington et al., 2012; Kader, 2003, 2005; Nellemann et al., 2009).

Discussion of food loss at the farm level now centers on recent estimates from just a few organizations, without basis in field measurement. The Rethink Food Waste through Economics and Data (ReFED)

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(2016) reported estimate of over 9.2 billion kilograms of food lost at the farm level annually in the US was derived from 16 grower interviews that concentrated on farms of less than 5.7 ha primarily using alternative growing practices (Berkenkamp and Nennich, 2015). The ReFED estimate also relies on Annual Vegetable Summary data, which reports on the area left unharvested for each crop, but does not include crops from fields that may have been harvested several times, then abandoned or destroyed (USDA-NASS, 2017a). Gustavsson et al. (2011) estimate for the Food and Agriculture Organization of the United Nations suggests that 20% of fruit and vegetables in North America are lost at the farm level, which includes both the field and packinghouse. Their estimate is not based on their own inquiry or field-level measurement, but instead cites other literature, which in itself is not based on field measurement (Cappellini and Ceponis, 1984; Golumbic, 1964; Harvey, 1978; Kader, 2005; LeClerg, 1964; Parfitt et al., 2010). Additionally, these earlier articles approximate losses based on estimated loss to plant pathogens. These estimates may no longer apply to modern vegetable production, as techniques, varieties, and efficiency have all improved.

Globally, researchers agree more study is needed to quantify the amount of edible crops that is lost at the production level and what factors contribute to these losses. This is needed to understand the opportunities available for further utilizing crops either for profit, or to supplement the emergency food system that can positively impact public health (Gunders, 2012; Gunders et al., 2017; Harvey, 1978; Kantor et al., 1997; Lundqvist et al., 2008; Neff et al., 2015). The World Resources Institute has developed a standard for reporting food loss and waste, the Food Loss and Waste Accounting and Reporting Standard, which ensures consistency in reporting across the supply chain (Lipinski et al., 2016). While that document helpfully documents criteria for developing reliable measurement techniques in general, it does not provide specific guidance on techniques to estimate losses at the production level.

The objective of this paper is to describe a method for better estimating amounts of available marketable and edible produce that remain in the field, based on the results of field-testing a method on 13 fields of vegetable crops grown on a 121-hectare North Carolina farm in 2016. The aim of presenting this case study is to demonstrate the use of the method through sampling and scaling of data to better understand what amount of fresh vegetables are lost in the field. Use of this protocol offers growers and others a better understanding of what amount and quality is left after the primary harvest. Growers may use the information for more informed decision-making when weighing potential returns vs costs of harvest. Food recovery organizations may use the data collection method to manage workflow and volunteers in surplus food management. Additionally, use of the method can be further tested and validated by food waste researchers, and the estimates generated can inform policy-making related to field losses for fresh produce.

1.1. Prior measurement studies

Field measurement of remaining, surplus, or unmarketable vegetable crops in the US can be complicated to coordinate and resource-intensive, and results in data from a single time point. Field sampling techniques provide a more concrete starting point for estimation in comparison to a grower's visual or perceived estimate of what remains in the field. This technique overcomes the limitation of underestimation that often occurs when visual estimates are reported (WRAP, 2017). Field sampling is considered to be a good choice of method when losses are unknown (Hartikainen et al., 2017) and losses need to be monitored on an ongoing basis (WRAP, 2017).

A few studies involving field measurement of vegetable losses within similar production management systems to the US industry have been completed in Europe. Hartikainen et al. (2017) used field measurement in combination with a variety of other methods to determine losses in carrot and onion in Nordic countries. Strid et al. (2014) used field measurement to assess lettuce crops in Sweden, and WRAP (2017) assessed lettuce in the UK. For carrots, sample areas of approximately 20 m^2 were harvested, samples were weighed, and the losses per meter of row calculated (Hartikainen et al., 2017). Numbers of piles of onions were left in the field, and average size piles were weighed and the edible but unutilized portion of the crop was calculated from these samples (Hartikainen et al., 2017). Both of these studies resulted in data that was not reported due to a low sample number (Hartikainen et al., 2018). In the lettuce study in Sweden, sample areas of 24 to 30 m^2 were marked and harvested, heads were collected, and the remaining crop per square meter was calculated (Strid et al., 2014). Researchers in the UK measured row lengths of unharvested areas of lettuce, calculating losses from the data (WRAP, 2017). Hartikainen et al. (2018) determined through questionnaire responses that 26% of the carrot crop and 15% of the onion crop is unutilized but considered to be edible in the Nordic countries. On average, 16.8% of the head lettuce crop, or approximately 3200 kg/ha of edible and inedible quality (excluding the outer leaves collected), was left unharvested in the field in Sweden (Strid et al., 2014). The lettuce left unharvested in the UK study was estimated at 19% of the marketed crop (WRAP, 2017). Providing a protocol for data collection across many crops could lay the groundwork for consistent data collection, prompting aggregation of data across regions and time points, thus enabling a better estimate of the true amount of on-farm losses.

Other related studies in developed countries and the US have used qualitative methods such as interviews and surveys to report growers' estimated rates of edible produce lost at the primary production level. Almost all of the interview-based studies have emphasized the imprecision or inaccuracy that may be present in their estimates, one describing a "reluctance to disclose" data (Milepost Consulting, 2012), along with wide variability and no way to confirm the estimates (Berkenkamp and Nennich, 2015; Hartikainen et al., 2017; Rogers, 2013; Snow and Dean, 2016; WRAP, 2011). The variability in reporting and data collection method makes the figures reported by these studies difficult to synthesize. The US studies both focused on farms less than 8 ha in size (Berkenkamp and Nennich, 2015; Snow and Dean, 2016), which may be able to reduce losses through strategies such as direct marketing to the consumer, which has been recommended as a solution to food loss on-farm (Gunders, 2012). While a large number of American farms are small, vegetable farms with positive profit rates providing significant yields to the nations' vegetable supply are generally larger than 40 ha, thus indicating a need for studies that work with farms of this size (USDA-ERS, 2013).

In 2016, North Carolina ranked in the top 10 states for US production of tomatoes, cucumbers, bell peppers, snap beans, watermelons, squash, cabbage, and sweetpotatoes (USDA-NASS, 2017a), making the state an ideal location for vegetable production research in many crops. The average farm in North Carolina is family owned (93.54%) and has been in operation for more than ten years (89.18%) (USDA, 2015). North Carolina has over 48 thousand farms averaging 69 ha, which is less than half the average farm size in the country (USDA-NASS, 2017a,b).

Reporting food loss and waste in other parts of the supply chain, such as the retail or household level, is often undertaken with a sampling and data extrapolation method (Lipinski et al., 2016). Estimating yield potential at the beginning of the season uses the same strategy, and the sampling method recommended here exceeds that which is recommended to growers, which is 3.05 m of one row (Maynard and Hochmuth, 2007), for more replicable accuracy. The method detailed in this report is purposefully straightforward and adaptable to a wide range of crops and categorizes the remaining crops broadly to enable use by growers and researchers interested in quickly gathering comparable data on food loss.

1.2. Description of the Farm used for the Field test cast study

The farm highlighted by the case study is owned and managed by a