Assessing the environmental impacts of healthier diets

Final report to Defra on project FO0427

School of Water, Energy and Environment
September 2018

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Revised version: 24 October 2017

Opinion and policy

The views and opinions expressed in this report are those of the authors and may not in any circumstances be regarded as stating an official position of Defra.

Acknowledgments

The authors thank Defra for funding and supporting the project and all the stakeholders who participated in the project and helped greatly in shaping and quantifying the dietary change scenarios. The authors also thank others who contributed in other ways, e.g. nutritional advice from Prof Joe Millward of Surrey University.

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Abbreviation	**Full wording**
AP	Acidification potential
CED	Cumulative energy demand
DRV	Dietary reference value
EP	Eutrophication potential
EU	European Union
EUR	European
GHG	Greenhouse gas
GHGE	Greenhouse gas emissions
GVA	Gross value added
GWP	Global warming potential
Hd	Head of population
LCA	Life cycle assessment
LCI	Life cycle inventory
LUC	Land use change
ME	Metabolisable energy
NDNS	National Diet and Nutrition Survey (rolling programme)
NGO	Non-government organisation
RDC	Regional distribution centre
RoW	Rest of World
WRAP	Waste & Resources Action Programme
WSF	Water scarcity footprint

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Summary

Concern about the public health impacts of dietary habits in the UK have led to initiatives to encourage healthier eating, notably in the dietary guidelines represented of the eatwell plate (FSA, 2007) and the Eatwell Guide (NHS, 2016c). A change in UK dietary habits towards healthier eating would result in changes in the type and quantities of food items in the national diet, with implications for agricultural, food and allied industries. More specifically, this could lead to changes in land use and farming practices, both for the UK and its trading partners, with associated effects on greenhouse gas emissions and other environmental impacts. In this context, and sponsored by Defra, this study set out using a series of scenarios to assess the environmental impacts of changing dietary habits and specifically the adoption of healthier eating in the UK, and in broad terms some of the likely social and economic impacts on the agricultural and food sector, through a set of hypothetical scenarios.

The main objectives were to:

i) determine the consumption of food under possible future food consumption scenarios in the UK, including the eatwell plate;

ii) quantify the production of agricultural commodities needed to meet the food needs of each scenario;

iii) quantify the environmental impacts of food commodity production and consumption by scenarios, and

iv) identify, in broad terms, the possible economic and societal impacts of dietary changes.

The study, beginning in 2011 used the eatwell plate (Food Standards Agency, 2010) as a basis for healthier eating. More recently, the eatwell plate has been replaced by the Eatwell Guide (Public Health England, 2016a) that, though broadly similar, differs with respect to the configuration of the food groups required to make up a balanced diet. The latter recommends more fruits, vegetables and fibre-rich starchy carbohydrates and fewer sugary foods and drinks.

The methods used to derive the hypothetical scenarios were based on a review of the driving forces for change in diets, which were examined using a PESTE (Political, Economic, Socio-demographic, Technological, Environmental) analysis based on publicly-available information. The PESTE analysis results were used as an input for a series of workshops involving over 40 delegates representing food producers, retailers, government, academia and NGOs, with the aim of developing future scenarios of food consumption in the UK. During the workshops, morphological analysis was used to develop scenarios. In addition to the baseline, six different scenarios were finally developed: Scenario 1 “The more we change the more we stay the same”, which was abbreviated to “Limited change”; Scenario 2 “Taking responsibility”; Scenario 3 “Big brother”; Scenario 4 “Tightening the belt”; Scenario 5 “Living for the third age”; while Scenario 6 was the “eatwell plate” which was based on healthy

eating according to the 2010 Guidelines. For each scenario, an assessment of nutrient and energy content of diets was carried out and a specific diet was identified.

For each scenario, a set of food commodities was associated with the dietary composition. The dietary composition was based on the following food groups:

- Starchy carbohydrates
- Fruit and vegetables
- Meat, fish and alternatives
- Milk and dairy foods, and
- Foods high in fats, salt and/or sugar.

Estimates of the relative strength and direction of influence of key drivers on the above dietary categories were derived from the participant workshops, scenario narratives and the review of literature from the PESTE analysis, considering each driver independently. A model was developed to quantify the effects of food consumption on agricultural commodities using inputs from the rolling programme of the National Diet and Nutrition Survey (NDNS) for both the household and the food service sector (Public Health England, 2014), the literature review and trade information. Values for commodity production were derived from sources including Department of Environment, Forestry and Rural Affairs (Defra) and the Food and Agriculture Organisation statistics (FAOSTAT, 2016).

The initial hypothetical scenarios were developed further to address possible internal inconsistencies and, more importantly, to enable the changes in drivers of dietary change to be directly related to the consumption (and hence production) of food commodities. However, they did represent the overall consumption but its distribution is clearly skewed with major under-consumption or over-consumption of certain foods in some population groups. Differences in diets among scenarios affect the balance of supply of agricultural commodities from domestic and international sources. It was assumed that production required to meet UK consumption is met either by food produced domestically or imported to the UK. Export quantities are assumed to remain constant amongst scenarios and are therefore excluded. It is noted that changes in the UK demand for food might result in changes in exports

Emissions and resource use resulting from the production of agricultural commodities and their processing were taken from the Cranfield agricultural systems life cycle assessment (LCA) model. This was developed to give better insights into sectors such as strawberries and tomatoes from the UK and Spain, imported beef, lamb and potatoes and poultry production. Where appropriate, data on other UK and overseas commodities were derived from the literature. In addition to greenhouse gas (GHG) emissions (characterised by the 100 year horizon global warming potential) of the different commodities, other environmental impacts considered were cumulative energy demand, eutrophication and acidification potentials, and ammonia and nitrate emissions.

While for some food products data were available from cradle to grave, this did not apply to sufficient commodities to use the sum of the LCA-derived burdens as the impact of food consumption. Hence, alternative data were used to quantify impacts of food manufacturing, distribution and consumption in the UK: national level statistics on energy consumption, a specific model for energy use in refrigeration, and national level survey data for household energy consumption for refrigeration and cooling came from national level survey, and data from the Department for Energy and Climate Change (DECC).

The environmental and social impacts assessed are therefore related to outputs from the scenarios not to actual trends in food consumption habits or to compliance with the 2016 eatwell plate. The analysis presented used major national data sets as well as tested models and expertise to interpret these and convert them to impacts. Several assumptions were needed about distribution methods, ways of consumptions and waste management along with sources of foods and the composition of complex purchased foods. Much effort was made to find best available data, but there limited environmental data availability for some foodstuffs, but these were a small proportion of total consumption. The main limitation to reinforce is that the consequences of environmental and socio-economic change result from hypothetical scenarios.

The results showed that achieving a national move to the eatwell plate would have major environmental benefits in reducing emissions of greenhouse gases (14%), ammonia (28%), nitrate (12%) and acidifying gases (4%). Most of the changes occur from primary production. The absolute reduction in greenhouse gas emissions was estimated to be 14 Mt CO_2e per year. These are in the same range as found by other research. The other scenarios, with smaller changes in food group consumption, showed smaller changes (0 to 7% reduction in greenhouse gas emissions) relative to the base case scenario. The total impacts on stress-weighted blue water consumption in five scenarios were relatively small, but the potential for increased consumption of some plant commodities from highly-stressed areas was noted.

Changes in the associated land requirement were more considerable. Achieving the eatwell plate resulted in large releases of grassland in the UK (about 4.8 Mha), but increased cropland requirements both in the UK (0.34 Mha) and overseas (0.48 Mha), in line with other research (Audsley, et al., 2011). It is plausible that increased cropland demands in the UK could be met from the most suitable grassland areas. Estimates of the predicted changes in the requirement for grassland varied widely depending on whether it was primarily a release of mainly hill and upland land or lowland, so central estimates are shown above.

The main changes in commodity demand and land use would be accompanied by major changes in agriculture. It is predicted that revenues in beef and sheep sectors would fall by up to 40% in the Eatwell scenario with a general shift in production away from the more disadvantaged areas in the wetter north and west of the UK. In contrast, milling wheat, potatoes and field vegetable revenues should increase by 70%, 30% and 30% respectively. Fish farmers and catchers (assuming the availability of a sustainable stock) would also benefit from increased revenues.

Impacts on household expenditure appeared to be small at a national scale, but there was some evidence that poorer households may be disadvantaged. The reduced environmental emissions were estimated to reduce the costs of externalities of food production by 17%: about £500 M per year.

These results reflect changes in national rather than individual consumptions. Therefore, the effects of the Eatwell scenario might be different across the population. Technological improvement such as reduction of salt, sugar and trans-fat were suggested for improving the quality of manufactured food. All dietary scenarios apart from Scenario 1 (limited change) showed some positive nutritional features such as increased starchy carbohydrate consumption and reduced red meat consumption together with reduced food wastage.

The hypothetical elimination of all avoidable food waste prior to delivery at a regional distribution centre would also reduce greenhouse gas emissions by 12%, and a 7% reduction over the whole food chain. This is similar, although smaller, to the reduction obtained with adopting the Eatwell diet.

This study predates the UK's referendum on membership of the European Union and subsequent consequences, commonly referred to as Brexit. This is likely to lead to changes in the economic and regulatory policies that have shaped UK agricultural and food industries over the last 40 years. The relative pricing of foods will almost certainly change and hence affect consumer choices and those impacts on both health and environmental burdens. At the time of writing, however, the outcomes are very uncertain and thus the possible implications for diet and the environment are not considered here.

1. Introduction

The production and consumption of food has major impacts on the environment, economy and social conditions of the UK population. For example, the food system has been estimated to contribute 160 to 250 Mt CO_2e to the UK's greenhouse gas (GHG) emissions, or about 19 to 25% of the national total GHG (Garnett, 2008, Audsley et al., 2010). The agricultural and food sector accounts for about 7% of total UK Gross Value Added and employs about 14% of the UK workforce.

Despite science-based dietary advice (e.g. British Nutrition Foundation, 2016, NHS, 2016), the population does not overall eat healthily. The rates of obesity and Type 2 diabetes (i.e. nutritionally related) are worryingly high. In England, the prevalence of obesity among adults rose from 14.9% to 25.6% between 1993 and 2014 (Public Health England, 2016b). In 2010, the rates in Scotland were slightly higher and were slightly lower in Wales and Northern Ireland. To fight obesity in childhood and its widespread across the UK population, the UK promoted a Childhood obesity plan (HM government 2016). However, about 3.6 million people in the UK have been diagnosed with diabetes (Diabetes UK, 2016) equivalent to about one in eighteen people. These statistics are associated with general over-consumption of fats (especially saturated fat), readily available simple sugars and meat (especially red) and under-consumption of starchy carbohydrates, fish and fruit and vegetables. Scarborough et al. (2012) cites eight papers that report the negative health outcomes of excessive meat consumption, some of which was related to under-consumption of fruit and vegetables.

The WWF and Food Climate Research Network (FCRN) sponsored work on dietary (and technological) change (Audsley, 2010, Williams et al., 2010). This showed that large scale reductions in livestock product consumption coupled with decarbonising the electricity system could support a reduction of 70% of GHG emissions to meet the long term, targets of the Climate Change Act of 2008. The Committee on Climate Change (CCC, 2016) included consideration of dietary change within their fourth carbon budget. Audsley et al. (2011) reported that a 50% reduction in UK meat and milk consumption would lead to a reduction in UK GHG emissions of 19%. Further, large areas of grassland would no longer be required and could be converted to either arable (with associated losses of soil C) or woodland with anticipated increases in aboveground C storage. Although the nutrient balance of the assumed changes in diet was checked, this study assumed an arbitrary change in diet e.g. 50% reduction in livestock product consumption.

The current study builds on these and related work to investigate the impacts of large scale change towards the consumption of healthier diets in the UK. Scenarios were developed using stakeholder engagement to move towards the balance of food groups that are encapsulated by the eatwell plate (Department of Health, 2010) and its underlying science (Gatenby et al., 1995). This presents the UK Government's best guidance for balanced healthier eating including the reduction of some food groups (e.g. saturated fat, sugar, salt) and the increase of others (e.g. fruit, vegetables and oily fish). The range of analyses was also extended to include environmental impacts apart from GHG, together with socio-economic factors.

The overall aims of the project were to:

i) determine the consumption of food under possible future food consumption scenarios in the UK, including the eatwell plate;
ii) quantify the production of agricultural commodities needed to meet the food needs of each scenario;
iii) quantify the environmental impacts of food commodity production and consumption by scenarios, and

iv) identify, in broad terms, the possible economic and societal impacts of dietary changes.

1.1. Structure

The report starts by briefly describing the approach followed to develop and quantify the selected scenarios of dietary change. The process of developing the original scenarios is given in Appendix A, with a summary presented in the main body of text. This is followed by a presentation of the results, discussion and conclusions. The report addresses the changes in agricultural commodities associated with the alternative scenarios, changes in land requirements, changes in nutrient supplies, and changes in the environmental and socio-economic impacts. This includes a summary of the water impacts, which were analysed and reported in a journal paper (Hess et al. 2015).

1.2. Food waste and population

The original scenarios included commentaries on the assumed changes in food waste and population change. In terms of food waste, it was eventually decided to analyse the combined impacts of different food waste rates with the changed diets themselves as this would confound the two and dietary change was the focus. A short section addresses food waste independently.

It was assumed that the UK population was stable, in line with the Defra project specification. Although it is probable that moving towards healthier eating will contribute to increasing life expectancy, but this was considered to be out of the scope of this project. Further, population change would confound the effects of dietary change *per se*.

1.3. Limitations

The development of the final report suffered from delays and the baseline data used for food consumption was 2010. Some changes will have occurred since then, but the rate of change is believed to be slow, so it is believed that the analyses are still valid. Although strong efforts were made to ensure that the most reliable data sources were used throughout, it is possible that alternative data sources are available. In early 2016, shortly before the final report was completed, the Government guidance on dietary intakes changed and the eatwell plate was revised (Public Health England, 2016). It was not feasible to reanalyse everything on the basis of the revised guidelines, hence the changes analysed must be viewed in that light.

2. Methods

2.1. Scenario development (1st phase)

The effects of changing national diets to become healthier were investigated to assess the likely impacts on the environment and socio-economic factors. Six scenarios of dietary change were developed with stakeholder engagement and morphological analysis (Ritchey, 2011) Full details are given in Appendix A. The scenario development started with a PESTE (political, economic, social, technological and environmental factor) analysis and two stakeholder workshops that broadly identified the expected dietary changes in each scenario. Further quantification was applied using a bespoke mathematical model to derive forecasts of proportional changes in the five food groups in the eatwell plate (Gatenby et al., 1995), i.e.

- Starchy carbohydrates
- Fruit and vegetables

- Meat, fish and alternatives
- Milk and dairy foods
- Foods high in fats, salt and/or sugar.

Following consultation with Defra, the original six scenarios were revised for the purposes of this project. One possible 'unhealthy' diet scenario was removed and a scenario-based on the recommended balance of food groups represented by the eatwell plate (FSA, 2010) was introduced. Thus, the six scenarios used involved one representing the baseline year (2010), four describing contrasting moves towards healthier eating, and one representing the recommended eatwell plate (Appendix A).

The eatwell plate is used here to represent both the broad food categories and the dietary guidelines of the Department of Health to provide a healthier diet, including micronutrient requirements. This analysis was also based on the original version of the eatwell plate (FSA, 2010) and not the revised version (Eatwell Guide) that was announced on 17 March 2016 (Public Health England, 2016).

The mainly narrative based descriptions of the scenarios developed in the workshops were refined to support the quantification of the impacts of dietary change on environmental, social and economic outcomes. This required the development of metrics to represent the strength of drivers of dietary change, such as disposable income and dietary preferences, and the effect of these on the consumption of particular food groups. The process of moving from the initial scenario narratives to quantification required some minor adjustments to the narratives to avoid internal inconsistencies and ensure parallel treatment across the scenarios of factors known to affect dietary outcomes and impacts.

Six scenarios were thus subsequently analysed and are summarised in Section 2.2.1.

Scenario 1: The more we change the more we stay the same (Limited change)

Scenario 2: Taking Responsibility

Scenario 3: Big Brother

Scenario 4: Diverging Diets

Scenario 5: Living for the Third Age: Towards an Eatwell Future

Scenario 6: The eatwell plate (Eatwell)

2.2. Scenario development (2nd phase) and quantification

The following steps were applied in revising the initial scenarios. The main characteristics of the scenarios were summarised in terms of key drivers affecting food consumption. These drivers were individually weighted for each scenario according to their relative strength and associated influence (low, medium, high) by scenario. The relative importance of each driver was also considered as this influences scenario outcomes.

The likely magnitude and direction of influence of the drivers on the consumption of individual food categories were assessed, each considered independently.

The likely combined impact of drivers on the consumption of major food categories within each scenario was considered in order to derive estimates of the relative change in mean national diet based on the rolling programme of National Diet and Nutrition Survey (Bates et al. 2011). Estimates were derived in fresh matter (g/head/day, i.e. as consumed), dry matter and other nutritional qualities. It was assumed that starting from the situation in 2010, scenarios were 'fully developed' after a period of 20 years. As indicated in Section 1.3, the demand estimates did not allow for change in the size or demography of the UK population that might occur in the future and that might differ between scenarios.

Estimates of consumption, domestic UK production and imports to the UK were derived for major food commodities for each scenario, together with estimates of land use and potential environmental effects. A spreadsheet was developed to support the analysis of scenarios. A sensitivity analysis of key drivers was carried out to identify the extent to which changes in key drivers could modify dietary outcomes within scenarios.

2.2.1. Key drivers affecting food consumption by scenario

The scenarios described in Appendix A are summarised in Table 1 in terms of the key drivers and their association with dietary outcomes, considered in terms of the mean national diet (g/hd/d consumed). These include high level drivers associated with prosperity and distribution of income, demography, food preferences and habits, and a range of market, technology and policy factors.

Table 1 Key drivers of diets for the UK by scenario for 20 years after the baseline (Part 1/2)

Key drivers	**Scenarios**					
	1 Limited change	**2 Taking responsibility**	**3 Big Brother**	**4 Diverging Diets**	**5 Living for the 3rd Age**	**6 Eatwell**
Aggregate disposable income: annual growth %	High: 2.5%	High: 2.5%	High: 2.5%	Medium: 1.5%	Low: 0.5%	Medium: 0.5%
Income distribution degree of inequity, geni coeff[a]	High inequity: geni = 0.40	Medium inequity, geni =0.35	Medium inequity, geni = 0.35	High inequity, geni = 0.40,	Low inequity geni = 0.30	Medium inequity, geni = 0.35
Age profile: (Proportion > 65)	19%	22%	20%	20%	26%	20%
Healthy eating. orientation:	Low	High: embedded commitment	Medium: high pre-prepared & processed content, but healthier options	Medium: polarised - high amongst wealthier cohorts	High, induced by policy and lifestyle, population buy-in	Very high
Diet disparities between high and low income groups	High.	Medium	Medium, though some pockets of dietary depravation	High, high food prices affecting less well off: large cohort of food poor	Low: lower disparities about lower incomes	Low
Lifestyle: relative importance of eating out versus home cooking (incl. institutional/works catering)	Medium	Low: home food preparation	High: work pressures purchase prepared food	Medium. eating out discouraged by high food prices, but low cost offerings compromise healthy eating	Low: more home cooking of fresh local foods,	Medium
Cooking knowledge and skills supporting home cooling and potentially healthier options.	Medium	High: associated with increased home food preparation	Low:	Medium: home cooking induced by high food prices, but high processed foods	High. linked to improved home nutrition and fresh foods	High: supporting healthier options
International food commodity prices: FAO food prices index (2011=232)	Medium: 420:	Low: 380	Medium: 400	High.450	High: 450	Medium
UK domestic food prices	Medium, pushed up by supply side regulation	Low	Medium	High	High	Medium
UK population in 2031 (million)	71	68	71	67	65	65

[a] a geni co-efficient of 0 is a perfectly equitable distribution

Table 1 Contd. Key drivers of diets for the UK by scenario for 20 years after the baseline (Part 2/2)

Key drivers	**Scenarios**					
	1 Limited change	**2 Taking responsibility**	**3 Big Brother**	**4 Diverging Diets**	**5 Living for the 3rd Age**	**6 Eatwell**
Domestic sourcing: strength of market or policy preference for domestic grown foods	Medium; no strong market or policy preference	Medium; no strong market or policy preference	Medium; no strong market or policy preference	Medium; no strong market or policy preference	High: favours local and domestic source	High
Market and policy drivers promoting healthier eating	Low some: Educational and media campaigns for healthier eating	High: profile campaigns, Increased personal interest in health and environment aspects	High: concerted govt action (with support from companies) to promote healthier eating and reduce environmental impact	Low: Limited govt action, high prices polarise relatively well off and poorer cohorts	High: Relative austerity; collaborative actions by govt and food industry to improve diets. Greater domestic sourcing	High
Technology factors favouring healthier options and eating	Medium Internet driven information	High: food technology enhancements: GM, nanotech, functional foods	Medium: expectations of technological solutions are not materialised	Medium: Food technology developments in production and processing driven by markets	High: Reformulation of production and processing technologies to achieve healthier diets, supported by 'incentives'	High
Adult obesity and dietary disorders: Proportion of adults overweight or obese	High: 26%	Low:20%	Medium: 23%	Medium 25%	Low: 20%	Low: 15%
Diet characteristics: degree of 'healthiness' incl. extent of dietary disorders and related disparities amongst groups	Low healthiness: Greater awareness but limited change: High disparities	High healthiness. Greater awareness and scope for healthier diets. Medium disparities	Medium healthiness: Consumers largely respond to policy drivers including fiscal measures. Medium disparities	Low healthiness, high disparities. Polarisation of diets according to disposable income. Diets of poorest deteriorate	High healthiness: Healthier eating promoted by combination of awareness and necessity. Low disparities	Very high healthiness, Low disparities
Waste percentage: % reductions in 'current' mass of waste by food group	50%, mainly driven by cost of waste	75%, due to awareness, commitment & technology	50% mainly driven by regulatory and fiscal drivers	50%, driven by regulation and market incentives	90%, driven by regulation, voluntary and economic incentives	90%, driven by regulation, voluntary and economic incentives

2.2.2. Summaries of scenarios: key drivers

Table 2 contains a summary of the relative values for key drivers by scenario for quick reference, where low (L), medium (M), high (h) and very high (VH) are based on the values in Table 1. The scenarios are also summarised in the form of brief narratives.

Table 2 Summary of the relative strength of the influence of key drivers on food consumptions behaviour by scenario for the UK (L: low, M: medium, H; high, VH: very high)

Drivers	Scenarios					
	1	**2**	**3**	**4**	**5**	**6 (Eatwell)**
Average income	**H**	**H**	**H**	M	L	M
Income disparity (greater proportion low income)	**H**	M	M	**H**	L	M
Proportion over 65	L	**H**	M	M	**H**	M
Health conscious	L	**H**	M	M	**H**	**VH**
Eating out	M	L	**H**	M	L	M
Cooking skills	M	**H**	L	M	**H**	**H**
Food price	M	L	M	**H**	**H**	M
Domestic sourcing	M	M	M	M	**H**	**H**
Technology	M	**H**	M	M	**H**	**H**
Policy drivers	L	**H**	**H**	L	**H**	**H**
Expected outcomes						
Obesity and dietary disorders	**H**	L	M	**H**	L	L
Dietary disparities	**H**	M	M	**H**	L	L

Scenario 1 The more we change the more we stay the same (Limited change)

This scenario assumes that current trends continue. Average incomes are relatively high, but unequally distributed, with a marked polarisation of dietary standards between better off and poorer social groups. Obesity levels are high amongst poorer groups. Policy drivers and technology responses towards healthy eating are low. There is little change in the key drivers that affect movement towards healthier eating. Food prices are moderate but subject to volatility, sometimes compromising gains in healthier eating especially amongst the poorest groups. Household waste has been reduced due to concerted effort by the food industry.

Scenario 2 Taking Responsibility

Individuals take greater responsibility for dietary health in response to healthy eating campaigns. Average incomes are relatively high, food prices moderate, and income disparity low, broadly favouring quality foods, and healthier balanced diets across the population as a whole. Greater food awareness, home cooking skills and home–based food preparation also favour healthier diets, further promoted by strong policy commitment and developments in appropriate food technologies. Campaigns to prevent waste and environmental impacts have helped to make major reductions in household food waste.

Scenario 3 Big Brother

Public and private sector organisations work together to change what people eat. Government promotes healthy eating to reduce diet related diseases and the burden of costs on the nation's health service. Industry is driven to reduce costs associated with the use of natural resources and the burden of environmental taxes and regulations. Although people understand the health and environmental aspects of their eating habits diets, they rely mainly on others to make dietary choices. Average income is relatively high and relatively evenly distributed. Moderate food prices and limited cooking skills encourage eating out and consumption of pre-prepared foods, albeit with healthier options. Campaigns to promote household waste have moderate impact.

Scenario 4: Diverging Diets

Moderate growth in average incomes, relatively unequally distributed, combined with high food prices leads to polarisation of diets. The healthiness of diets amongst the poorest groups deteriorates. Relatively high income groups, including prosperous elderly, favour healthy, environmentally benign foods, compared to relatively poorer households, which have grown in number, for whom these options are expensive. Whereas awareness of the health and environmental impacts of diets has grown generally, these are insufficient in the face of economic drivers, to change the consumption habits of large cohorts of the population. The demand for processed food remains high, but investments in food technology help to improve some dietary qualities. Economic pressures and food industry campaigns are effective in reducing food waste.

Scenario 5 – Living for the Third Age: Towards an Eatwell Future

Average incomes are relatively low, albeit relatively equally distributed. The population has declined, with outward migration of younger groups, leaving a relatively large elderly cohort. Food prices are high, and forced by a mixture of necessity and lifestyle change, diets have become healthier as a result of reduced consumption of relatively expensive meat products and processed food, especially associated with eating out. Home cooking and consumption of locally produced seasonal foods has increased. Food technologies have focussed on derived greater nutritional value for foods, supported by government partly within a framework of economic recovery/austerity management measures.

Scenario 6. The eatwell plate (Eatwell)

'You are what you eat', and vice versa, describes a scenario characterised by healthy eating that conforms to the 'eatwell plate' across the population as a whole. There is a gradual transition supported by policy interventions and industry collaborations that induces a move from the 2010 configuration to a healthy balance of the main dietary constituents. Waste is reduced to a minimum.

2.2.3. The effect of drivers on food consumption categories in the national diet

The relative magnitude of the influence of a driver varies amongst food categories. For example, the effect of changes in disposable income food varies according to the type of food. Increased income tends to favour higher quality, higher priced and less 'essential' attributes of food such as fresh meats and out of season fruits. Higher general food prices also affect food categories in different ways.

Broad estimates of the relative strength and direction of influence of key drivers on particular food categories in the diet were derived from participant workshops, scenario narratives and the review of literature that was part of the PESTE analysis (Appendix A), considering each driver independently (Table 2). Here, 0 (zero) to 3 (very high) shows the relative magnitude of influence and -/+ the direction of influence on consumption. For example, increases in aggregate income tend to lead to a relative fall in the consumption of starchy carbohydrates, especially of bread (-1) and potatoes (-2), and a relative increase in white (+1) and red (+2) meat products. However, a commitment to healthier diets tends to increase consumption of carbohydrates (+2), especially of cereal products, and reduce the consumption of red meats (-2). Similarly, the demand for commodities is also sensitive to relative prices. High general food prices are likely to favour the substitution of relatively high priced fresh fruits, vegetables and meats by cheaper processed versions, much of which are likely to be of poorer nutritional quality (Pollard et al., 2002).

Table 3 Estimated influences of drivers on the consumption of food categories in the UK national diet

Food Groups in National Diet and Nutrition Survey (NDNS)	Consum-ption, g/hd/d	Average income	Income disparity (greater proportion low income)	% over 65	health cons-cious	eating out	cook-ing skills	food price	domestic sourcing	tech-nology	policy drivers
Starchy carbohydrates	**234**	**0**	**1**	**0**	**2**	**1**	**0**	**2**	**0**	**2**	**2**
Pasta, rice and miscellaneous cereals	82	1	-1	-3	2	1	1	1	-1	2	3
Bread	82	-1	2	0	1	2	-1	2	1	1	1
Potatoes not cooked in fat	43	-2	2	2	1	-1	1	1	1	2	2
Cereals (breakfast)	27	1	-1	2	2	0	0	1	0	1	1
Fruit and vegetables	**407**	**2**	**-1**	**1**	**2**	**-1**	**1**	**-1**	**1**	**2**	**2**
Fruit	101	2	-1	1	3	0	0	-2	1	1	2
Fruit juice	59	2	-1	-1	2	1	0	-1	-1	1	1
Vegetables (not raw) including vegetable dishes	169	-1	2	1	1	-1	2	1	2	3	2
Salad and other raw vegetables	78	3	-2	0	3	1	2	-2	2	1	2
Meat, fish and alternatives	241	**0**	**-1**	**0**	**-1**	**1**	**0**	**-1**	**0**	**1**	**0**
White meat	58	1	1	-1	1	1	2	-1	1	1	2
Red meat	66	2	-2	0	-2	2	1	-3	1	1	-2
Processed meat	49	-3	2	0	-3	2	-3	3	0	3	-2
Beans, pulses, nuts and seeds	15	1	-2	-1	2	-1	-1	-2	0	1	2
Eggs and egg dishes	17	1	1	1	1	0	1	-2	1	2	0
Fish (oily)	10	3	1	3	3	2	1	-1	1	3	3
White fish and shellfish	25	2	1	2	3	2	1	-1	1	3	3
Milk and dairy foods	**199**	**1**	**-1**	**1**	**1**	**-1**	**0**	**-1**	**1**	**2**	**-1**
Milk (split according to current intake)	155	1	-1	1	0	-1	0	-1	1	2	-1
Cheese	14	2	1	0	1	1	0	-1	0	2	-1
Yoghurts, fromage frais and other dairy desserts	29	1	0	1	2	0	0	1	1	2	1
Foods high in fat and/or sugar	**156**	**-1**	**0**	**0**	**-2**	**0**	**0**	**0**	**0**	**-2**	**-2**
Potatoes cooked in fat	42	-2	2	-1	-3	2	1	2	1	-2	-2
Buns, cakes, pastries, and fruit pies	34	1	-1	3	-3	0	-1	-1	0	1	-1
Biscuits	13	-2	2	0	-1	-1	0	1	0	1	-1
Confectionery	3	1	-1	-3	-2	0	0	0	0	-1	-1
Chocolate	8	2	-1	-2	-1	0	0	-1	-1	-1	0
Spreads and cooking fat (not butter)	5	-1	3	1	-1	0	0	2	0	-2	-1
Butter, cream, ice-cream	25	1	-2	3	-2	1	2	-2	1	-2	-1
Sugar (table & soft drinks) and preserves	24	-2	1	-1	-2	0	0	2	0	-2	-2

2.3. Commodity quantification

The quantification of agricultural and fishery commodities produced and consumed was based on a development of the models of Audsley et al. (2010) and Audsley et al. (2011). The model related net commodity production and imports to food consumption using the National Diet and Nutrition Survey rolling programme surveys (NDNS, 2014). The survey covers 54 main food groups, which were sub-divided into three to eight smaller subsidiaries. The subsidiaries include some headings that effectively include only one item, e.g. *12R Skimmed milk* and others that include broader groups of items, e.g. *1E Pasta (other, including homemade dishes)*. The food groups in the NDNS survey were decomposed as far as possible into ingredients, which were related to the commodities that needed to be produced. A very simple pasta-based dish could require three commodities, i.e. wheat, tomatoes and milk (for cheese), but more complex one also exist. Where possible, this was based on data from the McCance and Widdowson food composition tables (Food Standards Agency, 2002), which provides many recipes to define the composition of manufactured and homemade dishes, but if not, data were derived from the literature or trade information.

The commodities needed were then aggregated from the sums of all commodities needed to produce all the survey items in order to represent total consumption before any scenario changes were introduced.

This approach meant that the commodity mix was driven by the commonplace consumption of complex foods, much of manufactured origin. The composition of these foods was reflected by the recipes given in Food Standards Agency (2002). The NDNS foods include these as well as less processed foods, e.g. fruit, vegetables. The changes in commodity production were inevitably constrained by the ingredient mix of complex foods, which was not changed (apart from some specific assumptions about salt and sugar that are addressed later). It should be noted that intakes of nutrients like salt is highly dependent on what manufacturers include in their products from bread to beef cottage pies.

The commodities consumed were related to a list of 100 core traded commodities that represent the food system. The relationships were scrutinised for consistency (e.g. production should exceed consumption to allow for waste, but not by an excessive amount. In some cases, apparent inconsistences result from non-food use of crops and crop products, e.g. oils being used as biodiesel or starch manufacture from potatoes or cereals. Where necessary, industry data was consulted to help resolve apparent inconsistencies, e.g. consumption of bottled water and soft drinks, which appeared to be under-reported in the NDNS. The higher industry-sourced value was thus used for these. Where apparent over-consumption of some commodities occurred, it was resolved by reassessing recipes, e.g. if tomatoes weights were as whole tomatoes or tomato puree (and thus applying scaling factors), whether choices of alternative ingredients unduly over-demanded commodities.

Food wastage was also accounted for using survey data from both household and the food service sector (WRAP, 2013a, 2013b, 2013c). Greenhouse gas emissions (GHGE) from food waste and food packaging were derived from WRAP (2010).

Animal feeds were addressed through the identification of crops and crop by-products that enter the food chain. For example, milling wheat as reported by Agriculture in the United Kingdom (AUK, 2014) was assumed to be for human consumption and all other wheat for animal feed or industrial use (e.g. fermentation to bioethanol). The feed wheat used by animal types (dairy and beef cattle, poultry, pigs and sheep) was quantified in individual Life Cycle Assessment (LCA) studies by Williams et al. (2006), Leinonen et al. (2012a, 2012b, 2015) and were collectively analysed to reconcile feed use to supply in Audsley et al. (2011), which was re-evaluated where new data arose. Hence, feed wheat for each resulting commodity (milk, poultry meat, eggs etc) could be related to feed wheat production. The same applied to all major animal feeds, e.g. barley, soy, oilseed cakes, sugar beet pulp and fermentation residues.

The result was a baseline quantification of commodities produced and consumed with a set of coefficients derived to relate the production and consumption of each commodity. These coefficients were retained in the subsequent scenarios.

To estimate the effect on agricultural commodities, dietary components were disaggregated using the NDNS food categories. Thus milk consumption was divided into whole, semi-skimmed, 1% and skimmed and cream. Cereals, spreads, meat and vegetables etc were similarly broken down into types. However, many of these NDNS categories are composites of commodities, such as “buns, cakes, pastries and fruit pies”. Analysis of recipes in Food Standards Agency (2002) showed that these are mainly composed of flour, sugar, fat and eggs, which were related to the commodity production of milling wheat, milk, vegetable oil, beet and cane sugar and eggs. Similarly, a basic pizza was assumed to be predominantly made from flour, oil, tomato and cheese. Hence, this was related to commodity production of milling wheat, vegetable oil, milk and tomatoes. The Household Consumption Survey provides some further breakdown of the categories purchased and consumed. Estimates were thus made of the commodities that are needed to produce the diet ingredients, based mainly on recipes given in Food Standards Agency (2002).

2.3.1. Data sources for commodity production

The core data used were agricultural production from Defra statistics (AUK, 2014), imports and exports (from FAO statistics, FAOSTAT, 2016) and HM Revenue & Customs UK trade information (HMRC, 2016), fish farming (Scottish Government, 2015) and fish landing information (MMO, 2015), and data from the British Soft Drinks Association (2016).

2.4. Changes in production under scenarios of change

The initial scenarios delivered factors that changed commodity consumption for the five broad food groups of the eatwell plate. The subsequent development of the scenarios identified drivers that were quantified so that they could modify the initial broad quantification in more nuanced ways, while still retaining the direction of the original scenarios. These resulted in proportional increases and decreases in consumption for each scenario that were then directly related to changes in production relative to the baseline situation.

The proportions of animal feeds needed to produce any animal commodity were assumed constant under the scenarios. Animal feeds tend to be formulated using least cost rations and available feeds depend on both domestic and world prices. It is beyond the scope of this project to forecast the changes in all commodity prices and supply to support further estimates of change. Changing ration formulation can have impacts on environmental burdens per unit output (e.g. Leinonen et al., 2014), but this tends to a second order compared with the primary production itself. Further, additional increases in industrial uses of crops could lead to additional supplies of, say, fermentation end products onto the market.

2.5. Changes in nutrition under scenarios of change

Nutrient supply was determined at two levels. First, by the changes in the five Eatwell categories:

- Fruit and vegetables
- Starchy foods (e.g. potatoes, bread, pasta)
- Dairy (e.g. milk, butter, yoghurt, cheese)
- Protein (e.g. meat, fish, eggs, beans and pulses)
- Foods high in fat, sugar or salt (HFSS)

Second, the nutrient composition of each food type consumed was taken estimated from the data from the Food Standards Agency (2002) to derive the overall average intake per person. An assumption was made that the target diets in the Eatwell scenario should have little effect on the overall average energy intake per capita. In contrast, it could be argued that a healthier diet, if linked with increased exercise, could result in increased dietary energy requirements. Further, energy intakes for some population groups were revised upwards in 2011 by the Scientific Advisory Committee on Nutrition (SACN, 2011).

It must be stressed that the national diet is just that: an average. It accommodates the consumption of 62 M people with a wide range of ages, lifestyles, cultural traditions and eating preferences. Hence, the proportion of fruit and vegetables according the Eatwell classification in the national diet is about right, but the distribution of consumption is clearly skewed with major under-consumption in some population groups.

2.6. Quantification of environmental impacts

The environmental impacts of the six scenarios were determined for three general areas:

- Primary production to the farm gate (or fishery equivalent)
- Processing and delivery to the Regional Distribution Centre (RDC)
- Retailing and consumption

Emissions from the production of agricultural commodities and their processing were taken from the Cranfield LCA model (Williams et al., 2006) and Audsley et al. (2010, 2011), supplemented by additional successor studies (e.g. Webb et al., 2013, Leinonen 2012 a,b) as well as analysis undertaken in this project. The latter gave better insights into analyses such as strawberries and tomatoes from the UK versus Spain, imported beef, lamb and potatoes and more detailed analysis of poultry production. Data on other commodities produced in the UK and overseas came from the literature. Where data were not available for commodities, the closest analogous commodity was used. These are mostly small components of the total production, so the effect of any error is small. The major commodities were the subject of specific LCA studies. Production methods were assumed to remain unchanged. Best efforts were made to ensure that data sources included the impact categories selected, i.e.

- GHG emissions, 100 year timescale, using the Intergovernmental Panel on Climate Change (IPPC) 2007 factors (Forster, 2007) for global warming potential (GWP), quantified as CO_2 equivalents (CO_2e)
- Cumulative energy demand, which includes renewable and non-renewable sources, but the overwhelming proportion is non-renewable, quantified in multiples of Joules (J). It is a broad indicator of resource use (CML, 2016).
- Acidification potential, which includes all acidifying gases, mainly sulphur dioxide (SO_2) from fossil fuel combustion and ammonia emissions from agriculture, quantified as SO_2 equivalents (SO_2 eq.) (CML, 2016).
- Eutrophication potential, which includes mainly nitrate and phosphate leaching and runoff from agriculture, quantified as phosphate equivalents ($P0_4^{3-}$ eq.) (CML, 2016).
- Ammonia, which comes mainly from agriculture and for which we have emission reduction targets under the UN Convention on Long-range Transboundary Air Pollution (UN, 1979).
- Nitrate, which comes mainly from the process of leaching from agricultural land and for which we have reduction targets to meet the needs of the EU Water Framework Directive (EU, 2000).

LCA studies include all significant upstream activities that contribute to the quantification of the environmental burdens of producing a commodity. Hence, the LCA of producing UK milling wheat includes the production of fertilisers, pesticides, machinery, diesel (and its subsequent use) together with all field operations and grain drying and storage (Williams et al., 2010). An LCA of egg production includes all feed crop production and processing, growing replacement hens, energy used to house and feed eggs, manure management (both energy used and emissions from), productivity of hens, losses of eggs and losses of feed, egg grading and packing (Leinonen et al., 2012a). LCA studies have different system boundaries and may go to the farm gate, factory gate, RDC, point of sale or through to consumption in the home.

For overseas commodities, transport can play a considerable role, but is heavily influenced by the mode, e.g. air freighted vegetables have much higher impacts than road hauled ones. Imported commodities were divided into European (EUR) and Rest of World (RoW). Where ever possible, the actual transport distances and modes were used (e.g. as quoted in LCA studies or derived from trade literature and, lastly, expert opinion). If not available, representative transport distance and modes were derived and applied, e.g. 1500 km road haulage for EUR, with refrigeration for vegetables or dairy products and 15,000 km refrigerated ship transport for RoW for fruit or vegetables.

Data sources were scrutinised to ensure that system boundaries were consistent and that, for example, additional transport steps were included or processing was excluded if it were to be derived from another source. For imported commodities, e.g. cheese, processing was assumed to occur in the country of origin, whereas food processing in the UK was derived from high level data.

Where multiple data sources were found, either the mean value was used or data from the most recent or most detailed research study available from scientific and technical perspectives were selected.

2.6.1. Missing LCA data

Whilst for many commodities there have been studies of the carbon footprint (i.e. the sum of all GHG emissions per unit produced), few studies include all the environmental impacts considered in this report. For a few commodities there are no studies that we are aware of. For such commodities, it was assumed that data for the nearest analogue applied, e.g. pears were assumed to be apples and goat meat was considered to be analogous to sheep meat. For missing environmental burdens, the missing values were estimated partly from what was known about the incomplete commodity and by analogy with the nearest equivalents. It should be stressed that data coverage for many domestic or European commodities was very good with minority RoW crops being least studied.

2.7. Environmental impacts after the farm gate

While some food products have been studied from cradle to grave, this did not apply to sufficient commodities to use the sum of the LCA-derived burdens as the impact of food consumption. Hence, alternative data was used to quantify impacts of food manufacturing, distribution and consumption in the UK. Domestic manufacturing impacts were quantified from national level statistics on energy consumption (DECC, 2015a), which are given by fuel type. Energy use and other specific emissions from refrigeration were quantified with the model of Audsley et al. (2010), but with enhancements and revised data. This model was based on foods purchased with estimates of the energy needs for distribution and refrigeration based on Tassou et al. (2009). Household energy consumption for refrigeration and cooling came from national level survey data (DECC 2015b). Energy consumption in the Hospitality and Food Service Sector (HaFSS) came from DECC (2015c). These were coupled with WRAP's data on food waste and estimates of the GHGE impacts of food waste from WRAP (2010).

There could be secondary effects the environmental impacts of major dietary change, but much would remain the same. Even with a large change from say red meat to vegetables and grains, few households would relinquish refrigeration and cooking would remain commonplace. Niche supply chains exist, but these are still overwhelmingly in the minority. While there may be environmental, social and economic impacts of these. Food purchase through major retailers seems set to dominate supply chains for the foreseeable future. It was thus concluded that aspects, such as alternative supply chains, should not be addressed but would remain constant in the analysis, so that the main focus of change is on primary production and delivery of food commodities to the RDC or point of manufacturing.

Energy use (e.g. as UK electricity or natural gas) was converted in all environmental impacts using the life cycle inventories (LCI) of the European reference Life Cycle Database (ELCD, 2016), but with UK electricity brought up to date with more recent data on GHGE per unit used (DEFRA, 2016).

2.7.1. Food waste calculation method

For each food type, production to retail quantities (P) must equate to Consumption (C) plus unavoidable losses (U) and avoidable losses (A), i.e.

$$P = C + U + A$$

The losses can be linearly related to P from activity data as:

$$U = \mu P$$

$$A = \alpha P$$

in which μ and α must be between 0 and 1.

To extend the analysis, we introduced another scalar of range 0-1 to modify avoidable losses, ε, such that

$$A = \alpha \varepsilon P$$

To start with in the baseline case, ε = 1.

Hence, $P = C + \mu P + \alpha \varepsilon P$

or,

$$P (1- \mu + \alpha \varepsilon) = C$$

Thus, potential production needed, when C is constant is given by

$$P = \frac{C}{(1- \mu + \alpha \varepsilon)} \qquad \text{Equation 1}$$

WRAP's household waste data on avoidable and unavoidable wastage rates were applied to the closest food groups that corresponded with the NDNS data in the diets model and hence the values of the coefficients described above. It was assumed that unavoidable wastage was constant, but avoidable wastage could be reduced to zero to estimate the maximum possible effect from the baseline.

2.8. Assumptions

2.8.1. Commodity sourcing

Unless otherwise stated, it was assumed that production required to meet UK consumption is met either by food produced domestically or imported into the UK. Export quantities were assumed to remain constant amongst scenarios and were therefore excluded here. It was noted that changes in the UK demand for food might result in changes in exports. For example, exports of UK produce could be redirected to meet increased domestic demand in the UK rather than met by increased domestic production. Conversely, exports might increase where domestic production was maintained but domestic consumption falls. It was assumed that changes in production requirements for commodities traded with European countries were shared equally between domestic and imported suppliers (but this may not necessarily apply in practice).

3. Results

3.1. Diets by scenario

The reader is reminded that the results were based on a constant population to focus on the effect of changing dietary composition. Although increasing the potential healthiness of diets should cause the population to expand through longer life spans this was outside of the scope of this study.

The results were based on the scenarios described in Section 2.2. For each scenario, the relative changes from the NDNS-based baseline national diet were projected forward for 20 years based on the importance of key drivers (Table 2) and the magnitude of influence by food category (Table 3).

The change in the fresh matter [1]consumption of 26 major food categories (g/hd/d) projected under the alternative scenarios relative to the baseline mean national diet is shown in Table 4. The proportional change in the national diet of the five major food groups are shown in Table 5 as (a) fresh matter consumption and (b) as dry matter equivalent.

Table 6 shows the changes in the national diet relative to the baseline diet in terms of (a) the proportional changes in the fresh and dry matter make-up of the diet and (b), the percentage change in fresh matter consumption (g/hd/d) for the five major food groups. Key features of the diets arising from each scenario are described briefly below.

Scenario 1 (Limited change): There is limited commitment to healthier eating, with growing disparity in dietary health between richer and poorer cohorts. There is an overall relative decline in carbohydrates (excluding those cooked in fats) and fruit and vegetables, and a rise in the proportion given to meats and foods high in fats and/or sugars. The consumption (g/hd/d) of starchy carbohydrates falls in total by about 10%, with proportionately greater reductions in potatoes and breakfast cereals. The consumption of fresh fruit and salads and raw vegetables declines by around 7% in total. The consumption of meat, fish and alternatives remains constant in total but the proportions given to red meat and processed meats increase relative to vegetable proteins and fish, associated with less healthy eating. The consumption of milk and dairy produce falls by about 5%, reductions in fresh milk and yoghurts are offset by processed products, especially cheeses. There is a continuing increase in the consumption of foods high in fat and sugar such as potato chips and cakes, mainly amongst low income groups. Food waste reduces by 50% from the baseline rate, mainly driven by the cost of waste.

Scenario 2 (Taking responsibility): in this scenario there is a general, popular commitment to improving dietary standards. The consumption (g/hd/d) of starchy carbohydrates increases by about 14% fresh matter, accounting for an increased proportion of the total fresh matter diet. There are notable increases in the two largest subcategories by weight, namely pastas and rice, and bread. The fresh matter consumption of fruit and vegetables increases by about 38% such that they account for over 40% of fresh matter intake for the diet as a whole. The consumption of meat, fish and alternatives declines marginally by about 3%, and a small reduction in the proportion of the diet given to this category of foods. Driven by healthier eating, there is a reduction in consumption of red meat (by 12%) and processed meats (by 27%) and increased consumption of white meats, vegetable proteins (by about 10%) and fish products (by about 25%). The consumption of milk and dairy produce increases by about 4% in fresh weight, mainly for cheese and yogurts. Foods high in fat and

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[1] Fresh matter is food that includes intrinsic water (or moisture). Nutrients are physically in dry matter, which is determined by oven drying to derive the dry matter concentration.

sugar reduce by about a third in terms of fresh matter consumption, with reductions spread evenly across all subtypes associated with healthier options in snack and institutional catering. Total consumption by weight, reflecting dietary changes, has increased by about 8%, although dry matter weight falls slightly. Food waste reduces by 75%, due to awareness, commitment and technology.

Scenario 3 (Big Brother): high profile campaigns toward healthy eating have some effect on the make-up of the national diet. The consumption of starchy carbohydrates increases by over 20% fresh weight, especially linked to increased bread and breakfast cereals. Fruit and vegetable consumption increases by about 17% by fresh matter weight, mainly in terms of vegetables and salads. Meat, fish and alternatives consumption falls marginally (by about 3%) by weight, and as a proportion of the total diet weight, with reductions in fresh and processed meats offset by increased fish consumption. The overall consumption of milk and dairy produce by weight increases by about 4%, mostly linked to cheeses and yoghurts. The fresh matter consumption of foods high in fat and sugar declines by almost 20%, evenly spread across most sub categories with an overall reduction in the proportion of total diet given to this category. Food waste reduces by 50% in this scenario driven by regulatory and fiscal drivers.

Scenario 4 (Diverging diets): Higher food prices place pressures on household budgets forcing some dietary changes with impacts that vary across social groups. The consumption of starchy carbohydrates (g/hd/d) increases by 18% overall with a notable increase in bread consumption by about 40%. Fruit and vegetable consumption declines by about 19%, particularly of higher priced fruits and salads and raw vegetables. The fresh matter consumption of meat, fish and alternatives declines by about 6%, The decline in red meat is partly offset by increased in white meat and processed meats taken as cheaper options, with large reductions in vegetable proteins and fish products. The share of the total fresh matter diet given to meats, fish and alternatives falls. Milk consumption falls by about 14%, mainly due to reductions in fresh milk consumption. The consumption of foods high in fat and sugar falls marginally (by 2%) by weight. Within this food category, the consumption of potatoes cooked in fats and processed spreads (linked to bread applications) increases by over 25% by fresh matter weight, partly substituting for purchased cakes, pastries and confectionary. Technology improvements help to reduce fats, sugar and salt content. Total fresh matter consumption increases marginally, with a slight fall in dry matter consumption relative to the baseline diet. Food waste reduces by 50% in this scenario driven by regulatory and market drivers.

Scenario 5 (Living for the Third Age): There is a transition to healthier diets across all social groups, largely driven by conditions of relative austerity. Diets are characterised by a 27% increase in starchy carbohydrate intake, for all subcategories except more expensive pasta and rice options. Consumption of fruit and vegetables increases by 19% overall, especially of processed and cooked vegetables. Consumption of meat, fish and alternatives declines by 4% by weight, reflecting reductions in consumption of relatively expensive red meats, partly offset by increases in white fish. A fall in the consumption of processed meats reflects less eating out and more home cooking. Milk and dairy food consumption increases by about 5% by fresh weight, with milk derivatives such as yogurts increasing in consumption. The consumption of foods high in fat and sugar declines by about 19%, promoted by a mix of economic necessity and lifestyle change. New product development reduces the content of fats and sugars in foods generally and in confectionery and convenience foods in particular. Overall consumption by fresh weight increases by about 10% due to dietary substitutions, with dry matter intake unchanged. Food waste declines by 90%, driven by regulation, voluntary action and economic incentives.

Scenario 6 (Eatwell): The Eatwell diet results in a configuration that meets the targets for nutrition and healthy eating. The fresh matter consumption of carbohydrates doubles by weight so that their share of total fresh matter dietary intake increases from 19% to 34%, with notable increases in bread and potato consumption. The proportion of fresh matter intake given to fruit and vegetables increases by about 24%, but with reduced consumption of sugar-rich fruit juices. Intake of meats, fish and alternatives falls by 10%, driven mainly by reductions in red and processed meats, with offsets by increased white meat, vegetable proteins and oily fish products. Consumption of dairy produce remains falls by about 5% of total fresh matter consumption, mainly due to reductions in fresh milk consumption. There is a 60% reduction in the fresh weight consumption of foods high in fats and /or sugars, evenly spread across all subcategories. Overall consumption by fresh weight and dry matter remain reasonably constant. Food waste declines by 90%, driven by regulation, voluntary action and economic incentives.

Table 4 Baseline intake of food groups in the national diet (fresh matter consumption) and predicted changes under each scenario

Diet constituents	**Baseline intake (g/hd/d)**	**Proportional change in intake (%)**					
		Scenario					
		1	**2**	**3**	**4**	**5**	**6**
Starchy carbohydrates	**234.0**	**-10.3**	**13.8**	**22.3**	**17.5**	**26.4**	**110.3**
Pasta, rice and miscellaneous cereals	82.0	-5.2	19.7	-3.2	-2.1	-5.9	62.6
Bread	81.9	-5.2	13.6	54.8	42.5	61.9	167.6
Potatoes not cooked in fat	42.7	-24.1	4.1	10.3	7.0	22.6	113.3
Cereals (breakfast)	27.5	-18.9	12.3	20.2	18.3	23.2	77.3
Fruit and vegetables	**407.3**	**-6.9**	**38.3**	**16.5**	**-19.1**	**19.0**	**23.6**
Fruit	101.1	-11.9	37.7	15.9	-28.1	11.0	19.6
Fruit juice	59.5	3.8	30.6	13.3	-19.6	5.6	-5.2
Vegetables (not raw) including vegetable dishes	169.0	-8.4	38.6	15.9	-8.4	30.6	32.0
Salad and other raw vegetables	77.7	-4.9	44.4	21.1	-30.3	14.7	32.6
Meat, fish and alternatives	**240.8**	**0.1**	**-3.0**	**-2.6**	**-6.4**	**-4.2**	**-10.3**
White meat	58.3	1.1	3.5	1.5	10.3	0.5	15.7
Red meat	66.0	5.5	-11.8	-11.4	-5.3	-19.5	-47.2
Processed meat	48.7	2.3	-27.1	-16.5	6.7	-11.3	-49.0
Beans, pulses, nuts and seeds	14.9	-20.7	9.6	3.0	-42.4	5.9	27.9
Eggs and egg dishes	17.5	2.3	11.0	7.7	-17.6	6.1	8.9
Fish (oily)	10.0	-2.6	27.8	22.9	-33.1	19.1	100
White fish and shellfish	25.4	-9.2	21.6	17.2	-33.7	16.0	20.8
Milk and dairy foods	**198.8**	**-5.2**	**3.8**	**4.3**	**-13.6**	**5.1**	**-4.6**
Milk (split according to current intake)	155.5	-5.1	2.0	1.2	-15.9	2.2	-10.0
Cheese	13.9	14.1	9.0	14.8	-7.7	8.2	1.3
Yoghurts, fromage frais and other dairy desserts	29.4	-14.7	10.7	15.9	-4.3	19.4	21.1
Foods high in fat and/or sugar	**155.5**	**6.9**	**-31.7**	**-18.7**	**-2.0**	**-18.9**	**-59.9**
Potatoes cooked in fat	41.8	14.1	-28.3	-16.8	25.8	-15.1	-49.3
Buns, cakes, pastries, and fruit pies	34.0	9.2	-35.3	-16.9	-18.8	-21.5	-64.7
Biscuits	13.4	-3.8	-30.6	-20.6	16.9	-14.0	-60.0
Confectionery	2.8	22.2	-34.3	-20.6	-9.9	-26.3	-65.7
Chocolate	8.5	20.6	-25.6	-14.5	-18.0	-23.1	-61.4
Spreads and cooking fat (not butter)	5.2	9.2	-25.3	-12.2	30.1	-10.8	-56.8
Butter, cream, ice-cream	25.4	-3.8	-26.4	-18.5	-21.5	-21.2	-63.4
Sugar (table & soft drinks) and preserves	24.5	1.1	-41.4	-26.1	-16.9	-21.7	-66.6
Total fresh matter (excluding drinks), (g/hd/d)	**1,236**	**1,185**	**1,341**	**1,327**	**1,284**	**1,333**	**1,286**
Dry matter intake (g/hd/d)	464	455	454	479	447	467	474

Table 5 Composition of national mean diet by scenario

(a) Proportion of total diet by food category on fresh matter consumption basis

Target	Dietary proportions	Baseline	Scenario					
			1	2	3	4	5	6
33%	Starchy carbohydrates	19%	18%	19%	22%	24%	22%	34%
33%	Fruit and vegetables	33%	32%	41%	36%	29%	36%	34%
12%	Meat, fish and alternatives	19%	20%	17%	18%	19%	17%	15%
15%	Milk and dairy foods	16%	16%	15%	16%	15%	16%	13%
8%	Foods high in fat and/or sugar	13%	14%	8%	10%	13%	9%	4%

(b) Proportion of total diet by food category on dry matter consumption basis

Target	Dietary proportions	Baseline	Scenario					
			1	2	3	4	5	6
53%	Starchy carbohydrates	32%	30%	36%	38%	38%	38%	56%
13%	Fruit and vegetables	13%	13%	18%	15%	11%	15%	14%
12%	Meat, fish and alternatives	21%	21%	20%	19%	19%	19%	15%
7%	Milk and dairy foods	8%	8%	8%	8%	7%	8%	6%
15%	Foods high in fat and/or sugar	26%	28%	17%	20%	25%	20%	9%

Table 6 Changes in the mean national diet by scenario relative to the baseline diet

(a) changes in the proportions of the diet given to five major food groupings by scenario by fresh matter content as changes in percentage points

Dietary proportions	Scenario					
	1	2	3	4	5	6
Starchy carbohydrates	-1%	0%	3%	5%	3%	15%
Fruit and vegetables	-1%	8%	3%	-4%	3%	1%
Meat, fish and alternatives	1%	-3%	-2%	0%	-2%	-5%
Milk and dairy foods	0%	-1%	0%	-1%	-1%	-3%
Foods high in fat and/or sugar	1%	-5%	-3%	1%	-3%	-8%

(b) changes in the proportions of the diet given to five major food groupings by scenario by dry matter content as changes in percentage points

Dietary proportions	Scenario					
	1	2	3	4	5	6
Starchy carbohydrates	-2%	4%	6%	6%	6%	24%
Fruit and vegetables	-1%	5%	2%	-3%	2%	1%
Meat, fish and alternatives	1%	-1%	-1%	-2%	-2%	-6%
Milk and dairy foods	0%	0%	0%	-1%	0%	-2%
Foods high in fat and/or sugar	3%	-8%	-6%	0%	-6%	-17%

3.2. Differences in nutrient intake by scenario

Diet intake can be measured in terms of fresh matter, dry matter and contents of energy, proteins, fats, starchy carbohydrates, micronutrients, simple sugars and salt. The eatwell plate proportions are defined in terms of high level food groups, but within these there are large differences in dry matter concentration, notably milk versus cheese and potato versus cereal. The scenarios derived from the workshops focus on the mix of dietary components within these major food groups.

The nutritional status of diets varies amongst scenarios, reflecting the composition of ingredients. Scenarios 2 and 6, for example, are associated with lower intakes of fat and higher intakes of vitamin C (Table 7). The eatwell plate (Scenario 6) is associated with higher starchy carbohydrate, protein and vitamin intake, and lower fats and sugar intake relative to the baseline diet (Table 7).

Nutrient requirements (i.e. Dietary Reference Values, DRVs) by population group and gender were taken from the British Nutrition Foundation (2015). Food properties were taken from Food Standards Agency (2002) and EEC (1990). The weighted average of each nutrient by age and gender was calculated using the UK Census for 2011. In effect, the nutrient requirements for the population are close the weighted average of male and female adults. The nutritional demands of all children is much smaller than that of all adults at the whole population level. No extra allowance was made at the national level for pregnancy or breast feeding. While these are of critical importance to those involved, the influence on total national dietary needs is insignificant. The UK energy requirements are “based on the average energy required for people of a healthy weight who are moderately active” and this is a fair approximation of national needs.

The British Nutrition Foundation (2015) gives data for total energy, energy from fats and carbohydrate, together with protein needs, minerals and vitamins. At a national level, there were not deficiencies of any vitamin or mineral. Although the sodium (common salt is sodium chloride) content in the eatwell plate fell by a factor of three (Table 7), the supply was still 1.5 times the recommended (weighted), 50% greater than the recommended intake of 2.4 g Na/d. Fibre (non-starch polysaccharide) increased from 15 to 22 g/d, but was still 21% below the target of 28 g/d.

Total metabolisable energy (ME) fell slightly from 9.3 MJ/d in the baseline and ranged narrowly from 8.8 to 9.4 MJ/d in the scenarios, with the Eatwell energy intake at 9.4 MJ/d, but this was just 2% higher than the weighted requirement of 9.3 MJ/d. The proportion of ME derived from fat fell from 28% to 20%, i.e. well below the upper limit of 35%. The fraction of energy from saturated fat halved from 2.8% to 1.4%, also well below to upper limit of 11%. The proportion of energy derived from all carbohydrates should be about 50% and it increased from 49% to 53%. The fraction of energy from simple sugars (intrinsic and extrinsic) fell substantially from 26% to 15%, but was still above the target of 5%.

Overall, the Eatwell diet of Scenario 6 came close to supply the dietary reference values for all main macro- and micro-nutrients, but salt and simple sugars were still somewhat oversupplied. Scenario 1 (limited change) was the worst diet with the highest intake of energy from fat and simple sugars and the lowest fraction of starchy carbohydrates. It must be remembered that these represent average nutrient intakes and that individual consumption varies considerably.

One difficulty in achieving complete agreement with Eatwell specification results from the consumption complex foods and the balance of nutrients contained therein. Manufactured foods often contain relatively high levels of salt, which constrained change somewhat, although effort was made to substitute sodium salt for potassium salt where possible.

Table 7 Consumption of selected dietary nutrients by scenario and comparison with recommended intake thresholds.

Nutrient	Unit	Base-line	Scenario						[Scen 6] / [Baseline]
			1	2	3	4	5	6	
Dry matter	g	453	442	436	463	433	447	491	109%
Metabolisable Energy	MJ	9.3	9.2	8.8	9.3	9.0	9.0	9.4	102%
Protein	g	88.8	88.0	90.7	92.2	88.3	91.6	99.5	112%
Fat	g	70.1	71.7	58.9	66.4	67.8	61.4	52.1	74%
Sat FAs in whole diet *	%	10%	10%	8%	9%	9%	9%	7%	70%
Poly FAs in whole diet	%	4%	4%	3%	4%	4%	3%	3%	85%
Trans FAs in whole diet	%	1%	1%	1%	1%	1%	1%	0%	62%
Carbohydrate	g	258	250	250	267	245	258	299	116%
Fraction of simple sugars in carbohydrates	%	55%	56%	51%	50%	37%	39%	27%	50%
Non starch polysaccharide (NSP), fibre	g	14.7	13.4	17.1	17.3	15.2	17.7	22.3	152%
Cholesterol	g	3.0	3.0	2.9	2.9	2.8	2.9	2.5	86%
Sodium	g	10.7	10.7	10.7	10.7	7.1	7.2	3.5	33%
Potassium	g	3.4	3.3	3.7	3.6	4.7	5.3	7.6	223%
Calcium	g	1.0	0.9	1.0	1.0	0.9	1.0	1.1	120%
Iron	mg	15.0	13.7	16.2	16.9	16.2	17.2	21.7	145%
Copper	mg	1.2	1.2	1.3	1.3	1.2	1.3	1.6	134%
Selenium	mg	50.4	49.1	54.1	54.3	49.7	53.5	67.1	133%
Iodine	mg	170	164	183	178	153	177	195	114%
Vitamin B6	mg	2.7	2.5	3.0	2.9	2.7	3.0	3.5	132%
Vitamin B12	mg	6.0	6.0	6.0	6.0	5.4	6.0	5.6	92%
Vitamin C	g	0.14	0.13	0.18	0.16	0.12	0.16	0.18	126%
Vitamin D	µg	3.1	3.0	3.2	3.3	3.0	3.2	3.9	124%
Vitamin E	mg	9.0	8.5	9.2	9.4	8.7	9.3	9.8	109%
Vitamin K1	mg	0.10	0.10	0.13	0.12	0.09	0.12	0.13	122%
Folate	mg	0.38	0.35	0.45	0.44	0.38	0.45	0.54	141%
Retinol Equivalent	mg	1.2	1.2	1.4	1.3	1.1	1.4	1.3	105%
Niacin equivalent	mg	22.4	21.2	24.2	25.8	24.4	25.7	34.3	153%
Alpha-tocopherol	mg	2.2	2.2	2.0	2.1	2.2	2.0	1.9	85%
Beta-tocopherol	mg	0.12	0.12	0.13	0.13	0.12	0.13	0.19	156%
Delta-tocopherol	µg	45	46	39	42	41	40	35	78%
Gamma-tocopherol	mg	0.72	0.72	0.68	0.72	0.75	0.68	0.86	118%
* FA = Fatty acids									

3.2.1. Micronutrient supplies

The Eatwell diet (and other healthier diets) apparently delivered most vitamins and minerals requirements at population average levels. A balanced diet provides all our needs. A poor diet that is low in nuts, seeds, fruit, green vegetables and vegetable oil is likely to be deficient in vitamins C, E and K. In contrast, a vegan diet is likely to be deficient in vitamin B12 and iron (particularly haem iron). The Eatwell Guide recommends at least one portion of oily fish a week. Fish oils are good sources of essential omega-3 fatty acids, e.g. eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which contribute to the synthesis of some eicosanoids that have at least anti-inflammatory properties (Moghadasian, 2008). There are however, plant based sources of short chain omega-3 fatty acids e.g. oils from linseed, walnut, rapeseed or soya. The British Nutrition Foundation (2016c) reported that "*the body is able to convert a small proportion of these fats into long chain omega-3s but this process is not thought to be overly efficient.*"

Overall, the reduction in red meat consumption, rather than complete elimination, should not cause micronutrient deficiencies at a population level. The Eatwell diet contains enough iron on average to meet needs (NHS, 2016a). Specific vulnerable population groups that maybe prone to vitamin or mineral deficiencies can obtain objective advice on meeting needs from the NHS website (NHS, 2016) or the British Nutrition Foundation (2016). Supplementation by ingestion or injection can largely be avoided through judicious food choices, but reliable supplements are available should they be needed.

3.3. Difference in the consumption of agricultural commodities between scenarios

Differences in diets result in differences amongst scenarios in the quantities of raw agricultural commodities produced to meet consumption needs (Table 8) especially regarding cereals, fruit, vegetables and meats. The eatwell plate (Scenario 6) results in marked increases in the consumption of cereals including rice and potatoes, and a reduction milk, meat and sugar. The changes in cereal consumption are based in direct human consumption and hence do not include feed (and biofuel) wheat or feed barley or oats. Demand for these three feed cereals will decrease from reduced meat and livestock product consumption. The reduction in wheat and barley will be particularly affected by monogastric livestock, in which the inclusion rates of cereals are considerable higher than in most ruminant diets (Leinonen et al., 2012ab, Audsley et al., 2011, Webb et al., 2014). At one end of the spectrum, most sheep obtain at least 90% metabolisable energy from forage. "Barley beef" is at the other end and the diet contains up to 95% concentrates of which a high proportion would be cereals. Most of the suckler beef population is forage based and the raising of a suckler calf requires about 11% of the metabolisable energy as concentrates, with a beef finisher about 25%. In both bases, the concentrates would include feed cereals along with by-products such as sugar beet pulp, wheatfeed, brewers' grains and oilseed meals. The barley shown below in Table 8 is dominated by malting barley for beer and spirit production, which is not assumed to change. The small amount of barley eaten directly as pearl barley malted drinks etc., is not recorded in national statistics.

Table 8 Production requirements to meet the annual UK consumption needs of 16 main agricultural commodities. Percentage changes by scenario relative to the baseline

Commodity	Baseline, (kt)	Scenario					
		1	2	3	4	5	6
Milk	17,706	1%	-14%	-7%	-16%	-13%	-30%
Wheat (milling)	7,178	-3%	1%	20%	19%	25%	70%
Potatoes	6,813	-3%	-13%	-4%	18%	3%	24%
Barley	1,656	0%	0%	0%	0%	0%	0%
Tomatoes	1,309	-6%	41%	18%	-21%	20%	24%
Chicken meat	1,591	1%	3%	1%	10%	0%	14%
Sugar (cane)	1,342	1%	-12%	-7%	-17%	-18%	-31%
Tomatoes	1,309	-6%	41%	18%	-21%	20%	24%
Pig meat	1,301	3%	-21%	-14%	3%	-13%	-46%
Oranges	1,280	-12%	38%	16%	-28%	11%	20%
Sugar (beet)	1,268	1%	-12%	-7%	-17%	-18%	-31%
Beef	1,074	4%	-10%	-10%	-4%	-15%	-42%
Bananas	949	-12%	38%	16%	-28%	11%	20%
Grapes	798	-12%	31%	15%	-22%	11%	23%
Apples	712	-4%	13%	5%	-9%	4%	7%
Eggs	732	2%	5%	0%	-16%	2%	2%
Carrots & turnips	712	-8%	39%	16%	-8%	31%	32%

3.4. Sourcing of agricultural commodities by scenario

Differences in diets affect the balance of supply of agricultural commodities from domestic and international sources. In Table 9, the supply responses are presented for four contrasting scenarios, namely the Baseline, Scenario 1 (Limited change), Scenario 4 (Diverging Diets, with uneven dietary health, especially amongst poorer cohorts) and Scenario 6 (The eatwell plate).

It is assumed that production required to meet UK consumption is met either by food produced domestically or imported to the UK. Export quantities are assumed to remain constant amongst scenarios and are therefore excluded. It is noted that changes in the UK demand for food might result in changes in exports. For example, exports of UK produce could be redirected to meet increased domestic demand in the UK rather than met by increased domestic production. Conversely, exports might increase where domestic production is maintained but domestic consumption falls. It is assumed that changes in production requirements for commodities traded with European countries are shared equally between domestic and imported suppliers (but this may not necessarily apply in practice). It is noted that the estimates are based on a constant population size.

Relative to the Baseline, Scenario 1 (Limited change) results in small (3%) percentage decline in cereals and potatoes, and a small (3%) increase in white and red meats, potentially shared proportionately between domestic and imported producers according to the current balance of trade. UK production of fruit and vegetables, as well as external sourcing of fruit, declines. For Scenario 4, falls in required production of milk affected both domestic and imported sources, whereas increased production of potatoes and cereals has potential to increase the share of domestic production. Poultry and pig production increase relative to beef, whereas other temperate fruits and vegetables decline. For Scenario 6, Eatwell according to the 2010 guidelines, UK production is likely to provide the bulk of increased need for wheat and potatoes, though UK production will account for the major reductions in dairy, beef and sugar (beet) commodities relative to the baseline. Domestic horticultural production is predicted to increase together with Imports of tropical produce. Rice imports increase in line with the increased carbohydrate component of the diet. It is noted that these estimates do not include possible changes in export quantities that may interact with production and import quantities. It is possible that increased demand for imported produce would, if incentives are sufficient, encourage domestic production of commodities to substitute for imports, notably imported vegetables and rice, and livestock feeds.

Table 9 Total UK consumption, production and imports of main agricultural commodities for the baseline scenario and change associated with selected diet scenarios relative to the baseline

Commodity	Baseline (kt)				Scenario 1: Changes relative to Baseline			
	Total consumption	UK Production	Imports from Europe*,	Imports from rest of world	Total consumption	UK Production	Imports from Europe*,	Imports from rest of world
Milk	17,706	11,104	3,301	3,301	1%	1%	1%	1%
Wheat (milling)	7,178	5,360	1,038	779	-3%	-3%	-3%	-3%
Potatoes	6,813	5,815	998	0	-3%	-3%	-3%	
Barley	1,656	1,656	0	0	0%	0%		#
Chicken meat	1,591	1,330	217	45	-6%	-6%	-6%	
Sugar (cane)	1,342	0	0	1,342	1%	1%	1%	1%
Tomatoes	1,309	90	1,219	0	-6%	-6%	-6%	
Pig meat	1,301	730	571	0	1%			1%
Oranges	1,280	0	640	640	1%	1%	1%	
Sugar (beet)	1,268	1,263	5	0	-12%		-12%	-12%
Beef	1,074	799	192	83	3%	3%	3%	
Bananas	949	0	0	949	4%	4%	4%	4%
Grapes	798	1	399	399	-12%			-12%
Eggs	732	655	78	0	2%	2%	2%	
Apples	712	233	307	172	-4%	-4%	-4%	-4%
Carrots & turnips	712	666	46	0	-8%	-8%	-8%	

Commodity	Scenario 4: Changes relative to Baseline				Scenario 6: Changes relative to Baseline			
	Total	UK Production	Imports from Europe*,	Imports from rest of World	Total	UK Production	Imports from Europe*,	Imports from the Rest of World
Milk	-16%	-16%	-16%	-16%	-30%	-30%	-30%	-30%
Wheat (milling)	19%	19%	19%	19%	70%	70%	70%	70%
Potatoes	18%	18%	18%		24%	24%	24%	
Barley	0%	0%			0%	0%		
Chicken meat	-21%	-21%	-21%		33%	33%	33%	
Sugar (cane)	10%	10%	10%	10%	14%	14%	14%	14%
Tomatoes	-21%	-21%	-21%		33%	33%	33%	
Pig meat	-17%			-17%	-31%			-31%
Oranges	-17%	-17%	-17%		-31%	-31%	-31%	
Sugar, beet	-28%		-28%	-28%	20%		20%	20%
Beef	3%	3%	3%		-46%	-46%	-46%	
Bananas	-4%	-4%	-4%	-4%	-42%	-42%	-42%	-42%
Grapes	-28%			-28%	20%			20%
Eggs	-16%	-16%	-16%		2%	2%	2%	
Apples	-9%	-9%	-9%	-9%	7%	7%	7%	7%
Carrots & turnips	-8%	-8%	-8%		32%	32%	32%	

* Export quantities are assumed to remain constant

Blank cells indicate no data value, zero indicates no change

3.5. International trade

Different scenarios have different impacts on the balance of UK and non-UK sourcing of agricultural food commodities measured in volumes of trade (Figure 1). Healthier eating tends to be associated with an increase in the relative proportion of domestically produced commodities in the diet, especially where livestock products are replaced by domestically grown plant-based products.

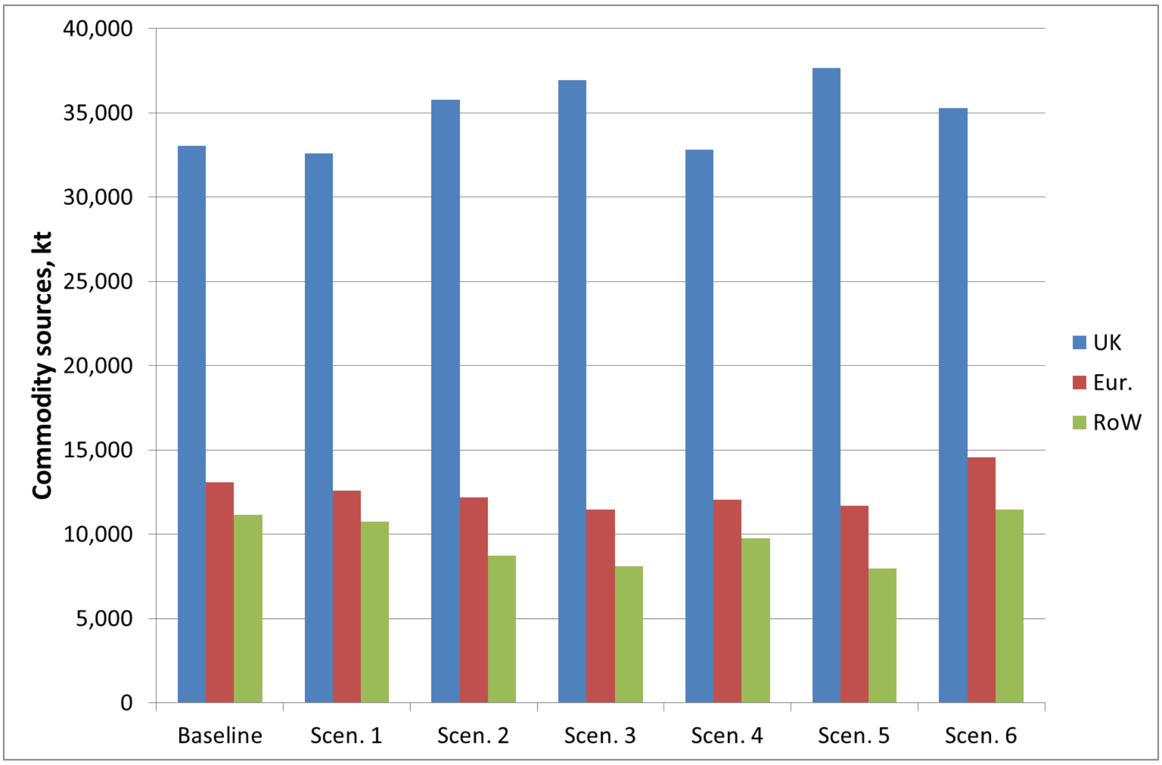

Figure 1 Estimated national and international sourcing (Europe and rest of world) of all agricultural commodities consumed in the UK by volume (000t) under each of six scenarios of dietary change

The UK is about 62% self-sufficient in the supply of all agricultural food raw commodities and 76% for indigenous type foods (Defra, 2016a; 2016b; 2015; 2012). The analysis developed here estimated a self-sufficiency of 58% overall supply. This is close to the official value and the difference probably results from the life cycle approach taken here, which includes food crops used for animal products that are produced overseas, but consumed in the UK.

The UK supplied 54% of all raw unprocessed food by value in 2014, 90% sourced from 22 countries (Defra, 2016b). The relative importance of different trading partners varies by types of food such that the impact of changing diets on international trade and trading partners varies considerably by commodity. Some trades are relatively concentrated. For instance, 90% of meat and meat imports are sourced from three countries; 90% of dairy products and birds egg imports from three countries. Others are more diverse. For example, 90% of imports of cereals and cereal preparations (including rice) are sourced from 12 countries (Defra, 2009b) and 90% of vegetables consumed in the UK are sourced from 24 countries (Defra, 2016b).

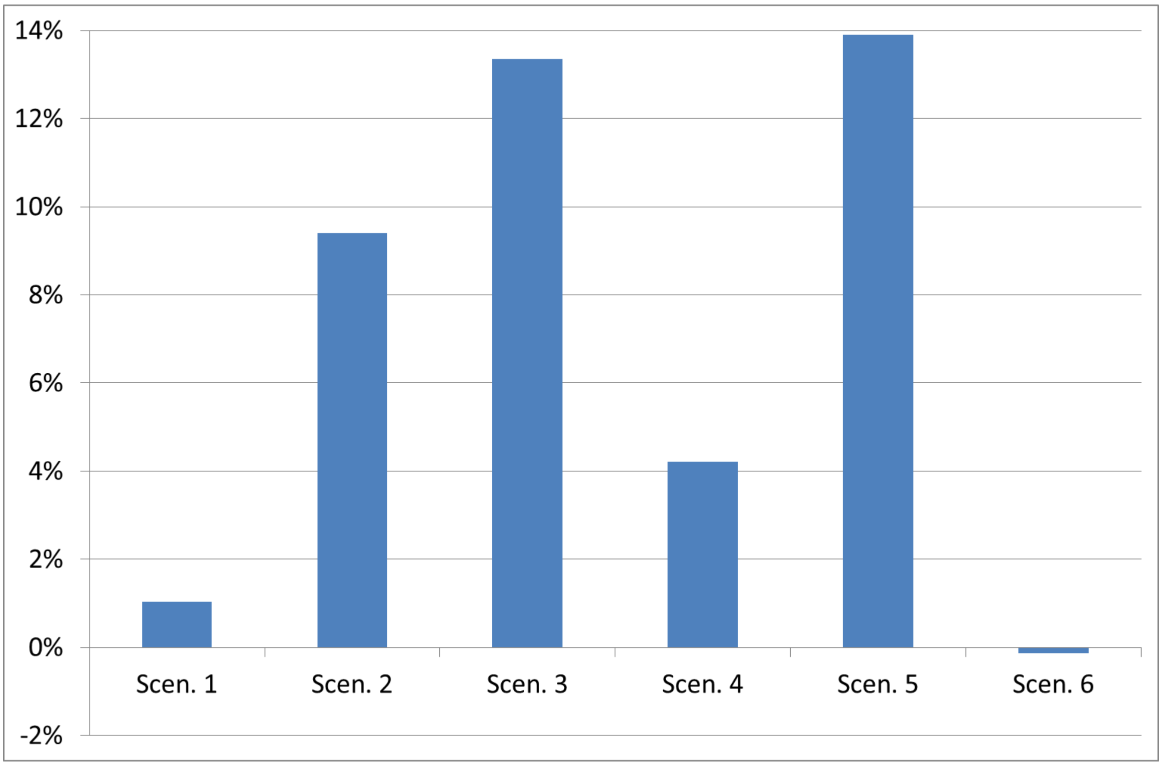

Figure 2 Percentage changes in the self-sufficiency of the UK in all agricultural commodities by scenario relative to the baseline

The Eatwell diet, Scenario 6, has a negligible effect on overall self-sufficiency in food production measured as home production expressed as a fraction of total new supply for use in the UK (that is home production + imports – exports), with the other scenarios actually increasing overall self-sufficiency (Figure 2). However, under this scenario the impact on self-sufficiency varies between different food groups. Broadly, the general decline in meat consumption reduces the amount of domestically produced and imported beef and pork, offset by increased home produced plant products, notably cereals and vegetables, supplemented by extra imports. In terms of impacts of the Eatwell diet on trading partners, the UK is currently about 80% self-sufficient in volume in beef and veal products. Almost 90% of imports come from EU countries, notably the Irish Republic (at 60% of total imports), the Netherlands, Germany and Poland (together accounting for about 15% of total imports) (HMRC, 2016).

In recent years, the UK has been self-sufficient in lamb and mutton with imports and exports in near balance (at 80-90,000 t per year). Assuming a pro-rata adjustment, imports would reduce by about 50% of current levels, affecting supply from New Zealand (that currently provides about 70% of total imports).

The Eatwell scenario involves a 14% rise in imports of poultry meat for which the UK is about 90% self-sufficient with imports and exports equivalent to 30% and 20% of home production respectively. Over 90% of imports come from the EU, mainly the Netherlands (approaching 40% of all imports). There is scope to redirect some of the export trade to the domestic market. The Eatwell scenario involves a 40% reduction in pig meat requirements, in which the UK is currently 60% self-sufficient. Virtually, all imports are sourced from EU member states with the major sources being Denmark, the Netherlands and Germany (HMRC, 2016).

Regarding milk and cream, the UK is about 63% self-sufficient in milk, with net imports accounting for about 37% of consumption. There are also exports, equivalent to about 3% of production, mainly in processed products. Most of the current imports are processed products e.g. butter, cheese, and milk powder. Thus, the major part of a 30% reduction in milk required probably would be borne by UK producers, with impacts on imports from EU members and New Zealand.

With respect to cereals, the UK is almost fully self-sufficient in small grain cereals (wheat, barley and oats), although this varies by variety and end-use, and by year according to harvest yields. Typically 15-20% of wheat production is exported as feed wheat, usually with a small overall positive annual trade gap. Most export trade (70% of total) is with EU member states (HMRC, 2016). The Eatwell scenario involves an increase of about 70% in the demand for milling wheat. It is assumed that this increased requirement would be met from domestic sources, facilitated by a switch in land use within the UK, possibly supplemented by imports from EU and the Americas (Table 10). An almost doubling in maize imports for poultry feeds and breakfast cereals, would most likely come from existing sources in Europe and the Americas. The 70% increase in rice imports would primarily come from Thailand, Vietnam, the USA and, in the case of Basmati rice, India and Pakistan. Assuming a constant ratio of cane and beet sugar in the diet, Eatwell reduces plantation-based cane sugar imports by about 31%, sourced mainly from developing economies under the International Sugar Agreement including countries such as Brazil, Guyana, Barbados, Mauritius, Malawi and Indonesia (ISO, 2016).

Eatwell involves an estimated 24% increase in potato production requirements. The UK is about 80% self-sufficient in potatoes, with the bulk of imports in out of season or processed forms from Europe and the Mediterranean basin. With respect to fresh vegetables, the UK is currently about 55% self-sufficient with nearly 80% of imports coming from the EU, mainly Spain (40% of total imports) and the Netherlands (29%). Smaller amounts of high value vegetables (e.g. mangetout, fine beans) are air-freighted from tropical regions, e.g. central Africa. An increase of demand for fruit of about 20%, for which the UK produces about 12% of its needs, would be expected to be met mainly from imports taken a large range of countries, about 35% of which came from the EU (mainly Spain) with South Africa, Costa Rica and Colombia as major non-EU sources (HMRC, 2016, FAO, 2016).

It is possible that a switch to the Eatwell diet shown in Scenario 6, could impact on the UK balance of payments as patterns of trade change. The prices of imported commodities (£/t) tend to be higher than for those that the UK exports with the difference equivalent to about 10-15% for meats, fresh vegetables and fruits and about 30% for wheat (Defra, 2010;2015). Furthermore, traded commodities vary in unit value (£/t). Thus, weight for weight, reducing net imports of livestock products relative to plant-based products in the Eatwell diet tends to reduce net import costs (and potentially the relative costs). The Eatwell diet also reduces the consumption of processed foods which could provide scope to substitute imports for domestic produce. However the Eatwell diet also increases the consumption of Mediterranean and tropical vegetables and fruits, which tend to be higher priced per unit weight due to transport and handling costs.

Table 10 Summary of possible impacts of Eatwell diet on UK international trade in food commodities relative to baseline.

Commodity	UK self-sufficiency: 2011-2015 [1]	Estimated change in UK imports by volume [2]	Trading partners affected
Milk and cream	103%	-30%	Mainly EU and NZ
Cereals (wheat and small grains)	103 % overall, wheat (90%)	+70%	EU and Americas
Maize	0%	+100%	North and South America, Thailand
Rice	0%	+70%	USA, SE Asia
Beef and veal	82%	-40%	EU, USA and South America
Lamb and mutton	100%	-50%	Mainly NZ and Australia
Pig and pork	60%	-40%	EU
Chicken meat	90%	+14%	EU, Brazil, Thailand
Potatoes	80%	+24%	EU and USA
Fresh vegetables	55%	+70%	mainly EU
Fruit	12%	+70%	EU, USA, Latin America
Sugar cane	0%	-30%	International Sugar Agreement members

[1] home production as a % of new supply (home production + exports- imports), based on period 2011-2015 (Defra, 20016a)

[2] % change in imports assuming import: export ratios remain constant as per baseline

3.6. Environmental impacts (emissions and energy use)

Different configurations of diet result in differences in greenhouse gas emissions (as GWP) amongst scenarios ranging from an increase of 1% to a decrease of 30% in the Eatwell scenario (Table 11). The baseline is clearly dominated by ruminant-derived commodities of milk and meat (Table 11).

For example, relative to the baseline, Scenario 2, Taking Responsibility, with its general improvements in dietary health, leads to an overall decrease in GWP of about 3% for the bundle of commodities assumed to make up the diet. Scenario 4, Diverging Diets, with a reduction in livestock production, shows an overall decrease in GWP of around 7% compared with the baseline. The eatwell plate, Scenario 6, shows an 18% reduction in GWP mainly attributable to reduced livestock, although these are offset by GWP associated with increased fish, cereals, fruit and vegetables, including greater imported proportions.

Table 11 Baseline greenhouse gas emissions (as GWP) and relative changes of main 16 impacting agricultural and marine commodities by scenario. These results include transport to the regional distribution centre, but not manufacturing in the UK.

Commodity	**Baseline greenhouse gas emissions (kt CO_2e/yr)**	**Scenario**					
		1	**2**	**3**	**4**	**5**	**6**
Milk	23,000	1%	-14%	-7%	-16%	-13%	-30%
Beef	19,300	15%	-8%	-8%	-4%	-14%	-41%
Sheep and goat meat	10,200	19%	-10%	-9%	-5%	-19%	-46%
Chicken meat	7,600	-14%	-4%	-6%	4%	-2%	7%
Pig meat	6,330	7%	-19%	-12%	3%	-13%	-45%
Wheat, milling	3,340	-5%	1%	20%	18%	25%	65%
Eggs	2,330	2%	5%	1%	-16%	2%	-4%
Tomatoes	2,060	-6%	41%	18%	-21%	20%	32%
Rice	1,470	-5%	19%	0%	0%	-3%	27%
Bananas	1,440	-12%	38%	16%	-28%	11%	20%
Sugar (cane)	1,380	1%	-12%	-7%	-17%	-18%	-31%
Potatoes	1,310	-3%	-13%	-4%	18%	3%	24%
Fish caught	1,150	-6%	25%	20%	-33%	18%	61%
Oil, rapeseed	990	-1%	-13%	-6%	6%	-14%	-12%
Grapes	770	-12%	31%	15%	-22%	11%	23%
Sugar (beet)	634	1%	-12%	-7%	-17%	-18%	-31%
Total all production	**97,000**	**-4%**	**-3%**	**-3%**	**-7%**	**-6%**	**-18%**

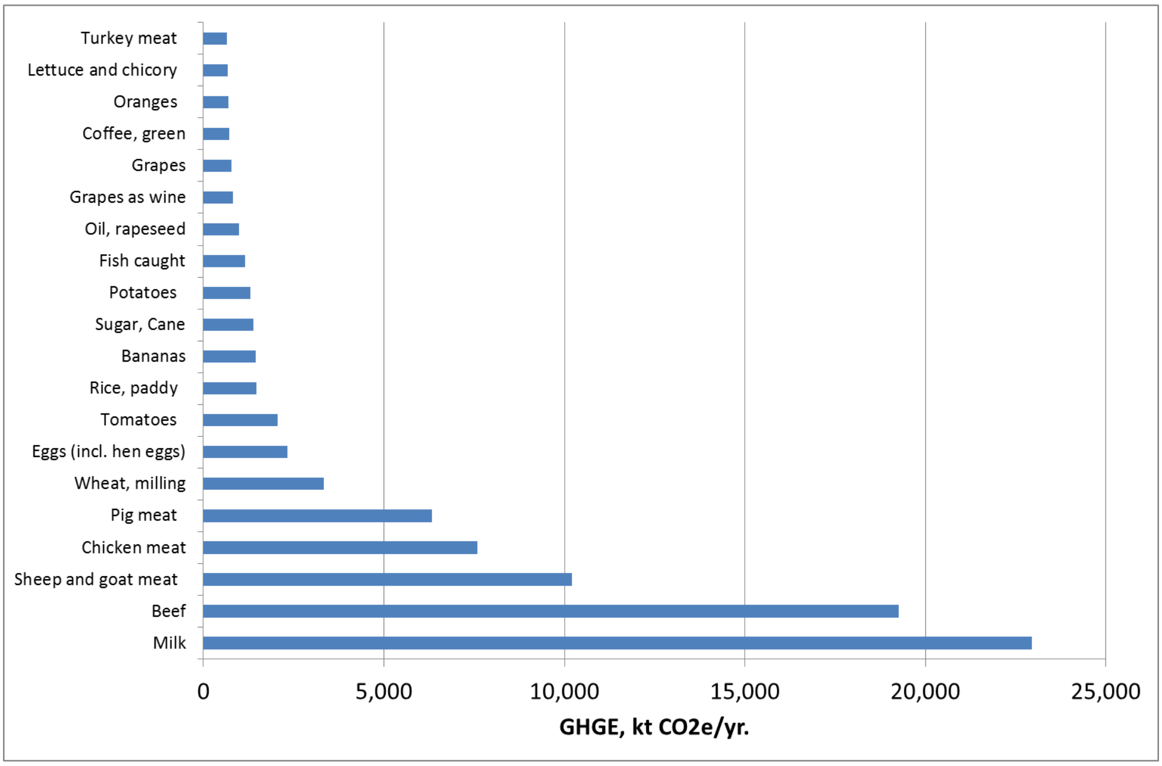

Figure 3 The 20 highest sources of GHGE in the baseline case for UK food consumption. These results include transport to the regional distribution centre, but not manufacturing in the UK.

Table 12 shows relatively small variation in most categories of environmental burden between scenarios: variation is greatest for NH_3 emissions. Greenhouse gas emissions, eutrophication potential, and NH_3 emissions are about 12-16% lower in the eatwell plate than the baseline. This is mainly driven by the reduced consumption of livestock products. The level of nitrate loss associated with the eatwell plate is estimated to be 28% lower than that for the baseline.

Table 12 Main environmental burdens up to the point of retail for the baseline and scenarios of dietary change. These results include transport to the regional distribution centre, but not manufacturing in the UK.

Environmental burden	Baseline	Scenario					
		1	2	3	4	5	6
Greenhouse gas emissions (Mt CO_2e)	97	97	94	94	90	91	83
Primary energy (PJ)	570	560	600	590	520	570	580
Eutrophication potential (kt PO_4^{3-} equiv.)	420	420	400	400	400	390	370
Acidification potential, (kt SO_2 equiv.)	1,360	1,350	1,380	1,370	1,290	1,350	1,310
NH_3 emissions (kt)	250	250	230	230	240	220	180
NO_3^- emissions (kt)	2,100	2,110	2,080	2,070	1,990	2,010	1,850

In addition to the burdens of primary production, burdens are incurred through the value chain represented by manufacturing, retail to domestic consumption, as well as in the food service sector (Table 13 and Figure 4 and Figure 6). These mainly represent the non-agricultural and non-fishing burdens. These show that the quantities of greenhouse gas emissions and cumulative energy demand are of similar magnitude between the value chain and primary production, while acidification in the value chain is about 12% of total emissions. Eutrophication potential, ammonia and nitrate emissions are negligible after primary production (Table 13 and Figure 4).

Table 13 Main environmental burdens after the regional distribution centre (RDC) (including retail, catering and domestic preparation) for the baseline and all scenarios

	UK Manuf-acturing	Retail	Food service sector	Dom -estic	Proportion of total with baseline
Greenhouse gas emissions (Mt CO_2e)	12.2	23.0	11.7	27.3	43%
Cumulative energy demand, (PJ)	196	327	183	423	66%
Eutrophication pot. (kt PO_4^{3-}equiv.)	0	0	0	1	0.3%
Acidification potential (kt SO_2 equiv.)	35.2	34.2	28.3	94.3	12%
NH_3 emissions (kt)	0.029	0.069	0.020	0.094	0.1%
NO_3^- emissions (kt)	0.014	0.009	0.009	0.048	0.0%

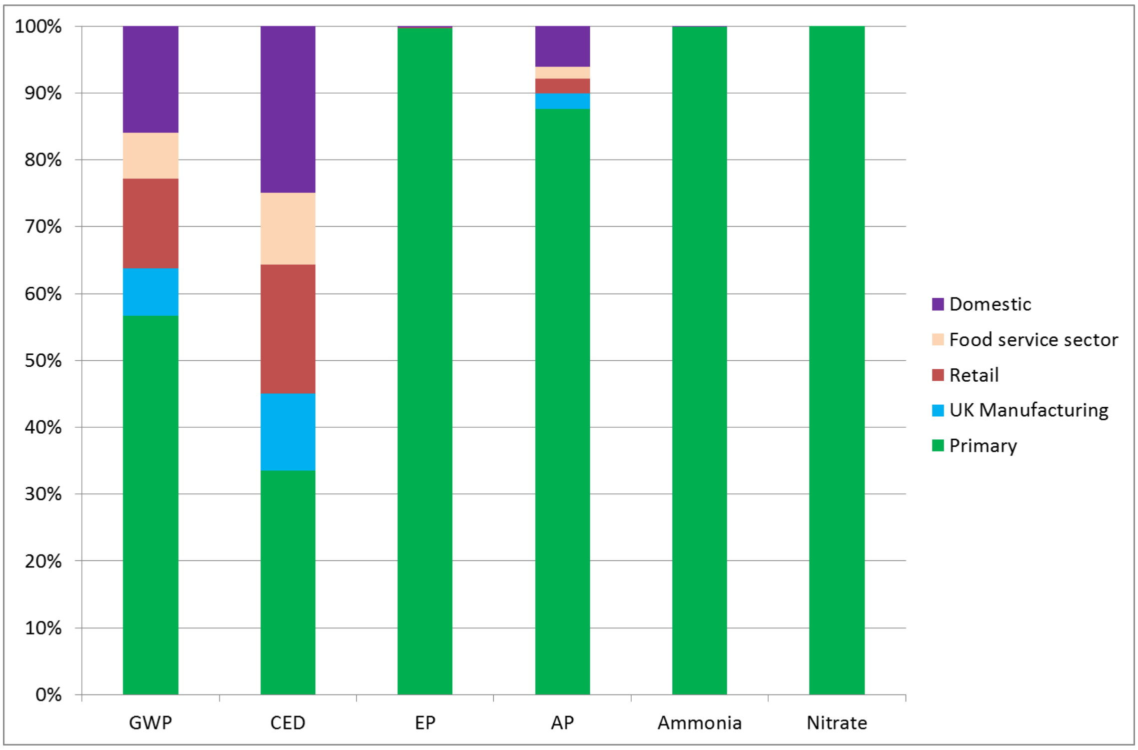

Figure 4 Breakdown of main environmental burdens from production to consumption. "Primary" includes all agricultural production and fish catching (and some manufacturing overseas), "manufacturing" includes all the UK food and drink industry. Energy use, refrigerant emissions and food waste are combined at each stage. Key: GWP is global warming potential, CED is cumulative energy demand, EP is eutrophication potential and AP is acidification potential.

The environmental burdens after the RDC were analysed using data that was in accord with the baseline food consumption. It was considered that this would not change substantially from the amounts of dietary change that were estimated here. Audsley et al. (2010) showed that large reductions in impacts after the RDC were possible, but depended largely on a decarbonised energy system.

The breakdown of burdens in the value chain after primary production showed a generally varied and inconsistent distribution of burdens between sources. These included both stages in the chain and splits between energy (and refrigeration) and food waste (Figure 5).

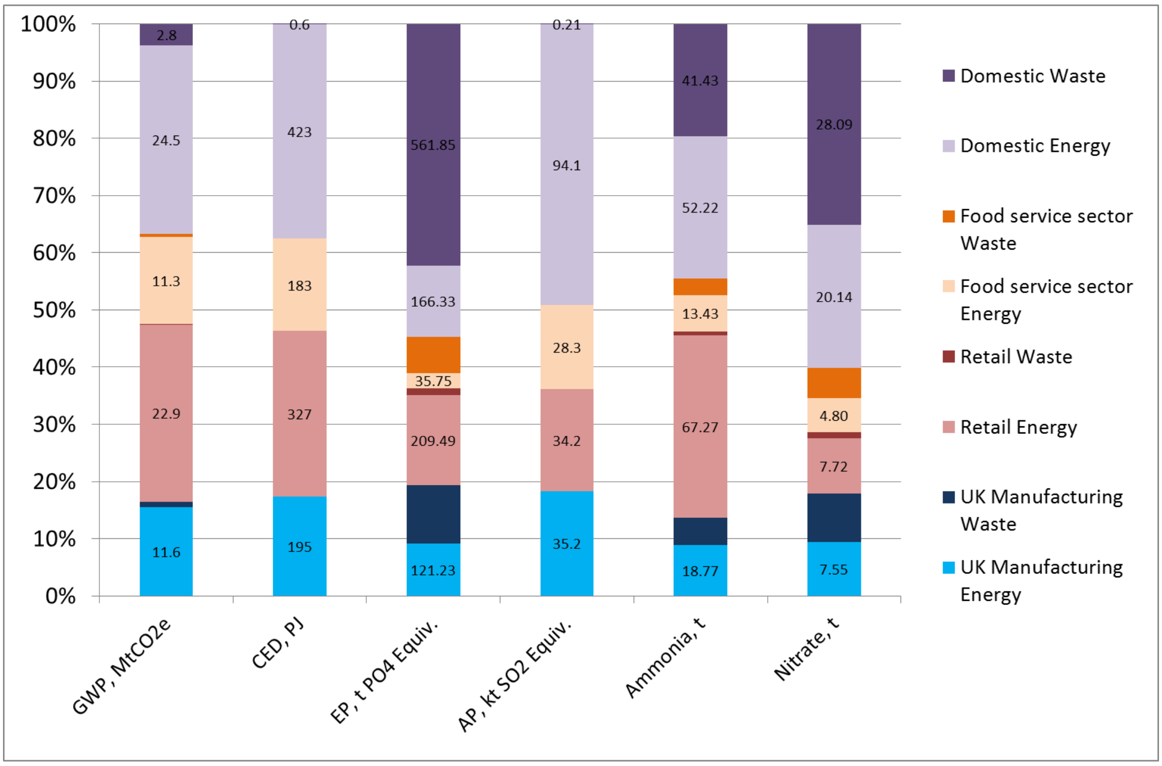

Figure 5 Breakdown of main environmental burdens after primary production. This is assumed to be the same in all scenarios.

As can be seen in Figure 6, the GHGE of food groups are strongly influenced by livestock production, with meat fish and alternatives (high proteins) dominating, especially in the baseline. In contrast, food groups that should be increasingly consumed, such as starchy carbohydrates and fruit and vegetables, contribute about one third of the GHGE of high proteins in the baseline case.

It is interesting that the foods high in fat, sugar or salt, of which official nutritional guidance seeks to reduce our consumption (NHS, 2016) contribute the lowest proportion of GHGE of the main food groups (Figure 7).

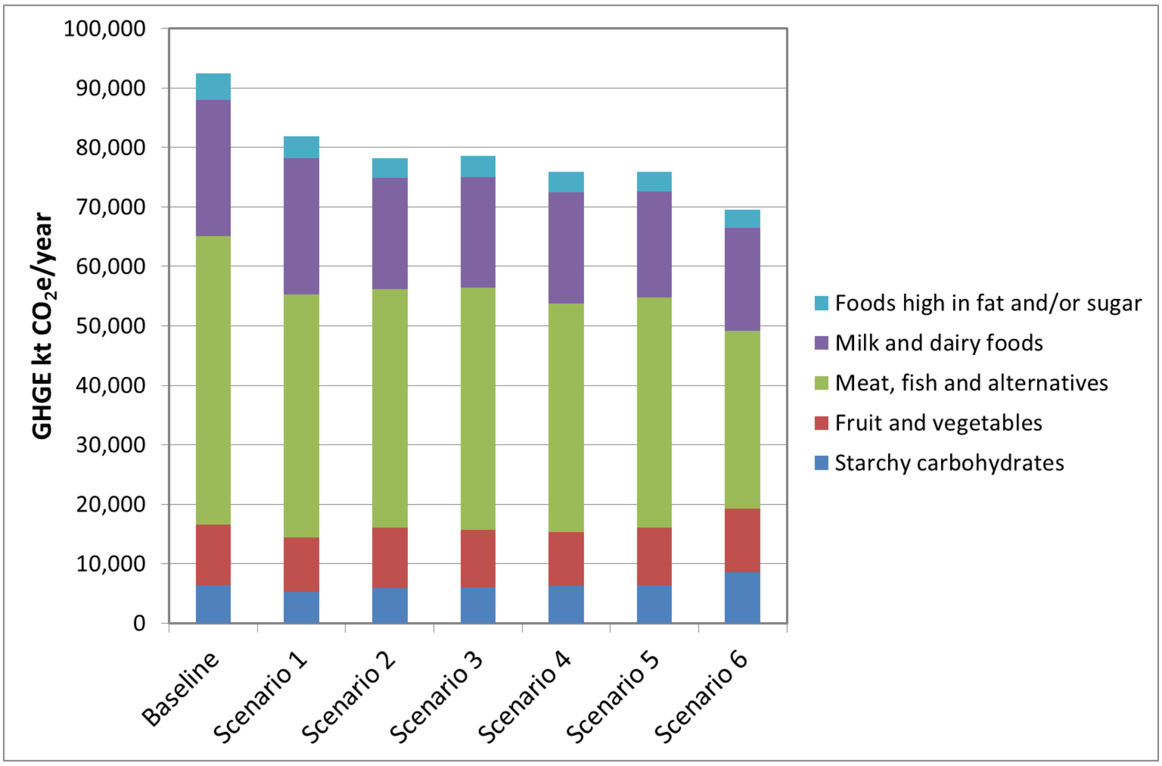

Figure 6 GHGE under scenarios of dietary change broken down by the Eatwell food groups up to the RDC

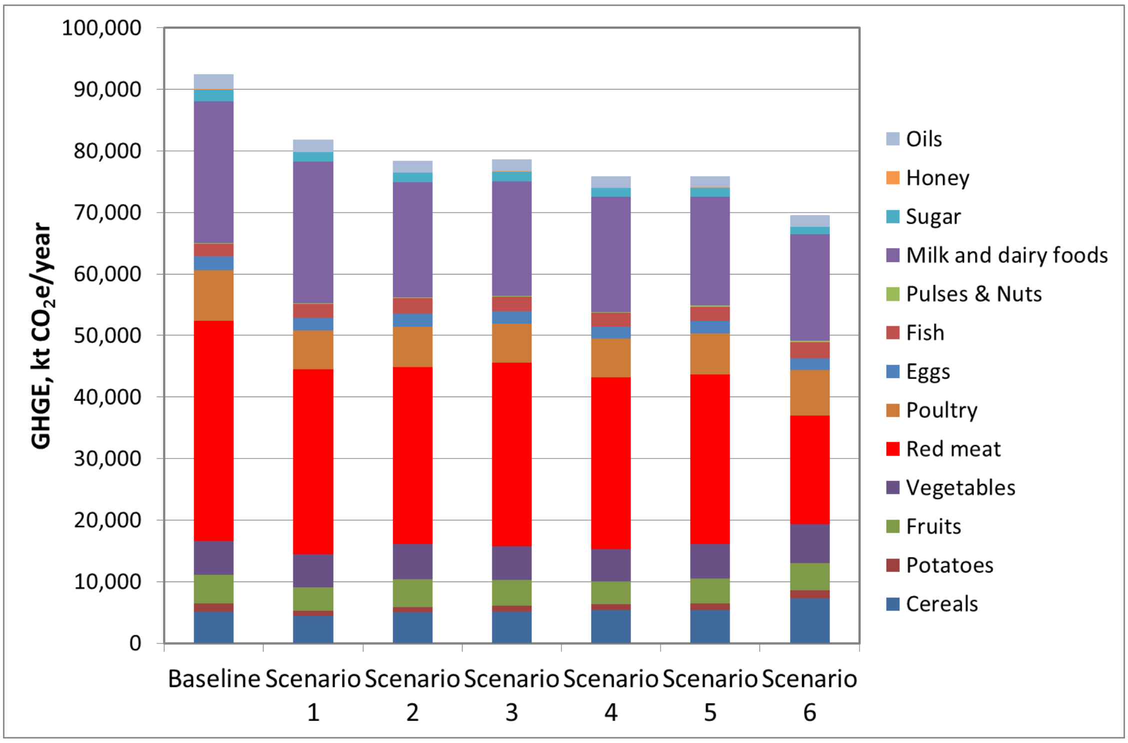

Figure 7 GHGE under scenarios of dietary change broken down by small food groups up to the RDC

3.6.1. Food waste

The hypothetical elimination of all avoidable food waste would reduce GHGE up to the regional distribution centre (RDC) by 12% and over the whole chain by 7% (Table 14). This is similar, although smaller, to the reduction obtained with adopting the Eatwell diet. The reductions in the other environmental impacts were 10-14% to the RDC and 5-12% over the whole chain. However, there were contrasts between the balances of impact reductions between adopting the Eatwell diet and reducing food waste. Reductions in nitrate leaching were about the same, while reductions in CED and AP were higher with food waste elimination and reductions in ammonia emissions were less with food waste elimination. This resulted from the differences between the “across the board” reductions in the needs of primary production (coupled with reduced impacts during waste management) by eliminating food waste compared with the realignment of production requirements to meet the Eatwell scenario.

Table 14 Main environmental impacts of the baseline with and without avoidable food waste

Impact	Baseline with current avoidable food waste	Baseline with no avoidable food waste	Reduction in impact to RDC	Reduction in impact over whole chain
GWP_{100}, (kt CO_2e)	96,904	85,493	12%	7%
Primary energy (TJ)	570,697	492,524	14%	5%
Eutrophication potential, (kt PO_4^{3-}equiv.)	416	367	12%	12%
Acidification potential, (kt SO_2 equiv.)	1,365	1,186	13%	12%
NH_3 emissions (kt)	248	223	10%	10%
NO_3^- emissions (kt)	2,105	1,852	12%	12%

3.7. Diets and land use

Differences in diets also affect the demand for land to meet UK consumption of food (Table 15). It is assumed that there is scope for the substitution of arable and grassland at the margins of land suitability and productivity. Grassland types were analysed from UK soils and climate data to assess suitability for conversion to arable by Audsley et al. (2011). The better grassland areas have some potential to switch to arable, and the poorer arable areas would be the first to switch to grassland if required. The poorest land, whether arable or grassland, would tend to be first to be taken out of production first in the event of surplus land. To reflect uncertainty about the substitution of arable land and grassland at the margin, three situations are considered regarding possible changes in grassland areas to reflect a reduction in grassland production altogether or a switch into arable. Where less grassland is required, grassland could be taken out of production pro-rata across all grassland types, or only on the poorest hill land, or possibly on land with good arable potential that can be released for arable production. The rates of substitution reflect the relative productivity of the different types of land (Table 16). Similarly a requirement to increase arable area could be met by converting grassland that is suited to arable production, with increases in the use of poorer grasslands if required. The actual change would depend on a range of economic forces and policy drivers and so these are indicative estimates. For further purposes here, substitution between arable and grassland is assumed pro-rata across land types.

For example, relative to the baseline, Scenario 1 increases the demand for UK grassland by 490 kha (Table 15). Assuming pro-rata increases across all grassland type, 300 kha of this increase would be in poorer hill and marginal areas and the rest on relatively good grasslands, including some 140 kha with arable potential. If the switch to grassland is confined to arable areas only, this would equate to about 313 kha of arable conversion to grass.

In contrast, if only the poorest grassland was used to meet the extra demand, this would require the equivalent of more about 2,650 kha, mainly of hill land. It is unlikely that this amount of additional grassland area exists. Meeting this change could thus not apparently be met by maintaining the current balance of imports and home product or the current balance of production systems.

The Eatwell scenario requires a net increase in UK land used for arable production of 230 kha and an additional 300 kha for arable production overseas. This includes a reduced demand for crops used in animal husbandry. There is also a potential to release about 4800 kha of grassland, assuming this is equally distributed across grassland of all qualities. There is also a large increase in demand for non-UK land linked to non-temperate cereals (paddy rice), fruits and vegetables of about 200 kha. The net change in land use is a release of about 4 Mha of land, which also includes the reduced demand for imported livestock products and livestock feeds (e.g. soy). The Eatwell scenario will also benefit specialist cereal producers of milling wheat more than feed wheat producers. There is also scope in the other scenarios to release grassland that has potential for arable use.

Table 15 Baseline grass and crop land use and *changes* in requirements under the scenarios of dietary change (decreases are shown in red)

Land use	**Baseline land use (kha)**	**Change in land use (kha)**					
		Scenario					
		1	**2**	**3**	**4**	**5**	**6**
UK grassland (Poor)	5730	290	-650	-630	-290	-1040	-2620
UK grassland (Good)	5490	200	-640	-500	-420	-840	-2170
Sub-total for grassland	11,220						
UK arable land	3340	-10	-150	60	170	60	330
UK horticultural land	50	0	20	10	-10	10	10
UK orchard land	20	0	0	0	0	0	0
Sub-total for UK	**14,630**						
Non-UK arable land	2700	-30	-30	30	80	110	300
Non-UK horticultural land	70	-10	30	10	-20	20	20
Non-UK orchard area	720	-60	200	100	-130	80	180
Non-UK plantation area	920	50	-60	-40	40	70	-110
Non-UK paddy area	140	-10	30	0	0	0	90
Sub-total for non-UK	4,550						

Table 16 Baseline grassland use and possible releases of grassland under the scenarios of dietary change (positive numbers show increase use and negative numbers show areas released from use). All areas are in kha. Grass qualities were defined by Audsley et al. (2011).

Key: In the **"Pro-rata**" release priority: **grass is released uniformly across qualities**. In the **"Arable land**" release priority: **grass with arable potential is released preferentially**. In**, "Hill land**", **hill and upland grass with little or no arable potential is released preferentially.**

Release priority	Very poor grass	Poor grass	Grass not suitable for arable	Marginal for arable	Moderate for arable	Good for arable	Total
Baseline use	4,170	1,560	1,520	1,040	1,790	1,140	11,220
S 1. Pro-rata	220	70	60	30	60	50	490
S 1. Arable land	0	0	0	0	0	310	310
S 1. Hill land	2,650	0	0	0	0	10	2,660
S 2. Pro-rata	-480	-170	-170	-120	-210	-130	-1,290
S 2. Arable land	0	0	-20	-60	-140	-710	-930
S 2. Hill land	-3,080	-500	-210	-10	0	-10	-3,820
S 3. Pro-rata	-460	-170	-150	-90	-160	-100	-1,130
S 3. Arable land	0	0	-20	-50	-120	-570	-750
S 3. Hill land	-3,000	-500	-120	0	0	0	-3,620
S 4. Pro-rata	-210	-80	-100	-90	-150	-90	-710
S 4. Arable land	0	0	0	-40	-80	-480	-600
S 4. Hill land	-1,700	-220	-170	-20	0	-10	-2,110
S 5. Pro-rata	-770	-270	-240	-160	-270	-170	-1,880
S 5. Arable land	0	0	-50	-90	-230	-850	-1,230
S 5. Hill land	-4,140	-640	-270	-10	0	-10	-5,070
S 6. Pro-rata	-1,930	-690	-620	-400	-700	-440	-4,780
S 6. Arable land	0	0	-340	-360	-1,130	-1,070	-2,890
S 6. Hill land	-4,170	-1,510	-950	-400	-10	-30	-7,080

Scenario 1, associated with limited positive change in diet, shows some increase in grassland areas and reductions in UK horticulture and orchard production. Generally, scenarios that reduce the consumption of dairy, beef and sheep products are associated with reductions in UK grassland areas (Figure 8). The extent to which these reductions are offset depends on the type of substitute commodities in the diet, notably the substitution of grass based bovine meat production with cereal-based white meat, in agreement with Hallstrom et al. (2015), the relative increase in as cereals or fruit and vegetables, and the extent to which these can be produced domestically on land suitable for cultivation or imported from other climatic zones. The relative reduction in UK grassland production (about 40% by area) and 10% increase in UK arable and horticultural areas are noteworthy for Eatwell Scenario 6, as is the 11% increase in non-UK land for horticulture, fruit and rice.

The impact of dietary change on UK grassland areas depends on assumptions regarding the type and productivity of grassland land taken up or released in response to changes in the demand for livestock products.

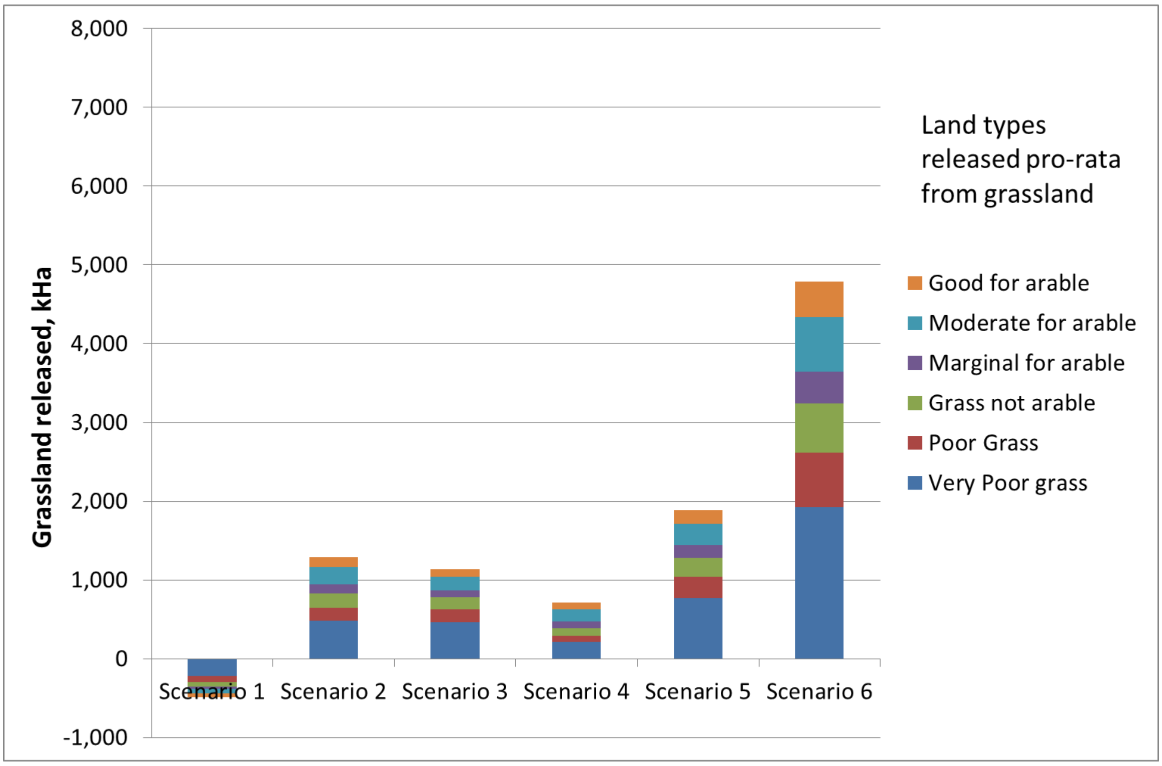

Figure 8 Potential releases of grassland of different qualities under scenarios of healthier eating relative to the baseline. Pro-rata release is assumed.

The implications of healthier eating will have major effects on land use and the landscape. The reduced demand for grazing livestock products will release substantial areas of grassland from agricultural production. The exact amount is hard to forecast, but the central estimate was a reduction in productive grassland of 40%, which would be the largest loss of agricultural grassland since the 1960s (Figure 9). The total grass area peaked in 1961 and then declined by 8% between 1961 and 1967 and by 17% from 1961 to 2000. This is equivalent to an annual decline of 110 kha in the 1960s and an annual decline of 30 kha until 2000. The larger change was from rotational grass (57% fall from 1961 to 2000) with the permanent area increasing by 5%. This net change in grassland area over 50 years is about half the scale that dietary change could cause, but which is anticipated to occur in more like 20 years. Hence, the visibility and detectability of the change, particularly with current digital means of communication, in this scenario would be higher than in the 1960s.

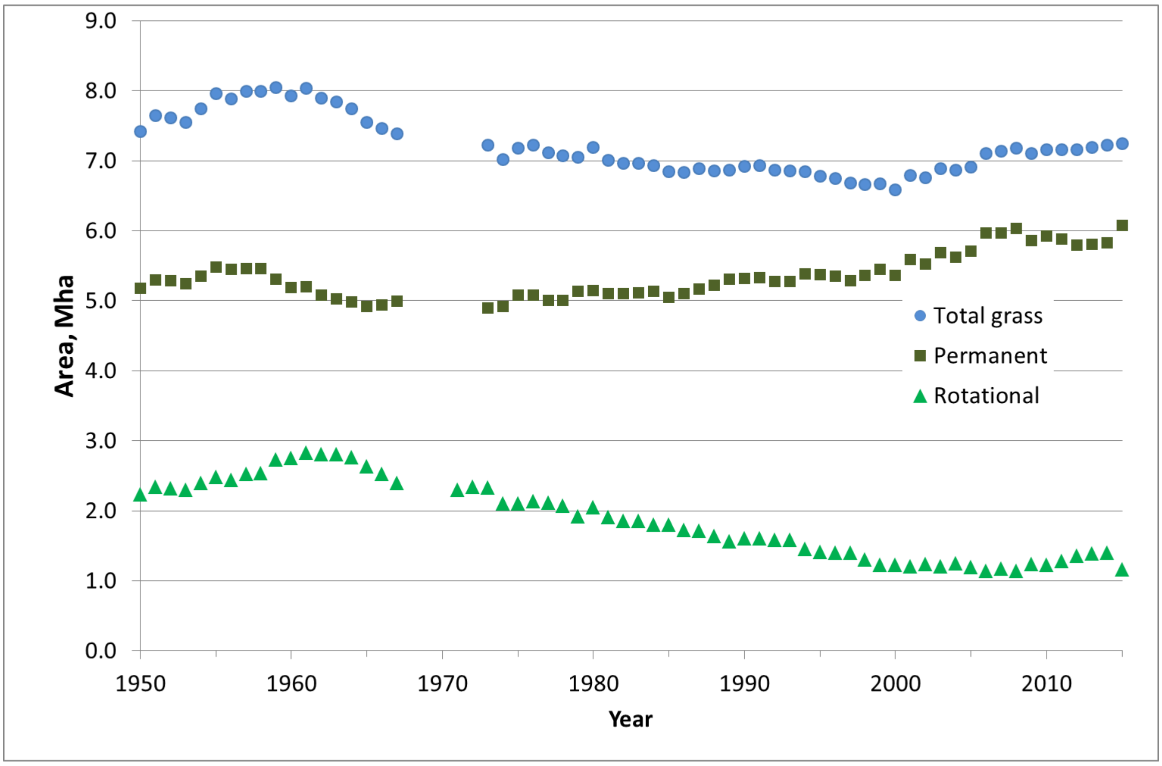

Figure 9 Changes in UK grass managed areas from 1950 to 2015 (i.e. not including rough grazing)

An optimistic outcome for UK livestock farmers, producing red meat, is that they are able to be more competitive than overseas farmers and hence supply an increasing share of the UK and overseas markets and so maintain current grassland areas. The environmental footprint of red meat produced in the UK is often less than in some other countries e.g. Brazil (Burgess et al. 2015). Such an expansion of UK livestock production would need to be considered in a global market where an increase in the demand for red meat due to rising average household incomes may be moderated by response to dietary guidance to reduce or limit red meat consumption. On balance, it seems unlikely, however, that all the farmers producing grazed livestock in the UK would be able to carry on as now. Some grassland areas could be used for other purposes such as bioenergy, woodland creation, agri-tourism, or as part of integrated livestock and forestry systems (e.g. agroforestry).

The three approaches of land release quantified show how widely different the outcomes could be (Figure 10). Agricultural land use is strongly influenced by a combination of market forces and policy interventions, mediated by the motivations and responses of farmers. Given the increased demand for crop land under healthier eating scenarios, it might be argued that livestock production should be preferentially retained in upland and hill livestock production and thus release lowland grassland with more potential for conversion to arable or bioenergy crops. However, lowland farmers have better land and therefore tend to have a competitive advantage in both crop and livestock production, although they would tend to focus on cropping systems in which they have greatest comparative advantage. It is likely that the impacts of a declining market for livestock products would be felt in the hill and upland sectors, unless measures were taken to support production on mainly social criteria.

It must be stressed that this analysis assumed no changes in the intensity of land use and associated yields in each of the production systems. Some farmers could approach reduced demand by the extensification of production e.g. reducing or eliminating N fertiliser use and minimising winter housing. Making better use of legumes like clover to fix atmospheric nitrogen is beneficial in reducing energy inputs from fertiliser but this tends to reduce yields of highly productive grassland (Audsley et al., 2011). With the same amount of agricultural input, lower yields would cause some increase in diesel use per ha (but more per t) for activities such as internal farm transport or field operations, such as silage making, but this is likely to have limited overall impact.

The highest direct proportion of GHGE from beef and lamb production comes from enteric methane (Williams et al., 2016) so extensification clearly has some GHG benefits, but would not radically reduce GHGE per unit output.

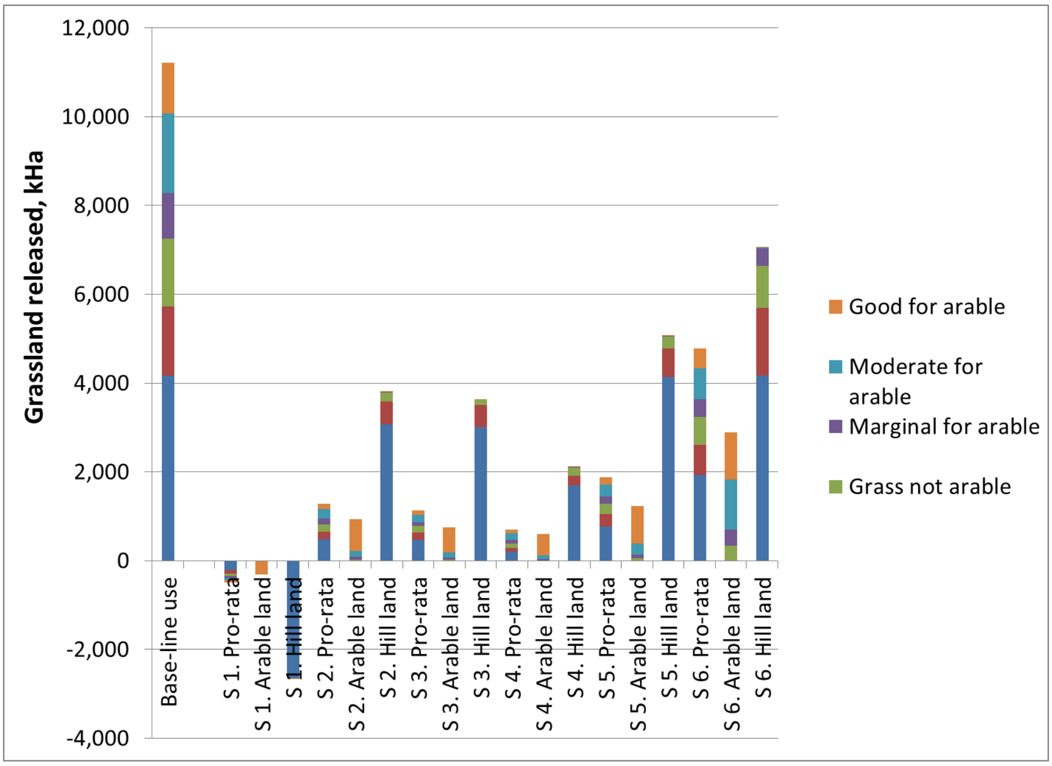

Figure 10 Contrasting alternative grassland releases under scenarios of dietary change. Key: "Pro-rata": grass is released uniformly across qualities, "Arable land": grass with arable potential is released preferentially, "Hill land": hill and upland grass with little or no arable potential is released preferentially.

Alternative land uses for release grassland were considered by Audsley et al. (2011). The extremes for GHGE were conversion to arable, with large losses of soil C and hence GHGE and conversion to woodland, with large sequestration potential. With a scenario in which livestock product consumption was uniformly decreased by 50%, conversion to arable could cause GHG emissions up to 8 to 17 Mt CO_2e yr^{-1} from soil C losses. In contrast, changes in soil C and increases in aboveground carbon storage associated with conversion to forestry could enable increased storage of up to 7.5 to 9.5 Mt CO_2e yr^{-1}. Hence, the results were of the same order of magnitude but opposite directions. The method used to calculate potential emissions from land use change were based on the methods used in the UK GHG inventory for Land Use, Land Use Change and Forestry (LULUCF) (Thomson et al., 2008). This includes default values for soil C densities at equilibrium for different land uses. Whilst tree planting shows distinct advantages in terms of aboveground carbon storage, planting trees on grassland can result in short-term losses (Upson et al., 2016) although there might be benefits in the long term (Paul et al., 2003; Huang et al., 2011; Hoogmoed et al., 2012).

The final GHG benefits of woodland production depend on end use. Substituting for materials or fuels with higher GHG intensity with timber is clearly beneficial in reducing reliance on non-renewable fuels, but most of the CO_2 taken up in biomass will eventually be released again some years after sequestration stops. Converting permanent pasture to arable has the most negative effect on soil C losses and so should be discouraged in favour of the conversion of rotational grassland.

Grassland could be abandoned if there is no alternative use that is economically viable (with or without subsidies): in effect resulting in unmanaged rewilding. However, while some actively promote rewilding (e.g. Peringer et al. 2006), there is a strong view that this ignores much of the science of ecosystem restoration (e.g. Nogués-Bravo et al, 2016, Higgs et al 2014, Jørgensen, 2015) and that active management to promote ecosystem restoration is required. Grassland can be also integrated into integrated forestry and livestock systems producing perennial crops and storing C (Hutchinson et al., 2007; Paustian et al., 2016).

3.7.1. Impact on wider ecosystem services

The economic analysis of impacts on wider ecosystem services shows that dietary change towards the eatwell plate has positive effects on the value of the provisioning and non-provisioning services. A major change would be the conversion of grassland to arable and possibly to woodland or returning to the wild. This would have a major impact on the appearance and character of regional landscapes. Whilst people often tend to favour the "status quo" in terms of future land use, in the long-term the conversion of grassland may be seen to be beneficial. For example a reduction in the use of grassland for production should increase the availability of land to support biodiversity. However there may be a societal benefit in ensuring the conservation of some unprofitable agricultural ecosystems that support valued flora. For example, fritillary-rich (*Fritillaria sp*) meadows may not be needed for livestock, but are a precious reservoir of emblematic biodiversity (English Nature, 2016).

3.8. Impact of dietary change on UK farming

3.8.1. Impact on farming sectors

In broad terms, differences in the production of commodities and associated land use have implications for different types of farming systems and related farm businesses in terms of activity levels, incomes and patterns of expenditure. A number of key scenario effects relative to the baseline case are apparent:

- Changes in grassland areas for grazing and forage fed livestock production.
- Changes in the arable sector linked to changes in cereals and field scale vegetables, especially potatoes and sugar beet.
- Changes in the horticulture and orchard sector associated with changes in dietary preferences, especially salad crops and soft and top fruits.
- Changes in the balance between total domestic UK and non-UK commodities especially associated with less meat and more fruit and vegetables in diets.

Table 17 summarises the likely type, magnitude and direction of impact on the main farming sectors in the UK due to scenarios of dietary change relative to the baseline. It is noted that the assessment focuses on dietary change relative to the baseline and does not adjust for changes in the size of the UK population. Compared with the baseline situation, Scenario 1, involving limited dietary change, shows a small positive effect on upland and lowland grassland farmers, and a small negative effect for UK horticulture. Scenario 6, the Eatwell diet, indicates relatively large reductions (relative to other scenarios) in production from all types of grassland farms, and relatively large increases in the activity of arable, horticulture and fruit farms.

Table 17 Possible relative impact of dietary scenarios on major types of farming system in the UK, showing magnitude (Low (L), Medium (M), High (H)) and direction (+ positive, - negative) of possible impact (positive in black; negative in red)

Sector	Scenario						Comment on sector
	1	2	3	4	5	6	
Upland grassland (mainly sheep)	+L	-M	-L	-L	-H	-H	Sensitive to reduced demand for beef and sheep products in diet: first to exit;
Lowland grassland (beef/sheep)	+L	-M	-M	-L	-H	-H	Retain comparative advantage in beef & sheep compared to uplands. Sensitive to demand for red and processed meats
Lowland grassland (dairy)	+L	-M	-L	-M	-M	-H	Dairy production sensitive to scenarios with low livestock products and low fat diets
Arable	+/-	+/-	+L	+M	+M	+H	Sensitive to carbo-hydrate balance in diet and switch to cereal based white meat products
Horticulture and orchard	-L	+H	+L	-M	+M	+H	UK horticulture (veg and fruits) reflect diet preferences and domestic sourcing: favoured by healthier eating

Scenario 1: Continuation of baseline trends
Scenario 2: Strong switch away from livestock products to increased field vegetables and horticultural production
Scenario 3: Moderate reductions in grass-based livestock and increased cereals and vegetables
Scenario 4: Strong increase in carbohydrates (cereals and potatoes), and switch to white meats and reduced vegetables/fruits
Scenario 5: Switch from livestock products to cereals and vegetables under relative ‘austerity’
Scenario 6: eatwell plate, reductions in livestock production, increased arable and horticultural production.

The demand for livestock products on grassland farms increases under Scenario 1 where there is some growth in demand for forage-fed red meat products, but otherwise generally falls where these are substituted in diets by concentrate-fed pig and poultry products, and by other vegetable proteins. Upland grasslands are particularly vulnerable to scenarios that reduce the demand for red meats, especially as they have relatively low comparative economic advantage and limited farming alternatives.

In broad terms, arable farmers experience a relative strengthening of demand under scenarios that promote healthier eating, or where some fresh meat products are perceived to be expensive. Cereals are, of course, grown for direct human consumption and for animal production. With respect to intensive ‘general cropping’ arable systems, potato and field vegetable production remains relatively strong under most scenarios, but the production of sugar beet declines markedly. The horticultural sector shows growth under all scenarios, except for Scenario 1 which is partly a continuation of the baseline scenario.

The scale and distribution of rewards to UK farmers are critically dependent on world market conditions and the degree of connectedness with international markets. The UK is a ‘price taker' for internationally traded agricultural commodities whereby the changes identified in the scenarios are unlikely in themselves to affect prices paid and received by farmers. A move towards healthier diets suggests a redistribution of income at the margin towards UK vegetable and fruit producers. The development of diet-oriented produce to meet new market demands, or the targeted substitution of existing imports of diet-driven produce, could offer viable market opportunity for farmers across all sectors. Examples include low fat livestock and dairy products, extending the range of cereals, and fruit and vegetable production in response to changing dietary preferences.

It is noted that Scenarios 2, 3, and 5 involve relative increases (of about 20%) in fish consumption as a substitute for livestock based proteins and oils and fats. This reduces the requirement for farmland and increases the contribution made by marine fisheries and aquaculture, including caged fisheries. Scenario 6 increases the contribution of fisheries in the diet from about 20% to about 29% of the fresh weight of total raw meat and fish products.

3.8.2. Impacts on farm incomes and employment

A switch from the baseline situation to Scenario 6 (Eatwell), everything else remaining constant, leads to a redistribution of UK farm income and employment out of the grazing livestock production into the arable sectors. For example, the estimated reductions in milk production (30%) and beef and sheep production (40%) assuming adoption of the Eatwell diet at the national scale, would result in similar magnitudes of revenue loss to these sectors, the bulk of which are located in western and northern areas of the UK on land not well suited to arable farming. Furthermore, a large proportion of grazing livestock farms comprises small businesses with relatively low profitability, dependent on farm income support (Defra, 2012, 2016). Grazing livestock farmers in disadvantaged hill and upland areas may be at particularly risk in the face of a declining domestic meat market, finding it difficult to compete with the comparative advantage of more fertile, and hence intensive, lowland grassland farmers. There may, however, be opportunities for upland farmers to adopt alternative land uses (e.g. forestry) or multi-functional land uses (e.g. agroforestry, agri-tourism). They could, with appropriate policy support, provide a range of ecosystem services associated with nature conservation, rural recreation, and hydrological and climate regulation.

In the extreme case, virtually all hill and upland grassland would switch out of production if the poorest grassland came of out of production first. Alternatively, lowland grassland farms, including dairy farms, may find it advantageous to switch from livestock to arable farming where land suitability allows, thus helping to retain market access for grassland farmers with otherwise limited options. It is clear, however, that a reduction in demand for red meat and dairy products under the Eatwell diet would affect the relative balance of livestock and arable farming in the UK, reducing the share of total UK agricultural income and employment going to predominantly grassland areas. In the absence of other opportunities, employment could be particularly affected in Scotland and Wales where agriculture, predominantly based on livestock farming, accounts for 3% to 4% of regional employment compared with 1% in England (Defra, 2012, 2016). Northern Ireland's livestock economy, where agriculture accounts for 6% of regional employment, is similarly disadvantaged. It is again noted that this discussion focuses on dietary make-up and assumes full adoption of the Eatwell scenario and with no allowance for population change or changes in age profile as it affects total food demand. The changes are solely concerned with the effects of dietary change.

A large reduction in pig production (of about 40% assuming full adoption of this scenario at the national scale) is partly offset by an increase in poultry (15%), implying some substitution within the intensive pig and poultry sectors. Overall there is a potential net loss of income to the sector of about 25%. Most producers operate at the medium to large scale, mainly in central and eastern parts of the UK. For the baseline situation, about 40% of UK pig and poultry consumption is imported. It is possible that UK pig producers in particular could maintain production to substitute for imports, thus offsetting potential losses in income. Some could switch to poultry if they can adapt to the very tight market specifications in the poultry sector.

The Eatwell diet increases potential revenue to the UK arable crop sector. A large increase in milling wheat (by 70% assuming full adoption at the national scale) would increase income to 'specialist cereal' robust farm types (Defra, 2009), and could offset income losses in the grassland sector for farms with suitable land. Some of this increase could be taken up by a drop in exports. A major change in cereal production, however, is the reduced demand for feed grains. Increased consumption of potatoes (by 24%) and field vegetables (by about 30%) benefits domestic production for the more intensive 'general cropping' farms, offsetting at a sectoral level the reduction in sugar beet production (reduced by 30%). The majority of arable and general cropping farms are in central and eastern England, and lowland Scotland. Sugar beet is currently only grown in eastern England.

The Eatwell scenario is predicted to increase the area of production in the UK horticultural and orchard sectors by about 28% and 8% compared to the baseline areas respectively, with pro-rata potential to increase revenue and employment in these sectors by similar amounts, assuming that the ratio of domestic production to imports remains constant. Concentrated in the central and southern parts of England, these are relatively high cost, high value added sectors with high labour requirements, much of it provided by migrant seasonal workers, and supported by irrigation. They face strong competition from imported produce.

In summary, the Eatwell diet has a mixed impact on income and employment in the UK agricultural sector. The biggest negative impacts are in the grazing livestock, pig and dairy enterprises where options for switching land to arable use are limited. Small-scale hill and upland beef and sheep farmers are particularly at risk, although there would be still some scope for high quality, regional products and opportunities for partial conversion of the land forestry and bio-energy products. The intensive livestock sector could show growth in poultry but a decline in pig production, with some scope for switching. Lowland mechanised production of cereals, field vegetables and potatoes expands. Horticulture expands subject to labour availability and competition from imports. The Eatwell diet broadly tends to favour the arable and horticultural sectors and thereby the southern and eastern parts of the UK, relative to the grassland based agricultural economies of the north and west.

3.9. Water impacts of different dietary scenarios

Estimates of the impact of dietary scenarios on the demand for water were reported by Hess et al. (2015a), a summary of which is presented here. The work was completed using the initial scenarios, i.e. before the final refinements. The results are broadly, but not wholly, compatible with all other aspects of the analysis. The analysis suggests that although there were not major differences in water requirements between scenarios, the increased sourcing of produce from regions already experiencing water stress could exacerbate pressures on the water environment in such areas.

The presented paper addresses the assessment of the water scarcity footprint for the different healthy food scenarios. The water scarcity footprint is accounted from the virtual water which is the water consumed during the production of a commodity or a service is known as the virtual, or embedded, water content of this product. It represents the total amount of freshwater consumed, expressed as volume per unit commodity. The virtual water can be distinguished between green water and blue water. The blue water component includes the water taken from the ground or surface water, while the green water refers to rainwater used by the vegetation at the point where it falls. The estimates were accounted for on the basis of food consumption for each different scenario diet, considering UK imports and arrival (from European Union good movements). By using this bottom-up approach it was possible to calculate the imported proportion from each country per commodity and weight the impact on the total Water Scarcity Footprint (WSF) of these countries. The water scarcity factor is the sum of the ratios of the total blue water consumptions for a certain product in a certain area and the water scarcity index for the concerned area.

The system boundary for assessing the water scarcity factor was the regional distribution centre. Hence, water used in transport, retail and preparation of food was disregarded, but these are typically negligible in comparison with the water required to produce commodities. Virtual water was partitioned between internal and external according to source country.

Under the alternative future scenarios, despite significant changes in the proportions of each food group in the diet, the total WSF and the proportion attributed to each food group are similar. The national WSF ranged from 2.89 to 3.02 Gm^3 H_2O eq. y^{-1} (-3% to +2% compared to baseline). This suggests that the alternative healthier eating scenarios analysed would have little effect on the overall blue water scarcity footprint of UK food consumption.

This is because, (a) only blue water consumption is considered to contribute to water stress, (b) reductions in consumption of commodities with a high virtual blue water content (e.g. meat from the UK), tend to compensated by increases in others or commodities produced in areas of water scarcity (e.g. fruit from Spain) and, (c) the healthier eating scenarios considered are fairly conservative, reflecting the plausible level of uptake of healthier eating over a 15 year time horizon. From this perspective, the impact of policies designed to promote healthier eating on global blue water scarcity may appear benign. However, the alternative dietary scenarios considered show differing regional impacts – with all but the most extreme dietary scenario producing increases in the potential contribution to domestic blue water scarcity (due largely to increased consumption of dairy products) and potentially large impacts on blue water scarcity in other countries associated with increased imports of irrigated fruit and vegetables from countries with an already high level of water stress (e.g. Spain, South Africa, and Israel). This demonstrates how policies developed to encourage one outcome (in this case healthier eating) may have unintentional consequences on the environment in distant locations.

These conclusions are sensitive to assumptions regarding sourcing and the water impacts may be offset if a greater proportion of imports are sources from locations with higher blue water productivity (t/m^3) and lower water stress. This also reduces the vulnerability of the UK food supply chain to water related risk.

3.10. Fish

Fish represent a special case in nutrition and production. Fish, especially oily fish, are regarded as a healthier dietary option. Fish come from two main sources: wild fish (the remaining major commercial food-hunting industry) and farmed fish (which are mainly marine).

With respect to wild fish, landings into the UK by UK vessels averaged about 400 kt/year over the period 2011 to 2013, with of which about 120 kt were demersal (mainly bottom fish such as cod, haddock, monks and coley) fish, about 140 kt pelagic (oily, mainly mackerel) and 150 kt shellfish (mainly crabs, mussels and nephrops, e.g. Dublin Bay prawn or langoustine) (MMO, 2015). Total landing of fish by the UK fleet were about 600 kt/year of fish into the UK and non-UK ports during the 2011 to 2013 period. Landings rose to 756 kt in 2014 mainly due to increased mackerel quota.

There was also a net import of about 220kt of fish and fish preparations into the UK (additional to UK fleet landings) comprising about 720 kt imports and 500kt exports (including UK caught fish sold abroad) in 2014. Demersal and shellfish fish, at about £1,800/t, are about three times the unit value of pelagic fish.

There were an estimated 11,845 fishermen in 2014. Of these, 45% were based in England, 42% in Scotland and the balance shared equally between Wales and Northern Ireland (MMO, 2015).

With respect to farmed fish, the UK has the largest aquaculture industry by value in the EU, producing about 205 kt of finfish and shell fish in 2012 valued at over £590 million, employing over 3,200 people (CEFAS, 2015). Of this, 85% by weight and 91% by value came from Scotland, accounting for about 60% of the total employment in the sector. Finfish, mainly Atlantic salmon, accounted for 86% by weight and 95% by value of total UK production.

The Eatwell diet involves an increase in fish consumption relative to the baseline of about 43% by weight. This is assumed to comprise a 100% increase in oily fish (pelagic) and a 21% increase in demersal and shellfish, although the balance could be modified to suit sourcing. Much of fish consumed in the UK are sourced from marine waters, e.g. cod, mackerel and sardines, but farmed salmon and trout are also major sources. Increased marine supply would rest on managed quota to achieve sustainable yields, while fish farming can produce large negative environmental impacts (Fisheries Research Services, 2016) that could restrict expansion of the industry (Scottish Government, 2016). A large proportion of the increase in demersal and shellfish requirements to support the Eatwell diet could be met through expansion in the UK aquaculture sector. This offers potential for income generation and employment creation especially in Wales, northern England and Scotland, although it was noted that the industry has stagnated in recent years following earlier growth (Defra, 2014).

3.11. Supply chain and food industry effects

The agricultural and food sector accounts for about 7% of total Gross Value Added (GVA) by the UK economy of which agriculture accounts for 9%, wholesaling 11%, and the rest is shared equally between non-residential catering (27%), and food and drink retailing (28%) and manufacturing (27%). This amounts to £108 billion (Statistica, 2015). The total agrifood sector employs about 14% of the total work force, within which agriculture accounts for 12%, wholesaling 6%, catering 39%, retailing 37% and manufacturing 32%. GVA/employee in the sector is relatively low at about 50% of the national average in most of the sub-sectors, except for wholesaling where it is close to the national average.

The changes to healthier diets could affect the size and distribution of incomes, employment and GVA of these sub-sectors. The switch to plant-based diets will affect agricultural incomes and employments with losses in the livestock sector partly offset by increases in the general cropping and horticultural sectors at the national scale. The effects will vary regionally. Incomes, employment and value added in the rest of the food supply chain will be affected by the balance between meat and plant based products as these affect different wholesaling and processing agents, the proportion of processed foods in the food basket, the proportion of food consumed outside the home, and the balance of domestic and imported foods. These various drivers of change were included in the scenario assessments and the estimation of required food production.

With respect to the eatwell plate, Scenario 6, there is a reduction in the trading of relatively high value meat based products, potentially affecting wholesaling, butchering, catering and retailing, although these could be partly offset by niche and targeted marketing. Reduced demand for processed foods affect rewards to the manufacturing sector, although healthier options low in fats and sugar could develop in response. The bakery and vegetable processing sectors could expand with new products to satisfy new preferences, and the drinks industry could introduce low sugar products. Catering could adjust to provide more vegetarian options, with a reduction in consumer spend offset by savings in input costs, with potential to increase profitability. Similarly food retailing could see a proportionate rise in bakery, vegetable and fish-based produce relative to trade in red meats, with implications for the configuration of the sector. Transport, handling and storage costs would be higher given lower dry matter contents (i.e. higher water contents) in the diet. The eatwell plate could support a resurgence in fish-mongering. Under this scenario a general increase in awareness of healthier eating potentially increases consumer connectedness with the food industry, favouring the return of artisan, quality-differentiated foods, with scope to add value and profit.

The UK fishing and aquaculture sector has a GVA of about £800 M, equivalent to about 20% of UK agriculture’s GVA. The overall impact of dietary change on incomes, employment, GVA and profitability in the food supply chain is difficult to determine. A switch to a potentially lower cost vegetarian diet could reduce the value of trade, but it is likely that the extension and improved quality of non-meat components will offset this. The effects of a decline in total volume consumption of livestock products is likely to be offset by higher value added from retained higher quality meats, particularly amongst specialist providers. The supply chain for UK produced fish products will see a significant expansion through healthier eating, helping to compensate for reductions in marine takings in coastal communities.

One important consideration is the general overfishing in the world. The FAO (2014) estimated that 77% of world fisheries are at least fully exploited with about 30% of these overexploited or depleted. In short, expansion of wild fish catching cannot by guaranteed and although the UK has some protected waters, it must rely on international fish stocks to supply its current fish supply.

3.12. Impact on household budgets of healthier eating

UK households spend about 16% of their income on food and drink (excluding alcoholic drinks) of which about 8% is on household food and 3% on food eaten out (Defra, 2015). Relative to the baseline the Eatwell diet, Scenario 6, requires increased household purchases of bread and potatoes, vegetables and fruits and reduction in purchases of livestock and dairy products, and processed foods high in fats and sugar.

A high level approximation was estimated from the food part of the UK Family Spending Survey (ONS, 2014). The costs of food groups in the survey were subjected to the same changes as for the diets themselves. The mapping between the data sources was not perfect, with slightly different groupings, but there was probably an 85% convergence. The results (Table 18) suggested moderate changes in household costs, with Scenario 4 (Diverging Diets) showing a 7% fall and Scenario 5 (Living for the Third Age: Towards an Eatwell Future) showing an increase of nearly 3%. This does not reflect any effects of changed demand on prices or more detailed sourcing that might occur with large scale dietary change.

Table 18 Total weekly expenditure, £ million, on household food under scenarios of dietary change using data from the Office of National Statistics to map onto the changing food groups

	Baseline	Scenario					
		1	2	3	4	5	6
UK weekly expenditure (£M)	1,780	1,750	1,800	1,810	1,650	1,820	1,760
Change from baseline		-1.6%	1.8%	2.0%	-7.1%	2.7%	-0.9%

The effect on household budgets of a switch to the eatwell plate depends on the absolute and relative prices of dietary constituents. For example, facing increased food prices of 22% between 2007 and 2014, households reduced quantities of purchases by 7.5%, but increased total expenditure by 18%, reflecting the 'essentialness' of food commodities. However, they 'saved' an average expenditure of 5.5% by trading down, notably for livestock products, i.e. switching to cheaper products within the same food category. There is evidence that households 'trade up' when prices fall, or switch to different food types. The effect of different income levels was considered in the scenario development.

It is difficult to determine the impact of the eatwell plate on household budgets. The baseline purchases for all income categories of household income are not well matched to the eatwell plate. Overall, the switch from relatively expensive livestock products to vegetable proteins, from processed foods high in fats and sugars, and the increased intake of carbohydrates should not of itself result in increased total household expenditure on food and (non-alcoholic) drinks. There may be scope for 'trading up' in some categories of food to higher priced, higher quality products. Lower income groups require a proportionately greater switch in purchases from low cost processed foods into fruit and vegetables to meet the eatwell plate, possibly increasing overall expenditure on food. Higher and seasonally variable prices for some vegetables and fruits, could force switching out or 'trading down' within this food category for low income groups, including a switch from fresh to frozen produce.

The underlying trends for 2010 baseline case, evident over the period 2010 to 2014 (Defra, 2015) suggest continued decline in carbohydrates, milk and dairy produce, quality fresh meats, and fruit and vegetables, and a rise in processed foods, especially those high in fats and sugars. Average household expenditure on food taken out of the household also declined. These trends reflect responses to increases in food prices and pressure on household budgets post-2008 recession, as well as some changing dietary preferences. A switch to the Eatwell diet requires a reversal in some of these observed baseline trends, particularly amongst low income groups with their greater reliance on low costs processed foods. The Eatwell diet could require low income groups to spend a larger proportion of household income on food and (non-alcoholic) drinks, causing some resistance to change. The food manufacturing and retail industry have an important role to play in developing low cost, healthier options that target the less well-off.

With respect to eating out, Eatwell could result in higher prices for freshly prepared foods to substitute for pre-processed meals. For low income groups, this may result in increased expenditure, trading down, or increased home preparation. The biggest effects on household expenditure are likely to be on low income families that regularly use fast food outlets.

There is some expectation that vegetarian meal options are lower priced, but this not necessarily true. For example, supermarket prices (noted through web searches of Tesco, Sainsbury's, Waitrose and ASDA on line groceries) for vegetarian sausages are mainly in the range £4-10/kg. Pork sausages range from £1-2/kg for the most basic types through £3-4.50/kg for typical basic branded types and towards £6-8/kg for premium brands. For those on lowest incomes, the transfer from lowest-cost processed meat could indeed be challenging. Another factor for those on low incomes is limited access to wider choices in shops if travel is difficult. Some housing areas are ill-supplied with food shops and may only support smaller convenience stores, in which food choice is inevitably more restricting. This is particularly the case for those without ready access to motorised transport.

Costs are also driven by motivation (and opportunity) to cook more from basic ingredients rather than (partly) pre-prepared foods for home consumption. Those with high time pressures (which includes the spectrum of socio-economic classes) will generally be most dependent on pre-prepared food.

3.13. Economic costs of environmental burdens associated with healthier eating

Indicative estimates of the economic costs of environmental burdens were by multiplying the estimated emissions contained in Table 11 by unit prices, £/t emission. The latter were drawn from several sources, including Spencer et al. (2008) on the UK Environmental Accounts for Agriculture, and estimates compiled by Graves et al. (2011; 2015) and Chatterton et al. (2015) for environmental burdens for the livestock sector and agricultural land use in the UK. UK GDP deflators (ONS, 2016) were used to convert estimates to 2015 £ values. Indicative environmental costs for the production and processing components of the food supply chain range between about £2.5 billion and £3.0 billion per year according to the scenario (Table 19). About 80% of total estimated environmental costs relate to GHG emissions, using a long-run social cost of carbon of £28/t CO2e (at 2015 prices) based on Stern (2008) and reviewed in Graves et al. (2015).

For the assumptions made, and the bundle of environmental emissions considered, all scenarios except Scenario 1 give lower environmental costs relative to the baseline (Table 19). Scenario 6 (Eatwell) gives total estimated environmental economic costs at 83% of the baseline case, with notable reductions in ammonia emissions, particularly associated with livestock production. There is considerable uncertainty in the estimates of unit rates (£/t equivalent) for environmental burdens, not least regarding the price of carbon in the case of GHG emissions, and spatially specific nitrogen emissions whose economic impact vary according to emission pathway and the sensitivity of receptors, including impacts associated with overseas production. These indicative estimates suggest that a move to healthier eating is associated with reduced total environmental economic costs.

Table 19 Indicative economic costs (£ million per year at 2015 prices) of selected environmental burdens for production and processing parts of the food supply chain for the baseline and healthier eating scenarios

Environmental burden	£/t (2015 prices)	Economic cost (£ million)							Ratio of 6 to baseline
		Base-line	Scenario						
			1	2	3	4	5	6	
GHGE, CO_2e [1]	28	2425	2425	2350	2350	2250	2275	2075	86%
Eutrophication potential, PO_4^{3-} Equiv. [2]	510	62.9	62.9	59.9	59.9	59.9	58.4	55.4	88%
Acidification potential, SO_2 Equiv. [3]	2.33	2.9	2.8	2.9	2.9	2.7	2.8	2.8	96%
NH_3 emissions [4]	2363	481	481	442	442	461	423	346	72%
NO_3^- emissions [5]	40	17.2	17.3	17.1	17.0	16.3	16.5	15.2	88%
Total		**2989**	**2989**	**2872**	**2872**	**2790**	**2776**	**2494**	83%
% Relative to baseline		100%	100%	96%	96%	93%	93%	83%	

Notes

1: Based on long term social costs of carbon at £25/tCO_2e (at 2009 prices) adjusted to 2015 prices using UK GDP inflator.

2: Based on equivalent P cost of £1,407/t P 2009 prices (Graves et al., 2011), converted at 3.065 PO_4^{3-} to P, converted to 2015 prices.

3: Based on £2.1 /t SO_2, 2009 prices (Graves et al., 2011) converted to 2015 prices

4: based on Ammonia air damage costs in 2015 prices (DECC, 2015) https://www.gov.uk/guidance/air-quality-economic-analysis.

5: Based on £160/t NO_3^--N 2009 prices (Graves et al., 2011) converted to NO_3^- equivalent at 4.43 NO_3^- to N, converted to 2015 prices

6: UK GDP deflators: 2009 to 2015 prices: 1 to 1.11 (ONS, 2016).

Using similar assumptions, estimates were derived of the environmental costs of the food chain beyond the regional distribution centre i.e. including retailing, waste, catering and domestic preparation of food (Table 20). Environmental costs in this part of the food chain predominantly relate to GHG emissions associated with energy for transport and food preparation. Estimates of emissions costs were not calculated for each of the six separate scenarios. However it is possible that reduced consumption of processed foods and increased consumption of fresh/raw products under Scenario 6 (Eatwell) could switch energy use from the production to the retail and domestic components of the supply chain. It is noted that environmental costs of the food chain beyond regional distribution centres are equivalent to about 72% of the environmental cost of primary production with the eatwell plate. Thus, of £4.3 billion/year estimated total environmental costs for Scenario 6, 58% relate to food production and about 42% to the retail and domestic aspects.

About 90% of the total estimated environmental costs relate to GHG. Estimates of environmental costs are therefore very sensitive to assumptions regarding the cost of GHGE. The shadow price of carbon of £28/t CO_2e used here is regarded as a relatively 'safe' estimate based on a review of carbon pricing (Graves et al., 2015). The estimated price of carbon based on the marginal cost of abatement in 2009 for example was £51/t CO_2e (with a range of £32 to £63/t CO_2e) (DECC, 2009; 2011).

Table 20 Indicative economic costs of selected environmental burdens for the food chain beyond the regional distribution centre, and those costs expressed as a proportion of the environmental burdens of primary production for the Eatwell scenario

Environmental burden		**Cost of emissions, at 2015 prices, (£M/year)**				**The total as proportion of primary production in Eatwell scenario**
	2015 prices (£/t)	**Retail chain and waste**	**Catering sector energy**	**Domestic energy**	**Total**	
GHGE, CO_2e [1]	28	810	314	680	1804	87%
Eutrophication pot. PO_4^{3-} Equiv. [2]	510	2.0	0.0	0.1	2.1	4%
Acidification pot. SO_2 Equiv. [3]	2.33	0.2	0.1	0.2	0.5	17%
NH_3 emissions [4]	2363	0.3	0.0	0.1	0.4	0.1%
NO_3^- emissions [5]	40	0.0	0.0	0.0	0.0	0.1%
Total for these sectors		**813**	**314**	**680**	**1807**	**72%**
% of total food chain emissions		45%	17%	38%	100%	
Notes 1-5 as Table 19						

4. Discussion

4.1. Main environmental impacts

Five diet scenarios for the UK were compared to a baseline diet. The assumed daily dry matter intake per capita was similar (454-479 g) for the six diets. The daily intake of metabolisable energy was also similar (8.8-9.4 MJ), which is equivalent to an intake of 2100 to 2250 kilocalories. This is similar to 2140 kcal value for the mean level of food energy purchased (including eating out and alcohol), for people aged above seven years in the UK (Defra, 2015). The differences between the diets are therefore primarily a result of the composition of the diet rather than the quantity or metabolisable energy density.

The environment costs associated with food waste, the retail sector, the catering sector and food preparation were also assumed to be consistent across the six scenarios (Table 20). It is noted that the greenhouse gas emissions beyond the farm gate are of a similar magnitude of those associated with on-farm production.

Moving towards healthier diets (exemplified by the Eatwell scenario) has generally beneficial effects on the environment, as quantified by the indicators used. The predicted reduction in UK greenhouse gas emissions by 14 Mt (14%) (Table 12) by moving from the current baseline to the eatwell plate is clearly a helpful contribution towards meeting our national and international targets. Much of this is from reduced consumption of livestock products, especially meat from cattle and sheep. There would, however, be a small increase (2%) in primary energy needs to support the Eatwell diet. There is much uncertainty about the GHG intensity of electricity, heat and transport fuel production in the future, so that the same values were assumed throughout in this analysis. It is entirely plausible that extra electricity demands would be met by more renewable sources (Burgess et al. 2012), so that overall resource consumption and electricity-derived GHGE would be lower in this area by the time the Eatwell diet was achieved. However much of the primary energy use in agriculture is through the use of diesel for field machinery and reducing the GHG intensity of this is more challenging (Burgess et al., 2012).

The reduction of GHGE associated with UK diets is substantial and cuts across economic sectors and countries, but UK agriculture is clearly the main source. In 2010, the Climate Change Committee (CCC) suggested that UK agriculture sector should reduce the non-CO_2e GHGE by 4.5 Mt by 2022 and concerns were expressed that these were not on target (CCC, 2016). The target represents 32% of the GHGE reductions calculated here. About 55% of GHGE in the baseline situation arises from primary production, with about 65% in the UK. Hence, despite the diversity of sources included in this analysis, dietary change must make a major contribution in meeting this target as well as making a broader contribution to other sectors and countries.

The annual reduction in UK ammonia emissions through adoption of the eatwell plate was estimated to be 70 kt (Table 12). This is almost the same as the reduction in total (or agricultural only) ammonia emissions from the baseline recording from 1990 to 2013 (Defra, 2015). That took the UK just under the target for revised UNECE Gothenburg protocol ceiling target for 2020. The additional reduction from dietary change would reinforce this and help with meeting possible revised targets.

The move to the eatwell plate was also associated with reductions in the emissions of nitrate (250 kt) and acidifying gases (55 kt SO_2 eq.) (Table 12), which helps meet international targets.

In order to focus on the impacts of dietary change, the analysis assumed that UK farming processes and the balance of imports and domestic production stayed the same. In reality, farming systems tend to become more energy and resource efficient over time through better application of science in animal and plant breeding, nutrition, precision farming and IT-based support systems. This would occur in parallel with dietary change and, apart from some niche areas, is unlikely to change within any sector as a direct consequence of dietary change.

4.2. Sustainability

Given the reduced environmental impacts of the eatwell plate and most intermediate scenarios, the environmental sustainability of our food consumption is clearly increased by moving towards healthier eating. The socio-economic characteristics are more complex with potential losers (e.g. farmers with grazed livestock) and winners (e.g. horticultural producers, some arable farmers, fish farmers and fishermen). These are unlikely to be in the same regions, given that grazing livestock production dominates the west and north, and horticulture and arable farming is most dominant in the east and south. Some overseas producers would also lose, e.g. red meat and cane sugar producers, while horticultural producers and some arable farmers would gain. The major changes that could occur in agriculture would have some major economic changes that might be mitigated if policies supported changed practices and outputs, e.g. trees or non-productive ecosystem services instead of sheep or beef cattle. One concern is that the additional demand for fish may not be met if world stresses on fisheries limit increased supplies or, worse, reduce them.

Given that the environmental impacts are measurable and help meet various national and international targets, it is reasonable to propose that these should take priority over the socio-economic impacts, which can be mitigated by policy-led interventions.

4.3. Food waste

The potential for reducing environmental impacts by eliminating avoidable food waste is considerable and of a similar magnitude to that from dietary change towards the eatwell plate. The fundamental question is by how much can waste actually be reduced? The human behavioural factors involved are many and complex, so that the maximum apparently avoidable food waste rates will never be fully reached. Behavioural factors will also strongly influence dietary change, so that the ends points are both speculative. Further, complete elimination requires a perfect match of production, processing and distribution with consumption preferences coupled with socio-economic drivers of behavioural change. Assuming a 50% uniform reduction in food waste, the environmental benefits are considerable, but the variability in current waste rates and hence potential across food groups means that it is difficult to forecast the realisable benefits.

4.4. Reduction in GHGE compared with other studies

At least nine other studies quantified the impacts of dietary change on UK GHGE (Aston et al. 2012 ; Audsley et al., 2010 ; Audsley et al., 2011; Berners-Lee et al., 2012 ; Green et al., 2015; Hoolohan et al., 2013 ; Horgan et al., 2016 ; MacDiarmid et al., 2012 and Milner et al. 2016). A further seven were reported analysed dietary change in Europe (Fazeni and Steinmüller, 2011; Meier and Christen 2012; Risku-Norja et al., 2009, Saxe et al., 2013, Tukker et al., 2011; van Dooren et al., 2014 and Vieux et al., 2012).

All of the above studies considered changes towards healthier eating scenarios in which targets were met by meeting nutritional standards, arbitrary reductions in livestock product consumption, substituting red for white meat or by adopting an existing dietary pattern (e.g. vegetarian and vegan). All the studies used broadly similar approaches of coupling LCA results with food group or commodity changes, but with some differences in the baseline populations, measures, data sources and system boundaries. Despite this, almost all scenarios of moving towards healthier and/or more sustainable eating in the UK resulted in GHGE reductions with a mean of -22% (-12% to -36%), compared with -14% in this study. The European results were broadly similar to the UK ones, but some had notably smaller changes, perhaps as a result of more balanced initial baseline. Including the European studies, reduced the mean to -19% (+2% to -36%), so still showing a clear beneficial effect of moving towards healthier diets.

The annual level of GHGE in the UK (from food production) was predicted to decline from 97 Mt CO_2e in the baseline scenario to 83 Mt CO_2e for the eatwell plate (Table 12). The associated mean baseline GHGE per capita in the studies reported above was 2.0 t CO_2e/yr, with a range from 1.4 to 3.2 t CO_2e/yr. For the baseline scenario, the total UK GHGE associated with food production (including the retail and domestic components) was about 170 Mt CO_2e resulting in per capita values of about 2.7 t CO_2e/yr overall. The results evidently fall in to the spectrum of European studies and indeed other UK studies. It is interesting to note that several UK studies used the same basic data sets of the NDNS rolling programme of around 2010 and used earlier data of Audsley et al. (2010, 2011) as the basis for their modelling.

One reason for differences in accounting is from land use change (LUC) emissions. These were either omitted (as suggested by van Middelaar et al., 2013) or included direct LUC only. Only one included indirect LUC. The main results in this study include only direct LUC. Audsley et al. (2010) used a top-down approach that included direct and indirect LUC to estimate global LUC GHGE from the UK food system. This amounted to about 100 Mt CO_2e/yr on top of the process-based emissions of about 150 Mt CO_2e/yr. The scope for deriving different results is considerable, but nonetheless the results of this study are compatible with others.

Hallstöm et al. (2015) conducted a meta-analysis of some of the studies noted above and showed that there are different routes to healthier and /or more sustainable eating (usually defined by reduced GHGE). In their analysis, the mean reduction in GHGE from the move to healthy diets was -12%, to vegetarian was -26% and -36% to vegan. An important distinction in this work is that the scenarios of dietary change were derived from stakeholder engagement about plausible magnitudes of change rather than arbitrary (but quite reasonable) aims. Hence larger changes found in a move to vegetarian and vegan diets are not contradicted by this study. Indeed, broadly similar outcomes were quantified by Audsley et al. (2010), Green et al. (2015) and Horgan et al. (2016). Identifying and quantifying the possibility of major reductions in GHGE is one thing, but achieving such massive changes as the complete elimination of meat from the diet would require a huge cultural change as well as ensuring a robust nutritional balance.

4.5. Ammonia, nitrate and water impacts compared

Westhoek et al. (2014) calculated that nitrogen emissions (e.g. nitrate to water and ammonia to air) in the EU from primary production could both be reduced by 40% with a major change to a diet including 50% less meat and dairy. This is noticeably a greater reduction that the nitrate leaching reduction (12%) perhaps because the UK seems to fall into the lower range of baseline leaching illustrated by Westhoek et al and the range of production systems in Europe differs from the specific set that feeds the UK. The fall of 28% in ammonia emissions in this report is more in line with the 40% of Westhoek et al. (2014). Considering differences in modelling methods, boundaries, geographical scope as well as diet make up between the present research and Westhoek et al. (2014); it is still reassuring that both studies achieved the same order of magnitude.

The approach to water use reported here has a smaller reduction than those derived by other making a similar analysis in Europe (Gerbens-Leenes et al., 2013; Vanham et al., 2013a, 2013b; Vanham and Bidoglio, 2014). This is partly a result of different methods. These other authors used the virtual water requirement (which includes green water that flows by evapotranspiration), while this study uses the blue water stress footprint of UK food consumption. We maintain that it is a more advanced approach and is more in line with ISO 14046 on water footprinting (ISO, 2014) that aligns water footprinting with LCA. However, our results were also marginally sensitive to a range of plausible future healthier eating scenarios, because reductions in consumption of commodities with a high virtual blue water content (e.g. meat from the UK), tend to compensated by increases in others or commodities produced in areas of water scarcity (e.g. fruit from Spain) and the healthier eating scenarios considered were fairly conservative. There was no opportunity to quantify the Eatwell scenario with this method.

4.6. Land use and other studies

The area of land associated with current UK food consumption is 14,630 kha in the UK and 4,550 kha outside of the UK (Table 15). Assuming a UK population of 63.2 million, from the 2011 Census (ONS, 2015), which coincides with the consumption data, this is equivalent annually to 0.23 ha/hd and 0.07 ha/hd from inside and outside of the UK respectively, Hence, the mean area, needed for food production per capita in the UK was 0.30 ha/hd in the baseline. Audsley et al. (2011) found 0.35 ha/hd using similar data and methods to the present study. These are both higher than the range of 0.14 to 0.21 ha/hd in four studies (three in the EU, one in the UK), (Arnoult et al., 2010, Meier and Christen, 2013, Temme et al., 2013 and van Dooren et al., 2014). One reason for relatively higher values in the UK is the explicit inclusion of poor quality grassland for hill and upland grazing livestock production which barely exists in the Netherlands, which was studied by Temme et al. and van Dooren et al. Arnoult et al. (2010) considered smaller reductions in meat consumption than in this study, hence land use demand would be less than this study. Meier and Christen (2013) analysed dietary change in Germany and their land requirement suggest generally more intensive beef production than in the UK with a land use need per unit output of about five times less than in our model. The reduction in land use with the eatwell plate and assuming uniform release of grassland was 21%, while the other studies reported reductions of 15 to 50% with the adoption of healthy diets. Thus, this study again aligns with the findings of others.

4.7. Socio-economic impacts

Auestad and Fulgoni (2015) reviewed 31 papers on sustainability and diets that were published up to 2014 and included at least one environmental indicator. Most were from Europe and published between 2010 and 2014. Few reported economic impacts or environmental impacts beyond GHGE. Their approach was from a multidisciplinary perspective in that sustainability is multi-dimensional and they concluded that: "*Many studies point to the need for a far more complete assessment of the environmental, social, and economic impacts of foods and diets. Research needs cut across multiple fields, including agriculture, nutrition, animal science, environment, social sciences, and economics.*" Our contribution on socio-economic impacts is thus novel and part of the multidisciplinary approach suggested by Auestad and Fulgoni (2015).

4.8. Meeting nutritional needs

Moving towards the Eatwell diet appeared to maintain the average supply of micronutrients and other essential macro-nutrients. There was still some residual over-supply of unwanted simple sugars, despite some adjustments to food choices. This was partly owing to the method used in that the choice of foods assumed to be available within each food group was limited and the composition included sugar and salt as given. *Ad hoc* modifications were made by choice editing to substitute potassium for sodium chloride to reduce sodium intake to the accepted level and for sugars to approach the acceptable level. While this works where sugar or salt is added to foods, intrinsic sugars and sodium cannot be altered. This is more limiting in the case of sugars than for salt, given their relative weighting in the composition of food (FSA, 2002). In practice, reducing sugar intake was applied primarily to soft drinks, given that alternatives are available now. It is also reasonable to assume that food science and technology will deliver better approaches to sugar avoidance in the near future.

Reducing salt intake could be challenging for some population groups, especially those who have added high quantities of salt in home cooking for many years. Further, about 75% of the salt we eat comes from pre-packaged food (British Heart Foundation, 2016), thus those with relatively high intakes of such foods are at greater risk. Hence, the British Heart Foundation (2016) recommends clearer labelling to help consumers reduce their sodium intake. Progress has been made in the UK with a salt reduction programme that started in 2003-4 (He et al., 2014). The programme has resulted in the reductions in “the salt content in many processed food and a 15% reduction in 24-h urinary sodium over 7 years”. Dietary intake in 2010, however, was still considerably above the recommended level in our analysis. The salt reduction programme relies on a voluntary approach by the food industry. A widespread approach is needed to effect a gradual reduction and allow people to adjust to reduced salt contents in manufactured foods (McGregor, 2017). For example, the salt content in bread was reduced by about 25% from 2001 to 2011. Gradual reduction can thus work, which can be aided by the use herbs and spices, although some consider that potassium chloride is an option (IOM, 2010). This whole area represents a considerable challenge to food manufacturers, who need to make commercially competitive products that appeal to a variety of consumer types, while endeavouring to meet more demanding nutritional standards and avoiding additional negative side effects. There is still a long way to go in that our needs for salt are about 0.5 g/d, but the last target that was considered to be achievable is < 6 g/d in 2015 and < 3 g/g by 2025 (National Institute for Health and Clinical Excellence (2010).

Making starchy carbohydrates more appealing is somewhat challenging. Deriving more energy from these in place of energy from fats and proteins is a fundamental change that is needed. This should also be accompanied by a higher fibre intake, so a move to more whole grain alternatives would be beneficial. Apart from providing fibre, whole grains have a lower glycaemic index than more processed alternatives and hence play a beneficial role in reducing type-2 obesity and diabetes (Taylor et al., 2015).

Salt-free basic examples of traditional staple foods such boiled potatoes, porridge, plain rice, bread, pasta, pizza base or maize based tortilla can be bland. Traditional cooking, manufacturers and the food service sector enhance the flavour and delivery with sugar, salt, fat and other ingredients. Hence these staple foods have become channels for delivering diverse taste and sensory experiences with relatively little apparent consideration of the health impact. For example, plain cooked potatoes contain only 0.2% fat, but chips contain an average (unweighted) of 12% fat (Figure 11) which is a 60 fold increase; the increase of saturated fat is 80 fold. However the range of fat in pre-processed chips is large and much lower fat alternatives are now apparently available e.g. McCain (2016) report chips comprising 2.1% total fat with 0.1% saturated fat. Human inventiveness must mean that there is room for further improvement in cooking methods or oil type.

Cereal-based foods also deliver a wide range of nutrients. The increases of total fat and saturated fat from plain pasta to pasta dishes are on average 4 and 16 respectively (Figure 11), again with a wide range on actual concentrations. One approach pioneered by Eat Balanced (2016) has been the design of nutritionally balanced pizza recipes for children, which are marketed through the food service sector for school lunches, which has been termed "health by stealth" (Lean, 2016). The pizzas are tasty whilst have lower concentrations of salt, sugar and fat than other selected pizza example as well as higher fibre contents (Sustainable Brands, 2016). Other examples should be possible in other sectors of the food market. Inspiration from respected, enlightened opinion leaders can also help e.g. "the Jamie Oliver Effect" (Smith, 2008).

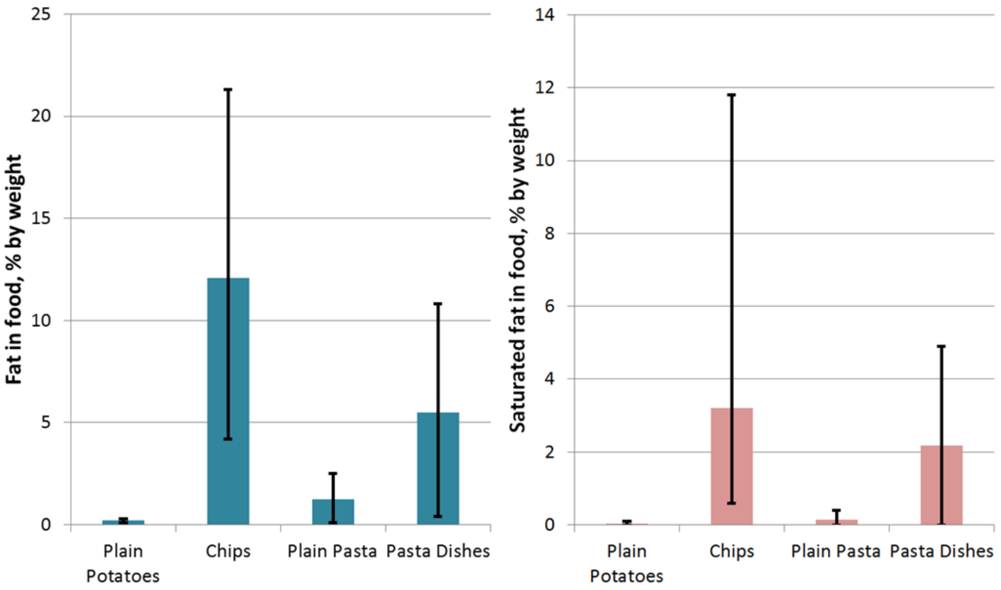

Figure 11 Total and saturated fat contents of plain potatoes and pasta compared with chips and pasta dishes. (FSA, 2002).

Eating more starchy carbohydrates and displacing energy from protein and fat, given the current national diet, are also major reasons for the reduction in environmental impacts by moving to the Eatwell diet. The negative environmental impacts of producing protein rich foods (to the farm gate or fish equivalent) are greater than staple carbohydrate rich crops. However there are also differences in the environmental impacts of staple carbohydrate foods. For example, Hess et al. (2015b) showed that potatoes and pasta had lower GHGE and stress weighted blue water use than rice both per unit weight of carbohydrate or per serving.

Milk and milk products create interesting opportunities and obstacles for healthier eating. Human breast milk provides all of the nutrients needed for the initial months of life. However beyond the initial months, UK citizens mainly consume cows' milk. Milk fat contains about 70% saturated fat and the current advice is to reduce saturate fat intake and hence choose lower fat milk and milk product alternatives (Public Health England, 2016). This is acceptable from the perspective of human nutrition, but the exact composition of cows' milk is linked to genetics (between and within breeds) and cow nutrition (low dietary fibre inclusion can lead to low milk fat syndrome). Once produced, milk is separated into skimmed and higher fat fractions, which can then be added back to produce products such as semi-skimmed milk. Producing milk fat is an energy intensive process that generates negative environmental impacts. If there is not a justifiable market for milk fat, then surplus needs to be used in as environmentally benign way as possible or prevented at source by producing less fatty milk, while preserving the other beneficial nutrients. One suggestion has been to use milk fat as a source of bioenergy or a as a feedstock for other processes.

4.9. Magnitudes of changes

The scenarios that were developed used the combined expert opinions of stakeholders to help first in the shaping and second in the quantification of the magnitude of change over 20 years. The collective opinion did not originally quantify a scenario that converged on the eatwell plate, indeed one of the original scenarios led to distinctly less healthy eating. (The revised Scenario 1 also showed a small change away from healthier eating. The scenario that was engineered to deliver healthy eating could only be achieved by making some assumptions about removing salt and sugar from various foods rather than straight moves between commodities. Time will tell what changes actually occur, but caution should be applied in expecting massive and fast changes towards not only the healthier diets that were modelled here, but those that go much further e.g. wholly vegetarian.

Achieving major dietary change needs large positive moves from the food manufacturing industry, the food service sector, retailers, education, opinion leaders and governments as well as the will of the population. Social science demonstrated how the physical positioning of foods in retail outlets can nudge consumers towards choosing foods likely to have beneficial effect on obesity (Bucher et al., 2016). Changes in diet, such as elimination of trans-fats, could apparently save thousands of premature deaths (NHS, 2015). Allen et al. (2015) suggested that improved labelling would be beneficial, but a total ban (implying legislation) would be most effective.

There are likely to be economic losers in major dietary change and potential losers are likely to wish to defend their livelihoods. This, together with established eating traditions and sensory based preferences will contribute towards the inertia to resist change.

4.10. Data quality and future perspectives of LCA research

The present research relies on data availability for life cycle assessment (LCA). The data collected here were based on research carried out by Audsley et al. (2010, 2011) that enables estimation of emissions related to food produced in UK. However it can be difficult to find high quality data on specific commodities produced outside the UK. For instance, LCA data for olive oil, peaches and apricots were mostly derived from Italian conditions (Ingrao et al., 2014, 2015) while most of the imports to the UK come from Spain. Other examples include mushrooms where a full LCA of mushroom cultivation is currently not available (Gunady et al., 2012). High quality data for fish farming and fisheries are limited to a few studies (Henriksson et al., 2012). Data on wine were scant and limited coming mostly from Italy, Australia and North America (Ardente et al., 2006; Fusi et al., 2014; Point et al., 2012). Also limited sources were found for tea and coffee (Azapagic et al., 2016; Coltro et al., 2006; Humbert et al., 2009; Roy et al., 2009) however these sources highlight that most of the impacts related to GHGE and energy consumptions occur in the household. There is an urgent need for further LCA research for most food items imported into UK to improve the accuracy of the impact assessment of UK national diet.

Several LCA studies also highlight that different crop management systems can result in very different environmental emissions (Brankatschk and Finkbeiner, 2015; Goglio, 2012; Goglio et al., 2014; Knudsen et al., 2014; Nemecek et al., 2011a, 2011b). Furthermore, the same systems can show considerable variation within and between countries (Biswas et al., 2010; Börjesson and Tufvesson, 2011; Chiaramonti and Recchia, 2010; Goglio et al., 2014; Kim et al., 2009). These potential sources of variation have not been included here but is worth further consideration in future studies.

5. Conclusions

Scenarios of dietary change towards healthier eating in the UK were developed using morphological analysis and the magnitudes of changes in consumption of food groups in six scenarios were quantified. These were related to the changes in agricultural commodity and fish production required to support the new consumption patterns. The environmental impacts of producing these commodities were calculated using detailed life cycle assessments up to delivery to a regional distribution centre, and high level estimates of energy use, food waste and refrigerant emissions for the retail and domestic components of the food chain. The same data were also used to estimate the range of land use change both in the UK and overseas, and the socio-economic impacts.

One scenario was designed to meet the dietary recommendations summed up by the eatwell plate, while others were based on expected changes from expert stakeholders. The eatwell plate was associated with reduced consumption of fat, extrinsic sugar, salt and meat (especially red meat) with increased consumption of starchy carbohydrates, fruits, vegetables and oily fish.

Achieving a national move to the eatwell plate would have major environmental benefits in reducing greenhouse gas emissions (14%), ammonia (28%), nitrate (12%) and acidifying gases (4%) relative to the baseline. Most of the changes occur from primary production. The absolute reduction in greenhouse gas emissions was estimated to be 14 Mt CO_2e per year. These were in the same range as found by other authors. The other scenarios, with smaller changes in food group consumption, showed smaller changes (0 to 7% reduction in greenhouse gas emissions). The total impacts on stress-weighted blue water consumption in six scenarios were relatively small, but the potential for increased consumption of some plant commodities from highly stressed areas was noted.

The hypothetical elimination of *all* avoidable food waste prior to delivery at a regional distribution centre would reduce greenhouse gas emissions by 12%, and a 7% reduction over the whole food chain. This is similar, although smaller, to the reduction obtained with adopting the Eatwell diet.

Predicted changes in UK land use were considerable. Achieving the eatwell plate nationally would result in large releases of UK grassland from livestock production (about 4.8 Mha) but would increase the need for cropland both in the UK (0.34 Mha) and internationally (0.48 Mha). It is plausible that increased requirement for cropland could be met from the conversion of rotational grassland areas. Estimates of changes in the grassland required varied widely between possible extreme interpretations of releasing mainly hill and upland land or lowland, so central estimates are shown above.

The changes in commodity demand and land use are anticipated to be accompanied by major changes in agriculture. Revenues in beef and sheep sectors would fall by up to 40% in the Eatwell scenario with a general shift in production away from the more disadvantaged areas in the wetter north and west of the UK. However, the impacts of such changes could be mitigated by policies to support alternative and multi-functional land use. In contrast, milling wheat, potatoes and field vegetable revenues should increase by 70%, 30% and 30%

respectively. Fish farmers and fishermen (assuming the availability of a sustainable stock) would also benefit from increased revenues.

Impacts on household expenditure appeared to be small at a national scale, but there was some evidence that poorer households may be disadvantaged. The reduced environmental emissions were estimated to reduce the costs of annual externalities of food production by 17%, which is equivalent to about £500 million.

These results reflect changes on national consumption rather than individual consumption. Therefore, the effects of the scenarios might be different in different population groups. Technological improvement such as reduction of salt, sugar and trans-fat were suggested for improving the health-properties of processed food. All dietary scenarios apart from Scenario 1 (limited change) showed some positive nutritional features such as increased starchy carbohydrate consumption and reduced red meat consumption together with reduced food wastage.

The hypothetical elimination of all avoidable food waste prior to delivery at a regional distribution centre would also reduce greenhouse gas emissions by 12%, and a 7% reduction over the whole food chain. This is similar, although smaller, to the reduction obtained with adopting the Eatwell diet.

The consequences of the outcome of Brexit negotiations on consumer dietary habits and UK agricultural food industries have not been considered here.

6. References

AFRC (1993). Energy and protein requirements of ruminants: an advisory manual AFRC Technical Committee, compiled by G Alderman and B Cottrill, CAB, Wallingford.

Allen, K., Pearson-Stuttard, J., Hooton, W., Diggle, P., Capewell, S., O'Flaherty, M. (2015). Potential of trans fats policies to reduce socioeconomic inequalities in mortality from coronary heart disease in England: cost effectiveness modelling study. British Medical Journal 351, 4583. doi: 10.1136/bmj.h4

Ardente, F., Beccali, G., Cellura, M., Marvuglia, A. (2006). POEMS: A Case Study of an Italian Wine-Producing Firm. Environmental Management 38, 350–364. doi: 10.1007/s00267-005-0103-8.

Arnoult, M.H., Jones, P.J., Tranter, R.B., Tiffin, R., Traill, W.B., Tzanopoulos, J., 2010. Modelling the likely impact of healthy eating guidelines on agricultural production and land use in England and Wales. Land Use Policy 27, 1046–1055. doi:10.1016/j.landusepol.2010.02.001

Audsley, E., Morris, J., Williams A. (2015). Using systems-based life cycle assessment to investigate the environmental and economic impacts and benefits of the livestock sector in the UK. Journal of Cleaner Production 86, 1-8.

Audsley, E., Angus, A., Chatterton, J., Graves, A., Morris, J., Murphy-Bokern, D., Pearn, K., Sandars, D., Williams, A. (2011). Food, land and greenhouse gases. The effect of changes in UK food consumption on land requirements and greenhouse gas emissions. The Committee on Climate Change. http://tinyurl.com/CCC-LU-2010 Accessed 21 April 2016.

Audsley, E., Brander, M., Chatterton, J., Murphy-Bokern, D., Webster, C., Williams, A. (2009). How low can we go? An assessment of greenhouse gas emissions from the UK food system and the scope to reduce them by 2050. WWF-UK. http://www.fcrn.org.uk/fcrn/publications/how-low-can-we-go Accessed 21 April 2016.

Auestad, N., Fulgoni, V.L. (2015). What current literature tells us about sustainable diets: emerging research linking dietary patterns, environmental sustainability, and economics. Advances in Nutrition: An International Review Journal 6, 19–36. doi:10.3945/an.114.005694.

AUK (2014). Agriculture in the United Kingdom 2014, Defra. https://www.gov.uk/government/statistical-data-sets/agriculture-in-the-united-kingdom Accessed 21 April 2016.

Azapagic, A., Bore, J., Cheserek, B., Kamunya, S., Elbehri, A. (2016). The global warming potential of production and consumption of Kenyan tea. Journal of Cleaner Production 112, Part 5, 4031–4040. doi: 10.1016/j.jclepro.2015.07.029

Bates, B., Lennox, A., Swan, G. (2011). National Diet and Nutrition Survey: Headline results from years 1 and 2 (combined) of the rolling programme (2008/2009 – 2009/10). Department of Health, England. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216484/dh_128550.pdf

BBC (2012). Scottish team develops 'nutritional' pizzas http://www.bbc.co.uk/news/uk-scotland-18663969

Berlin, J. (2002). Environmental life cycle assessment (LCA) of Swedish semi-hard cheese. International Dairy Journal 12, 939–953. doi: 10.1016/S0958-6946(02)00112-7

Biswas, W.K., Graham, J., Kelly, K., John, M.B. (2010). Global warming contributions from wheat, sheep meat and wool production in Victoria, Australia – a life cycle assessment. Journal of Cleaner Production 18, 1386–1392. doi: 10.1016/j.jclepro.2010.05.003

Börjesson, P., Tufvesson, L.M. (2011). Agricultural crop-based biofuels – resource efficiency and environmental performance including direct land use changes. Journal of Cleaner Production 19, 108–120. doi: 10.1016/j.jclepro.2010.01.001

Brankatschk, G., Finkbeiner, M. (2015). Modeling crop rotation in agricultural LCAs — Challenges and potential solutions. Agricultural Systems 138, 66–76. doi: 10.1016/j.agsy.2015.05.008

British Heart Foundation (2016). Salt. https://www.bhf.org.uk/about-us/our-policies/preventing-heart-disease/salt.aspx

British Nutrition Foundation (2015). Nutrition Requirements. https://www.nutrition.org.uk/attachments/article/234/Nutrition%20Requirements_Revised%20Nov%202015.pdf

British Nutrition Foundation (2016a). Nutrition Requirements. https://www.nutrition.org.uk/attachments/article/907/Nutrition%20Requirements_Revised%20June%202016.pdf. Accessed 23 April 2017.

British Nutrition Foundation (2016b). Healthy eating for vegans and vegetarians. https://www.nutrition.org.uk/healthyliving/helpingyoueatwell/veganandvegetarian.html. Accessed 23 April 2017.

British Nutrition Foundation (2016c). Nutrition for pregnancy. https://www.nutrition.org.uk/healthyliving/nutritionforpregnancy.html. Accessed 23 April 2017.

British Soft Drinks Association (2016). Changing Tastes. The UK Soft Drinks Annual Report, 2015. http://www.britishsoftdrinks.com/write/MediaUploads/Publications/BSDA_Annual_Report_2015.pdf. Accessed 21 April 2017.

Brodt, S., Kendall, A., Mohammadi, Y., Arslan, A., Yuan, J., Lee, I.-S., Linquist, B. (2014). Life cycle greenhouse gas emissions in California rice production. Field Crops Research 169, 89–98. doi: 10.1016/j.fcr.2014.09.007

Bucher, T., Collins, C., Rollo, M.E., McCaffrey, T.A., De Vlieger, N., Van der Bend, D., Truby, H., Perez-Cueto, F.J.A. (2016). Nudging consumers towards healthier choices: a systematic review of positional influences on food choice. British Journal of Nutrition, 115 (12), 2252-2263. doi: 10.1017/S0007114516001653

Burgess, P.J., Sanchez Martinez, P.J., Williams, A.G. (2015). At what scale should livestock-forest systems be considered? Poster at World Congress of Integrated Crop-Livestock-Forest Systems. 12-17 July 2015, Brasilia, Brazil. https://www.agforward.eu/index.php/en/news-reader/id-13-17-july-2015.html

Burgess, P.J., Rivas-Casado, M., Gavu, J., Mead, M., Cockerill, T., Lord, R., van der Horst, D., & Howard, D.C. (2012). A framework for reviewing the trade-offs between renewable energy, food, feed and wood production at a local level. Renewable & Sustainable Energy Reviews 16, 129-142. doi:10.1016/j.rser.2011.07.142

CCC (2016). Committee on Climate Change, Meeting Carbon Budgets 2016 Progress Report to Parliament, Presented to Parliament pursuant to Section 36(1) of the Climate, Change Act

2008, June 2016. https://documents.theccc.org.uk/wp-content/uploads/2016/06/2016-CCC-Progress-Report.pdf

CEFAS (2015). Aquaculture Statistics for the UK, with a focus on England and Wales, Centre for Environment, Fisheries and Aquaculture Science, Weymouth.

Chatterton, J., Graves, A., Audsley, E., Morris, J., Williams, A. (2015) Using systems-based life cycle assessment to investigate the environmental and economic impacts and benefits of the livestock. Journal of Cleaner Production 86, 1-8. doi: 10.1016/j.jclepro.2014.05.103

Chiaramonti, D., Recchia, L. (2010). Is life cycle assessment (LCA) a suitable method for quantitative CO_2 saving estimations? The impact of field input on the LCA results for a pure vegetable oil chain. Biomass and Bioenergy 34, 787–797. doi: 10.1016/j.biombioe.2010.01.022

CML (2016). CML-IA Characterisation Factors. https://www.universiteitleiden.nl/en/research/research-output/science/cml-ia-characterisation-factors Accessed 21 April 2016

Coltro, L., Mourad, A., Oliveira, P., Baddini, J., Kletecke, R. (2006). Environmental profile of Brazilian green coffee. International Journal of Life Cycle Assessment 11, 16–21. doi: 10.1065/lca2006.01.230

DECC (2009). Carbon Valuation in UK Policy Appraisal: A Revised Approach (128 pp.) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/245334/1_20090715105804_e____carbonvaluationinukpolicyappraisal.pdf

DECC (2011). A Brief Guide to the Carbon Valuation Methodology for UK Policy Appraisal. October 2011. Department of Energy & Climate Change, London. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48184/3136-guide-carbon-valuation-methodology.pdf

DECC (2015b). Energy Consumption in the UK (ECUK) Domestic data tables 2015 update. Tables 3.03, 3.05, 3.10 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449107/3._domestic_data_tables.xlsx Accessed 21 April 2016

DECC (2015c). Energy Consumption in the UK Service sector data tables 2015 update. Table 5.02. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449111/5._services_tables.xlsx Accessed 21 April 2016

Defra (2009). Farming Statistics Note on the Revised EC Classification of Farm Types. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/182207/defra-stats-foodfarm-landuselivestock-june-results-typology.pdf

Defra (2014). United Kingdom Multiannual National Plan for the Development of Sustainable Aquaculture. https://consult.defra.gov.uk/fisheries/european-maritime-and-fisheries-fund-in-the-uk/supporting_documents/Multiannual%20National%20Plan%20for%20the%20Development%20of%20Sustainable%20Aquaculture.pdf or http://tinyurl.com/sus-aqua-2014

Defra (2015). Environmental impact: Air quality. Indicator DC1: Ammonia. Emissionshttps://www.gov.uk/government/uploads/system/uploads/attachment_data/file/458429/agindicator-dc1-03sept15.pdf. Accessed 23 April 2017.

Defra (2015). Family Food, 2014. Defra, London. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/485982/familyfood-2014report-17dec15.pdf

Defra (2016). Greenhouse Gas Conversion Factor Repository http://www.ukconversionfactorscarbonsmart.co.uk/ Accessed 21 April 2016

Defra (2016b). Food Statistics Pocketbook 2015, Department for Environment, Food and Rural Affairs. London. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/526395/foodpocketbook-2015update-26may16.pdf Accessed 7 Jul 2016

Defra (2016c). Agriculture in the United Kingdom data sets https://www.gov.uk/government/statistical-data-sets/agriculture-in-the-united-kingdom

Department of Health (2010). NHS Choices: 8 tips for healthy eating http://www.nhs.uk/Livewell/Goodfood/Pages/eight-tips-healthy-eating.aspx

Diabetes UK (2016). Diabetes Prevalance 2016 (November 2016) https://www.diabetes.org.uk/Professionals/Position-statements-reports/Statistics/Diabetes-prevalence-2016/

Doublet, G., Jungbluth, N. (2010). Life cycle assessment of drinking Darjeeling tea. Conventional and organic Darjeeling tea. ESU Services, Uster, Switzerland.

Eat Balanced (2016). http://www.eatbalanced.com/

EEC (1990). EEC Council Directive of 24 September 1990 on nutrition labelling for foodstuffs (90/496/EEC. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1990L0496:20081211:EN:PDF

ELCD (2016). The European Reference Life Cycle Database. http://eplca.jrc.ec.europa.eu/ELCD3/ Accessed 21 April 2016

English Nature (2016). http://www.english-nature.org.uk/citation/citation_photo/1002417.pdf

EU (2000). The EU Water Framework Directive - integrated river basin management for Europe. http://ec.europa.eu/environment/water/water-framework/index_en.html

FAO (2014). Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department. The State of world fisheries and aquaculture: opportunities and challenges. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/3/d1eaa9a1-5a71-4e42-86c0-f2111f07de16/i3720e.pdf

FAOSTAT (2016). Food, Agriculture and Fishery statistics. http://faostat3.fao.org/browse/T/*/E

Finnegan, W., Goggins, J., Clifford, E., Zhan, X., n.d. Global warming potential associated with dairy products in the Republic of Ireland. Journal of Cleaner Production. doi: 10.1016/j.jclepro.2015.08.025. Available on-line.

Fisheries Research Services (2016). Environmental Impacts of Fish Farming. http://www.gov.scot/uploads/documents/ae01environimpact.pdf

Food Standards Agency (2002). McCance and Widdowson's The composition of foods. 6th Summary Edition. Cambridge, Royal Society of Chemistry. Online version at http://tinyurl.com/FSA-COFIDS Accessed 21 April 2016

Food Standards Agency (2007). How the eatwell plate differs from the “Balance of Good Health” plate. http://collections.europarchive.org/tna/20100927130941/http://food.gov.uk/healthiereating/eatwellplate/howdiffers

Food Standards Agency (2010). Using the eatwell plate. http://collections.europarchive.org/tna/20100927130941/http://food.gov.uk/healthiereating/eatwellplate

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz, M., van Dorland, R. (2007). Changes in atmospheric constituents and in radiative forcing. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt., K.B., Tignor, M. and Miller, H.L. (eds) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm

Fusi, A., Guidetti, R., Benedetto, G. (2014). Delving into the environmental aspect of a Sardinian white wine: From partial to total life cycle assessment. Science of the Total Environment 472, 989–1000. doi: 10.1016/j.scitotenv.2013.11.148

Garnett, T. (2008). Cooking up a storm. Food, greenhouse gas emissions and our changing climate. Food Climate Research Network, University of Surrey. http://www.fcrn.org.uk/sites/default/files/CuaS_web.pdf

Gatenby, S.J., Hunt, P., Rayner, M. (1995). The National Food Guide: development of dietetic criteria and nutritional characteristics. Journal of Human Nutrition and Dietetics 8, 323-334

Goglio, P. (2012). CERES application: Field case studies to estimate N_2O emissions from cropping systems within the LCA context.

Goglio, P., Gabrielle, B., Colnenne-David, C., Laville, P., Doré, T., Desjardins, R.L., (2014). Assessing GHG mitigation options for crops at regional level using eco-system modelling and LCA, in: Proceedings of the 9th International Conference LCA of Food 2014. Presented at the LCAfood2014, San Francisco.

González-García, S., Hospido, A., Moreira, M.T., Feijoo, G., Arroja, L. (2013). Environmental Life Cycle Assessment of a Galician cheese: San Simon da Costa. Journal of Cleaner Production 52, 253–262. doi: 10.1016/j.jclepro.2013.03.006

Graves, A., Morris, J., Chatterton, J., Audsley, E., Williams, A., Webb, J., Parker, C., Ward, J., Dinsdale, A., Harley, M., Hanley, N. and Acs, S. (2011). Economic and Environmental Impacts of the Livestock Sector in the UK. Defra Project ACO2010. Cranfield University, April 2011

Graves, A.R., Morris, J., Deeks, L.K., Rickson, R.J., Kibblewhite, M.G., Harris, J.A, and Farewell, T.S., Truckle, I. (2015). The total costs of soil degradation in England and Wales. Ecological Economics, 119, 399–413.

Gunady, M.G.A., Biswas, W., Solah, V.A., James, A.P. (2012). Evaluating the global warming potential of the fresh produce supply chain for strawberries, romaine/cos lettuces (*Lactuca sativa*), and button mushrooms (*Agaricus bisporus*) in Western Australia using life cycle assessment (LCA). Journal of Cleaner Production 28, 81–87. doi: 10.1016/j.jclepro.2011.12.031

Hallström, E., Carlsson-Kanyama, A., Börjesson, P., 2015. Environmental impact of dietary change: a systematic review. Journal of Cleaner Production 91, 1–11. doi:10.1016/j.jclepro.2014.12.008

Hassard, H.A., Couch, M.H., Techa-erawan, T., McLellan, B.C. (2014). Product carbon footprint and energy analysis of alternative coffee products in Japan. Journal of Cleaner Production 73, 310–321. doi: 10.1016/j.jclepro.2014.02.006

He, F.J., Brinsden, H.C. and MacGregor, G.A. (2014) Salt reduction in the United Kingdom: a successful experiment in public health, Journal of human hypertension, 28 (6), 345–352 doi:10.1038/jhh.2013.105

Henriksson, P.J.G., Guinée, J.B., Kleijn, R., de Snoo, G.R. (2012). Life cycle assessment of aquaculture systems—a review of methodologies. International Journal of Life Cycle Assessment 17, 304–313. doi: 10.1007/s11367-011-0369-4

Hess, T., Andersson, U., Mena, C., Williams, A. (2015a). The impact of healthier dietary scenarios on the global blue water scarcity footprint of food consumption in the UK. Food Policy 50, 1–10. doi:10.1016/j.foodpol.2014.10.013

Hess, T., Chatterton, J., Daccache, A., Williams, A. (2015b). The impact of changing food choices on the blue water scarcity footprint and greenhouse gas emissions of the British diet: the example of potato, pasta and rice. Journal of Cleaner Production 112, 4558-4568. doi:10.1016/j.jclepro.2015.08.098

Higgs, E., Falk, D.A., Guerrini, A., Hall, M., Harris, J., Hobbs, R.J., Jackson, S.T., Rhemtulla, J.M., Throop, W. (2014). The changing role of history in restoration ecology. Frontiers in Ecology and the Environment 12, 499–506. doi:10.1890/110267

HM Government (2016). Childhood Obesity. A Plan for Action. Report of the UK government, Whitehall, London, UK.

HMRC (2016). HM Revenue & Customs, https://www.uktradeinfo.com/Statistics/OverseasTradeStatistics/Pages/OTS.aspx) Accessed 21 April 2016

HMRC (2016). Build your own tables. Data by commodity code. https://www.uktradeinfo.com/Statistics/BuildYourOwnTables/Pages/Home.aspx

Hoogmoed, M., Cunningham, S., Thomson, J., Baker, P., Beringer, J., Cavagnaro, T. (2012). Does afforestation of pastures increase sequestration of soil carbon in Mediterranean climates? Agriculture, Ecosystems and Environment 159, 176–183.

Huang, Z., Davis, M.R., Condron, L.M., Clinton, P.W. (2011). Soil carbon pools, plant biomarkers and mean carbon residence time after afforestation of grassland with three tree species. Soil Biology and Biochemistry 43 (6), 1341–1349.

Humbert, S., Loerincik, Y., Rossi, V., Margni, M., Jolliet, O. (2009). Life cycle assessment of spray dried soluble coffee and comparison with alternatives (drip filter and capsule espresso). Journal of Cleaner Production 17, 1351–1358. doi: 10.1016/j.jclepro.2009.04.011

Hutchinson, J.J., Campbell, C.A., Desjardins, R.L. (2007). Some perspectives on carbon sequestration in agriculture. Agricultural and Forest Meteorology 142, 288–302. doi: 10.1016/j.agrformet.2006.03.030

Ingrao, C., Matarazzo, A., Tricase, C., Clasadonte, M.T., Huisingh, D., 2015. Life Cycle Assessment for highlighting environmental hotspots in Sicilian peach production systems. Journal of Cleaner Production 92, 109–120. doi: 10.1016/j.jclepro.2014.12.053

Ingwersen, W.W. (2012). Life cycle assessment of fresh pineapple from Costa Rica. Journal of Cleaner Production 35, 152–163. doi: 10.1016/j.jclepro.2012.05.035

IOM (Institute of Medicine) (2010). Strategies to Reduce Sodium Intake in the United States. Washington, DC: The National Academies Press.

Iraldo, F., Testa, F., Bartolozzi, I. (2014). An application of Life Cycle Assessment (LCA) as a green marketing tool for agricultural products: the case of extra-virgin olive oil in Val di

Cornia, Italy. Journal of Environmental Planning and Management 57, 78–103. doi: 10.1080/09640568.2012.735991

ISO (2014). ISO 14046:2014 Environmental management -- Water footprint -- Principles, requirements and guidelines. http://www.iso.org/iso/catalogue_detail?csnumber=43263

ISO (2016). International Sugar Organization http://www.isosugar.org/About/Role.html

Jørgensen, D. (2015). Rethinking rewilding. Geoforum 65, 482–488. doi:10.1016/j.geoforum.2014.11.016

Kendall, A., Marvinney, E., Brodt, S., Zhu, W. (2015). Life cycle–based assessment of energy use and greenhouse gas emissions in almond production, Part I: Analytical framework and baseline results. Journal of Industrial Ecology 19(6), 1008-1018. doi: 10.1111/jiec.12332

Kim, S., Dale, B.E., Jenkins, R. (2009). Life cycle assessment of corn grain and corn stover in the United States. International Journal of Life Cycle Assessment 14, 160–174. doi: 10.1007/s11367-008-0054-4

Kim, D., Thoma, G., Nutter, D., Milani, F., Ulrich, R., Norris, G. (2013). Life cycle assessment of cheese and whey production in the USA. International Journal of Life Cycle Assessment 18, 1019–1035. doi: 10.1007/s11367-013-0553-9

Knudsen, M.T., Meyer-Aurich, A., Olesen, J.E., Chirinda, N., Hermansen, J.E. (2014). Carbon footprints of crops from organic and conventional arable crop rotations - Using a life cycle assessment approach. Journal of Cleaner Production 64, 609–618. doi: 10.1016/j.jclepro.2013.07.009

Kristensen, T., Søegaard, K., Eriksen, J., Mogensen, L. (2015). Carbon footprint of cheese produced on milk from Holstein and Jersey cows fed hay differing in herb content. Journal of Cleaner Production 101, 229–237. doi: 10.1016/j.jclepro.2015.03.087

Lean, M. (2016). http://www.gla.ac.uk/schools/medicine/staff/mikelean/

Leinonen, I, Williams, A. G., Wiseman, J., Guy, J., Kyriazakis, I. (2012a). Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: Egg production systems. Poultry Science 91, 26-40. doi: 10.3382/ps.2011-01635

Leinonen, I, Williams, A. G., Wiseman, J., Guy, J., Kyriazakis, I. (2012b). Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: Broiler production systems. Poultry Science 91, 8-25. doi: 10.3382/ps.2011-01634

Leinonen, I., Williams, A.G., Kyriazakis, I. (2015). Comparing the environmental impacts of UK turkey production systems using analytical error propagation in uncertainty analysis. Journal of Cleaner Production 112, 141-148. doi: 10.1016/j.jclepro.2015.06.024

Leinonen, I., Williams, A.G., Waller, A.H., Kyriazakis, I. (2014). Comparing the environmental impacts of alternative protein crops in poultry diets: The consequences of uncertainty. Agricultural Systems 121, 33-42 http://dx.doi.org/10.1016/j.agsy.2013.06.008

Leiva, F., Saenz-Díez, J.-C., Martínez, E., Jiménez, E., Blanco, J. (2016). Environmental impact of mushroom compost production. Journal of the Science of Food and Agriculture 96, 3983–3990. doi: 10.1002/jsfa.7587

Martins, L., Eugenio, F., Rodrigues, W., Brinate, S., Colodetti, T., Amaral, J., Jesus Junior, W., Ramalho, J., dos Santos, A., Tomaz, M. (2016). A bitter cup: the estimation of spatial distribution of carbon balance in Coffea spp. plantations reveals increased carbon footprint in tropical regions. Plant, Soil and Environment 61, 544–552. doi: 10.17221/602/2015-PSE

Marvinney, E., Kendall, A., Brodt, S. (2015). Life cycle–based assessment of energy use and greenhouse gas emissions in almond production, Part II: Uncertainty analysis through sensitivity analysis and scenario testing. Journal of Industrial Ecology 19(6), 1019-1029. doi: 10.1111/jiec.12333

McCain (2016). Products. https://www.mccain.co.uk/products/chips/rustic-chips/

McDonald, P., Edwards, R.R., Greenhalgh, J.F.D., Morgan, C A, Sinclair, L.A., Wilkinson, R.A. (2011). Animal Nutrition (7th Edition), Prentice, Hall, Harlow.

Meier, T., Christen, O., 2013. Environmental Impacts of Dietary Recommendations and Dietary Styles: Germany As an Example. Environmental Science & Technology 47, 877–888. doi:10.1021/es302152v

Milà i Canals, L., Muñoz, I., McLaren, S., Brandão, M. (2007). LCA methodology and modelling considerations for vegetable production and consumption. CES Working Paper 02/07, University of Surrey. ISSN: 1464-8083. This paper is a result of the Rural Economy and Land Use (RELU) programme funded project RES-224-25-0044 (http://www.bangor.ac.uk/relu). Accessed 21 April 2016

MMO (2015). UK Sea Fisheries Annual Statistics Report 2014, Marine Management Organisation (MMO), https://www.gov.uk/government/statistical-data-sets/uk-sea-fisheries-annual-statistics-report-2014 Accessed 21 April 2016

Moghadasian, M.H. (2008). Advances in dietary enrichment with N-3 fatty acids. Critical Reviews in Food Science and Nutrition 48, 402–410. doi:10.1080/10408390701424303

MSS (2015). Scottish Fish Farm Production Survey 2014. Marine Scotland Science, Edinburgh, http://www.gov.scot/Resource/0048/00484806.pdf

National Institute for Health and Clinical Excellence (2010). Guidance on the prevention of cardiovascular disease at the population level. https://www.nice.org.uk/guidance/ph25

Natural England (2012). Valuing Ecosystem Services: Case Studies from Lowland England. Annex 4 - Knepp Castle Estate Re-wilding: Sussex . http://publications.naturalengland.org.uk/publication/2319433

NDNS (2014). National Diet and Nutrition Survey: results from Years 1 to 4 (combined) of the rolling programme for 2008 and 2009 to 2011 and 2012. http://tinyurl.com/NDNS-2014 Accessed 21 April 2016

Nemecek, T., Huguenin-Elie, O., Dubois, D., Gaillard, G., Schaller, B., Chervet, A. (2011a). Life cycle assessment of Swiss farming systems: II. Extensive and intensive production. Agricultural Systems 104, 233–245. doi: 10.1016/j.agsy.2010.07.007

Nemecek, T., Dubois, D., Huguenin-Elie, O., Gaillard, G. (2011b). Life cycle assessment of Swiss farming systems: I. Integrated and organic farming. Agricultural Systems 104, 217–232. doi: 10.1016/j.agsy.2010.10.002

NHS (2015). UK ban on trans fats 'would save thousands of lives'. http://www.nhs.uk/news/2015/09September/Pages/UK-ban-on-trans-fats-would-save-thousands-of-lives.aspx

NHS (2016a). Iron deficiency anaemia. http://www.nhs.uk/conditions/Anaemia-iron-deficiency-/Pages/Introduction.aspx

NHS (2016b). Vitamin B12 or folate deficiency anaemia – Diagnosis. http://www.nhs.uk/Conditions/Anaemia-vitamin-B12-and-folate-deficiency/Pages/Diagnosis.aspx

NHS (2016c). The Eatwell Guide. http://www.nhs.uk/Livewell/goodfood/Pages/the-eatwell-guide.aspx

Nikkhah, A., Khojastehpour, M., Emadi, B., Taheri-Rad, A., Khorramdel, S. (2015). Environmental impacts of peanut production system using life cycle assessment methodology. Journal of Cleaner Production 92, 84–90. doi: 10.1016/j.jclepro.2014.12.048

Nilsson, K., Flysjö, A., Davis, J., Sim, S., Unger, N., Bell, S. (2010). Comparative life cycle assessment of margarine and butter consumed in the UK, Germany and France. International Journal of Life Cycle Assessment 15, 916–926. doi: 10.1007/s11367-010-0220-3

Nogués-Bravo, D., Simberloff, D., Rahbek, C., Sanders, N.J. (2016). Rewilding is the new Pandora's box in conservation. Current Biology 26, R87–R91. http://dx.doi.org/10.1016/j.cub.2015.12.044

ONS (2014). Family Spending, 2014 Edition. http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/rel/family-spending/family-spending/2014-edition/index.html

ONS (2015). UK population mid-year estimate. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates

ONS (2016). Gross Domestic Product https://www.ons.gov.uk/economy/grossdomesticproductgdp

Paul, K., Polglase, P., Richards, G. (2003). Predicted change in soil carbon following afforestation or reforestation, and analysis of controlling factors by linking a C accounting model (CAMFor) to models of forest growth (3PG), litter decomposition (GENDEC) and soil C turnover (RothC). Forest Ecology Management 177(1–3), 485–501.

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G.P., Smith, P. (2016). Climate-smart soils. Nature 532, 49–57. doi: 10.1038/nature17174

Pelletier, N., Arsenault, N., Tyedmers, P. (2008). Scenario modeling potential eco-efficiency gains from a transition to organic agriculture: life cycle perspectives on Canadian canola, corn, soy, and wheat production. Environmental Management 42, 989–1001. doi: 10.1007/s00267-008-9155-x

Peringer, A., Schulze, K.A., Stupariu, I., Stupariu, M.-S., Rosenthal, G., Buttler, A., Gillet, F. (2016). Multi-scale feedbacks between tree regeneration traits and herbivore behavior explain the structure of pasture-woodland mosaics. Landscape Ecology 31, 913–927. doi:10.1007/s10980-015-0308-z

Point, E., Tyedmers, P., Naugler, C. (2012). Life cycle environmental impacts of wine production and consumption in Nova Scotia, Canada. Journal of Cleaner Production 27, 11–20. doi: 10.1016/j.jclepro.2011.12.035

Pollard, J., Kirk, S.F.L., Cade, J.E. (2002). Factors affecting food choice in relation to fruit and vegetable intake: a review. Nutrition Research Reviews 15, 373. doi:10.1079/NRR200244

Pribila, B.A., Hertzler, S.R., Martin, B.R., Weaver, C.M., Savaiano, D.A. (2000). "Improved lactose digestion and intolerance among African-American adolescent girls fed a dairy-rich diet". Journal of the American Dietetic Association. 100 (5): 524–8; quiz 529–30. doi:10.1016/S0002-8223(00)00162-0. PMID 10812376. Retrieved 2009-02-03.

Public Health England (2014). National Diet and Nutrition Survey: Results from Years 1-4 (combined) of the Rolling Programme (2008/2009 – 2011/12) Executive summary. Public Health England, London, UK.

Public Health England (2016a). Eatwell Guide. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/528193/Eatwell_guide_colour.pdf

Public Health England (2016b). Adult Obesity: UK and Ireland Prevalence and Trends. https://www.noo.org.uk/NOO_about_obesity/adult_obesity/UK_prevalence_and_trends

Ritchey, T. (2011), Modelling Alternative Futures with General Morphological Analysis, World Future Review, volume Spring 2011, pages 83-94

Roy, P., Nei, D., Orikasa, T., Xu, Q., Okadome, H., Nakamura, N., Shiina, T. (2009). A review of life cycle assessment (LCA) on some food products. Journal of Food Engineering 90, 1–10. doi: 10.1016/j.jfoodeng.2008.06.016

Rugani, B., Vázquez-Rowe, I., Benedetto, G., Benetto, E. (2013). A comprehensive review of carbon footprint analysis as an extended environmental indicator in the wine sector. Journal of Cleaner Production 54, 61–77. doi: 10.1016/j.jclepro.2013.04.036

SACN (2011). Dietary Reference Values for Energy. Scientific Advisory Committee on Nutrition, 2011. ISBN: 9780108511370 http://tinyurl.com/SACN-Energy-2011

Scarborough, P., Allender, S., Clarke, D., Wickramasinghe, K., Rayner, M. (2012). Modelling the health impact of environmentally sustainable dietary scenarios in the UK. European Journal of Clinical Nutrition 66, 710–715.

Scottish Government (2015). Scottish Fish Farm production Survey 2014 report http://www.gov.scot/Publications/2015/09/6580 Accessed 21 April 2016

Scottish Government (2016). Extending planning controls to marine fish farming http://www.gov.scot/Publications/2004/10/20078/45112

Sikkema R., Junginger M., McFarlane P., Faaij A. (2013). The GHG contribution of the cascaded use of harvested wood products in comparison with the use of wood for energy. A case study on available forest resources in Canada. Environmental Science and Policy 31, 96-108. http://dx.doi.org/10.1016/j.envsci.2013.03.007

Smith, G. (2008). The Jamie Oliver Effect. Andre Deutsch; 2nd Revised edition.

Spencer, I., Bann, C., Moran, D., McVittie, A., Lawrence, K., Caldwell, V. (2008). Environmental accounts for agriculture. Defra project SFS0601. Final report. Jacobs UK Ltd. London.

Statistica (2015). Gross value added (GVA) of the agri-food sector in the United Kingdom (UK) in 2014, by sector (in billion GBP). https://www.statista.com/statistics/281923/agri-food-sectors-gross-value-added-in-the-united-kingdom-uk-by-sector/

Stern, N. (2007). The Economics of Climate Change: The Stern Review. Cambridge University Press, Cambridge. http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf

Sustainable Brands (2016). Mars UK Advises Limited Consumption of Its Products High in Salt, Sugar, Fat http://www.sustainablebrands.com/news_and_views/marketing_comms/sustainable_brands/mars_uk_advises_limited_consumption_its_products_h

Svanes, E., Aronsson, A.K.S. (2013). Carbon footprint of a Cavendish banana supply chain. International Journal of Life Cycle Assessment 18, 1450–1464. doi: 10.1007/s11367-013-0602-4

Tassou, S., Hadawey, A., Ge, Y., Marriot, D. (2009). Final report on "Greenhouse gas impacts of food retailing". Defra-funded project FO0405. http://tinyurl.com/Defra-FO0405 Accessed 21 April 2016

Taylor, J.R.N., Emmambux, M.N., Kruger, J. (2015). Developments in modulating glycaemic response in starchy cereal foods. Starch - Stärke 67, 79–89. doi:10.1002/star.201400192NHS (2016) http://www.nhs.uk/Livewell/Vegetarianhealth/Pages/Vegetarianhealthhome.aspx

Temme, E.H., van der Voet, H., Thissen, J.T., Verkaik-Kloosterman, J., van Donkersgoed, G., Nonhebel, S., 2013. Replacement of meat and dairy by plant-derived foods: estimated effects on land use, iron and SFA intakes in young Dutch adult females. Public Health Nutrition 16, 1900–1907. doi:10.1017/S1368980013000232

Thanawong, K., Perret, S.R., Basset-Mens, C. (2014). Eco-efficiency of paddy rice production in Northeastern Thailand: a comparison of rain-fed and irrigated cropping systems. Journal of Cleaner Production 73, 204–217. doi: 10.1016/j.jclepro.2013.12.067

Thomson, A.M. (editor), D.C. Mobbs, R. Milne, U. Skiba, A., Clark, P.E. Levy, N. Ostle, S.K. Jones, M.F. Billett, M. van Oijen , N. Ostle, B. Foereid, W.S. Fung, P. Smith, Alice Holt: R.W. Matthews, E. Mackie, P. Bellamy, M. Rivas-Casado, J. Grace, C. Jordan, A. Higgins, R.W. Tomlinson (2008). Inventory and projections of UK emissions by sources and removals by sinks due to land use, land use change and forestry. Annual report for Defra Project GA01088

UN (1979). Convention on long-range transboundary air pollution http://www.unece.org/fileadmin/DAM/env/lrtap/full%20text/1979.CLRTAP.e.pdf

Upson, M.A., Burgess, P.J., Morison, J.I.L. (2016). Soil carbon changes after establishing woodland and agroforestry trees in a grazed pasture. Geoderma 283, 10-20.

van Dooren, C., Marinussen, M., Blonk, H., Aiking, H., Vellinga, P., 2014. Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns. Food Policy 44, 36–46. doi:10.1016/j.foodpol.2013.11.002

van Middelaar, C.E., Berentsen, P.B.M., Dolman, M.A., de Boer, I.J.M. (2011). Eco-efficiency in the production chain of Dutch semi-hard cheese. Livestock Science 139, 91–99. doi: 10.1016/j.livsci.2011.03.013

van Rikxoort, H. van, Schroth, G., Läderach, P., Rodríguez-Sánchez, B. (2014). Carbon footprints and carbon stocks reveal climate-friendly coffee production. Agronomy for Sustaintainable Development 34, 887–897. doi: 10.1007/s13593-014-0223-8

VEERU (2016). Research reports by the Veterinary Epidemiology and Economics Research Unit (VEERU), Department of Agriculture, The University of Reading http://www.veeru.rdg.ac.uk/section1/Research.htm

Vegetarian Society (2016). Fact sheets https://www.vegsoc.org/veggieaware

Webb, J., Audsley, E., Williams, A., Pearn, K., Chatterton, J. (2014). Can UK livestock production be configured to maintain production while meeting targets to reduce emissions of greenhouse gases and ammonia? Journal of Cleaner Production 83, 204–211. doi:10.1016/j.jclepro.2014.06.085

Webb, J., Williams, A.G., Hope, E., Evans, D., Moorhouse, E. (2013). Do foods imported into the UK have a greater environmental impact than the same foods produced within the UK? International Journal for Life Cycle Assessment 18, 1325–1343. doi: 10.1007/s11367-013-0576-2

Westhoek, H., Lesschen, J.P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D., Leip, A., van Grinsven, H., Sutton, M.A., Oenema, O. (2014). Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. Global Environmental Change 26, 196–205. doi:10.1016/j.gloenvcha.2014.02.004

Williams, A.G., Audsley, E., Sandars, D.L. (2007). Environmental burdens of livestock production systems derived from life cycle assessment (LCA). In: Garnsworthy, P. (Ed), 41st University of Nottingham Feed Conference, Sutton Bonington, Nottingham, Nottingham: Nottingham University, 171-200

Williams, A.G., Audsley, E., Sandars, D.L. (2006). Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. (IS0205). www.agrilca.org Accessed 21 April 2016

Williams, A.G., Audsley, E, Chatterton, J.C., Murphy-Bokern, D., Brander, M. (2010). Greenhouse gas emissions from UK food and drink consumption by systems LCA: current and possible futures. LCA-Food 2010: VII International conference on Life Cycle Assessment in the agri-food sector. Bari, 22-24th September 2010, p 363-368, University of Bari, Eds. Notarnicola, B., Settani, E., Tassielli, G., Giungato, P.

Wiltshire, J., Tucker, G., Williams, A.G., Foster, C., Wynn, S., Thorn, R., Chadwick, D. (2009). Scenario building to test and inform the development of a BSI method for assessing GHG emissions from food. Final report to Defra on research project FO0404, London. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=1856&FromSearch=Y&Publisher=1&SearchText=FO0404&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

WRAP (2010). Methodology for assessing the climate change impacts of packaging optimisation under the Courtauld Commitment Phase 2. http://www.wrap.org.uk/sites/files/wrap/Carbon_Methodology_-_Nov_2010_V101.f1571b4f.10324.pdf Accessed 21 April 2016

WRAP (2013a). Household Food and Drink Waste in the United Kingdom 2012. ISBN: 978-1-84405-458-9. http://www.wrap.org.uk/sites/files/wrap/hhfdw-2012-summary.pdf Accessed 21 April 2016

WRAP (2013b). Waste in the UK Hospitality and Food Service Sector – Full Technical Report available on application at www.WRAP.org.uk. Accessed 21 April 2016

Appendix A. Summary of the interim report on scenario development

The interim report presented the process and outcomes of the development of future scenarios of UK food consumption and evaluating their impact on UK diets. The document starts with a review of the driving forces for change in diets, which were examined using a PESTE (Political, Economic, Socio-demographic, Technological, Environmental) analysis based on publicly available information. The PESTE analysis was carried out to identify the key drivers for potential dietary change within the UK Society.

Among the political factors analysed there were public procurements, responsibility deals, food labelling, school meals, curriculum, taxation, behavioural changes, campaigns and grants. Instead, food price, agricultural commodity prices; labour costs; exchange rates; energy prices; retail food prices; income; the local supply of healthy food; the economy employment, food energy requirements; UK-self-sufficiency, trade and food security; Land use and productivity and water charging combined with agricultural productivity were the economic factors considered. Several socio-demographic factors were also included in the PESTE analysis, such as population trends and structure, the ageing of population, long-term migration, household composition, lifestyle and health trends, energy intake, dietary and eating out trends, attitudes towards health and the behaviour of the ethical costumer. In the PESTE analysis, the technological factors included were the introduction of novel technologies and the information and communication technologies (ICT). Instead the environmental factors considered were greenhouse gas emissions, pollution, water, waste, soil and biodiversity.

This analysis was used as an input for a series of workshops with stakeholders. These workshops, which were supported by over 40 delegates representing food producers, retailers, government, academia and NGOs, were aimed at developing future scenarios of food consumption in the UK drawing on expertise from multiple stakeholders. During these, a morphological analysis was carried out to develop the scenarios. The morphological analysis consists in 5 separate phases: system analysis and key drivers identifications, projection development, consistency analysis, Raw scenario selection, development and validation of scenario narratives. The consistency analysis was based on scoring different key factor projections to discover the interactions between them. Five different scenario were developed scenario 0 “the more we change the more we stay the same”; Scenario 2 “taking responsibility”, scenario 3 “big brother”, Scenario 4 “Tightening the belt” (renamed “diverging diets” in the current report), Scenario 5 “Living for the third age”. For each scenario, an assessment of nutrient and energy content of diets was carried out and a specific diet was associated with them in a specific workshop.

The scenario 0 “the more we change the more we stay the same” assumes that current trends continue. It was the most likely future identified by our stakeholders. There has been little change in the make-up of our diets or in the patterns of eating in and out of the home, though over the twenty years food has become relatively more expensive. There have been incremental changes to the foods which make up our diets but no wholesale acceptance that diets are either unhealthy or unsustainable. Education is underpinning some long-term improvement. There have also been several campaigns aimed at changing the way we eat which have resonated with certain sections of society.

The Scenario 2 “taking responsibility” pictures a future in which individuals have assumed greater responsibility for dietary health. It has resulted from campaigns led by NGOs who have highlighted the link between what people eat and their health. In particular, famine in parts of the world affecting over 1 billion people questioned the morality of food waste and excessive consumption in the West. There is also widespread recognition that food production can have an adverse impact on the environment. People have changed their diets to eat healthily; they are more self-sufficient and take an ethical stance on all their food purchasing decisions. Food is not scarce it has increased in price but not relatively compared with the previous decade.

The Scenario 3 “Big brother” pictures a future in which both public and private sector organisations have worked together to bring about significant changes in what people eat. These changes were driven by the need to improve resource efficiency: in Government because of continued rising costs in the NHS, in industry because their environmental impacts became increasingly priced in the market. While people understood there was a link between their diets and health and the impact of food production on the environment, they relied on others to make the hard choices for them. This approach has brought beneficial changes, though the public are sceptical about the motives of corporations.

The Scenario 4 “Tightening the belt” pictures a future in which there has been a sustained increase in the price of certain foods driven by global demand from China and India in particular and near collapse in stocks. A succession of poor harvests across the world contributed to this state. As more of the world’s population look to adopt a ‘western’ style diet this has resulted in scarcities throughout the EU. The UK economy never fully recovered from the recession of 2009 and austerity is still the order of the day. People had to tighten their belts and started to shop around changing both their purchasing habits and the composition of their diets.

Finally, the Scenario 5 “Living for the Third Age” pictures a future in which diets have changed radically and individuals see it is in their long-term interest to adhere to Eatwell guidance. A conflation of events brought this about. The UK economy went through a long period of austerity and disposable incomes grew only slowly. At the same time the price of food increased relatively because of a succession of poor harvests and rising global demand for ‘western style’ diets. The costs of age-related items like pensions and health care were transferred increasingly from the State to individuals. Society adopted lifestyles that maximise longevity which led to choice editing by food companies and product re-formulations.

Assessing the environmental impacts of healthier diets. Final report to Defra on project FO0427

Williams, Adrian

2018-09-27

Williams A, Morris J, Audsley E, et al., (2018) Assessing the environmental impacts of healthier diets. Final report to Defra on project FO0427. School of Water, Energy and Environment, Cranfield University, September 2018

http://dspace.lib.cranfield.ac.uk/handle/1826/13574