Dietary choices and greenhouse gas emissions – assessment of impact of vegetarian and organic options at national scale

Helmi Risku-Norja*

Economic Research,
MTT Agrifood Research Finland,
31600 Jokioinen, Finland
Email: helmi.risku-norja@mtt.fi
*Corresponding author

Sirpa Kurppa

Biotechnology and Food Research,
MTT Agrifood Research Finland,
31600 Jokioinen, Finland
Email: sirpa.kurppa@mtt.fi

Juha Helenius

Department of Agricultural Sciences,
University of Helsinki,
Finland
Email: juha.helenius@helsinki.fi

Abstract: This study quantifies the sources of agricultural GHG emissions and explores the impact of diet on GHG emissions in Finland. The emissions associated with production of basic food items were quantified for four diet options. For current average food consumption, emissions from soil represent 62% of the total. The emissions due to enteric fermentation contribute 24%, and energy consumption and fertiliser manufacture both about 8%. Regarding GHG emissions, environmental performance of the extensive organic production is poor. A strict vegan diet would nearly halve the agricultural GHG emissions, but reduction of the total emissions would be about 8%. Reducing the GHG emissions through food consumption would require large-scale changes among the entire population. Instead of stressing the impact of individual citizens' diet choices, more attention should be paid to social learning. Attention should be paid to the overall sustainability of food supply, not only to the GHG emissions.

Keywords: food consumption; per capita per annum; vegan and non-ruminant diet; conventional and organic production; sources of agricultural GHG.

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Biographical notes: Helmi Risku-Norja is a Senior Research Scientist with educational background in natural sciences and education. She has been working at the MTT Agrifood Research Finland since 1997 in projects dealing with material flows, eco-efficiency and environmental impacts of agriculture. In the recent years her research activity has been shifted towards sustainability research with focus on rural issues, local food, sustainability and food education.

Sirpa Kurppa is Professor at the MTT Agrifood Research Finland, and has more than 25 years of research experience incorporating environmental issues into production of arable and horticultural plant biomasses and implementation of the key issues of sustainable development into food and feed chain and rural entrepreneurship. The concrete tools in the research are the supply chain management based LCA (Life Cycle Assessment), ecodesign of food and rural products and a foresight approach in rural development and in rural-urban interaction.

Juha Helenius is Professor of Agroecology at University of Helsinki. He has studied biological diversity and landscape change in agriculture, and more recently, issues dealing with ecological sustainability of food production and consumption systems.

1 Introduction

There is growing concern about the environmental impacts of food production, and attempts to slow down climate change are not compatible with continuously increasing use of non-renewable fossil energy in food production and for transport. The environmental consequences of food production have increasingly concerned Greenhouse Gas (GHG) emissions, and discussion has focused particularly on dairy cattle whose enteric fermentation produces considerably more methane than is produced from pork and poultry production (Steinfeld et al., 2006).

The benefits of organic production over conventional production appear to be widely accepted in public discussion (EC, 2005; Isoniemi et al., 2006; EU, 2007). One of the central arguments is absence of chemical fertilisers in organic production, the manufacture of which consumes large amounts of fossil fuel with consequent GHG emissions (IFOAM, 2007). As a response to the growing concern about the environment, large-scale organic production has been offered as an overall solution to the environmental problems of agriculture worldwide created by the present global food markets (Halberg et al., 2006; Badgley et al., 2007; IFOAM, 2007).

It has been also argued on environmental grounds that a vegetarian diet would pay dividends (Helms and Aiking, 2003; Keyzer et al., 2003; Zhu and Ierland, 2004; Vinnari et al., 2005). Increasing the share of locally grown vegetarian products was shown to reduce GHG emissions when compared with diets more reliant on imported vegetables and animal products (EEA, 2005; Foster et al., 2006), but the impact of dietary choice has also been questioned (Wallén et al., 2004).

There is a strong belief that consumers can make a positive contribution to reducing the environmental load through food purchases by substituting animal-based products, especially dairy cattle products, for vegetarian products (Ministry of the Environment, 2008). These changes in purchasing are encouraged through various tools designed for consumers (Hansmann et al., 2005; Hyvönen and Perrels, 2008; PATT, 2008). Public discussion is lively, and the interest in personal carbon emissions suggests that among environmentally aware consumers there is a willingness to change individual food consumption habits.

This study addresses these questions in light of data from Finland, where the contribution of the whole food production chain to the total GHG emissions is about 24% (Mäenpää, 2004). Organic production has been established as an alternative production mode, although about 6.5% share from farming (MMM, 2008) is fairly modest. The available farmland would, however, allow significant increase in organic production without compromising the degree of food self-sufficiency (Lötjönen et al., 2004; Risku-Norja et al., 2008).

Milk products represent about 30% of the average Finnish diet and beef comprises 26% of the meat consumed. About 40% of the consumed beef is a side product of milk production. Dairy products together with beef provide, thus, 33% of the total energy intake in the current average Finnish diet (MMM, 2007). Although the consumption of vegetable products has been slowly increasing during recent decades, compared with the national standard dietary recommendations, current average food consumption in Finland is still biased towards animal products (MMM, 2007). Currently only about 1–5% of Finns are vegetarians, some of whom eat fish, eggs and/or milk products. The number of orthodox vegans is about 0.43% (Vinnari et al., 2009). More often the reasons for veganism concern personal health, animal welfare or simply food price rather than environmental considerations (Väänänen and Mäkelä, 2007).

Various surveys have shown that Finnish consumers prefer domestic products to imported ones and often also organic to conventional food, if such products are reasonably priced (Isoniemi et al., 2006). It was reported, however, that consumers more often express their ideals about food choices rather than make actual choices (Piiroinen and Järvelä, 2006). Nevertheless, through the demand-supply mechanism consumers are identified as important actors in deciding the fate of domestic, and specifically of organic, food production (e.g. Hyvönen and Perrels, 2008).

The focus of this paper is the agricultural GHG emissions. The contribution of soil, fertiliser manufacture, energy consumption and the animals' enteric fermentation and dung to total agricultural GHG emissions is quantified, and the GHG emissions in primary food production are compared for four diet scenarios: present day 'business as usual' average food consumption, a nutritionally balanced diet based on national health impact dietary recommendations, a diet with no milk products and with no ruminant meat, and a vegan diet. Also, the GHG emissions associated with conventional and organic production are compared. The aim is to assess how such diet and/or production system choices, if generalised to the entire nation, would contribute to the goals of reducing GHG emissions in agriculture, in the food chain as a whole and in total. Using such a scenario assessment we wish to stimulate critical discussion on the environmental impacts of food consumption patterns, with the possibilities for consumer choices to 'save the planet'.

2 Material and methods

The study deals with the GHG emissions from agricultural production, including fertiliser use and energy consumption, of the food necessary to satisfy Finnish consumption requirements. Domestic production meets the need of about 85% of the basic foodstuffs currently consumed in Finland (MMM, 2007). In this study it was assumed that meat, milk, eggs, fish, grains, potato, sugar, oil seeds, vegetables, fruit, berries and feed for animal husbandry were domestically produced. This is an approximation as imports balance the exports of some of these commodities. Fully imported food items that are not possible to produce in the boreal agriculture of Finland, i.e. mainly citrus fruit and rice, were not considered in the calculations. Exclusion of these items is justified by assuming that the studied diet scenarios would share equal amounts of consumption of these. Wild berries and even fish in the Finnish case are not agricultural products, and these items were ignored in the calculations.

The field area needed to produce food plants and fodder for livestock to meet consumption demand was calculated on the basis of the following data: food consumption (MMM, 2007), feed requirements of production animals (Tuori et al., 2002), long-term average yield per hectare of various food and feed crops, output per animal of various animal products and factors converting yields to food (MMM, 2008). The number of different production animals to satisfy annual demand for animal products was calculated on the basis of these data.

The greenhouse gases considered here comprise methane (CH_4) from enteric fermentation of the production animals, CH_4 from dung, carbon dioxide (CO_2) and nitrous oxide (N_2O) from agricultural soil as well as the CO_2 associated with fertiliser use and agricultural energy consumption. The CH_4 emissions from production animals were quantified using the animal-specific emission factors (Statistics Finland, 2007), and the emissions of N_2O and CH_4 from dung were calculated on the basis of published data (Pipatti, 2001). For the GHG emissions from soil, the average Finnish annual value of 2819 kg CO_2 equivalents ha^{-1} (Statistics Finland, 2007) was used. The emissions from fertiliser manufacture were calculated using the value 2.28 kg CO_2 equivalents kg^{-1} total fertiliser and assuming application of fertilisers according to the terms of the Finnish environmental subsidy scheme (Puurunen et al., 2004), under which ca. 90% of farms and farmland is operated. The energy consumption, electricity and fuel oil, for the various agricultural products, was obtained from farm model data (Risku-Norja and Mäenpää, 2007). The associated GHG emissions were calculated using the emission factor 2.68 g CO_2 l^{-1} for oil, and 250 g CO_2 kWh^{-1} for electricity (Foster et al., 2006). The GHG emissions into the atmosphere were expressed as CO_2 equivalents, and the conversion factor of 21 for CH_4 and 310 for N_2O were used (IPCC, 2005). The details of the calculations and the exact figures for the calculation parameters were published in a separate report (Risku-Norja et al., 2007).

A special feature of the Finnish food system is a relatively large proportion of meat from game, especially elk (*Alces alces*), and from reindeer (*Rangifer tarandus*). Reindeer meat and game meat together represent only about 2.5% of consumed food (MMM, 2007), but this amount is associated with large populations of the animals. In estimating the GHG emissions associated with wild elk and with extensively herded reindeer the whole supporting population[1] was accounted for, and only metabolic methane production from these sources was included. No GHG emission factors are available for reindeer and game animals, and the CH_4 emissions were approximated by using the factors associated with ewes for reindeer and deer, and those with beef cattle for elk.

The national diet scenarios, for which the GHG emissions in agriculture were approximated, were:

BAU: the present day 'business as usual' average Finnish diet.

NUH: a nutritionally balanced diet based on national health impact dietary recommendations, and including an increased share of food of plant origin, reduced share of food of animal origin, and only 60% of the present day milk consumption (Helakorpi et al., 2003).

REX: a 'ruminants excluded' diet with no milk products and with no ruminant meat; pork and poultry replacing beef and mutton.

VEG: a vegan diet with no milk and meat products and introducing an oat-based milk substitute at a level equal to the current day milk consumption; according to the ingredient declaration of the commercial product, the milk substitute contains 10% oat, which corresponds with 100 grams extra oat *per capita* per day.

The GHG emissions were quantified for each basic food item in each scenario on an annual *per capita* basis. In compiling the dietary options the total energy intake was kept constant, and the options were nutritionally balanced in terms of reasonable daily intakes of carbohydrates, fats and proteins (Table 1).

Table 1 The dietary options used in the GHG calculations and expressed on the basis of daily *per capita* consumption

	BAU		*NUH*		*REX*		*VEG*	
	g	*kJ*	*g*	*kJ*	*g*	*kJ*		*kJ*
Wheat	132	1887	148	2118	160	2290	160	2290
Rye	45	584	70	918	70	918	70	918
Barey	3	35	15	213	20	284	20	284
Oat	12	180	25	374	80	1196	140	2093
Rice*	14	217	11	171	11	171	14	211
Potato	191	595	250	777	250	777	250	777
Sugar	85	1414	81	1346	70	1163	60	995
Vegetable oils	15	542	20	744	27	1004	49	1822
Pea	3	45	5	68	5	68	17	232
Vegetables, excl. tomatoes	116	126	230	251	232	253	233	254
Fruit, excl.citrus	93	206	152	339	152	339	125	278
Garden berries	19	40	85	348	85	348	85	348
Wild berries*	19	40	152	623	152	623	152	622
Citrus fruit*	13	35	13	36	13	36	0	0
Tomato	31	26	35	30	35	30	35	30
Eggs	26	164	30	193	35	225	0	0
Milk	1082	3257	680	1503	0	0	0	0
Beef	51	396	32	250	0	0	0	0
Pork	94	848	35	316	75	677	0	0
Poultry	43	262	45	273	82	497	0	0
Mutton	1	11	1	9	0	0	0	0
Reindeer, game	8	34	8	33	8	33	0	0
Offals*	4	22	4	23	4	23	0	0
Fish*	37	187	39	199	39	199	0	0
kJ, Total		11153		11153		11153		11153

Notes: BAU – current average food consumption; NUH – nutritionally balanced diet based on dietary recommendations; REX – diet with no milk products and with no beef or mutton; VEG – vegan diet.

*Not accounted for in the GHG calculations.

For comparison of conventional and organic production options, the GHG emissions were first calculated on the basis of conventional production. Subsequently the impact of organic production on the emissions was estimated using three simplifying approximations:

1 manufactured fertilisers not used in organic

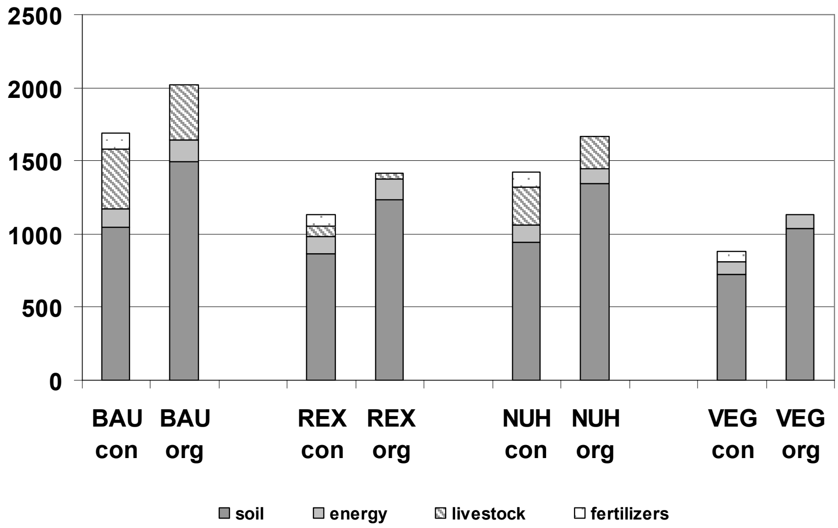
2 for the same amount of production extensive organic production needed 30% more cultivated area (Kirchmann et al., 2007; Risku-Norja and Mäenpää, 2007)

3 the feed requirements of the animals were the same as in conventional production, consequently also the output per animal was the same.

3 Results

The results from quantifying the GHG emissions for the basic food items in the four dietary options suggest that dietary choice makes a great difference. Comparing the present day average food consumption (BAU) with the purely vegan diet (VEG), the GHG emissions of the primary phase of food production would be approximately halved. The other options would also result in apparently significant reductions in GHG emissions. If the food was produced organically, the GHG emissions of the diet options would be approximately 20% higher (Figure 1).

Figure 1 GHG emissions due to primary food production associated with the four dietary options, kg CO_2 equivalents *per capita per annum*. 'Soil' comprises food and fodder production, 'livestock' comprises the GHG emissions from the manure and metabolism



Notes: BAU – current average food consumption; NUH – nutritionally balanced diet based on dietary recommendations; REX – diet with no milk products and with no beef or mutton; VEG – vegan diet; con – conventional production; org – organic production.

The GHG emissions were quantified for the primary production. The total annual GHG emissions for Finnish consumption are about 11,000 kg CO_2 *per capita*, of which the share from food is 24% or about 2600 kg (Mäenpää, 2004). The figure includes also the emissions associated with imported items that are produced abroad for Finnish consumption. The approximately 1700 kg CO_2 equivalents from agriculture comprise 73% of the GHG emissions associated with food. Therefore, the impact of dietary choice on total personal GHG emissions, depending on the diet option, ranges from about 2.6% to 7.5% reduction in the total per capita emissions due to Finnish consumption of goods and services. The impact on the total GHG emissions of the Finnish economy is even less, 2.2–6.6% (Table 2). This is because the emissions associated with the Finnish export industry comprise about 42% of the total GHG emissions of the Finnish economy (Mäenpää, 2004), and these are not included in the GHG emissions associated with Finnish consumption.

Table 2 GHG emissions for the four dietary options, and, in comparison to BAU, reduction achievable (kg CO_2 equiv. per capita per annum). The relative reduction achievable in emissions from agriculture, from food consumption, from domestic consumption, and from national emissions (%) is also shown

	BAU	*NUH*	*REX*	*VEG*
GHG emissions of primary production, kg CO_2 equiv.	1692	1421	1134	879
Reduction of the GHG emissions, kg CO_2 equiv.		270	558	812
Reduction compared to GHG emissions of agriculture, %		16.0	33.0	48.0
Reduction compared to GHG emissions of food consumption, %		10.8	22.9	34.2
Reduction compared to total GHG emissions of consumption, %		2.57	5.17	7.53
Reduction compared to total GHG emissions of Finnish economy, %		2.19	4.52	6.59

Notes: BAU – current average food consumption; NUH – nutritionally balanced diet based on dietary recommendations; REX – diet with no milk products and with no beef or mutton; VEG – vegan diet.

The relative contributions of cultivated soils, fertiliser manufacture, agricultural energy consumption and animals to the GHG emissions from primary production, food production, total GHG emissions of Finnish consumption and total emissions of the Finnish economy are shown in Table 3. Depending on the dietary option, the soil represents 62–82% of the emissions from primary production, the fertilisers 7–8%, agricultural energy consumption 8–11% and livestock metabolism and dung 0–24%. However, the relative shares of the agricultural GHG emissions are effectively diluted when compared with the total emissions or even with the emissions associated with food consumption.

3.1 Reliability of the results

The conversion factors for N_2O and CH_4 are internationally accepted values (310 for N_2O, 21 for CH_4, IPCC, 2005),[2] and the calculations for farmland requirements are based on the long-term national averages of yield and production levels, which are the best available data. The primary energy consumption and the CH_4, CO_2 and N_2O emissions associated with fertiliser manufacture and transport were deduced from the data of a single study (Grönroos et al., 2005) assuming consumption of 3.6 MJ primary energy per kWh and emissions equivalent to 250 g CO_2 per kWh. The obtained emission factor

2.28 kg CO_2 equivalents kg^{-1} total fertiliser (inclusive phosphorus and potassium) is very close to the value of 1.98 kg CO_2 equivalents kg^{-1} N-fertiliser based on the LCA data from Yara (Frank, pers. com. 2009). Thus, the results regarding CO_2 equivalents associated with fertiliser manufacture appear also reliable and express the relative differences between the dietary options fairly accurately. Data on agricultural energy consumption are somewhat less accurate. Since no data were available for several of the organic production lines, the missing data were approximated assuming that the energy consumption in organic plant cultivation is 10% and in organic animal production 23% higher compared with conventional production; the percentages represent the average difference between organic and conventional production in the available data.

Table 3 Relative contribution of the soil, fertilisers, energy consumption and livestock on GHG emissions from agriculture, food consumption, total consumption and the Finnish economy for the four dietary options

	BAU	*NUH*	*REX*	*VEG*
Share from the GHG of agriculture, %				
Soil	61.7	66.2	76.1	82.6
Fertilisers	6.78	6.94	7.18	7.91
Energy consumption	7.39	8.51	10.5	9.47
Livestock	24.1	18.4	6.3	0.0
Share from the GHG of food consumption, %				
Soil	40.6	37.5	35.4	30.6
Fertilisers	4.46	3.94	3.34	2.92
Energy consumption	4.86	4.83	4.87	3.50
Livestock	15.9	10.42	2.94	0.00
Share from total GHG emissions of consumption, %				
Soil	9.68	8.94	8.44	7.28
Fertilisers	1.06	0.94	8.44	0.70
Energy consumption	1.16	1.15	1.16	0.83
Livestock	3.78	2.48	0.70	0.00
Share from total GHG emissions of Finnish economy, %				
Soil	8.29	7.62	7.33	6.63
Fertilisers	0.91	0.80	0.69	0.63
Energy consumption	0.99	0.98	1.01	0.76
Livestock	3.23	2.12	0.61	0.00

Notes: BAU – current average food consumption; NUH – nutritionally balanced diet based on dietary recommendations; REX – diet with no milk products and with no beef or mutton; VEG – vegan diet.

The annual GHG emissions of 1692 kg CO_2 equivalents per capita presented here for current food consumption are very close to the 1658 kg CO_2 equivalents calculated using the IPCC (Intergovernmental Panel on Climate Change, www.ipcc.ch) approach, including only the GHG emissions from soils and livestock (Statistics Finland, 2007). Adding the GHG emissions associated with fertiliser manufacture and energy consumption to the IPCC figure would result in somewhat higher emissions than obtained here. The difference is explained by the fact that in reality the production from animal husbandry in Finland is somewhat in excess of the domestic demand, and this is accounted for in the IPCC calculations, which are based on actual animal numbers, whereas the present calculations are based on the amount of food consumed.

The emissions associated with reindeer and game ruminants are very rough estimates. For lack of specific emission factors, the factors were chosen on the basis of animal size. The main purpose of including reindeer and game in the study was to draw attention to and stimulate research on this issue.

4 Discussion

Primary production is reported by Foster et al. (2006) to be responsible for approximately 60–90% of GHG emissions in the food chain; this is in agreement with the 73% obtained in the present study. The major source of GHG emissions during primary food production is the cultivated soil. Fertiliser manufacture represents less than 10%, and the contribution from agricultural energy consumption is of the same order of magnitude (Table 3). Therefore, regarding GHG emissions, the environmental performance of extensive organic production is poor compared with conventional production as it involves increased cultivated acreage and consequently also higher consumption of fuel energy in comparison with conventional cultivation. Similar results have been reported elsewhere (Foster et al., 2006; Thomassen et al., 2006), although improving knowledge on soil carbon storage and nitrous oxide emissions could change current thinking (Niggli et al., 2008).

However, there are environmental impacts other than GHG emissions, and the positive impact of organic farming on biodiversity was demonstrated in several studies (Bengtsson et al., 2005; Fuller et al., 2005; Hole et al., 2005). Assessments of farming practices, including prohibition of biocide use, crop rotation, mulching and use of cover crops indicate environmental benefits from organic farming (Pimentel et al., 2005; Gliessman, 2007) and organic production has been emphasised as one contributing factor in promoting sustainable agriculture within the EU (EC, 2005). The importance of diversity of cultivated species has been lately stressed at global scale, and instead of focusing production on the three major cereals, rice, wheat and maize, there is a need to revive the local food plant species and cultivars and landrace animals in order to secure both the species and genetic diversity necessary for food production and adequate nutrition as well as to provide material for breeding new genotypes to secure adaptation to changing environments (Lang and Heasman, 2004).

Global food security is a growing challenge as the world population increases and the area of farmland *per capita* continuously shrinks. At the same time, as a consequence of improving living standards, use of animal products is increasing (WRI, 2006), which increases both environmental and health costs of food production. A solution is not provided by global organic food markets, because 'big organic' has increasingly become part of the mainstream global food trade controlled by large agrifood corporations (Follett, 2009). It is characterised by large-scale industrial mode of production with monocultures and competition based on price and efficiency (Pollan, 2006). It also means placeless food, with the producers and consumers distanced from each other (Follett, 2009). International trade means long-distance transport, increased energy consumption and greater GHG emissions (Schlich and Fleissner, 2005; Foster et al., 2006; Pimentel and Pimentel, 2007).

The actual capacity of organic agriculture should be seriously considered at local and national scales before advocating large-scale shifts towards more extensive organic production. The available farmland *per capita* in Finland is about 0.43 hectares, which is enough for food self-sufficiency, inclusive of the production of animal feed based on domestic cultivars, and to secure independence from import of basic food and feed items. With increased vegetarian food consumption, national food self-sufficiency in Finland could be based on organic production (Risku-Norja et al., 2008).

Dietary choice appears to have an impact on GHG emissions. Choosing the vegan diet over the current average diet, GHG emissions from primary food production would be nearly halved. Because food represents only about 24% of the total GHG emissions (Mäenpää, 2004) and agriculture comprises about 70% of the GHG of food production, such a radical change in food consumption would mean a reduction of about 7% in the total *per capita* GHG emissions attributable to consumption. Moreover, the environmental benefits of vegan diets are not clear-cut. It has been shown that increasing the share of vegetarian products in the diet decreases nutrient surpluses and greenhouse gas and acid emissions. On the other hand, strictly vegan diet as a policy choice is not optimal in terms of effect on the diversity of wild species (Risku-Norja et al., 2008). This is because areas covered with vegetation throughout the year are especially important for maintenance of diversity of wild species in agro-environments. Grasslands, green fallows, and cultivated and natural pastures all secure habitat heterogeneity and provide abundant ecological niches for farmland birds, overwintering invertebrates and for game species, some of which have recently become rare or extinct (Benton et al., 2003; Weibull et al., 2003; Hietala-Koivu et al., 2004). These areas have been created by and are maintained to a large extent by dairy cattle and other grazing animals.

As regards climate change, it is the total absolute volume of GHG emitted into the atmosphere that is crucial, not the percentage reduction in personal GHG emissions. To achieve a significant (several percents) reduction in total national volume of GHG emissions would require large-scale changes in the average Finnish food consumption habits. Even then the impact on total emissions would only amount to a few percent. Such dramatic changes are hardly realistic because food system is rigid, food is cultural, and consumer attitudes towards food and consumer behaviour are not consistent; citizens express various demands and wishes that change over time and depend on general overall trends and personal circumstance, including purchasing power. The direct impact of the changes on individual food consumption habits on the environment is, therefore, restricted and can only be gauged over a very long time span, if at all.

As in the case of ethical consumption, diffusion of the idea of sustainable food consumption requires social learning (Brekke et al., 2003; Starr, 2009; Young, 2009). Compared with individual citizens, institutional consumers and public catering represent a more homogeneous consumer group with somewhat better prerequisites for consistent behaviour. If public catering were committed to the principles of sustainable food provisioning, it could provide a more effective channel for improving sustainability in the food sector. This is done already to some extent through the sheer volume of public food purchases, but most importantly through food and sustainability education for citizens. Public catering already plays an important role in guiding nutritional behaviour among Finns, and it has contributed to increased use of vegetarian products and improved public health (Helakorpi et al., 2003). Similarly to nutritional education, public catering could take an active role in social learning by providing a clear signal regarding the kind of food that meets the sustainability criteria.

Sustainable food supply includes socio-cultural and ethical aspects as well as economic feasibility; it is not merely a matter of ecological sustainability and ecological sustainability is not merely a matter of GHG emissions. The basic requirement is for adequate production of food, and every nation should have the right to basic food security. Initiatives for sustainable catering have emerged in Italy, UK, Denmark and in Sweden, among other countries, featuring the use of local and organic food (Morgan and Sonnino, 2005; Mikkelsen et al., 2007). The Finnish committee for sustainable production and consumption proposed that the use of organic and local food by catering organisations is to be increased annually by 10–15%. However, to date, the recommendation has not been realised and, at present, customers are rarely informed about the origin and production ethics of the food provided by public catering (Ministry of the Environment, 2008).

In general, the prerequisite for sustainable consumption is to introduce services to substitute for material consumption. Although food itself cannot be substituted, a lot can be done at the household level to improve sustainability of food provisioning (Halme et al., 2006; Virtanen et al., 2009). Responsibility for sustainable food consumption cannot solely be pushed onto the consumers, and recommendations alone are not sufficient. There is a need to develop effective policy measures and instruments with the primary aim of improving overall sustainability of food provisioning (Collins and Fairchild, 2007).

5 Conclusions

The major source of GHG from food production is cultivated soil. Contribution from fertiliser manufacture and agricultural energy consumption is small compared with the GHG emissions from soil. With the current food consumption the share of GHG represented by animals is about 24%. Regarding GHG, the environmental performance of organic production is poor compared with conventional production.

The impact of giving up animal husbandry on total GHG emissions could result, at maximum, in about 7% reduction in total emissions for all consumption. To have any impact on the actual volume of GHG emissions through changed food consumption would require large-scale changes among the whole population and a shared view of the extent of the necessary changes. Instead of stressing the impact of individual citizens' food choices, more attention should be paid to designing effective policy instruments and to social learning. Public catering has the potential to exert a positive influence through volume of food purchases and setting an example by implementing food and sustainability education for its own activities. Consumer information is important from the viewpoint of food and sustainability education, leading eventually to adopting more sustainable lifestyles in the coming generations.

Environmental considerations for food production and consumption should not be restricted to GHG emissions. Rather than focusing on the environment, low carbon diets and carbon bonuses, or on organic versus conventional comparisons, attention should be paid to overall sustainability of food supply.

References

Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M.J., Aviles-Vazquez, K., Samulon, A. and Perfect, I. (2007) 'Organic agriculture and the global food supply', *Renewable Agriculture and Food Systems*, Vol. 22, No. 2, pp.86–108.

Bengtsson, J., Ahnström, J. and Weibull, A. (2005) 'The effects of organic agriculture on biodiversity and abundance: a meta-analysis', *Journal of Applied Ecology*, No. 421, pp.261–269.

Benton, T.G., Vickery, J.A. and Wilson, J.D. (2003) 'Farmland biodiversity: is habitat heterogeneity the key', *Trends in Ecology and Evolution*, No. 18, pp.182–188.

Brekke, K.A., Kverndokk, S. and Nyborg, K. (2003) 'An economic model of moral motivation', *Journal of Public Economics*, Vol. 87, Nos. 9–10, pp.1967–1983.

Collins, A. and Fairchild, R. (2007) 'Sustainable food consumption at a sub-national level: an ecological footprint, nutritional and economic analysis', *Journal of Environmental Policy and Planning*, Vol. 9, No. 10, pp.5–30.

EC (2005) *Agri-environment measures – overview on general principles, types of measures, and application*. Available online at: http://ec.europa.eu/comm/agriculture/publi/reports/agrienv/rep_en.pdf (accessed on 5 November 2008).

EEA (2005) *Household Consumption and the Environment*, EEA Report No. 11, European Environment Agency, Copenhagen.

EU (2007) Available online at: http://74.125.77.132/search?q=cache:MQO5Uw6IsgwJ:eur-lex.europa.eu/LexUriServ/LexUriServ.do%3Furi%3DCONSLEG:2002D0741:20070703:FI:PDF+s%C3%A4hk%C3%B6+p%C3%A4%C3%A4st%C3%B6ker*&cd=6&hl=fi&ct=clnk&gl=fi&lr=lang_fi&client=firefox-a

Follett, J.R. (2009) 'Choosing a food future: differentiating among alternative food options', *Journal of Agricultural & Environmental Ethics*, Vol. 22, No. 1, pp.31–51.

Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A. and Mylan, J. (2006) *Environmental Impacts of Food Production and Consumption: A Report to the Department for Environment, Food and Rural Affairs*, Manchester Business School, DEFRA, London.

Fuller, R.J., Norton, L.R., Feber, R.E., Johnson, P.J., Chamberlain, D.E., Joys, A.C., Mathews, F., Stuart, R.C., Townsend, M.C., Manley, W.J., Wolfe, M.S., Macdonald, D.W. and Firbank, L.G. (2005) 'Benefits of organic farming to biodiversity vary among taxa', *Biology Letters*, No. 1, pp.431–434.

Gliessman, R.S. (Ed.) (2007) *Agroecology: The Ecology of Sustainable Food Systems*, Lewis Publisher, Boca Raton, Florida.

Grönroos, J., Seppälä, J., Voutilainen, P., Seuri, P. and Koikkalainen, K. (2005) 'Energy use in conventional and organic milk and rye bread production in Finland', *Agriculture, Ecosystems and Environment*, No. 117, pp.109–118.

Halberg, N., Alrøe, H.F. and Kristensen, E.S. (2006) 'Synthesis: prospects for organic agriculture in a global context', in Halberg, N., Alrøe, H.F., Knudsen, M.T. and Kristensen, E.S. (Eds.): *Global Development of Organic Agriculture: Challenges and Prospects*, CABI Publishing, pp.343–367.

Halme, M., Hrauda, G., Jasch, C., Kortman, J., Jonuschat, H., Scharp, M., Velte, D. and Trindade, P. (2006) *Sustainable Consumer Services Business Solutions for Household Markets*, Earthscan, London.

Hansmann, R., Scholz, R.W., Francke, C-A.C. and Weymann, M. (2005) 'Enhancing environmental awareness: ecological and economic effects of food consumption', *Simulation & Gaming*, Vol. 36, No. 3, pp.364–382.

Helakorpi, S., Patja, K., Prättälä, R., Aro, A. and Uutela, A. (2003) *Health Behaviour and Health Among Finnish Adult Population*, *Spring 2003*, National Public Health Institute, Helsinki.

Helms, M. and Aiking, H. (2003) 'Food and the environment: towards sustainability indicators for protein production', in Tiezzi, E., Brebbia, C.A. and Usó, J.L. (Eds.): *Ecosystems and Sustainable Development*, WIT Press, Ashurst, UK, pp.1047–1056.

Hietala-Koivu, R., Järvenpää, T. and Helenius, J. (2004) 'Value of semi-natural areas as biodiversity indicators in agricultural landscapes', *Agriculture, Ecosystems & Environment*, Vol. 101, No. 1, pp.9–19.

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V. and Evans, A.D. (2005) 'Does organic farming benefit biodiversity?', *Biological Conservation*, No. 122, pp.113–130.

Hyvönen, K. and Perrels, A. (2008) *CLIMATE BONUS. Linking carbon footprints, personal emission monitoring, and personal emission monitoring, and bonus card systems*. Available online at: http://extranet/vatt.fi/climatebonus

IFOAM (2007) *Organic agriculture's role in countering climate change*. Available online at: http://www.ifoam.org/organic_facts/benefits/pdfs/climate_change_english_new.pdf (accessed on 30 October 2008).

IPCC (2005) *CORRIGENDUM (GPGAUM-Corr.2001.01, 15 June 2001)*. Available online at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/

IPCC (2006) *Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use, IPCC-NGGIP Publications*, Intergovernemental Panel on Climate Change.

Isoniemi, M., Mäkelä, J., Arvola, A., Forsman-Hugg, S., Lampila, P., Paananen, J. and Roininen, K. (2006) *Kuluttajien ja kunnallisten päättäjien näkemyksiä lähi- ja luomuruoasta*, Edita, Helsinki.

Keyzer, M.A., Merbis, M.D., Pavel, I.F.P.W. and Wesenbeeck, C.F.A.v. (2003) 'Can we feed the animals? Origins and implications of rising meat demand', *SWOW Working Paper*, No. 01-05R, pp.1–30.

Kirchmann, H., Ryan, M.H. and Bergström, L. (2007) 'Plant nutrient use efficiency in organic farming – consequences of exclusive use of organic manures and untreated minerals', *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, Vol. 2, No. 076, pp.1–12.

Lang, T. and Heasman, M. (2004) *Food Wars – The Global Battle for Mouths, Minds and Markets*, Earthscan, London.

Lötjönen, T., Muuttomaa, E., Koikkalainen, K., Seuri, P. and Klemola, E. (2004) *Laajamittaisen luomutuotannon teknologia – taloudellinen toteutettavuus ja ekologinen kestävyys (Production technology of large-scale organic farming as an economic and ecological challenge)*, Maa-ja elintarviketalouden tutkimuskeskus.

Mäenpää, I. (2004) *Kulutuksen ympäristökuormitus (Environmental impact of consumption)*, Thule Institute, University of Oulu. Available online at: http://www.ymparisto.fi/download.asp?contentid=42088&lan=FI

Mikkelsen, B.E., Vittersø, G., Roos, G., Vramo, L. and Bergström, K. (2007) *The Public as Political Consumer – Case Findings from Implementation of Organic Procurement Polices in Public Food Systems in Scandinavia*, Helsinki, Finland.

Ministry of the Environment (2008) *Getting more from less. Proposals for Finlands' national programme to promote sustainable consumption and production*. Available online at: http://www.ymparisto.fi/default.asp?contentid=62075&lan=en

MMM (2007) *Balance Sheets for Food Commodities 2006*, Information Centre of the Finnish Ministry of Agriculture and Forestry, Helsinki.

MMM (2008) *Yearbook of Farm Statistics 2007*, Information Centre of the Finnish Ministry of Agriculture and Forestry, Helsinki.

Morgan, K. and Sonnino, R. (2005) *Catering for sustainability. The creative procurement of school meals in Italy and the UK*. Available online at: http://www.brass.cf.ac.uk/uploads/cateringforsustainability1.pdf

Niggli, U., Fliessbach, A., Hepperly, P. and Scialabba, N. (2008) *Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems*, FAO.

PATT (2008) *Carbon footprinting, personal CO_2 emissions*. Available online at: http://w.plant-a-tree-today.org/NewQuickOffset.asp

Piiroinen, S. and Järvelä, K. (2006) *Kokemuksella ja tiedolla. Tutkimus kuluttajien ruoan valinnasta (Using experience and information. A study of consumers' food choice)*, Kuuttajatutkimuskeskus, Helsinki.

Pimentel, D. and Pimentel, M. (2007) 'Transport of agriculture supplies and food', in *Food, Energy and Society*, CRC Press, Tayor & Francis Company, pp.257–259.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D. and Seidel, R. (2005) 'Environmental, energetic comparisons economic comparisons of conventional and organic farming systems', *BioScience*, Vol. 55, No. 7, pp.573–582.

Pipatti, R. (2001) *Greenhouse Gas Emissions and Removals in Finland*, Technical Research Centre of Finland, Espoo, Finland.

Pollan, M. (2006) *The Omnivore's Dilemma: A Natural History of Four Meals*, The Penguin Press.

Puurunen, M., Turunen, H., Knuutila, K., Uusitalo, P., Turtola, E., Lemola, R., Laitinen, P., Ylivainio, K., Risku-Norja, H., Jansson, H., Karhu, E., Grönroos, J., Mattila, P., Pyykkönen, S., Ekholm, P., Granlund, K., Rankinen, K., Räike, A., Heliölä, J., Kuussaari, M., Pykälä, J., Schulman, A. and Hietala-Koivula, R. (2004) *Horisontaalisen maaseudun kehittämisohjelman väliarviointi: Manner-Suomi*, MMM Publications 1/2004: 272, [28] p.

Risku-Norja, H., Hietala, R., Ketomäki, H. and Virtanen, H. (2007) *Paikallinen ruokajärjestelmä: ruoantuotanto ja -kulutus sekä ympäristövaikutukset. Aineisto ja menetelmät (Localisation of food production and dietary changes: environmental impacts)*, Technical report, MTT – AgriFood Research Finland. Available online at: http://www.mtt.fi/mtts/pdf/mtts135.pdf

Risku-Norja, H., Hietala, R., Virtanen, H., Ketomäki, H. and Helenius, J. (2008) 'Localisation of primary food production in Finland: production potential and environmental impacts of food consumption patterns', *Agricultural and Food Science*, Vol. 17, No. 2, pp.127–145.

Risku-Norja, H. and Mäenpää, I. (2007) 'MFA model to assess economic and environmental consequences of food production and consumption', *Ecological Economics*, Vol. 60, No. 4, pp.700–711.

Schlich, E. and Fleissner, U. (2005) 'The ecology of scale: assessment of regional energy turnover and comparison with global food', *International Journal of LCA Studies*, Vol. 10, No. 3, pp.219–223.

Starr, M.A. (2009) 'The social economic of ethical consumption: theoretical considerations and empirical evidence', *Journal of Socio-Economics*, No. 38, pp.916–925.

Statistics Finland (2007) *Greenhouse gas emissions in Finland 1990-2005*, National inventory report for the UNFCCC. Available online at: www.stat.fi/greenhousegases (accessed on 20 May 2007).

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. and deHaan, C. (2006) *Livestock's Long Shadow. Environmental Issues and Options*, Food and Agricultural Organization of the United Nations, Rome.

Thomassen, M.A., van Calker, K.J., Smits, M.C.J., Iepema, G.L. and de Boer, I.J.M. (2006) 'Life cycle assessment of conventional and organic milk production in the Netherlands', *Agricultural Systems*, No. 96, pp.95–107.

Tuori, M., Kuoppala, K., Valaja, J., Aimonen, E., Saarisalo, E. and Huhtanen, P. (2002) *Rehutaulukot ja ruokintasuositukset*, MTT, Jokioinen.

Väänänen, V. and Mäkelä, J. (2007) *Terveellistä ja luonnolista ruokaa. Elävän ravinnon syöjien näkemyksiä ruokavalionsa perusteista ja käytännöistä*, Kuluttajatutkimuskeskus, Helsinki.

Vinnari, M., Montonen, J., Härkänen, T. and Männistö, S. (2009) 'Identifying vegetarians and their food consumption according to self-identification and operationalized definition in Finland', *Public Health Nutrition*, No. 12, pp.481–488.

Vinnari, M., Vehmas, J. and Luukkanen, J. (2005) 'Animal based food consumption in the EU – do we decrease our meat consumption when the income levels rise?', in Vilska, T. and Haanpää, L. (Eds.): *Life Styles and Social Change. Essays in Economic Sociology*, Turku School of Economics and Business Administration, Turku.

Virtanen, Y., Hyvärinen, H., Katajajuuri, J-M., Kurppa, S., Nousiainen, J., Saarinen, M., Sinkko, T., Usva, K., Virtanen, J., Voutilainen, P., Ekholm, P., Grönroos, J., Koskela, S., Väänänen, S. and Mäenpää, I. (2009) *Elintarvikeketjun ympäristövastuun taustaraportti*, MMM Laatukietju, Helsinki.

Wallén, A., Brandt, N. and Wennersten, R. (2004) 'Does the Swedish consumer's choice of food influence greenhouse gas emissions?', *Environmental Science & Policy*, No. 7, pp.525–535.

Weibull, A., Östman, Ö. and Granqvist, Å. (2003) 'Species richness in agroecosystems: the effect of landscape, habitat and farm management', *Biodiversity and Conservation*, No. 12, pp.1335–1355.

WRI (2006) *Earth trends*. Available online at: http://www.earthtrends.wri.org/searchable_db (accessed on 28 August 2006).

Young, H.P. (2009) 'Innovation diffusion in heterogeneous populations: contagion, social influence, and social learning', *The American Economic Review*, Vol. 99, No. 5, pp.1899–1924.

Zhu, X. and Ierland, E.v. (2004) 'Protein foods and environmental pressures: a comparison of pork and Novel Protein Foods', *Environmental Sciences*, No. 1, pp.254–276.

Notes

1 200,000 reindeer, 84,000 elk and 5000 white-tailed deer (pers. com. Aslak Ermala, Finnish Game and Fisheries Research Institute, October 2008).

2 The new values 298 for N_2O and 25 for CH_4 are not yet widely applied (IPCC, 2006).