Paper prepared for the International Ecological Footprint Conference, Cardiff, 8-10 May 2007:
Stepping up the Pace: New Developments in Ecological Footprint Methodology, Applications

A0001-33

Our health, our environment:
The Ecological Footprint of what we eat

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Abstract: Links between poor nutrition and a range of serious illnesses such as obesity and coronary heart disease have long been established. In this study we describe how different diets, food components, and production methods can be evaluated using the Ecological Footprint. We also present the results of a randomly selected sample from a "typical" Scottish pre-"Hungry for Success" campaign (H4S) school menu compared to a menu that meets the nutritional H4S standards. The method accounts for direct and indirect environmental impacts, combining existing National Footprint Accounts with input-output-analysis. Based on data from the UK National Food Survey, the final Footprints were modelled using the REAP software tool. The results show that by eating a diet that follows nutrition recommendations, the Ecological Footprint can be reduced significantly. Further reductions could be achieved by choosing plant based over animal based foods, and local over imported food. We will demonstrate that an integrated policy approach is needed to address the problems in food production and consumption from a health, environmental, and socio-economic perspective.

Keywords: Food consumption, diets, public health, direct and indirect environmental impacts, Ecological Footprint

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1. Introduction

1.1. Health

The food we eat, and the way it is produced and manufactured, has a significant impact on public health, the environment, and the economy. Figures from England, Scotland, and Wales show that obesity and associated diseases are increasing rapidly. Treating diet-related illnesses costs the NHS at least £2bn each year (NHS, 2005; WHS, 2004; BHF, 1998). However, obesity is a serious problem world wide (Schäfer Elinder, 2005).

Nutrition-related diseases such as obesity, coronary heart disease and diabetes result in costs for providing in-patient care in hospitals, annual GP visits, community care, NHS prescriptions, and workdays lost through illness or invalidity as a result of diet-related ill health (DoH, 2003). Obesity is mainly caused by over-consumption of low cost, energy-dense foods and a lack of physical activity, in turn, these behaviours are influenced by economic and social factors including income inequality in developed countries (Pickett et al., 2005).

1.2. The costs of over-production and over-consumption

Worldwide, 2 billion people live on an animal based diet and 4 billion on a plant-based diet. During the latter half of the 20th century, world population doubled while meat consumption quadrupled (De Boer et al., 2006). Environmental impacts from agriculture are expected to increase further due to trade and trends in the food market (ibid.).

Flanked by the sedentary lifestyles of most EU citizens, this situation must also be seen within the wider economic and environmental context.

Over the last decades, improvements in agricultural productivity have lead to a massive increase in energy intake, eased by declining real prices for food (Schäfer Elinder, 2005). Several studies have suggested that overproduction of food followed by excessive consumption is the main cause for an increase in Body-Mass-Index (BMI) in developed countries (ibid.; Putnam, et al., 2002; Silventoinen et al., 2004)). In developed countries, being overweight is rather the norm than the exception, but at the same time, more than 3 billion people in the world are malnourished (Pimentel & Pimentel, 2003a).

In North-Western Europe, increasing incomes since the 1880s have led to stark long-term increases in animal products (Grigg, 1995). However, while the EU’s Council Resolution on Health and Nutrition has called its Member States to promote healthy eating habits and wants to see nutrition integrated into Public Health and associated sectors such as agriculture (EC, 2002) the EU also spends around €2bn per year on the dairy sector alone to maintain production levels above 20% of domestic demand. So far, the EU’s Common Agriculture Reform has only achieved a 1% reduction in the production of grains and livestock (Schäfer Elinder, 2005). OECD wide, agricultural subsidies amounted to $350bn (£194bn /€288bn) in 2003 (OECD, 2004). These are paid in equal amounts by taxpayers and consumers (Schäfer Elinder, 2005).

1.3. Feeding the world

Currently, word population is growing at an annual rate of 1.2%, equivalent to an addition of 77 millions of people per year. Proportions for world cereal production that is used for livestock range between 40 and 75 % (De Boer et al., 2006; Carvalho, 2006). With a maximum world grain capacity estimated at 3300 million tonnes – 60% more than today – and a world net population growth estimated between 26 and 73 per cent, the gap between food production capacity and global population levels is set to widen until 2050 (Gilland, 2002; Carvalho, 2006). Slowing population growth along increasing agricultural production are therefore seen by some as crucial in combating under-nourishment and feeding the global population; at the same time, agricultural intensification as historically experienced in the “green revolution” will further entail the inputs of fossil fuels while the use of pesticides in particular has had a profound impact on biodiversity. Furthermore, technology may not be able to provide the miraculous solutions needed to feed an ever growing population (ibid.). According to the Food and Agriculture Organization, "sustainable intensification without further degradation of natural resources and environment still remains a challenge" (FAO, 2003). This statement was also echoed in the Millenium Ecosystem Assessment report (MEA, 2005).

1.4. Environmental impacts

Because providing food causes environmental impacts from local to global levels (Wood et al., 2006) impacts can be worsened severely by over-consumption and overproduction of food.

Livestock production is the single largest user of land. It has important implications for ecosystems and ecosystem services, either directly through grazing or indirectly from feedstock production (Bruinsma, 2003). Environmental impacts from agriculture are expected to increase further due to global trade and the trends in the food market (Grigg, 1995). Although research suggests that energy efficiencies in North American, Australian, and European food systems are not directly comparable, the key global impacts of agriculture on the environment can be summarised as:

- Erosion and soil degradation of about one third of the world’s cropland over the last 40 years.
- Agriculture is responsible for 80% of deforestation (Pimentel, 1994; Kendall and Pimentel, 2004).
- Water stress: Agriculture is highly water intensive, ranging from between 500 to 2000 litres of water per kg of various crops to between 150,000 to 200,000 litres per kg of fresh beef – mostly for growing the feeding crops (Pimentel & Pimentel, 2003b; Wood et al. 2006; WWF et al., 2006).
- Pressure from greenhouse gas emissions (ibid.).

Not accounting for processing, distribution and preparation, global agriculture consumes between 20 to sometimes more than 50% of the direct energy within the total food supply chain (Wood et al., 2006; Hoffmann, 2002 and 2004). Furthermore, livestock production in general, but non-rangeland systems in particular, are one of the most inefficient ways to provide protein. For example, 6 kg of high-quality plant protein is required to gain 1kg of high-quality meat (Goodland, 1997; Pimentel & Pimentel, 2003b). In the US, where the population doubled over the past 60 years and is expected to double again in the next 70 years, food production systems use 50% of the total US land area, about 80% of the fresh water, and 17% of the fossil energy supply. US livestock currently consumes 7 times more grain than what is directly eaten by the population. Annually, 90% of US cropland loses soil 13 times faster than is sustainable; in addition, 60% of pastures are overgrazed and eroding (Pimentel & Pimentel, 2003b).

Using an extended input –output approach for Europe, research on behalf of the European Commission identified meat and meat products, followed by dairy, as those with the greatest environmental impacts for the total production chain including distribution (Tukker et al., 2006). Life cycle results from a Swedish study (Carlsson-Kanayama et al., 2003) identified food consumption as one of the most polluting activities. The detailed results were less clear-cut, however, because the magnitude of environmental impacts from different products varied due to a multitude of factors related to animal or plant origin, processing, technology, and distribution.

The UK food chain is also very resource intensive, with the largest economic activities and environmental burdens generally located at the processing stage and subsequently, households who purchase these products. For the UK economy, per year agriculture produces 90 million tonnes in material flows, food and drink processing 80 millions, and imports associated with food 34 million tonnes (Barrett et al., 2006). Research conducted by the Stockholm Environment Institute (SEI) has quantified the differences of various diets for the UK in terms of the Ecological Footprint, including meat and plant based diets, and between imported and exported food (Barrett et al., 2006; Frey and Barrett, 2006).

For meat, dairy and fish products, the latest report commissioned by Defra on Environmental Impacts of Food Production and Consumption highlights the prominent role of the agricultural stage in terms of global warming impacts and acidification (Foster et al., 2006). Unfortunately, the results from these different studies presented in this section are not directly comparable as they vary regarding research methods, scope and goals, set of indicators, data consistency and system boundaries.

This paper does not aim to address the carrying capacity for different food systems or diets. Rather, using an input-output approach supported by bottom-up data, we present first estimates of the Ecological Footprint for different diets, school menus, imported and exported food, and between organic and conventional produce.

2. *Method and assumptions*

The Ecological Footprint is a sustainability indicator that measures the total environmental pressure of the human population in spatial terms. It estimates the land and sea area that is needed to provide all the resources for a population in a given area, and for absorbing its emissions. The Footprint is calculated as a standardized area equivalent to a world average area, expressed in global hectares (gha). It provides a snapshot of consumption for a region, organisation, or person in a given year. SEI's approach includes direct and indirect environmental impacts and ensures that the method is consistent with the Global Footprint Network accounts. The food Footprints were based on the latest available physical data from the National Food Survey (NFS) in the UK. NFS data have been matched with UK food consumption data and the final Footprints were modelled using the REAP software tool[1]. The most recent method has been described in several publications by SEI, for example, Wiedmann et al. (2006).

REAP is a sophisticated model developed by SEI with CURE and WWF that measures the environmental pressures associated with human consumption. It and can be used at the local, regional and national level and assess the full life-cycle impacts of greenhouse gas emissions, air pollutants, energy consumption, heavy metals, Ecological Footprint, and material flows of products and services. REAP can also model the impacts of different policies and create plausible scenarios of the future. These can then be set against targets or compared to alternative futures based on selected trends or

[1] http://www.sei.se/reap

assumptions. All indicators take into account the direct and indirect pressures of consumption of products and services throughout the full economic supply chain.

In this paper we compare the average UK food Footprint with Footprints from diets that are comparable to the UK's Dietary Reference Values. The nutritional energy value of the average UK diet was not assessed. For a meaningful comparison of diets, food amounts were based on the Optimized Mixed Diet concept for children and adolescents developed by Kersting et al. (2005) using the Food and Agriculture Organization's and World Health Organization's *Food based Dietary Guidelines*. This approach provides quantitative recommendations for daily food amounts to meet nutritional standards. Since the concept is framed around 11 food categories it is flexible enough to allow for a variety of dietary choices within the nutrition recommendations. As a first approach, these were used for comparison with the average UK diet and adjusted for different energy recommendations. The recommendations were extrapolated for adults and adjusted to vegetarian diets in line with nutrition recommendations by the German Nutrition Society and the British Dietetic Association (DGE, 2004; BDA, 2004; Kersting, 2006).

3. Results

3.1. Differences between the average UK diet and a "healthy" diet

In terms of annual tonnes consumed, the average UK diet contained considerably less (around 40 %) amounts of food than suggested in the healthy diet. This, however, does not say anything about the nutritional or caloric value of the food eaten but could be explained by imbalances in eating habits, such as preferences for energy-dense foods. Table 1 compares the different food proportions eaten by the average person in the UK, and the food proportions in the example of a health diet. In comparison with the average eating habits in the UK, the healthy option included much more fruit and vegetables, less dairy, meat, high-fat and sugar foods, and no alcohol. While beverages in the healthy eating example consisted of mineral water, they contained mainly soft and alcoholic drinks (14% and 4%) for the UK average diet.

Food group proportions	Recommended %	UK average %
Beverages and plant foods		
Beverages (water, fruit juices)	21	20
Vegetables	10	10
Fruit	30	10
Bread/Cereals	13	14
Potatoes/Pasta	4	8
…..subtotal	**78**	**62**
Animal foods		
Milk/Milk products	15	20
Meat/Sausages	2	9
Eggs	<1	1
Fish	<1	1
…..subtotal	**19**	**31**
High-Fat, High-sugar foods		
Tolerated food groups (sweets, sugar…)	2	5
Oils/ Fats	1	2
…..subtotal	**3**	**7**

Table 1. Comparison of recommended food selection based on Kersting et al. (2005) with UK averages.

For food consumed within the home the food Footprint of the average person in the UK was 0.82 global hectares (gha) compared with 0.64 gha per person for the healthy diet. This is a reduction of 22%, despite the much higher amounts of food consumed (Figure 1). In terms of the Ecological Footprint per tonne of food eaten, the average UK diet is 128% higher than for the healthy option (1.42 gha per tonne compared to 0.62 gha per tonne). Figure 2 shows that the different food choices have different Footprints. Most of the impacts in the diet of the average person in the UK came from high meat consumption; this was responsible for almost half of the impacts (46%) followed by dairy products (9%) and alcoholic drinks (8%). The high Footprint of meat products was due to the large area of land needed for growing fodder, and the energy used in production, processing and distribution. In contrast, the ecological profile of the healthy diet reflected a higher consumption of fruit, vegetables and cereals, and only a moderate proportion of meat products. Although meat still has a relatively high Footprint in the healthy diet (16%), the healthy option contained only 2% meat compared to 9% in the average diet.

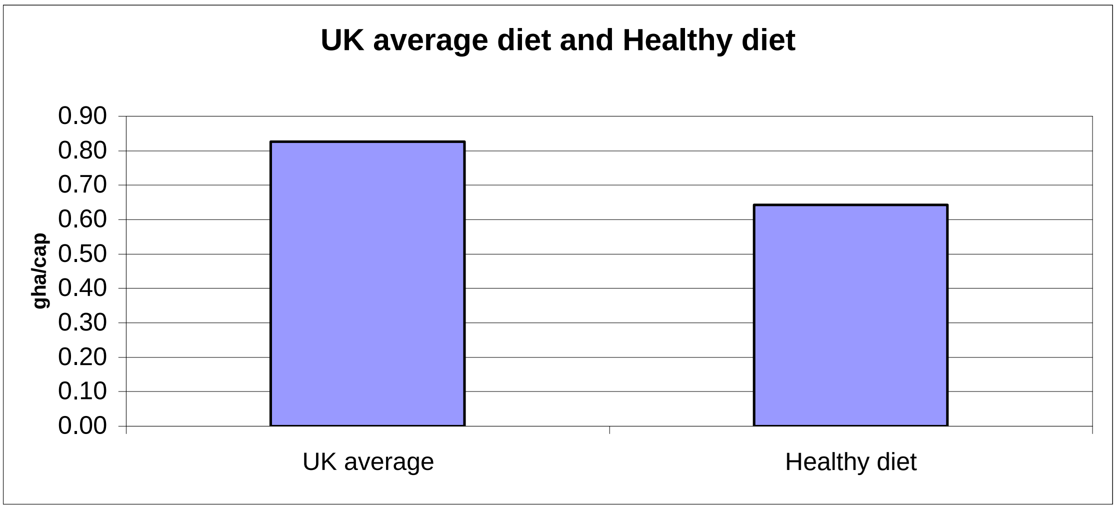

Figure 1. Comparison UK average with healthy diet

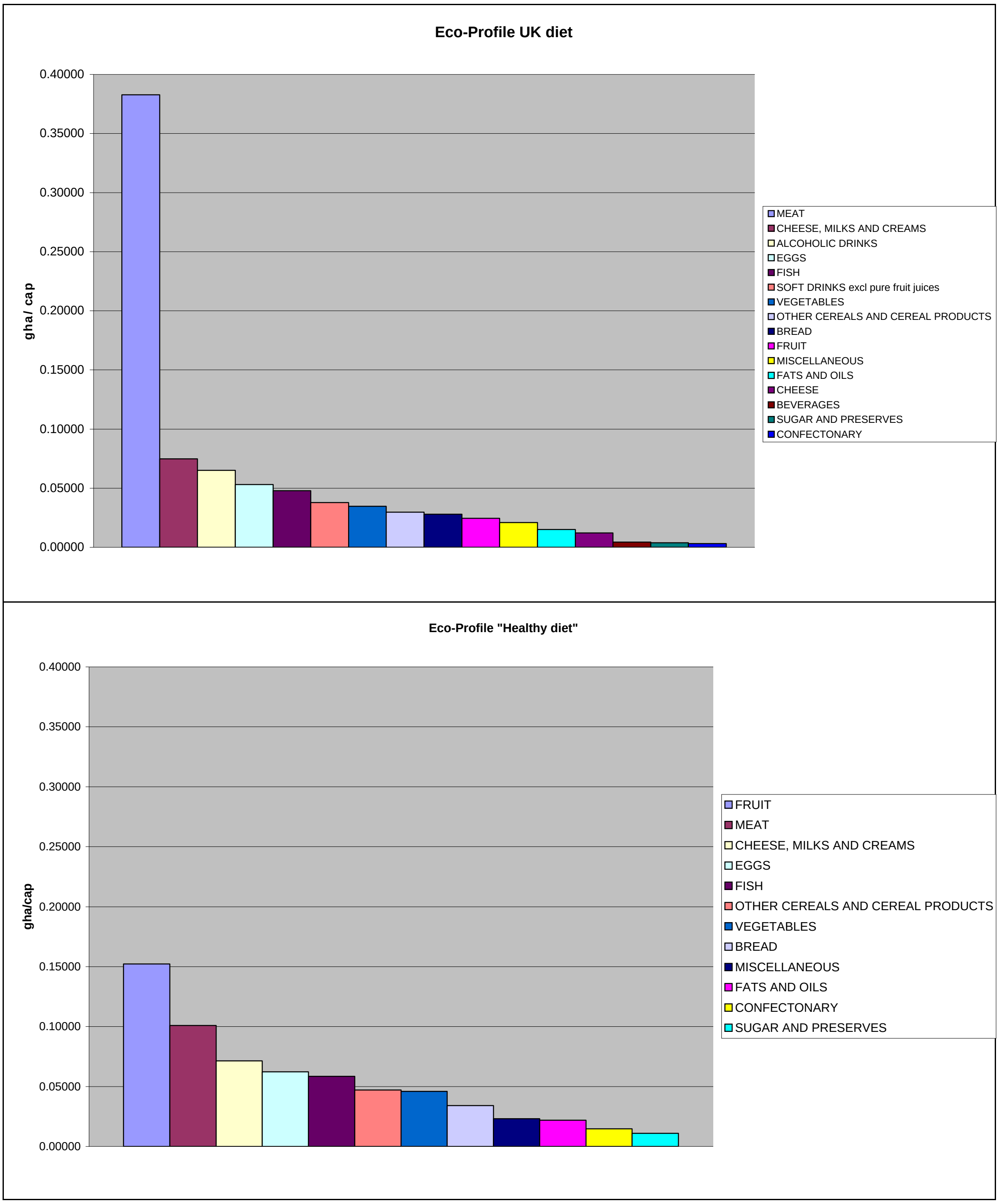

Figure 2. Comparison average UK diet and a diet that meets nutrition recommendations

3.2. *Comparison of different school lunches*

Our study also measured the Ecological Footprint of two typical meal menu choices as served in Scottish schools. The menu choice before the introduction of “Hungry for Success” (H4S) campaign in Scotland was a cheese pizza accompanied by potato chips, peas, soft drink, dessert of apple crumble and skimmed milk. The H4S menu choice consisted of chicken-vegetable curry accompanied by rice, boiled potatoes, and fruit yoghurt for dessert. It was prepared according to the Scottish nutrient standards for school lunches, which are based on UK Dietary Reference Values (Figure 3).

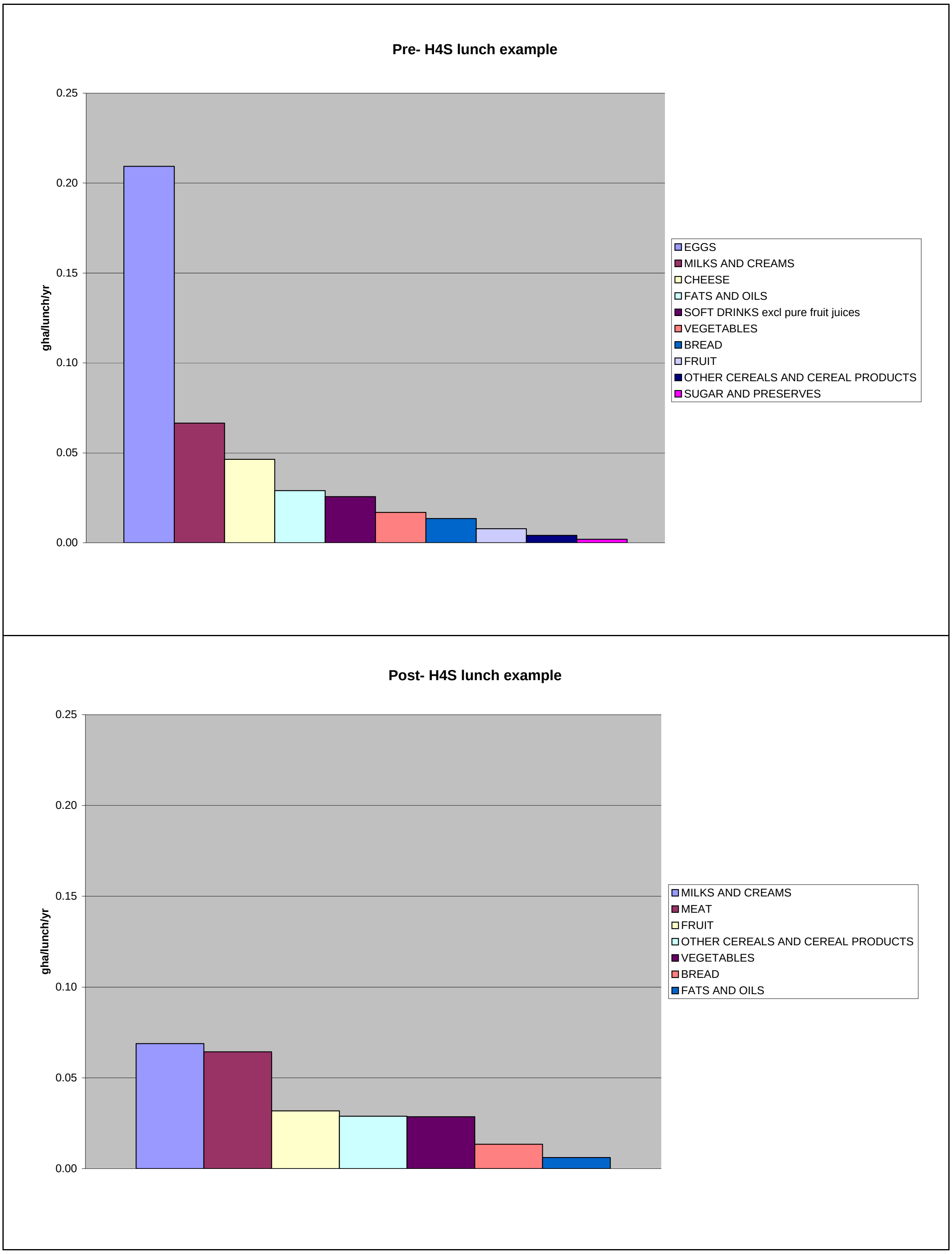

Figure 3. Footprint of school lunch example before and after "Hungry for Success" in Scotland

These menus are just two examples of possible, different food choices that did not attempt to provide a nutritional evaluation but show that a significant Footprint reduction can be achieved by a healthier choice:

- The Footprint of the H4S menu is 42% lower than before and had 83% fewer added fats compared to the previous menu.
- Eggs, milk, cheese and fats had the highest Footprints in the Pre- H4S lunch.
- The H4S menu contained only half the amount of animal products compared to the Pre-H4S menu.
- Although dairy products and meat also had the highest Footprints in the H4S menu, their footprints were 50% lower than in the previous choice.
- Even without meat, a lunch can have a high Footprint if ingredients are not chosen wisely. For example, too much fat, eggs and dairy products can result in a relatively high Footprint.

These results suggest that a wide uptake of "Hungry for Success" menus could provide substantial benefits not just for health but also the environment. However, more detailed, wider and long-term studies are needed to verify this.

3.3. Comparing a healthy vegetarian diet with a healthy low-meat diet

A vegetarian diet that is varied and rich in wholegrain products, vegetables, pulses and fruit, and that includes moderate amounts of dairy products and eggs, can meet the requirements of a healthy and wholesome diet. In addition, the low amounts of animal fats and cholesterol are beneficial in preventing obesity and coronary heart disease (DGE, 2004; Elmadfa and Leitzmann, 1990). A vegetarian diet that includes moderate amounts of milk and eggs can reduce the Footprint by 40% compared with a diet that is low in meat products but that also meets nutrition recommendations (Figure 4 and Figure 5).

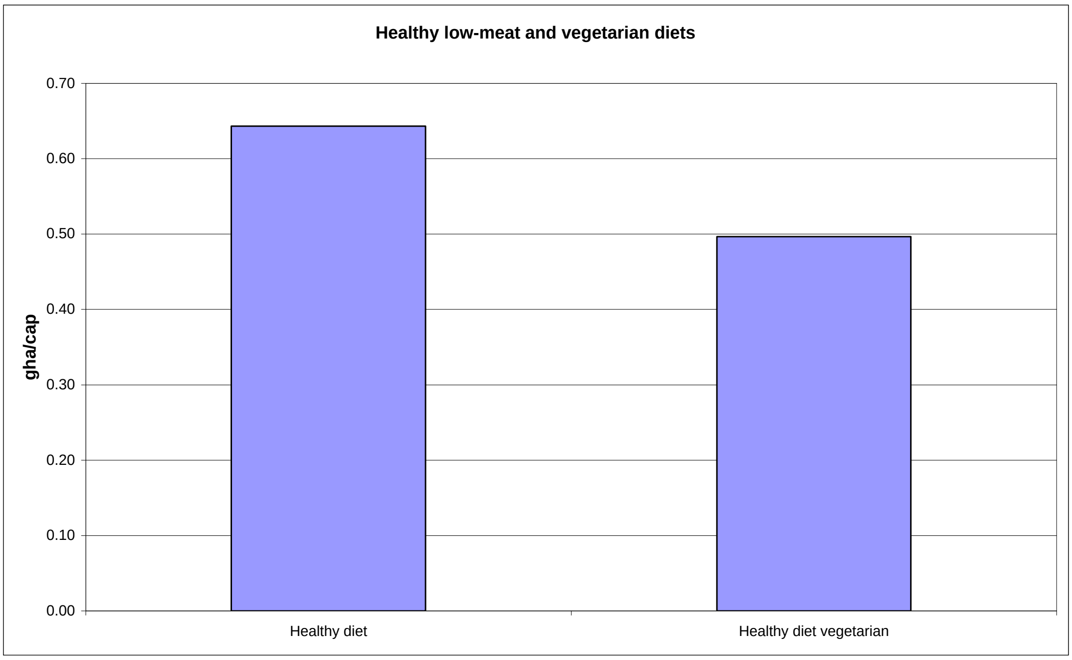

Figure 4. Comparison vegetarian and low-meat diet, both meeting nutrition standards

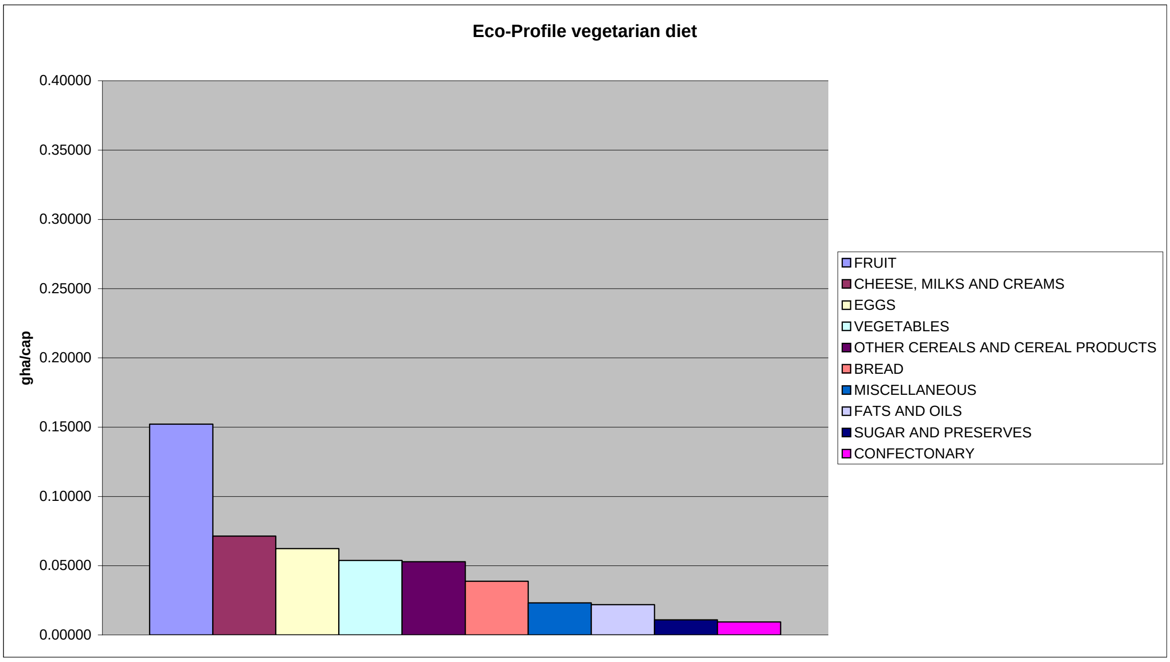

Figure 5. Ecological profile of a healthy vegetarian diet

3.4. British and imported food

The UK currently imports around 40% of its food (SEI, 2006). If all food consumed in the UK was also produced in the UK, the food Footprint could be reduced by 57% per capita compared to a diet based entirely on imports (Figure 6). With regard to imported and local food, this study looked at the macro level of national material flows from imports and thus did not disaggregate domestic transport into private consumer food shopping. Although the REAP software accounts for transport by final demand, it was not possible to include this within the scope of this study. This, however, could be done in future projects.

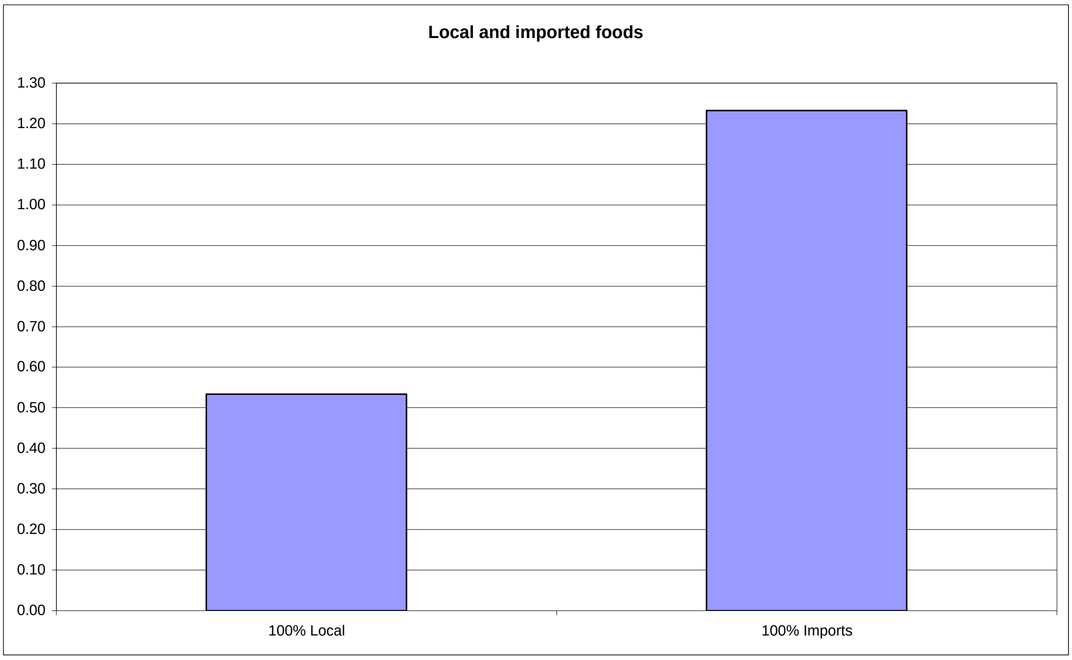

Figure 6. Comparison imported and local (British) food

3.5. Organic compared to conventional food

SEI's input-output based results for the UK show that eating organic food can reduce the average food Footprint by a further 2% (Figure 7). Due to data availability, presently not all direct and indirect resource flows in organic production systems could be included.

Present life cycle studies that compare the environmental impacts of both farming systems are inconclusive because of high variations between different products, different environmental indicators, functional units (for example, impacts per product or per area) or simply due to comparability problems (De Boer, 2003; Williams et al., 2005; Foster et al., 2006; Van der Werf et al., 2007). Wood et al. (2006) used a hybrid life cycle assessment / input output approach and included all direct and indirect effects of both farming systems for Australia (Wood et al., 2006). The major outcomes of the study, expressed as impact per A$ spent, were:

- On-site energy requirements were slightly higher for organic farming through use of petrol and diesel fuels in weed control, manure spreading, more mechanical work, and lower employment density.
- Conventional farms used more indirect energy than organic farms, resulting in higher indirect greenhouse, nitrogen oxide, and sulphur dioxide emissions due to increased use of machinery, pesticides, fertilizers, and other chemicals.
- Significant differences in on-site and indirect impacts.
- Conventional farms had a higher water use than organic farms.
- On-site land disturbance was slightly lower for organic farms.
- Total impact intensities were all higher for conventional farming systems, in terms of energy and greenhouse gas intensity these differences were 56% and 211%, respectively.
- Some of the key results were that the total energy intensity in conventional farming systems was 56% higher than in organic farming.

Because for the UK such a comprehensive analysis is currently missing, our results for organic foods are probably underestimated.

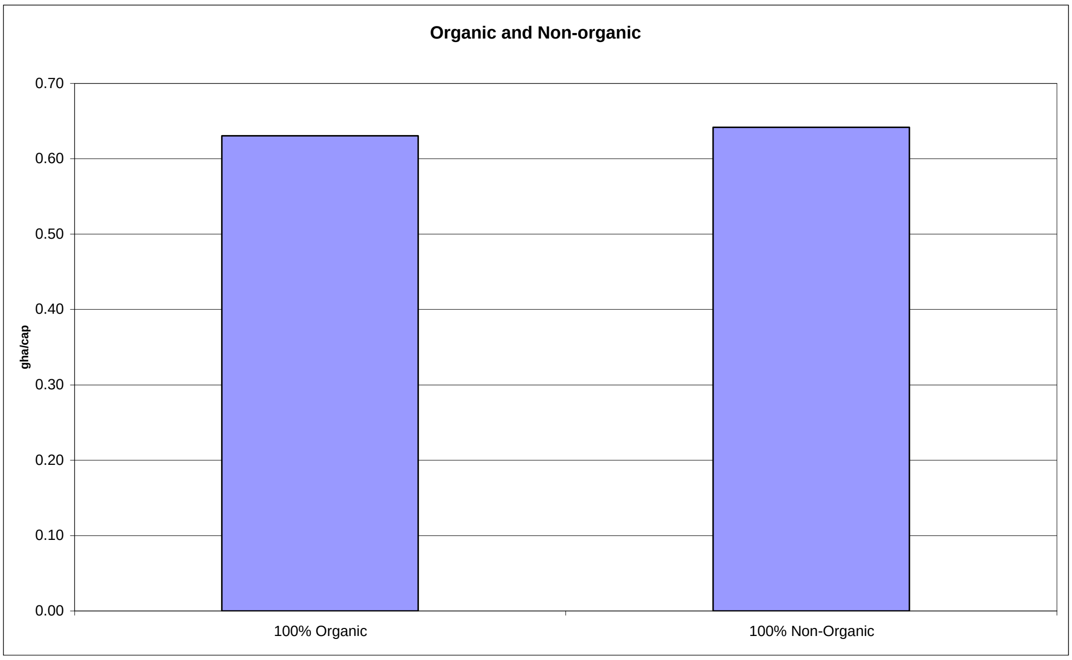

Figure 7. Organic versus conventional food

3.6. The best diet?

The ideal diet - one that meets nutritional requirements and also has the lowest Footprint possible – seems to be one that is healthy, vegetarian, local and organic. According to our results presented here, such a diet could reduce the food Footprint by 44%. In contrast, a diet consisting of 100% imports would exceed the average diet by almost half. The low-meat diet achieved a reduction of 22% compared to the UK average but the food Footprint could be reduced significantly further by choosing an organic or local diet. Note that our reduction for organic food systems is most likely conservative (Figure 8 and Table 2).

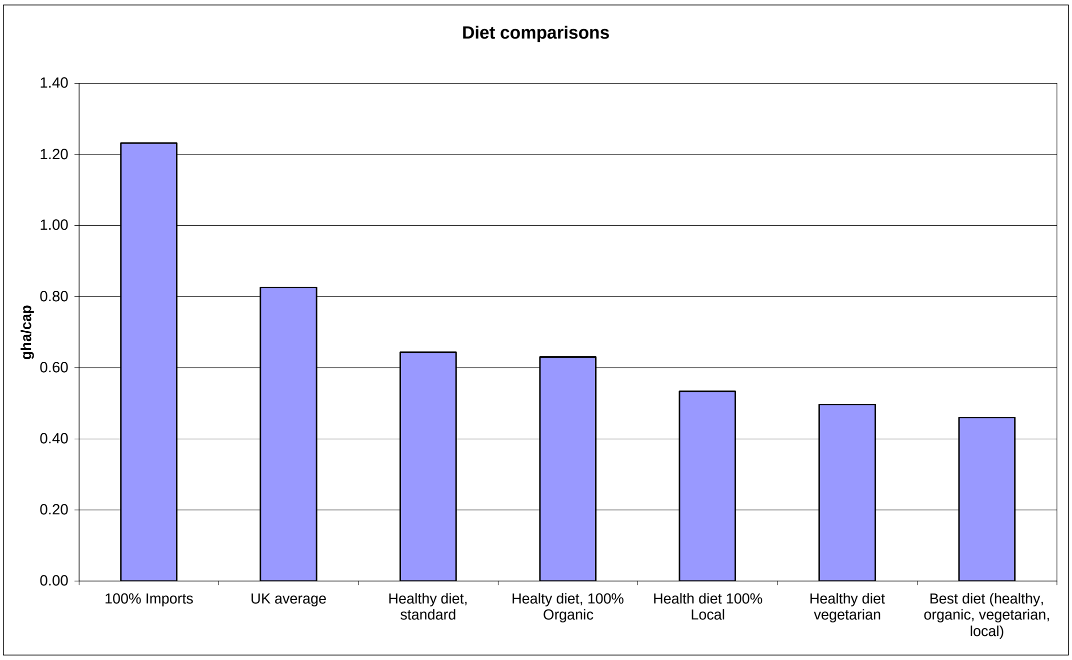

Figure 8. Ranking of different diets

Diet	Footprint (gha/cap)	Net change
100% Imports	1.23	49%
UK average	0.83	100%
Healthy diet, standard	0.64	-22%
Healthy diet, 100% Organic	0.63	-24%
Health diet 100% Local	0.53	-35%
Healthy diet vegetarian	0.50	-40%
Best diet (healthy, organic, vegetarian, local)	0.46	-44%

Table 2. Footprint results from all diets with net changes compared to UK average

4. Discussion and conclusion

The results presented in this paper showed that a healthy diet based on nutrition recommendations can reduce the Ecological Footprint by 22% compared to the average British diet - and that the Footprint can be reduced further by choosing a vegetarian option or by buying local and organic food. These results are particularly surprising since the amount of food consumed in tonnes was higher in the nutritionally balanced diets than for the average UK consumption. Since obesity is a major problem in the UK, this may be explained by unhealthy food choices, especially preferring high-fat, energy-dense foods to fruit, vegetables and cereals. This is supported by the difference in the food group proportions eaten, and because in terms of Footprint per tonne of food the Footprint for the average UK diet was 128% higher than in the healthy options.

In the school lunch example we showed that a diet not containing meat but high amounts of dairy and egg could have a higher Footprint than a healthy option that includes animal products in moderation. This finding also supports a previous study by Carlsson-Kanyama et al. (2003) for Swedish menus, although their study used a bottom-up life cycle approach. A “best diet” that serves both health and the environment is one that combines all four criteria (healthy, vegetarian, local, organic) and could reduce the UK food Footprint by around 44% per capita.

With regard to local and imported food, this study only assessed the impacts from food imports to the UK but did not disaggregate transport into food shopping by final consumers. This, however, could be done in the future. In the past, “food miles” have been identified as a significant source of CO_2 emissions. Emissions from food transport gave rise to around 20 million tonnes of CO_2 emissions in 2002, of which 10 million tonnes were emitted in the UK and the remainder overseas. They account for 1.8% of the total annual UK CO_2 emissions. Only 0.1% of UK food miles are currently due to airfreight. Although the environmental impacts from aviation are important for air freighted products, and their proportions are very small when considering the total amount of food consumed, emissions from airfreight are growing fast (DEFRA 2006; Foster et al, 2006). Life cycle data assessing particular food items suggest that the environmental impacts of car-based consumer shopping outweigh the impacts from transportation within the distribution system itself (Foster et al., 2006; Pretty et al, 2005; DEFRA 2006). If the life cycle impacts for single food items from “farm to fork” are assessed, the Swedish study by Carlsson-Kanyama et al. (2003) underlined that all life cycle stages, including refrigeration and cooking in the home, should be taken into account before conclusive results can be obtained.

At present, our examples on organic and conventional food systems are limited because not all direct and indirect impacts could be included for the UK. The current results on the environmental impacts from both farming systems are not conclusive for the UK and are solely based on life cycle assessments using a bottom-up approach. While these can provide a very high level of detail, traditional life cycle methods suffer from system boundary problems, incompleteness, and lack of comparability. To our knowledge, the most comprehensive analysis of both systems is the study by Wood et al. (2006) for Australia, using a hybrid input-output and life cycle approach. One of the key findings of that study was that the total and indirect impacts from conventional agriculture are significantly higher than from organic agriculture. We therefore believe that our results for organic farming are underestimated and that addressing these direct and indirect impacts from upstream supply chain interactions is important for identifying areas that contribute to more sustainable farming practices. At present, such a study for the UK is missing. SEI is currently seeking funding to undertake such a study.

To conclude, food production and consumption are highly resource intensive and pose significant problems for the environment through all process stages. This applies particularly to systems that include livestock farming. In addition, excess food consumption and an imbalanced choice of foods not only have severe consequences for our individual health; they also place an unnecessary burden on the NHS, on agricultural demand, on the economy but also on sustainable development. If over-production of food leads to over-consumption, ill health, and higher economic costs then central to these problems must surely be a much stricter reduction in farm subsidies at the EU level. It is also in the interest of national and local governments to address these challenges by incorporating healthy eating firmly into the public health agenda, as already seen in Scotland, and to address the underlying socio-economic causes for obesity. In short, integrated policy approaches are needed address the problems in food production and consumption from a health, environmental, and socio-economic perspective. The problems associated with food production and consumption are not confined to the local level but have global implications – especially in terms of their global warming potential through fossil-fuel intensive agriculture, processing, transport, and the intensive use of pesticides and water. Whether future agricultural output can be reconciled with feeding a growing human population is subject to debate and not subject of this study. However, it will depend on the interaction between complex factors such as energy and other resource inputs, agricultural methods, ecological thresholds, technological change, and most likely, a significant shift in dietary patterns.

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