Final report

Food waste in primary production

– a preliminary study on strawberries and lettuces

Research to quantify the scale and causes of food waste and economic losses

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Front cover photography: Photo of a lettuce field post-harvest

Executive summary

Defra and WRAP commissioned this research to quantify food waste in primary production in the English lettuce and strawberry sectors – two commercially important fresh produce crops. The research was also intended to: identify key sources and causes of food waste in primary production; indicate what interventions could be made to reduce food waste; and develop guidance for quantifying food waste in primary production that could be replicated in other sectors.

Method

Several key definitions are set out below. Where relevant, these are aligned with the FUSIONS Definitional Framework[1]:

- Food waste in primary production is that which arises from when a crop becomes mature and ready for harvest, to when it leaves the farm.
- Food waste includes the removal from the human food supply chain of food that has or had the potential to be eaten i.e. crop is ripe/mature and is not diverted to animal feed or re-distribution for humans.
- Avoidable and unavoidable food waste is considered[2].

Data was collected at the end of the 2015 season on losses during that season.

Given the relative novelty of this area of research, resource constraints, and guidance provided by the industry steering group, three approaches to collecting information were used: a web survey; on-farm data collection; and one-to-one interviews with growers. These methods were designed to complement one another and capture a mix of quantitative and qualitative information.

Strawberries

The research examined a sample of 15 strawberry growers in 7 counties across England. The area planted by participating growers was 738 hectares (16% of UK production).

There is no available data on the total number of growers in the strawberry sector, which limits how information from this project can be extrapolated to the sector as a whole. All data should therefore be considered indicative.

We estimate that 9% of the mature strawberry crop was wasted in primary production in the UK in 2015 (c. 10,000 tonnes across the whole sector). Based on this, we estimate the value of strawberry crop wasted in the UK to be £24m.

The principal causes of strawberry waste were pest and disease damage (arising after the crop had matured) or fruit being misshapen or the wrong size (i.e. not meeting

[1] *FUSIONS (2014) Definitional Framework for Food Waste. Full Report*

[2] *In WRAP's 2016 report on the 'Quantification of food surplus, waste and related materials in the grocery supply chain' the term 'theoretically avoidable food waste' is used to define food waste that could in theory be edible (with or without further processing). The report notes, however, that in reality, not all theoretically avoidable food waste can be prevented and therefore the term 'practically avoidable' is used to describe what could realistically be prevented (in the timeframe of Courtauld 2025). The concepts of 'theoretically' and 'practically' avoidable are of particular relevance to agricultural systems and are explored in more detail in the method and results section.*

customer specifications). There was no evidence of significant 'over production' across the year: growers reported excess supply only for a few weeks of peak production.

Growers considered plant breeding, improvements in production practice (including improved agronomy, improved pest control and better waste monitoring), and more flexible size specifications as key ways to reduce strawberry waste.

Lettuces

In the lettuce sector, the research drew upon a sample of 14 lettuce growers in 10 counties across England. The total area of whole head lettuce planted by participating growers was 3,273 hectares (54% of UK production).

There is no available data on the total number of growers in the lettuce sector, which limits how information from this project can be extrapolated to the sector as a whole. All data should therefore be considered indicative.

We estimate that 19% of lettuce crop was not harvested by growers in 2015 (38,000 tonnes across the whole sector, of which 29,000 tonnes would typically be sold assuming a trimming rate of 24%[3]). Based on this, we estimate the value of lettuce crop wasted in the UK was £7m.

Once harvested, growers estimated 24% of lettuce head weight was left in the field as a result of trimming, although there is greater uncertainty about the scale of this and the degree to which it is avoidable.

Growers identified more accurate forecasting and programming, changes to specifications on size/weight, and improvements in production methods (including better staff training and better waste monitoring) and practice as key ways to reduce waste in lettuce production.

Conclusions & recommendations

This research has identified that crop waste levels in the primary production of lettuce and strawberry crops in England are relatively significant, variable between growers and influenced by a complex set of factors. This includes factors internal to growers' businesses, but one key finding is that external factors are likely to have a strong influence on waste in agricultural sectors too.

Addressing this is likely to require a combination of different initiatives and collaborative, supply chain approaches: no single actor or initiative can provide a complete solution. To test this we recommend piloting whole supply chain collaborative approaches to mapping and identifying solutions to waste.

Finally, it is worth noting that waste data collection in both the lettuce and strawberry sectors was variable, but growers report seeing the benefits of better measurement of waste. As part of efforts to tackle farm waste we recommend the development of tools or methods that help growers monitor and benchmark their performance. It is likely that each sector will need to develop approaches that suit the specifics of their production systems and value chains.

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[3] This value was extrapolated to the whole UK from the waste rates seen in this project and Defra Basic Horticultural Statistics, which report UK total production of 124,000 tonnes of field-grown lettuce in 2014.

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Glossary

AHDB-Horticulture – formerly the Horticultural Development Company (HDC), AHDB-Horticulture was established in 1986 with a remit to fund research and development and communicate results to UK growers.
Courtauld Commitment 2025 – a voluntary agreement, brokered by WRAP, that brings together organisations across the food system – from producer to consumer – to make food and drink production and consumption more sustainable. The agreement aims to cut the resource needed to provide our food and drink by one fifth over ten years.
Fertigate – The application of fertiliser via irrigation water.
Food waste – Food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed, including the following destinations: composting, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea but not including food or inedible parts of food removed from the food supply chain to be sent to animal feed.
FUSIONS – FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) is a project about working towards a more resource efficient Europe by significantly reducing food waste. The project ran for 4 years, from August 2012 to July 2016. It was funded by the European Commission Framework Programme.
Practically avoidable food waste – food waste that could realistically be prevented given current technological and economic constraints.
Theoretically avoidable food waste – food waste that could in theory be edible (with or without further processing).

Acknowledgements

This research would not have been possible without the support, first and foremost, of the many growers we interviewed and spoke with during the course of the project. Thanks also to the members of the project steering groups for their advice and input during the course of the research.

1 Introduction

1.1 Project context

WRAP has previously published a UK estimate for food waste at primary production of around 3 million tonnes, but stressed that this was indicative, and based on a 2004 Environment Agency synthesis of evidence available at that time. Based on a recent FUSIONS report on food waste across the EU-28[4], it would seem that this could be a significant over-estimate. The FUSIONS report estimates food waste in primary production across the whole of the EU-28 at around 9 million tonnes, although this is based on data from only six countries. It should be borne in mind that monitoring food waste in primary production is a new area across the whole of the EU and WRAP will be working with key organisations in the sector to develop, by 2018, a more robust estimate of food waste at this stage of the supply chain[5], as announced at the launch of Courtauld 2025[6]. Given the high level of uncertainty over the amount of waste pre-farm gate, the earlier 3 million tonne estimate has been withdrawn.

WRAP, working with Defra, was keen to address the lack of reliable data by commissioning a more targeted piece of research. The intention was to enable a better understanding of this waste and, if justified, identify interventions to improve the profitability of UK farming, reduce food waste and improve resource use efficiency. Insights from this current piece of research will feed in to wider collaborative work on food waste in primary production.

1.2 Research objectives

The primary objective of the research was to quantify on-farm food waste in lettuce, strawberry and potato sectors. These sectors were chosen by WRAP and Defra as they are high volume/high value sectors and are likely to suffer from food waste due to the perishable nature of the crop.

The secondary objectives of the research were as follows:

- identify 'hotspots' of on-farm food waste (i.e. points within the production systems where the most losses arise);
- understand the causes of on-farm food waste;
- indicate what interventions could be made to reduce on-farm food waste, where appropriate; and

[4] *FUSIONS (2016) Estimates of European food waste levels.*

[5] *In February 2016, the AHDB, BRC and NFU hosted a round table discussion on food surplus and food waste linked to primary production of fresh produce. The session was chaired by WRAP. The round table agreed to use a definition of food waste in line with that proposed by the EU FUSIONS project. It was evident that there is a joined up aspiration to address food surplus and waste wherever it arises, including at these earliest parts of production, even though there are issues on the table which are difficult. The group agreed that it would work on how to reduce waste in primary production and to do that through a whole chain approach involving the establishment of working groups looking at data, communications and practical projects and tools – aligned with the ambitions of the Courtauld Commitment 2025'.*

[6] *The Courtauld Commitment 2025.*

- develop a standardised method for quantifying on-farm food waste which is possible to replicate for other crops and which could be made available publicly.

While research was initiated in the potato sector, it was halted due to unforeseen resource constraints. The findings of the literature review are included in Annex 1 to this report – however there is no quantification of waste or causes of waste.

1.3 Project steering group

To ensure the research was credible, three steering groups were established by WRAP. The members of the project steering group included stakeholders from each sector and provided feedback on the proposed research approach, helped promote the work within industry and also gave feedback on the project report.

1.4 About this report

This report has been produced for WRAP, Defra and key industry stakeholders.

This report comprises six sections:

- Section 2 contains an **overview of the strawberry and lettuce sectors** covering topics such as production methods, growing locations, etc.
- Section 3 summarises the **methods** used to gather information on farm food waste (i.e. web surveys, grower interviews and on-farm data collection/measurement)
- Section 4 sets out the **results** of the analysis of the data collected, including the quantification of the proportion of mature crop 'lost' at key stages in the production stages of lettuce and strawberry
- Finally, Section 5 contains **conclusions** and **recommendations** on potential interventions to reduce farm food waste and priorities for further research

In addition to these main sections, this report contains a number of annexes:

- **Annex 1**: Literature review
- **Annex 2**: Survey and interview questions
- **Annex 3:** Lettuce types included in analysis
- **Annex 4**: Guidance for quantifying on-farm food waste in UK horticulture
- **Annex 5**: References

2 Sector profiles

Members of the research team from the University of Warwick developed 'sector profiles' for strawberry and lettuce sectors. These profiles helped inform the research approach and interpretation of results. The profiles cover the following topics:

- Markets
- Growing locations
- Growing methods and trade
- Types and varieties of crop
- Economics and farm gate prices

2.1 Markets

Strawberries are a great success story of modern agriculture[7]. In the last 15 years, improved varieties and especially improved production technologies have resulted in massive increases in both volume and quality[8]. Strawberries have gone from a three-week treat during the height of the summer season to almost a staple fruit product that is available for half the year. Almost all strawberries are sold fresh for immediate consumption and although the supply chain is short it is not necessarily simple. A majority of strawberries are grown on contract to the multiple retailers with the balance going via the wholesale and processing markets.

The lettuce market is diverse and comprises a number of different types and production approaches. In the last 10 years, the sector has evolved beyond the traditional crisp head lettuce and now encompasses a number of different types and colours. An increasing proportion of lettuce is now sold as pre-cut and often pre-washed bags of salad, hence increasing its processing and its value. Lettuce consumption is seasonal with greatest demand during the warm summer months. All lettuce is sold fresh for immediate consumption. There is effectively no secondary market.

2.2 Production methods

The production of strawberries has become very specialised. In 2014, AHDB-Horticulture reported that 158 strawberry growers paid a levy[9]. Whilst the number of levy payers does not provide a wholly accurate reflection of the number of growers as it is likely to exclude a few smaller scale producers, it does provide a reliable indicator.

[7] http://www.hortweek.com/soft-fruit-market-report-berry-boost/article/1136003 *[Accessed 12/12/2014].*
[8] http://www.fruitnet.com/fpj/article/163159/mega-strawberry-crop-beats-last-year *[Accessed 12/12/2014].*
[9] *AHDB Horticulture Personal communication.*

Table 1: Strawberries – Summary of historical production statistics[10].

Year	*Area (ha)*	*Output (1000 t)*	*Yield (t/ha)*	*Value (£M)*
2000	3,289	37.3	11.34	83.9
2001	3,416	36.6	10.71	80.7
2002	3,275	41.4	12.64	94.0
2003	3,322	47.1	14.18	109.0
2004	3,453	52.5	15.20	100.4
2005	3,898	68.6	17.60	136.8
2006	4,065	67.5	16.61	127.6
2007	4,206	83.1	19.76	155.1
2008	4,384	94.0	21.44	194.8
2009	4,426	98.5	22.25	221.3
2010	4,469	95.7	21.41	238.9
2011	4,596	101.9	22.17	245.2
2012	4,648	94.8	20.40	223.4
2013	4,606	94.4	20.50	217.8

The value of the sector has increased considerably in the last 15 years although it is still small in comparison to other agricultural sectors, e.g. potatoes and milk which respectively have annual values of £940 million and £4,214 million[11].

The production of lettuce is similarly very specialised. In 2014, AHDB reported that 94 lettuce growers paid a levy[12]. This figure is likely to exclude a few smaller producers. UK production of lettuce is fairly stable with the area under lettuce and output changing little since 2000 (see table below). However, the basic statistics mask the innovation and industry consolidation that has occurred since 2000[13]. New varieties, double and triple cropping, irrigation and baby-leaf types have changed the profile of the industry.

Table 2: Lettuce (field vegetables) production statistics[14]

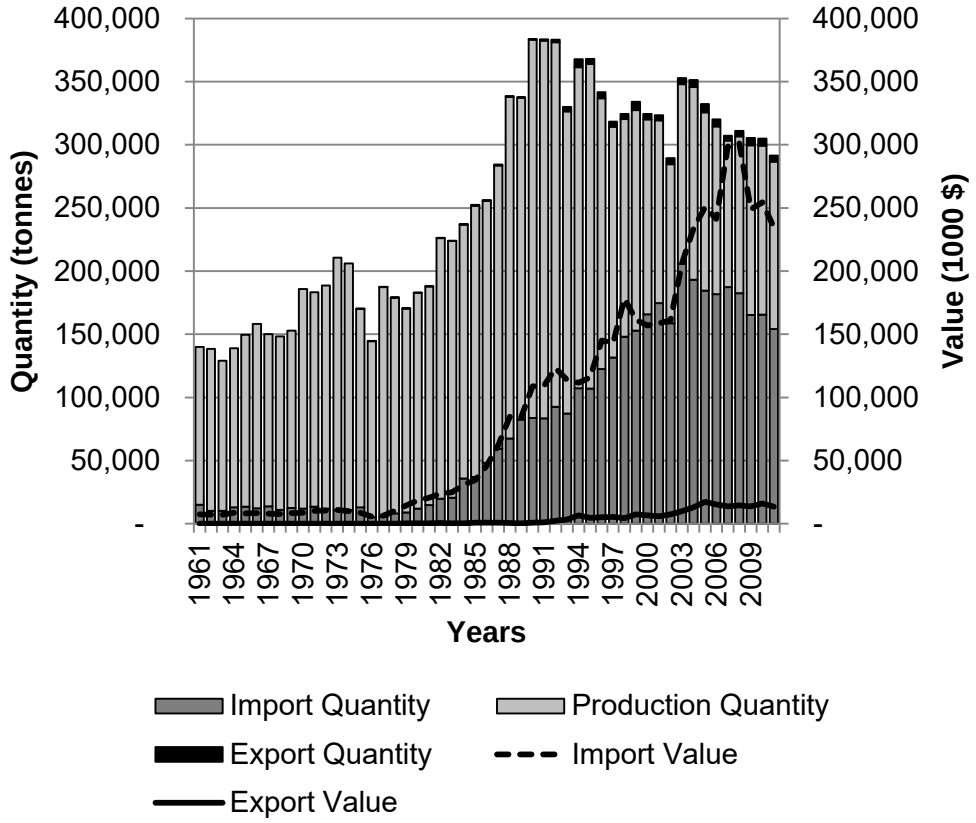
Year	*Area (ha)*	*Output (t)*	*Yield (t/ha)*	*Value (£M)*
2000	6,410	136,000	21.2	63.6
2001	5,270	124,000	23.5	78.1
2002	4,776	110,000	23.0	67.5
2003	5,543	126,000	22.7	85.3
2004	6,010	143,000	23.8	79.3

[10] *Defra Basic Horticultural Statistics 2014. https://www.gov.uk/government/statistics/basic-horticultural-statistics-2014 [Accessed 05/12/2014].*
[11] *Defra. Agriculture in the UK 2013.*
[12] *AHDB Horticulture Personal communication.*
[13] *The Ecologist. www.theecologist.org/News/news_analysis/1083133/inside_the_salad_megafarm_supplying_the_uks_appetite_for_lettuce.html (Accessed 14-01-2015).*
[14] *Defra Basic Horticultural Statistics 2014. www.gov.uk/government/statistics/basic-horticultural-statistics-2014 [Accessed 02/12/2014].*

2005	5,601	133,000	23.7	72.5
2006	6,069	126,000	20.8	96.4
2007	6,075	108,000	17.8	81.8
2008	5,592	117,000	20.9	97.6
2009	6,349	128,000	20.2	110.0
2010	6,060	127,000	21.0	132.3
2011	6,063	126,000	20.8	129.3
2012	5,894	116,000	19.7	141.5
2013	5,935	117,000	19.7	138.8

Lettuce production in the UK has been decreasing in the past decades, whilst lettuce imports have increased steadily (see figure below). Before 1984, lettuce imports accounted for less than 10% of the national supply; between 1985 and 2000 this share increased to 50% and, since the start of the new millennium, lettuce imports have ranged between 50-60% of national supply. This data reveals the growing national reliance on imported lettuce to satisfy local demand.

Figure 1: UK lettuce trade and home production statistics (FAOSTAT)



2.3 Location of production

Strawberry production occurs all over the UK, however, the majority is located in Norfolk, Suffolk, Kent, Herefordshire, Shropshire, Staffordshire, Hampshire and Somerset.

In spite of the unprecedented growth in national production (Figure 4) imports of strawberries have increased considerably in the past three decades due to consumer demand to have strawberries all year round. In 2011, strawberry imports accounted for 30% of national supply. After a peak reaching the 50% landmark in 1996-1997, imports have seen their share decrease in part due to the country's capacity to independently supply the strawberry market during the peak of the season in the summer, e.g. between June and October

Figure 2: UK strawberry production and import between 1961-2011[15]

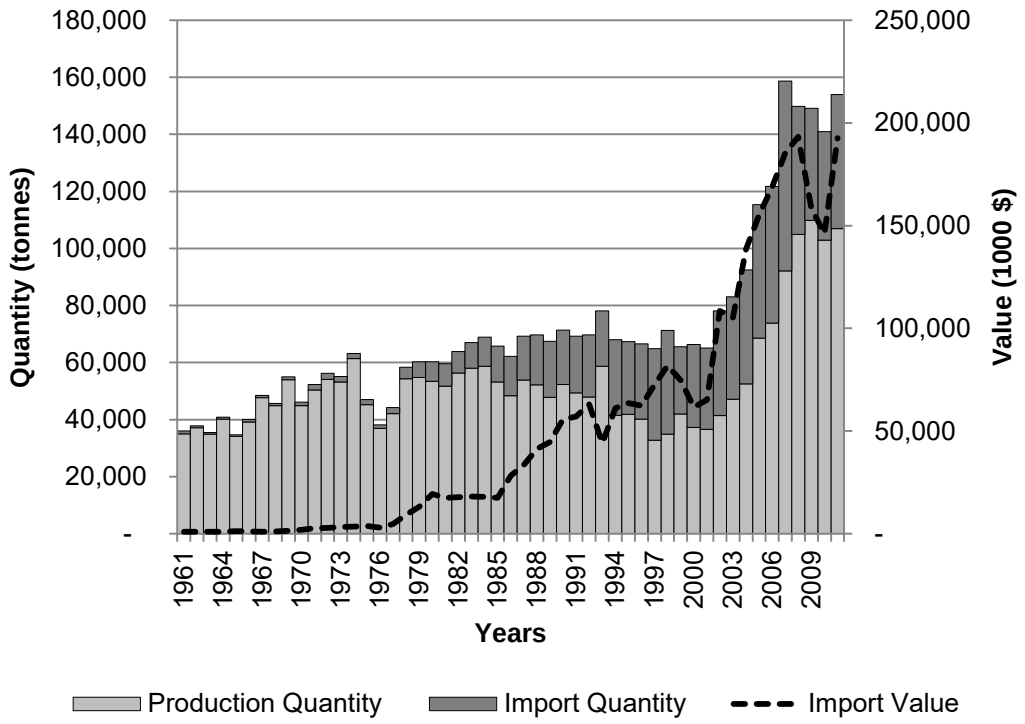


Table 3: Country of origin & seasonal summary of strawberries[16]

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
UK				X	X	X	X	X	X	X		
Spain	X	X	X	X	X							
Morocco	X	X	X	X								X
Egypt	X	X	X								X	X
Israel	X	X									X	X

Lettuce can also be grown in most areas of the UK, however, the majority of production occurs in the Vale of Evesham, the south coast areas (mainly Sussex), Shropshire, Lancashire and Lincolnshire.

[15] *FAOstat, 2014*
[16] *http://www.britishsummerfruits.co.uk/html/strawberries.htm*

Figure 3: Location of the British Leafy Salads Association members[17]

2.4 Production methods

Strawberries, like many horticultural crops, have become a specialised growing operation. In the UK, the vast majority of strawberries are grown in polytunnels that allows the growing season to last from March to October and which protects the crop from the vagaries of weather. A majority of strawberries are produced in specialised growing media (peat/coir mixes) although soil based systems still exist. Most crops are fertigated and access to a reliable water supply is critical to production. Protected production allows more sophisticated pest and disease control. Harvesting is done by hand and is therefore an expensive part of the production process. Table-top or gutter type production systems are becoming popular as they increase the efficiency of the labour used.

Different types, ever- or June-bearing will be established at different times to try and supply fruit throughout the season. The best growers expect that 95% of their fruit will be class 1 and therefore sold fresh while class 2 fruit can be sold into the processing, jam or juicing market. The introduction of polytunnels for the production of soft fruit in the UK in the 1990s has contributed to increase the industry's standards and ensure a higher and more stable supply of

[17] *British Leafy Salads. www.britishleafysalads.co.uk/about/members.shtml [Accessed 12-12-2014]*

strawberries. However, strawberry consumption is directly linked to weather conditions; a warm summer will register a higher demand for strawberry fruit. Open field and pick-your-own production is now niche.

Lettuce, like strawberries, has also become a specialised growing operation. UK field production typically starts in March and crops will be sequentially planted to allow cropping through to autumn. The length of the season is governed by soil condition and temperature in both spring and autumn. Depending on the soil type, production methods and availability of irrigation water, the same land may be double or triple cropped. Crop type will also influence output since head lettuce is very different to baby leaf salad so it is difficult to generalise. Head lettuce is assessed for maturity and quality by the picker who will judge what is suitable and what is not. Crop not making the grade will be left to a second harvesting pass or discarded in the field. Baby leaf is harvested using a specialised harvester that takes all of the crop.

2.5 Types and varieties of crops

All three sectors have numerous types of product. For strawberries, the most common variety is by far Elsanta but growers are increasingly adopting other varieties such as Sonata, Sweet Eve, Driscoll's Jubilee, Ava Rosa, Lambada, Darselect, Elsinore, Everest, Red Glory, Capri Luscious and Malling Centenary.

Type of lettuce varies depending on market channel: the most popular include Iceberg, Little Gem, Romaine, Butterhead, and Multi-Leaf and Speciality varieties[18]. Lettuce also varies in colour with red types becoming more popular.

2.6 Economics

Most strawberry growers supply on contract to the major supermarkets, frequently through producer organisations, and therefore a farm gate price is a bit of a misnomer since many contracts are renegotiated on an annual basis. Growers who supply more than one multiple are likely to agree different prices based on the size and delivery conditions attached to the contract. This information is confidential. Unlike mainstream crops, standardised farm management values are provided as quite wide ranges and will rarely relate to individual operations. The wholesale price for strawberries is unlikely to reflect the cost to the multiple supermarkets but is useful for context[19] (see Table 4).

[18] *Elsoms Seeds. www.elsoms.com/downloads (Accessed 02/12/2014)*

[19] *Defra. https://www.gov.uk/government/statistics/historic-statistics-notices-on-wholesale-fruit-and-vegetable-prices-2014*

Table 4: Wholesale price of strawberries (2014)

Month (2014)	May	Jun	Jul	Aug	Sep	Oct
Price (£/kg)	1.88	1.53	2.25	2.18	2.35	2.21

Nix[20] suggests that the gross margin for June bearers is between £1,333 and £14,739 per hectare and between £1,979 and £32,983 for ever bearers. The SAC Farm Management Handbook does not supply any financial projections. The costs of production are equally variable and based on the sophistication of the production system; this can be very variable although the very best growers are now evolving to very similar systems. For most systems, the variable costs will between £43,164 and £112,041 per hectare. Labour in the form of harvesting and grading/packing will typically account for between 32% and 43% of variable costs.

The major market is for fresh fruit and a large majority of fruit goes down this route. However, strawberries are delicate and perishable, so class 2 fruit is sold to the processing, jam and juicing markets, however, this market is very small in comparison to the fresh market.

As with strawberries, most lettuce growers also supply on contract to the major supermarkets and therefore a farm gate price is a bit of a misnomer since many contracts are renegotiated on an annual basis. Growers who supply more than one multiple are likely to agree different prices based on the size and delivery conditions attached to the contract. This information is confidential. Unlike mainstream crops, no standardised farm management values are available. The wholesale price for lettuce is unlikely to reflect the cost to the multiple supermarkets but is useful for context[21].

Table 5: Wholesale price of lettuce

Month (2014)	May	Jun	Jul	Aug	Sep	Oct
Cos (£/head)	0.53	0.53	0.46	0.44	0.49	0.50
Crisp (£/head)	0.33	0.38	0.32	0.37	0.42	0.33

[20] *John Nix Farm Management Pocketbook, 44th edition (2014)*
[21] *Defra. www.gov.uk/government/statistics/historic-statistics-notices-on-wholesale-fruit-and-vegetable-prices-2014 [Accessed 14-01-2015]*

3 Method

Three approaches to data collection were undertaken: a web survey, on-farm data collection, and one-to-one grower interviews. These methods were intended to complement one another and capture a range of quantitative and qualitative data. A literature review was conducted at the beginning of the project in December 2014. The results of the review were used to inform the scope and the research methodology of this project (see Annex 1).

3.1 Relevant definitions

Several definitions are important to understand the scope of this research. The relevant definitions used in this project align with the EU FUSIONS definitions[22]:

"Food means any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be consumed by humans…"

For the purposes of identifying when a 'crop' becomes a 'food', *"The food supply chain starts when… [crops are] ready for harvest…, not just those that are harvested and subsequently not used."* Therefore a crop that matures but is subsequently damaged, eg by weather or pests, or which is not harvested for commercial or other reasons, is considered food waste.

"Food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed, including the following destinations: composting, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea but not including food or inedible parts of food removed from the food supply chain to be sent to animal feed."

In February 2016, the AHDB, BRC, NFU[23] hosted a round table discussion, chaired by WRAP, on food surplus and food waste linked to primary production of fresh produce. The group agreed that it would work together to reduce waste in primary production and to do that through a whole chain approach. The round table also agreed a definition of food waste in line with the FUSIONS definition.

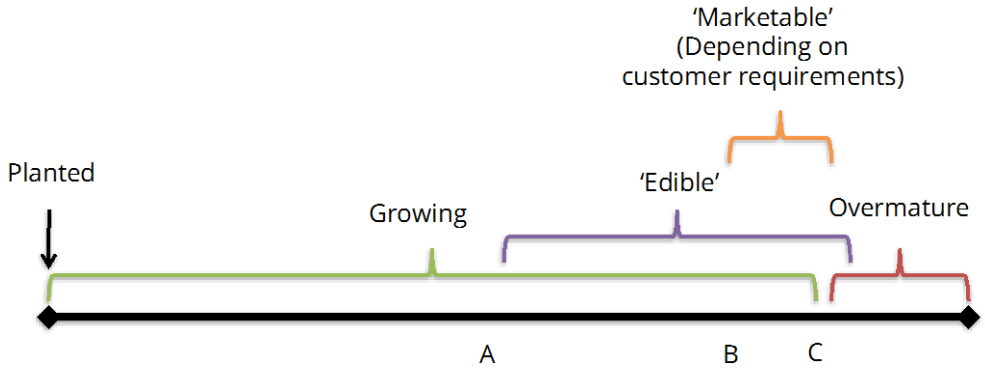
It is worth noting that for many crops the point at which they become 'mature' or 'ready to harvest' is a grey area and driven as much by commercial/market considerations than crop physiology or edibility. Creating an unambiguous and consistent cut-off boundary between 'food' and 'non food' is therefore difficult. The example of lettuce is shown in Figure 4 below: the lettuce crop is edible before it becomes marketable and fully mature. Since the data in this project is largely based on grower estimations, the grower's interpretation of this boundary was key, and the grower was necessarily an equal partner in judging

[22] FUSIONS Food Waste Quantification Manual (*http://www.eu-fusions.org/phocadownload/Publications/FUSIONS%20Food%20Waste%20Quantification%20Manual.pdf*)

[23] *The British Retail Consortium, the National Farmers' Union and the Agriculture and Horticulture Development Board.*

when crop crossed the line from immature to mature (non-food to food). This may introduce an element of uncertainty in the data, in that each grower may have interpreted the boundary in a slightly different way.

Figure 4: Defining crop maturity – Lettuce example



It is worth noting that pest and disease damage is a driver of waste that can occur both before and after maturation. As the scope of this project examines waste of mature crop (i.e. 'food'), crop waste due to pest and disease damage that occurs prior to maturation is not within scope. Again, as the point of maturity is a grey area for many crops, determining whether pest and disease damage occurred before or after maturity (or both) is difficult to do accurately without very specific in field measurement. To reduce the potential for including immature crop waste we explained the scope of the project to the growers we interviewed.

3.1.1.1 Avoidable vs. unavoidable waste

In WRAP's 2016 report on the '*Quantification of food surplus, waste and related materials in the grocery supply chain*[24]' the term 'theoretically avoidable' food waste is used to define food waste that could in theory be edible (with or without further processing). The report notes, however, that in reality, not all theoretically avoidable food waste can be prevented and therefore the term 'practically avoidable' is also used to describe what could realistically be prevented. The concept of 'theoretically' and 'practically' avoidable waste are of particular relevance to agricultural systems given the inherent unpredictability of production systems and consumer demand.

In describing food waste in this project we have adopted these terms to explore the degree to which the waste can be addressed and reduced.

It is also important to consider how *inedible* parts of crops are dealt with in this project (e.g. the base of iceberg lettuce or strawberry hulls). If disposed of at home by the consumer, these inedible fractions of food would be considered

[24] *WRAP2016* http://www.wrap.org.uk/content/quantification-food-surplus-waste-and-related-materials-supply-chain

unavoidable[25]. However, given the boundaries of this research are the farm we have considered them *all theoretically avoidable* from the point of view of the grower (i.e. in theory, the grower could grow, harvest and sell a crop with no food waste left on farm).

A commentary on the avoidability of different types of waste is included in the next section. Overall we propose that there is very little completely *unavoidable* crop waste in primary production – major sources of waste are all theoretically avoidable. There is, however, a notable difference between what is theoretically avoidable and practically avoidable, from a commercial and technical point of view. Within the scope of this research we were unable to ascertain the degree to which waste is *practically* avoidable. This is an area for further research.

3.2 Sources of food waste in primary production

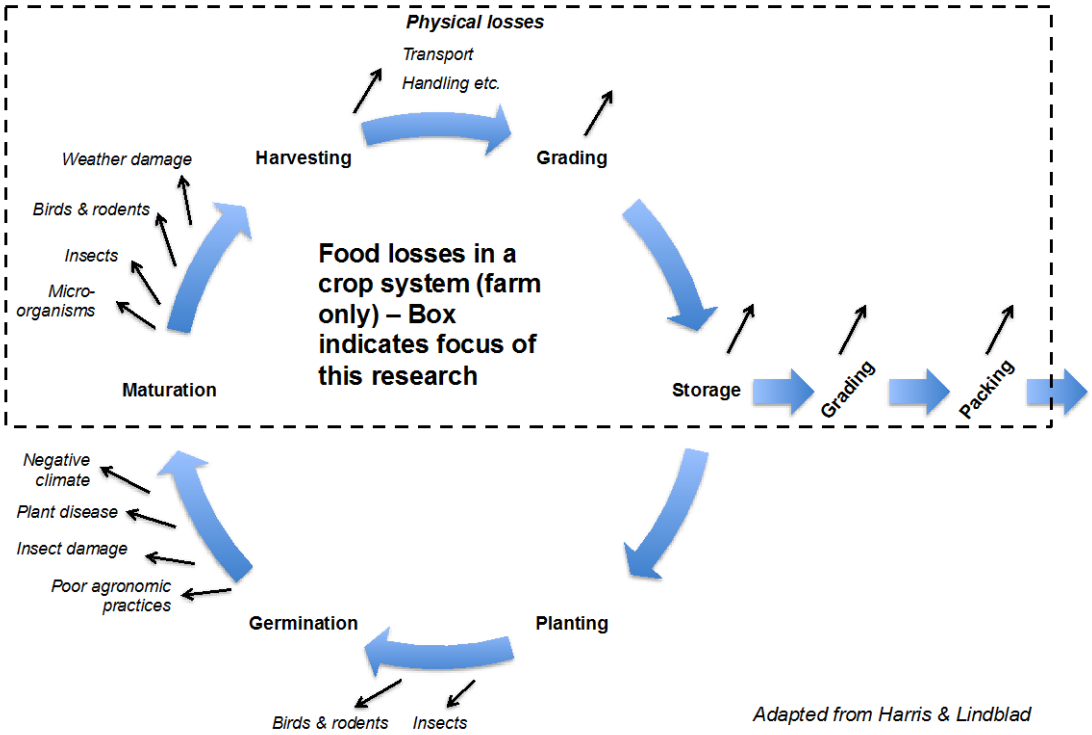
Any loss of food arising pre-farm gate is included. This includes any waste arising from harvest, grading, storage and processing when carried out on farm (see Figure 7 below)[26]. In fact, the two crops researched in this project had very little post harvest grading, storage or processing, because of the need to get these highly perishable crops to customers as quickly as possible once an order is received from the customer.

In order to design an appropriate data collection method the research team had to identify and describe the anticipated key sources of waste in lettuce and strawberry production. This was done though desk-based research and discussion with the steering groups and individual growers as part of a piloting process. The key sources of waste are summarised in Table 10 below. No additional sources of waste were identified as a result of the interview processes later in the research.

[25] *For example, WRAP (2013) Household Food and Drink Waste in the United Kingdom 2012. Final Report. In fact this analysis presented the unavoidable fraction of whole items thrown away by consumers (e.g. the banana skin of a whole banana) as all avoidable, rather than split into the avoidable (banana flesh) and unavoidable fractions (banana peel).*

[26] *While it is acknowledged that some post-harvest processes (such as cold storage of potatoes) can occur on farm or off farm, it was decided to keep the unit of analysis as 'the farm'. Given the research was going to identify where waste arose on farm these inconsistencies between businesses could be accounted for in the analysis of overall waste.*

Figure 5: Sources of on-farm food waste[27]



[27] *Adapted from Harris & Lindblad*

Table 6: Key sources of waste in lettuce production

Type	*Waste*	*Description*	*Typical fate*	*Avoidability*
Head	**Trimming**	*Outer leaves of crop removed during harvest and packing. Mainly occurs in-field on harvesting rig or during picking process itself.*	*Ploughed into soil*	*Theoretically avoidable*
Head	**Unharvested heads**	*Heads are selectively harvested as rig passes through the field. This is due to quality requirements e.g. lettuce heads too large/small.*	*Ploughed into soil*	*Theoretically avoidable*
Head & baby leaf	**Unharvested areas or batches**	*Whole areas of crop are ploughed in due to significant damage or demand/supply mismatch.*	*Ploughed into soil*	*Theoretically avoidable*
Head & baby leaf	**Internal quality check rejection**	*Quality issues are picked up in cold store before being sent to customer.*	*Returned to land and ploughed into soil, occasionally landfilled (if packaged); very occasionally sent to animal feed*[28]	*Theoretically avoidable*
Head & baby leaf	**Customer rejection**	*Customer sends back product due to quality issue.*	*Returned to land and ploughed into soil; landfill (if packaged); very occasionally sent to animal feed*[28]*)*	*Theoretically avoidable*

[28] *Not considered 'food waste' under the definitions discussed in the proceeding sections*

Table 7: Key sources of waste in strawberry production

Waste	*Description*	*Typical fate*	*Avoidability*
Outgrading in-field during harvest	*Fruit with quality issues are separated out during harvest in the field.*	*Picked and disposed of on farm e.g. compost, burying on farm[29]; occasionally sent to industrial composter or anaerobic digester*	*Theoretically avoidable*
Internal quality check rejection	*Quality issues are picked up in cold store before being sent to customer.*	*Disposed of on farm e.g. compost, burying; occasionally sent to industrial composter or anaerobic digester; very occasionally sent to animal feed[30]*	*Theoretically avoidable*
Customer rejection	*Customer sends back product due to quality issue.*	*Disposed of on farm e.g. compost, burying; occasionally sent to industrial composter or anaerobic digester; very occasionally sent to animal feed[30]*	*Theoretically avoidable*

3.2.1 Timeframe

Rather than collect information on 'average' historic waste from growers it was decided to ask for information on waste during the 2015 harvest. While it was acknowledged that waste can vary significantly from year-to-year and 2015 might have not been 'typical', it was decided that grower perceptions of a specific and recent season would be more consistent and reliable than a more subjective and general 'average'. To put 2015's harvest and associated waste in historical perspective, growers were also asked to compare 2015 to previous years (see Annex 2 for exact interview questions).

3.3 Data collection approaches

Given the relative novelty of this area of research and inevitable resource constraints, three approaches for collecting information on farm waste were used. More detail on these approaches is outlined in the sub-sections that follow.

3.3.1 Web survey

The web survey was designed to capture key quantitative and qualitative data on the quantities and causes of waste as well as the views of growers on how to reduce waste.

[29] *As is explored later in this report, the rise of the Spotted Wing Drosophila (SWD) has meant that growers are now recommended to pick and dispose of all damaged/diseased fruit to stop the spread of this pest*

[30] *Not considered 'food waste' under the definitions discussed in the proceeding sections*

The survey included closed and open questions and targeted the entire lettuce and strawberry grower population. The survey was developed and refined through stakeholder evaluation and piloted among the target audience (see Annex 2). The goal of the web survey was to capture as large a sample of the population as possible, to increase the breadth and robustness of the data.

The survey was distributed to growers via AHDB-Horticulture email alerts and newsletters in early November. Growers were able to respond to the survey between 4th and 29th November 2015. This time period was chosen as it was at the end of both sectors' seasons and so growers were likely to have as clear a view of waste for 2015 as possible. The survey was promoted through industry stakeholders such as the NFU and in farming media for several weeks prior to opening as well as during the survey period.

To further encourage participation, growers were e-mailed directly by the research team using a contacts database developed at the start of the project. The database included 95 strawberry growers and 69 lettuce growers. All participants were also entered into a prize draw for a tablet computer, as an incentive to take part and as part of a strategy to maximise response rates.

It was anticipated from the beginning of the project that achieving high levels of uptake would be difficult – and this was the feedback from the steering groups. Despite concerted efforts before and throughout the survey period, the uptake was extremely limited; four responses were received for the strawberry survey, two of which had volunteered to be interviewed, and two responses were received for the lettuce survey, one of which was due to be interviewed.

At the end of November 2015, when it became clear that web survey responses would not reach the levels necessary for a meaningful analysis, the decision was made to switch research resources to delivering more face-to-face interviews. These interviews were already beginning to yield useful results – and a good coverage of total growing area was anticipated. This experience is an important learning for future projects that wish to quantify waste in other sectors.

3.3.2 Grower interviews

The second approach to gathering evidence on food waste were the one-on-one interviews with growers. In all, semi-structured interviews were undertaken with 13 lettuce growers and 12 strawberry growers.

The interviews were used to collect data on the quantity of waste as well as qualitative information on the causes of, and solutions to, crop waste. Purposive snowball sampling was used to identify and recruit interviewees; i.e. interviewees were initially identified through sector profiling and expert advice from the project steering groups, and later through asking interviewees to recommend other growers. A simple recruitment table with columns on size, location, and majority production style was used to make sure the sample was made as representative as possible with the chosen

recruitment strategy and to avoid oversampling of any particular geographical area or farm size.

The research team approached growers by phone or e-mail. Growers who consented to be interviewed were visited by one or two members of the research team; the lead interviewer was present at all interviews to maintain consistency of approach and interpretation. Interviews took place at the end of the season from October 2015 to January 2016, when growers had time to spare and were able to reflect over the season as a whole. The questions from the web survey were used as the structure for a discussion on waste (see Annex 2). All interviews were recorded with the consent of the growers, and later transcribed and anonymised[31]. This was to ensure a minimum amount of error was introduced in capturing the views of growers. After the interviews were completed and transcribed and data was extracted, growers were contacted with any final questions and/or clarifications.

3.3.3 Farm data collection (lettuce farms only)

The final approach to gathering evidence on lettuce waste was the use of farm data – either from existing farm records (e.g. planting data) or through dedicated measurement during and after harvesting. This approach was developed through discussion with the lettuce steering group, who identified that the complexity and variety of the production systems would make estimating waste in an interview challenging. Thus, the goal of the data collection was to obtain more in-depth and accurate data on lettuce waste, that could be used to compare against the results coming from the interviews.

Data was collected over the 2015 harvest season by three lettuce growers. Table 8 summarises the approach taken across the three businesses. The lettuce growers were also interviewed at the same time as the other growers.

3.3.4 Combining data approaches in the analysis

To make use of the new contacts identified by the web survey the decision was made to approach the four growers who had completed the survey and conduct telephone interviews with them. This enabled the research team to combine the quantitative waste estimates from the two methods and ensure they were comparable. Web survey respondents were contacted first by email and then by phone so that further questions could be asked, clarifications could be made, and further discussion could be had. This was done after the completion and transcription of the interviews so that the research team were able to determine any additional assumptions that needed to be understood in the survey data. The follow-up conversations were designed to make sure that the quantitative data were comparable. Due to their shorter length and the method in which we conducted them (by phone rather than in-person), we have not included them in the qualitative analysis of causes of waste and potential solutions.

[31] *The recordings are due to be destroyed as soon as the project report is completed and signed-off*

Given that some of the interviewees referred to farm records (e.g. planting and harvesting data) we have combined the results from the interviews and farm data collection approaches to give our overall estimates of crop waste. Differences in waste levels reported by these two groups are explored, however.

Table 8: Summary of data collection methods for lettuce growing companies

	Farm T	***Farm X***	***Farm L***
Grower type	*Hand-harvested wholehead to retail.*	*Hand-harvested wholehead to retail*	*Hand-harvested specialist wholehead to processing (bagged salads)*
Data sources	*Existing farm planting and harvesting records*	*Existing farm planting and harvesting records*	*Data collected specifically for WRAP research project*
Trimming waste	• Grower unable to commit resource to measure this (as crop sold 'by the head' it does not represent an economic loss to the grower)	• Not measured	• One of harvesting team weighed a sample of heads in each batch harvested to establish weight of crop wasted during trimming process. This was done across the whole season, with c. 10 heads being sampled each time
Unharvested heads	• Number of heads harvested recorded by harvesting manager. This is subtracted from plantings data to establish field waste. Reasons for significant waste recorded on data sheets	• Number of heads harvested recorded by harvesting manager. This is subtracted from plantings data to establish field waste. Reasons for significant waste recorded on data sheets	• One of harvesting team counts heads left unharvested in field after harvesting of block has finished. This is compared with typical planting densities and establishment rates to estimate field waste • Major reasons for waste noted for each batch
Unharvested areas	• Same data source as above	• Same data source as above	• Lengths of crop left unharvested were measured using a trundle wheel. This was compared to crop planting data to establish proportion of crop ploughed in
Rejected by customer or internal quality check	• Established at end of season from QA and rejections records	• Established at end of season from QA and rejections records	• Established at end of season from QA and rejections records

3.4 Data confidentiality and privacy

The Data Protection Act 1998 applies to organisations holding information about individuals in electronic (and sometimes paper) format. Any personal information collected during this research has been handled according to eight principles:

- Fairly and lawfully processed;
- Processed only for the specific purposes of this project;
- Adequate, relevant and not excessive;
- Accurate and, where necessary, kept up to date;
- Not kept for longer than is necessary (project end dates can change over time, but we expect that all relevant information will be securely destroyed by the end of 2016);
- Processed in line with the rights of the individual;
- Kept secure; and
- We do not expect to transfer the data to anyone, but certainly will not transfer it to countries outside the European Economic Area.

Non-personal data collected in relation to this project during interviews, farm visits and the web survey was used solely for the purposes of this project and has been treated in the strictest confidence. Information based on this data was anonymised before it was shared with WRAP and Defra, and before any project outputs were published. All non-aggregated, non-anonymised data (e.g. interview recordings and transcripts) are to be destroyed on completion of the project.

Web survey and interview data was collated and anonymised with any personal information detached from the responses. Each survey and interview response was given a randomly generated identification code to enable easier data analysis; these codes are not traceable to personal information and are only connected with personal information in a separate password protected file and server, accessible only to two members of the research team. This is to ensure that the data, once analysed and presented, cannot be used to identify any participating farm or grower.

3.5 Sample representativeness

In order to understand the representativeness of the growers we interviewed and collected data from, the research team needed to find publicly available industry data on grower numbers, sizes, locations, production method, and market channels.
The most likely sources – AHDB-Horticulture – does not require levy payers to submit this information.

Because of this we used information on the number of levy payers along with horticulture statistics from Defra to develop our best understanding of the target population size (i.e. number of growers). In addition we used the research team's understanding of the target population and guidance from the project steering groups to develop a guide for sampling recruitment in order to obtain as representative sample as possible within the confines of the population-level data available and the sampling method.

3.6 Quantitative and qualitative analysis

Quantitative data on farm baseline statistics (size, production level, production methods, and market channels) along with data on waste quantity were extracted from interview and farm data collection records. It was entered into an Excel workbook and cleaned. The total tonnage of crop waste and percentage of total production were calculated. The relative importance of different sources of waste was also calculated (see Table 6 above). Due to the size of the sample and the potential for sampling bias, only basic descriptive statistics were undertaken.

A thematic analysis was used to capture and understand qualitative data gathered during interviews. As the transcription of recordings was undertaken, patterns and emerging themes were developed for analysis within the structure of the project's aims. The transcripts were then coded against these themes.

3.6.1 Environmental and economic impacts of crop waste

As part of the research brief WRAP requested that the impact of farm waste be quantified in terms of:

- Economic cost to growers
- Greenhouse gas emissions
- Water
- Energy
- Calories

Given the resource constraints of the project, 'life cycle' and economic analyses were not undertaken for each grower. Instead, data on average crop waste from our research were combined with the best available secondary data on the environmental impacts, economics and nutritional values typically associated with lettuce and strawberry production (see table below for a summary of methods and assumptions). This analysis provides a reasonable estimate of associated impacts and aligns with methods used in other WRAP reports to quantify the sector-level impacts of waste[32].

As is explored later in the discussion section of this report, a more detailed economic analysis of the impacts and potential solutions for reducing crop waste in agriculture would be an extremely useful area for further research.

[32] *WRAP, 2013*

Table 9: Methods for calculating crop waste impact scenarios

Impact (Unit)	*Method description*	*Scenario assumptions*
Economic (£m)	For **strawberries**, growers considered the main cost of crop waste to be the lost revenue from lost sales. This reflects wider economics of the sector in the UK where there is growing demand for British strawberries and little over-supply (something we explore in the discussion section of this report). Therefore, we calculated the economic impact of strawberry waste to be the *value of edible crop that was disposed of* on farm. In contrast, for **lettuces**, where there is often over-supply in the market, growers considered the economic cost to be the total cost of crop waste inputs to production. Therefore we calculated the economic impact of lettuce waste to be *the variable cost of production of crop that was left unharvested in the field*.	Strawberries Crop value: £2,340/tonne (based on value and tonnes of strawberries produced in UK – Defra Horticultural Statistics). Lettuce Variable cost of production of field lettuce: £6,055/hectare (based on 2014 study by ADAS for Defra[33] on the economics of weed control). For both crops, the theoretical maximum values and costs were calculated (e.g. the economic cost of all lettuce waste). Not all of this will be practically avoidable, as was discussed above
Greenhouse gas emissions (tCO_2e)	For both sectors we used peer reviewed life cycle analysis of UK lettuce and strawberry production to calculate the carbon footprint of crop that was wasted. Total tonnes of crop waste were multiplied by the carbon footprint per tonne of crop reported. Both studies examined UK field-based production systems that were comparable to those typically seen in our study and representative of the bulk of UK production	Strawberries: Williams et al. (2008) Comparative Life Cycle Assessment of Food Commodities Procured for UK Consumption through a Diversity of Supply Chains. Lettuce: Hospido (2009) The role of seasonality in lettuce consumption: a case study of environmental and social aspects[34]
Energy (MJ)	For both sectors we used peer reviewed life cycle analysis of UK lettuce production to calculate the embodied energy needed to produce the proportion of crop that was wasted: Total tonnes of crop waste were multiplied by the energy use per tonne of crop reported.	Same references as for greenhouse gas calculation
Water (m^3)	For both sectors we used data on irrigation water use in UK horticulture to calculate the total volume of water used to produce crop that was wasted. Total tonnes of crop waste were multiplied by the water use per tonne of crop reported.	ERDF 'WATERR' Project Irrigation Business Review Findings[35]
Calories (kcal)	For both sectors we used data on typical nutritional content of foods. Total tonnes of crop waste were multiplied by calorie per tonne of crop reported.	Public Health England - Composition of foods integrated dataset (CoFID)[36]

[33] *ADAS (2014) An economic assessment of electric weed control and comparable alternatives. Defra*
[34] *Hospido et al, 2009*
[35] *NIAB, East Malling Research, 2013*
[36] *Public Health England, 2015*

3.7 Challenges and limitations

This project was subject to certain limitations in capturing a representative sample and collecting accurate and comprehensive data.

For the reasons set out below, all data reported should be considered indicative, rather than being capable of statistical analysis.

Understanding the population being studied is the first step to obtaining a representative sample. There is no publicly available comprehensive data on the population of either the lettuce or the strawberry sectors. Defra has some statistics on hectarage grown in the UK (not split out by country) and within the sectors various sector bodies will also have privately held information (e.g. AHDB's database on their levy payers). The project did its best to collate information where available and develop its own understanding the populations of both sectors.

Best efforts were made to ensure a representative sample, but the sampling and recruitment strategies did not eliminate selection bias. There were limitations in the sampling strategy due to access to and understanding of the grower population. Additionally there were growers who could not be reached or did not agree to participate in the study. It is possible that those growers who did agree to speak with us are systematically different from those who did not (for example, in level of data collection or level of waste).

Finally, the data collected through the interviews and survey is likely subject to reporting and recall bias. It is important to understand that the data on waste levels and causes is based on self-reported data and grower estimations and perceptions. Some growers collected higher levels of information than others; the higher end collected detailed information on amounts and causes by field/polytunnel, while the lower end collected very little to no information at all.

Growers' ideas on ways to reduce waste complement their understandings of where and why waste occur. While it's possible that the previous discussion on waste primed the growers to already be considering those areas as ways to improve, we consider this correlation to be a validation that the causes discussed by the growers are representative of their experiences and understanding.

4 Results

This section presents the results of our analysis of the lettuce and strawberry waste data collected from growers. First we summarise the coverage of the sectors we achieved during the course of the research.

4.1 Strawberries

4.1.1 Population coverage

The sample population in the strawberry sector consisted of 15 strawberry growers in 7 counties across England. 12 growers were interviewed in person; 2 participated in the survey and were interviewed by phone; and 1 participated in the survey. One of the growers interviewed in person did not respond to follow-up questions and their data had to be omitted from the quantitative analysis. Data from 14 growers was used in the quantitative analysis, while only data from the 12 interviewees was used in the qualitative analysis.

The total area planted in the sample was 738 hectares. For a rough comparison, the United Kingdom's total hectarage planted in 2014 was around 4,800 hectares.[37] Below we compare the sample to the population, reported by key characteristic; in order to maintain confidentiality and the anonymity of the growers who participated, further detail on individual farms within the sample cannot be reported.

Table 10**: Size of strawberry sample population with Defra UK comparison**

	Field & polytunnel (ha)	***Glasshouse (ha)***
Defra (UK total)	3,623	255
Our sample	657	81

Table 11**: Size of operation of strawberry growers in sample**

Range	***Number of growers***
0-49ha	8
>50ha	7

Table 12**: Production styles (% of total area) of strawberry growers in sample**

Glasshouse	**Polytunnels, Tabletop**	**Polytunnels, Ground Level**	**Field grown**
11%	36%	49%	4%

Table 13**: Direct customers of strawberry growers in sample (% of sales)**

Retail	**Wholesale**	**PYO/Farm shop**	**Processing**	**Other**
86%	8%	1%	3%	2%

[37] *Data taken from Defra's Basic Horticultural Statistics, 2014. 2015 data was not available at time of publication.*

4.1.2 Data quality and representativeness

In order to determine whether 2015 was a representative growing year (i.e. not an extreme one especially with regards to weather or an external event) growers were asked their opinion on waste during the past season in comparison with other seasons – whether it was average, better, or worse. The opinion of a majority of the growers (74%) was that this year was an average or better year for waste, despite the cold start to the season. This suggests that the findings of the project are likely to be representative or slightly under-representative of average waste in the strawberry sector, and unlikely to be over-representative, when considering external influences.

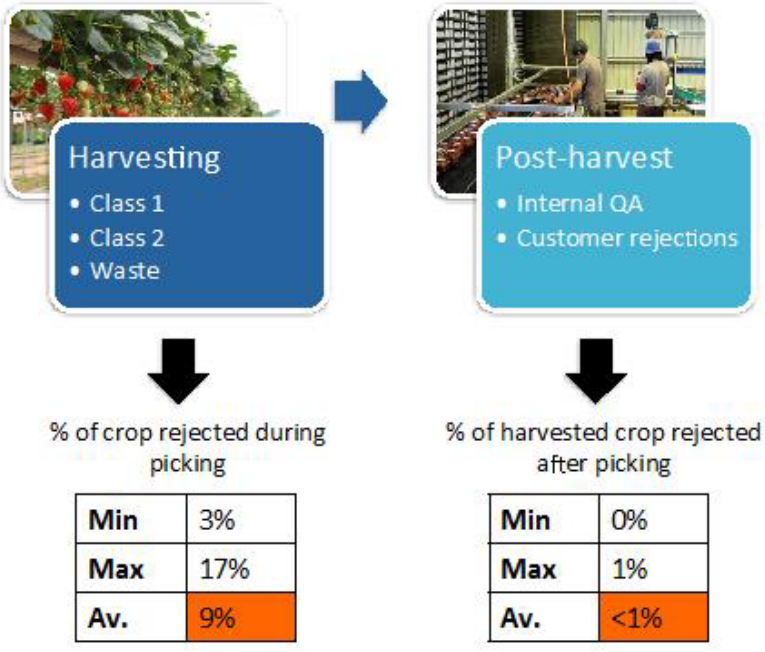
As discussed in the methodology section, the information on waste collected during interviews are generally based on grower estimates. However it is important to note that In the strawberry sector, an emerging threat from the invasive Spotted Wing Drosophila (SWD) has meant that in the past few years, growers have been advised to pick diseased and damaged fruit and dispose of it properly (e.g. buried or composted), in an attempt to mitigate the threat. In the past, growers might leave fruit they can't sell on the plant, especially near the end of its season, or might have disposed of it less methodically. An unintended consequence of this change in practice is that all strawberry growers now have at least a visual assessment of the waste on their farm. The majority of growers we spoke with (64%) reported that they collect information on waste, though the type, level, and amount of data collected varied by grower.

4.1.3 Quantity and management of strawberry waste

For the reasons described above (section 3.7), all data reported should be considered indicative, rather than being capable of statistical analysis.

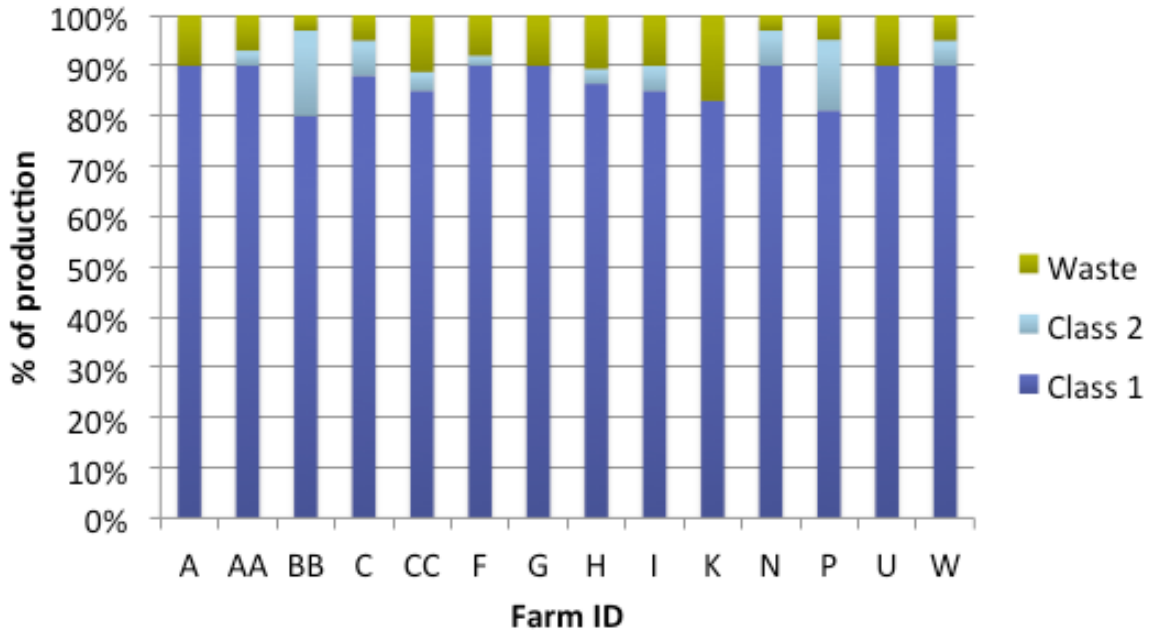
From the research we estimate that 9% of the mature strawberry crop was wasted in primary production in 2015 (c. 10,000 tonnes). Based on this, we estimate the value of strawberry crop wasted in the UK to be £24m. All of this waste is theoretically avoidable, however the degree to which it can be practically avoided is a complex question and it was not within the scope of this study to address.

Figure 6: Summary of strawberry waste rates *at each stage* of production



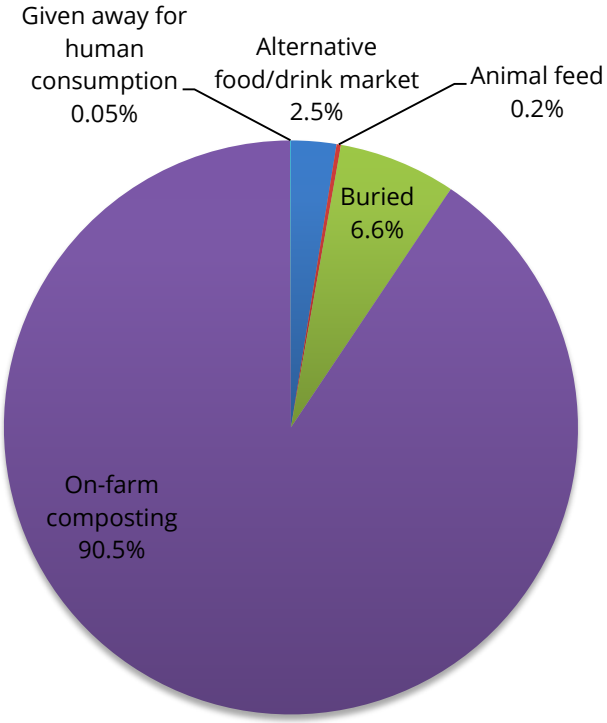
Waste rates varied between growers: between 3% and 17% of production was disposed of as crop waste. Ten out of 14 growers sold crop as Class 2 (see Figure 7 below). Given the complexity of the factors influencing waste levels – and the data constraints of the project, we were not able to draw any clear correlations between waste levels and grower characteristics, such as farm size, supply chain structure, contract type, crop variety, farming method, etc. Growers did however self-report a perceived benefit of actions such as finding secondary markets for crops and better communication with customers. This is discussed in more detail in Section 4.3.

Figure 7: Proportion of total strawberry production that goes to waste



The vast majority of unmarketable strawberries were picked and disposed of on-farm to mitigate the risk of spreading crop pests and disease. Most of this was done on-site, rather than sending fruit to an off-site industrial composting or anaerobic digestion facility. A typical scenario would see a grower putting waste fruit in bins without oxygen, and after a number of weeks spreading it on a compost heap or back on a field. A small proportion of waste was buried (see Figure 8 below).

Figure 8: Management of strawberries not sold as Class 1 or 2

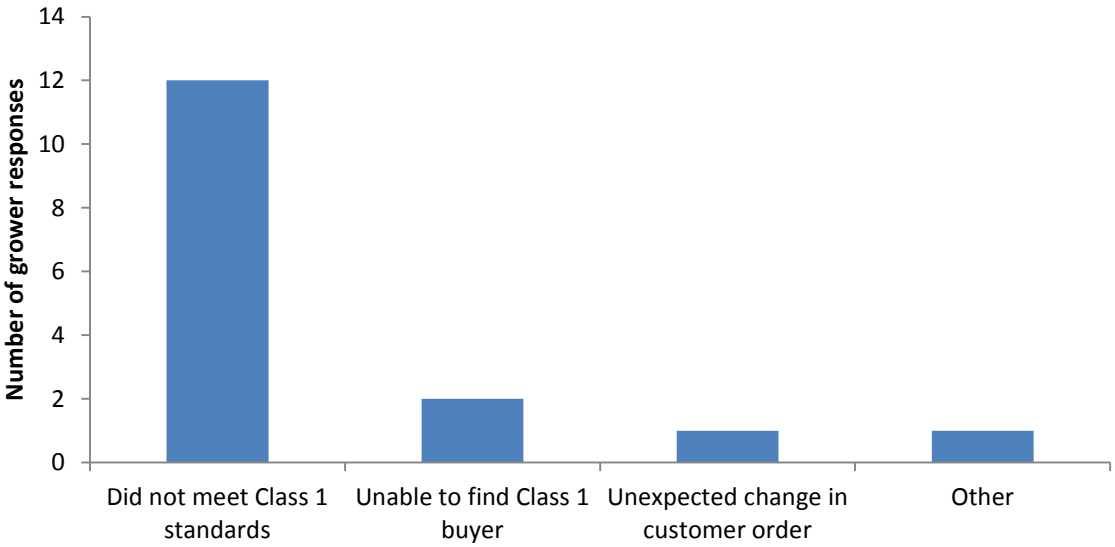


4.1.4 Causes of waste – and potential solutions

Growers' primary goal is to sell as much of their crop as possible as Class 1; this is the highest value they can get for their crop. Growers will sell fruit as Class 2 when necessary, but the price they receive at this level is much lower and reduces the profit margin substantially. Occasionally, growers will sell fruit to a secondary market such as frozen puree, or donate it for human consumption, but generally fruit that cannot be sold into either market is waste.

Growers did not consider changes in customer order or inability to find a buyer as significant reasons for strawberries not being sold as Class 1, though these problems do exist. At certain times in the season, gluts can occur, making it difficult for growers to sell their fruit. While some growers identified this as a reason for occasional waste, grower responses generally identified it as not very common but significant when it occurred.

Figure 9: Reasons for not selling fruit as Class 1[38]



Most growers did not feel that different market channels generated different levels of waste, though some spoke about differences in specifications and flexibility between customers. Oversupply was considered a potentially significant cause of waste by only two growers, and then only at certain times of the season, generally in mid-summer.

Almost all growers believed that the most significant reason they were unable to sell strawberries into the Class 1 market was because the fruit did not meet Class 1 standards (i.e. it was not due to over-supply in the market). To be eligible for the Class 1 market, strawberries must meet certain quality requirements. Quality requirements exist on several levels. At the top level, there are overarching requirements on quality control, set by European Union regulations, that pertain to all strawberries sold, regardless of market or customer. Strawberries fall under the Specific Marketing Standards in EU Regulation 543/2011. The minimum quality requirements specify that strawberries must be intact, undamaged, sound, clean, practically free from pests and pest damage, free of abnormal external moisture, and free of any foreign smell and/or taste. The regulations also include minimum requirements on size, shape, and colour. The EU regulations are comprised of three classes of strawberries – "Extra", "Class I", and "Class II".

In addition to these requirements, there are more specific requirements set by individual customers, who are generally retailers or high-end wholesale markets. These requirements vary in specifics but include similar conditions on size, shape, colour, BRICS level (sugar), blemishes, and damage. These standards are generally stricter than those set by the EU. For example, the minimum berry size for Class 1 set by most customers of the growers we spoke with was 25mm, but the EU only specifies a minimum of 18mm for its "Class I" category.

When fruit does not meet Class 1 standards, the fruit can either be sold as Class 2, generally wholesale, or is unsalable and considered a waste. To be sold as Class 2, fruit

[38] *Some growers responded with more than one answer*

again must meet certain requirements, similar to the EU requirements for Class 1 but with few restrictions. For example, a fruit with a mis-shaped bottom may not be eligible for Class 1 but would be saleable as Class 2. Too mis-shaped, however, or too large/small, etc., and the fruit is also ineligible for Class 2.

When a fruit cannot be sold on the fresh market, other secondary markets do exist. Strawberries that do not meet quality requirements can be frozen, pureed and added to yoghurts, baked goods, etc., or made into jam, juice, etc. However these secondary markets are not always economically attractive. Several of the growers interviewed utilised jam as a secondary market, but none considered that outlet to result in any reduction in waste, possibly because the percentage of production diverted to that market was, in their opinion, negligible. Two other strawberry growers had freezing facilities built on-site. Increasing problems with marketing frozen and puree products were reported due to product coming from Europe being too cheap to compete with. For growers who do not have freezing capabilities on-site or nearby, freezing is not always a viable option. The price for freezing berries is not competitive with the fresh market of either class, and orders must be arranged at the beginning of the season. Growers would, of course, much rather get a higher price for their crop, and reported they would rather wait and try to ensure a buyer for all of their saleable crop than be locked in to selling some at a much lower price. It was also suggested that the market for frozen strawberries was not particularly strong, though some saw potential growth in it.

The classing system, and the quality standards that underpin it, provides a helpful framework through which waste and its root causes can be analysed and understood.
Growers have mixed and nuanced views of quality standards. No grower believed that standards should be eliminated or had an entirely negative opinion of them. Several growers, on the other hand, did have a completely positive opinion of standards and would change nothing about them.

Grower quote

"At the end of the day, the most important thing is that we put fruit that consumers want to buy in the punnets. And by saying that, I mean they want to come back and buy more. Not just going to look at it and it looks nice, but it's got to eat well, it's got to taste good… it's got to perform."

The majority of the growers fell somewhere in the middle; they recognised the importance and value of having high standards in place, but would like to see more flexibility or options on certain requirements, especially at during times of oversupply that may happen mid-season.

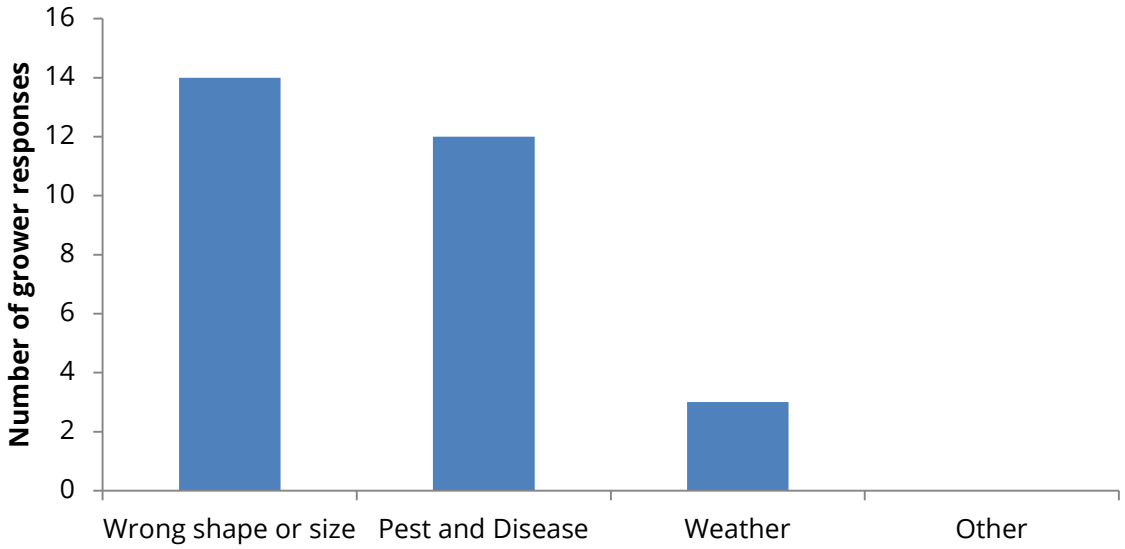
Reasons cited by growers for fruit not meeting Class 1 standards primarily included wrong shape and/or size and damage by pest and/or disease that occurred after maturity. Weather was not

Grower quote

"You can understand your damage, your wet bruising, your mildew, rots, etc., but actually for size and misshape when you throw it in there, you just think…[it's a waste]."

considered a significant cause of waste or reason for not meeting Class 1 standards, though could play a small role in waste overall. For example, this year many growers talked about the cold start to the season. For some growers, this affected pollination, leading to a higher proportion of misshapen strawberries later on.

Figure 10: Reasons for not meeting Class 1 standards[39]



Pest and disease damage was cited by almost all growers as a significant cause of waste. Certain diseases (mildew) and pests (Western flower thrip) were mentioned by many. A reduction in chemical tools available to control pest and disease was seen as an important factor in these; however, while almost all growers acknowledged the reality of this reduction, some were very concerned. Their view was that certain controls are approved in other countries but not the UK and/or the EU – putting growers at a disadvantage. A number of growers mentioned the desire for greater support from government and associated agencies so that products could be developed and approved more easily, especially in emergency situations. Biological controls are seeing an increase in use and interest, though are not yet able to substitute completely for chemical controls.

The other major cause of waste was fruit being the wrong shape and/or size. As mentioned earlier, growers appreciated the importance of quality standards to the value of their product and the growth of their market share within fresh produce. Growers who did express some frustration with standards generally focused on fruit that was edible and good quality, but just a bit too small or large to be sold into the intended market; size seemed to cause more waste than misshapes. A few growers reported having customers that were a little more flexible or understanding, especially at certain times of the year (for example, at the end of the season plants begin throwing smaller fruit) or if a grower had a flush of misshapes. Other customers might offer temporary specifications for short periods of time when necessary, or sell a "value" line where growers could sell this just-out-of-spec fruit for a lower price than Class 1 but a better return than Class 2.

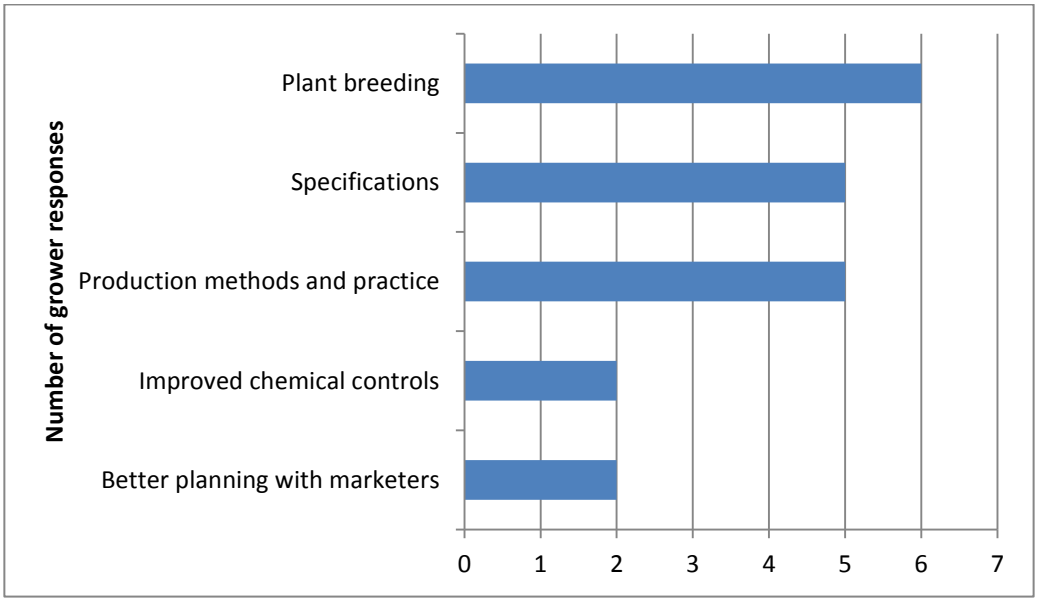
[39] *Some growers responded with more than one answer*

The most commonly mentioned way to reduce waste was to develop better plant varieties that throw higher percentages of Class 1. Many believed it was possible to have plants that only produced Class 1 fruit – a new variety with a very high percentage of Class 1 yield, Malling Centenary, has generated a lot of excitement among growers

However, while the growers believed more of the fruit they grew should be acceptable for sale, they did not believe that the primary answer was to change specifications. Plant breeding and production practice were viewed as equally important in ensuring that as much fruit as possible went to the fresh market. This is covered in more detail in the discussion on ways to reduce waste.

It is worth noting that almost all of the growers interviewed were part of a marketing group and/or a producer organisation, through which they sold most to all of their crop. Producer organisations have the benefit of scale; they have access to a number of customers as well as a large amount of data on their members' current and anticipated supply. One large producer organisation has recently begun requiring all of its growers to submit daily pick data and stock levels as well as anticipated yield for the following week every single evening. The information and volume that the producer organisation therefore has to work with allows them to "see" supply issues as they are coming, whether that means over- or under-supply or general size and shape problems. They can then pass on this insight so that customers can react with relevant offers, such as temporary specifications in times of high demand and low supply. Having the producer organisation as an intermediary with invested sector interest may buffer strawberry growers from certain levels of risk and variation between customers and market channels.

Figure 11: Ways to reduce waste in strawberry production[40]



[40] *Some growers responded with more than one answer*

4.1.5 Environmental and economic impact of strawberry waste

The value of strawberry crop wasted in the UK was estimated to be £24m (c. 10,000 tonnes). All of this is theoretically avoidable. The value of UK production of strawberries was £244m in 2014. The economics of farm food waste is explored in more detail in the discussion section of this report.

The environmental impact and nutritional content of producing this wasted crop is summarised in Table 14. The most significant impact was the calorific value lost. Three billion kcal is equivalent to the annual daily reference intake of 1.2 million adults[41]. The water use associated with the wasted produce is notable at 0.5% of agriculture's total annual water consumption[42]. The greenhouse gas implications are minimal (<0.02% of total greenhouse gas emissions from UK agriculture[43]).

Table 14: Environmental and nutritional impact of strawberry waste on farm

	Impacts associated with waste	***Calculation***
Water	590,000 m^3 (irrigation)	Resource use and greenhouse gas emissions associated with production and management of crop area needed to produce volume of strawberries wasted in 2015 (c. 400 hectares). Crop area was used to calculate the environmental impact of crop waste because the best environmental footprint data was reported in impact per hectare, rather than per tonne of crop produced.
GHGs	10,000 tonnes CO_2e	
Energy	130,000 GJ	
Calories	3bn kcal	Nutritional content of strawberry fruit wasted on farm in 2015.

[41] [41] *Public Health England, 2016 (based on the daily reference intake for adult males of 2,500 kcal)*
[42] *Defra, 2015 (126M cubic metres total water abstraction for England & Wales)*
[43] *DECC, 2016 (49.1Mt CO_2e)*

4.2 Lettuce

4.2.1 Population coverage

Our sample population consists of 14 lettuce growers in 10 counties across England. Among the lettuce growers, total hectarage planted (including multiple cropping) for field grown lettuce (whole head) was 3,273 hectares. For some context, the UK's total area of whole head lettuce planted for 2014/15 was 6,043 hectares. The comparison cannot be made directly as our hectarage comes from England only, while Defra's number includes the whole of the UK. Defra does not provide data on baby leaf.

Terminology for lettuce type in both head lettuce and baby leaf is complicated and can vary by grower. For the purposes of this study, we collected data on all types that the grower considered relevant for "head lettuce" and "baby leaf", and then grouped types afterwards during analysis (see Annex 3). With the exception of Chinese leaf (Chinese cabbage), we included all types in our analysis. This means that for our baby leaf dataset, it may be more accurate to refer to the overall crop as "leafy salads" rather than "lettuce". We chose to keep non-lettuce types in the baby leaf analysis for two reasons: the growers included it in their data when we asked about baby leaf, and non-lettuce types (e.g. baby spinach) comprise the majority of the baby leaf data.

Lettuce that is not sold directly to retail or wholesale as packaged whole heads or bagged baby leaf is generally sold to "processing". This includes lettuce sent to ready-to-eat, prepared foods, and catering markets.

Table 15: Population coverage (head lettuce)

Data source	Protected lettuce (ha)	Field lettuce (ha)
Defra – UK (2014)	338	6,043
Sample	14	3,273

Table 16: Size of operation (head lettuce)

Size range	Number of growers
<99ha	4
100-399ha	5
>400ha	5

Table 17: Direct customers by percentage of production

Whole head retail	Whole head wholesale	Processing	Other
46%	7%	42%	5%

Figure 12: Proportion of head lettuce types grown by growers in sample

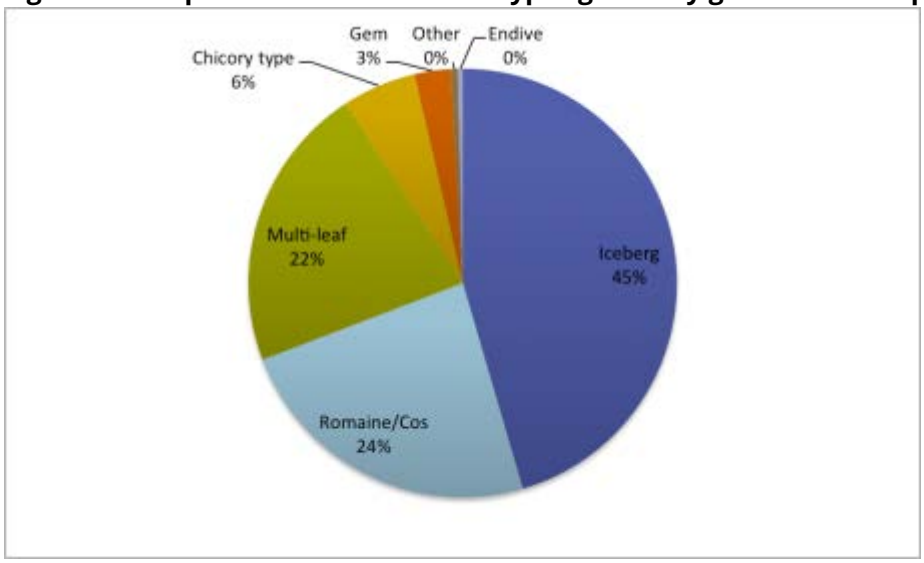


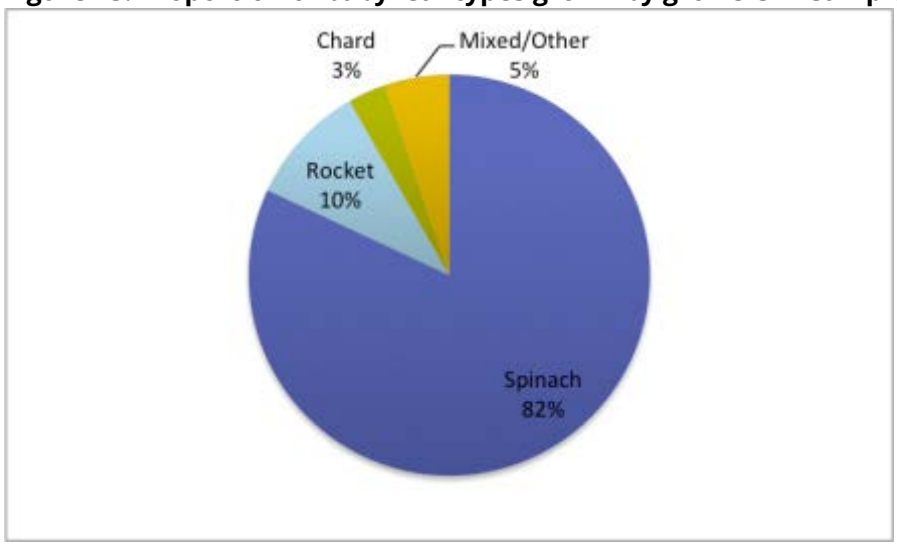
Table 18: Size of operation (baby leaf) of growers in sample

Size range	Number of growers
<99ha	3
100-199ha	3
>200ha	3

Table 19: Direct customers by percentage of production of growers in sample

Retail	Wholesale	Processing	Other
0%	4%	91%	5%

Figure 13: Proportion of baby leaf types grown by growers in sample



4.2.2 Data quality and representativeness

In order to determine whether 2015 was a representative year for waste (i.e. not an extreme one especially with regards to weather or an external event) growers were asked how they felt the past year had been in terms of waste – whether it was average, better, or worse. 43% of growers felt that this year was an average year for waste, with 53% split evenly between believing it was a better year than average and believing it was

a worse year than average. This would suggest that the findings of the project are likely to be representative of average waste in the lettuce sector, when considering external influences.

Just over half of the growers said that they collected information on waste. For wholehead growers who are selling by the head, it is more likely they will have data on the number of heads planted and harvested – and so a reasonable understanding of field waste from ploughing in or selective harvesting. For growers selling by the tonne to processors, there was far less field level data collected on the number of harvested heads.

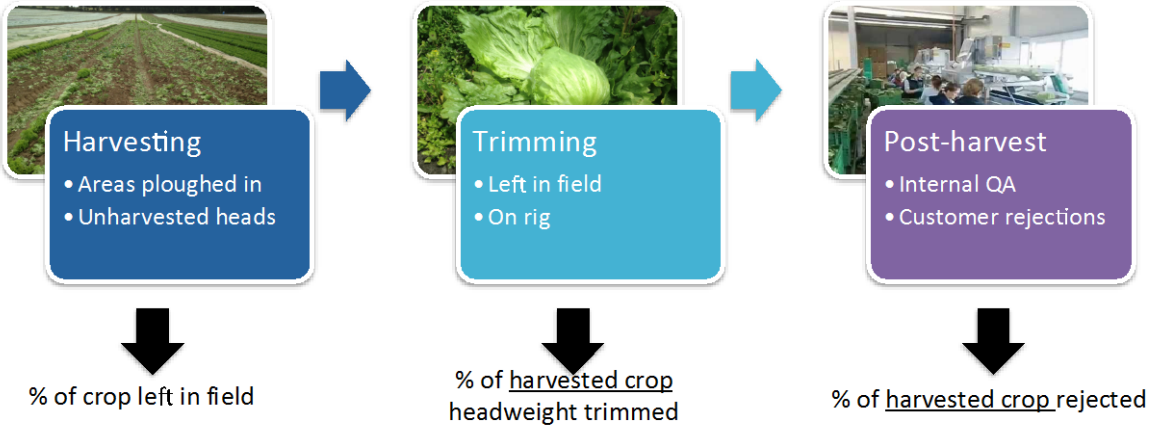
No grower we spoke to collected information on the scale of trimming waste. This is due to the difficulty in collecting this information and also the reality that for many growers it does not represent a significant economic cost: if a grower is selling by the head, as long as it is within an acceptable headweight range they will get paid the same amount of money by their customer.

4.2.3 Quantity and management of lettuce waste

For the reasons described above (section 3.7), all data reported should be considered indicative, rather than being capable of statistical analysis.

The main types of waste were: whole areas of crop ploughed in before harvesting, individual unharvested heads, and trimming (see Figure 14 below). These cover wholehead and babyleaf growers. We estimate that 19% of lettuce crop was not harvested by growers in 2015 (c. 40,000 tonnes of lettuce[44]). Once harvested, growers estimated 24% of lettuce head weight was left in the field as a result of trimming (c. 40,000 tonnes of lettuce leaf and base) – although there is much greater uncertainty about the scale of this and the degree to which it is avoidable.

Figure 14: Wastage rates *at each stage* of lettuce production



% of crop left in field

Min	7%
Max	47%
Av.	19%

% of harvested crop headweight trimmed

Min	5%*
Max	41%
Av.	24%

*One outlier was removed

% of harvested crop rejected

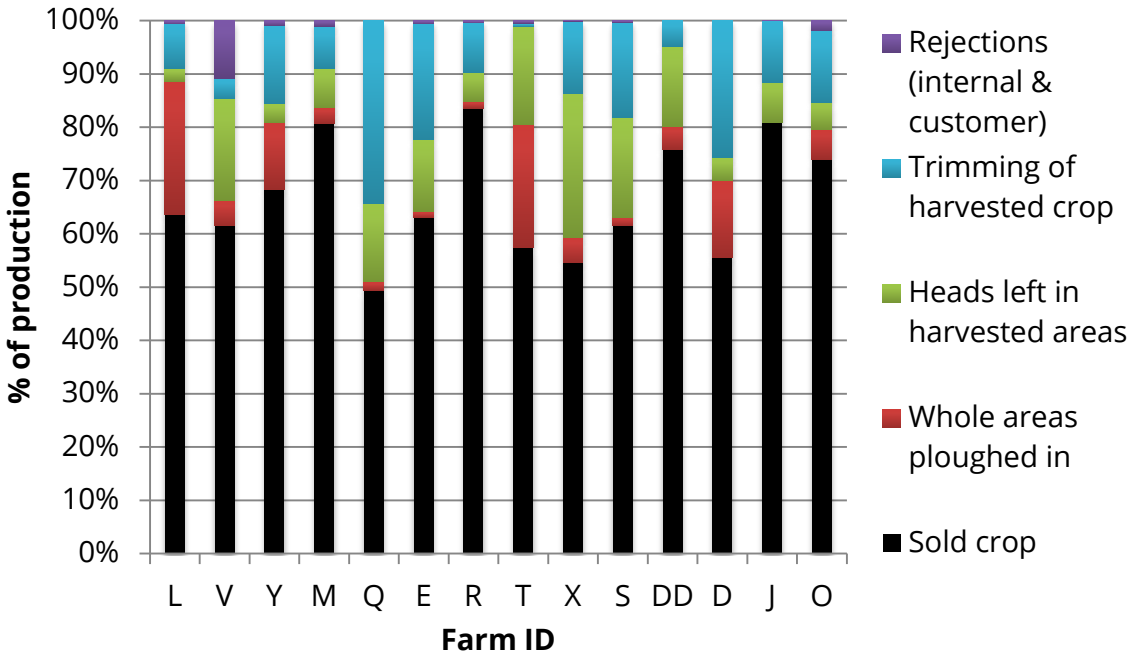
Min	0%
Max	15%
Av.	1%

Averages were weighted by production size of grower.

[44] *This weight is that of the total lettuce head – a quarter of this would typically trimmed before being sent to customer*

Lettuce waste was more complicated to measure than strawberry waste, because there are more places in the farm production process where waste can occur, and estimations and calculations had to take into consideration the wide variation in planting density, headweights and trim percentage that occurs between lettuce types. Overall, lettuce waste was higher and more variable than those seen in strawberry production (see Figure 15 below). Similarly to strawberries, however, there was a very small proportion of crop rejected once it has been harvested (excluding trimming waste). Given the complexity of the factors influencing waste levels – and the data constraints of the project – we were not able to draw any clear correlations between waste levels and aspects such as farm size, supply chain structure, contract type, crop variety, farming method, etc. Growers did however self-report a perceived benefit of actions such as investing in closer working relationships with customers or supply chain integration. This is discussed in more detail in Section 4.3.

Figure 15: Overall proportion of lettuce crop weight that is sold and wasted



4.2.4 Causes of waste – and potential solutions

Lettuce wasted through hectares ploughed-in, as individual heads left during harvest, during trimming, and in the pack house (if on farm and separate from harvesting rigs) is almost always returned to the land. Lettuce wasted through rejections that come back to the farm of origin is either composted and returned to the field, or binned and sent to landfill – when the lettuce is returned in its packaging it is often cheaper and more time efficient to bin the lettuce rather than unpack each head or bagged salad, if the grower does not send waste to industrial composting/anaerobic digestion facilities.

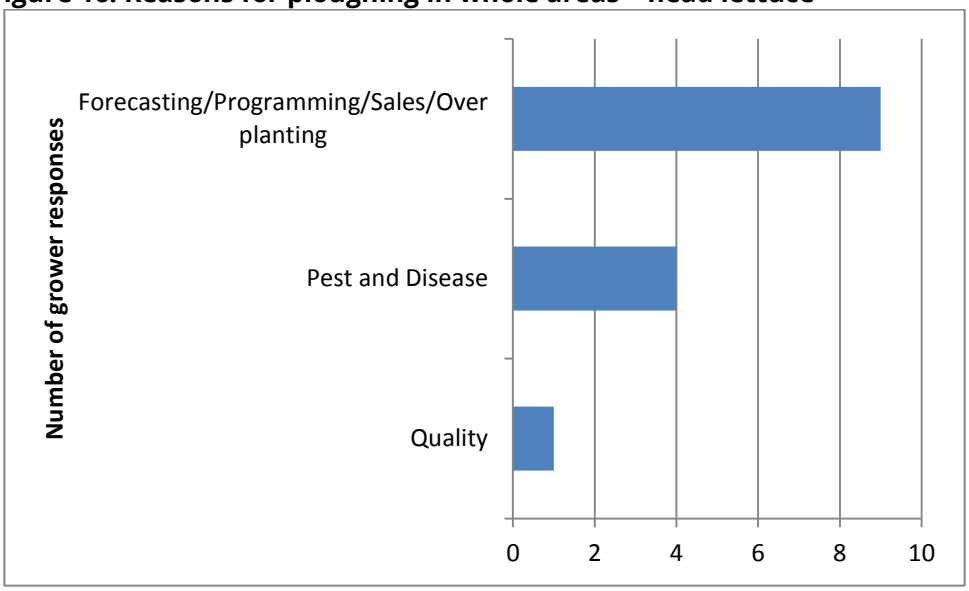
All growers incorporate some form of oversupply into their planning, though different growers understand the term in different ways. All agreed that oversupply is unavoidable – it is much more costly to growers, both in an immediate sales sense as well as in a long-term supplier relationship sense, to have too little crop than to have too much. Generally, oversupply tends to be between 10-15%; this is the budgeted

oversupply, which can in reality be larger if production is good and sales are not, or less if the reverse is true. This budgeted oversupply is a bit less than the actual waste levels seen in this research (i.e. 19%).

Lettuce growers do not operate on contracts but rather on "programmes". These programmes help the grower know how much lettuce they will need to produce, generally by type and by week, for each customer. Programmes can be developed by the grower on their own, based on their historical understandings of what their customers need, or they can be developed by the grower and their customer together. However in both of these cases, there is no actual contract, and the customer is not obligated to buy the agreed-upon amounts. If consumer demand is low, for example when the weather is bad, the customer can and will place an order below what was programmed.

While the grower is also not legally obligated to provide the programmed amount, to not deliver on an agreed programme can be severely detrimental to their marketing relationships and to future orders. As one grower put it, "*You only let down [certain customers] once*" (see Box 2 in Section 11).

Figure 16: Reasons for ploughing in whole areas – head lettuce[45]



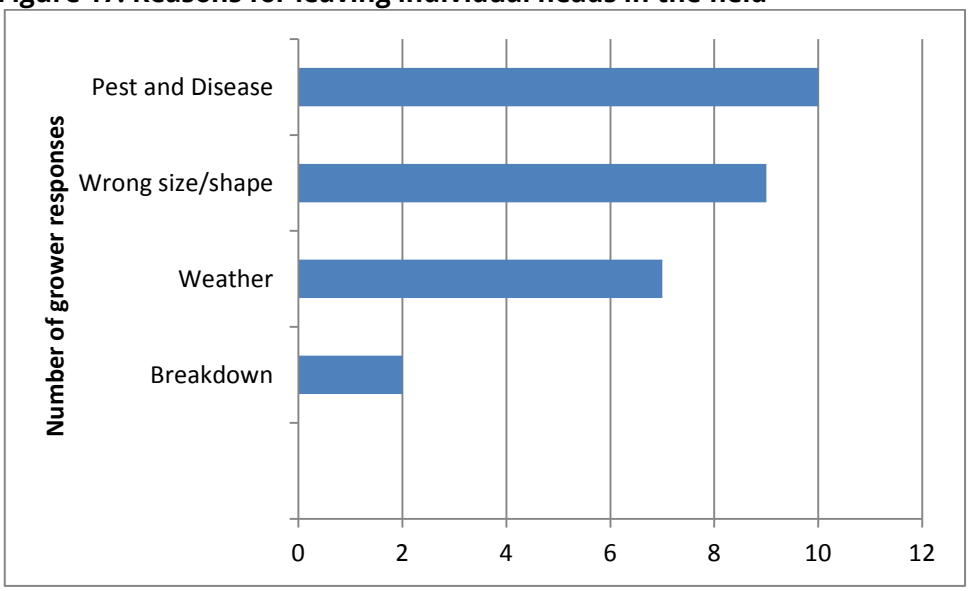
In head lettuce, growers considered inaccurate customer programming and demand forecast planning to be the largest causes of waste when it came to ploughing in whole areas of crop. The issues of customer programming and demand forecast planning are clearly closely intertwined, so much so that we were not able to allocate the root cause of waste to either one in particular. The other significant reason cited for ploughing in whole areas of crop was pest and disease damage (occurring after maturity).

When it came to reasons for individual heads being left in the field, specifications, pest and disease (occurring after maturity), and breakdown were the major reasons cited. Breakdown is a term that is interpreted by growers in different ways – sometimes growers use it to refer to a specific disease-related problem, and sometimes they use it

[45] *Some growers responded with more than one answer*

to refer to a physiological problem caused by heat and too-swift internal growth. As it is less systematically defined we have kept it separate from the specifications and the pest and disease waste categories. Oversupply or supply/demand mismatch did not figure as a cause in this area, because a batch of lettuce is generally only harvested if the grower has an order for it. As in strawberries, quality requirements in lettuce exist on several levels; lettuce also fall under the Specific Marketing Standards in EU Regulation 543/2011. Also as in strawberries, the quality requirements set by retailers and other customers tend to go beyond those set by EU regulation. In general, lettuce growers felt specifications were only a major cause of waste when it came to size/weight. The minimum and maximum weights set by retailers are often higher (in terms of minimum weights) and lower (in terms of maximum) than those set by EU regulation.

Figure 17: Reasons for leaving individual heads in the field[46]



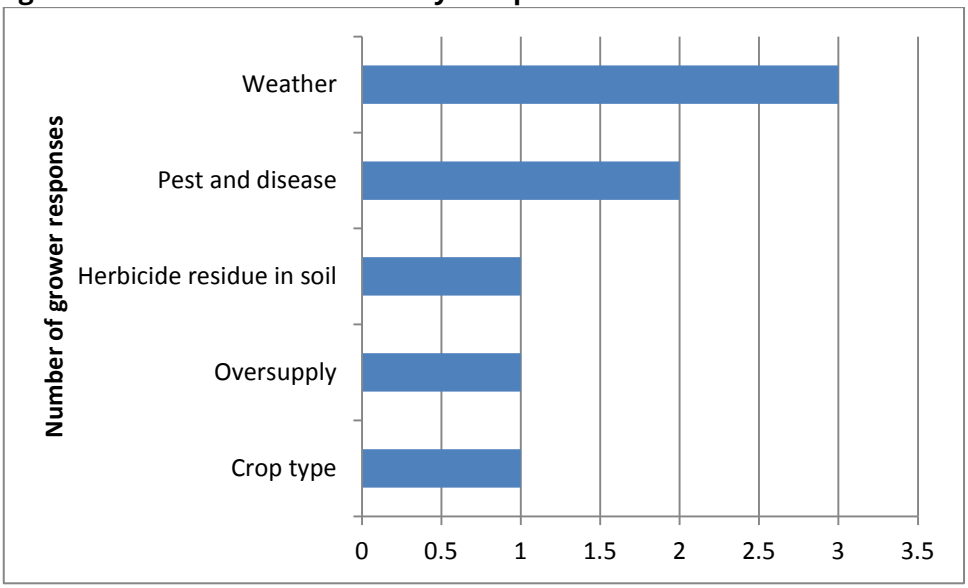
Finally, waste in trimming was generally a combination of specifications, especially among hearted crops like romaine where only the heart is wanted, and of pest, disease, and other damage. A small percentage of trimming could be unavoidable, to deal with the older, damaged outside leaves that would not be considered edible. However, feedback from growers was unable to clearly establish the extent to which trimming waste was avoidable – and the degree to which they represent an environmental or economic impact. This may reflect the subjective nature of deciding whether this waste is edible or not and deciding what might be considered acceptable by consumers. Trimming waste is not typically thought of as waste by growers, and they do not collect any information on it.

In baby leaf, the major causes of waste are somewhat different, as crop is either harvested or not; individual leaves or small sections are not left behind. There is also no trimming involved. Therefore waste is generally restricted to whole areas ploughed in, or to rejections, although the latter accounts for a very small percentage of overall waste. Growers cited pest and disease and weather damage as the most significant reasons for

[46] *Some growers responded with more than one answer*

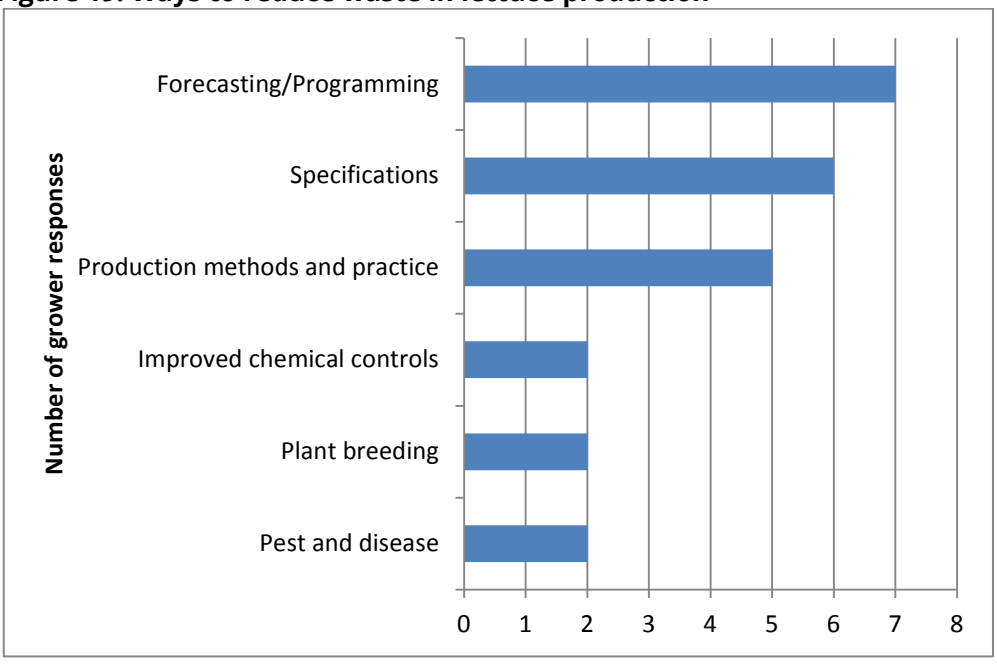
waste in baby leaf; baby leaf is typically much more fragile and susceptible to damage (cosmetic or serious) by external forces than head lettuce is.

Figure 18: Causes of waste in baby leaf production[47]



Half of the growers interviewed believed that the type of market channel(s) a grower sells through has an impact on levels of waste. For example, we spoke with some growers who grew and processed lettuce, and felt that they had more flexibility and greater control over managing demand and supply variations; they also had greater incentive to work with what they had, and make it work within their specifications.

Figure 19: Ways to reduce waste in lettuce production[48]

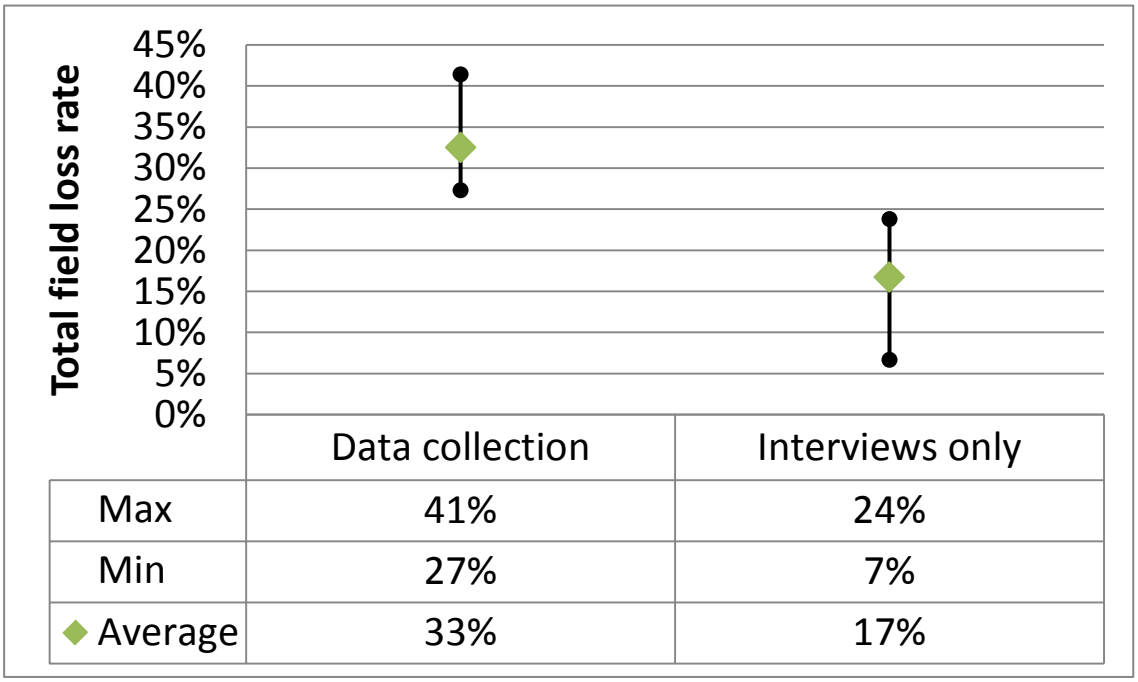


[47] *Some growers responded with more than one answer*
[48] *Some growers responded with more than one answer*

The most commonly mentioned way to reduce waste dealt with accurate forecasting and programming. Growers recognised that their own forecasting errors comprised part of the problems they encountered in matching their supply to the demand, both when agreeing programmes at the beginning of the season, and when planning weekly and daily orders with their customers. However, they also suggested that many customers could be better at developing more accurate programmes or in alerting growers to issues with agreed programmes as early as possible.

Other commonly cited ways to reduce waste included a change or reduction in specifications (generally around head size) and growers' own production methods and practices. Less commonly mentioned were better management (and options for management) of pest and disease, and the development of plant varieties better able to withstand the vagaries of weather and pressure by pest and disease. This is in contrast to the strawberry sector, where this was seen as far more important.

Box 1: Differences in farm waste levels between interview and data-derived estimates



	Data collection	Interviews only
Max	41%	24%
Min	27%	7%
◆ Average	33%	17%

Levels of waste found through data collection were consistently higher than waste determined through interviews. While growers who sell head lettuce by head (generally to retailers) will have a good idea of how many heads they planted versus how many they sold (e.g. harvested), those who sell by weight (generally to processing) may not have this information. We believe this suggests that growers underestimate levels of waste, which has implications for the data and findings in this report, as it is largely based on grower estimation (with the exception of the data from the on-farm collection).

As we did not conduct any on-farm data collection in strawberries we do not have the data available to determine whether strawberry growers accurately assess their waste.

The implication of these findings is that if a farm waste benchmarking was to be done in the UK, on-farm data collection would be needed to ensure accuracy.

4.2.5 Environmental and economic impact of lettuce waste

The cost of producing the lettuce that is ploughed in on farm in the UK is approximately £7m (c. 40,000 tonnes). The economics of farm food waste are explored in more detail in the discussion section of this report.

The environmental impact and nutritional content of producing the wasted crop is summarised in Table 20. The most significant impact was the calorific value lost. Eight billion kcal is equivalent to the annual daily reference intake of 3.2 million adults[49]. The water use associated with the wasted produce is notable at 0.7% of agriculture's total annual water consumption[50]. The greenhouse gas implications are minimal (<0.01% of total greenhouse gas emissions from UK agriculture[51]).

Table 20: Environmental and nutritional impact of lettuce waste

	Result	***Calculation***
Water	900,000 m^3 irrigation	Resource use and greenhouse gas emissions associated with production and management of crop area needed to produce lettuce crop that was ploughed-in in 2015 (c. 6,000 hectares). Crop area was used to calculate the environmental impact of crop waste because the best environmental footprint data was reported in impact per hectare, rather than per tonne of crop produced.
GHGs	5,500 tonnes CO_2e	
Energy	125,000 GJ	
Calories	8 bn kcal	Nutritional content of all lettuce material trimmed and not harvested in UK in 2015.

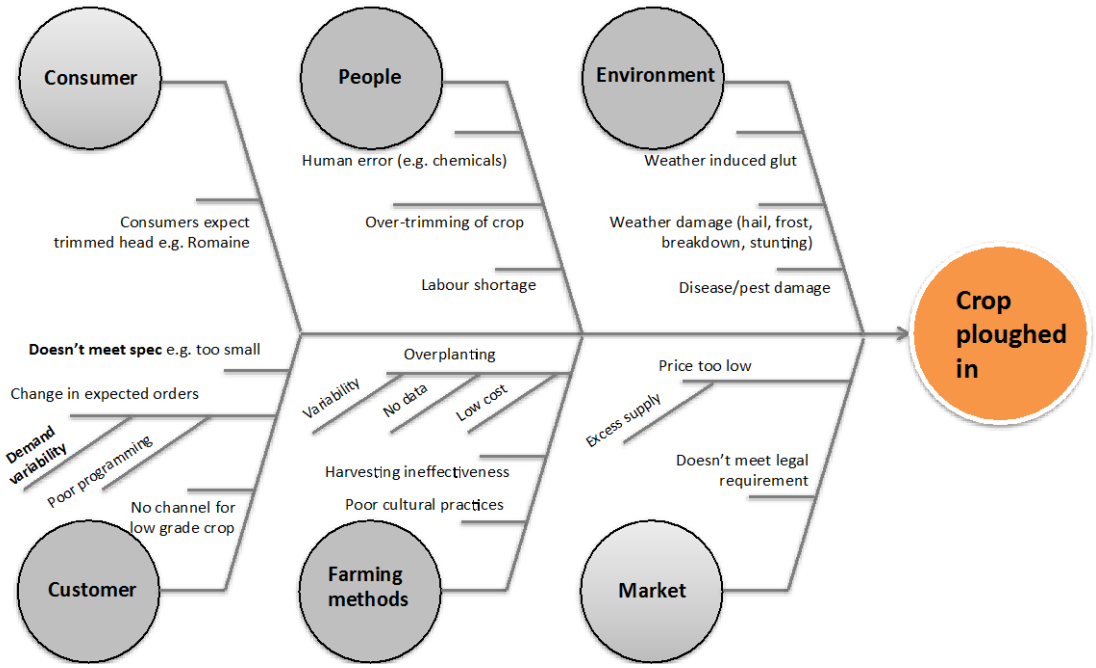
4.3 Examples of practices that reduce farm waste

At the start of the project we had anticipated that, based on the research, we might be able to identify specific 'good practices' that had a measurable impact upon the levels of crop waste within our sample of farms.

Unfortunately the complexity of the causes of waste identified in the research and data constraints meant that we were unable to demonstrate clear links between specific practices and waste levels seen on farms. By way of example, Figure 20below summarises the potential causes behind lettuce waste using the framework of a 'cause and effect' or 'fishbone' diagram. In that sector we identified six broad categories of cause that result in crop being ploughed in – these range from environmental factors through to supply chain (customer) relationships. To attribute different levels of waste to these causes would require a more detailed examination of the production and marketing of this crop than was possible within this project.

[49] *Public Health England, 2016 (based on the daily reference intake for adult males of 2,500 kcal)*
[50] *Defra, 2015 (126M cubic metres total water abstraction for England & Wales)*
[51] *DECC, 2016 (49.1Mt CO_2e)*

Figure 20: Cause and effect diagram of lettuce field waste



Nevertheless, during the course of the research a range of different practices were identified that have the potential to influence the levels of waste in primary production. These range from the development of new varieties to greater supply chain collaboration. Eleven of these practices are summarised in Table 21 below – along with a commentary on whether growers undertook these practices and perceived that there were waste reduction benefits. It is worth noting that members of the project steering group were surprised at the lack of grower identification of the importance of managing mildew in lettuce. Although mildew was mentioned by a few growers, primarily as an example of disease damage, it was not their primary concern.

It is recommended that these practices are explored in more detail in the future to establish their potential effectiveness and practicality. This is explored in more detail in the conclusion section that follows.

Table 21: Summary of potential practices to reduce crop waste in primary production

			Examples identified within sample of growers	
Practice	**Theory of change**	**Barriers/challenges**	**Strawberry**	**Lettuce**
More integrated marketing & supply chain collaboration	Through collaboration, information sharing and planning, mismatches in supply and demand can be better managed so that surplus crop can be sold or overproduction reduced.	Finding a model that works for all parties. Creating trust in relationships. Greater integration means that supply chain partners are more dependent on one another.	One producer organisation (PO) is collecting detailed production data from growers to try and manage supply more closely.	One grower saw improvements in supply management where a customer had directly invested in their production.
Increase diversity in customer base	Given the inevitable variability in crop quality, by having a diversity of customers with different needs more crop can be sold.	May not be practical in some instances.	Not mentioned.	One grower identified this as a strategy by which they reduce crop waste.
Co-operate with other growers to manage shortfalls and surpluses	Growers can trade crop with each other to meet changes in demand/supply, manage risk and reduce over-production. This is already happening in the lettuce sector, to a degree.	Competition law – this approach is straying near to cartel-type activities. Trust is needed between growers. There is no guarantee that crop will be available.	Not mentioned.	This was mentioned by one grower as a means of managing surplus or inadequate supplies of crop.
Send lower grade crop to manufacturing/ processing	Surplus crop can be diverted to alternate uses or processed (e.g. freezing, puréeing). Even though the crop value may be lower this can still have a net economic benefit to grower (e.g. they are harvesting strawberries anyway).	Potential customers want confirmed supply of crop of a minimum quality – a grower may not want or be able to do this early in the season. Economics of processing may not be favourable e.g. competition with cheap imports was identified by growers.	3 growers send crop to jams, but did not consider it a good way to reduce waste or recoup much economic value – despite being an 'obvious' way to deal with surplus.	One grower was using waste lettuce crop in a new line of drinks products. Overall there were limited examples of secondary markets.

			Examples identified within sample of growers	
Practice	**Theory of change**	**Barriers/challenges**	**Strawberry**	**Lettuce**
Redistribute surplus crop for human or animal consumption	If surplus crop is hard to reduce due to the inherent variability of supply and demand then strategies and options for utilising surpluses (beyond sending to manufacturing or processing, as described above) need to be developed.	The cost of harvesting surplus lettuce could be economically unviable – and 'gleaning' may be disruptive and pose unacceptable risks to farming businesses (e.g. contamination, crop disease, etc.). Waste crop has a low dry matter content and so their value as animal feed is potentially limited[52].	Not mentioned. Very little crop sent to animal feed.	Only one grower allowed very low level gleaning on their site. Very little crop sent to animal feed.
Work with customers to have more flexible quality specifications	By accepting a wider range of crop quality, growers can either sell more product or reduce the amount of overproduction. This could be one element of a more integrated approach to marketing (above).	Lower quality crop could undermine consumers' perception of product as 'high quality' 'premium'. Lower grade product lines could cannibalise sales of higher grade (and higher value) products if no overall increase in consumption was seen.	One of the most commonly suggested potential practices to reduce waste. Since the project started, some retail supply chains have been rolling out this approach e.g. Tesco 'Perfectly Imperfect' strawberries.	Mentioned by growers as potential solution, primarily with regards to temporary influxes of over- or under-sized crop.
Develop new crop varieties that produce more consistent fruit or are less prone to disease, etc.	Historically, varietal development has been one of the key tools farmers and growers have used to produce higher quality crops.	Long lead times, investment costs and need to limit impacts on key product attributes e.g. flavour, sweetness, etc.	Commonly suggested intervention. Excitement in industry about a new variety with high Class 1 yields.	Not mentioned.

[52] *For example, University of Florida IFAS Extension guidance on the 'Utilization of Cull Vegetables as Feedstuffs for Cattle'*

			Examples identified within sample of growers	
Practice	**Theory of change**	**Barriers/challenges**	**Strawberry**	**Lettuce**
Change chemical /biological tools or improve agronomy	Pests and disease can affect mature crop and mean that they are inedible or not of sufficient quality.	Active & complex area of research. Potential barriers to greater adoption include consumer acceptance and regulations. For instance, one grower mentioned that biological control insects could be found in consumer products and be rejected on quality grounds. Chemical controls have the potential to have wider environmental impact if not responsibly used or tested sufficiently.	Improved chemical options were a commonly suggested area for change to address crop waste e.g. combating mildew and thrips. Growers also discussed need to compete with non-EU growers who had access to a larger array of chemical controls.	Not mentioned frequently.
Better training of staff	Lettuce and strawberry production require significant input of time. Human error is a potential cause of waste e.g. over-trimming of crop; errors in agronomy; crop planning errors; etc.	Could further increase the already-growing cost of labour; waste savings may or may not outweigh additional labour cost.	Not mentioned.	Mentioned by growers who trim lettuce and sell to processors by the kg. Here there is a clearer cost to business of over-trimming crop, so easier to make business case.
Better monitoring of waste	By better monitoring and communication of waste, growers can identify and track improvements. Growers mentioned "you can't manage what you don't measure".	This intervention by the grower will not tackle some of the fundamental external drivers of waste in agricultural systems (i.e. highly variable supply and demand) This needs to be done in combination with some of the interventions mentioned above. Improvements in production efficiency are used as negotiating point by customers.	The recent changes in practice due to Spotted Wing Drosophila combined with increasing harvesting costs have put waste higher on the agenda of growers.	Growers who sell head lettuce can monitor planting and cutting rates – and this is a KPI used within the business. However not clear how this information reduces waste, given other drivers of waste in sector. One grower who harvests for processing found the monitoring of trimming losses useful.

			Examples identified within sample of growers	
Practice	**Theory of change**	**Barriers/challenges**	**Strawberry**	**Lettuce**
Application of 'lean' practices in horticulture	'Lean' is a well established approach to increasing resource efficiency in a number of sectors e.g. manufacturing. It provides a framework for identifying and addressing causes of waste (including 'over production'). The use of lean approaches in horticulture has been explored through projects commissioned by AHDB Horticulture[53] and the IGD[54].	We found limited examples of 'lean' being applied in horticulture to reduce overproduction from variable demand. It would be worth exploring the degree to which lean can tackle this sort of waste	Not mentioned.	Not mentioned.

[53] *AHDB (2008) Lean manufacturing - Achieving efficient use of labour in protected edible crops http://horticulture.ahdb.org.uk/sites/default/files/research_papers/PC%20257%20final%20report%202008.pdf*
[54] *IGD (2007) Food Chain Centre (nd) Applying Lean Thinking to the Fresh Produce Industry http://www.ifr.ac.uk/waste/Reports/Fresh%20Produce-Applying%20Lean%20Thinking.pdf*

5 Conclusions & recommendations

This research has identified that on-farm food waste to lettuce and strawberry crops in England are relatively significant, variable and influenced by a complex set of internal and external factors. Addressing waste is likely to require different interventions by different stakeholders in each sector – for example better supply/demand management in lettuce value chains and better pest/disease management, varietal development, and flexibility of size specifications in strawberries. This is explored in more detail in the sections that follow.

Before considering wider conclusions and recommendations we summarise the degree to which the outputs meet the initial objectives of the research (see Table 22).

Table 22: Review of research outcomes against the initial objectives

Objective	*Met?*	*Comments*
1. Quantify on-farm food waste	Yes	In both sectors we have shown the range of waste that occur on-farm and have managed to speak with a significant proportion of growers in both sectors. The results align broadly with industry expectations.
2. Identify 'hotspots' of on-farm food waste	Yes	We have a good understanding of where in the production cycle major waste occurs. These were consistently observed between growers.
3. Understand the causes of on-farm food waste	Yes	We have identified that there are many drivers of on-farm waste and that in some crops and stages of production some causes are likely to be more important than others. The precise interaction between these drivers and the relative contribution of one cause versus another is much harder to calculate (i.e. we were unable to say that % of waste was due to change in consumer demand vs. % of waste from pest damage). To achieve this an extremely detailed assessment of crop planning, marketing and production would need to be undertaken.
4. Indicate what interventions could be made to reduce on-farm food waste, where appropriate	Yes	Interventions need to be relevant to the key drivers. As we explore below, it is likely that interventions will need to be collaborative and be designed with a strong understanding of broader market economics.
5. Develop a standardised method for quantifying on-farm food waste which is possible to replicate for other crops and which could be made available publicly.	Partially	Since the beginning of this project global multi-stakeholder initiatives have developed standardised methodologies for food waste quantification (including in agriculture): FUSIONS Quantification Manual and the WRI Food Loss & Waste Accounting & Reporting Standard. This project has also identified that transferability of approach between sub-sectors beyond general principles is challenging – each will have its own characteristics that will need to be accommodated. It is recommended that the outputs of this project be used to draft guidelines for the application of that global standard in UK horticulture (see Annex 4).

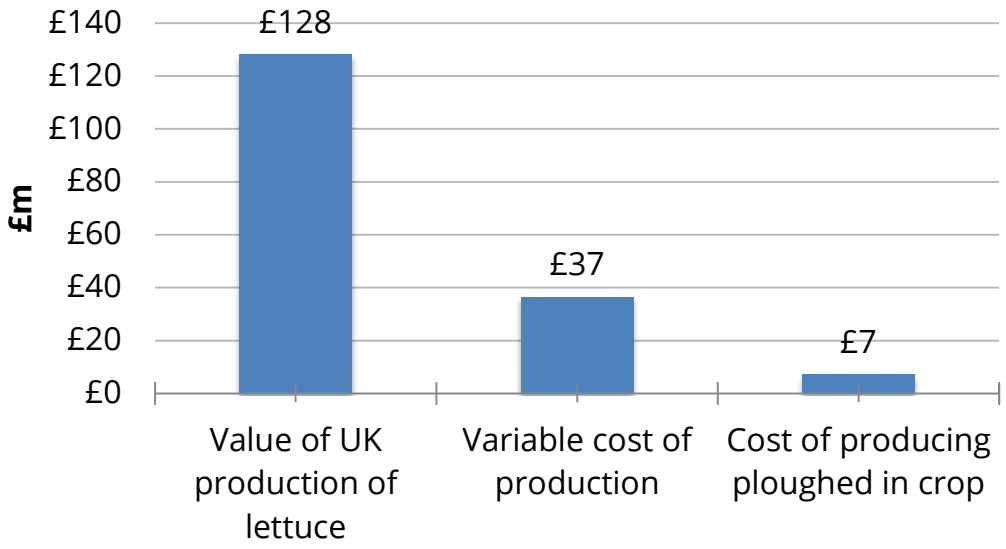
In this section we draw upon the findings of the crop waste analyses, grower interviews and an examination of the economics of sectors to develop wider project conclusions and recommendations.

5.1 Recommendation 1: Assess the economics of farm waste & potential solutions

The levels of waste in the lettuce sector are higher than in the strawberry sector. From our assessment farm waste in the lettuce sector is widespread. From discussions with growers it is clear that waste has become accepted as a part of doing business. However from what we have seen this is not because lettuce growers are less professional or less skilled than strawberry growers. On the contrary, profit margins are smaller in the lettuce sector and it is a more consolidated industry, so one might expect that the incentives to be efficient are greater.

Our conclusion is that a significant proportion of waste in the lettuce sector is due to a combination of high supply/demand variability and concerns about losing business in a mature, competitive market. These concerns were expressed by growers of all sizes (see Box 2 below). Put simply: the potential benefits from having less crop waste are considered by growers to be outweighed by the risk of losing a customer. Figure 21 below presents sector economic data relevant to this question: we estimate the cost of ploughing-in surplus crop is relatively small compared to the total value of the crop to the sector.

Figure 21: Economics of lettuce crop waste in the context of total market value[55]



The implication of this finding is that any strategy for addressing lettuce waste needs to pay significant attention to managing surplus so that it does not become waste. For instance, improving demand/supply management and redistributing or diverting surplus crop to alternate uses – although the latter may not be economically viable.

[55] *Value of UK production from Defra Horticultural Statistics (2015); UK cost of production multiplies assumptions on typical variable cost of production (£6,000/Ha) by total area produced in UK (6,000); Economic benefit from waste reduction assumes production costs are reduced by 19% and released land is used to produce alternate cereal crop (assumes a net margin of £264/hectare – an assumption taken from the Farm Business Survey results for 'General cropping'. In reality, it is highly unlikely that waste could be reduced completely and so the actual economic benefit is likely to be less than £7m.*

Box 2: Three lettuce grower views on managing supply risk

Growers acknowledge the role their own forecasting plays and that it may be possible to narrow the surplus produced through their own planning, however perceived fears over losing business were evident from discussions and appear to be driving farming practices. Below are extracts of transcriptions from interviews with three growers about the risks of under-production:

"*We always have this sort of attitude that it costs you more not having the crop than it does actually having it, because if you haven't got it it's an absolute nightmare, you're in danger of losing the whole order then, and that'll end up costing you a lot more than just a bit of crop loss."*

"*If you think you're going to sell 10k units a week, you can't grow 10k, you have to have a surplus, it's as simple as that. Because customers like XXXX and XXXXX, you don't let them down many times before 'pop!' you're out the door. That's the way it is - you know, occasionally if you have problems they'll work with you, but as a rule of thumb if you went through the summer thinking well, we're going to play safe, we're going to produce pretty much what we're going to sell, consistently let them down, you'd be gone, or that part of the business would be gone. It's just not an option*."

"*Well if you think about it, we dare not let the customer down, so we've always got to overproduce. You're never going to get a situation where the customer will give us a programme and every week it will be that amount. If the sun shines in the summer, we sell a lot. If it rains, orders collapse. So how do you manage that? You have to overproduce*."

This use of surplus production as a risk management strategy is part of a much larger economic backdrop that we identified and propose as important to understand in any effort to reduce waste in agriculture, more broadly. This bigger picture also emerges from a comparison of lettuce and strawberry sectors (indeed, an examination of the differences between sectors has been at least as revealing as an examination of differences between growers in the same sector).

Overall, our conclusion is that factors external to the grower's business will have a strong influence on the levels of waste in many agricultural sectors – and so will be critical to consider this when exploring the feasibility of potential solutions. Some noteworthy characteristics that could drive farm waste are summarised in Table 23 below. The importance of sector economics in driving farm waste has been seen in other unrelated agricultural sectors e.g. historic disposal of male calves from dairy herds[56].

[56] *Male calves are a by-product of dairy herds. In the UK it has been uneconomic to raise them for meat. Solutions have included multi-stakeholder initiatives to improve the market e.g. Beyond Calf Exports Stakeholders Forum*

Table 23: A comparison of the economics of strawberry and lettuce markets

Sector characteristic	*Strawberry*	*Lettuce*	*Relevance to crop waste*
Industry lifecycle	Mature/Growth (see Figures 23 and 24 below)	Mature/Declining (wholehead) (see Figures 23 and 24 below)	Growing markets have strong demand and can absorb oversupply. Mature/declining markets are highly competitive and more likely to exhibit over-supply
Availability of imports in peak season	Yes – can act as source if demand is strong in UK	Low. In peak season UK production must meet demand	The import option may take pressure off strawberry growers and provide more flexibility to meet variable demand
Costs of producing crop	Fruit needs to be picked due to disease risk. Labour cost high and rising	Crop can be ploughed in without harvesting (and labour) if no demand	Greater incentive in strawberry production to utilise potential crop waste
Land needed	Polytunnels	Tolerant of land types, less growing infrastructure	As there are infrastructure constraints to expansion in the strawberry sector there is a greater incentive to maximise outputs from each hectare of land
Brand value	76p/portion "British strawberries"	8p/portion	Strawberry is higher value and so there is a greater incentive to try and market crop
Secondary markets	Some potential e.g. Class 2 & processing	Few proven routes – 1 grower juicing crop was interviewed	Strawberry crops have more marketing options and so this can help mitigate waste
Marketing & sales "ethos"	"We'll sell as much as we can grow"	"We can't let down the customer"	Based on the view from the project steering group that there was a different ethos in the sectors – which may be reflective of the characteristics above

Figure 22: Historic UK supply of lettuce (value is inflation adjusted)[57]

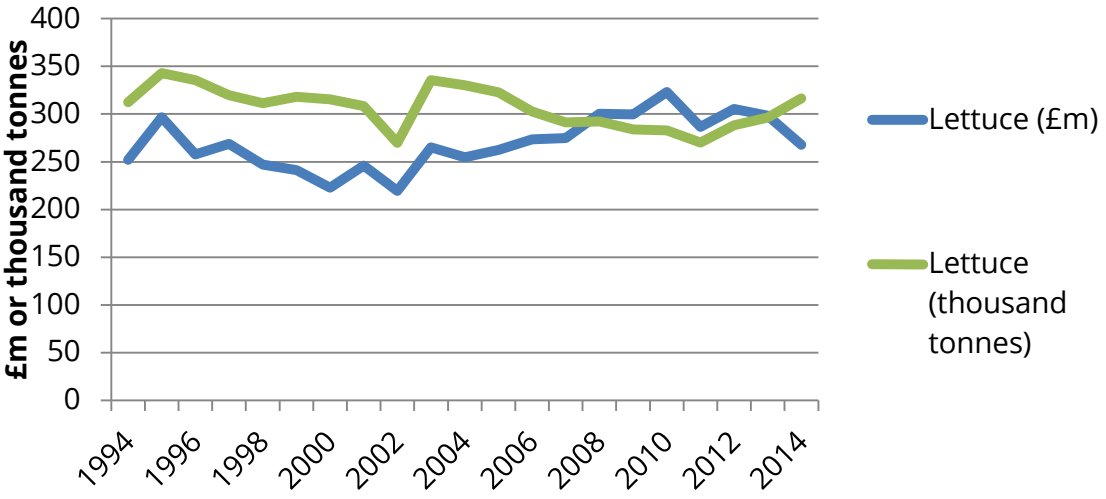
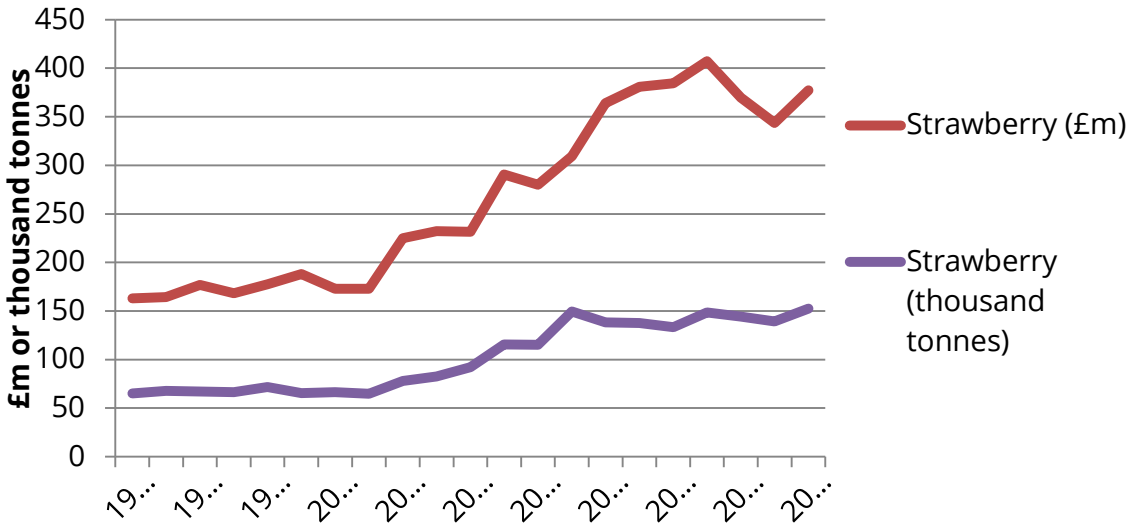


Figure 23: Historic UK supply of strawberries (value is inflation adjusted)[58]



As part of this economic assessment, the interplay between UK production and overseas imports also needs to be considered. For example, it would be useful to explore whether the UK is 'offshoring' strawberry crop waste to trading partners e.g. Morocco and Spain. In other words, to what extent strawberry waste in the UK is mitigated by spare capacity overseas. Does a good crop and average demand in UK mean significant 'hidden' waste in Spain and Morocco producers? These potential consequential impacts of changes to policy need to be considered to avoid initiatives having no impact – or potentially detrimental impact on the levels of waste that result from UK consumption of agricultural products.

[57] *The net supply of lettuce was calculated using Defra's Basic Horticultural Statistics (2014): Home production plus imports minus exports.*

[58] *The net supply of strawberries was calculated using Defra's Basic Horticultural Statistics (2014): Home production plus imports minus exports.*

In conclusion, we recommend that the *economics* of crop waste and crop waste solutions are modelled in more detail in a variety of sectors. We were only able to touch on this topic relatively lightly within the scope of our research. In particular we think an exploration of the likely cost/benefits to different actors in the supply chain of different interventions would be useful. As part of this there is also the need to explore the degree to which some types of waste identified in this research can be reduced – in particular the difference between the theoretical and practical avoidability of trimming waste in lettuce production.

5.2 Recommendation 2: Pilot novel, collaborative solutions to farm waste

Given that the causes of farm waste are complex and have internal and external factors, it is likely that meaningful reductions will require collaborative, whole supply chain solutions: one of the overarching conclusions of this project is that no one actor is likely to have the power to tackle waste alone.

To test this we recommend piloting whole supply chain collaborative approaches to mapping and identifying solutions to waste. This has been tried successfully in some sectors (e.g. the WRAP Whole Chain Resource Efficiency project on potato losses[59]) – however we recommend similar work in other supply chains. For crop waste reduction initiatives to have real systemic impact it is important that crop waste across the whole value chain is optimised – and that actions take into account consequences upon other supply chains. For example, how combining UK grown and imported strawberries might act to mitigate or increase on-farm waste (see section above).

[59] *WRAP, 2014*

5.3 Recommendation 3: Enable better quantification and benchmarking of farm waste

Waste data collection in lettuce and strawberry sectors was variable – but growers report seeing the benefits of better measurement of waste (see Box 4 below). As part of efforts to tackle farm waste we recommend the development of tools or methods that help growers monitor and benchmark their performance. As part of this project we have provided a commentary on the pros/cons of different approaches to quantifying farm waste, based on our experiences (see Annex 4) – however each sector will need to develop approaches that suit the specifics of their production systems and value chains.

Box 3: A strawberry grower's perspective on optimising waste

*"[**We started to collect detailed data on loss quantity and cause because we] just realised the size of the prize, the opportunity for us**.*

*"A simple phrase we don't use enough that I like is "you can't manage what you don't measure" - so how can you do anything about it unless you know what it is? And you ask most growers still now what's [your waste] on that fruit, they'll go 1%, you know, what's your Class 1 percentage, 99%. Actually it's about 90%. So partly driven by the fruit fly spotted winged drosophila, because we started to have to collect it, so you're paying to collect it and it comes within harvest costs, and then there's the cost of collation, distribution to the bio-digester and therefore there's a value chain if you like, you're adding in, so therefore **you might as well try and work out where the waste is and what you can do about it. And I think that's one of our opportunities to massively improve what we do, because it's a lot bigger than we thought it was and a lot bigger than most people think it is.** And that's interesting in lettuce and industries that are more mature with lower margins probably historically were in the same place, and you know berries has been in a very good place for a number of years and it's becoming a lot more marginal - the industry's become a lot more saturated, there's less market opportunities at certain times of year.*

*"If you draw average accounts for berry growers they're making less money than they were 5 years ago, [and with the] Living Wage coming in we've really got to [look at] marginal gains - you know if you can improve 1% of your grade out, what's that worth to you? ...Improve that 1%, there [could be] be a lot of profit behind it. We're not there yet, we haven't got those figures in terms of scale, but **if we can get that mentality in our business then we can make it and then [if] you [have] the data, you know what you can do about it."***

Annex 1 – Literature review

5.4 Introduction

This literature review was conducted at the beginning of the project, in December 2014. It was not intended to be a fully comprehensive review of all literature on on-farm food loss; rather, its aims were to collate and analyse the current (at the time) state of research on on-farm food losses for the purpose of informing the focus and research methodology of this project. The project budget and timeline did not allow for a comprehensive update of the literature review at the end of the project, but some key references, published during the project's time span, have been added.

5.5 Objectives

The purpose of this literature review is to collate, synthesise, and incorporate current research on the topic of on-farm food losses. The process seeks to identify key data sources and literature and summarise their results, quantification methods, causes, and potential interventions. The findings of this literature review, especially with regards to quantification methods and key causes of crop loss, will influence and inform the design of the method used in this project/research.

The literature review covered the potato sector as well as strawberry and lettuce sectors. While research was initiated in the potato sector, it was halted due to unforeseen resource. The findings of the literature review and pilot interviews with potato growers are included in this report – however there is no quantification of losses or causes of loss.

5.6 Method

A semi-systematic search was performed to identify relevant literature on on-farm food losses. Academic portals Web of Science and Science Direct were searched with no restriction on time or location, and grey literature, including reports, was located and accessed through government research portals (Defra, EU), AGRICOLA, and searches on relevant producer, retailer, and grower association sites (e.g. Tesco, McCain, Potato Council, etc.). The reference lists from key articles and reports were crosschecked to ensure that no relevant studies had been overlooked during the systematic searches. Finally, results were supplemented by internal searches of WRAP, University of Warwick, and 3Keel reference folders as well as a semi-systematic search of Google using the same key words and scanning the first four returned pages of results.

Key words included farm, on-farm, post-harvest, quantification, food crop loss, and food loss, in different iterations. Results yielded by the searches were scanned first by title and then by full-text for relevancy; relevancy was determined by the presence of content on definitions, quantification and quantification methods, drivers/causes, hotspots, and/or interventions relating to food crop loss and food loss. Searches were not restricted by geographical location or product type and there were no explicit exclusion criteria in order to

capture as much relevant literature as possible. Additional special searches were undertaken in both the academic and grey literature searches for the specific product types and regions assessed in this report (England, the UK; potatoes, lettuce, and strawberries). Documents considered to be relevant and important for inclusion in the literature review were compiled in Mendeley.

5.7 Definitions of food loss

At the time of writing, there was no recognised standard definition of food loss; rather organisations and reports tend to use their own working definitions, which are adapted to the needs of their particular work or research question. To start with, the term food loss is often used interchangeably with food crop loss. This lack of standardisation contributes to the diversity of results produced by these studies and reports, but is difficult to avoid. Food crop loss/food loss is a naturally complex subject, and any comprehensive definition of it must include consideration of a number of terms at once: crop loss, loss, food, avoidable/edible, unavoidable/inedible, 'recycling', diversion, as well as the food supply chain and its component parts. Additionally, food loss has historically been approached from two difference perspectives: a crop loss perspective, with associated environmental concerns, or a food perspective, with associated food security concerns. These different viewpoints have added to the confusion over the definition and scope of food losses[60].

The topic is complex enough that the House of Lords, in their 2013-2014 Session Report on EU food crop loss prevention, concluded that a standardised universal food crop loss definition "defies the complexities of the European food supply chain," recommending instead standardised approaches to defining material and crop loss flows at each stage of the food supply chain.[61] The FUSIONS project, a pan-European initiative, is currently doing just this: working on standard approaches to food crop loss definition and measurement[62]. Ultimately, their definition will be applicable to all food supply chain stages, food product categories, and different geographical scales.

Concurrently working from the other end is World Resources Institute (WRI), which is currently developing a protocol for quantifying food loss/crop loss[63]. FUSIONS is a partner in the project, making it likely that the protocol will align with and complement the pan-European definition. Similarly, FUSIONS is developing a food waste Quantification Manual, published in March 2016.[64] This lack of an existing standard definition has resulted in currently existing studies and reports creating and using their own definition of food loss/food crop loss.

60 HLPE, 2014
61 HoL, 2014
62 Ostergren et al., 2014
63 WRI, 2015
[64] FUSIONS, 2016

5.8 Food loss quantification

The lack of a standard definition for food loss has ensured that there is, as of yet, no standard method for assessing food loss; this in turn means that the scope and boundary conditions which might be applied to an assessment have not been agreed. As a consequence, existing estimates vary with supply chain type, geographical location, unit of measurement (e.g. weight, calorific value, lost inputs, greenhouse gas impacts), commodity and method (Table 24). This makes it difficult to synthesise data and results across studies. Some research does seek to explicitly address this heterogeneity; Garrone et al[65] propose a conceptual model to support the analysis of the supply chain, both as a whole and as individual parts.

The World Resources Institute's Food Loss and Waste Accounting & Reporting Standard, once finished, will standardise food loss and crop loss quantification[66]. WRAP is on the Steering Committee of this initiative and members of the research team are contributing to the 'Upstream' Technical Working Group that is exploring quantification in agriculture.

A number of relevant studies were conducted 20-30 years ago[67] [68] [69], but the age of their data means that the information and conclusions that can be drawn from them are no longer useful.

Despite methodological difficulties, researchers have continued to estimate losses across different systems and this work has been compiled by the FAO into a recent report "Global food losses and crop loss: Extent, Causes, and Prevention"[70]. This report is now commonly cited in current work[71] [72] [73]. The report quantifies losses occurring through the entire global food chain and suggests that approximately 1.3 billion tonnes of food are lost or wasted globally each year. The report also found that more food is lost in the industrialised world than in developing countries (on a per-capita basis), and identified consumer behaviour and lack of coordination between different supply chain as main drivers in developed countries. A more recent study, also commissioned by the FAO, builds on this report by focusing on low and middle-income countries in Europe and Central Asia[74].

[65] *2014*
[66] *WRI, 2015*
[67] *Booth et al., 1982*
[68] *Mian et al., 1987*
[69] *Rhoades, 1986*
[70] *Gustavsson et al., 2011*
[71] *Lipinski et al., 2013*
[72] *Redlingshoer et al., 2012*
[73] *Bond et al., 2013*
[74] *Themen, 2014*

Table 24: **Summary of on-farm loss quantification studies and their methods**

Author	*Location*	*Crops*	*Method*	*On-Farm Crop loss Levels*	*Definition of Loss*
Gustavsson et al 2011 (method in Gustavsson 2013)	Europe	Fruits and Vegetables	Production volumes collected from FAO Statistical Yearbook 2009; crop loss percentages were collected from extensive literature search; national and regional Food Balance Sheets from 2007 were used to quantify losses and crop loss; statistical models were used to deal with major data gaps	20%	"Food losses refer to the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption. Food losses take place at production, post-harvest and processing stages in the food supply chain (Parfitt et al., 2010). Food losses occurring at the end of the food chain (retail and final consumption) are rather called "food crop loss", which relates to retailers' and consumers' behaviour. (Parfitt et al., 2010)." Excludes feed and parts of products which are not edible.
WRI/Lipinski 2013	Developed Countries	General	Data based on Gustavsson et al 2011	10%	""Food loss and crop loss" refers to the edible parts of plants and animals that are produced or harvested for human consumption but that are not ultimately consumed by people. In particular, "food loss" refers to food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer. Food loss is the unintended result of an agricultural process or technical limitation in storage, infrastructure, packaging, or marketing. "Food crop loss" refers to food that is of good quality and fit for human consumption but that does not get consumed because it is discarded—either before or after it spoils. Food crop loss is the result of negligence or a conscious decision to throw food away."

Author	*Location*	*Crops*	*Method*	*On-Farm Crop loss Levels*	*Definition of Loss*
Themen 2014	Ukraine, Turkey, Armenia	Fruits and Vegetables	Used data from Gustavsson et al 2011; refined data on low and middle income countries through statistical data (FAO Food Balance Sheets, State and Industry Statistics); Existing research; and key informant interviews	24% in middle income countries; 14% in low income countries	"For the purposes of this study, food losses are understood to refer to food that between the moment of its readiness for harvest and the moment it becomes a final product ready for consumption it is spilled, spoiled or otherwise lost. Losses are considered as unintended results primarily of poor practise and a lack of technology. Food Crop loss, on the other hand, is understood to refer to food that has reached the stage of a final product ready for consumption but that is discarded and not consumed. Such crop loss results from a deliberate act or omission, generally by retailers and consumers."
Roels et al 2010	Flanders	Horticulture	Combines governmental statistical data and private data sources with expert estimates and author calculations	0-30%	"Based on the broad OECD definition, we define food loss as any reduction in the food available for human consumption in the food supply chain, from harvest to consumption. We make a distinction between unavoidable (non-edible food elements) and avoidable (edible food elements) food loss."
Beretta et al 2012	Switzerland	General (incl. horticulture, animal, fruit, cereals)	Used data from Gustavsson et al 2011 and five farmers	14% (refers to calorific content)	The definition employed in this paper refers to food which is originally produced for human consumption but then directed to a non-[human] food use or crop loss disposal." Includes avoidable and unavoidable losses.

Author	*Location*	*Crops*	*Method*	*On-Farm Crop loss Levels*	*Definition of Loss*
Jones	USA	Vegetable	Primary data collection with contemporary archaeology techniques; interviews; site visits; secondary data sources. Losses were measured in weight, value, and % of available food supplies.	18% in vegetable industry	No specified definition.
Abass 2013	Tanzania	17 crops, including maize, sunflower, and pigeon peas	Primary research: Methods included a cross-sectional survey approach - widespread questionnaires, validated with focus group interviews in each village and with physical inspections of several random farm homesteads in each village at three points in the year.	15% of 'economically important' post-harvest losses	No specified definition.
Strid et al 2014	Sweden	Lettuce	Data scaled up from field study and interview with 5 farmers during harvest period. Biomass left on test squares on harvested fields was weighed 1 hour after harvest.	15%	"At the farm, only the crop loss of high quality heads was considered, and not the type of crop loss occurring at the field during harvest (e.g., peeled off outer leaves and damaged heads left on the field), since this was defined as production losses instead of food crop loss."

Author	*Location*	*Crops*	*Method*	*On-Farm Crop loss Levels*	*Definition of Loss*
Kaguongi et al 2014	Kenya	Potato	Survey, publicly available data, validation workshop	12.8% loss	"Food destined for human consumption that falls out of the human food chain is considered as food loss or crop loss. This approach distinguishes between 'planned' non-food uses and 'unplanned' non-food uses, with the latter being counted as loss. Food loss occurring at the end of the food chain (retail and final consumption) is called 'food crop loss' and is the result of retailer and consumer behaviour."
NRDC 2012	USA	6 fruit and veg crops; Head Lettuce reported here	Primary data collection through in-person interviews; small sample size meant no statistical analysis was performed	4-10%	"Crop shrink: The difference between the volume of edible crops available for harvest and the volume entered into commerce for human consumption."
Terry et al 2011; Mena et al 2014	UK	11 fruits and vegetables; Strawberry, Lettuce, and Potato reported here, respectively	Semi-structured interviews	3-4%; 5-10%; 4-15%	"For this research we followed the definition form the EU Crop loss Framework Directive, which states that crop loss is "any substance or object the holder discards, intends to discard or is required to discard"."
Potato Council 2012	UK	Potatoes	Not mentioned	42%	No specified definition. Likely to cover post farm-gate stages as well as on farm.

Other recent studies have focused their quantifications by area, commodity, or scope within the food supply chain, or used the FAO's data to assess and discuss causes, hotspots, and interventions. Roels et al,[75] working in Flanders, estimating that the total food loss in the Flemish primary sector in 2010 was between 534,000 and 817,000 tonnes. Beretta and colleagues[76] quantified food losses in calorific content throughout the entire food value chain in Switzerland, finding that 48% of total calories produced (including edible crop yields at harvest time) are lost. Jones[77] used anthropological and archaeological methods to estimate food loss in the US, determining that overall farm food losses are approximately 18% in the vegetable industry. Abass and colleagues[78] quantified post-harvest losses in seventeen crops in Tanzania, finding that 15% of economically important postharvest losses occur in the field. Affognon et al[79] conducted a meta-analysis of post-harvest losses in Sub-Saharan Africa and determined that the vast majority of loss estimates (80.4%) were related to storage.

A few studies focused on loss in the potato and lettuce supply chains have been conducted. Strid et al[80] followed what they termed the "crop loss flow" of Swedish iceberg lettuce from field to retail shelf; they found that at the "farm level" (after produce had reached harvestable stage) 3 tonnes of high quality lettuce heads were wasted per ha/year compared to 19 tonnes harvested. Kaguongo et al[81] assessed ware potato post-harvest losses in Kenya, following the FAO's[82] approach in regards to scope of supply chain analysis. It found that up to 95% of (recorded) damage and loss occurs at the production level, and is caused largely by inappropriate harvesting tools and the lack of well-trained labour. In 2012, the Natural Resources Defense Council (NRDC) found that loss in head lettuce in the US (termed more specifically as "shrink") to be 3-6% pre-harvest shrink, 1-4% in-situ shrink, and 1-4% packing culls (% by weight of total available harvest, low-high estimate)[83]. The primary causes of the loss found by these studies are discussed in the next section.

Several studies have been also conducted in the UK specifically. WRAP[84] [85] assessed estimated loss in eleven fresh produce types in the UK in 2011, including potatoes, lettuce, and strawberries, in retail and wholesale supply chains from field to customer, finding that loss is most significant for lettuce at

[75] *Roels et al., 2010*
[76] *Beretta et al., 2012*
[77] *Jones, 2004*
[78] *Abass et al., 2013*
[79] *Affognon et al., 2014*
[80] *Strid et al., 2014*
[81] *Kaguongo et al., 2014*
[82] *Gustavsson et al., 2011*
[83] *Milepost, 2012*
[84] *Terry et al., 2011*
[85] *Mena et al., 2014*

the field end of the chain, while for potatoes it is most significant during grading and storage.

The War on Crop loss project, a 5-year project started in 2008 by Waitrose and Solanum (Produce World), found that half of the losses in the potato supply chain occurred directly on farm; 6% were graded out at field level before or soon after lifting began, a further 12% during initial grading, and storage crop loss accounted for 5%[86]. During packing, size grading took out 2%, and post-washing defects removed 22%. Another WRAP project analysed the whole potato supply chain of the Co-operative and found that their on-farm harvester losses average at 3%, while storage and dirty grading and sizing accounts for a further 16%.[87]

The scarcity and heterogeneity of the existing data on quantification of food loss, and the reliance of the literature on the data of a few key studies, highlights the necessity for more primary research on the subject. It also means that the data cannot be combined in any sort of meta-analysis, to draw wider or more robust conclusions. However while the extant data on quantification of food loss is limited, the literature on drivers of food crop loss is much more extensive and comprehensive and may be helpful in guiding the development of new quantification studies.

5.9 Drivers and hotspots

Drivers and hotspots of food loss vary considerably between developed and developing countries, type of food product, and stage within the food supply chain. As the focus of this report is on on-farm food loss in the UK, this literature review has necessarily focused its efforts on drivers and hotspots of on-farm food loss in developed countries.

Of food losses arising on-farm, the literature reports a mixture of causes; some arising on-farm and some arising elsewhere in the food supply chain. The integration of the supply chain means that players downstream (including consumers) can and do influence what happens in the field and post-harvest.

[86] *Potato Council, 2012*
[87] *WRAP, 2014*

Table 25: **Types of food loss & crop loss driver**[88]

Location	*Type of driver*	*Examples*	*Reference*
Before crop maturity	Environmental	Weather damage e.g. frost, rain; Pests	Gunders et al 2012
On-farm, after crop maturity	Environmental	Weather damage e.g. frost, rain; Pests	Gunders et al 2012
		Food safety	NRDC Left Out 2012, Gunders et al 2012
	Technical	Mechanical damage from harvesting; Unharvested crop (missed by harvester)	NFU response (2013)
	Human	Insufficient labour for harvesting	NRDC Left Out 2012, Gunders et al 2012
	Commercial	Quality standards/requirements	Bond/GFS 2013, Gustavsson et al 2011, NFU 2013 (response) Gunders et al 2012, Potato Council 2012, Terry et al 2011, HoL
		Limited market for produce that doesn't meet grade specifications	NFU response (2013), NRDC Left Out 2012, NFU 2012 (catalyst)
		Walk-bys	NRDC Left Out 2012, Jones
		Cancelled retail orders	NRDC Left Out 2012, Gustavsson et al 2011, NFU 2012 (catalyst)
		Contractual requirements e.g. crop specifications, inability to sell excess to 3rd party, over production to ensure meeting contracted crop amounts	Gustavsson et al 2011, NFU 2013 (response)
	Economic	Excess supply due to seasonal demand changes; Uneconomic to harvest lower grade fruit	NRDC Left Out 2012
Storage	Technical	Improper storage conditions (too warm, too humid, inconsistent refrigeration, poorly trained employees etc)	Gunders et al 2012
Consumer	Human	Attitudes towards abundance (consumers not placing	Gustavsson et al 2011

[88] *Categorisation developed by research team based on review of causes*

Location	*Type of driver*	*Examples*	*Reference*
		adequate value on food)	
		Quality preferences; attitudes towards abundance	Gustavsson et al 2011, Hodges 2011

The literature suggests that commercial arrangements are responsible for a large percentage of on-farm food loss across sectors. Quality standards required by manufacturers and retailers can result in up to 40%[89] of harvested produce being rejected at grading[90] [91] [92] [93] [94] [95] [96]; this problem is compounded by the fact that there can be limited options for produce that does not meet specifications[97] [98]. Contractual obligations, in which producers must ensure the delivery of agreed quantities, are reported as often leading to over-production as farmers plant more product than is needed to ensure that they are able to meet their contracted demands; resulting in excess yield which is often left in the field and ploughed back under[99] [100] [101]. "Walk-bys," when farmers walk by a harvestable crop and choose not to harvest it (generally for quality or contractual reasons), are commonly cited as a primary cause of on-farm food loss[102] [103]. Similarly, cancelled retail orders can also result in un-harvested produce[104] [105].

5.10 Interventions and recommendations

Most of the literature on drivers and quantification of food losses also discuss interventions or recommendations to mitigate the aforementioned drivers; some of these interventions have been used and case studies are offered, while others are put forward as potential methods for preventing known causes. As interventions generally target specific causes and drivers, they also can be grouped by segment in the food supply chain.

Many interventions focus on the producer-retailer relationship, aimed at mitigating the major drivers of overproduction and quality standards. Recommendations include improving supply chain communications[106] – both among farmers[107] as well as between farmers/producers and retailers/manufacturers[108], developing markets for 'sub-standard' products[109] [110] [111], and modifying grading standards[112]. Some interventions are

[89] *Bond et al., 2013*
[90] *Gustavsson et al, 2011*
[91] *NFU, 2013*
[92] *Gunders et al, 2012*
[93] *Potato Council, 2012*
[94] *Terry et al, 2011*
[95] *HoL, 2014*
[96] *NFU, 2012*
[97] *NFU, 2013*
[98] *Milepost, 2012*
[99] *Gustavsson et al, 2011*
[100] *NFU, 2013*
[101] *Gunders et al, 2012*
[102] *Milepost, 2012*
[103] *Jones, 2004*
[104] *Milepost, 2012*
[105] *NFU, 2013*
[106] *Ibid*
[107] *Gustavsson et al 2011*
[108] *NFU, 2012*
[109] *Gunders, 2012*
[110] *Milepost, 2012*
[111] *Gustavsson et al., 2011*
[112] *Milepost, 2012*

more technical in nature, including increased use of production planning systems and promotion of technology development and knowledge transfer[113] [114].

Other interventions and recommendations focus on the consumer and consumer behaviour. Current recommendations include consumer surveys by supermarkets to assess true consumer quality demands[115] and selling produce closer to consumers to avoid strict quality standards[116], while the most popular recommendation concerns promoting public awareness about crop loss[117] [118] [119] [120] [121]. In 2014 French supermarket chain Intermarché initiated the successful "Inglorious Fruit and Vegetable" food waste reduction campaign, focused on selling "undesirable" fruit and vegetables in natural form or in soups and juices[122]. Recently a number of UK supermarkets have begun their own "ugly fruit" campaigns, including ASDA, Morrisons, and Tesco.[123][124][125] Some reports further suggest that changes in legislation and business behaviour are also necessary if consumer behaviour is to be successfully shifted.[126]

Finally, interventions and recommendations that focus on the farm specifically include innovations in farm worker management to address labour shortages[127], development of shared logistics like collaborative warehousing or storage[128] and advances in technology such as optical sorting enable more economic grading[129] and advance weather forecasting[130].

While some of these interventions and recommendations are beginning to be put into practice, with a handful of case studies here and there, many of them remain theoretical. Despite the wider availability of data on causes of food loss in general, the lack of quality data on food loss quantification makes it difficult to determine the best places in the food supply chain to intervene for greatest impact.

[113] *Gustavsson et al., 2011*
[114] *Parfitt et al 2010*
[115] *Gunders 2012*
[116] *Ibid*
[117] *Parfitt et al 2010*
[118] *Lipinski et al., 2013*
[119] *French-Brookes, 2012*
[120] *Ibid*
[121] *HLPE, 2014*
[122] *Godoy, 2014*
[123] *ASDA, 2016*
[124] *The Grocer, 2016*
[125] *The Grocer, 2015*
[126] *Parfitt et al., 2010*
[127] *Milepost, 2012*
[128] *Parfitt et al., 2010*
[129] *Tong Peal Engineering, 2014*
[130] *CDKN, 2012*

Annex 2 – Survey and interview questions

Lettuce

Section 1: About your farm and crop

1. *How many hectares of whole head lettuce did you grow in 2015? This should include multiple cropping of the same land. (Leave blank if not applicable).*

2. *How many hectares of baby leaf lettuce did you grow in 2015? This should include multiple cropping of the same land. (Leave blank if not applicable).*

3. *How many heads of whole head lettuce did you sell in 2015? (Leave blank if not applicable).*

4. *Acknowledging that there is variability across varieties and times in the season, please estimate the average headweight of lettuces sold. (Leave blank if not applicable).*

5. *How many tonnes of baby leaf lettuce did you sell in 2015? (Leave blank if not applicable).*

6. *In 2015, what per cent of total sales volume did you supply into the following market channels?*
   - *Processing, retail*
   - *Processing, wholesale*
   - *Whole head, retail*
   - *Whole head, wholesale*
   - *Other (if other, please specify)*

Section 2: Losses of whole areas of crop

7. *Did you have to plough-in whole areas of crop this year? If the answer is 'yes', please estimate the total loss of lettuce by tonnes or hectares:*
   a. *Whole head*
   b. *Baby leaf*

8. *How significant were the following reasons for ploughing the crop in? Please rate options from 'very significant' to 'not significant':*
   - *Unexpected change in customer order*
   - *Over-planting of crop to ensure adequate supply*
   - *Demand forecasting error*
   - *Pest/disease damage*
   - *Other (if other, please specify)*

9. *What per cent of oversupply do you build into your crop plan to manage production risk?*

Section 3: Harvesting losses

10. *During whole head harvesting, individual plants can remain unharvested in the field if they do not meet quality requirements. Please estimate the percentage of lettuce heads that are left unharvested like this, across a whole season.*

11. *Over the course of the season, how significant are the following causes of loss in driving over all losses? Please rate options from 'very significant' to 'not significant':*
    - *Wrong shape/size*
    - *Mechanical damage*
    - *Pest/disease damage*
    - *Weather damage*
    - *Other (please specify)*
    - *Not applicable*

12. *During harvesting and packing of whole head lettuce, the outer leaves are trimmed. Please estimate the typical percentage of the head that was removed this year.*

13. *Please score the reasons for trimming lettuce heads (from 'not important' to 'very important'):*
    - *Crop too large*
    - *Leaf defects*
    - *Pest/disease*
    - *Other damage to outer leaves*
    - *Soil on leaves*
    - *Other (please specify)*
    - *Not applicable*

Section 4: Post-harvest losses

14. *Once off the field, did you send or dispose of harvested crop to destinations other than your intended customer(s) this year (e.g. sold to secondary markets, sent to animal feed, AD or landfill)? If 'yes', please estimate the amount of lettuce.*
    a. *tonnes of whole head*
    b. *tonnes of baby leaf*

15. *Why did you send harvested lettuce to the destination(s) other than your intended customer(s)? Please rate options from 'always' to 'never':*
    - *Unexpected change in customer order*
    - *Quality check identified problems with harvested crop*
    - *Other (please specify)*

16. *Where was the crop sent? Please rate options from 'always' to 'never'*
    - *Sent to composting/anaerobic digester*
    - *Used for animal feed*
    - *Sold to alternate food markets*
    - *Given away for human consumption e.g. food banks*
    - *Other (please specify)*

Section 5: Concluding questions

17. *Were there any other sources of lettuce crop loss on your farm that we have not covered? If so please estimate the tonnes and explain the cause and how they were disposed of.*

18. *If you supply through more than one market channel, do any of your market channels generate greater levels of losses than others? If yes, please explain which ones.*

19. *Thinking about all losses covered in this survey, do you think that this year they were less than usual, greater than usual or about average?*

20. *Please estimate the economic cost to your business of all the losses that you have identified in this survey. For example lost sales, cost of wasted inputs, crop loss disposal costs.*

21. *Do you regularly collect information on crop losses?*

22. *What are some ways to reduce loss?*

Strawberry

Section 1: About your farm and crop

23. *How many hectares of strawberries did you grow in 2015?*

24. *How many tonnes of strawberries did you sell in 2015?*

25. *In 2015, what market channels did you supply strawberries into? (% by PYO/farm shop; processing; wholesale; retail).*

26. *What percentage of your production was:*

    a. Polytunnels + table top
    b. Polytunnels + ground level
    c. Glasshouse
    d. Field grown

27. *Was your production soil based, growing media based, or hydroponic?*

Section 2: Crop losses

28. *In 2015, what proportion of your crop was sold as Class 1?*

29. *Of the crop that was not sold as Class 1, how significant were the following reasons? Please rate options from ' very significant' to 'not significant':*
    - *Unexpected change in customer order*

- *Unable to find Class 1 buyer*
- *Did not meet Class 1 standards*
- *Other (please specify)*

30. *Of the crop that did not meet Class 1 standards, how significant were the following reasons?*
- *Wrong size or shape*
- *Pest or disease damage*
- *Weather damage*
- *Other (please specify)*

31. *What percentage of the crop that <u>did not</u> go to Class 1 went to the following destinations?*
- *Buried in ground (e.g. to mitigate disease risk)*
- *Used for animal feed*
- *Sold to alternative food/drink markets*
- *Given away for human consumption e.g. food banks*
- *Sent to composting/anaerobic digester*
- *Landfilled*
- *Other (please specify)*

32. *Of the crop that did not meet Class 1 standards, at what point were they graded out?*
- *During picking*
- *During packing*
- *Pre/post storage*
- *Other (please specify)*

<u>Section 3: Concluding questions</u>

33. *If you supply through more than one market channel, do any of your market channels generate greater levels of losses than others? If yes, please explain which ones.*

34. *Thinking about all types of crop loss, do you think crop losses this year were less than usual, greater than usual or about average?*

35. *Please estimate the economic cost to your business of the losses described above. For example lost sales, cost of wasted agricultural inputs, crop loss disposal costs.*

36. *Do you regularly collect information on crop losses?*

37. *What are some ways losses could be reduced?*

Annex 3 – Lettuce types included in analysis

This table was developed in collaboration with the project steering group.

Type of lettuce as given by grower	*Head lettuce or baby leaf*	*Type category*	*Included/ excluded*
Apollo	Head lettuce	Speciality	Included
Baby leaf	Baby leaf	Mixed/Other	Included
Baby red leaf	Baby leaf	Mixed/Other	Included
Batavia	Head lettuce	Speciality	Included
Big leaf red lettuce	Head lettuce	Speciality	Included
Boar's blood	Baby leaf	Mixed/Other	Included
Butterhead	Head lettuce	Round/Flat	Included
Chard	Baby leaf	Chard	Included
Chinese leaf	Head lettuce	Chinese leaf	Excluded
Coarse frisee	Head lettuce	Chicory type	Included
Cos	Head lettuce	Romaine/Cos	Included
Dolce verde	Head lettuce	Romaine/Cos	Included
Endive	Head lettuce	Chicory type	Included
Escarole	Head lettuce	Chicory type	Included
Fine frisee	Head lettuce	Chicory type	Included
Gem	Head lettuce	Gem	Included
Green batavia	Head lettuce	Speciality	Included
Green multi-leaf	Head lettuce	Multi-leaf	Included
Green salanova	Head lettuce	Multi-leaf	Included
Iceberg	Head lettuce	Iceberg	Included
Little Gem	Head lettuce	Gem	Included
Lollo biondo	Head lettuce	Speciality	Included
Lollo rosso	Head lettuce	Speciality	Included
Mini-cos	Head lettuce	Romaine/Cos	Included
Mini-romaine	Head lettuce	Romaine/Cos	Included
Mizuna	Baby leaf	Mixed/Other	Included
Multi-leaf	Head lettuce	Multi-leaf	Included
Multi-leaf Lollo rosso	Head lettuce	Multi-leaf	Included
Multi-leaf Red batavia	Head lettuce	Multi-leaf	Included
Other	Baby leaf	Mixed/Other	Included
Radicchio	Head lettuce	Chicory type	Included
Red Batavia	Head lettuce	Speciality	Included
Red batavia	Baby leaf	Mixed/Other	Included
Red chard	Baby leaf	Chard	Included
Red Oak	Head lettuce	Speciality	Included
Red Salanova	Head lettuce	Multi-leaf	Included
Rocket	Baby leaf	Rocket	Included
Romaine	Head lettuce	Romaine/Cos	Included
Solid vein cos	Head lettuce	Romaine/Cos	Included
Specialties	Head lettuce	Speciality	Included
Spinach	Baby leaf	Spinach	Included

Annex 4 – Guidance on quantifying food waste in UK horticulture

As part of the original Terms of Reference for this research there was a requirement to "develop a standardised methodology for quantifying on-farm food losses which is easy to replicate for other crops and which could be made available publicly". However, a combination of external factors and learnings from the research has meant that a different approach became more appropriate.

First of all, during the course of this research the World Resources Institute and global partners, including WRAP, consulted upon and published the Food Loss and Waste (FLW) Accounting & Reporting Standard[131]. This comprehensive document sets out a structured and globally agreed approach to scoping, analysing and communicating levels of food waste. This provides an excellent framework for ensuring waste quantification and reporting is more consistent and of a higher quality across many sectors. It also provides guidance in a number of areas that were a challenge within this research e.g. sampling strategies, expressing waste as environmental impact, identifying causes and drivers of waste, etc.

In addition to this significant new publication, our research also identified significant differences in how waste can be quantified in just different types of crops (lettuce and strawberries). Because of this we think it is difficult to make specific recommendations on the most appropriate approaches for other agricultural sectors (beyond the sorts of general principles identified in the FLW Accounting & Reporting Standard). For instance, methodological approaches for quantifying waste in cherry production will need to be tailored to the specifics of that production system, typical data availability in that sector, etc. Also, as highlighted in the FLW Accounting & Reporting Standard, the most appropriate method to use will depend on the intended use of the results – for example the identification of waste 'hotspots' does not require the same precision as efforts to benchmark and report waste quantities to external stakeholders. The FLW Accounting & Reporting Standard provides guidance and tools for organisations looking to make these decisions.

As a result of these developments, this section therefore provides a commentary on the project's key learnings against the ten steps recommended in the FLW Accounting & Reporting Standard (see

Figure 24 below).

Each step has a separate section below and takes a similar format: at the top of the section there is a shaded box containing a short description of the step (the text is

[131] http://www.flwprotocol.org

taken verbatim from the FLW Accounting & Reporting Standard). Underneath the box, one or more paragraphs explore relevant learnings from our research.

Figure 24: Overview of steps recommended in FLW Accounting & Reporting Standard

Step 1: Define goals

> "*An entity should determine why it is quantifying FLW in order to determine what to quantify and how to undertake the quantification. Goals may relate to food security, economic performance, environmental impact, or some combination of the three*."

Given the likely challenges and resource implications of collecting waste data in agriculture this step is critical to undertake thoroughly. This will avoid wasting time collecting unnecessary data – or results that do not have sufficient precision to meet the needs of the research commissioned.

Step 2: Review accounting and reporting principles

> "*An entity quantifying and reporting FLW should adhere to five basic principles for accounting and reporting: relevance, completeness, consistency, transparency, and accuracy. These principles are intended to guide implementation of the standard, especially in situations that are not directly covered by the standard*."

No relevant learnings – this is standard accounting best practice.

Step 3: Establish scope

> "*This step involves determining the timeframe, material type(s), destination(s), and boundary that will be covered by the FLW inventory*".

Before developing a research methodology, it is important to develop a clear understanding of the crop production system and cycle, customer channels, and the typical characteristics of the grower population (e.g. average size, location, etc.).

To reach this understanding it is important to engage the sector at the beginning of the project and programme in sufficient time to speak with growers. The support and participation of stakeholders and key industry groups will likely be vital to:

- Understand and access growers;
- Get feed back on strategic aspects of the project, e.g. preferred data collection approach;
- Identify likely points at which waste might arise;
- Establish what data is already collected on waste by growers; and
- Understand differences between varieties/types of crop.

Timeframe

Cropping data gathered from growers during delivery of this project showed significant variation across a growing season as a result of changes in growing conditions and market demand. This poses important challenges to ensuring that data collected is representative of the season as a whole.

Inter-annual variation is also likely to exist although this was not quantified in our research. Differences in waste levels between years were an issue commonly expressed by growers and the project steering group.

Rather than collect information on 'average' historic waste from growers it was decided to ask for information on waste during the 2015 harvest. While it was acknowledged that waste can vary significantly from year-to-year and 2015 might have not been 'typical', it was decided that grower perceptions of a specific and recent season would be more reliable than a more subjective and general 'average'. To put 2015's harvest and associated waste in historical perspective, growers were also asked to compare 2015 to previous years.

Material type

In the FLW Accounting & Reporting Standard "Material type" refers to "*whether the material that was removed from the food supply chain and quantified in an FLW inventory is food, associated inedible parts, or both*". We used the comparable terms 'theoretically avoidable' or 'avoidable', which were also used in WRAP's 2016 report on the '*Quantification of food surplus, waste and related materials in the grocery supply chain*'. The term 'theoretically avoidable' food waste is used to define food waste that could in theory be edible (with or without further processing).

There were inedible parts of crops dealt with in this project (e.g. the base of iceberg lettuce and strawberry stalks). If disposed of at home by the consumer, these inedible

fractions of food would be considered unavoidable[132]. However, given that the boundaries of this research was the farm, we considered them *all theoretically avoidable* from the point of view of the grower i.e. in theory, the grower could grow, harvest and sell a crop with no food waste left on farm.

Overall we identified that there was very little completely *unavoidable* crop waste in primary production – major sources of waste are all theoretically avoidable. There is, however, a notable difference between what is theoretically avoidable and practically avoidable, from a commercial and technical point of view. Within the scope of this research we were unable to ascertain the degree to which waste is *practically* avoidable. This is an area for further research and needs to be considered in the scoping of future work in this area.

Destination of waste

The FLW Accounting & Reporting Standard allows users of the standard to define which of 10 possible destinations should be considered 'waste'. We adopted the recommendation of the FUSIONS report to the European Commission that "food waste" should refer to food and associated inedible parts sent to all destinations except animal feed and bio-based materials/biochemical processing.

In February 2016, the British Retail Consortium, National Farmers Union and AHDB[133] hosted a round table discussion, chaired by WRAP, on food surplus and food waste linked to primary production of fresh produce. The group agreed that it would work together to reduce waste in primary production and to do that through a whole chain approach. The round table also agreed a definition of food waste in line with the FUSIONS definition.

Boundary

The FLW Accounting & Reporting Standard requires that users "*shall report the boundary of their FLW inventory and describe it in terms of: food category, lifecycle stage, geography, and organizational unit. Description includes listing the classification source(s) used and relevant codes, where applicable".* Defining the boundaries of studies of waste in primary production can be challenging at both ends of the production process.

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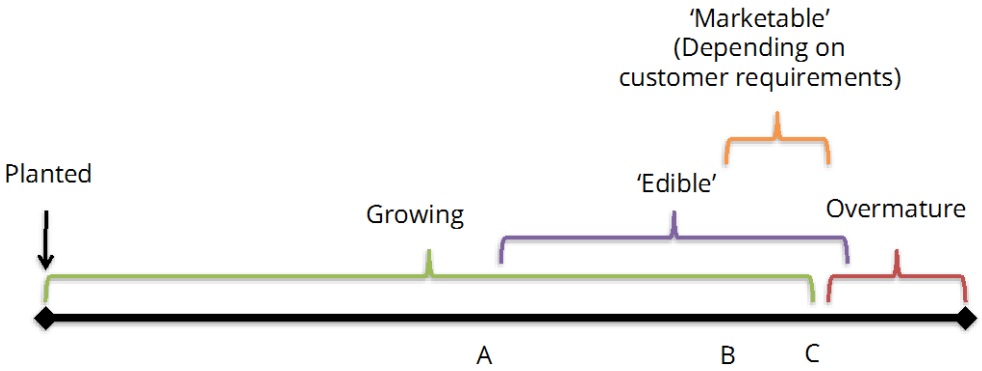
[132] For example, WRAP (2013) Household Food and Drink Waste in the United Kingdom 2012. Final Report. In fact this analysis presented the unavoidable fraction of whole items thrown away by consumers (e.g. the banana skin of a whole banana) as all avoidable, rather than split into the avoidable (banana flesh) and unavoidable fractions (banana peel).

[133] The British Retail Consortium, the National Farmers' Union and the Agriculture and Horticulture Development Board.

Following the FUSIONS definitions, a crop only becomes 'food' when it reaches maturity and any loss occurring before then is considered 'pre-harvest' and out-of-scope. However, for many crops the point at which they become 'mature' or 'ready to harvest' is a grey area and driven as much by commercial/market considerations than crop physiology or edibility. Creating an unambiguous and consistent cut-off boundary between 'food' and 'non food' is therefore difficult. The example of lettuce is shown in Figure 27 below: the lettuce crop is edible before it becomes marketable and fully mature. Since the data in this project is largely based on grower estimations, the grower's interpretation of this boundary was key, and the grower was necessarily an equal partner in judging when crop crossed the line from immature to mature (non-food to food). This may introduce an element of uncertainty in the data, in that each grower may have interpreted the boundary in a slightly different way.

Figure 25: Defining crop maturity – Lettuce example



It is also worth noting that pest and disease damage is a driver of waste that can occur both before and after maturation. As the scope of this project examines waste of mature crop (i.e. 'food'), crop waste due to pest and disease damage that occurs prior to maturation is not within scope. Again, as the point of maturity is a grey area for many crops, determining whether pest and disease damage occurred before or after maturity (or both) is difficult to do accurately without very specific in field measurement. To reduce the potential for including immature crop waste we explained the scope of the project to the growers we interviewed.

At the other end of the production process, our research boundary was drawn at 'farm gate'. This was the point at which the strawberry or lettuce crop was transported off farm. This didn't pose any significant challenges as crop was not stored for long and not graded any further - so waste levels were low. However in some crops, for example potatoes, waste levels from storage and post harvest grading are likely to be more significant. It therefore pays to ensure that waste can be expressed for different stages in the production cycle.

Some operations can occur either on farm or off farm, e.g. crop grading. In these situations, it is valuable to agree with growers and sector representatives in advance whether or not the operation should be considered in or out of scope. In this research, it was agreed that operations 'typically' occurring on farm would be in scope.

If the study does only examine a proportion of a supply chain it is important to be aware that an initiative to improve efficiency at one stage of the supply chain may increase waste somewhere else. It is therefore most useful to take a 'whole chain' approach to reducing waste – as exemplified by projects such as the WRAP Whole Chain Resource Efficiency projects[134].

Step 4: Decide how to quantify FLW

> *"An entity decides whether to undertake a new calculation and/or use existing data, and chooses the quantification method(s) to use in developing the FLW inventory. The method(s) chosen will be influenced by an entity's particular goals, established scope, and other circumstances such as resource availability (e.g., human, financial) and whether it has direct access to the physical FLW."*

Our study used all three categories of quantification approach described in the FLW Accounting & Reporting Standard: measurement; approximation and inference. In broad terms measurement is the most accurate approach, but is time intensive, whereas inference relies on existing sources of information, though can be less accurate. For example the research team and growers:

- Inferred waste levels in lettuce growing by comparing planting records with harvesting records and accounting for a typical proportion of crop that does not establish and reach maturity
- Approximated waste quantities in strawberry growing through examination of records of the number of bins filled with strawberries for proper disposal. We also approximated waste in both sectors through surveying growers' views and experiences of crop waste levels
- Measured lettuce head trimming losses by weighing a sample of heads before and after trimming by harvesting teams. The number of individual lettuce heads left unharvested in fields were also counted to quantify in-field waste rates

Our experience – and those of growers who measure crop waste – suggests that growers may underestimate levels of waste if asked to estimate this. Therefore surveys

[134] http://www.wrap.org.uk/content/whole-chain-resource-efficiency

have limited usefulness for detailed quantification of loss levels (see Table 30 below). Also, data on some sources of loss were not routinely collected by growers. For example, all of lettuce growers we spoke to did not collect data on trimming losses and many lettuce growers selling by the tonne to processors did not track the rate at which heads were left unharvested in fields.

Table 26: Data collection methods and finding

Method	***Description***	***Pros***	***Cons***
Survey (online)	A survey was developed with feedback from the steering group and piloted with a small number of growers. The survey was e-mailed to levy payers and promoted in trade media and via the project's industry network. A prize of a tablet computer was offered to incentivise responses.	Low cost. In theory this method can reach many growers in a short amount of time.	Growers are time poor and response rates may also be poor, despite targetted approaches and incentives. It was not possible to follow-up emails with phone calls to encourage participation. Approach depends on quality of email contacts. Difficult to explore complexities within constraints of web survey format. Responses likely to be grower estimates of waste levels.
Survey (Face-to-face)	A single member of the research team went to interview all growers in the study. A semi-structured approach was used and recordings were taken and transcribed.	Enables wider exploration of issues. Greater participation rate as growers were recruited by phone. Time can be spent explaining scope of study and quality of responses is better than survey.	More expensive than web surveying – c. 1 day spent per grower. Many crop waste rates were estimated where the grower did not collect data.
Measurement and inference	The research team worked with three lettuce growers to identify sources of existing data within the business – and in one case helped design and implement a process	Greatest level of data quality. Enables analysis of waste over time and between crop varieties, locations, etc.	Most resource intensive – both for the research team providing support to the grower, and the grower. No extra staff were employed, so approaches had to fit within current workloads.

	for collecting trimming loss and field loss data.

Step 5: Gather & analyse data

"*An entity begins assembling the data necessary for FLW quantification. The standard provides detailed guidance on a number of approaches for gathering, calculating, and analysing data related to FLW. The standard also covers approaches for recording the causes of FLW, an option that is recommended for identifying effective FLW reduction strategies*."

Sampling data

- We were unable to find good information from industry representative bodies or official government data on the size and characteristics of the grower populations for both strawberries and lettuces. This meant that is it was difficult to ensure our sample was representative. This could be a challenge in some other sectors of agriculture in the UK and elsewhere.
- Gathering information across the growing season will also be important to ensure the levels of waste recorded are representative.

Recruiting growers to interview

The FLW Accounting & Reporting Standard recommends that a random sample of growers is recruited to ensure selection bias is avoided. We were unable to achieve this as we lacked good quality contact details for all growers – this is likely to be the case in other sectors. Instead we used existing industry networks and contacts – as well as Internet searches – to identify potential growers. Phoning and speaking to growers was essential to get engagement and commitment to participate – emails would go unanswered and should not be relied upon.

To maintain transparency and foster engagement in the research, we offered to provide feedback on the research to all participants, identifying how their business compared to others within the study.

Face-to-face interviews were an excellent means of building trust with growers and fully exploring many of the complex issues driving waste. However to get this commitment we had to be sensitive to grower work commitments and be flexible. It was also important to leave sufficient time for follow-up questions & clarifications.

Confidentiality

The research collected potentially sensitive commercial information. We also recorded all interviews to ensure we captured the conversations with growers properly. Clear and reliable approaches to data confidentiality and data protection were therefore important considerations.

The Data Protection Act 1998 applies to organisations holding information about individuals in electronic (and sometimes paper) format. Any personal information collected during this research has been handled according to eight principles:

- Fairly and lawfully processed;
- Processed only for the specific purposes of this project;
- Adequate, relevant and not excessive;
- Accurate and, where necessary, kept up to date;
- Not kept for longer than is necessary (project end dates can change over time, but we expect that all relevant information will be securely destroyed by the end of 2016);
- Processed in line with the rights of the individual;
- Kept secure; and
- We do not expect to transfer the data to anyone, but certainly will not transfer it to countries outside the European Economic Area.

Non-personal data collected in relation to this project during interviews, farm visits and the web survey was used solely for the purposes of this project and was treated in the strictest confidence. Information based on this data was anonymised before it was shared with WRAP and Defra, and before any project outputs were published. All non-aggregated, non-anonymised data (e.g. interview recordings and transcripts) were to be destroyed on completion of the project.

Web survey and interview data was collated and anonymised with any personal information detached from the responses. Each survey and interview response was given a randomly generated identification code to enable easier data analysis; these codes are not traceable to personal information and are only connected with personal information in a separate password protected file and server, accessible only to two members of the research team. This is to ensure that the data, once analysed and presented, cannot be used to identify any participating farm or grower.

Step 6: Calculate inventory results

"*Once data have been gathered and analysed, inventory results can be calculated. The standard provides guidance on performing the necessary calculations. Entities may express FLW in terms or units of measurement in addition to weight (to convey environmental impacts, nutritional content, or financial implications), or use a normalization factor to generate a metric such as FLW per capita*".

The biggest challenge in calculating crop waste was attributing quantities to causes and drivers. Although the FLW Accounting & Reporting Standard provides examples of how this can be presented, in practice we found this difficult – especially in the absence of

good records or measurement of waste. To properly examine the causes and underlying drivers of waste a more detailed examination of production planning, agronomy, marketing and external factors need to be assessed. This needs to be considered when scoping research and defining the methodology.

Step 7: Assess uncertainty

> *"In this step, an entity goes through the process of identifying and documenting sources of uncertainty that may arise in the calculation of an FLW inventory. The standard provides suggestions as to how specific forms of uncertainty can be anticipated and minimized."*

No relevant learnings – this was not addressed within the research.

Step 8: Perform review (Optional)

> "*In this optional step, an entity undertakes either an internal or external assurance process to ensure the accuracy and consistency of the FLW inventory*."

The lettuce and strawberry research project did not undergo a formal review or assurance process, however valuable input was provided by a steering group.

Step 9: Report FLW inventory

> "*Having completed the prior steps, an entity should report its FLW. The standard provides guidance on reporting the required information as well as the recommended elements that may be added to the inventory report."*

Where appropriate, we would encourage results are shared with WRAP. It is important that results are properly communicated and interpreted. The FLW Accounting & Reporting Standard provides guidance on how to communicate results in a way that ensures they are interpreted properly.

Step 10: Set target & track over time

> "*An entity may wish to set targets for FLW reduction and use the standard to track progress toward those targets over time. The standard provides guidance on setting an FLW reduction target and tracking it, including information on selecting a base year, monitoring performance, and making adjustments to the base year calculation as needed*."

No relevant learnings – this was not addressed within the research.

Annex 5 – References

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