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Sustainable Food Consumption at a Sub-national Level: An Ecological Footprint, Nutritional and Economic Analysis

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ABSTRACT *This paper uses the ecological footprint to measure the environmental impact of food and drink consumption at a sub-national level. The case study area selected is Cardiff, the capital city of Wales. The paper begins by explaining what an ecological footprint is and how it is measured. We describe how an ecological footprint was calculated for Cardiff, with specific emphasis on the food and drink component. The main part of this paper focuses on Cardiff's ecological footprint results for food and drink and how we might begin to make residents' consumption more sustainable. We present and analyse the results of several scenarios developed to reduce the environmental impact of Cardiff's food and drink consumption. These scenarios focus on changing the type of food and drink that the average Cardiff resident consumes at home. Here we also analyse the results from a nutritional and economic perspective. Finally, in the Conclusions section we discuss the value of using the ecological footprint to measure the environmental impact of consumption at a sub-national level. We also discuss how this combined analysis can provide a more comprehensive account of food and drink consumption at the sub-national level, and better inform policy decisions on sustainable food and drink consumption.*

KEY WORDS: Ecological footprint, expenditure, nutrition, sustainable food consumption

Introduction

The production and consumption of food is resource intensive and has been shown to have large environmental consequences (McMichael, 2005; White, 2000). Our main aim has been to investigate how we can begin to make Cardiff's food and drink consumption more sustainable. Cardiff provides an interesting case study for three main reasons. First, food and drink consumption was responsible for almost 25% of Cardiff's total ecological footprint in 2001 (see Collins *et al.*, 2005, 2006). Second, Cardiff has recently produced its first 'Local Food

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and Health Strategy' (Cardiff Health Alliance, 2006). A key part of this strategy is concerned with promoting sustainable food consumption. Combining ecological footprint and nutritional analysis could assist in the implementation of this Strategy. Finally, reducing the environmental impact of the average Cardiff diet may only require residents to make marginal changes to the type of food and drink they consume and therefore could make a sustainable diet more achievable compared to some diets suggested to date, e.g., Duchin (2005) and Leitzmann (2005).

The ecological footprint has provided us with a new assessment tool by which to gain insights into the environmental impacts of food and drink consumption patterns and to begin to assess the likely effect of different scenarios in reducing this impact. We also consider how these changes impact on the consumer from a nutritional and economic perspective. The paper is organized into six sections. Below in Section 2 we briefly explain what an ecological footprint is and how it is measured. In Section 3, we outline why Cardiff Council wanted to measure the city's ecological footprint and the reason for including 'sustainability' in the Cardiff Local Food and Health Strategy. Section 4 reports on Cardiff's ecological footprint results for food and drink in 2001. In Section 5 we present the results of several scenarios developed to reduce Cardiff's footprint for domestic food and drink consumption. In this section we also analyse each scenario from a nutritional and economic perspective. Finally, in the conclusions section we briefly explain the value of using the ecological footprint to analyse the environmental impact of food and drink consumption at a sub-national level. We also discuss the value of combining the ecological footprint with a nutritional and economic analysis and how this can provide a more comprehensive approach from which to inform policy decisions on sustainable food consumption.

What is an Ecological Footprint?

The ecological footprint is an aggregated indicator of demand on nature and is measured using a standardized area unit termed a 'global hectare' (gha), and is usually expressed on a per capita basis (gha/cap). The ecological footprint estimates the area of land required to support the resource consumption of a defined population, usually for one year. For example, the demands of that population in terms of their food, travel and energy use. This demand on nature can be compared with the Earth's available biocapacity, which translates into an average of 1.8 gha/cap in 2001 (WWF, 2006). However, humanity is currently using 2.2 gha/cap which indicates a situation of 'overshoot' where nature's capital is being spent faster than it is being regenerated. Overshoot may permanently reduce the Earth's ecological capacity (WWF, 2006).

As the ecological footprint relates to the consumption activities of a defined population it has potentially many applications. For example, the footprint has been applied to organizations, cities, regions and individuals. There is currently no complete catalogue of studies undertaken in the UK, however, based on interviews conducted with key footprint consultants it is estimated that between 60 and 70 footprint studies were undertaken between 1999 and 2004 (see Collins & Flynn, in press). In the UK, local, regional and devolved governments have shown a strong interest in the footprint and the Welsh Assembly Government has formally adopted the ecological footprint as one of its headline indicators

for sustainability (National Assembly for Wales, 2004a). This paper analyses the environmental impacts of food and drink consumption at a sub-national level. The unit of analysis is Cardiff, the capital city of Wales. A recent ecological footprint study of Cardiff has shown that food and drink consumption is the largest single component and was responsible for almost a quarter of the city's overall footprint for 2001 (see Collins *et al.*, 2005, 2006).

Ecological Footprint Analysis: Strengths and Limitations

Although the ecological footprint is being widely used and applied in the UK and elsewhere, the concept has faced a number of criticisms. Amongst the main points, critics have argued that the footprint does not accurately reflect the impacts of human consumption (see Ferng, 2002; Lenzen & Murray, 2001; van den Bergh & Verbruggen, 1999); it does not allocate responsibilities of impact correctly (see Herendeen, 2000; McGregor *et al.*, 2004); and does not provide decision-makers with a useful tool for policy-making as there is limited understanding of how different consumer activities relate to impact (see Ayres, 2000; Ferng, 2002; Moffatt, 2000; van Bergh & Verbruggen, 1999; van Kooten & Bulte, 2000). A recent study has found that prior to 2003, policy development officers in UK local government were not able to engage with the ecological footprint as a process or use the results to inform policy decisions as they had limited involvement in developing an ecological footprint for their area and had a lack of trust in their footprint results (see Collins *et al.*, 2005; Collins & Flynn, in press). For a more recent critique of the ecological footprint concept see McDonald and Patterson (2004, pp. 52–54). A more general debate on the concept can be found in Ferguson (2001) and van Vuuren and Smeets (2001).

However, as the ecological footprint aggregates the impact of different consumption activities into a single measure (i.e., global hectares) it offers policy-makers the potential to clearly identify and compare the environmental impact of different activities. For example, how we travel, the food we eat and how we heat our homes. Table 1 below compares the ecological footprint for the UK, Wales and Cardiff and shows the relative size of each of the different components in the footprint. More promising still, the footprint provides the potential for policy-makers to prioritize their actions in a more informed and integrated manner. Policy-makers can thus potentially measure the effectiveness of policies to pursue sustainable development. One reason why the ecological footprint may be helpful to policy-makers is because of its communicative power. The footprint personalizes sustainability by assessing the impact of consumption from a consumer perspective (i.e., it takes into account the impact of residents within a defined boundary rather than the industries in a particular locality). It therefore has the potential to be a useful concept and tool from which to communicate to people, and for them to appreciate the link between their local (consumption) activities and global environmental impacts. Although the effectiveness of the ecological footprint as a decision support tool has yet to be demonstrated, results from an ecological footprint study of Cardiff have shown that it can support local government officers and politicians to contribute to more informed debates about a vision of a sustainable Cardiff (see Collins & Flynn, in press).

National ecological footprints (the 'National Footprint Accounts') have traditionally been calculated based on a country's domestic production, imports

Table 1. Ecological footprint for Cardiff, Wales and the UK in 2001

Component Areas	Cardiff [gha/capita]	Wales [gha/capita]	UK [gha/capita]
Food and drink [(a)]	1.33	1.29	1.34
Energy	0.99	0.92	0.90
Travel [(b)]	0.99	0.78	0.72
Housing	0.16	0.17	0.18
Consumables	0.64	0.64	0.75
Services	0.26	0.24	0.32
Holidays abroad	0.10	0.10	0.12
Capital investment [(c)]	0.74	0.74	0.74
Government [(d)]	0.41	0.41	0.41
Other [(e)]	−0.03	−0.03	0.12
Total	5.59	5.25	5.35
Waste[(f)]	0.81	0.71	0.71

Notes: For more detailed results see Barrett *et al.* (2005) and Collins *et al.* (2005). (a) Includes catering services. (b) Includes transport services and air travel. (c) Capital Investment or Gross Fixed Capital Formation (GFCF): Relates principally to investment in tangible fixed assets such as plant and machinery, transport equipment, dwellings and other buildings and structures. The Footprint calculations assume shared responsibility, i.e., equal values for UK and Wales. (d) Includes central and local government. The Footprint calculations assume shared responsibility, i.e. equal values for UK and Wales. (e) Includes non-profit institutions serving households, valuables, changes in inventories and overseas tourists in the UK; the latter one leading to an overall negative Footprint. (f) The Footprint for waste is not included in the 'standardised' Footprint calculations but instead is treated as a satellite account as the impacts of household consumption can only be counted once, either as 'inputs', when products are bought or consumed, or as 'outputs', when products are discarded. As the Footprint methodology used here considers the environmental impacts of consumables, double counting would occur if the impact of waste from these consumables was also included in the final result.

and exports of primary and secondary products together with an estimate of the embodied energy of secondary products (Monfreda *et al.*, 2004). However, this method does not assign accurately the resource flows to final consumption categories as it omits all mutual interrelationships between product sectors and excludes the environmental effects of tertiary products, e.g., services. To address these issues, researchers based at the Stockholm Environment Institute (SEI), University of York have developed a methodology that allows intermediate resource flows to be assigned to final consumption. A detailed description of this method is published in Wiedmann *et al.* (2005) and addresses issues including the accounting of capital investment, the embedded impacts throughout all consumption categories as well as limitations and assumptions inherent to the method.

The method developed by SEI takes the existing National Footprint Accounts provided by the Global Footprint Network (GFN, 2004) as a starting point. The total footprint of the UK is then disaggregated by economic sector and reallocated to final demand by using input-output analysis based on economic supply and use tables. The breakdown of final demand categories includes detailed household consumption activities according to the 'Classification of Individual Consumption According to Purpose' (COICOP) classification system and a detailed breakdown of capital investment. With this method it is possible to calculate footprints for sub-national areas (e.g., Cardiff) or socio-economic groups, whilst ensuring full comparability of results with the National Footprint Account data. The method can be applied to every country for which a National Footprint Account exists and where appropriate economic and environmental accounts are available.

This methodological approach to footprinting is also designed to capture the resource use and environmental impacts that residents generate via their direct consumption and has a number of distinct advantages for policy-makers. First, as the method uses standardized, official and annual statistics, this increases its robustness and reliability as an indicator. This also encourages the development of comparative (national and international) studies that can promote methodological innovation because of their comparability. Second, by using localized and detailed household expenditure data, footprints can be generated at regional and local levels. The method has been successfully used to calculate the footprint of the UK, Wales and Cardiff (see Barrett *et al.*, 2005; Collins *et al.*, 2005, 2006). Finally, by allocating the footprint to final demand categories the method highlights consumer responsibilities, which in turn are valuable in developing policy scenarios. Below we outline why Cardiff Council wanted to measure the city's ecological footprint, and the reason for including 'sustainability' within Cardiff's Local Food and Health Strategy (Cardiff Health Alliance, 2006).

Cardiff's Ecological Footprint: Setting the Context

As part of the 'Reducing Wales' Ecological Footprint' Project (see Barrett *et al.*, 2005), an ecological footprint study was undertaken of Cardiff, the capital city of Wales (see Collins *et al.*, 2005). Between January 2003 and January 2005, a partnership including the BRASS Research Centre at Cardiff University, Cardiff Council, SEI, and the World Wildlife Fund, Cymru undertook a collaborative project to measure Cardiff's ecological footprint.

Cardiff Council had specific reasons for wanting to undertake an ecological footprint study of the city. First, policy officers wanted a clearer picture as to the scale of the environmental challenge that the City faces if it is to become more sustainable. The ecological footprint study would provide the Council with an initial benchmark for the City, and future footprinting exercises could then be used to track the Council's performance. Second, the Council's Local Sustainability Strategy (Cardiff Council, 2000) and Community Strategy (Cardiff Council, 2004) endorsed the footprint and the Council wanted to mainstream the project and its outcomes into existing policy. From the viewpoint of the Council's Sustainable Development Co-ordinator, the inclusion of the ecological footprint in these strategies had meant there was the potential that the Council would be able to go beyond its rhetorical commitment to sustainable development and demonstrate that it was taking positive action. Thirdly, the ecological footprint would provide the Council with a resonant tool and metaphor from which to promote awareness of sustainable consumption and lifestyles. Finally, data developed within the project and the overall ecological footprint results would provide policy officers with additional evidence from which to inform debate and policy development within the Council. More specifically, the team of sustainability officers within the Council hoped that the ecological footprint study could answer the following questions: What is Cardiff's ecological footprint per capita? What is Cardiff's footprint made up of? What are the most significant areas of resource use within the City? Is the Council prioritizing the right areas to reduce the City's footprint? Are the Council's current policies sufficient to move the City towards more sustainable consumption? How can the data derived from the ecological footprint study be used to

inform policy, manage resources more sustainably and raise awareness of sustainable lifestyles?

Sustainability is also included as a key theme in Cardiff's Local Food and Health Strategy (Cardiff Health Alliance, 2006; Fairchild & Morgan, 2006). It was important for members of the Cardiff Health Alliance that food was encompassed in its widest sense, and five overarching themes including 'sustainability' were used to develop the strategy and is central to its key objectives.

We now turn to provide an overview of the method used to measure Cardiff's ecological footprint with specific emphasis on the food and drink component.

Calculating Cardiff's Ecological Footprint for Food and Drink

The calculation of Cardiff's ecological footprint for food and drink was based on household expenditure on food and drink for 2001 (using the 'Classification of Individual Consumption According to Purpose' COICOP categories) by socio-economic breakdown using 'A Classification Of Residential Neighbourhoods' (ACORN) Groupings for Cardiff. COICOP data which is available from the UK ONS Statistics divides household expenditure into 12 categories, for example '01: food and non-alcoholic beverages' and '02: alcoholic beverages and tobacco'. Each of these first level categories has two further levels of subdivision. '01: food and non-alcoholic beverages' is subdivided as '01.1: food' and '01.2: non-alcoholic beverages'. As shown in Table 2, each of these categories can then be further sub-divided.

ACORN profile data is available from CACI (a UK marketing data company) for almost two million postcode areas in the UK of which there are 56 'typical' neighbourhood categories referred to as ACORN 'types'. (ACORN profiles by postcode can be viewed on the Internet via: www.upmystreet.com). The ACORN profile data ranges from ACORN Group 1 (wealthy achievers, suburban areas), Type 1 (wealthy suburbs, large detached houses) to ACORN Group 17 (people in multi-ethnic, low-income areas), Type 54 (multi-ethnic, high unemployment, overcrowding). Type 55 is 'unclassified'.

The amount of food and drink consumed by Cardiff residents in 2001 was estimated in three stages. The first involved calculating expenditure on food

Table 2. Breakdown of COICOP categories for food and non-alcoholic beverages

Level 1	Level 2	Level 3
01. Food & non-alcoholic beverages	01.1 Food	01.1.1 Bread & cereals
		01.1.2 Meat
		01.1.3 Fish
		01.1.4 Milk, cheese & eggs
		01.1.5 Oils & fats
		01.1.6 Fruit
		01.1.7 Vegetables
	01.2 Non-alcoholic beverages	01.2.1 Coffee, tea & cocoa
		01.2.2 Mineral waters, soft drinks, fruit & vegetable juices
02. Alcoholic beverages & tobacco		

and drink for each ACORN type in the UK. From this, the total expenditure for all Cardiff residents on food and drink items and related services (e.g., catering services, restaurants, cafes, street vendors and canteens) was calculated based on the city's ACORN profiles. The average expenditure per Cardiff resident was also calculated.

The second stage involved calculating Cardiff's expenditure for individual COICOP categories relating to individual food and drink products and related services. As the ONS Household and Expenditure Survey (see ONS, 2003) only provides detailed expenditure for COICOP categories at a regional and devolved government level, it was assumed that Cardiff residents have the same level of expenditure per food and drink product as a resident in Wales. In the third and final stage, the amount of food and drink consumed by Cardiff was estimated using the average price of products and services in Wales as conversion factors. In this calculation several assumptions were made in using these figures as conversion factors. First, the cost of food and drink products and services in Cardiff are similar to the rest of Wales. Second, resident expenditure patterns in Cardiff are the same as that at a Wales level. Finally, the propensity to purchase products within a particular price range is not accounted for. It is important to note that the cost of food and drink and related services in Cardiff may be higher or lower than for other areas in Wales and therefore Cardiff resident's actual expenditure and consumption may be more or less.

Having described the approach used to estimate how much food and drink Cardiff's residents consumed in 2001, below we outline how the energy requirements were estimated for food and drink production, import and transportation within the UK, and therefore Cardiff.

Estimating Energy Requirements for Food Production and Processing

The ecological footprint for food and drink consists of two main components: 'real land' requirements (i.e., crop, pasture, sea) and 'energy land'. The former relates to the area of land required to rear and grow food produce, the later refers to the 'embodied' energy required for food production and its processing. In the ecological footprint methodology developed by SEI and used for this study it was assumed that organic and conventional food products have similar 'real land' requirements. Although organic agricultural methods tend to produce lower yields, this assumption was made as at the time of this study there was no reliable data available on land requirements for organic agriculture in the UK (Barrett *et al.*, 2005)

The energy land component can be divided into two elements: the 'embodied energy' required to produce raw materials (e.g., milk) and the 'embodied energy' required to process the raw material into a final product (e.g., yoghurt). In this footprint method, the energy requirements for conventional raw products and their processing was based on data collected for an Energy Analysis Program (EAP) in the Netherlands as specific data was not available for food production and processing in the UK (for more information see Wilting *et al.*, 1999). The energy requirements for organic food production were estimated using data from a report prepared by ADAS UK Ltd on 'Energy use in organic farming systems'. ADAS is a UK company that provides independent science-based information, advice and implementation services to

Governments and organizations working in the environmental, agricultural and rural sectors (see http://www.adas.co.uk). At the time of this study, as there was no specific data relating to energy requirements for the processing of organic food products in the UK, it was assumed that the process was as energy intensive as that for conventional food products.

Food imports. The proportion of Cardiff's food and drink that had been imported was based on the amount and origin of food and drink imported into the UK. This was calculated using information from three key data sources: an ONS Survey on PRODucts of the European COMmunity (PRODCOM) (ONS, 2001), a Department for Environment, Food and Rural Affairs (DEFRA) report on Agriculture in the UK 2002 (DEFRA, 2002a) and UK Trade Data on imports and exports compiled by HM Customs and Excise.

Food transportation. The ecological footprint for food and drink also includes the impact of transporting food products from the farm to the food retailer. The impact of all international transport to the UK border was calculated for each food item imported from eight world regions by considering the distance traveled by different modes of freight transport and the weight of the load. Distances traveled to distribute food within the UK (and therefore to Cardiff) was estimated using data on the 'Transport of Goods by Road in Great Britain 2001' (DETR, 2002).

Cardiff's Ecological Footprint Results (2001)

The overall ecological footprint for Cardiff was 1.72 million global hectares in 2001—the year for which the most recent household expenditure data was available at a sub-national level. On a per capita basis, the ecological footprint of an average Cardiff resident is 5.59 global hectares. Compared to other studies which have used the same ecological footprint methodology, Table 1 shows that Cardiff's footprint is greater than that for the average UK and Welsh resident (5.35 gha/cap and 5.25 gha/cap respectively) (see Barrett *et al.*, 2005). The magnitude of these figures clearly show that the level of consumption by Cardiff residents is currently unsustainable as they are using resources more than three times the average 'earthshare' of 1.9 gha/cap. To be sustainable, Cardiff residents would need to reduce their ecological demand by 68%. For a more detailed account of Cardiff's ecological footprint see Collins et al (2005).

As shown in Table 1 and Figure 1, almost one quarter of Cardiff's ecological footprint is made up of consumption of food and drink, and that together with three other components—travel, energy and consumables—contribute 70% of the total footprint. That four factors can so dominate the Cardiff footprint is indicative of how contemporary patterns of consumption have major implications for resource use. From an ecological perspective, Table 1 and Figure 1 raise major challenges regarding the long-term sustainability of the average Cardiff lifestyle.

The results suggest that fundamental changes are needed to the purchasing and consumption practices of the Cardiff resident if the footprint figure for food and drink is to be reduced. Is it possible, for instance, to shrink the relative size of the food and drink component? To simply replace some food items with low impact alternatives is at best likely to slow the rate of growth in the food footprint, but may not result in a diet that is nutritionally adequate. Decoupling

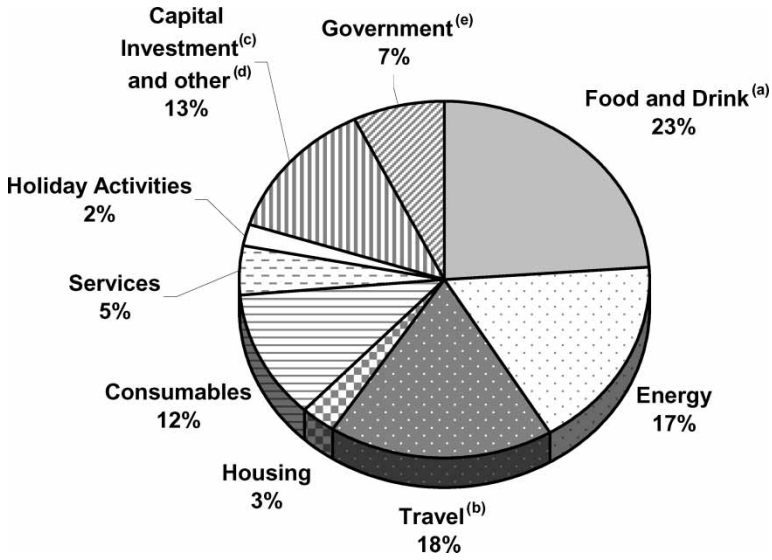

Figure 1. Major components of Cardiff's ecological footprint
Notes: (a) Includes catering services. (b) Includes transport services and air travel. (c) Capital Investment or Gross Fixed Capital Formation (GFCF) relates principally to investment in tangible fixed assets such as plant and machinery, transport equipment, dwellings and other buildings and structures. (d) includes non-profit institutions serving households, valuables, changes in inventories and overseas tourists in the UK. (e) Includes central and local government. The Footprint calculations assume shared responsibility, i.e., equal values for UK, Wales or Cardiff.

consumption and resource use will, on the footprint results, require a more fundamental change to residents' purchasing behaviour and what they consume, for example, in relation to the type, preparation and use of foods by manufacturers and in the home.

Before we explain why Cardiff's ecological footprint for food and drink is so large, we begin by analysing residents consumption patterns in more detail.

Cardiff's Food and Drink Consumption

Based on the ACORN profile of Cardiff and average household expenditure on food and drink products in Wales, it is estimated that the average Cardiff resident consumed 675.5kg of food and drink in 2001 (see Table 3). This is estimated to be almost 6% more than that consumed by an average resident in Wales (see Barrett *et al.*, 2005). The majority of food and drink consumed by the average Cardiff resident was at home (608.4 kg/capita), 5% more than the average resident in Wales (see Barrett *et al.*, 2005). The amount of food and drink consumed by Cardiff residents outside the home (i.e., in restaurants, fast food outlets and canteens) was 9% more than that for the average resident in Wales (67.1 kg/capita compared to 61.0 kg/capita) (see Barrett *et al.*, 2005).

Table 3 shows the types and quantities of food and drink consumed by a Cardiff resident in 2001. The category with the largest consumption was 'fruit and vegetables' (29.1%). The second largest category was 'milk and dairy

Table 3. Cardiff's ecological footprint results for food and drink consumption (2001)

Food type	Total consumption per person per year (domestic & eating out) [kg] *(% total amount)*	Domestic consumption only per person per year [kg]	Total imported per person per year [kg] *(% imported per category)*	Food EF [gha/capita]	Food transport EF [gha/capita]	Total EF [gha/capita]
Milk and diary products	142.8 (21.1%)	128.6	29.4 (20.6%)	0.372	0.004	0.375
Meat and meat products	72.5 (10.7%)	65.3	28.0 (38.6%)	0.438	0.002	0.440
Oils, fats and spreads	5.3 (0.8%)	4.8	3.2 (59.8%)	0.048	0.000	0.049
Fruit and vegetables	196.4 (29.1%)	176.9	99.1 (50.4%)	0.130	0.007	0.137
Cereals and cereal products	79.7 (11.8%)	71.7	9.9 (12.4%)	0.093	0.002	0.095
Non-alcoholic beverages	75.1 (11.1%)	67.7	8.3 (11.0%)	0.043	0.002	0.045
Alcoholic beverages	73.3 (10.8%)	66.0	23.6 (32.2%)	0.126	0.003	0.128
Sugar and confectionary	24.2 (3.6%)	21.8	11.3 (46.8%)	0.053	0.001	0.053
Other (e.g., peanut butter, pickles and sauces)	6.1 (0.9%)	5.5	2.3 (37.0%)	0.008	0.000	0.008
Total	675.5	608.4	215.0 (31.8%)	1.309	0.021	1.331

products' which accounted for 21.1% of the total amount consumed. This was followed by 'cereals and cereal products' (11.8%) and 'meat and meat products' (10.7%). Similar quantities of 'alcoholic' and 'non-alcoholic' beverages were consumed, accounting for 10.8% and 11.1% of the total respectively.

Whilst there are concerns about the low consumption of fruit and vegetables amongst residents in the UK, it is estimated that the average Cardiff resident consumed almost seven portions a day. This figure is greater than the Food Standards Agency (FSA) recommendation of 'five a day' (FSA, 2005). If 'fresh potatoes' are excluded, as they are not included in 'five a day' it is estimated that the fruit and vegetable consumption is reduced to six portions a day. In addition, consumption of milk and dairy products are also higher than government recommendations (FSA, 2005).

Cardiff's Food and Drink Ecological Footprint

Cardiff's consumption of food and drink creates a footprint of 1.33 gha/cap and is responsible for almost a quarter of Cardiff's total ecological footprint for 2001 (5.59 gha/cap). This footprint figure for food and drink is 3% larger than that for Wales (1.29 gha/capita) but similar to that for the UK (1.34 gha/capita) (see Table 1). As the ecological footprint is calculated on a per capita basis, the footprint results presented in Table 3 are based on average expenditure on food and drink items by residents of all ACORN groupings in Cardiff. However, within Cardiff there will be residents that have different patterns and levels of expenditure and so therefore may have a smaller or larger footprint for food and drink.

The reason why Cardiff has a large ecological footprint for food and drink relates to the scale, type and pattern of residents consumption. The average Cardiff resident consumed a total of 675.5 kg of food and drink, almost 6% more than the average resident in Wales. Domestic food consumption accounts for more than two thirds of Cardiff's total footprint for food and drink (0.900 gha/capita) (see Table 4). Based on UK figures for organic consumption, organic food and drink accounted for 1.1% of the total food and drink consumed by the average Cardiff resident compared to 98.9% for food and drink produced using conventional methods. As the production of conventional food is more energy intensive compared to the production of organic food, this requires substantial amounts of energy and therefore generates a much higher impact.

A further reason as to why Cardiff's footprint figure for food and drink is so large is that residents also consume large amounts of food and drink outside the home, including restaurants, fast food outlets and canteens. Eating out is responsible for almost one third of Cardiff's footprint figure for food and drink (0.431 gha/cap) compared to 0.900 gha/capita for food consumed at home

Table 4. Ecological footprint for Cardiff's food and drink (2001)

	Food EF [gha/cap/yr]	Food transport EF [gha/cap/year]	Total food EF [gha/cap/year]
Domestic	0.866	0.015	0.900 (67.6%)
Eat out	0.429	0.007	0.431 (32.4%)
Total	1.309 (98.3%)	0.022 (1.7%)	1.331 (100%)

(see Table 4). The footprint figure for eating out is disproportionately high compared to the total amount consumed because the production, preparation and service of food in these outlets is more energy intensive compared to that at home, and these indirect effects result in a large footprint figure.

The food and drink categories that were found to contribute the most to Cardiff's footprint were 'meat and meat products' and 'milk and dairy products' (see Table 3). When combined these two categories accounted for almost two thirds of the average Cardiff food and drink footprint. These food items create a large footprint for two main reasons. First, they are consumed by Cardiff residents in large quantities. Second, on a per kilogram basis these food and drink products have a large ecological impact as large amounts of energy are required to produce them (see Collins *et al.*, 2005).

Food transportation. The ecological impact of food transportation on the Cardiff food and drink footprint is shown in Table 3. Based on UK import data for food and drink, it is estimated that almost one third of the total amount consumed by Cardiff residents in 2001 was imported (215.0 kg/capita). Those food and drink categories consumed by Cardiff residents that had the largest amount of imports were 'fruit and vegetables', 'milk and dairy products', 'meat and meat products' and 'alcoholic beverages'. Based on the footprint methodology used here, the results suggest that food transportation does not contribute significantly to the overall environmental impact of food and drink. For example, 'milk and dairy products' have a total footprint figure of 0.375 gha/cap, of which 1% is attributable to food transportation (0.004 gha/cap) compared to 0.372gha/cap for food production (see Table 3).

Food related waste. When considering the impact of Cardiff's footprint for food and drink, it is not only the purchase of these items that need to be considered but also whether they are consumed or not. In 2001, Cardiff's households produced 30,605 tonnes of food waste (see Collins *et al.*, 2005). This is almost 0.1 tonnes (100 kg) waste per average resident per year, and is equivalent to 16.4% of the total food eaten at home per year (608.4 kg) (see Table 3)

The ecological footprint for waste is calculated based on the quantity and composition of waste materials produced, its transportation, and how it is subsequently managed and disposed of (i.e., landfilled or recycled). As shown in Table 1, the ecological footprint for waste is not included in the 'standardized' footprint calculations but instead is treated as a satellite account as the impacts of household consumption can only be counted once, either as 'inputs', when products are bought or consumed, or as 'outputs', when these products are discarded. As the footprint methodology used here considers the environmental impacts of consumables, double counting would occur if the impact of waste from these consumables was included in the final result. Nevertheless, both in terms of their value for policy-makers and communicating to citizens, the environmental impact of resource use, it is very important to calculate this satellite account. In 2001, Cardiff's waste created a footprint result of 0.81 gha/cap, 17% larger than that for Wales and the UK (see Table 1). The reason for this is that Cardiff residents are more wasteful and they recycle less compared to the average Wales and UK resident. Home compostable waste (e.g., vegetables & fruit) and other kitchen waste (e.g. meat) when combined were found to be

responsible for more than one fifth of Cardiff's footprint result for household waste (0.18 gha/cap) (see Collins *et al.*, 2005).

Assessing the nutritional composition of a diet. The type and quantity of food and drink items consumed by an average Cardiff resident (derived from the ecological footprint calculation) was also analysed using NetWISP 3.0 (Tinuviel Software, UK), a nutritional analysis programme used to compare the scenario diets developed with the current UK Dietary Reference Values (DRV's) (DoH, 1991). When calculating the nutritional adequacy of diets in the UK, the Reference Nutrient Intake (RNI) is aimed for. This represents a sufficient or more than sufficient amount of a nutrient for 97% of the population. The RNI is based on age, gender, height, weight and activity levels of an individual (DoH, 1991). In this paper the nutritional analysis is based on that of an average male. A 32-year-old was selected as this is the mid-point between the age category (19 to 50-years-old) of adults in the UK DRV report (DoH, 1991). A height of 175 cm was taken as this represents the 50th percentile UK male adult height (DoH, 1991). A weight of 90 kg was taken as this is the average weight used by the UK government in calculating guideline daily amounts on food labels (Rayner *et al.*, 2004). Both daily activity and leisure activity were taken as 'not active' as this is used by the UK government to calculate the first physical activity level (PAL) for energy requirement for UK adults (DoH, 1991). This 'average' person and 'average' diet obviously represents just that, and within Cardiff there will be individuals who eat much less, and more healthily, with different requirements due to differing genders, ages, physiques and lifestyles. However, this process of ascertaining whether different scenarios are nutritionally adequate for different sections of the community residing in Cardiff, or any other location, is a useful one and will need to be undertaken in order to verify that dietary changes recommended for a sustainable diet are nutritionally adequate.

Estimating expenditure on food and drink. The estimated expenditure by a Cardiff resident on food and drink consumed at home was calculated based on the cost of items sold in three supermarkets that had stores located within the Cardiff boundary. Those supermarkets that were selected aimed to reflect the range of supermarkets within the city, and included a leading, middle of the range and a low cost UK supermarket (Mintel, 2005).

A survey of conventional and organic food and drink items sold in each supermarket was undertaken during April 2005 by visiting their website or in-store. The range of individual food and drink items used to calculate expenditure was based on those listed in Table 5. For each food and drink item, a wide range of products were selected to reflect the range available for purchase in each store. For example, products selected under 'poultry (uncooked)' included; whole chicken; chicken portions (e.g., breast, wing and thigh); diced and minced chicken; and turkey. The selection of food and drink items did not include products consisting of mixed ingredients, such as ready meals. Products selected from each supermarket also aimed to reflect the range of costs for each food item available, including the most and least expensive. Based on this, the average (mean) cost per kilogram for conventional and organic food and drink items was calculated for each supermarket. The range of expenditure for each food and drink item was based on the least and most expensive average (mean) cost from the three supermarkets surveyed.

Table 5. Food items replaced and used alternative substitutes

Food items	Ecological footprint per kilogramme (domestic consumption) [gha/kg]	Scenario 1: Increased consumption of organic food and drink (87.97%)	Scenario 2: Replaced food items with EF ≥ 0.006 gha/kg	Scenario 3: Replaced food items with EF ≥ 0.004gha/kg	Scenario 4: Replaced food items with EF ≥ 0.002gha/kg	Scenario 5: Vegetarian diet
Milks & dairy products						
Wholemilk	0.0014	R: organic	I = cream	I = cream	I = cream	NC
Skimmed milk	0.0014	R: organic	NC	NC	NC	NC
Yoghurt and fromage frais	0.0017	R: organic	NC	I = ice cream	I = ice cream	NC
Other milks and dairy products	0.0017	R: organic	NC	NC	NC	NC
Cream	0.0061	R: organic	R = wholemilk	R = wholemilk	R = wholemilk	NC
Cheese	0.0111	R: organic	R = eggs	R = eggs	R = eggs	I = beef/veal, poultry (cooked) & fish
Eggs	0.0012	R: organic	I = cheese & mutton/lamb	I = cheese & mutton/lamb	I = cheese & mutton/lamb	I = mutton/l amb & poultry (uncooked)
Ice-cream and other frozen dairy	0.0043	R: organic	NC	R = yoghurt & fromage frais	R = yoghurt & fromage frais	NC
Meat & meat products						
Beef and veal	0.0157	R: organic	R = pork	R = pork	R = pork	R = cheese
Mutton and lamb	0.0076	R: organic	R = eggs	R = eggs	R = eggs	R = eggs
Pork/ham/bacon	0.0019	R: organic	I = beef/veal	I = beef/veal	I = beef/veal, poultry cooked & other meats	R = cereals
Poultry (uncooked)	0.0016	R: organic	NC	NC	NC	R = eggs
Poultry (cooked)	0.0032	NC	NC	NC	R = pork/ham/bacon	R = cheese
All other meats	0.0022	NC	NC	NC	R = pork/ham/bacon	R = cereals
Total fish	0.0101	R: organic	R = other cereals	R = other cereals	R = other cereals	R = cheese
Oils, fats & spreads						
Butter	0.0115	R: organic	R = margarine	R = margarine	R = margarine	R = margarine

Margarine	0.0066	NC	I = butter & low fat spreads	I = butter & low fat spreads	I = butter & low fat spreads	I = butter & low fat spreads
Low-fat and dairy spreads	0.0067	R: organic	R = margarine	R = margarine	R = margarine	R = margarine
Vegetable and salad oils	0.0038	R: organic	NC	NR	NR	I = animal fat
Other fats (animal)	0.0026	NC	NC	NR	NR	R = vegetable and salad oils
Fruits & vegetables						
Fresh potatoes	0.0003	R: organic	NC	NC	NC	NC
Fresh green vegetables	0.0003	R: organic	NC	NC	NC	NC
Other fresh vegetables	0.0004	R: organic	NC	NC	NC	NC
Processed vegetables	0.0005	R: organic	NC	NC	NC	NC
Fresh fruit	0.0005	R: organic	NC	NC	NC	NC
Other fruit (e.g., tinned)	0.0005	R: organic	NC	NC	NC	NC
Fruit juices	0.0011	R: organic	NC	NC	NC	NC
Cereals & cereal products						
Bread	0.0005	R: organic	NC	NC	NC	NC
Flour	0.0007	R: organic	NC	NC	NC	
Cakes	0.0016	NC	NC	NC	NC	
Biscuits	0.0014	R: organic	NC	NC	NC	
All other cereals	0.0010	R: organic	I = fish	I = fish	I = fish	I = pork/ham/bacon & other meats
Non-alcoholic beverages						
Tea	0.0035	R: organic	NC	I = coffee	R = 50% water	NC
Coffee	0.0045	R: organic	NC	R = tea	R = 50% water & 50% tea	NC
Cocoa/drinking chocolate	0.0056	R: organic	NC	R = water	R = water	NC
Branded food drinks (e.g., Horlicks)	0.0019	R: organic	NC	NC	NC	NC
Soups	0.0011	R: organic	NC	NC	NC	NC
Mineral water	0.0001	R: organic	NC	I = cocoa/ drinking chocolate	I = cocoa/drinking chocolate, 50% tea & 50% coffee	NC
Soft drinks (concentrated)	0.0002	R: organic	NC	NC	NC	NC

(*Table continued*)

Table 5. Continued

Food items	Ecological footprint per kilogramme (domestic consumption) [gha/kg]	Scenario 1: Increased consumption of organic food and drink (87.97%)	Scenario 2: Replaced food items with EF ≥ 0.006 gha/kg	Scenario 3: Replaced food items with EF ≥ 0.004gha/kg	Scenario 4: Replaced food items with EF ≥ 0.002gha/kg	Scenario 5: Vegetarian diet
Soft drinks (ready to drink)	0.0002	R: organic	NC	NC	NC	NC
Soft drinks (low cal, concentrated)	0.0002	NC	NC	NC	NC	NC
Soft drinks (low cal, ready to drink)	0.0002	NC	NC	NC	NC	NC
Alcoholic beverages						
Beer and lager	0.0005	R: organic	NC	I = spirits	I = spirits & wine	NC
Wine	0.0022	R: organic	NC	NC	R = beer	NC
Spirits (e.g., whisky)	0.0041	R: organic	NC	R = beer	R = beer	NC
Sugar & confectionary						
Sugar	0.0007	R: organic	NC	NC	NC	NC
Honey, preserves, syrup & treacle	0.0009	R: organic	NC	NC	NC	NC
Chocolate confectionary	0.0046	R: organic	NC	R = non choc confectionary	R = non-choc confectionary	NC
Non-choc confectionary	0.0010	NC	NC	I = choc confectionary	I = chocolate confectionary	NC
Other						
Other	0.0010	R: organic	NC	NC	NC	NC
% total replaced	—	86.8	5.79	9.10	15.49	10.93

Notes: EF = ecological footprint; kg = kilogram; gha = global hectares; I = food items included; R = f ood items replaced with; NR = no food replacement to ensure diet is palatable; NC = no change.

The estimated average (mean) expenditure by a Cardiff resident on domestic food and drink was calculated on a yearly basis, as for the ecological footprint analysis. This involved calculating the average (mean) cost of conventional and organic food and drink items per kilogramme for all supermarkets in April 2005 and multiplying this by the total amount of food and drink (conventional and organic) consumed by a Cardiff resident in 2001. Seasonal variations were not taken into account.

Reducing Cardiff's Ecological Footprint for Domestic Food and Drink Consumption

Cardiff's food and drink consumption does have a large ecological impact. The total and domestic food and drink footprint figures are equivalent to 74% and 55% of the global 'earthshare' of 1.8 gha/capita. The types and quantities of food and drink that are consumed, how they are produced, where they are consumed and the waste produced all generate significant impacts. So, how might we begin to reduce the largest component of the Cardiff footprint? How might Cardiff residents begin to reduce the environmental impacts associated with their food and drink consumption? To begin to provide some possible answers and direction we have developed five scenarios to illustrate how this might be achieved. It is crucial that any suggested changes made to the Cardiff diet are also nutritionally adequate and affordable, therefore we have also analysed the results of each scenario from a nutritional and economic perspective.

The ecological footprint method has shown that the types of food and drink consumed and how they are produced have ecological consequences. As food and drink consumed by Cardiff residents at home is responsible for two thirds of the total ecological footprint figure for food and drink, our scenario development has focused on changes to domestic consumption. This is also an area of consumption where residents can make the most significant change as it focuses on their purchasing behaviour as consumers. The first scenario considers increasing Cardiff's consumption of organic products, and calculating the impact that this would have in reducing the city's food and drink footprint. The following four scenarios then consider altering the types of food and drink that are consumed at home by replacing those with a large ecological impact per kilogram with low impact alternatives. The final scenario then considers the impact associated with a 'typical' vegetarian diet which involves replacing all meat and meat products which have a large ecological impact per kilogram.

For each scenario we calculate the domestic and total ecological footprint for food and drink per resident per year. We also assess whether each scenario would be nutritionally adequate for the 'average' male resident and identify any possible deficiencies or excesses that might occur. In addition, we calculate the average (mean) and the range of expenditure for domestic food and drink per capita per year.

The 'Average' Cardiff Diet (2001)

In 2001, the average Cardiff resident consumed 608.4 kg of food and drink at home. This created a footprint figure of 0.900 gha/capita (see Table 6). Based on the cost of items available in the three supermarkets surveyed, the average (mean) expenditure by a Cardiff resident on domestic food and drink was £1,946.35 per year,

Table 6. Summary of scenario results

Diet scenario	% total food and drink replaced with alternatives	Domestic food and drink ecological footprint gha/capita/year (% reduction)	Total food and drink ecological footprint gha per capita/year (% reduction)	Average (mean) expenditure per capita/yr *(range per capita/yr)* [£]	Nutritional comments
Cardiff diet (2001)	—	0.900	1.331	£1,946.35 *(£1,181.53–£2620.44)*	Four nutrients and energy below RNI: carbohydrates, dietary fibre, vitamin B6 & polyunsaturated fats
Scenario 1: Organic diet (87.97% organic)	86.8	0.595 *(33.9%)*	1.0256 *(22.9%)*	£2,554.26 *(£1,655.95–£3,108.57)*	UK nutritional analysis not available for organic food and drink
Scenario 2: Replacing food items with EF ≥0.006gha/kg	5.8	0.663 *(26.4%)*	1.094 *(17.8%)*	£1,807.99 *(£1,150.49–£2,447.17)*	Four nutrients and energy below RNI: polyunsaturated fats, carbohydrates, dietary fibre & folic acid
Scenario 3: Replacing food items with EF ≥0.004gha/kg	9.1	0.597 *(33.7%)*	1.028 *(22.8%)*	£1,648.24 *(£922.26–£2,287.86)*	Three nutrients and energy below RNI: total fats, polyunsaturated fats & dietary fibre
Scenario 4: Replacing food items with EF ≥0.002gha/kg	15.5	0.552 *(38.7%)*	0.983 *(26.1%)*	£1,410.16 *(£761.79–£1,979.97)*	Five nutrients and energy below RNI: total monounsaturated & polyunsaturated fat, dietary fibre & salt
Scenario 5: Typical vegetarian diet	10.9	0.822 *(8.7%)*	1.253 *(5.9%)*	£1,649.62 *(£905.17–£2,290.22)*	Eight nutrients and energy below RNI: total, saturated, monounsaturated & polyunsaturated fats, protein, dietary fibre, salt &vitamin B6

Note: EF: ecological footprint; gha: global hectares.

with a range of between £1,181.53 and £2,620.44 depending on which supermarket food and drink items were purchased from (see Table 6). The largest proportion of expenditure was on 'fruit and vegetables' (28.6%). This was closely followed by 'meat and meat products' (25.0%) and 'alcoholic beverages' (21.1%).

Nutritional Analysis of the 'Average' Cardiff Diet (2001)

The dietary analysis revealed that compared to the Balance of Good Health (BOGH)[1] the average Cardiff diet could be considered to be moderately healthy (see Table 3). The consumption of 'fruit and vegetables' and 'cereals and cereal products' was slightly lower than the RNI. Whereas 'milk and dairy foods', 'oils, fats and spreads' and 'sugar and confectionary' consumption were more than that recommended. Alcohol beverage consumption was also high, but within safe limits.

To examine the nutritional adequacy of the average Cardiff diet it is necessary to consider in greater detail, not just the macronutrient (protein, fat, carbohydrate) but also the distribution within these nutrients (e.g., saturated versus unsaturated fat) and micronutrient content of the diet (e.g., vitamins and minerals), compared to the RNI. In the average Cardiff diet, 4 out of 18 nutrients (carbohydrates, dietary fibre, vitamin B6 and polyunsaturated fats) and energy failed to meet the recommended level (RNI or equivalent) (see Table 6), but only dietary fibre (50% of RNI) and polyunsaturated fats (85% of RNI) were low enough to raise any concern. It is fair to assume that foods eaten outside the home (which make up 10% of an average Cardiff diet) would contain sufficient extra carbohydrates and thus vitamin B6, but may be deficient in dietary fibre and possibly polyunsaturated fat (Prentice & Jebb, 2003). Fourteen nutrients fell above the RNI but none dangerously so.

Scenario 1: Increased Consumption of Organic Food and Drink

Food and drink which has been produced organically has a lower ecological impact per kilogram compared to that which has been prepared conventionally as less energy intensive methods are used to produce food. Based on UK average figures, organic food and drink accounted for only 1.1% of the total amount consumed by Cardiff residents in 2001. Here we consider the extent to which increased consumption of organic food and drink could reduce the Cardiff footprint. In this scenario the proportion of organic food and drink consumed was increased from 1.1% to 87.9%. This is the amount of food and drink that could be replaced with organic alternatives available from the three supermarkets surveyed. Organic products were not available for food items such as animal fats, non-chocolate confectionary and 'other meats'.

As shown in Table 6, increasing the proportion of organic food and drink to 87.9% could reduce the domestic and total food and drink footprint figure by 33.9%, and 22.9% respectively. However, if we consider the economic cost associated with this scenario, increasing the proportion of organic food and drink to this level could increase the average (mean) expenditure per resident from £1,946.35 to £2,554.26 (an increase of 31.2%). From a nutritional perspective the impact of this scenario cannot be assessed as there is currently no UK data available of the nutritional content of organic food and drink and how it compares with conventional products.

The environmental impact of producing different types of food and drink is considerable. For example, beef and veal generates a footprint figure of 0.0157 gha/kg (when consumed at home) compared to fresh potatoes which has a footprint of 0.0003 gha/kg (see Table 5). This is because the production of beef and veal is more energy and resource intensive and requires larger areas of land. The following four scenarios consider altering the types of food and drink that are consumed at home by replacing those that have a large ecological impact per kilogram with low impact alternatives

Scenario 2: Replacing Food Items with an Ecological Footprint ≥ 0.006 gha/kg

In this scenario we replace those food and drink items that have an ecological footprint ≥ 0.006 gha/kg with low impact alternatives (i.e., items with a footprint <0.006 gha/kg). The selection of replacement food and drink items was based on having a similar nutritional value. For example, beef was replaced with pork, and cheese with eggs. In this scenario the individual food items that were replaced included cream, cheese, beef and veal, mutton and lamb and other meats. Those items that were used as replacements are listed in Table 5. Although butter, margarine, low fat and dairy spreads each have a footprint ≥0.006 gha/kg, they were not replaced with low impact alternatives. This was because the average Cardiff diet and the scenario diet consisted of a large amount of bread and was considered to be unpalatable without some form of spread. Instead, butter, low fat and dairy spreads were replaced with margarine, as this type of spread has the lowest footprint per kg (0.0066 gha/kg) (see Table 5). Overall, 5.8% of the Cardiff diet was replaced with alternatives (see Table 6).

The results from this scenario show that replacing food items with a footprint ≥0.006 gha/kg with low impact alternatives could reduce the domestic footprint figure by 26.4%, and the total food footprint by 17.8% (see Table 6). The average (mean) expenditure on domestic food and drink per capita would be £1,807.99 per year, which is 7.1% less than the average Cardiff diet in 2001 (see Table 6). The nutritional impact of this scenario was that four nutrients and energy fell below the RNI, of particular note is the decrease in folate (folic acid). This may have long term health consequences, for example, in reducing the production of red blood cells thereby increasing the possibility of anaemia (DOH, 1991). Vitamin C intake also reduced slightly, but not below the RNI. Although total energy and polyunsaturated fatty acids and dietary fibre intake improved, these were still below the recommended levels.

Scenario 3: Replacing Food Items with Ecological Footprint ≥ 0.004 gha/kg

This scenario builds on the previous one and focuses on replacing food and drink items that have a footprint of ≥0.004 gha/kg with low impact alternatives (i.e., a footprint of <0.004 gha/kg). Those food items that were used as replacement foods were made on a nutritional basis. For example, ice-cream was replaced with full fat yoghurt, and spirits with beer. In this scenario, 9.1% of the total amount food and drink consumed in 2001 was replaced with low impact alternatives (i.e., a footprint < 0.004 gha/kg) which were also of a similar nutritional value (see Table 5). In keeping the diet palatable, butter, low fat and dairy spread were replaced once again with margarine, as the diet consisted of a large amount of bread.

If food and drink items with a footprint of $\geq$ 0.004 gha/kg were replaced with low impact alternatives, this could reduce the domestic and total food footprint even further, by 33.7% and 22.8% respectively. Expenditure on domestic food and drink would be £1,648.24 per capita/year, 15.3% less than the average Cardiff diet in 2001 (see Table 6).

Nutritionally this scenario was not as detrimental as for Scenario 2, or in Scenarios 4 and 5 presented below. Only three nutrients (total and polyunsaturated fat, and dietary fibre) and energy were found to be below the recommended levels. Although the amount of dietary fibre in this scenario was the greatest with 78% of the recommend amount, it could be improved further, for example by adjusting the types of fruits and vegetables or cereal products consumed. This was also the only scenario that did not exceed the current maximum recommendation of 6 grams of salt per day (FSA, 2005).

Scenario 4: Replacing Food Items with an Ecological Footprint $\geq$ 0.002 gha/kg

This scenario considers replacing food and drink items that have an ecological footprint of $\geq$0.002 gha/kg with low impact alternatives (i.e., a footprint of $<$0.002 gha/kg). Once again food items used as replacements were made on a nutritional basis. Overall, 15.5% of the total food and drink was replaced with alternatives (see Table 6). As with the previous two scenarios, margarine was not replaced, and used as a replacement for butter and low fat spreads.

The results from this scenario show that replacing food items with a footprint of $\geq$0.002 gha/kg with low impact alternatives, could reduce the domestic footprint figure by almost 40% and the total food and drink footprint by 26.1% (0.983 gha/cap) (see Table 6). Food would then become the second largest component of Cardiff's overall ecological footprint (5.59 gha/cap) after travel and domestic energy (see Table 1). The average expenditure on domestic food and drink would be £1,410.16 per capita/year, almost 28% less than the average 2001 diet (see Table 6).

Compared to the average Cardiff diet (2001), this scenario would reduce the total fat intake, although this would be at the expense of poly and monounsaturated fats, sometimes referred to as the 'good fats' because of their ability to reduce some of the risk factors for coronary heart disease (i.e., blood clots) (DoH, 1991). The carbohydrate content of the diet was favourable and close to the RNI, and although the fibre content was low it was higher than the average 2001 diet. The salt intake was also appreciatively and positively reduced to around 70% of the advised maximum, and levels of all the other micronutrients (minerals and vitamins), with the exception of Vitamin B_6 were retained at levels above the RNI.

Scenario 5: A 'Typical' Vegetarian Diet

A vegetarian diet is defined by the Vegetarian Society as not containing any meat, poultry, game, fish, shellfish or crustacea, or slaughter by-products such as gelatine or animal fats (Vegetarian Society, 2006). There are different types of vegetarian diets, but the 'lacto-ovo-vegetarian', the most common type, contains both dairy products and eggs. A vegetarian diet is often postulated as being environmentally sustainable as it excludes meats which require large areas of land and energy to produce per kilogram compared to vegetable or cereal

products. In this scenario we are interested in assessing the extent to which a vegetarian based diet at home could reduce the Cardiff food and drink footprint.

In this scenario, 10.9% of the total food and drink was replaced with vegetarian alternatives that were nutritionally similar. For instance, cheese was used to replace beef and veal, poultry, and fish as they contain broadly similar nutrient groups e.g. protein and fat. The results from this scenario show that if Cardiff residents adopted a vegetarian diet at home, this could reduce the domestic footprint by 8.7% and the total food and drink footprint by almost 6%.

The extent to which this vegetarian diet reduces the food and drink footprint is surprising, as the reduction is not as much as that for Scenarios 2, 3 or 4. This is because the vegetarian diet presented here consists of more cheese (3.4% compared to 0.9% in the 2001 diet). Cheese is a popular replacement for meat in vegetarian diets (Nathan *et al.*, 1997). However, cheese has a large ecological footprint (0.011gha/kg) as it is highly processed and requires a large amount of energy and land to produce, and was responsible for 28.3% of the total footprint of the vegetarian diet.

In this scenario although a similar proportion of the diet is replaced with alternative foods as for Scenario 3, the domestic footprint figure is reduced by 8.7% compared to 33.7%. The reason for this is that those foods used as replacements in Scenario 3 have a lower ecological impact per kilogram. For example, pork which was used as a replacement for beef and veal has an ecological impact almost six times lower than cheese (0.0019 gha/kg compared to 0.011 gha/kg) (see Table 5).

Based on the average cost of food and drink items sold in supermarkets, this typical vegetarian diet would cost the average Cardiff resident £1,649.62/year. This is 15% less than the cost of the average diet in 2001, but similar to that for Scenario 3 (see Table 6).

Our nutritional analysis of this scenario shows that there are no nutritional benefits associated with this diet as 8 out of 19 nutrients fell below the RNI (total fat, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, protein, dietary fibre, salt, vitamin B_6) and energy. Whilst a reduction in saturated fats in the diet is beneficial, the reduction in 'good' fats is not as favourable.

Conclusions

The ecological footprint has provided us with a new assessment tool by which to gain insights into the environmental impacts of food and drink consumption patterns and to begin to assess the likely effect of different scenarios in reducing this impact. In using the ecological footprint, the results show that Cardiff's food and drink consumption has a large ecological impact and accounts for almost a quarter of the overall ecological footprint for 2001. This footprint result of 1.33 gha/cap is equivalent to 74% of the total 'earthshare' of 1.8 gha/capita. The reason why Cardiff has a large ecological footprint for food and drink is due to the scale, type and pattern of residents' consumption. As the footprint analysis here is based on the 'average' resident, for those with higher levels of consumption, reducing their impact in this area will prove to be even more of a challenge.

Although the Cardiff results are based on surrogate data, the results do highlight a number of issues in terms of understanding the environmental impacts associated with food and drink consumption. First, individual food and drink

items require different amounts of energy and resources to produce and result in different ecological impacts. Second, different methods of food and drink production have different resource use implications. Third, the production and processing of food and drink has a significant ecological impact, and these can be greater than that for their transportation.

Cardiff's footprint for food and drink could be reduced by changing the types of food and drink that residents consume, and this can be achieved in a number of different ways. However, some scenario options will require residents to make more significant changes to the types of food and drink that they consume. In some instances this can lead to economic (cost) benefits to the consumer and would not adversely affect the nutritional composition of their diet.

The results have shown that Scenario 4, which would involve replacing food items with an impact of ≥ 0.002 gha/kg, would bring about the greatest reduction in the footprint and result in food and drink becoming the second largest component of Cardiff's overall footprint. However, this scenario would involve residents replacing almost 16% of foods and drink items with alternatives which may preclude many from adopting this type of diet. It may be possible to introduce smaller changes to the diet as shown in Scenarios 2 and 3 and still achieve considerable reductions in the footprint.

Increasing the amount of organic food and drink consumed would also bring about a significant reduction in the food footprint (22.9%). Although this scenario would not require Cardiff residents to make any changes to the types of food and drink consumed, there would be a significant increase (31.2%) in the cost to the consumer. As the average UK household (with two adults and children) with an income level below the national average spends approximately £1,326 on food (see Dower *et al*., 2001), this scenario may not be affordable by all residents living in Cardiff. In addition, it is questionable whether the current targets for increased organic production within the UK are sufficient to support the level of demand for organic food and drink that would arise from Scenario 1 (DEFRA, 2002b; NAfW, 2004b). However, a similar reduction in the food and drink footprint could be achieved by Scenario 3, and would involve replacing only less than 10% of the total food and drink and cost on average 35.5% less than the organic diet.

The adoption of a vegetarian diet would result in only a small reduction in the food and drink footprint (5.9%). The impact of this scenario was surprising as the diet excluded all 'meat and meat products' which have a large ecological impact. Furthermore, the nutritional analysis revealed that this diet was also the least adequate of all the scenarios considered. Foods other than cheese and eggs could have been introduced as replacement foods, e.g., soya or other legumes. However within some of the food and drink categories used by the ecological footprint calculation there was insufficient discrimination to allow for this.

Combining the ecological footprint with a nutritional and economic analysis of each scenario also raises interesting issues as to which approach might be the most effective in terms of achieving sustainable consumption at a sub-national level. The combined analysis also raises challenging issues about the accessibility and affordability of some of the scenario diets considered here. The evidence provided here suggests that a single approach may not be appropriate for all residents living in Cardiff, due to different social, cultural and economic factors. A range of approaches need to be developed and promoted if Cardiff's residents are to adopt more sustainable patterns of food consumption.

To reduce Cardiff's food and drink footprint, all components of the ecological footprint would need to be considered when setting targets due to their inter-relationship, for example, food and waste. Developing policies on sustainable food consumption need to be undertaken with caution as attempts to reduce the footprint of food and drink could lead to an increase in another. For example, increasing the proportion of food prepared within the home could lead to an increase the footprint of the domestic energy component. Furthermore, if the footprint results for food and drink are considered in isolation this could lead to policy decisions that are not nutritionally adequate. Although Scenario 4 could bring about the greatest reduction in Cardiff's food and drink footprint it would result in a diet with five nutrients below the RNI of an average male adult.

Although the ecological footprint method used in this study relies on standardized and official statistics on food and drink consumption and expenditure, it does lend itself to the use of surrogate data when calculating the food and drink footprint at a sub-national level. If ecological footprint analysis is to be used to inform policy decisions on sustainable food consumption, policy-makers should be aware of the limitations associated with this approach and the benefits of combining it with other forms of analysis. Combining the ecological footprint approach alongside a nutritional and economic analysis, could engage and support different professional groups such as sustainability officers and health care professionals in developing policies on achieving more sustainable patterns of food and drink consumption within their locality.

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Note

1. The UK BOGH recommends that the diet contains equal proportions fruit and vegetables and starchy foods (e.g., rice, pasta, potatoes, sweet potatoes, bread) and account for 33–35% of the diet, approximately 10% protein foods (e.g., meat, fish, eggs), 12% dairy foods (e.g., milk and milk products) and no more than 8% sugar, fats, etc. If alcohol is consumed, it should make up no more than 7% of the total energy intake.

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