

Developing statistical food waste data collection on the primary production of fruit and vegetables

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Abstract

Purpose

In order to meet global goals of reducing food waste, we need feasible monitoring methods to verify the impacts of reduction measures. In this study, we developed a method of gathering food waste data related to the primary production of fruit and vegetables using a farmer questionnaire.

Methods

A data collection form was planned and tested for this purpose. Data was collected on the volumes of different uses of yields, and the reasons why part of the yield does not end up in food use. The crop species that were included in this pilot study were food potatoes, carrots, white cabbage and strawberries.

Results

In primary production, the share of food use of the total yield was highest for potatoes (96 %) and lowest for carrots (72 %). 86 % of strawberries and 90 % of white cabbage were used as food.

Conclusions

In the future, it is recommended that this kind of survey would be added to annual crop production surveys that cover agricultural and horticultural enterprises in Finland. It is important to design the questionnaire so that it is as easy as possible to answer to improve the response rate and decrease the reporting load of farmers.

Keywords: food loss, food waste, agriculture, horticulture

1. Introduction

It has been estimated that up to one third of the food produced for human consumption is lost or wasted globally (Gustavsson et al. 2011), meaning that also one third of the resources used for food production are used in vain. The UN has set a sustainable development goal that aims to halve the global food waste at the retail - and consumer levels and reduce food losses in production and supply chains by 2030 (UN 2016), which is supported by the EU Commission (EU 2015). According to the Commission's 'resource efficient Europe' roadmap, the aim is to reduce waste generation and utilize all waste as a resource by 2020 (EU Commission 2011). To meet these targets the EU Commission is about to establish a common enactment for its member states to monitor food waste in all steps of the food chain (EU Commission 2018).

The EU Commission target of monitoring food waste creates pressure to improve food waste monitoring in the member states. In industrialized countries food is mainly wasted at the consumption level (Gustavsson et al. 2011), and hence the focus needs to be on the consumption level. However,

consumers can also cause food waste indirectly by demanding perfect cosmetic quality related to the size, shape and appearance of food products (Gobel et al 2015), which leads to losses and waste in the primary production stage of the food chain. In fact, in primary production especially fruit, vegetables, roots and tubers have been shown to suffer from relatively large losses varying from 10 - to 30 percent of the production volume (Gustavsson et al. 2011, Hartikainen et al. 2018). Food loss and waste in the primary production of potatoes, vegetables and fruit have been quantified in several studies in Europe (Beausang et al. 2017; Beretta et al., 2013; Davis et al. 2010; Hartikainen et al., 2014, 2018; Jordbruksverket 2009; Olsson et al. 2011; Redlingshöfer et al., 2017; Roels et al., 2010; Strid et al. 2014; Terry et al. 2011), USA (Johnson et al. 2018) and Australia (McKenzie et al. 2017). However, most of these the assessments are based on expert estimates or interviews with only a few farmers, and it has been stated that there is still a great need for more detailed, systematic and consistent data about food waste especially from primary production (Chaboud, 2017; Redlingshöfer et al., 2017).

While food waste has been studied extensively in the past years (Møller et al. 2014; Stenmarck et al. 2016), the waste data is still often limited to small and/or skewed samples (Hartikainen et al., Xue et al. 2017). The most common methods of collecting food waste data have several drawbacks. For instance, at the household level the waste bag analysis method is bound to a certain area, and hence the sample does not represent all the households of a country. Furthermore, while it is possible to include all types of households in a food waste diary study, the method is based on the households' own reporting, which often leads to underreporting the waste volumes (Hartikainen et al., van Herpen et al. 2016). Similarly, in primary production the methods used have their limitations and thus the results need to be carefully studied and hasty interpretations should be avoided.

The aim of this pilot project was to contribute to the EU Commission target to monitor food waste in primary production, with the focus on horticultural products. As a result, a method was established to collect statistical food waste data from horticultural producers using a questionnaire. As different food waste definitions exist, the questionnaire was formed so that the data can be applied using varying definitions. The project was carried out in cooperation between the statistics production and research units of the Natural Resources Institute Finland (Luke). The project was carried out between 9th of September 2017 and 8th of May 2018.

2. Materials and methods

In Finland, national waste statistics do not include waste from agriculture (Statistics Finland 2018). The current Finnish waste statistics only monitor municipal waste, which includes all type of waste from the food chain, and there is no common system to monitor the actual amount of food waste data in Finland. Hence, there is no monitoring system to provide comprehensive knowledge on the amounts and causes of losses and waste throughout the supply chain. Due to the lack of monitoring system, food waste and side flows in agriculture have been previously studied in two projects in Finland (Hartikainen et al. 2014, 2018). In the fruit, vegetable and tuber category, these studies included the production of iceberg lettuce, strawberries, potatoes (Hartikainen et al. 2014), carrots, onions and green peas (Hartikainen et al. 2018). The studies were based on questionnaires sent to farmers, representing 6-25 % of the annual production of the studied crops.

In the current study, knowledge from the past studies was used, and a questionnaire (Appendix 1) was designed to collect data from horticultural producers. The most important fruit, vegetable and tuber crops in terms of the total yield and production value were selected for this study. From open field vegetables, carrots and white cabbage were selected. Potatoes were selected from tuber crops, and strawberries from the fruit and berry production category.

To allow direct comparison with the previous studies (Hartikainen et al. 2014, 2018), we present the background information (e.g. response rates) and results of the previous studies attached to the data from the present study in the sections concerning data subjects (2.3.), and results (3). The differences between studies are further discussed in section 4.3.

2.1. Definitions and terminology

Currently, several definitions for food waste are used. Some definitions include only the parts intended for food use (Hartikainen et al. 2018), while others also consider non-food parts such as peel as food waste (Östergren et al., 2014). To solve this problem, the EU Commission has instructed a task group to come up with a uniform definition of food waste, which will be used in the monitoring of food waste in member states.

The term “food waste” is not commonly used in horticultural production in Finland and may lead to variation in answers due to the various ways of understanding the term. According to the previous studies (Hartikainen et al. 2014, 2018), in the Finnish language the term “waste” rather refers to materials that are handled as municipal waste, than to horticultural products that are, for instance, composted on the farm. The term “loss” is commonly perceived to mean a storage loss, which is only part of the food waste and loss that needs to be considered. As the terms “food waste” and “food loss” are not clear, to avoid misinterpretations and ambiguity we decided to ask the respondents where their yield ends up (food use, feed use, composting/bio-waste, energy use, left in field, or for some other use (Figure 1), and why part of the yield is not used for food. This allows the results to be used to calculate the amount of food waste using different food waste definitions. When needed, the term “side flow” was used to describe biomass that is initially produced for food use, but for some reason is used for something else or is not used (left on field) (Figure 1).

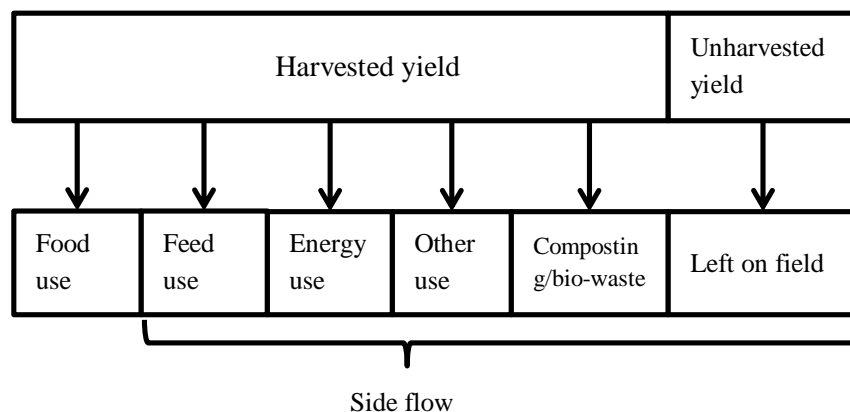


Figure 1 Uses of yield and terminology in this project.

2.2. Questionnaire

In following the content of the questionnaire (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**) and the answer options (Table 1) are described in detail. The use of crops includes all activities on the farm (storage, post-harvest treatment, packaging) before any further processing (1.). Farmers were also asked to define a percentage-based distribution of the applications for which their crops are used (1.). In addition, farmers were asked to describe why part of their harvested – and unharvested crop is used for purposes other than food (2. and 3.). Unharvested crops only included ready-to-be-harvested crops. Farmers were asked to indicate the volume of unharvested crops (2. and 3.).

Table 1 Answer options

1. Uses of the harvested yield, divided by volume	<ul style="list-style-type: none"> - Use as food, including any further processing on the farm - Animal feed - Composting/bio-waste collection - Energy - Other, please specify (open-ended answer).
2. Reasons for unharvested crops, divided by volume	<ul style="list-style-type: none"> - Factor related to size, weight, shape or appearance / the buyer's criteria not fulfilled - Larger crops than expected / crops ready for harvesting earlier than expected - Difficulties with sales - Storage losses, rotten - Other, please specify (open-ended answer)
3. Reasons for harvested crops NOT used as food, divided by volume	<ul style="list-style-type: none"> - Overproduction/not profitable/no suitable buyer - Factor related to size, weight, shape or appearance / the buyer's criteria not fulfilled - Availability of workforce - Technical problems (e.g. damaged lifting equipment) - Harvesting losses (e.g. some crops pass through lifting equipment or not all strawberries are picked) - Weather - Diseases, pests - Other, please specify (open-ended answer)

The content of the questionnaire was discussed at several project meetings between different experts who represented Luke's official statistics (crop and horticultural statistics) and Luke's "food waste" -research team. The concepts used on the drafted questionnaire were tested by means of a group interview conducted by the Questionnaire Testing and Design team at Statistics Finland (Statistics Finland 2017). The testers were recruited from Luke (many Luke employees are part-time farmers). The requirement was that each tester must be a farmer or otherwise involved in horticultural production. As a result, the group consisted of eight people as requested by Statistics Finland.

With regard to the data system required for the collection of data, the project team cooperated with the Centre for ICT Services of the National Land Survey of Finland which maintains Luke's data collection programs. The tested questions were entered into the data system, and the verifiers required and instructions on how to complete the form were also added. The name and contact details of each respondent were auto-filled, together with the crop-specific yield in 2017 in kilos (potatoes/carrots/cabbages/strawberries). The respondents were unable to change these details, but they were able to enter additional information in the comment field. The auto-filling was carried out in accordance with the crop production survey (on potatoes) or the horticultural production survey (on carrots, cabbages and strawberries) of autumn 2017. Only one crop per farm was included in order to make the questionnaire simpler to understand and faster to fill in. The respondents logged in to the application using a username and password sent to them.

2.3. Data subjects

The data subjects of the project were farms that produce horticultural products and/or potatoes. All the data subjects were selected from among those who responded to the production surveys in autumn 2017 so that it was possible to auto-fill the yield values. Producers of carrots, cabbages and strawberries were selected from the horticultural production survey and producers of potatoes were selected from the crop production survey.

Greenhouse producers were excluded from the survey as their inclusion would have required a separate data collection system for reasons of data protection. Only Finnish-speaking farms were included, as translating the questionnaire and the terms into Swedish (the other official language in Finland) would have required more specific expertise and testing time. With regard to farms producing several of the studied crops, only the crop with the largest surface area was selected. The

study ensured that the pilot study conducted for farms produced a sufficient amount of data for further purposes.

The farms (578 farms) were distributed as follows (proportion of full-country yield in brackets): 133 potato farms (77%), 37 cabbage farms (74%), 58 carrot farms (91%) and 350 strawberry farms (91%). The average response rate of acceptable answers varied between 23 and 38 percent (Table 2).. The data was collected from 19 February to 13 March 2018 (Table 3).

Table 2 Response rates in primary production the present study compared to those of Hartikainen et al. (2014, 2018).

Product	Response rate, % (accepted responses)	Number of accepted responses/ questionnaires sent	Share of final total yield of the crop, %	Reference
Carrots	25	14/58	14	The present study
	10	27/293	7-8	Hartikainen et al. 2018
Food potatoes	23	31/133	10	The present study
	14	72/497*	6	Hartikainen et al. 2014
White cabbage	38	14/37	18	The present study
Strawberries	34	116/350	21	The present study
	21	68/317	13	Hartikainen et al. 2014

* The questionnaire was sent to all potato producers but only farmers with early potatoes and engaged in food potato production were included in the assessment (excluding feed, starch and seed potato production).

Table 3 Timing of the questionnaires, the present study compared to those of Hartikainen et al. (2014, 2018).

Reference	Primary production
The present study	February-March 2018
Hartikainen et al. (2014)	March 2013
Hartikainen et al. (2018)	April 2014

3. Results

By combining the data on the uses of harvested yield and the share of unharvested yield, we calculated the total side flows that are not used as food. The share of food use of the total yield was highest for potatoes (96 %) and lowest for carrots (72 %) (Table 4). 86 % of strawberries and 90 % of white cabbage were used as food. For feed use and composting, the shares were largest for carrots, 11% and 5 %, respectively. The share of the unharvested yield was largest for strawberries (12 %) and carrots (11 %). Variation in the total shares of side flow were relatively large for all of the studied crops except white cabbage (Table 5). Variation was largest for strawberries, 0-100 %, followed by carrots, 0-79% and food potatoes, 0-40% depending on farm. For white cabbage, the share of side flow varied from 0 to 10 %. The standard deviation of the share of side flow was 4% for white cabbage and more than 10 % for the other crops.

Table 4 The uses of yields in primary production, data from previous studies by Hartikainen et al. (2014, 2018). Comparing data from the questionnaires sent in Finland.

Product	Food use	Left in field	Feed use	Composting / bio-waste	Energy use	Other	Reference
Carrots	72%	11%	11%	5%	0%	2%	The present study
	74%	4%	11 %	8%	0%	3%	Hartikainen et al. 2018
Food potatoes	96%	1%	1%	1%	0%	1%	The present study
	89%	2%	3%	1%	0%	5%	Hartikainen et al. 2014
White cabbage	90%	7%	3%	0%	0%	0%	The present study

Strawberries	86%	12%	0%	1%	0%	1%	The present study
	86%	11%	0%	3%	0%	0%	Hartikainen et al. 2014

Table 5 Variation in the results, total side flow in primary production

Product	Weighted mean	Mean	Standard deviation	Variation	Reference
Carrots	28 %	30 %	23 %	0-79 %	The present study
	26 %	21 %	15 %	0-50%	Hartikainen et al. 2018
Food potatoes	4 %	7 %	12 %	0-40 %	The present study
	11 %	13 %	11 %	0-50%	Hartikainen et al. 2014
White cabbage	10 %	3 %	4 %	0-10%	The present study
Strawberries	14 %	13 %	17 %	0-100 %	The present study
	14 %	17 %	14 %	2-40%	Hartikainen et al. 2014

Side flows were also classified according to the reasons why the produce was not used as food. The most important reasons for side flows of potatoes, white cabbage and carrots were differences in size, weight, shape and appearance, as well as overproduction (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**). For strawberries, the most important reasons were weather conditions and plant diseases.

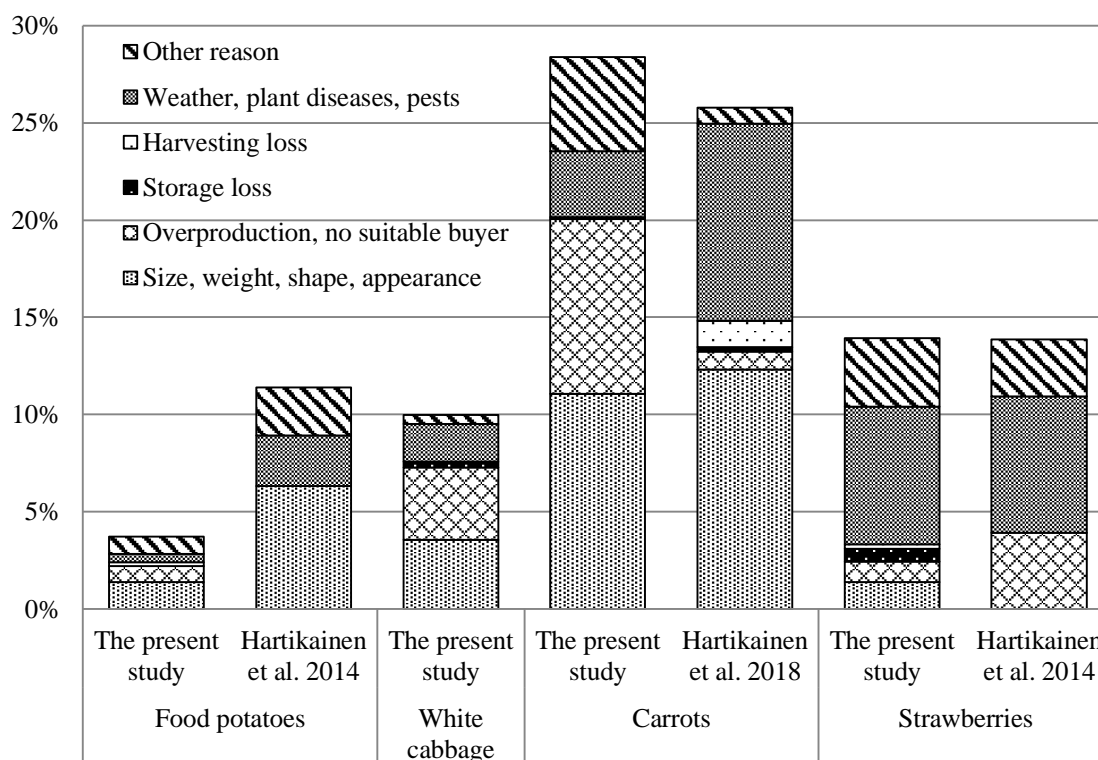


Figure 2 Reasons, why part of the yield is not used as food in primary production, results from the present study compared with data from previous studies by Hartikainen et al. (2014, 2018).

4. Discussion

4.1. Shares of food waste according to different food waste definitions

To demonstrate the impact of using different food waste definitions, the share of food waste was calculated for carrots, white cabbage, food potatoes and strawberries according to three different food waste definitions (Figure 3, Table 9). As can be seen, the share of the side flows can vary greatly depending on the definition. The definition by Hartikainen et al. (2014) results in the smallest shares. This suggests that the differences in the definitions should be taken into account carefully in the planning of future food reduction targets. According to Hartikainen et al. (2014), the targets should focus on the yield that could be still used as food. Hence, damaged and spoiled food should not be counted as food waste, because the damage, especially weather damage, is often very difficult or impossible to avoid. According to Hartikainen et al. in latter stages (after agriculture) damaged and spoiled produce is counted as food waste because the damage could be avoided with more careful planning. As different food waste definitions exist, we recommend that future questionnaires are formed so that the data can be applied using the various definitions.

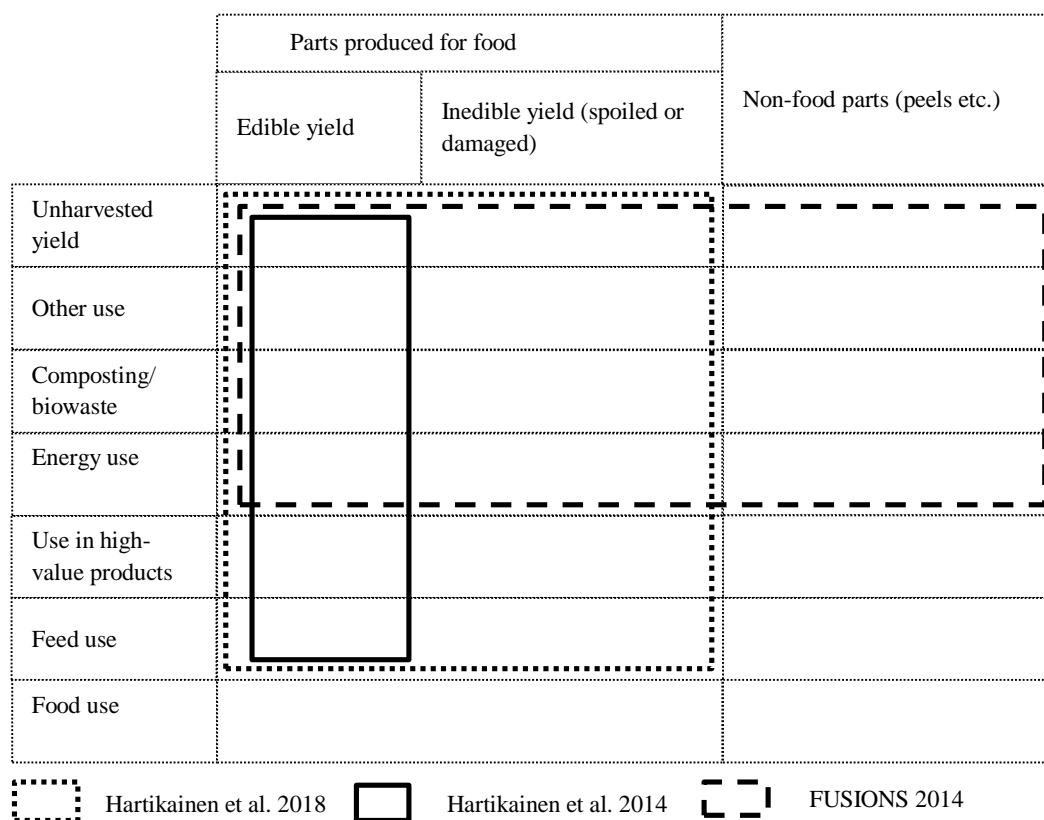


Figure 3 Definition of food waste according to the different food waste definitions.

Table 6 Share of food waste in the primary production of carrots, white cabbage, food potatoes and strawberries according to the different definitions of food waste.

Food waste definition	Carrots	White cabbage	Food potatoes	Strawberries
Hartikainen et al. 2018	28 %	10 %	4 %	14 %
FUSIONS 2014	18 %	7 %	3 %	14 %
Hartikainen et al. 2014	11 %	5 %	1 %	2 %

4.2. Comparison of assessment methods for food waste monitoring

To meet the food waste reduction targets set by the UN (2016) and EU (2015), the EU Commission is about to establish a common enactment for its member states to monitor food waste in all steps of the food chain (EU Commission 2018). To do this, we need an assessment method that is systematic and consistent and relatively low cost to implement. In the present study, we have tested food waste data gathering by questionnaires as part of the annual national statistical crop production surveys. Farmer questionnaires were preferred in the present study due to their relatively low cost of implementation allowing a relatively large share of farms to be included. The share of side flows in the primary production of potatoes, vegetables and fruit has previously been assessed using farmer questionnaires in a few research projects (Berenkamp & Nennich 2015, Beretta et al. 2013, Hartikainen et al. 2014, 2018, Milepost consulting 2012, Snow & Dean 2016). In addition, farmer interviews have been carried out by Beausang et al. (2017), Olsson et al. (2011), Strid et al. (2014) and Terry et al. (2011).

However, there is a risk that the respondents understand the questions differently than the person who formulated them. In the present study for example, there was an option “Other, please specify” for the question “How and where are harvested crops used?”, and it was selected in some cases where crops were clearly used for food, such as for direct sales, outdoor market sales and pick-your-own strawberries. In addition, waste and crops remained in the field were also reported under “Other, please specify. This problem can be solved if the data collection can be supplemented with interviews, as the interviewer can give additional information to the respondent if there is a lack of clarity. The risk of misinterpretation can also be reduced by testing the questionnaire beforehand and by giving more detailed crop-specific response instructions.

It can also be difficult for the farmers to estimate the share of the unharvested yield. In previous research projects, the share of the unharvested yield has been estimated based on field measurements for several crop species (Hartikainen et al. 2017, Strid et al. 2014, Johnson et al. 2018 and McKenzie et al. 2017). In the study by Johnson et al. (2018) in the USA, field measurements gave remarkably larger estimates for unharvested yields for certain crops (up to 85 % of marketed yield for watermelons and 68 % for cucumbers), than previous farmer estimates from the same country (e.g. 5 % for all vegetables in general, Snow & Dean 2016). They state that there is a risk of underreporting if only farmer questionnaires or interviews are used. However, these results are based on studies conducted in different parts of the country and do not necessarily include the same crops. In a previous study conducted in the Nordic countries by Hartikainen et al. (2017), the share of the unharvested yield of carrots was estimated both by field measurements and farmer questionnaires in Finland and Norway. The results differed relatively little between the two methods (although the measurements were made only on a few farms that were not representative of average carrot farms): the measured unharvested carrot yield was on average 6.2 % of total yield in Finland and 4.7 % in Norway, while the farmer estimates were on average 4.4 % in Finland and 4.5 % in Norway. In the same study, similar methods were used to estimate unharvested onion yields in Sweden, and also here the difference was relatively small 2 % vs. 4 % for field measurements and farmer estimates, respectively. Furthermore, Strid et al. (2014) studied iceberg lettuce side flows in Sweden using both field measurements and farmer interviews. The share of the total unharvested biomass (including also lower leaves that are not considered part of yield) was on average 59 % (range 45-67 %) according to measurements and 30-50 % according to farmer estimates).

It should be noted that field measurements are more labour-intensive than questionnaires and fewer farms can be included. The share of side flows can vary greatly between farms (e.g. between 0-

50% on carrot farms in Hartikainen et al. 2017), and it is critical to include a representative sample of farms in the data collection. Field measurements are also temporally more limited than questionnaires and interviews because the fields need to be examined as soon as possible after harvests, as wild animals may also visit the fields after harvest and eat part of the yield that is left. Later on it would also be harder to figure out which part of the yield was still edible during harvest. Another limitation of field measurements is that they only take into account the unharvested yield, and do not tell about the other losses occurring on the farm, e.g. during storage and sorting. According to our results (Table 5), the unharvested yield may represent only a small share of total side flow depending on the crop species.

4.3. Differences compared to previous national studies

In the present study, we were able to achieve larger response rates and a larger share of the total primary production volumes for Finnish carrots, food potatoes and strawberries than Hartikainen et al. (2014, 2018) (Table 2). However, in the present study our respondents generally represent larger producers of potatoes and carrots as the total number of respondents was relatively small. For instance, the carrot farms included in the study had around 3 times larger carrot yields (yields over 600 thousand kilos) than an average Finnish carrot yield (around 200 thousand kilos) (Luke 2018), whereas, the average yield size in Hartikainen et al. 2018 was close to the country average (213 thousand kilos). Hence, while the present study represents a larger share of the Finnish yield, it over-represents the big farms. This can be a problem when estimating overall waste figures for the total Finnish crop production, and hence it is recommended that all farm sizes are included in future questionnaires.

One possible factor that could have affected the response rates of the questionnaires is their timing. Generally, response rates can be expected to be higher when they are timed so that the farmers are not busy with critical field work operations, such as sowing and planting in the spring or harvesting in the autumn. However, in **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** it can be seen that the timing of the questionnaires in the different studies were relatively close to each other in the spring when the growing season has mainly not yet started in Finland.

The values obtained in the present study on the uses of yields in primary production are relatively similar for carrots and strawberries as in Hartikainen et al. (2014, 2018), but the share of food use of the potato yield seems to be greater in the present study (Table 5). The over presentation of larger farms could partly explain the difference. Additionally, possible reasons for this difference could be the different weather conditions or market conditions between the years studied.

Variability and standard deviations were relatively large between the respondents both in the present study as well as the previous Finnish studies (Table 5).

The level of importance indicated for the reasons that part of the yield was not used as food in primary production differ between the studies. The most important reason given for carrots and food potatoes were differences related to size, weight, shape and appearance, and for strawberries, problems related to weather, plant diseases and pests in both the present study and Hartikainen et al. (2014, 2018). However, in the present study, the second most important reason given for food potatoes and carrots was overproduction (or difficulties in finding a suitable buyer), which was only of minor importance in Hartikainen et al. (2014, 2018). For strawberries, the second most important reason were differences related to size, weight, shape and appearance in the present study, and overproduction in Hartikainen et al. (2014).

Without the size limitation the representativeness of the sample would probably have been much better than the previous studies by Hartikainen et al. (2014, 2018). This is probably because the

questionnaire of the present study is much shorter. Moreover, the Statistical Services unit of Luke is a well-known actor concerning farmer questionnaires, and the researchers of Hartikainen et al. (2014, 2018) did not have this type of credibility to engage farmers to reply to the questionnaires. Hence, it is suggested that the Statistical Services unit of Luke will send out the questionnaires in future as a part of annual crop production surveys that cover agricultural and horticultural enterprises in Finland. The present study was conducted as a separate data collection process in spring, when more information about the use of crops was available. However, since the annual surveys are conducted in the autumn (Luke 2018), respondents will need to estimate the future use of their crops. This will increase the complexity in responding to the survey, and therefore we recommend that the collection of the waste data from agriculture should be repeated with less frequency, for example, every four years. Telephone interviews are also needed for future questionnaires to improve the response rates.

4.4. Choice of crop species

Fruit and vegetables include a wide range of different crop plants and as can be seen from our results, the shares of the side flows, as well as the reasons that part of the yield is not used for food can vary greatly. However, to avoid excessively increasing the reporting load for the farmers, it should be considered whether only a few crop species could be selected to represent larger groups. In previous studies, Hartikainen et al. (2014, 2018) selected plant species that represented a large share of the total national fruit and vegetable production (carrots and potatoes), combined by species in which the part that is harvested as the yield is distinctly different (iceberg lettuce and green peas), although their production volumes are less extensive on the national scale. Also, to account for fruit and berry production, strawberries were included (Hartikainen et al. 2014).

In the future, larger crop groups could be selected, such as: greenhouse vegetables, field vegetables, fruit, and berries. For data collection, one or two important crop species from each group could be selected. In Finland, these could be greenhouse vegetables (tomatoes or cucumbers), field vegetables (carrots and white cabbage or onions), fruit (apples), and berries (strawberries). Previously, greenhouse vegetable crops have been excluded from the studies because the share of side flows in their production is very small (Franke et al. 2016). However, the production volume of greenhouse vegetable crops is relatively large in Finland (Luke 2018), and to get an overall picture of fruit and vegetable production, it should also be taken into account.

5. Conclusions and recommendations for further steps

The aim of this pilot study was to test a method for the collection of statistical food waste data from horticultural producers which would be suitable for monitoring food waste in primary production to contribute to the EU Commission's target (2018). We recommend the monitoring to be done as part of the annual national crop production surveys that cover enterprises producing agricultural and horticultural crops. We prefer questionnaires rather than field measurements due to their lower cost, allowing a larger share of farms to be included. We acknowledge that interviews tend to lead to slight underestimations of waste amounts. However, questionnaires are a significantly more cost-effective method in comparison to other methods such as field measurements.

When collecting data from farmers, it is important to design the questionnaire so that it is as easy as possible to answer to improve the response rate and reduce the reporting load for the farmers. To avoid misinterpretations, the questionnaires should be designed carefully, and more detailed crop-specific instructions should be given to the respondents. It is also important to ensure the representativeness of the results by including different types of farms according to the national

distribution of farm sizes. To ensure that the data can be applied for different uses, we recommend that future questionnaires include a number of questions, so that the data can be applied using different food waste definitions.

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7. References

- Beausang, C., Hall, C., Toma, L.: Food waste and losses in primary production: qualitative insights from horticulture. *Resour Conserv. Recy.* 126, 177–185 (2017)
- Berkenkamp, J., Nennich, T.: Beyond Beauty: The Opportunities and Challenges of Cosmetically Imperfect produce. Report 1: Survey Results From Minnesota Produce Growers. http://www.ngfn.org/resources/ngfn-database/Beyond_Beauty_Grower_Survey_Results_052615.pdf (2015)
- Beretta, C., Stoessel, F., Baier, U., Hellweg, S.: Quantifying food losses and the potential for reduction in Switzerland. *Waste Manage.* 33, 764–773 (2013) <https://doi.org/10.1016/j.wasman.2012.11.007>
- Chaboud, G.: Assessing food losses and waste with a methodological framework: insights from a case study. *Resour. Conserv. Recy.* 125, 188–197 (2017) <https://doi.org/10.1016/j.resconrec.2017.06.008>
- Davis, J., Wallman, M., Sund, V., Emanuelsson, A., Cederberg, C., Sonesson, U.: Emissions of Greenhouse Gases from Production of Horticultural Products – Analysis of 17 products cultivated in Sweden. Göteborg: SIK – The Swedish Institute for Food and Biotechnology. <http://www.diva-portal.org/smash/get/diva2:943913/FULLTEXT01.pdf> (2011)
- EU Commission: Food waste monitoring – update. EU Platform on Food Losses and Food Waste. https://ec.europa.eu/food/sites/food/files/safety/docs/fw_eu-platform_20181206_flw_pres-03.pdf (2018)
- EU: Closing the loop – an EU action plan for the circular economy. COM/2015/0614 final. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614> (2015)
- EU Commission: Roadmap to a resource efficient Europe. COM (2011), 571 (2011)
- Gustavsson J., Cederberg C., Sonesson U., van Otterdijk R., Meybeck A.: Global Food Losses and Food Waste. Rome: Food and Agriculture Organisation of the United Nations. <http://www.fao.org/docrep/014/mb060e/mb060e00.pdf> (2011)
- Göbel, C., Langen, N., Blumenthal, A., Teitscheid, P., Ritter, G.: Cutting food waste through cooperation along the food supply chain. *Sustainability* 7, 1429–1445 (2015) <https://doi.org/10.3390/su7021429>
- Hartikainen, H., Kuisma, M., Pinolehto, M., Rääkkönen, R., Kahiluoto, H.: Food waste in primary production and food processing. Foodspill 2 -Final project report. (In Finnish) MTT Report 170 <http://www.mtt.fi/mttraportti/pdf/mttraportti170.pdf> (2014)
- Hartikainen, H., Riipi, I., Katajajuuri, J.-M., Silvennoinen, K.: From measurement to management – Food waste in the Finnish food chain, “Food waste management: Solving the wicked problem”, Palgrave Macmillan 2019, submitted in 2018
- Hartikainen, H., Svanes, E., Franke, U., Mogensen, L., Andersson, S., Bond, R., Burman, C., Einarsson, E., Eklöf, P., Joensuu, K., Olsson, M.E., Rääkkönen, R., Sinkko, T., Stubhaug, E., Rosell, A., Sundin, S.: Food losses and waste in primary production. Case studies on carrots, onions, peas, cereals and farmed fish. *TemaNord* 2016:557 (2017)
- Johnson, L.K., Dunning, R.D., Gunter, C.C., Bloom, J.D., Boyette, M.D., Creamer, N.G.: Field measurement in vegetable crops indicates need for re-evaluation of on-farm food loss estimates in North America. *Agricultural Systems*, 167, 136–142 (2018)
- Jordbruksverket: Ekonomi-Kalkyler för odling av grönsaker på friland, Jordbruksinformation 25. Jönköping: Ascard, J; Håkansson, B; Söderlind, M. (2009)
- Katajajuuri, J.-M., Silvennoinen, K., Hartikainen, H., Heikkilä, L., Reinikainen, A.: Food waste in the Finnish food chain. *Journal of Cleaner Production* 73: 322–329 (2014) Accessed 15 June 2018
- Luke: Horticultural Statistics 2017. <http://stat.luke.fi/en/horticultural-statistics> (2017) Accessed 28 June 2018

- McKenzie, T. J., Singh-Peterson, L., & Underhill, S. J.: Quantifying Postharvest Loss and the Implication of Market-Based Decisions: A Case Study of Two Commercial Domestic Tomato Supply Chains in Queensland, Australia. *Horticulturae* 3, 44. (2017)
- Milepost Consulting: Left-Out: An Investigation of the Causes and Quantities of Crop Shrink, commissioned by the Natural Resources Defense Council. https://www.nrdc.org/sites/default/files/hea_12121201a.pdf (2012)
- Møller, H., Hanssen, O.J., Gustavsson, J., Östergren, K., Stenmarck, Å., Dekhtyar, P.: Report on review of (food) waste reporting methodology and practice. FUSIONS report. <http://www.eu-fusions.org/index.php/download?download=7:report-on-review-of-food-waste-reporting-methodology-and-practice> (2014) Accessed 3 January 2019
- Olsson, M., Andersson, S., Ekelund Axelson, L., Larsson, G.: Kvalitet och tillväxt för lökprodukter. Sveriges lantbruksuniversitet. Landskap trädgård jordbruk: rapportserie 45, 2011 <http://pub.epsilon.slu.se/9397/> (2011)
- Östergren, K., Gustavsson, J., Bos-Brouwers, H., Timmermans, T., Hansen, O. J., Møller, H., Anderson, G., O'Connor, C., Soethoudt, H., Queded, T., Eastal, S., Politano, A., Bellettato, C., Canali, M., Falasconi, L., Gaiani, S., Vittuari, M., Schneider, F., Moates, G., Waldron, K., Redlingshöfer, B.: FUSIONS definitional framework for food waste (full report). The Swedish Institute for Food and Biotechnology, Sweden. <https://www.eu-fusions.org/phocadownload/Publications/FUSIONS%20Definitional%20Framework%20for%20Food%20Waste%202014.pdf> (2014) Accessed 3 January 2019
- Redlingshöfer, B., Coudurier, B., Georget, M.: 2017. Quantifying food loss during primary production and processing in France. *J. Clean. Prod.* 164, 703–714 (2017). <https://doi.org/10.1016/j.jclepro.2017.06.173>
- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A.: A safe operating space for humanity. *Nature* 461, 472–475 (2009) <https://doi.org/10.1038/461472a>
- Roels, K., Vangeyte, J., Linden, V. and Gijsegheem, D.: Food losses in primary production: the case of Flanders. http://pure.ilvo.vlaanderen.be/portal/files/990443/2012_05_10_Food_losses_in_primary_production_the_case_of_Flanders_fv.pdf (2010)
- Silvennoinen, K., Katajajuuri, J.-M., Hartikainen, H., Heikkilä, L., Reinikainen, A: Food waste volume and composition in Finnish households. *British Food Journal* 116, 1058–1068 (2014)
- Snow, T., Dean, E.: Food Loss in Vermont: Estimating Annual Vegetable & Berry Loss. A Salvation Farms' Analysis. http://salvationfarms.org/VT_Food_Loss_Study_2016.pdf. (2016)
- Statistics Finland: Questionnaire Testing and Design. https://www.stat.fi/tup/lomaketiimi/index_en.html (2017) Accessed 28 June 2018
- Statistics Finland: Waste statistics. https://www.stat.fi/til/jate/index_en.html (2018) Accessed 3 January 2019
- Stenmarck, Å., Jensen, C., Queded, T., Moates, G.: Estimates of European Food Waste Levels. Stockholm, Sweden. www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf (2016) Accessed 3 January 2019
- Strid, I., Eriksson, M., Olsson, M., Andersson, S.: Svinn av isbergssallat i primärproduktionen och grossistledet i Sverige Jordbruksverket. Rapport 2014, 06 https://www.jordbruksverket.se/download/18.37e9ac46144f41921cd3665/1396256017000/Svinn+isbergssallat_140331.pdf (2014) Accessed 3 January 2019
- Terry, L.A., Mena, C., Williams, A., Jenney, N., Whitehead, P.: Fruit and vegetable resource maps, Mapping fruit and vegetable waste through the retail and wholesale supply chain, Cranfield University, WRAP. (2011)
- UN: Goal 12: Ensure sustainable consumption and production patterns. <http://www.un.org/sustainabledevelopment/sustainable-consumption-production/> (2016) Accessed 28 December 2018
- van Herpen, E., van der Lans, I., Nijenhuis, M., Holthuysen, N., Kremer, S., Stijnen, D.: Consumption Life Cycle Contributions. Assessment of practical methodologies for in-home waste measurement”, EU Horizon 2020 REFRESH. Wageningen, The Netherlands: Wageningen University and Research, 131 pp. <https://eu-refresh.org/sites/default/files/D1.3%20final%20report%20Nov%202016.pdf> (2016)
- Xue, L., Liu, G., Parfitt, J., Liu, X., Van Herpen, E., Stenmarck, Å., O'Connor, C., Östergren, K., Cheng, S.: Missing Food, Missing Data? A Critical Review of Global Food Losses and Food Waste Data. *Environ Sci Technol.* Jun 20;51(12):6618–6633 (2017). doi: 10.1021/acs.est.7b00401.