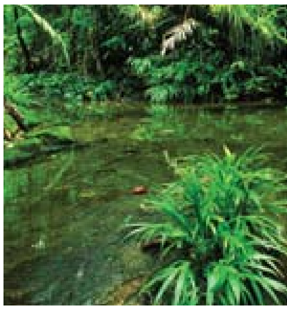
Environmental impacts of the UK food economy with particular reference to WWF Priority Places and the North-east Atlantic



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Donal Murphy-Bokern

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Donal Murphy-Bokern
Murphy-Bokern Konzepte
48393 Lohne-Ehrendorf
Germany

www.murphy-bokern.com

Murphy-Bokern Konzepte

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Foreword

WWF is a science-based organisation. We advance our work on the basis of the best independent scientific evidence. This report was commissioned by WWF-UK in late 2007 to support the development of our One Planet Food programme, which we launched in 2009. The purpose of this work was to develop a common understanding of what the most significant factors are in the relationship between the provision of our food and the protection of our natural environment.

In protecting the natural environment, WWF combines work in threatened habitats with strategic efforts to address the underlying economic and social pressures behind environmental degradation. Taken globally, food production accounts for 23% of humanity's ecological footprint. Some 38% of the world's ice-free land is farmed, while many of our fisheries are in a rapid state of decline. We are undermining many of the ecosystem services that are fundamental to our own well-being and the sustainability of our own global food systems. It is clear that we must regard our food system as a major component of our efforts to reduce pressures on the natural world. The purpose of this report was to help WWF orientate and prioritise its approach to food. It provides a review of the broad global impacts of UK food consumption, sets out the climate change effects, and considers the implications of food for the wider environment.

WWF recognises that we can conserve much of life on Earth by conserving the most exceptional ecosystems and habitats – places that are particularly rich in biodiversity; places with unique animals and plants. To this end, we have identified 35 ‘Priority Places’ that require special protection. This study looks systematically at the connections between our food consumption and these Priority Places, and describes the impacts on them and how these may be reduced. We identify 10 Priority Places affected significantly by UK food consumption, and examine how we affect the north-east Atlantic ecoregion. Even though the majority of UK food is produced in the UK, our food system has a long reach in terms of environmental impact.

In the development of our One Planet Food programme, our work has helped us gain a common understanding of what matters most. It has underpinned a deep debate in WWF and informed our interactions with our partners and with government on the issue. Our findings show clearly that we need to look beyond some current emblematic issues and focus on the underlying processes that matter most, in the full range of farming systems and the technologies used. It is vital that we foster sustainable consumption patterns, increase the resource-use efficiency of food production, increase the efficiency of nutrient use in agricultural systems, improve farmland as a habitat, and eliminate deforestation and other forms of land-use change to agriculture.

These are big challenges. We invite you to be part of the solution.

Mark Driscoll
Head of One Planet Food Programme
WWF-UK

Executive summary

This study examines the impacts of the UK food economy to inform WWF policy on food. It takes an industrial ecological approach, examining the impacts of the UK food economy from a consumption perspective.

The study comprises six interrelated activities:

1. A broad appraisal of the burdens arising from the UK food system with emphasis on greenhouse gas emissions, the impacts on the nitrogen and water cycles, and impacts on biodiversity.
2. A detailed examination of trends in the consumption of food commodities.
3. An examination of the UK's sourcing of food and the effects on global food commodity flows.
4. A systematic analysis of interactions between the UK food economy and food production affecting WWF's 35 Priority Places.
5. A detailed appraisal of the effect of UK food on WWF Priority Places.
6. An assessment of the role that policy could play in furthering WWF interests through a consumer-oriented food policy.

Approach
The work is based on a detailed analysis of commodity consumption, production and trade data from the UK Department for Environment, Food and Rural Affairs (Defra), the United Nations Food and Agriculture Organisation (FAOSTAT), the US Department of Agriculture, and a range of commercial sources. The sourcing of UK food, including animal feedstuffs, was examined. The burdens arising from the production of food under UK and similar European conditions were quantified using current estimates of the burdens associated with this production available from Defra research (Williams et al., 2006). This in turn informs a broad analysis of the literature on the burdens arising from UK food consumption.

The work was initiated to inform the development of a food policy in WWF-UK. Interactions between the UK food economy and WWF's 35 Priority Places are identified from the FAOSTAT Trade Matrix. The literature on the development of food production in relevant Priority Places was examined, especially for effects of changes in production on key ecosystems. The effects of food production in Priority Places, especially changes in food production, were examined in detail.

UK consumption, production and imports
Most of the food consumed in the UK comes from UK farms and fisheries. Although dependence on imports is increasing, the UK is about 58% self-sufficient in all foods, and about 72% self-sufficient in indigenous food. The trend between 1990 and 2005 was towards increasing reliance on imports associated with the combination of a 15% increase in commodity consumption and a decrease in UK agricultural output. Imports grew by 51% (by weight) between 1990 and 2005. An increase in the weight of commodity consumed could occur just through switching foods if high density foods such as meat and cereals are substituted by low density bulky foods such as fruit and vegetables. However, over the last 10 years, consumption has increased for nearly all commodities including meat. Statistics reveal reliance on near-neighbours for imported supplies of major commodities, particularly meats. Production in north-western Europe accounted for about 95% of meat and 90% of dairy supplies in 2005. The UK is part of a north-west European meat supply system which is the single biggest importer of soy.

In 2005, the UK meat supplies that came from outside north-western Europe were dominated by meat from South America. This, combined with the trade in soy, directly connects the UK food economy with land use in South America. A minor change in the consumption of imported beef in the UK was associated with the UK becoming Brazil's most important developed country customer for beef. It is estimated that the UK market has served as the driver behind 7-10% of the growth of the Brazilian beef industry up until 2005. This growth is occurring mainly in the Amazon region even though the supplies to the UK may come from other parts of Brazil.

UK fruit and vegetable consumption is increasing and UK production is decreasing. These changes are large, both in relative and absolute terms, and have led to major increases in commodity flows from the Mediterranean basin, South Africa, South America, and a wide range of tropical and subtropical countries. Other food imports associated with significant (usually increasing) agricultural activity affecting WWF Priority Places include palm oil, coffee, fruit juice, wine and olive oil.

Environmental burdens

The UK food economy is directly responsible for greenhouse gas (GHG) emissions equivalent to at least 32 million tonnes of carbon. This is dominated by 14 million tonnes of carbon equivalent as direct emissions from UK agriculture and 2.1 million tonnes of carbon equivalent from fertiliser production for the UK. A further 1 million tonnes of carbon can be attributed to the farm production of livestock products in other countries for UK consumers, bringing the total emissions attributable to the primary production of food in the UK to ca 17 million tonnes of carbon equivalent. Considering the emissions from UK food manufacture, distribution and retail (15 million tonnes of carbon equivalent), the direct emissions from the production of food for UK consumption (including the upstream fertiliser production) exceeds 32 million tonnes of carbon. This is equivalent to 17% of the emissions attributed to the UK in greenhouse gas emission inventories. In addition to these, there are emissions from other imported commodities such as fruit and vegetables, wine, fruit juice, tea, coffee, palm oil, etc.

In addition to these direct emissions, there is the UK's share of indirect emissions due to land-use change, e.g. deforestation. Deforestation accounts for 18% of global emissions. This is a major part of the global food economy's impact on the environment. The UK food economy is directly connected to regions where deforestation is occurring, especially through the trade in beef and palm oil. The emissions from deforestation that can be attributed to the UK food system have not been quantified, but even 1% (reflecting the UK population as a proportion of the global population) of the 2 billion tonnes of carbon equivalent due to deforestation globally is very significant (20 million tonnes of carbon).

It is clear that the delivery of food up to the point of consumption is significant: food is comparable to transport and domestic energy consumption in terms of its role in personal carbon footprints. Overall, UK agricultural emissions have a downward trend, associated with reductions in UK nitrogen fertiliser use and livestock numbers, particularly cattle. In addition, driven by climate change agreements, some parts of UK food manufacture are reducing energy use. Against this, consumption and imports are increasing and there has been an increase in the consumption of refrigerated foods. Refrigeration is estimated to be responsible for 3.0-3.5% of UK greenhouse gas emissions, including 42% of the emissions from energy use in supermarkets (Garnett, 2007).

The majority of emissions directly arising from agriculture arise from the nitrogen cycle, so this study looks particularly at how the UK food economy interacts with the nitrogen cycle and how the effects of this can be mitigated. In agriculture, the trace gas nitrous oxide or N_2O, a product of the nitrogen cycle with a global warming potential that is 296 times that of CO_2, dominates, along with substantial contributions from methane. Atmospheric N_2O concentrations have increased from a pre-industrial level of 270 parts per billion by volume (ppbv) to a current level of 319 ppbv. In addition, the manufacture of nitrogen fertilisers represents the major fossil energy input into agriculture, accounting for 1.2% of the world's energy consumption in 1998.

The study also looks at impacts on soil carbon and water resources, and outlines effects on soils. Sequestration of carbon in agricultural soils has significant greenhouse gas mitigation potential globally (Smith et al., 2007). Crop productivity is important because sequestration occurs when the input of biomass into soils increases. Much of the debate about a special role for organic farming or reduced tillage in sequestration distracts from an understanding of the underlying processes – the effects are dependent on the increase in biomass returned to soils.

The report argues that concerted efforts to improve the nitrogen balance of UK agriculture would encourage reductions in soy imports and fertiliser application while maintaining or increasing production through improved recycling of organic nutrients and improved utilisation in crops and animals. This would have benefits in terms of biodiversity, resource protection and pollution. Reconnecting crop and livestock production and conserving reactive nitrogen and phosphorus within the soil/plant/animal system is central to the development of a more eco-efficient agriculture. Moreover, evidence on impacts on biodiversity generally indicates that a more diverse land-use pattern, such as that associated with mixed farming or a more complex pattern of perennial and annual crops (autumn and spring sown) would be beneficial.

WWF's Priority Places

The UK food economy interacts directly through significant trade in food with the following Priority Places:

- The Atlantic Forest (Brazil, Paraguay and Argentina)
- Borneo
- The Cerrado-Pantanal of Brazil and neighbouring countries
- Choco-Darien (Colombia, Panama and Ecuador)
- Fynbos (South Africa)
- Mediterranean sea, forests and Balkan rivers and streams
- New Guinea and its offshore islands
- Sumatra

These direct interactions are due to imports of beef from Brazil; soy from Brazil; palm oil from Borneo, Sumatra, Colombia (Choco-Darien) and New Guinea; fruit, vegetables and olive oil from the Mediterranean and Brazil; and coffee from Sumatra. In addition, the UK food economy has a huge impact on the north-east Atlantic, through fisheries.

The UK food economy has significant indirect interactions with the following Priority Places:

- The Amazon and Guineas
- The Northern Great Plains

The indirect interactions are due to global trade in beef, soy and cereals, and are very significant in the case of the Amazon. Beef and soy imports from the Cerrado of Brazil have raised the value of Cerrado land, causing the production of beef for Brazilian consumption to move northwards to the Amazon. In the US, the Northern Great Plains are under threat from a broad range of forces caused by the global increase in cereal and soy prices.

The effect of UK food imports on these Priority Places could be dwarfed by biofuel imports if a significant market for biofuels developed. Biofuels pose a significant threat to the Northern Great Plains, and to all Priority Places where oil palm is grown. The market for biofuels is potentially so large that it is difficult to envisage a significant contribution to transport from biofuels without large effects on land-use change and biodiversity in Priority Places.

The UK food economy has had a very profound effect on the north-east Atlantic. UK fish consumption is moderate by European standards but still represents 2% of world fisheries production and has significant consequences for sensitive fish stocks and the wider environment. The key consumption issue is UK consumers' preference for demersal whitefish species such as cod native to UK waters but which are now over-exploited. In addition to depleting stocks, bottom trawling of the north-east Atlantic causes long-term physical damage to the marine environment.

Food policy development
The purpose of this work was to inform the development of WWF-UK's policy on food. The following is a discussion of the results in the context of such policy development.

Focusing on what matters
There has been an explosion in public interest in food matters in the UK, especially in the last two years. Food policy is now under the spotlight, prompted by celebrities, input from NGOs, and contributions from public bodies such as Defra. This gives the impression of a crowded arena. However, some of the debate is focused on issues that either don't matter much or is tangential to food and agriculture with respect to the global environment. A focus on what matters would be a significant step forward for the UK food-related impacts on the environment. This means avoiding being side-tracked by past and present emblematic issues and conflicts encapsulated in terms such as organic food and farming, food miles, GMOs, large versus small-scale farming, industrial farming, factory farming, chemical farming, etc. What matters is fostering sustainable consumption patterns, increasing the resource-use efficiency of food production, increasing the efficiency of nutrient use in agricultural systems, improving farmland as a habitat, and eliminating deforestation and other forms of land-use change to agriculture.

Focusing on primary production and some supply chain hotspots
Overall, emissions from the food system are dominated by primary production (i.e. growing crops and raising animals) and some emission hotspots in manufacture and retail. Primary production alone accounts for about half of the UK food system's direct GHG emissions. Indirect emissions associated with deforestation are linked to primary production. Further, the food economy's direct impact on biodiversity via land occupation and land-use change arises almost solely in primary production. Hotspots in manufacturing and retail include energy use in refrigeration, particularly for chilled fresh food where some high food wastage is recorded, for example in the case of salads.

The food manufacturing and distribution system is tightly interlinked and the literature indicates that consumer expectations of the retail sector (partly conditioned by retailers) have some special characteristics in the UK. Consumers' expectation of the provision of a huge range of fresh produce in perfect visual condition all the time accessible through the 'one-stop-shop' leads to more losses in the fresh produce supply chain. It also leads to pesticide use to improve the appearance of produce.

The level of consumption
Looking at the UK food economy as part of the north-western European food economy, there is a case for addressing the rise in UK commodity consumption, particularly meat consumption, to reduce global resource use, greenhouse gas emissions and pressure on key habitats, and contribute to a more equal distribution of scarce food resources. The UK food system is an integral part of the wider EU food economy, and is particularly strongly linked to agriculture in Ireland, the Netherlands, Denmark, France and Germany. Looking at global commodity trade it is clear that north-west European countries are a major force in the international trade of commodities impacting of ecosystems of global importance. The EU is the biggest market for soy importing the equivalent of about 45 million tonnes of soybean per year. The EU is also the second biggest market for palm oil in the world. The UK was the largest developed economy market for Brazilian beef in 2005.

In developing any policy on consumption, it is important to consider some context. UK personal intake of many commodities is moderate compared with other developed economies. Direct links between consumption and with key impacts in Priority Places such as the Amazon are rare and/or weak. Growth in consumption of some commodities is due partly to the adoption of low-calorie 'healthy' foods such as fruit and especially fruit juice.

Apparent meat consumption is a reasonable indicator of the resource intensity of the food economy from a consumption perspective. Meat consumption is 84kg/capita/year carcass equivalent in the UK. This is typical of Europe and below the US (123 kg). But it is twice the world average (40). Moderating meat consumption is clearly part of consumer action to reduce the role of the UK food economy in global greenhouse gas emissions and deforestation.

In addition to being the means of 'harvesting' pasture covering 26% of the ice-free land surface, livestock also consume about one third of the cereal harvest (ca 670 million tonnes) and the meal from about 200 million tonnes of soybeans. So the increasing demand for livestock products is the main driver behind the increasing demand for food over the last 20 years. Moderating the consumption of livestock products in the developed and transitional economies is potentially a cornerstone in a policy on global food prices and food security for the poor where constrained supply is causing price rises. In developing policy, the important positive role of livestock in food production and diets worldwide must be recognised. Social justice means extending the benefits of the livestock sector to the poor. The development of the UK poultry sector illustrates how efficient production leads to affordable high quality food, raising the living standards of low-income households. Minor changes in consumption of livestock products in Europe can have significant effects on European farm businesses in the short term. We have seen this recently in Europe where a small increase in milk supply combined with a small contraction in demand has led to a significant reduction in farm-gate milk prices. Similar short-term price effects affect pig and poultry producers. However, this may be a short-term price that may need to be paid if integrated food and agriculture policies to address global environmental challenges are adopted.

A balanced approach to policy on the consumption of livestock products is required, particularly in developing countries. Cattle, sheep and goats 'harvest' grassland, much of it native grassland or other land not suitable for crop production. They are also a source of income for 1 billion of the world's poor. The challenge for policy on consumption in the developed economies has a complexity which demands more than just a position on vegetarianism. It is about fostering a pattern of consumption and production that harnesses the potential eco-efficiency of livestock, and delivering to as many people as possible the benefits that moderate consumption of livestock bring to most diets. Recognising the high value of livestock products in the human diet would help foster the moderation in developed countries' consumption that is essential if we are to improve nutrition across the world without further serious damage to the environment. In aquaculture, a move away from piscivorous fish such as salmon towards herbivorous fish (e.g. carp and tilapia) would reduce the impact of the fish portion of our diets. In relation to wild fisheries, UK consumers in particular should be encouraged to draw on a wider range of seafoods, reducing the pressure on over-exploited demersal white fish stocks.

Product certification and supply chain stewardship

There needs to be greater understanding and ready acceptance of the rationality of economic behaviour driving change in production, particularly land-use change in key habitats such as the Amazon. The market for agricultural land in regions affected by damaging land-use change needs greater attention. It is important to understand the rational private interests causing land-use change at the point and place of change and to strategically address the underlying economic forces. This would lead to the more prompt advocacy of economic instruments and the effective harnessing of markets to protect natural resources and the environment. From a UK consumption and production viewpoint, harnessing sophisticated UK food markets has the potential to play a key role in complementing the role of markets for carbon and avoided deforestation.

Effective product certification and supply chain stewardship enables consumers (and retailers or manufacturers on their behalf) to send signals to producers rewarding high environmental and social standards. This could be an important contribution which complements 'top-down' regulation of land tenure and use. It could also complement and accompany markets for carbon and avoided deforestation. This report advocates that the positive encouragement of environmentally and socially just production through preferential access to high value markets has the potential to influence production asset values, in particular the land market drivers behind deforestation. The prospect of future differentials in the value of produce would be quickly incorporated into land values, providing an economic lever on land-use change. Through the vertically integrated supply chains, stewarded in particular by retailers and some manufacturers with valuable brands, UK consumers have influence and power. The use of certification has the merit of circumventing poor regulation and difficulties in the governance of land use. It harnesses local peer-to-peer pressure. Much of the framework of extensive certification coverage is already in place. Market mechanisms to pay for ecosystem services provided by forests are emerging through Reduced Emissions from Deforestation and Degradation (REDD) and the Clean Development Mechanism. These add to the market-based possibilities which could synergise with product certification. The soy and palm oil roundtables are beginning to make an impact. Mechanisms that can lead to the certification of beef are emerging in South America. We also have the example of the Marine Stewardship Council which is now having a significant impact on seafood consumption in the UK.

The links between the UK food economy and emerging agricultural economies could be used to influence. The UK's presence as a customer in key producing countries is an opportunity. Boycotting certain products will only increase emerging agricultural economies' reliance on indiscriminate global commodity markets. The type of production that brings environmental, social and economic benefits to poor countries warrants support and the UK's sophisticated retail sector, and certification along the lines of that provided by the Marine Stewardship Council, provide a way of linking such production preferentially to the UK market. Preferential access for responsible producers to developed food economies such as that of the UK offers an alternative to commodity trading serving as a basis for establishing differentials in asset (land) values between responsibly and irresponsibly or illegally farmed land. A land market focused approach to deforestation seeks to reduce the value of inappropriately deforested land and increase the value of forest, thus reducing or eliminating the capital return to conversion. New markets are opening up opportunities to increase the value of retaining forest under the Clean Development Mechanism, Carbon Offsetting through for example Voluntary Carbon Standard, and the recently announced Reducing Emissions from Deforestation and Degradation (REDD). Recent developments in Earth observation complement this, opening up opportunities for a wide range of organisations and private citizens to observe environmental change.

Eco-efficient production

To meet rising demand sustainably, world crop production may need to double by 2050 without further destruction of natural resources and burdens on the environment. This means supporting knowledge-intensive farming, innovation and technical change. As we have seen since 1990 in the UK, a reduction in food production or an increase in consumption will result in increasing reliance on global food markets. Directly or indirectly, increased consumption and/or reduced production in Europe will increase agricultural expansion in emerging agricultural economies. As illustrated by the example of the effects of imports of beef from Brazil, changes in UK demand seem small relative to total supplies but the effects at the margins can be significant. From a global food supply and environmental viewpoint, it could be argued that Europe is morally obliged to farm its resilient productive soils well, using all the knowledge-based approaches available.

Associated with the need to appreciate the role of efficient production, the reality of emerging agricultural super-powers such as Brazil needs acceptance. These new agricultural regions need support in developing eco-efficient and socially just production practices. Raising the efficiency of agricultural production in areas away from key habitats will reduce pressure on land-use change, especially if accompanied by production certification. This will contribute to global food security, addressing the social consequences of high food prices. There is also a case for focusing on the restoration of production capacity in countries of the former USSR that have experienced declines in agriculture. Efforts to increase production need to embrace all types of agriculture from the technically sophisticated, for example in the Cerrado of Brazil and in Europe, to small-scale subsistence farming found around the world. Pitting recognisable or branded farming systems against each other is not a positive contribution to this effort. Raising eco-efficiency will require full consideration of the benefits of all of the technologies available combined with the development and deployment of these technologies in support of environmentally and socially just productive agriculture. An overarching theme for all systems and scales of production will be the harnessing and enhancement of biological cycles and the conservation of key resources such as soil carbon, nitrogen, phosphorus and water.

The report presents a comprehensive set of approaches to greenhouse gas emissions. It argues for a systems approach to the nitrogen cycle. Closing nutrient cycles, particularly by reconnecting animals to the crop resource that they are fed with, is important together with efficient animal and plant production overall. The global movement of nutrients in animal feedstuffs presents a fundamental challenge and is a root cause of resource use inefficiency in the global food system. 'Nitrogen miles' are more important than 'food miles'. A systems approach to the nitrogen cycle gets to the root of the problem and avoids conflicts between nitrous oxide and other pollution emissions from the nitrogen cycle such as ammonia and nitrate. It is argued that nitrogen and phosphorus balances might be useful tools in the UK, as they have been to an extent in other European countries. Cap and trade systems used for nitrogen in the US are also relevant.

UK agricultural and food policy
The role of UK public policy in influencing global development is also emphasised – CAP reform, trade negotiations, and the role of research and development. UK policy makers have had success in recent years in driving forward beneficial change at an international level – particularly the reform of the CAP in 2003. UK policy-makers have also advocated a cautious approach to the development of biofuels and biogas, avoiding environmental down-sides of biofuel and biogas development experienced in other European countries and the US. The UK is also a world leader in developing policy on sustainable food consumption.

Despite the reductions in UK public investment in research over the last 15 years, the UK public agricultural research base is still a science and technology resource of global significance. Traditionally it has had an outward looking perspective and a history of supporting global agriculture with knowledge and technology. Public science policy could provide greater rewards for researchers who establish partnerships with developing agricultural economies and who address research questions of practical significance to food production in environmentally sensitive regions of the world.

1 Introduction and methods

1.1 BACKGROUND

The Ecological Footprint and One Planet Living (now called One Planet Future) concepts championed by WWF have now been adopted into the political mainstream in the UK, most clearly by David Miliband when Secretary of State for Environment, Food and Rural Affairs. In his first speech on farming at the Royal Show in July 2006, Mr Miliband outlined Defra's agricultural policy vision by setting out 'One Planet Farming' as well as One Planet Living as necessary to minimise the impact on the environment of patterns of food production and consumption. At the same time, the Defra Strategy for Sustainable Farming and Food was extended to further the development of "a profitable and competitive domestic farming industry which is a positive net contributor to the environment, while reducing the environmental footprint – at home and abroad – of our food consumption". This brought English and Welsh policy beyond "Improving the environmental performance of farming" as set out in 2002 to encompass global impacts across the whole production, supply and consumption chain. Since about 36% of UK food is imported, Defra acknowledged that it is necessary to consider how the UK food chain contributes to environmental impacts abroad. In his speech at the WWF Summit in March 2007, Mr Miliband acknowledged the WWF 'One Planet Living' concept as "an invaluable lodestar for economic and social policy".

1.2 WWF'S FOOD PROGRAMME

Even though WWF has been instrumental in the development of this lodestar, it has not until now developed a comprehensive public position on food and agriculture. To address this, WWF-UK is developing a food programme as part of its strategy to stabilise and reduce the ecological footprint of the UK and to reduce the key environmental impacts of UK food consumption on places and species that have been identified as global priorities for conservation.

This work reported here is a wide ranging study of the relationship between UK food consumption and burden on the environment conducted to support the development of WWF's food programme. The work:

1. Examines trends in UK food consumption.
2. Assesses trends in the supply of food within and to the UK.
3. Provides a broad assessment of the burdens arising from the production of food for the UK, in the UK, and under conditions similar to the UK.
4. Provides an assessment of the impacts of the production of food for UK consumption in WWF Priority Places affected.
5. Considers these results in relation to the ongoing debate on UK food policy.

1.3 METHODOLOGY

The work was based on a detailed analysis of commodity consumption, production and trade data from the UK Department for Environment, Food and Rural Affairs (Defra), the United States Department of Agriculture (USDA) and the United Nations Food and Agriculture Organisation (FAO). Unless otherwise stated, all data on commodity flows come from the FAO (FAOSTAT, 2006). The sourcing of UK food commodities, including animal feedstuffs, was examined. This identified the proportion of the UK food consumption to which available UK Life-cycle assessment (LCA) data can be applied (e.g. data presented by Williams et al, 2006). The burdens arising from the production of food under UK and similar north European conditions (regional production) were quantified using current estimates of the burdens associated with this production. This informed a broad analysis of the literature on the burdens arising from UK food consumption.

Significant interactions between the UK food economy and WWF's 35 Priority Places were identified. The literature on the development of food production in Priority Places was searched, especially for effects of change in production on key ecosystems. The drivers behind environmental change linked to food production in Priority Places in relation to major commodity flows were examined in detail.

Finally, the evidence base was assessed in relation to implications for the development of food policy to address the conservation of resources, reduction of waste, and the protection of biodiversity in WWF's Priority Places.

2 Trends in UK food consumption and supply

2.1 TRENDS IN UK FOOD CONSUMPTION

The data reported here relate to the commodity equivalents of the food products purchased, i.e. the food materials entering the UK food economy for UK consumption in terms of the traded commodities used.

Although the total weight of commodity used to produce the food consumed in the UK is not an exact measure of food consumption, conclusions can be drawn from some clear trends. For the UK as a whole, the consumption of food commodities rose from 61 million tonnes in 1990 to 70 million tonnes in 2005, an increase of 15%. The details of these changes are set out in Table 1. Growth in population accounted for a proportion of this increase, but the main underlying driver is the 10% growth in per capita consumption as traded commodity. The increase is broad-based across a wide range of plant and livestock-based commodities.

Cereals and pulses

Total cereal and pulse commodity consumption increased from 20.4 million tonnes in 1990 to 21.4 million tonnes in 2005. Direct human consumption increased from 6.8 to 8.5 million tonnes. This was due to a 1.4 million tonnes (29%) increase in the consumption of wheat, and a doubling in the consumption of rice to 531,000 tonnes. Even though poultry production increased during this period, maize imports declined indicating that the increased consumption of all wheat (from 10.7 to 13.8 million tonnes) is due to the increased use of wheat in poultry feeding, associated with a reduction in net wheat exports.

Table 1: Commodity food consumption of food in the UK in 1990 and 2005 (FAOSTAT, thousand tonnes)

Commodity	1990	2005	Change %	Commodity	1990	2005	Change (%)
Almonds	31	27	-13	Lemons and limes	88	118	34
Animal fats	159	94	-41	Lentils	12	18	52
Anise, fennel etc.	4	7	73	Lettuce and chicory	334	300	-10
Apples	952	1026	8	Maize	608	606	0
Apricots	22	65	200	Marine fish, other	4	10	155
Artichokes	0	1	72	Misc. meat (inc. camel)	12	21	71
Asparagus	3	8	126	Milk, whole, fresh	13691	14442	5
Avocados	14	28	93	Molluscs	51	46	-9
Bananas	437	658	50	Mushrooms and truffles	153	199	30
Barley	785	708	-10	Natural honey	28	32	15
Beans, green	37	40	7	Nutmeg, mace, etc.	1	1	34
Beans, dry	63	55	-12	Nuts	14	22	56
Bird eggs	602	559	-7	Oats	101	106	5
Bovine meat	1032	1041	1	Misc. oilseeds	0	23	5093
Broad beans, dry	0	0		Olives	56	406	619
Cabbages etc	453	268	-41	Onions (inc. shallots)	524	621	19
Carrots and turnips	550	537	-2	Oranges	573	1178	105
Cashew nuts	11	29	169	Misc. melons etc.	82	145	76
Cassava	0	0		Palm nuts (nut equiv.)	369	337	-9
Cauliflowers, broccoli	312	252	-19	Papayas	1	11	628
Cephalopods	5	1	-77	Peaches and nectarines	145	145	0
Cereals	47	237	409	Pears and quinces	156	205	31
Cherries	13	23	72	Peas, dry	174	169	-3
Chestnuts	3	2	-32	Peas, green	467	226	-52

Chicken meat	882	1598	81	Pepper (Piper spp.)	4	6	42
Chillies, peppers (dry)	3	6	73	Pig meat	1174	1228	5
Chillies, peppers (green)	46	123	167	Pineapples	209	353	69
Cinnamon (canella)	1	1	28	Pistachios	4	5	33
Citrus fruit	3	46	1621	Plantains	0	17	15164
Cloves	0	0	-4	Plums and sloes	74	135	82
Cocoa beans	103	123	20	Potatoes	5361	6843	28
Coconuts	75	69	-8	Pumpkins, squash etc.	22	29	35
Coffee, green	125	120	-5	Rabbit meat	1	0	-71
Cottonseed	15	2	-86	Rape and mustard seed	986	1345	36
Cranberries, blueberries	0	4	933	Raspberries etc.	20	18	-10
Crustaceans	136	224	65	Rice, paddy	275	531	93
Cucumbers, gherkins	176	161	-8	Rye	30	19	-39
Currants, gooseberries	21	23	9	Sesame seed	6	10	66
Dates	8	12	44	Sheep and goat meat	418	351	-16
Demersal fish	620	518	-16	Soybeans	1143	752	-34
Duck, goose	26	49	89	Spices	7	9	26
Edible offal	240	180	-25	Spinach	1	6	408
Eggplants (aubergines)	5	13	184	Strawberries	60	85	43
Figs	7	7	-2	Sugar beet	5457	4901	-10
Freshwater fish	89	149	68	Sugar crops	8362	8066	-4
Garlic	5	6	24	Sunflower seed	321	284	-11
Ginger	6	12	102	Tangerines, mandarins	151	312	106
Grapefruit and pomelo	112	174	54	Tea and Maté	143	129	-10
Grapes	2453	3623	48	Tomatoes	1218	1441	18
Groundnuts	279	247	-11	Turkey meat	144	207	44
Guavas, mangosteens	13	47	257	Vanilla	0	0	0
Hazelnuts	17	9	-45	Misc. vegetables	1285	3370	162
Kiwi fruit	8	22	169	Walnuts	9	13	38
Large Pelagic fish	175	240	37	Watermelons	20	33	64
Leeks, alliaceous veg.	77	44	-44	Wheat	4700	6073	29
Leguminous vegetables.	18	11	-36	Yams	2	6	155

Meat, milk, eggs and fish

Meat consumption grew from 4.1 million tonnes in 1990 to 4.8 million tonnes in 2005, an increase of 17%. This increase occurred in two phases: 1990-1993 and 2003-2005. It is due almost entirely to a nearly two-fold increase in poultry meat consumption. Beef consumption decreased in the mid-1990s but demand recovered between 2000 and 2005 to the point it was in 1990. Consumers reduced beef consumption and increased poultry meat consumption in the mid-1990s and are now recovering the consumption of beef. The increased consumption of poultry over the last 20 years now adds to rather than displaces beef.

The consumption of milk increased by only 5% during this period in line with population growth. This growth has occurred between 2000 and 2005 in particular, so the statistics indicate that the UK is currently going through a phase of rising consumption.

The UK consumers account directly for about 1.4 million tonnes of fish commodity (including shellfish) per annum (FAOSTAT, Table 2). Consumption on a raw commodity basis has increased steadily since 1990 when it was about 1.2 million tonnes. Demersal fish consumption declined from 667,000 to 597,000 tonnes while pelagic fish (e.g. herring, tuna) consumption rose from 173,000 to 225,000 tonnes. Consumption of shellfish and freshwater-farmed fish also rose. In addition to these supplies to consumers, the UK also consumes about 1.1 million tonnes of industrial fish, mainly for producing feed for aquaculture. Overall, the UK food economy accounts for about 2% of the world's fishery production.

Table 2: UK fish production, trade and consumption in 1990 and 2003

	Production quantity (1000 tonnes)	**Import quantity (1000 tonnes)**	**Export quantity (1000 tonnes)**	**Domestic supply (1000 tonnes)**	**Feed quantity (1000 tonnes)**	**Food quantity (1000 tonnes)**	**Food/capita (kg)**
1990							
Fish, Seafood	**818**	**2285**	**566**	**2550**	**1405**	**1181**	**20.7**
Freshwater Fish	50	64	22	92	0	91	1.6
Demersal Fish	326	445	129	642	10	667	11.7
Pelagic Fish	333	1545	310	1568	1395	173	3.0
Misc. marine fish	2	11	3	4	0	4	0.1
Crustaceans	49	195	73	188	0	188	3,3
Cephalopods	7	2	2	8	0	8	0.1
Molluscs, Other	51	23	27	48	0	49	0.9
2003							
Fish, Seafood	**919**	**2394**	**882**	**2431**	**1095**	**1374**	**23.1**
Freshwater Fish	155	110	77	188	0	186	3.1
Demersal Fish	278	499	220	557	0	597	10.1
Pelagic Fish	316	1415	411	1320	1095	225	3.8
Misc. marine fish	1	15	3	13	0	13	0.2
Crustaceans	62	313	104	271	0	271	4.6
Cephalopods	9	6	7	8	0	8	0.1
Molluscs, Other	98	36	61	73	0	73	1.2

While fish consumption has increased since 1990, overall, apparent UK fish consumption per capita has declined since 1950 and at 23kg fish commodity per year in 2005 is relatively low by EU 15 standards. This is about 50% higher than the world average (excluding China). Personal intake of fish has been stable at 7-8kg per capita per year since about 1975 (Defra statistics on consumption of selected household foods, 1942 to 2000). This contrasts the rest of the world where average fish consumption has grown seven-fold since 1950.

Overall, the UK food economy is characterised by moderate fish consumption by developed country standards. However, the type and origin of fish preferred by UK consumers means the UK has played a major role in the depletion of fish stock in the north-east Atlantic. Some 43% of UK fish consumption is demersal fish (e.g. cod, haddock, plaice) compared with 18% for the world. The UK is also a significant consumer of tuna at about 100,000 (Marine Fisheries Agency, 2006). Direct human consumption of small pelagic fish (e.g. sardine, herring) and shellfish is relatively low.

There are no significant links between UK fish consumption and the 35 WWF Global Priority Places, but the connection to WWF's north-east Atlantic ecoregion is very strong and it could be argued that the UK food economy has been the single largest factor in the decline of north-east Atlantic fish stocks.

Fruit, vegetables and nuts

There is a general trend towards increased consumption of fruit and vegetables combined with a greater increase in the demand for a diverse range of exotic or out-of-season produce. Fruit (including wine and juice) consumption increased by 52% (5.6 million tonnes to 8.5m tonnes) with tropical and Mediterranean fruit increasing by 62% and 60% respectively. While tropical fruit consumption growth is from a low base (0.7 million tonnes in 1990), the growth consumption of Mediterranean fruit is significant in both absolute and relative terms. It increased from 3.6 million tonnes in 1990 to 5.8 million tonnes in 2005. Growth in consumption has been particularly strong since 2000. Bananas and pineapples account for 95% of tropical fruit imports. The consumption of pineapple increased particularly strongly – from 209,000 tonnes in 1990 to 353,000 tonnes in 2005.

The consumption of salad species (tomatoes, lettuce etc.) and mushrooms increased from 1.9 to 2.1 million tonnes. This is particularly significant as it includes a large proportion of crops grown under glass and perishable crops grown in southern Europe. There was a 162% increase in the consumption of a diverse range of vegetable species. The increase in this category accounted for more than half the total increase, reflecting the shift away from native seasonal produce to more diverse and exotic vegetables.

Britons consume about 440,000 tonnes of nuts per year. Consumption has decreased slightly since 1990. However, the consumption of more recently popular but lower volume species is increasing. This mirrors the general pattern of increasing diversity in the consumption of plant products.

Oilseeds
The consumption of oilseeds (including olives but excluding palm oil) increased by 50% from 1.4 million tonnes to 2.1 million tonnes. Half of this increase is due to a six-fold increase in the consumption of olive oil. There was also a 37% increase in rapeseed consumption.

FAO trade statistics record that the UK's consumption of palm oil doubled between 1990 and 2005 from 348,000 tonnes to 707,000 tonnes. This period predates a biodiesel industry in the UK so the increase occurred in traditional uses, both food and non-food.

Herbs and spices
The consumption of major herbs and spices increased by 61% from 23,000 tonnes to 37,000 tonnes. The largest single component is ginger which more than doubled from 6,000 to 12,000 tonnes. It also includes about 6,000 tonnes of black pepper.

Beverages – tea, coffee and cocoa
The consumption of tea and coffee declined while the consumption of cocoa products increased. Britons have developed a taste for high quality chocolate products and this accounted for much of the growth in the consumption of cocoa. The import of chocolate products from near neighbours such as Belgium, Germany and the Netherlands more than doubled during this period from 120,000 tonnes to 270,000 tonnes.

Sugar
Sugar consumption decreased from 13.8 million tonnes in 1990 to 12.9 million tonnes in 2007.

2.2 TRENDS IN UK FOOD PRODUCTION

The annual UK production of food commodities for the years 1990 and 2005 is presented in Table 3. There has been a general decline in the production of a wide range of agricultural commodities in the UK. Production of beef, fruit, vegetables, pigmeat, sheepmeat and potatoes has declined, typically by 20-30%. There were significant declines in the production of horticultural crops. In addition, UK capture fisheries and fishing capacity are in long-term decline due to dwindling fish stocks in the north-east Atlantic.

The changes in the supply of beef and veal are complex due to the effects of BSE and FMD in this period. The UK was broadly self-sufficient in beef in the early 1990s. Beef and veal production declined in the 1990s, but consumption recovered to the 1990 levels by 2005. However, UK beef production now includes older cattle following the re-admission of 30-month-plus cattle into the food chain in 2006. UK beef production was 868,000 tonnes in 2006. Re-admission of older cattle increased domestic supplies by just over 100,000 (13% increase in supply over 2005). The UK was 81% self-sufficient in beef and veal in 2006.

The period 1990-2005 was characterised by contracting forces due to a decline in real prices for most commodities and the introduction of set-aside as a condition for EU payments in the early 1990s. The removal of 'compulsory' set-aside in 2008 and the upward trend in many commodity prices point to some recovery in UK agricultural output.

The UK's major capture fisheries produced about 670,000 tonnes for human consumption in 2005, a reduction since 1990. Most of this comes from the north-east Atlantic, and so represents the UK consumers' connection to a very complex marine ecosystem that is stressed by decades of over-exploitation. Aquaculture production in the UK totalled approximately 172,500 tonnes in 2005 following a steady rise over the previous 20 years.

Table 3: Production of food commodities in the UK in 1990 and 2005 (thousand tonnes)

Commodity	**1990**	**2005**	**% change**
Apples	309	219	-29
Asparagus	2	2	46
Barley	7897	5495	-30
Beans (inc. string b.), green	30	21	-31
Bird eggs (incl. hen eggs)	628	615	-2
Bovine meat	1063	762	-28
Broad beans, horse beans, dry	81	130	61
Cabbages and other brassicas	493	308	-37
Carrots and turnips	569	833	46
Cauliflowers and broccoli	306	219	-29
Misc. cereals	69	68	-1
Cherries (incl. sour cherries)	2	1	-34
Chicken meat	805	1360	69
Chillies and peppers, green	3	14	295
Crustaceans	49	59	20
Cucumbers and gherkins	105	59	-44
Currants and gooseberries	19	22	19
Duck, goose or guinea fowl meat	29	45	53
Edible offal	161	115	-28
Equine meat	2	4	102
Grapes	2	1	-38
Leeks, other alliaceous vegetables	70	50	-29
Leguminous vegetables	14	9	-33
Lettuce and chicory	299	140	-53
Linseed	70	89	27
Misc. meat	10	6	-39
Milk, whole, fresh	15251	14577	-4
Mushrooms and truffles	123	74	-40
Natural honey	3	5	82
Oats	530	532	0
Pears and quinces	37	24	-35
Peas, dry	320	161	-50
Peas, green	555	133	-76
Pig meat	950	706	-26
Rapeseed and mustard seed	1258	1902	51
Raspberries and other berries	22	10	-54
Rye	40	40	-1
Sheep and goat meat	379	331	-13

Spices	5	2	-54
Strawberries	52	63	20
Sugar beet	7902	8687	10
Tomatoes	139	80	-43
Turkey meat	175	211	21
Misc. vegetables	621	339	-45
Wheat	14033	14863	6

2.3 TRENDS IN UK FOOD IMPORTS

The annual UK net import of food as food commodity equivalents for 1990 and 2005 is summarised in Table 4 (FAOSTAT). Reflecting increased consumption and decreasing domestic production, imports of almost all food commodities rose between 1990 and 2005, thus increasing the potential for resource depletion and environmental burdens outside the UK.

Self-sufficiency, which is calculated as the value of raw food produced divided by the value of all raw food consumed, is estimated to be 58% for all food in 2005. This compares with less than 50% in 1956 and more than 70% in the early 1990s when UK self-sufficiency peaked. The UK was 72% self-sufficient in indigenous food in 2005, compared with about 60% in 1955 and 86% in the early 1990s.

Table 4: Net import of agricultural commodities in the UK in 1990 and 2005 (thousand tonnes, (FAOSTAT))

	1990	2005	% change		1990	2005	% change
Almonds	26	27	0	Lettuce and chicory	82	167	103
Animal fats	105	60	-43	Maize	1521	1336	-12
Anise, badian, fennel etc.	4	8	75	Misc. meat	Trace	8	2478
Apples	449	754	68	Milk, whole, fresh	704	2013	186
Apricots	28	70	147	Millet	11	17	53
Artichokes	Trace	1	117	Mushrooms and truffles	41	131	217
Asparagus	2	7	259	Natural honey	23	27	22
Avocados	10	40	288	Nutmeg, mace, cardamoms	1	1	50
Bananas	462	702	52	Nuts	20	23	15
Beans, green	8	6	-18	Oats	-5	-28	463
Beans (incl. cow peas), dry	129	123	-4	Oilseeds	12	44	260
Bird eggs (incl. hen eggs)	42	76	81	Olives	75	438	489
Bovine meat	86	261	203	Onions (inc. shallots)	272	322	18
Cabbages, other brassicas	54	49	-8	Oranges	553	1018	84
Carrots and turnips	29	52	81	Other melons, cantaloupes)	89	158	77
Cashew nuts	7	28	286	Palm nuts-kernels (nut equiv.)	1705	2506	47
Cassava (fresh and dried)	63	19	-70	Papayas	2	8	475
Cauliflowers and broccoli	35	124	256	Peaches and nectarines	159	197	24
Cereals, nec	14	302	2106	Pears and quinces	117	238	103
Cherries	13	26	103	Peas, dry	-36	2	-105
Chestnuts	3	2	-44	Peas, green	2	10	436
Chick peas	10	18	74	Pepper (Piper spp.)	4	6	41
Chicken meat	86	317	269	Pig meat	269	554	106
Chillies and peppers, dry	3	8	119	Pineapples	194	361	86
Chillies and peppers, green	41	139	237	Pistachios	4	6	59
Cinnamon (canella)	1	1	35	Plantains	4	16	339
Misc. citrus fruit	7	39	429	Plums and sloes	65	116	79
Cloves	0.17	0.24	41	Potatoes	676	973	44
Cocoa beans	226	363	61	Pumpkins, squash etc	18	36	98

Coconuts (incl. copra)	269	154	-43	Rabbit meat	2,04	0,4	-80
Coffee, green	132	135	3	Raspberries and other berries	1	8	1419
Cottonseed	15	10	-33	Rice, paddy	399	602	51
Cranberries, blueberries	1	5	898	Sesame seed	10	14	38
Cucumbers and gherkins	67	123	84	Sheep and goat meat	53	34	-36
Currants and gooseberries	1	12	1761	Sorghum	-34	6	-118
Dates	10	17	68	Soybeans	983	1305	33
Duck, goose, guinea fowl	-1	4		Spices	3	9	202
Edible offal	54	64	17	Spinach	2	8	383
Eggplants (aubergines)	6	16	151	Starchy roots	22	16	-30
Equine meat	-1	-1	2	Strawberries	23	51	124
Figs	7	11	68	Sugar beet	-1133	-2075	83
Fruit, (inc. persimm.)	75,69	63	-17	Sugar cane and sugar crops	9975	8532	-14
Garlic	5	11	104	Sunflower seed	356	383	8
Ginger	5	13	165	Sweet potatoes	3	20	583
Grapefruit and pomelo	108,56	170	57	Tangerines, mandarins etc.	164	348	113
Grapes	2164	3818	76	Tea and Maté	141	125	-12
Groundnuts	331	253	-24	Tomatoes	1018	1306	28
Guavas, mangoes etc.	13,56	62,04	358	Turkey meat	9	-17	-289
Hazelnuts	17	9	-47	Vanilla	0,01	0,05	400
Kiwi fruit	6	35	450	Vegetables, (inc. okra)	1047	3188	204
Leeks etc.	5	15	186	Walnuts	10	14	41
Leguminous vegetables	Trace	Trace	-84	Watermelons	21	40	92
Lemons and limes	91	136	50	Yams	3	6	154
Lentils	12	18	53				

Cereals and pulses

The UK is self sufficient in temperate cereals. It imports high protein wheat for bread-making but this is balanced by exports. This trade enables the mixing of wheat to address seasonal variation in quality. The UK is also a net exporter of barley – including exports in the form of whisky. The UK imports the equivalent of about 600,000 tonnes of rice. Major exporters are India and the US. Beyond India and the US, the role of UK rice imports in a large number of smaller producer economies is small.

Beef

The global trade in meat and meat products is complex, and establishing a useful picture of the flows driven by UK consumers is not straightforward. The UK was broadly self-sufficient in beef in the early 1990s, with exports of about 400,000 tonnes to continental Europe balanced by imports from Ireland (230,000), Australia (6,000), Argentina (6,000), Uruguay (7,000), and Brazil (3,000), and imports from other EU countries. The UK has developed a deficit in beef over the last decade which grew to a net import of about 260,000 in 2005. Imports fell in 2006 associated with the return of cattle over 30 months old to the UK domestic market. Defra production statistics indicate that this decline in beef production was linked to the decline in the number and suitability of calves for beef production coming from the dairy herd. Dairy cow numbers declined due to increased milk yield per dairy cow and this was associated with the shift from dual-purpose British Friesian dairy cows to the Holstein-Friesian whose male calves are less suitable than British Friesians for meat production. In addition, low-cost South American beef became available. It is estimated from the various statistical resources of Defra and the FAO that imports from South America accounted for about 100,000 tonnes carcass equivalent in 2005. The sources of imports from outside the EU are Brazil, Uruguay, Argentina, Australia and New Zealand with 66,000 tonnes exported directly to the UK from Brazil according to FAOSTAT. This represents a 20-fold increase in beef imports from Brazil since 1990, and about 6% of Brazil's beef exports in volume terms and 8% in terms of economic value. Other statistical sources also indicate that Brazilian exports to the UK grew steadily until recent EU import restrictions. Brazilian government statistics cited by the Association of Brazilian Beef Exporters record exports of 114,000 tonnes to the UK in 2006. Amigos da Terra (2008) cites Brazilian government statistics showing that the UK imported more than 80,000 tonnes. This includes a high proportion of boned beef. It is concluded that annual UK imports of Brazilian beef may have significantly exceeded the equivalent of 100,000 tonnes carcass weight by 2006. Statistics (FAOSTAT 2006) also indicate that the UK is responsible for 7% of Brazilian beef exports on the basis of economic value.

By 2005, the UK was the largest importer of Brazilian beef in the developed western economies, and accounts for more than a quarter of EU imports. UK consumers are third to the Netherlands and Bulgaria in terms of per capita consumption of Brazilian beef. Imports to the UK from South America are generally characterised by high value boned beef cuts, with the corresponding lower value meat and offal exported elsewhere. Considering the leading role of these high value beef products in exports, it can be argued that UK consumers represent Brazil's most important high value western developed economy export market.

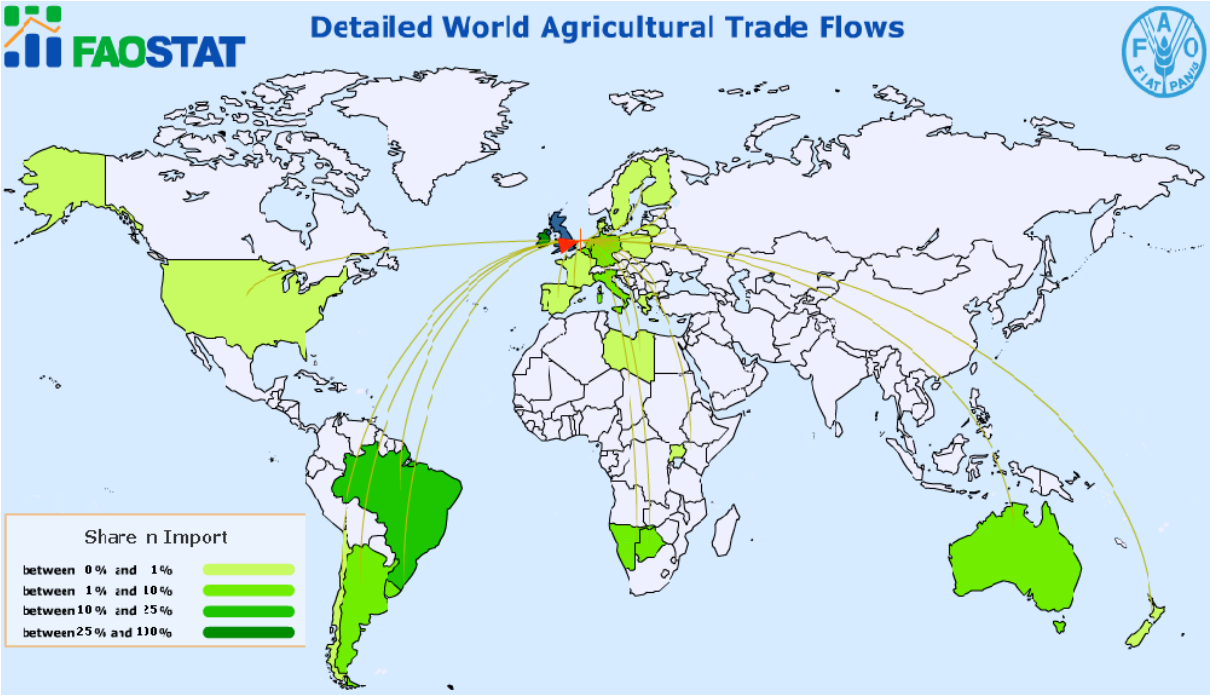

Figure 1: Sources of UK boned beef imports in 2005 (FAOSTAT)

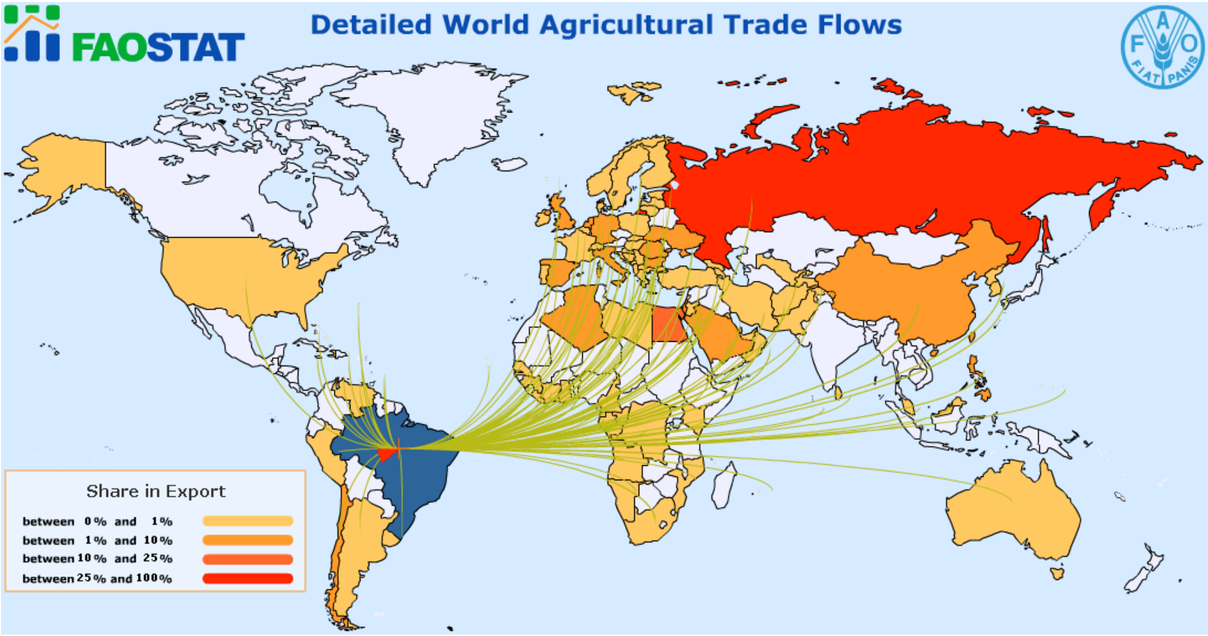

Figure 2: Destinations of Brazilian boned beef exports in 2005 (FAOSTAT)

Poultry meat
The UK is a net importer of about 300,000 of poultry meat, dominated by chicken meat. Over the period 1990-2005, the UK moved from 92% to 88% self-sufficiency, against a background of a two-fold increase in consumption. Thus, the growth in the demand for poultry meat has been largely met by growth in UK production. Trade flows in poultry meat are complex, but the overall picture is that north-western Europe is a net exporter to the rest of the world – an extraordinary position given the land availability in the region. At the UK level, the dominance of domestic supplies masks significant growth in net imports, particularly since 2003. Imports of chicken meat increased more than three-fold between 1990 and 2005. The major source of imports into north-western Europe from outside the EU is Brazil. The UK imported about 54,000 tonnes of chicken meat from Brazil while the Netherlands and Germany imported 109,000 tonnes and 64,000 tonnes respectively from Brazil in 2005. Thus, the UK draws on a pool of European imports from Brazil. Brazil's export of poultry meat to north-west Europe is a recent phenomenon. In assessing this development the South American perspective should be considered. The UK and its major west European trading partners are minor players in the 10-fold growth of Brazilian poultry exports since 1990 (ca 282,000 tonnes in 1990 to ca 2,752,000 tonnes in 2005). The driver behind the Brazilian poultry meat industry is growth in meat consumption in less developed countries, including Brazil itself.

Sheepmeat
The UK is about 90% self-sufficient in sheepmeat. UK imports from outside the EU exceed the UK's deficit, giving a net import of about 40,000 tonnes. Trade flows are complex with the UK serving as a distributor of a total import from outside the EU of 119,000 tonnes in 2006, dominated by New Zealand lamb. Overall, UK sheepmeat consumption draws on resources in New Zealand, Australia and Ireland.

Pigmeat
Nearly all pigmeat consumed in the UK is produced in the UK or by near neighbours. The UK is therefore part of a relatively closed European pigmeat pool which draws on resources outside the EU, particularly soy. The Netherlands and Denmark are particularly important trading partners and both are major importers of wheat, maize (from France) and soy (from Brazil and Argentina). Therefore, the connection between UK consumption and impacts outside the EU are indirect and manifest in the import of soy. Within the EU, pigmeat production results in major flow of nutrients in wheat and maize, particularly to the Netherlands and to the Weser-Ems region of northern Germany.

Eggs
The UK is a net importer of about 91 million dozen eggs and is 89% self-sufficient (Defra 2006, FAOSTAT). Like pigmeat, nearly all imports are from near European neighbours. Consumption is stable. The principal impact outside western Europe arising from UK consumption is through the import of soy.

Milk and dairy products
The UK is a net importer of milk products (equivalent to about 2 million tonnes of milk per year equivalent). This is largely accounted for by a net import of 106,000 tonnes of butter and 274,000 tonnes of cheese. The UK is a major importer of New Zealand butter. New Zealand butter is exported to the EU largely through Denmark and Belgium from where it is re-exported to other EU countries. It can be assumed that most of the butter imported to the UK is produced either by near neighbours such as Ireland, or by New Zealand. Cheese comprises a diverse range of products. Some 90% of imports are from near neighbours, particularly France. Indirect traded impacts relate to the import of feedstuffs, particularly soy.

Animal feedstuffs and soy
Drawing on the data provided by Williams, Audsley and Sandars (2006), it is estimated that livestock products consumed in the UK embody about 23 million tonnes of concentrate feedstuffs. About 18 million tonnes of this supports UK livestock production, and 5 million tonnes is embedded in imported livestock products. Imports of livestock products are dominated by products from near neighbouring countries, with agricultural production systems similar to the UK, so UK data on concentrate feed inputs can be applied. The UK imports about 5 million tonnes of animal feedstuffs. This trade is dominated by net imports of about 1.6 million tonnes of soy meal, 0.8 million tonnes of soybeans and 1.3 million tonnes of maize. The remaining fraction is dominated by co-products, principally meal of rapeseed (ca 135,000 tonnes), meal of other oilseeds (1.2 million tonnes), and citrus pulp (273,000 tonnes). Maize imports have a slight downward trend, while soy imports have increased by nearly 50% since 1990.

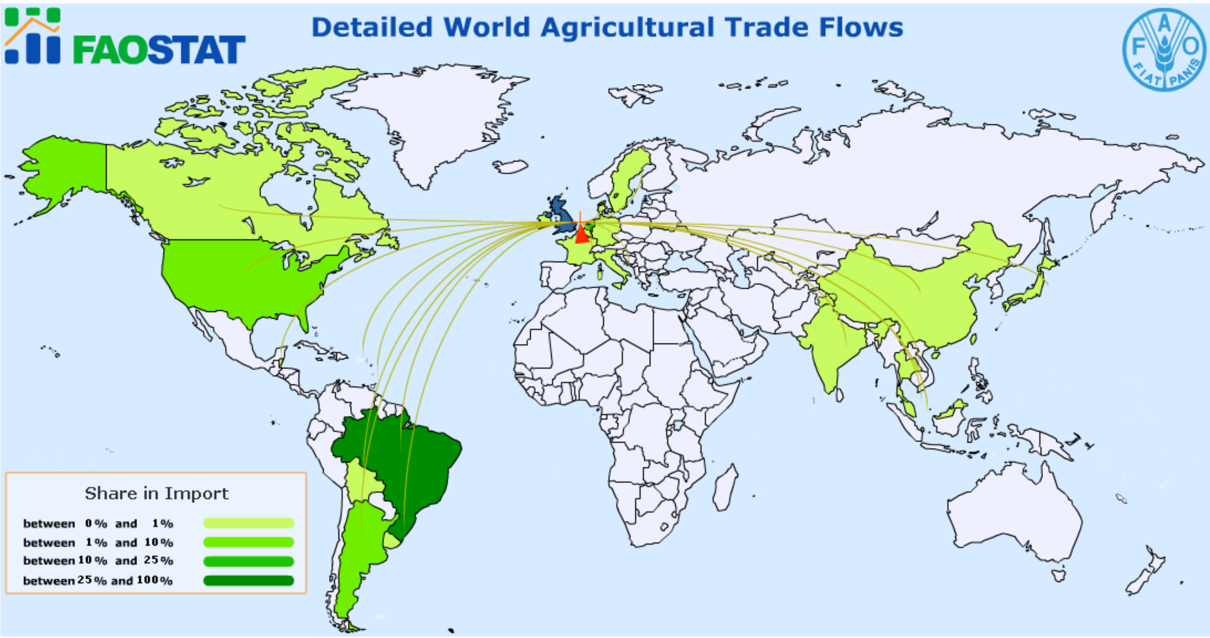

Figure 3: Sources of UK soy meal imports in 2005 (FAOSTAT)

According to FAO statistics, the UK imports approximately 1.1 million tonnes of soy meal from Brazil and 0.3 million tonnes from Argentina. The trade is both direct and indirect, principally through the Netherlands. Thus, it is estimated that Brazil and Argentina are responsible for about 90% of soy meal supplies. The situation is broadly similar for other countries producing pig and poultry meat for the UK market.

Soy consumption embodied in animal product imports is largely confined to pigs and poultry, with smaller quantities embodied in eggs, beef and milk products. It is estimated that the UK's import of 554,000 tonnes of pigmeat embodies 222,000 tonnes of soy meal within about 1.5 million tonnes of feed (based on Dalgaard, Halberg and Hermansen, 2007). Some 321,000 tonnes of poultry meat (in 2005) embodied the consumption of about 700,000 tonnes of poultry feed. Poultry feeds are about 22% soy meal. Thus it is estimated that imported poultry meat embodies the consumption of a further 154,000 tonnes of soy meal. From this it is concluded that UK food consumption draws on a soy resource equivalent to about 3 million tonnes of soy meal per year. This aligns with 'bottom-up' estimates based on LCA data provided by Williams, Audsley and Sandars (2006). Assuming that 90% of supplies are from Brazil and Argentina, it is estimated that the UK is responsible for about 2.7 million tonnes of soy meal exported by these two countries.

Argentina and Brazil produced 98 million tonnes of soybean in 2006 (USDA 2008). Converting UK soy meal data to soybean equivalents (soybean being 80% meal), the UK food economy is responsible for nearly 3% of these countries' soy production. This trade reflects the link between increasing poultry meat consumption and increasing soy requirements. Based on a soy meal yield of 2 tonnes per hectare, the production of soy supporting the consumption of livestock products in the UK covers 1.5 million ha in Argentina and Brazil.

The UK imports about 135,000 tonnes of fishmeal per year. Imports have declined – from 233,000 in 2001 to 139,000 tonnes in 2006 (FAO GLOBEFISH 2006). Imports from outside the EU are dominated by supplies from Iceland and Peru.

Maize

The UK animal feed industry draws heavily on UK cereal production as a source of carbohydrate for concentrate feedstuffs. The UK and the Netherlands are significant importers of maize with net imports of about 1.3 and 1.7 million tonnes respectively. France is the main exporter.

Small grain cereals

The UK is self-sufficient in temperate small grain cereals. It imports high protein wheat for bread-making but this is balanced by exports. This trade enables the mixing of wheat to address seasonal variation in quality. The UK is also a net exporter of barley, mostly exported as whisky.

The UK imports the equivalent of about 600,000 tonnes of rice a year. Major exporters are India and the US. The impact of UK rice consumption in a large number of smaller sources is small.

Vegetable oils and oilseeds.

The import of vegetable oil commodities (excluding palm oil) is about 410,000 tonnes per year. This is dominated by 53,000 tonnes of olive oil, 125,000 tonnes of sunflower oil, and 46,000 tonnes of sunflower seed. These imports are overshadowed by the supplies of oilseed rape from within the UK. The UK is a net exporter of rapeseed so the UK demand of 1.3 million tonnes is met by UK production. The consumption of olives and lower volume oil commodities is increasing. France, Spain, Italy and Greece are the major sources of olive products imported to the UK.

The net import of palm oil has more than doubled in 15 years to 707,000 tonnes in 2005. This accounted for about 2% of world production and means that per capita consumption in the UK is more than twice the world average. Although accounting for 50% of UK supplies, UK palm oil imports from the major producers Indonesia and Malaysia represent only about 1% of these countries' production – a volume of oil which makes the UK's role in these two oil palm economies roughly in line with the UK population as a proportion of the global population. UK consumption plays a major role in other producer countries. Exports to the UK comprise a major proportion of exports from Papua New Guinea, Brazil and Colombia.

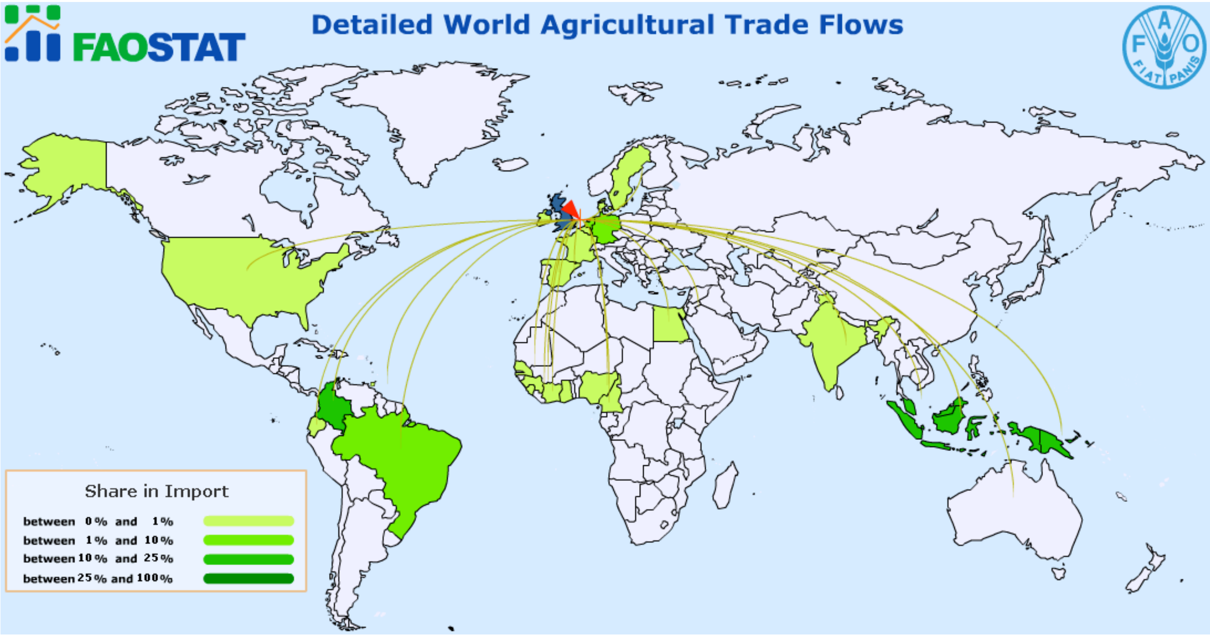

Figure 4: Sources of UK imported palm oil in 2005 (FAOSTAT)

Tropical fruit

The 70% increase in pineapple consumption since 1990 is met by a few major exporters – Costa Rica, Indonesia, Philippines and Thailand. Fresh pineapple is the most important product category, and for this the UK market is the direct destination of 50% of Brazilian exports and 44% of exports from Costa Rica. For bananas, the UK was responsible for 60-100% of the exports of five countries: Belize, Cameroon, Dominica, the Dominican Republic, and Jamaica.

Non-citrus Mediterranean fruit

This a major growth category. It is dominated by 210,000 tonnes of peaches and apricots and the equivalent of 3.8 million tonnes of grapes (including grapes in the form of wine). France and Spain are major suppliers to the UK and it can be assumed that the UK draws heavily on southern Europe for supplies. UK demand accounts for 50% of French apricot exports, and 10-20% of South African exports of apricots, avocados and melons. Spain is a major supplier, but production for the UK is relatively small compared to that for other markets. The UK is also a major customer for a growing fruit industry in Brazil.

Citrus fruit

Oranges remain the dominant citrus fruit. Fresh oranges account for only about one third of imports – two thirds comprise orange juice products. Statistics indicate that UK consumers are drawing on a European pool of citrus fruit juice products that is drawing on supplies from Brazil. Brazil is by far the largest exporter of citrus products. Assuming that one third of the imports to the UK come from Brazil through this pool, the UK is associated with 5-10% of Brazil's citrus fruit industry which is based in the Atlantic Forest and the Cerrado Priority Places.

Temperate fruit

Imports of temperate fruit are increasing faster than consumption is, reflecting the decline in UK production. The UK imports about 1.2 million tonnes of temperate fruit, 750,000 tonnes of which is accounted for by apples or apple products. Supplies are diverse but broadly speaking associated with Mediterranean countries.

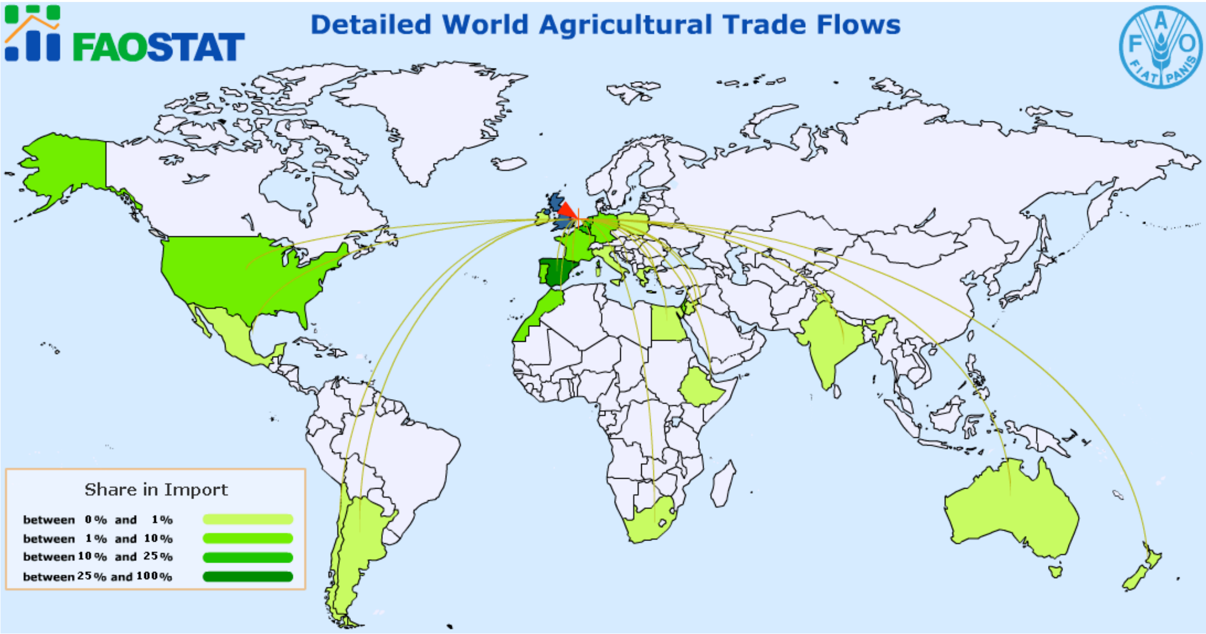

Figure 5: Sources of UK strawberry imports in 2005 (FAOSTAT)

Apples and apple product imports comprise approximately 514,000 tonnes of fresh apples, 16,000 tonnes of un-concentrated juice, with the balance as concentrated juice (equivalent to approximately 220,000 tonnes of apples). Fresh imports are dominated by produce from France, South Africa, New Zealand. UK imports account for about 50% of French exports, one third of South African exports, and about 22% of New Zealand exports. In addition, the UK accounts for about 10% of Brazilian exports and 3% of Chilean exports.

The situation with apple juice and juice concentrate is complex. Imports of apple juice nearly trebled since 1990, and there has been a six-fold growth in concentrate imports. China and Poland are major exporters and UK imports are dominated by German exports. In turn, German imports are dominated by products from China and Poland. It is thus concluded that the UK is a significant player in the growth in demands for apple products from China and Poland.

UK consumption of pears is increasingly dependent almost entirely on imports. Argentina, China and Chile are major exporters.

Imports account for about 59% of UK strawberry consumption dominated by out-of-season strawberries. Imports have grown from 19,000 tonnes in 1990 to 46,000 tonnes in 2005. There seem to be some indirect imports of strawberries from Spain, in particular through Belgium. Spain exports about 226,000 tonnes of strawberries, mainly to other EU countries. The UK consumer is responsible for at least 10% of Spanish exports. The UK is also increasing imports from Morocco.

Herbs and spices

The UK is a significant importer. The dominant spices are ginger and black pepper. Black pepper is imported from Malaysia, Vietnam and Indonesia in particular. Supplies of other spices are also traditional and dominated by the Middle East, India and China. Indonesia is a major supplier of black pepper and other tropical spices.

Beverages – coffee, tea and cocoa

The consumption of tea and coffee is declining, but cocoa is increasing. Consumption amounts to imports of 120,000-130,000 tonnes for coffee and tea. In relation to world trade, UK tea consumption is more significant than the consumption of coffee or cocoa products. These are globally traded commodities so UK consumption may be regarded as drawing on a global pool of supplies. Nevertheless, some direct connections between the UK and specific producer regions are evident. UK tea imports represent a significant proportion of the tea exports of India

(16%), Indonesia (14%), Kenya (27%) and Tanzania (35%). Cocoa imports are dominated by supplies from Ghana, the Ivory Coast and Nigeria. Exporters of confectionery products to the UK draw on the same sources. So it is concluded that cocoa-related impacts are largely confined to these countries. The UK imports are part of a much larger world trade. The UK is a relatively minor force in the international coffee trade. UK supplies can be traced in particular to Brazil, Columbia, Indonesia and Vietnam. Exports to the UK from any of these countries do not exceed 5% of their total coffee exports.

Vegetables
The UK is a net importer of about 4 million tonnes of vegetables. About 10% of these imports come from Spain. Other major exporters are France, Belgium, the Netherlands and Poland. These imports comprise a very diverse range of products.

The UK is a net importer of the equivalent of nearly 1 million tonnes of potatoes mostly from near neighbours. With the exception of 200,000 tonnes of fresh 'out-of-season' potatoes imported from Mediterranean countries, imports are dominated by fresh and especially processed potatoes from Netherlands, Germany, France and Belgium. Imports from the Mediterranean are about 110,000 tonnes (Israel), 22,000 tonnes (Egypt), 29,000 tonnes (Spain), and 17,000 tonnes (Cyprus). The UK imports potatoes from Spain but this is a small proportion of Spanish exports. The UK consumption drives about half of exports from Israel and Cyprus.

Nuts
The UK consumes about 614,000 tonnes of nut commodities. Overall, there has been a decline in consumption, particularly for groundnut and coconut, with significant increases for a wide range of pistachios and cashew nuts. The US is the major source of groundnut, Indonesia and the Philippines are major suppliers of coconut. The growing trade in cashew nuts is based on supplies from the tropics, particularly Brazil, Benin, and the Ivory Coast.

Fish
The UK is only about 38% self-sufficient in fish on a commodity basis (FAOSTAT statistics for 2003). While the UK is a moderate consumer of fish commodities by developed economy standards, a key feature is the import of fish and fish products associated with the depletion and degradation of sensitive ecosystems, particularly the north-east Atlantic ecoregion and the wider North Atlantic. The Marine Fisheries Agency data (MFA, 2006) records the UK as importing a total of 1.9 million tonnes of fish and fish products for direct human consumption in 2006 while exporting about 0.4 million tonnes. In addition, about 1 million tonnes of fish commodities (FAOSTAT) as 200,000 tonnes of fishmeal (Huntington, 2004) are imported.

Drawing on a range of data sources, it is concluded that about half of imports can be traced to fisheries in the north-east Atlantic. When combined with the UK's own production, this means that the UK food economy draws nearly 80% of its supplies directly or indirectly from this sensitive ecoregion, or from nearby Iceland whose fisheries affect the north-east Atlantic. There are significant imports of demersal fish, particularly cod and haddock, pelagic fish (e.g. herring) and the UK is a large importer of fishmeal from other north-east Atlantic countries.

UK imports of fish for human consumption from outside Europe (ca 400,000 tonnes) are also associated with environmental degradation. The UK imports about 100,000 tonnes of tuna, mainly from the Seychelles, Mauritius and Thailand and about 43,000 tonnes of shrimps (MFA, 2006). India and Thailand are major suppliers of shrimps.

2.4 OVERVIEW OF THE UK FOOD ECONOMY'S RESOURCE FLOWS

The picture that has emerged from this analysis of statistics is one of a growing UK food economy that still draws the majority of its food from UK production. Although dependence on imports is increasing, the UK is 58% self-sufficient in all foods, and about 72% self-sufficient in indigenous food. Consumption at the traded commodity level grew by 15% between 1990 and 2005 in terms of commodity weight, against a background of a ca 5% increase in population. However, there is little evidence that Britons are consuming more in terms of basic nutrients. Data on energy intake (Defra, 2007) shows a consistent and steady decline in food energy intake since 1964. Even though energy intake is not a totally reliable measure of total food intake, the juxtaposition of declining personal energy intake (Defra, 2007) with increased flows of commodities into the food economy suggests an increasing role of waste.

The UK Waste Resources Action Programme (WRAP) estimate that UK households waste 30% of the food purchased and that about 60% of the food wasted is edible (WRAP, 2008). Some 42% of the food wasted by consumers is fruit and vegetables. The WRAP report and most of the publicity in the UK relates to analysis of waste post-purchase. There is also evidence that this level of wastage at the consumer level extends through the food chain and that one third or more of the food grown is wasted (Mesure, 2008). Defra research led by Imperial College London gathered anecdotal evidence from manufacturers of chilled foods that indicated that volatility in retailers' order quantities coupled with demand forecast inaccuracy make it difficult for manufacturers to estimate material requirements and to plan production. This, coupled with the supermarkets' demands on suppliers for supplies at short notice, encourages over-production to ensure orders are met. In the opinion of the British Retail Consortium, waste at retail outlets is driven by food safety concerns, legislative requirements, marketing, poor vendor compliance and consumer expectations of constant availability and uniformity of appearance, which is often mistaken for higher quality. The major issue for retailers is to ensure availability of a wide range of products at all times to reduce the chance of customers visiting competitors. This can cause over-supply and waste (Imperial College, 2007). Views reported by Mesure (2008) are consistent with this and indicate that interactions between retailers and consumers on one side and retailers and suppliers on the other are a root cause of a great deal of waste. Underlying this are consumers' expectations and responses, many of which have been conditioned by retailers.

Imports grew by 51% between 1990 and 2005 by weight due to a combination of a 15% increase in consumption at the national level and a decrease in UK agricultural output. Statistics reveal heavy reliance on near neighbours for imported supplies of major commodities, particularly meats. Overall, 80% of UK food comes from the EU. By examining the flows of commodity in and out of the UK food economy, this analysis has revealed quantified and localised resource flows that are influencing agricultural activity outside north-western Europe.

This analysis highlights the high dependence on production in the UK and in north-west Europe for meat and dairy products. Production in north-western Europe accounts for about 95% of meat and 90% of dairy supplies. However, this data masks important marginal changes. The 5% of meat supplies that came from outside Europe in 2005 was dominated by beef from South America. By 2005, the UK had become the most important developed economy importer of meat from Brazil. The direct (soy meal) and embodied (in livestock products) import of soy is a major resource flow from South America, especially Brazil. The UK livestock products sector contributes a wider European reliance on South American resources. In considering the UK's approach to this resource flow, it must be kept in mind that it represents only about 3% of Brazilian and Argentinean soy production. While the UK is the major developed-economy importer, analysis of agriculture in South America reveals that local consumption of livestock products is the major driver behind production.

The major commodity flows are under the control of a relatively small number of businesses. Concentration of production is associated with negative social outcomes in producer communities although total wealth may increase as exemplified by the beef sector in Brazil (Margulis, 2004). The soy industry is dependent on intensive capital investment in remote areas and this leads to concentration in the crop handling, processing and trade. Much of the beef production and all beef processing is concentrated in a small number of businesses, particularly for export. In the case of palm oil, a few European-based manufactures have a major influence on supply chains.

UK fruit and vegetable consumption is increasing and UK production is decreasing. These changes are large both in relative and absolute terms and cause major commodity flows from Mediterranean countries, South America, and a wide range of tropical and subtropical countries. Much of this trade has a bilateral character, perhaps driven by the multiple retailers' sourcing arrangements. By definition, horticultural products are consumed in their harvested form, so some of this trade is highly visible to consumers, for example the import of fresh green peas from Kenya, and asparagus from Peru.

3 Environmental impacts of food consumed in the UK

3.1 GLOBAL IMPACTS

The aim of this study was to examine environmental impacts of the production of food for the UK, particularly in relation to WWF's 35 Priority Places. The majority of the food consumed in the UK is produced in the UK, so even with imports of agricultural inputs it is reasonable to assume that the majority of environmental burdens arise in the UK. Burdens that arise from production in the UK that have impacts on WWF Priority Places are particularly relevant in this study. There is consensus that the provision of food accounts for a significant proportion of the environmental burdens arising from consumption in European countries. There is also consensus in the scientific community that primary production accounts for about half the burdens arising directly from the food economy. Burdens arising from primary production for key UK produced commodities were examined by Williams et al. (2006) with the following results (from the updated models provided by Cranfield University):

The main burdens and resources used arising from the production of field and protected crops in the current national proportions of production systems.

Impacts & resources used per t	Bread wheat	Oilseed rape	Potatoes	Tomatoes
Primary energy used, GJ	2.5	4.9	1.4	130
GWP_{100}, t CO_2 (1)	0.80	1.4	0.2	9.4
Eutrophication potential, kg PO_4^{3-}	3.1	8.2	1.0	1.5
Acidification potential , kg SO_2	3.2	9.1	0.8	12
Pesticides used, dose-ha	0.9	0.7	0.4	0.5
Abiotic resource used, kg antimony (2)	1.5	2.8	0.9	100
Land use (Grade 3a), ha	0.15	0.33	0.030	0.0030
Irrigation water, m^3			21	39

(1) GWP_{100} uses factors to project global warming potential over 100 years. (2) ARU antimony is the element used to scale disparate entities.

The main burdens and resources used in animal production in the current national proportions of production systems.

Impacts & resources used per t of carcass, per 20,000 eggs (about 1 t) or per $10m^3$ milk (about 1 t dm)	Beef	Pig meat	Poultry meat	Sheep meat	Eggs	Milk
Primary energy used, GJ	27	21	15	26	14	26
GWP_{100}, t CO_2	7	3.7	2.9	7	3.1	5.4
Eutrophication potential, kg PO_4^{3-}	121	66	32	207	40	50
Acidification potential, kg SO_2	296	241	96	495	140	143
Pesticides used, dose ha	1.2	1.6	1.5	0.9	1.2	0.8
Abiotic resource use, kg antimony	34	38	28	29	35	31
Land use (1)						
Grade 2, ha	0.03			0.07		0.22
Grade 3a, ha	0.63	0.65	0.61	0.49	0.54	0.96
Grade 3b, ha	0.81			1.32		
Grade 4, ha	0.64			1.06		

(1): Grazing animals use a combination of land types from hill to lowland. Land use for arable feed crops was normalised at grade 3a.

The production of livestock products, especially from cattle and sheep, results in large emissions on a per unit output basis. Diets high in animal products have a large greenhouse gas emissions footprint.

Fishing is a major user of fuel oil accounting about 1.2% of world oil use. Tyedmers, Watson and Pauly (2005) provide an analysis of fuel use in fishing. From their results it is concluded that the greenhouse gas emission from fuel use in fishing to be about 1.8 t CO_2 per tonne of fish landed. Thus, on average, even though fishing is an energy intensive activity, it compares favourably to meat in terms of greenhouse gas emissions. In summarising a wide range of LCA studies, Tyedmers (2008) identifies fishing as the main source of greenhouse gas emissions in fish production.

3.2 GREENHOUSE GAS EMISSIONS

World wide, agriculture related activities are responsible for about a third of the world's greenhouse gas emissions (Figure 6). Deforestation is the dominant cause.

In agricultural production, the relationship between energy use and global warming gas emissions is different to most other sectors. N_2O from the nitrogen cycle dominates, accounting for 80% of the GHG emission from wheat production for example. In addition, methane from livestock production, particularly from cattle and sheep, is a potent global warming gas emission.

The Food Climate Research Network reports that the UK food chain (production, processing and retail) accounts for 19% of UK GHG emissions. The UK Cabinet Office reports 18% with just under half attributed to UK farming and fishing. For Western Europe as a whole, the EU Environmental Impact of Products (EIPRO) study (Tukker et al., 2006) identified food as responsible for 20-30% for most categories of environmental burdens, including greenhouse gas emissions. For greenhouse gas emissions, this 20-30% attributable to food comprises 4-12% for meat, 2-4% for dairy products, and about 1% for cereal products. So livestock products account for 6-16% of greenhouse emissions attributable to the European economy. Fruit and vegetables account for about 2% of the EU's GHG emissions.

UK agriculture is directly responsible for the emission of the equivalent of 14 million tonnes of carbon as carbon dioxide (11 %), methane (37 %) and nitrous oxide (53 %) (HMG 2006). In addition to this, the manufacture of nitrogen fertilisers (registered in GHG inventories as an industrial emission) is the most important cause of emissions upstream of agriculture. About 1.2 million tonnes of nitrogen as fertiliser is used in UK agriculture. Assuming 80% is ammonium nitrate and 20% is urea (Williams et al., 2006), the manufacture of this fertiliser emits the equivalent of 2.1 million tonnes of carbon, the equivalent of 1.2% of the UK total GHG emission. In addition to the UK direct agricultural emission, we can add agricultural emissions from nearby countries exporting to the UK. Livestock products represent the majority of imports. Their production, especially of poultry and pig meat, is similar in LCA terms to that of the UK. So drawing on UK LCA data (Williams et al., 2006), it is estimated that the production of these imported livestock commodities emits the equivalent of about 1 million tonnes of carbon on a life-cycle basis up to the farm-gate.

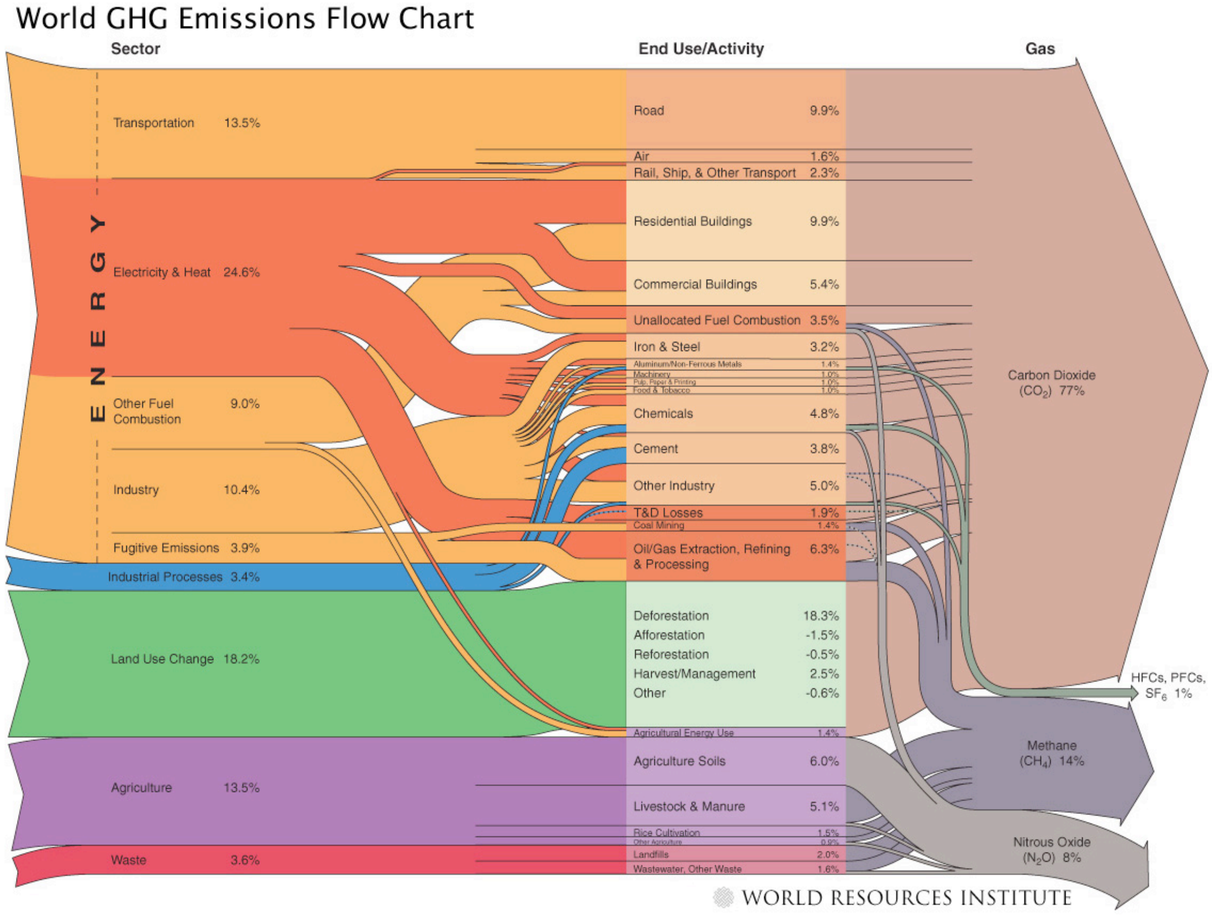

Figure 6: Flow of global greenhouse gas emissions

Overall, UK agriculture, fertiliser production, and livestock production for the UK in near-neighbouring countries is responsible for the emission of about 17 million tonnes C per year. To put this in context, this compares to a total emission of 179 million tonnes from the UK.

Garnett (2008) estimates that the UK food chain is responsible for a GHG emission equivalent to 38 million tonnes of carbon, or 17% of the emissions embedded in UK consumption. In addition, there is also the UK's share of indirect emissions due to land use change, e.g. deforestation. The proportion of global emissions from land use change attributable to the UK food economy has not been estimated, but even 1% (reflecting the UK population as a proportion of the global population) of the 2 billion tonnes of carbon equivalent due to deforestation globally is very significant (20 million tonnes carbon).

It is clear that the delivery of food up to the point of consumption is significant: food is comparable to transport and domestic energy consumption in terms of its role in personal carbon footprints.

Commentaries (e.g. CLA, NFU and AIC, 2007) on the greenhouse balance of UK agriculture frequently focus on the level of direct emissions from UK agriculture relative to the UK as a whole (i.e. 7% for UK agriculture). Such comparisons need to be considered with caution as they do not include emissions embedded in imports (e.g. fertilisers and soy) and they depend on the size of all other emissions. Agriculture would have represented nearly 100% of anthropogenic greenhouse gas emissions in pre-industrial Britain.

Greenhouse gas emissions from UK agriculture are falling (HMG 2006). It is difficult to assess trends in greenhouse gas emissions for the food economy as a whole as they are the result of a number of counteracting and poorly understood activities – for example rising commodity consumption is counteracted by increased production efficiency in Europe, and increased energy efficiency in manufacturing is counteracted by increased car use in shopping. Overall, further but modest reductions in emissions from primary production are expected, and it is also expected that energy consumption in industry and retail will decline. Significant greenhouse gas savings by the food economy could be made through a complete decoupling of food production from deforestation and a reduction in the consumption and production of animal products, especially from ruminants (cattle and sheep). Life-cycle assessment consistently reveals the large burdens associated with delivering livestock products (e.g. Williams et al., 2006). Livestock account for 70% of agricultural land use world (30% of the earth's land surface), and more than half of the greenhouse gas emissions attributable to agriculture (Steinfeld et al. 2006). Reducing livestock consumption and production would reduce emissions directly through reductions in methane from ruminants and waste management, and nitrous oxide from forage and feed production. Further indirect reductions would result from reduced nitrogen related enrichment of habitats, from nitrate leaching and ammonia emissions. The biggest effect for the environment could be through the indirect effects of livestock on land use change where the production of forage and crops for the livestock sector is a factor driving deforestation. Expansion in livestock is a major factor in the increased demand for feed grains and the recent decline in world stocks of key food commodities such as wheat. A reduction in livestock consumption would relieve pressure on world food supplies and thus contribute to the alleviation of the global food economy's greatest problem: hunger.

3.3 AGRICULTURE AND THE NITROGEN CYCLE

Nitrogen is the major 'GHG nutrient' (Williams et al., 2006). Nitrous oxide (N_2O), a trace gas and a very potent GHG, is a product of the nitrogen cycle. The intensity of the nitrogen cycle is raised in agro-ecosystems by nitrogen fixation: the manufacture of artificial nitrogen fertilisers and biological fixation by legume crops such as peas and soy. N_2O concentrations in the atmosphere have increased from a pre-industrial level of 270 ppbv to a current level of 319 ppbv. In the case of manufactured fertilisers, manufacture also releases carbon dioxide through the use of fossil fuels. European nitrogen fertiliser manufacture, which is relatively efficient, results in the emission of the equivalent of 7.5 kg CO_2 per kg N (ca 2 kg C). Overall, Kongshaug (1998) estimates that fertiliser production consumes approximately 1.2% of the world's energy and is responsible for approximately 1.2% of the total GHG emissions. The direct N_2O emission from soil arising from all forms of nitrogen fertilisation is equivalent to 1 kg carbon per kg N introduced into the system. Overall, when emissions from other ecosystems enriched by losses to the air and water from agricultural soils are taken into consideration, the equivalent of more than 2.7 t carbon is emitted as N_2O for every tonne N introduced into agri-ecosystems, including from nitrogen fixed biologically by legumes. Reducing man's intervention in the nitrogen cycle through raising the efficiency of nitrogen use in agriculture is central to the mitigation of greenhouse gas emissions from primary food production.

3.3.1. Nitrogen fixation

Agriculture more than doubles the input of reactive nitrogen entering the global nitrogen cycle. The resulting enrichment leads to the addition of about 4 million tonnes of extra nitrous oxide to the atmosphere. Prior to industrialisation, the productivity of agriculture was limited by availability of reactive nitrogen, i.e. organic nitrogen, nitrate and ammonium in soils. The fixation of nitrogen in reactive forms through the synthesis of nitrogen fertiliser and through the cultivation of nitrogen fixing species such as clover, peas and soy addresses this limitation. This fixation is the starting point of a cascade of nitrogen transformations, each one responsible for losses to the environment. The anthropogenic input of reactive nitrogen has been increased ten-fold since 1860 to more than 150 million tonnes, with two thirds (100 million tonnes) of this due to fertiliser manufacture (Enquete Commission, 1994; Jensson and Kongshaug, 2003; Braun 2007). About a further 32 million tonnes is added in the cultivation of legumes. Overall, the fixation of N in synthetic fertiliser equals the background natural fixation (Figure 7).

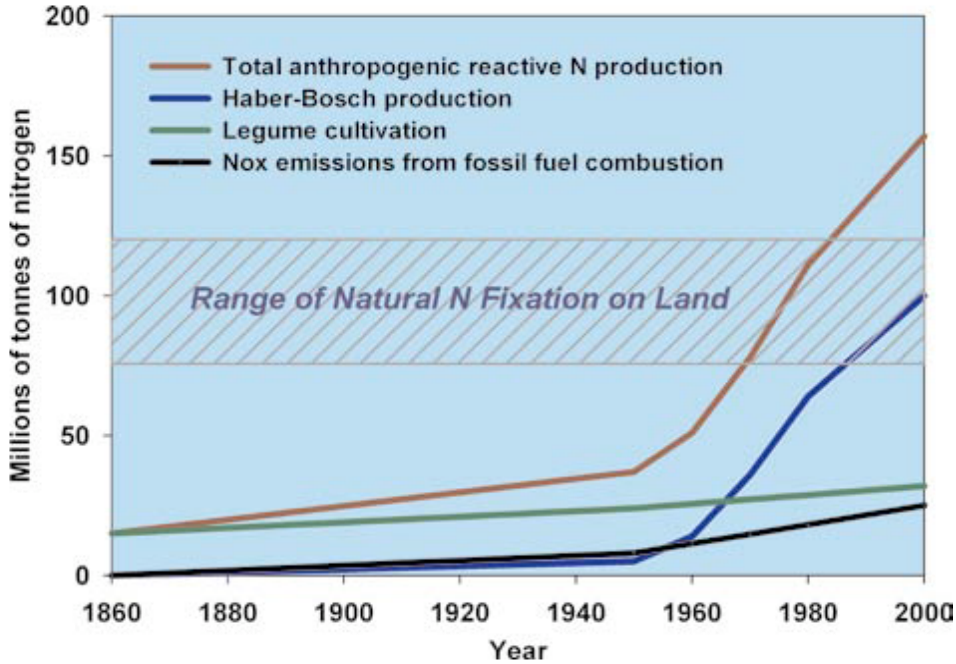

Figure 7: Historical trends of reactive nitrogen formed annually by human activity, including cultivation of N-fixing legume crops. For comparison, also shown is the “natural range” of N fixation (about 100 million tonnes of N per year) that occurs in native terrestrial ecosystems. Based on data in Galloway et al., 2004 and Smil, 2001, cited by Braun 2007

3.3.2. Nitrogen in production cycles

The losses and impacts of nitrogen cascade through supply chains. For every 100 kg of manufactured or biologically fixed N entering the pigmeat production system, 17 kg end up in the product consumed Braun (2007). Despite some recycling of manures back to the soil, more than 4 kg nitrogen is lost to the environment for each kg nitrogen recovered in the product - much of the loss ending up as ammonia in air, nitrate in water, and nitrous oxide (Figure 8). Tackling GHG emissions from agriculture involves addressing losses at each stage of the production cycle.

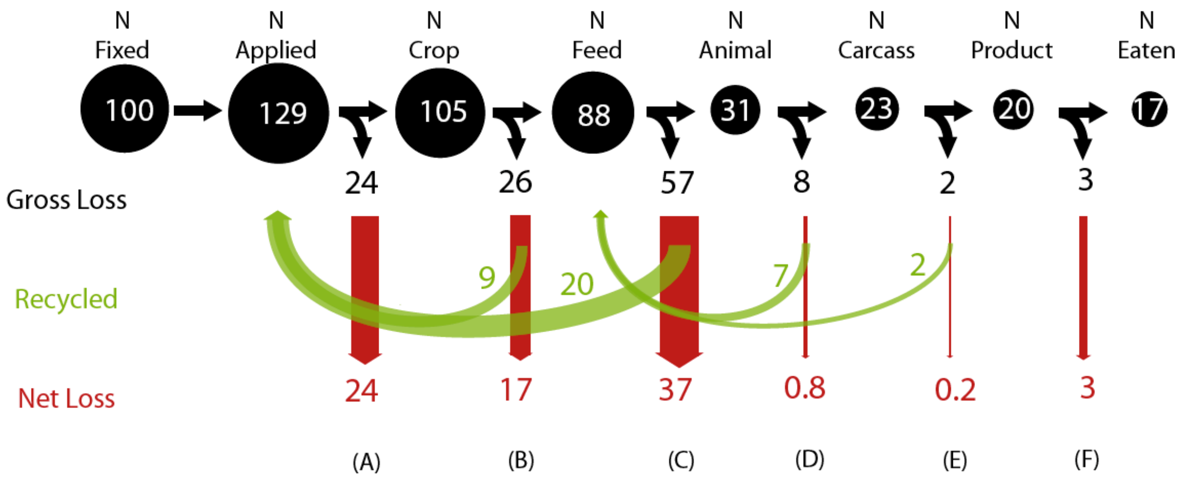

Figure 8: Nitrogen losses that occur between the application of N fertilizer on a farmer’s field until the food is consumed for a typical industrial pig production system. From Galloway et al. cited by Braun (2007)

3.3.3. Increasing the efficiency of crop nitrogen use

Increasing the efficiency of nitrogen use by the growing crop is the first step in the mitigation of direct emissions from land management. Improved efficiency of nitrogen use within the soil/crop system provides opportunities to reduce the input of synthetic fertilisers. When achieved together with efficient high yielding crop production, it reduces pressure to expand agricultural land and thus land-use change pressures on forests and other habitats.

The efficiency of nitrogen use has improved in Europe. According to the European Environment Agency and the OECD, at EU-15 level the gross nitrogen balance in 2000 was calculated to be 55 kg ha^{-1}, which is 16% lower than the balance estimate in 1990 (66 kg ha^{-1}). In 2000 the gross nitrogen balance ranged from 37 kg ha^{-1} (Italy) to 226 kg ha^{-1} (the Netherlands). All national gross nitrogen balances show a decline in estimates of the gross nitrogen balance between 1990 and 2000, apart from Ireland (22% increase) and Spain (47% increase). The general decline in nitrogen surpluses is due to a small decrease in nitrogen input (-1.0%) and a significant increase in nitrogen output (10%). Nitrogen use efficiency has increased through increased output.

3.3.4. Crop nitrogen content

The second mitigation point in the nitrogen cycle is manipulation of crop nitrogen content – both N concentration and N (protein) quality. Improvement of wheat for direct human consumption is generally focused on high protein content (i.e. nitrogen) in grain. However, for animal feeding, energy in the form of starch is the main requirement. Breeding crops such as wheat and barley specifically for high starch and low protein content has three potential benefits – it reduces the concentration of nitrogen in the grain and therefore reduces the nitrogen requirement of the crop, increases crop yield, and reduces the nitrogen excretion by animals fed on the grain. Defra funded research in the UK is currently examining the potential of breeding wheat for high starch and reduced protein content and is a good example of a strategic systems approach to improving the nitrogen economy of food chains.

3.3.5. Recycling nitrogen

The third mitigation point is at the point of the recycling of excreted nitrogen. This is the biggest mitigation target. About half of the nitrogen entering the pig production system (and even more in other systems) is lost from manures or the soil during or after manure application. Making the most efficient use of the N in organic manures is essential. Technologies such as slurry injection, manure treatment, and accurate rate and timing of manure application are vital. Losses of up to 80% of mineral nitrogen in slurry through ammonia emissions when broadcasting slurry are common damaging sensitive ecosystem downwind of application. Reducing these emissions conserves nitrogen within the soil/plant system and offers the opportunity of establishing a virtuous circle of ammonia reductions, nitrogen conservation, and reduced fertiliser inputs.

Anaerobic digestion (AD) for biogas is worthy of mention here. The by-product of AD is 'digestate', a liquid in which the nitrogen and phosphorus from the feedstock (manure, crop material and food waste) is conserved in a plant available form. The use of anaerobic digestion within integrated crop/animal systems has the potential to improve the nitrogen efficiency of the whole system if the improved availability of nitrogen in digestate is used to replace synthetic fertiliser nitrogen. This is enhanced even further where food wastes are processed offering the opportunity to recycle nitrogen from food wastes.

3.3.6. Nitrification inhibition

Through nitrification, the relatively immobile ammonium N-form (NH^{4+}) is converted into highly mobile nitrate-N (NO^{3-}) leading to leaching and denitrification (with emissions of nitrous oxide). In nitrogen limited natural ecosystems, nitrification is reduced to a relatively minor flux and there is a high degree of internal nitrogen cycling with minimal losses. However, in agri-ecosystems, nitrification driven by larger inputs of reactive N is a major process and can be regarded as the gateway to the major points of losses from the agricultural N cycle. This is particularly so where animal manures are entering the soil-plant system. Suppressing nitrification is potentially a key part in any strategy to improve N recovery and nitrogen use efficiency in cropping systems where animal manures or urea fertiliser are used. Even though nitrification inhibitors have been available for some decades, the more recent demand to increase nitrogen use efficiency in agriculture driven by climate change policies puts this technology back in the spotlight. The concept of biological nitrification inhibition (BNI) has been proposed utilizing traits found in natural ecosystems (Subbarao et al., 2006).

3.3.7. System changes

The efficient recycling of nitrogen emitted by animals requires the linking of crop and animal production. However, industrial livestock production is footloose and not closely tied to the land base used for feed inputs (Naylor et al., 2005). Separation of livestock from the land that feeds them is happening at all scales: within farms, at the local scale where crop and animal farming may be separated between specialised neighbouring farms, to the global scale where highly concentrated livestock production supported by the global movement of feed grains has resulted in the de-coupling of livestock from the natural resource base (Figure 9). Much of the effort to improve the nitrogen use efficiency in whole agricultural systems relies on the re-coupling of crop and livestock production and the efficient use of the nutrients emitted by animals in crop production. Public policy can have profound effects. For example, the reduction of transport subsidies for Canadian wheat stimulated the use of wheat for animal feed on the prairies re-coupling crop and animal production with environmental benefits (Doan and Paddock, 2003). The agriculture sector in the Cerrado of Brazil is seeking to increase the integration of animal and feed production offering potential benefits. This however is hindered by EU policies that put higher tariffs on livestock products compared with livestock feed – such policies directly support environmentally damaging decoupled livestock production.

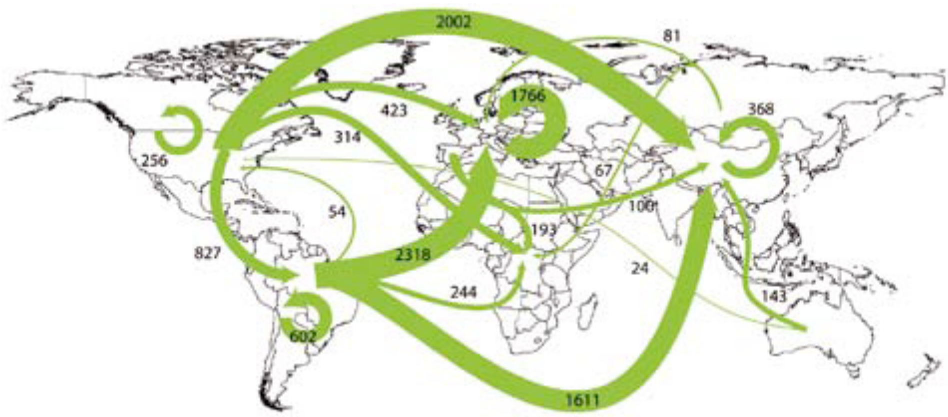

Figure 9: Nitrogen contained in internationally traded crops, by continent. 2004 data in thousands of tons of N; minimum requirement for drawing a line is 20,000 tons N. The total amount of nitrogen transferred in the trade of crop commodities was 11.5 million tonnes in 2004. (From Braun, 2007)

3.4 CROP-BASED AGRICULTURE AND THE CARBON CYCLE

Agriculture's impact on the carbon cycle arises from energy use and from net carbon emissions from soil and land-use change, particularly deforestation.

3.4.1. Energy use in agriculture

In OECD countries, around 3-5% of energy is consumed directly in the agricultural sector. The figure for UK agriculture is lower at about 0.6% (Warwick HRI, 2007) due to the dominance of other sectors of the economy. Direct energy inputs into field crop production, particularly diesel for cultivation machinery, represents the largest single fossil energy input into agriculture (36%). Protected crops account for 26%. Overall, direct energy use in agriculture is responsible for only a small part of greenhouse gas emissions from agriculture. Thus, the scope for mitigation of agricultural GHG emissions through energy saving is small.

There is consensus in the literature (e.g. Smith et al., 2005) that for most products the distance food has travelled ('food-miles') is not a reliable indicator of environmental burdens. Long distant bulk transport by sea and by rail is efficient. Modern road-based logistical operations within the UK are also efficient. As a result, transport is usually only a minor component of the life-cycle environmental burdens of foods.

3.4.2. Soil carbon sequestration – conservation tillage.

The world's soils are estimated to contain 1500 G tonnes of organic carbon which is roughly twice that in the atmosphere (Schlesinger and Andrews, 2000). Oxidation of soil organic matter accounts for a natural flux of about 75 G tonnes per year through which carbon entering the soil from plants is returned to the atmosphere.

Modified soil management, particularly a switch to reduced cultivations, is widely regarded as a means of increasing soil carbon sequestration. Since it is widely believed that soil disturbance by tillage was the cause of the historical loss of soil carbon (for example following the ploughing of prairie soils), it is assumed that soil carbon sequestration can be obtained on tilled soils by replacing intensive plough based cultivations with less intensive methods. Some farmers in the US receive payments in return for practicing reduced or 'conservation' tillage. However, the consequences of reduced tillage for soil carbon are not straight-forward. More than twenty years ago, Powlson and Jenkinson (1981) at Rothamsted in England concluded that conservation tillage "has little effect on soil organic matter, other than altering its distribution in the profile". In an analysis of the results of more recent field experiments covering a wide range of soil (including tropical soils), Baker et al. (2007) conclude that the widespread belief that reduced tillage favours carbon sequestration may simply be an artefact of sampling methodology with reduced tillage resulting in a concentration of soil organic matter in the upper soil layer rather than a net increase through the soil.

Even if reduced tillage does not result in net carbon sequestration, it is very clear that it does increase the carbon content of the upper soil layer. In particularly, the recently deposited 'young' or light fraction of organic matter is especially important for soil structural development (Shepherd, Harrison and Webb, 2002) and raising its organic fraction reduces erosion. Landers (2001) reports these benefits for the Cerrado of Brazil. Other reports cite benefits for groundwater as the increased surface organic matter content facilitates percolation of rainwater.

Ultimately, soil organic matter represents one of several carbon pools maintained by the Net Primary Production (NPP) of an ecosystem, the NPP being the gross primary production through photosynthesis minus respiration. Over time, steady-state equilibria will establish and the carbon content of the soil will remain unchanged as long as carbon inputs and outputs remain unchanged. Under natural conditions, the soil organic matter content is determined by the vegetation cover and its net productivity, soil texture and chemistry, climate, and drainage. Biologically productive natural ecosystems such as forest and grassland return large amounts of relatively slowly degradable organic matter to soils and thus are associated with high soil carbon contents. In the conversion of forest to farmland the production of food is increased but the total biological productivity is often reduced in the switch from perennial to annual vegetation. Conversion, especially to annual crop production, is thus associated with a reduction in carbon inputs in organic matter. It is estimated that the conversion of natural vegetation to farmland since 1850 has led to the loss of between 20 and 40 billion tonnes of carbon, mostly from soil sources. This can be reversed with the biggest carbon sequestration benefits obtained where soil carbon has been most depleted. A switch from an agri-ecosystem that supports a low soil carbon content to one that supports high levels of soil carbon, for example a switch from intensive arable cropping with removal of straw to perennial agro-forestry or permanent grassland will deliver net carbon sequestration in depleted soils until a new steady state is achieved – a process which can last several decades and even centuries. It can be assumed that sequestration will be greatest in the soils most depleted in relation to their natural ecosystem state.

3.4.3. Soil carbon sequestration - crop residue incorporation.

Soil carbon content increase is largely a consequence of transition from low to high returns of organic matter to the soil. In most cereal crops, the crop residue accounts for about half the above-ground biomass. A switch from the removal of straw from the field to its incorporation into the soil is thus expected to disrupt an existing 'low soil carbon' equilibrium providing carbon sequestration in the transition to a new equilibrium. In a 10 t grain ha^{-1} winter wheat crop, a switch from straw removal to incorporation would increase annual inputs of carbon into the soil from about 2.5 t ha^{-1} to about 6.5 t ha^{-1} (the original 2.5 being 1.5 t from the root system plus 1 t in stubble). The question for soil carbon management from a greenhouse gas policy viewpoint is about the affect this extra carbon has on soil carbon contents in the longer-term. The Broadbalk continuous wheat experiment at Rothamsted in England records a difference of 40 t C ha^{-1} after 150 years due to the additional input of 35 t ha^{-1} of farmyard manure every year. Farmyard manure is about 25% dry matter, so this application represents an additional input of about 4.4 t C ha^{-1} per annum or about 660 t C ha^{-1} over the 150 years. It is estimated that about 5% of the additional carbon input remained in the soil carbon pool. So it is not surprising that some long-term experiments show a lack of response in soil carbon contents considering the small responses over relatively short experimental time periods in relation to the background carbon contents. Annual crop residues are rapidly decomposed in arable production systems and a relatively small proportion of the residue ends up as stable soil organic matter. Considering the literature evidence drawn on here, it is concluded that 5 – 10% of the additional crop residue introduced to the soil following a switch to crop residue incorporation contributes to the long-term soil carbon pool. Translated to high yielding European wheat crops, this represents an additional 0.20 – 0.40 t C ha^{-1} per annum from a switch to the incorporation of straw. The Broadbalk experiment shows that this transitional period is long – soil organic matter levels are still slowly increasing in manure treated plots after 150 years.

3.4.4. Soil carbon sequestration - growing good crops.

The supply of organic matter to the soil from a crop is positively correlated with that crop's growth and yield. Smith et al. 2007 emphasise the role of improved agronomy in supporting soil carbon storage. They estimate the potential of improved agronomy to be up to 0.13 – 0.34 tonnes C ha^{-1} per annum depending on the region, with the higher potentials in moister regions. Improved agronomy increases crop growth and carbons returns to soil. This includes using better varieties, nutrition and crop protection, reducing fallowing, and the production of 'catch' and 'green manure' crops that have the double benefit of conserving nitrogen and adding organic matter to the soil. The Broadbalk experiment provides data that enable the effect of crop yield on soil organic matter to be examined. Plots yielding 2 tonnes wheat ha^{-1} per annum have about 7 tonnes ha^{-1} less soil carbon than synthetically fertilised plots yielding 9 tonnes ha^{-1}. Boguslawski (1981) reports a similar effect from a continuous rye cultivation experiment started in 1878 in Germany. Considering the cumulative difference in carbon returns from the crops summed over more than a century, these differences in soil carbon due to crop yield differences are small but show that crop productivity plays a role in retaining the soil carbon reserve in agro-ecosystems.

3.4.5. Land use change

Globally, terrestrial ecosystems are currently a small net sink for carbon dioxide of about 0.2 and 0.7 G tonnes C per year (Watson, 2000). This is because expansion in higher latitude forestry and soil carbon sequestration from improved land-use practices and other measures outweigh emissions of about 1.6-1.7 G tonnes C per year from tropical deforestation. Tropical deforestation, which has allowed the agricultural land area in developing countries to expand by 500 million ha since 1960 (FAOSTAT), is a very major component of greenhouse gas emissions. This trend is likely to continue into the future (Smith et al., 2007).

Estimating CO_2 emissions from deforestation is not straight-forward. The life-cycle effect of clearance depends on the clearance method used and the fate of harvested timber and land. Clearance is followed by many years of losses from soil used for annual crops such as soy. It is estimated for example that tropical forests and forest soils contain 194 and 122 tonnes C ha^{-1} respectively, compared with equivalent figures of 3 to 122 for cropland (Steinfeld et al., 2006). Burschel (1993) estimated that there are about 375 tonnes C ha^{-1} stored in wild forest ecosystems. So the conversion of tropical forest to crop production results in a loss of about 200 tonnes C ha^{-1}. In addition, subsequent ruminant based land-use systems are additional sources of other greenhouses gases such as methane. There is some evidence that the top 30 cm of tropical soils under grassland accumulate more carbon after forest clearance (Cerri et al. 2003) but their report does not refer to changes in carbon deeper in the soil which could be significant.

The challenge lies in slowing and reversing deforestation whilst enabling increases in crop production over the next 50 years to meet the demand for animal products. In reporting to the FAO, Steinfeld et al. (2006) emphasise the importance of maintaining food supplies as a prerequisite for forest protection and reforestation. Their wide-ranging report emphasises that resource use efficiency is key to reducing environmental impact of agriculture, especially the impacts linked to deforestation. They repeatedly cite the importance of the intensification of production on the most suitable productive soils. Sommer et al. (2004) also identify the intensification of agriculture on better agricultural land as essential to forest protection. Looking at fertiliser use, they concluded that the sequestration of carbon on land protected from agriculture far outweighs the emissions associated with the production of fertiliser needed. They go as far as to advocate carbon credits for fertiliser use as a means to finance the technical change involved. Landers (2001) draws attention to the benefits of improved crop production using zero tillage in South America where there are many millions of hectares of degraded pastures in the Cerrado region. He argued that tillage technology now exists to turn these degraded pastures into productive cropland, which would reduce the pressure to clear forest for food production. The potential is such that it would allow the required expansion in agricultural output for many years with further forest clearance. He concluded that it should be possible to promote a policy of incentives to improve crop production, supported by international funding so that the reclamation and improvement of cleared areas would become significantly more profitable than clearing new land.

The interactions between agriculture, forestry and the wider environment are extremely complex from a policy perspective. Looked at simply, maintaining and increasing yields on good agricultural land can be regarded as contributing directly to the relief of pressure on the frontier between agriculture and forestry - the doubling of productivity on a hectare of agricultural land provides the food resource base for preventing the deforestation of a corresponding hectare of forest. With a historical perspective, this can be deduced from European and North American experience. In the developed economies, high production efficiency has opened up the opportunities to reduce agricultural land areas, and have allowed reforestation, for example the planting of willow for wood fuel in Europe. However, these economies benefit from high land prices, rents, mature institutional arrangements, and well developed government systems. The situation in much of the tropics is different. A significant proportion of clearance is due to the rural poor seeking land. In particular, poor definition of property rights for local people and weak land tenure for local communities compromise local agricultural development. Alongside this, the claiming of communally or state owned land resulting in low prices for ‘frontier’ land as a factor in production does not induce the necessary innovation, and a vicious cycle of rural poverty and land clearance prevails. Society also needs to put a value on the preservation of native vegetation as an incentive for intensification of production on already-cleared land. The Clean Development and Reduced Emissions from Deforestation and Degradation (REDD) mechanisms could address this. Bilateral arrangements between countries, such as the recently announced measures between Australia and Papua New Guinea to avoid deforestation are also relevant (Australian Broadcasting Corporation, 2008).

3.5 EUTROPHICATION – NITRATES, PHOSPHATES AND AMMONIA

3.5.1. Nitrate

Nitrate is probably the first eutrophication pollutant to receive serious attention in public policy. It is emitted from all soils in drainage water, and is present in the discharges from sewage treatment plants. The environmental impact relates mainly to its contribution to eutrophication of marine and coastal waters and some lakes. Concerns over impacts on human health from nitrates in drinking water are the prime reason for regulation to date. EU legislation requires controls to limit concentrations in surface waters to 50 mg nitrate per litre.

Agriculture is estimated to be responsible for 61% of nitrates in water in England (ADAS, 2006) and is generally the source of 50-80% of the nitrate load in Western Europe (EEA, 2005). The contribution from agriculture is particularly high in Belgium, Denmark, and northern Germany due to the concentration of pig and poultry production. The contribution from agriculture is also high in Ireland. Emissions to water bodies generally arise from nitrate released from the decomposition of organic matter (including manures) in soil rather than directly from artificial fertilisers. Organic matter decomposition rates are high in well aerated and moist soils in the late summer and early autumn when crop uptake is low. Rainfall in autumn and early winter carries a large proportion of the nitrate released in summer and autumn from the soil into drainage water and thus the environment. The resultant concentration in water bodies depends greatly on rainfall – the higher the surplus rainfall the greater the dilution leading to lower concentrations for a given emission. Thus, water bodies in the drier east of the UK are much more prone to high concentrations compared with the wetter west. In East Anglia, an emission of only 15 kg N ha^{-1} as nitrate is sufficient to exceed the 50 mg nitrate per litre where excess rainfall is less than 150 mm per year (Defra 2002). Therefore, even though artificially fertilised arable crops have low total nitrate emissions, concentrations in water from arable land in England can be high in low rainfall areas.

Driven by concerns over nitrate, the nitrogen surplus of wheat grown in the UK has fallen from 70 kg ha^{-1} in the 1980s to about 25 kg ha^{-1} in 2007. This is associated with a reduction in fertiliser nitrogen application of 1.6 million tonnes in the 1980s to about 1.2 million tonnes in 2007. Nitrogen loads in most western European countries are also generally decreasing particularly due to the effect of controls on livestock densities and manure applications. Despite these improvements, most north-west European countries are having difficulty complying with the EU Nitrates Directive.

3.5.2. Phosphorus

Shortage of phosphorus controls the growth of algae in most unpolluted fresh waters so elevated phosphorus in water is the most common cause of eutrophication. UK agriculture contributes over 12,000 tonnes of phosphorus to surface waters annually (White and Hammond, 2006). It is a potent nutrient, so emissions that are trivial from a farming (economic) point of view are highly significant environmentally. Losses arise from soluble inorganic phosphate fertilisers added to soils, mostly eroded from the soil into surface waters on soil particles. In addition, only a small fraction of the phosphorus in crops fed to animals is retained by the animals and is excreted. Thus the feeding of arable crops to animals results in secondary losses of P.

Excess soil phosphorus is characteristic of areas in northern Europe where livestock is intensively produced. Particularly in countries exporting pig and poultry products to the UK such as the Netherlands, northern Germany, Denmark, and some parts of Ireland, water bodies have been very significantly impacted by elevated phosphorus levels. Phosphorus levels in water bodies are high where soil enriched with P has been eroded into waterways. This is marked where soils are cultivated or eroded from livestock poaching.

The relative role of agriculture in the phosphorus eutrophication of water bodies depends greatly on the effectiveness of the control of emissions from other sectors, particularly water treatment.

Human sewage is a major pollutant in many countries due to phosphorus. Tertiary waste water treatment is common in Germany for example and this removes phosphorus from urban and industrial waste waters. As a result, in Germany, agriculture is responsible for a large proportion of emissions. In the intensive livestock region of Weser-Ems, which is typical of north European intensive livestock production supplying the UK, agriculture is responsible for a loss of nearly 2 kg P ha ha^{-1} year ha^{-1} (83% of emissions). In Poland and the Baltic, where waste water treatment is less intensive, arable agriculture accounts for more than 63% of total loading (EEA, 2005). Phosphorus is a long-term pollutant. Soils with elevated levels take decades and even centuries to return to pre-agricultural levels. In addition, phosphorus may be elevated in river and lake sediments originating from material eroded from agricultural land providing a source of eutrophication long after emissions from farm land have decreased.

3.5.3. Ammonia

Ammonia (NH_3) is the pungent smelling gas from urine and the main source of ammonia emissions is livestock wastes. It is a major source of reactive nitrogen in the natural environment and is a transboundary pollutant of particular significance in north-west Europe (Figure 10). The global systems nature of the nitrogen problem is illustrated by a comparison between Figure 9 and Figure 10. The global movement of nitrogen from the Americas to Europe and the Far East is associated with high ammonia emissions in Europe and the Far East. Ammonia has effects on the environment through acidification and eutrophication when deposited on land, and also causes the formation of ammonium particles in air contributing to smog formation. Contrary to recent speculation and debate in the UK, evidence that smog particles from ammonia have health impacts is difficult to find. The livestock sector, particularly cattle, poultry and pigs, is responsible for about 74% of emissions in the European Union (Sutton, 2006). Emissions from artificial fertilisers accounts for another 9%. Thus, agriculture is responsible for more than four fifths of ammonia emissions in Europe. In the UK, livestock are directly responsible for about 77% of emissions, with an additional 12% from soil. UK ammonia emissions have fallen from about 380,000 tonnes in the early 1990s to 318,000 in 2005. This fall is largely due to reductions in non-agricultural emissions and reductions in emissions from fertilisers. The emissions from cattle, which account for about half of all emissions, remained largely unchanged over the last 20 years.

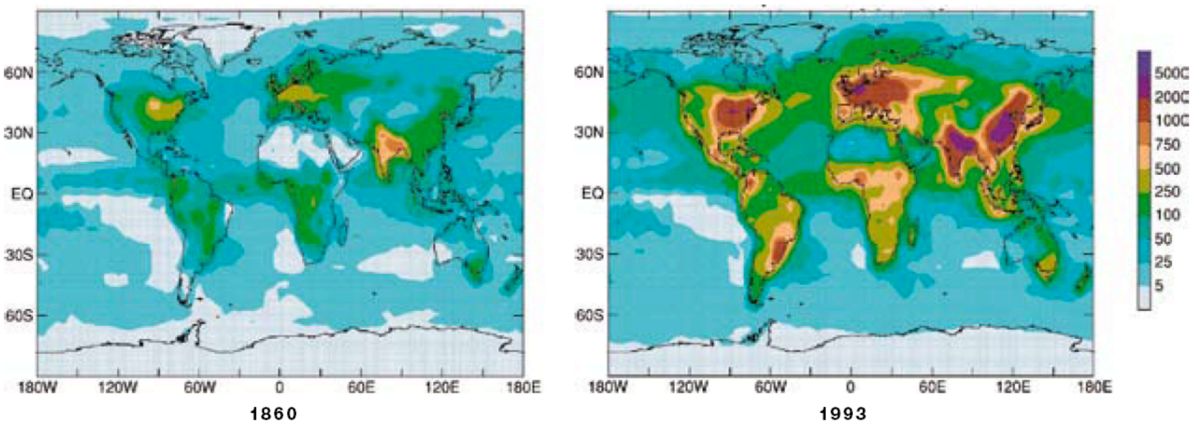

Figure 10: Comparison of atmospheric deposition of total inorganic nitrogen across the globe estimated for 1860 and 1993. Units for the values shown in the colour legend are milligrams nitrogen per metre squared per year. Adapted from Galloway et al., 2004

Ammonia is not a global pollutant in the way carbon dioxide is but it has transboundary effects on sensitive habitats in Europe and it is now the focus of a significant international policy effort. The UNECE Convention on long-range transport of air pollutants (the Gothenburg Protocol) and the EU Directive setting National Emissions Ceilings includes ammonia as one of four key air pollutants, and the Emission Ceilings Directive has set a target of just under 297,000 tonnes for the UK for 2010. UK emissions have reduced by about 15% since 1990, and emissions are now around 315,000 tonnes per year.

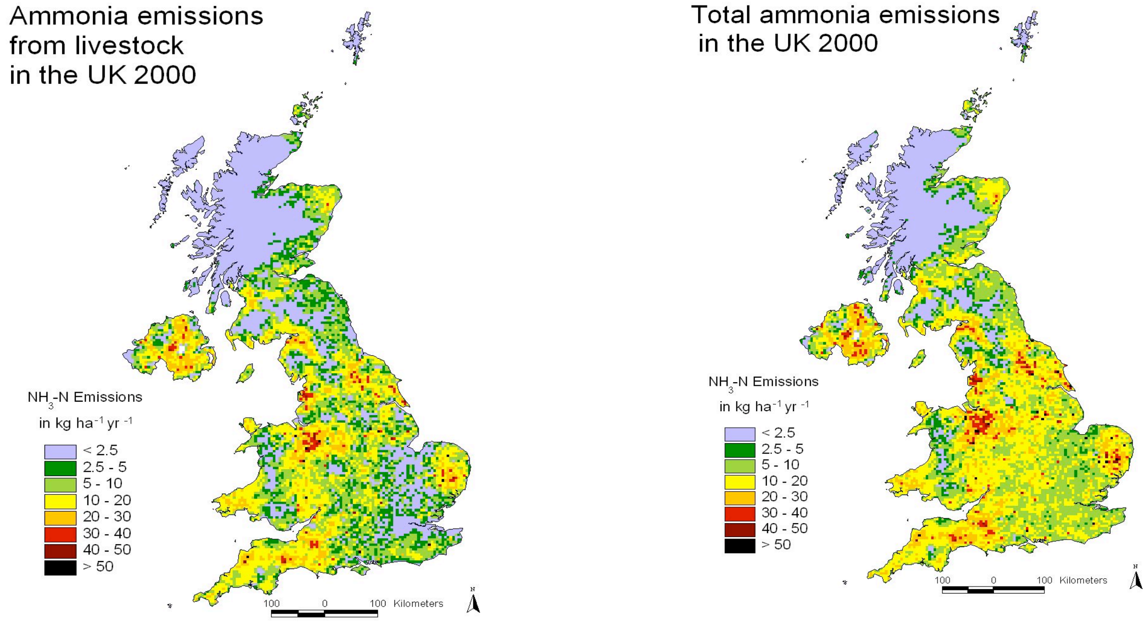

Figure 11: Maps of emissions of ammonia from livestock and total ammonia emission in the UK (derived from the AENEID (Atmospheric Emissions for National Environmental Impacts Determination model by Mark Sutton and others at the Centre for Ecology and Hydrology)

Ammonia gas and ammonium particles are transported long distances and deposited to ecosystems as a dry deposit or in rainfall. Since the major source is in rural areas, a wide range of semi-natural and sensitive wild ecosystems are affected. Ecosystems such as heath and moorland are particularly sensitive. In other ecosystems such as deciduous forests, nitrogen responsive grasses thrive at the expense of woodland flowers. Overall, a wide range of European ecosystems are estimated to be suffering from the effects of ammonia.

Sutton (2006) sets out two key points in developing ammonia reduction strategies: the need for an integrated approach to manage nitrogen in agriculture and the need spatial strategies to minimise the impacts of a given level of emission. An integrated approach would focus on conserving reactive nitrogen within the agricultural system with increases in nitrogen use efficiency and concurrent reductions in nitrogen inputs and emissions. This strategic approach seeks to exploit synergistic effects – e.g. reduced nitrogen inputs, more effective nitrogen use, and it dwells less on ‘end-of-pipe’ and single pollutant approaches. The need for a spatial approach arises from the reality that it is not possible to avoid all exceedances of critical loads while maintaining the current level of livestock farming in north-west Europe. There is huge spatial variation in deposition with very high loads down-wind from large livestock facilities. It is possible to reduce burdens on sensitive habitats through spatial planning of livestock production and landscape level measures such as buffer strips. From a global viewpoint, the relocation of livestock production to arable regions of the world with resilient soils may contribute to reduction in impacts. Ammonia deposition in such arable dominated eco-systems generally has a lower impact compared with emissions in close to forest, heath and moorland.

3.5.4. Pesticides

Pesticides by their very nature can have large impacts on the environment, impacting directly and indirectly on biodiversity. There are more than 300 pesticide active ingredients in use in UK agriculture across the whole range of crops grown, and this is a good reflection of the range used world-wide.

Western Europe, where the UK sources most of its food, is a major consumer of pesticides accounting for 20% of the world market. In addition, other food suppliers to the UK are major users, for example South America. Thus, UK food supplies draw heavy on agricultural systems that use pesticides intensively.

Pesticide use, in terms of weight of active ingredient, has declined in Western Europe from about 3 kg ha^{-1} in 1990 to 2 kg ha^{-1} in 2000. Much of this is due to the introduction of more effective pesticides. The number of pesticide applications per crop in the UK has increased but this may be due to more precise use of pesticides and not necessarily due to increased intensity of use or increased impact from use.

Only about 0.1% of the weight of pesticide applied reaches its target. The remaining 99.9% is emitted to the environment (Pimental and Levitan, 1986). As a result, pesticides are found in all environmental compartments: soils, plants, air, surface and ground water. Generally speaking, in the case of modern agricultural pesticides used carefully, acute direct impacts of this contamination outside the field are rare and transitory. Direct chronic impacts on non-target species in the field are common and have major effects on biodiversity through tropic effects. At the acute level, there are 5 to 10 serious pollution incidents in the UK arising from misuse.

The incidence of pesticide in water is a reasonable indicator of the transfer of pesticide outside the target crop system. In the UK, about 6% of river water samples register concentrations of individual pesticides in excess of the 0.1 parts per billion limit for water. Records of pesticides in water are dominated by two herbicides in particular; isoproturon and diuron. Isoproturon is widely used to control grassweeds in cereal production and diuron is used outside agriculture to control weeds on pavements. Persistent widespread contamination of the environment outside the crop system arises from relatively few pesticide/target complexes, and agriculture is not the only source.

Most pesticides are broad-spectrum, therefore they have indirect and broad tropic effects within ecosystems. Indirect effects are highly significant, and probably the most important cause of pesticide related environmental degradation in developed countries. Ewald and Aebischer (1999), reported a significant negative correlation in a UK farming area between broad spectrum insecticide use and the densities of insects over a period when insecticide use rose from 10% of fields in 1970 to 60-80% in 1990. The UK Farm Scale Evaluations (FSEs www.farmscale.org.uk) of herbicide tolerant crops showed how the complete removal of weeds using effective herbicides removes the foundation of the food chain on cropped land and indirectly impacts on farmland biodiversity. A fuller account of pesticide impacts is provided in the section on biodiversity below. The basis for including consideration of indirect effects into the regulation of pesticides has been investigated (Defra 2005). Research has also established approaches to the assessment, in a regulatory context, of the environmental impact of changes in crop production practice in general (Defra research project AR0317).

Pesticide use in horticultural and fruit crops is frequently high with more than 10 treatments per year. Lillywhite et al. (2007) applied the Pesticide EIQ rating to an assessment of crops and concluded that the environmental impact of pesticide applications to some horticultural crops such as apples and strawberries is generally higher than to the widely grown crops such as wheat. Horticultural crops are high value. Weeds, pests and diseases can have quality impacts, especially for fresh consumption. In addition, harvest technology often requires weed free crops. A great deal could be done in some crops to reduce pesticide use if the market was more tolerant of cosmetically less-than-perfect fruit and vegetables.

Environmental policy debate, at least in the UK, has shifted its focus away from pesticides and crop protection in recent years. Since 1990, the UK has experienced a huge increase in the profile of the environment in Government yet Government policy on crop protection and pesticides may have become less clear. The 1990 Government Command Paper on the Environment, 'This Common Inheritance' set out the reduction in pesticide use as a policy objective. This clear measurable objective has been replaced with the aim to reduce pesticide impacts – an objective that is difficult to measure progress against. Progress made in other countries such as Sweden, Denmark and in the Netherlands in reducing reliance on synthetic pesticides is not mirrored in the UK. Despite the large research investment into introducing consideration of indirect effects into the regulatory system, it is unclear if and how consideration of indirect effects could be incorporated into pesticide regulation in the UK. Comparative Risk Assessment which is argued by some as a means of introducing a culture of continuous improvement in crop protection practice has not been adopted. The regulatory system approves pesticides but provides no information on the relative effects on various elements of the environment of approved pesticides.

3.6 SOIL LOSS – EROSION AND DEGRADATION

Soil loss is inextricably linked to agriculture. Montgomery (2007) provides an excellent overview of the challenge of erosion and agriculture from a geological viewpoint identifying erosion as a major constraint on the long-term sustainability of agriculture. Under natural vegetation, soil erosion rates stabilise to the rate of soil formation in the long term, and these erosion rates range from 0.0001 mm to 0.01 mm per year in most flat to moderately sloping landscapes, and up to 0.1 to 100 mm per year in steep sloping Alpine topography. The rate of erosion under agricultural management is 10 to 100 times this background geological level, with an average of 0.64 for cropland. So world-wide, soils under agricultural management are eroding 10 to 100 times faster than they are being formed meaning that agricultural is unsustainable over relatively short historical time frames – 100 to 1,000 years. This simple constraint on the lifespan of agricultural soils explains reasonably well the pattern of the rise and decline of historical civilisations. Soil loss rates are high under modern agriculture and agricultural land is expanding at the expense of native vegetation – so the amount of vulnerable land at risk is increasing. Pre-agriculture rates of erosion require a mean continental erosion rate on the order of 0.016 mm per year, resulting in the accumulation of ca 5 million tonnes of sediment per year. Available data suggest that present farmland denudation is proceeding at a rate of ca 0.6 mm y^{-1} (ca. 75 G tonnes yr^{-1}). This equates to the loss of 5-10 million ha of arable land each year. Much of this soil is removed from agricultural land and 'entombed' in deposits that cannot be used for productive purposes. For the UK food economy, erosion of soils in the Mediterranean used for fruit and vegetable production is particularly significant.

3.6.1. Conservation tillage

Intensive land cultivation methods, particularly based on ploughing, are a major cause of severe soil loss. Especially where the topsoil layer is thin, conventional tillage contributes to soil loss. Loss is a feature of soil disturbance and loss of vegetation cover. Even where disturbed soils do not suffer surface loss, particles can be lost from cultivated soil through sub-surface drains.

The link between agriculture and soil erosion is largely due to the increased exposure of the soil to rainfall and the disturbance of the soil surface using tillage. Against the background of accepted benefits, the utility of ploughing was first questioned in the 1930s by Edward H. Faulkner, in a manuscript called "Ploughman's Folly" (Faulkner, E.H., 1943). Since the 1930s and during the next 75 years a move to reduced tillage systems that do not invert soil has been advocated and only recently gained widespread acceptance with the introduction of herbicide tolerant GM crops and machinery developments. These systems use less fossil fuel, reduce runoff and erosion of soils. Data reported by Derpsch, 2005 indicates that the extent of no-tillage adoption worldwide is just over 95 million hectares, dominated by the US, Brazil and

Argentina. The FAO position is that if farmers applied ecologically sound cultivation methods, millions of hectares of agricultural land could be protected or saved from degradation and erosion.

The literature refers to drastic reductions in soil erosion through conservation tillage – more than 90%. In addition to conservation tillage, bi-cropping in situations vulnerable to soil erosion greatly reduces erosion risk as exemplified by the bi-cropping of maize with white clover (IGER 2001).

Water infiltrates easily on soils under conservation agriculture, increasing the groundwater level, reducing surface runoff and thus soil erosion. It is reported by the FAO that after some years of conservation farming, natural springs that had disappeared in for example the Cerrado of Brazil started to flow again.

3.6.2. Soil carbon

The affect of land use change driven by agriculture on soil carbon (organic matter) is already covered. Recent research (Bellemy et al., 2005) shows that UK soils have lost carbon over the last 25 years at a rate of 0.6% per year (in relation to the carbon content in about 1975). They attribute this largely to climate change rather than to soil management practices. The largest losses occurred on wet and organic soils which are most vulnerable to climate warming and dry summers.

The UK food economy depends largely on stable European soils which were converted to agriculture centuries ago. These soils now have generally low and steady-state carbon contents. Close examination of soils data show that some arable soils with low organic matter contents are now accumulating carbon. This may be linked to increases in crop residue returns following the ban of straw burning in the 1980s. Only major change in land use could cause UK agriculture to be cause of major releases of soil carbon and likewise, only major changes in soil management, such as a significant increase in grassland or woodland, could make UK agricultural soil a net sink for carbon for a period after conversion.

3.6.3. Toxic substances in soil – contamination.

The contamination of soil with toxic substances has been a major cause of soil degradation, particularly in Europe over the last 60 years. Heavy metal contamination is common in Europe due largely to Europe's mining and industrial legacy. UK food consumption is associated with further contamination in a number of ways:

Copper is an essential nutrient for plants and animals as well as a toxin at high levels. Copper is added to animal feeds for nutritional reasons. In the past, high levels of copper were fed in the diet to pigs, and as a result some soils in Europe, for example in Belgium, are heavily contaminated with copper.

Sewage sludge is applied to land, and this practice has increased in the UK in response to restrictions on dumping sludge in the sea. Sludges contain a wide range of trace heavy metals with cadmium and mercury being toxic with no nutritional purpose. These additions are a consequence of the water industry and industry more generally, not food or agriculture. Other contaminants are persistent organic compounds, again not from agriculture. In addition, depending on source, phosphorus fertilisers can contain traces of cadmium and other heavy metals.

3.7 SOIL AS A POLLUTANT OF WATER, I.E. 'SILT'

Soil is a pollutant of water as suspended particulate and is a particular problem wherever soil is tilled and where livestock remove vegetation through poaching or over-grazing. The resulting sediments play a complex role in river and lake ecosystems. Even though sediments provide habitat for many organisms, sediments can negatively impact on aquatic ecosystems through the siltation of gravel habitats for fish and invertebrates, reduction of plant growth due to turbidity and by acting as a carrier of nutrient, chemical and microbial pollutants. Overall, particulate in rivers and lakes arising from agriculture represent a serious and perhaps under-appreciated challenge in restoring water bodies to a 'good' ecological status under the EU Water Framework Directive. Particulate clogging gravel beds is a major impediment to the restoration of trout and salmon to European rivers. The silt contents of spawning gravels in many English rivers lie above the threshold likely to reduce the survival of salmonid eggs and fry. A survey of 51 river reaches found that most lowland sites in eastern England had a silt content in the critical range, while most upland sites in south west England had relatively little silt (Defra 2002).

3.8 AGRICULTURE AND THE HYDROLOGICAL CYCLE – WATER

Trenberth et al. (2006) provide an overview of the Earth's hydrological cycle. Fresh water accounts for only 2.6% of the Earth's water resources, and 99% of this is in the form of ice and ground water. Fresh water in rivers, lakes, wetlands and soil account for only 1% of fresh water resources. Agriculture has a profound effect on these fresh water resources and associated wetland and aquatic biodiversity. The impacts can be categorised as follows:

Reducing fresh water capacity – drainage
Altering evapotranspiration
Water abstraction – irrigation

In contrast to the nitrogen and phosphorus cycles, agriculture's impact can be positive and negative for the same process, depending on circumstances – for example agriculture can have negative impacts by increasing and decreasing evapotranspiration or increasing or decreasing soil water content.

3.8.1. Reducing fresh water capacity - drainage

Drainage is a major feature of the infrastructure supporting agriculture in north-east Europe and a large proportion of the UK's food supply comes from drained land. Wetlands, moorland and bogs and fens have been drained to the point where entire landscapes in north-west Europe have been transformed and are now unrecognisable in relation to their original state. In addition, large areas of mineral soils have sub-surface drainage, ranging from permanent piped drains through to temporary mole drains in clay soils. All these measures accelerate the transfer of water from soil to streams and rivers and accelerate the drying of soil. This reduces the storage of water on farmland and increases the connectivity of river basins, i.e. it shortens the time between rainfall and arrival of water in streams and rivers. This increases the intensity of river flooding after rainfall.

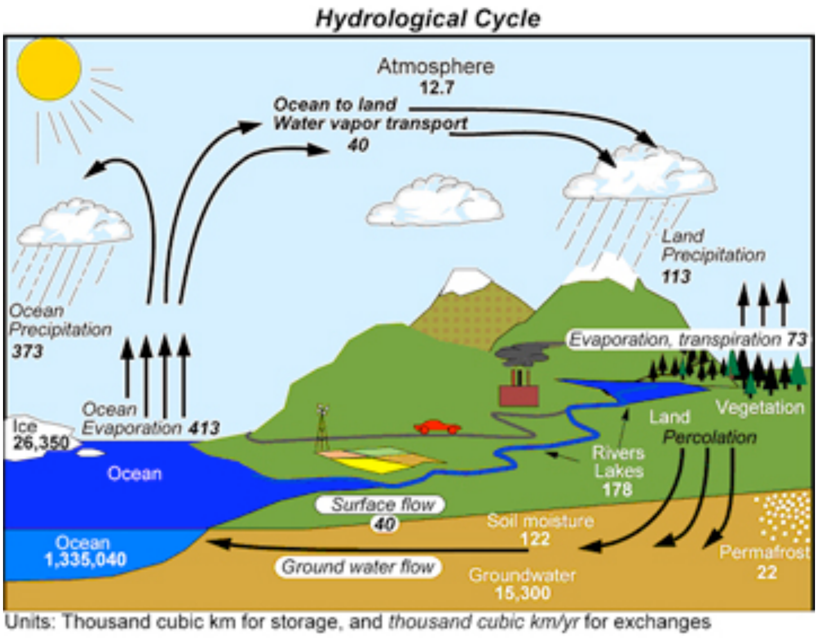

Figure 12: Estimated global water cycle. Water storage is given by the non-italic numbers in cubic km, while fluxes of water are given in thousands of cubic km/hr by the italic numbers (From Trenberth et al., 2006)

Agriculture has been also a major driver behind the arterial drainage of streams and rivers, a great deal stemming from the Arterial Drainage Acts of 1930 (for the UK) and 1945 for Ireland. The 1930 Arterial Drainage Act was targeted at the drainage of 1 million ha, mostly in eastern England. Water courses were straightened and deepened and obstructions removed to increase flow. This had a huge effect on aquatic and wetland ecosystems destroying salmon populations for example. In some instances, whole river basins have been transformed. The case of the arterial drainage of the Boyne in Ireland provides an example of the changes driven by the expansion of European agriculture. A whole river system including associated wetlands over about 1300 km of waterway was subjected to radical dredging in the 1970s to lower the bed of the river and its tributaries. The process created an entirely new bed and bank regime and removed of pre-existing and extremely valuable fishery and riparian habitat (Reynolds, 1989). In upland areas, blanket peat and moorland has been drained leading to loss of wetland and accelerated oxidation of peat causing carbon emissions.

Most of this is in the past, and European food consumption is no longer connected to significant new drainage in Europe. The question now is what is the role of the food economy in facilitating restoration. UK river systems and drained lands can be re-wilded or at least drainage impacts can be mitigated by natural regeneration of river topography. The UK food economy includes a wide range of parties with an interest in the process of re-wilding and wetland regeneration.

3.8.2. Altering evapotranspiration

Agricultural vegetation normally has a different water uptake and transpiration pattern compared with the vegetation it replaces. The planting of crops that transpire more water than the vegetation they replace increases soil water deficits and delays and reduces winter recharge of aquifers and drainage systems leading to reduced river flows (Stephans et al. 2001). Most arable crops are deeper rooted and transpire more water than extensive grassland, so the expansion of arable crops onto grassland, for example on the Downs in England, usually impacts negatively on water resources. Arable crops root to 1 to 2 meters whereas forest roots to 8 meters or more. Replacing forest or scrub with arable crops reduces peak soil moisture deficits and thus alters hydrology. This can have negative impacts where there is a distinct wet season such as in the Cerrado. The capacity of soils to absorb excess rainfall is reduced with profound implications for hydrology and local climate.

Evapotranspiration from trees plays a vital role in regulating rainfall in some ecosystems. The removal of forest and scrub from the Cerrado of Brazil is thought to increase the risk of long and intense dry seasons in the Cerrado, affecting the Cerrado and the adjacent Amazon.

3.8.3. Water abstraction - irrigation

The most obvious and visible impact of agriculture on water resources is that arising from irrigation. The UK is a major importer from the southern states of the EU and the majority of UK consumption impacts via irrigation are in the EU, Israel, and South Africa. Baldock et al. (2000) provide a very good overview of water abstraction for agriculture and its impacts in the EU. Their report is summarised here.

Agriculture accounts for around 30% of total abstracted water use in the EU with 60% in most southern countries and zero to over 30% in northern countries. It is the source of a number of environmental concerns, such as over-abstraction of water from rivers and subterranean aquifers, soil erosion, salinisation, alteration of pre-existing semi-natural habitats; and, secondary impacts arising from the intensification of the agricultural production permitted by irrigation.

Within the EU, water demand for irrigation is relatively insignificant in Ireland and Finland, modest in Sweden, Luxembourg and Denmark, of increasing regional importance in the UK, Belgium, the Netherlands, Germany, Austria and France, and nationally significant in Portugal, Spain, Italy and Greece. High value fruit and vegetable crops account for most irrigation. Potatoes are one of the main irrigated crops in northern Europe, and account for half of the water abstracted for agriculture in the UK. In recent years, the irrigation of olive plantations to meet the huge increase in demand for olive oil has developed. Because most irrigation practised in southern Europe is on a large numbers of small farms, the socio-economic importance of irrigated agriculture is significant. Traditionally, much of the irrigation practised in Europe has consisted of gravity-fed systems, where water is transported from surface sources via small channels and used to flood or furrow-feed agricultural land. However, in an increasing number of regions, irrigation using pumps, often drawing water from subterranean aquifers, is the most common practice. It is often in these areas where large quantities of water used and where the impact on the environment can be most severe.

Between 1980 and 2000, the irrigated area rose from around 2.9% to over 3.5% of the total land area of the EU. In some countries the most rapid increases were during the 1980s and growth has been slower since then (e.g. Spain, Portugal, Italy), while in others the most significant expansion was in the 1990s (e.g. France and UK). Technical change has resulted in a series of significant transformations in irrigation technology. The most recent drip systems are more efficient in their use of water but they are often far too costly for the majority of small irrigators in the south. In Europe, the adoption of the most efficient water use systems tends to be concentrated in regions where farms are relatively large businesses, crops are high-value and/or water pricing is well established (e.g. Netherlands, UK, some regions of Spain and Italy). Simple low cost drip irrigation systems do exist and are promoted in developing countries (Gail Smith, personal communication in 2008).

The environmental impacts of irrigation are variable and not well-documented in many EU countries. Some environmental impacts can be very severe. In general, the regions with the most severe problems of permanent resource pressure are concentrated in the southern states, whereas these pressures are often only severe during drought periods in the northern countries. Impacts are usually site specific, and they can be profound, even where they may occur only for a relatively short period.

Across Europe as a whole, the main types of environmental impact arising from irrigated agriculture are:

- Water pollution from nutrients and pesticides.
- Aquifer exhaustion by abstraction of irrigation water
- Displacement of extensive agriculture and valuable semi-natural ecosystems
- Gains to biodiversity and landscape from certain traditional or 'leaky' irrigation systems in some localised areas (e.g. creating artificial aquatic habitats).
- Increased erosion of cultivated soils on slopes.
- Salinisation, or contamination of water by minerals, of groundwater sources.
- Both negative and positive effects of large scale water transfers, associated with irrigation projects.

Of these, the most significant problems are indicated in relation to:

- A combination of over-abstraction of groundwater supplies, salinisation and pollution by nutrients, pesticides and other farm inputs in significant areas of intensive irrigated agriculture. These include the Spanish interior, many parts of the Mediterranean coastline from southern Portugal across to Greece, and some localised areas in northern Europe including parts of the Netherlands.

- Soil erosion, arising both from intensive irrigation itself, and from the abandonment of formerly hand-irrigated, traditional terrace agriculture in the hills. Erosion is a serious concern in some Mediterranean including Spain, Portugal and Greece; the desiccation of former wetlands and the destruction of former high nature value habitats including dryland arable, low intensity pastures and sensitive aquatic environments by the expansion of irrigated agriculture and its knock-on effects.

A variety of measures is available for mitigating the negative impacts of irrigation and enhancing environmental benefits where these are achievable. Some of these are technical or site specific but many could also involve policy changes and adjustments to the institutional management of water at national and regional levels.

Some technical measures can be applied to increase the efficiency of irrigation systems, reducing both abstractions and soil erosion, switching from sprinklers to drip irrigation for example. However, the environmental gains may be very limited if more efficient techniques do not result in lower net water use, but simply allow an increase in irrigated volume or area. In practice, major investment in new technology can be extremely costly and may therefore be beyond the reach of many small businesses.

There is a range of possible measures to reduce the quantity of water used in irrigation in order to mitigate environmental damage. These include economic and regulatory policies such as water metering, charging, licenses and time-limited abstraction permits. Controls over where irrigation can be practised can also avoid damage. Such measures are within the competence of different authorities, including regional and national government, water management institutions and other more local organisations.

3.8.4. Virtual water

In recent years, the concept of a trade in virtual water, i.e. the water embedded in the production of agricultural products, has been widely adopted (Allan, 2003). This is all the water transpired by crops and forage, drinking water for animals, and water used in processing and manufacture. The virtual water content of products is typically 1,000 to 20,000 times their weight with the lower quantities for cereal crops and the higher quantities for livestock products. All vegetation transpires water, and the data on virtual water alone make no distinction between the transpiration of scarce or plentiful water, rain-fed or irrigated crops.

In informing food consumption, it is important to distinguish between the use of water that contributes to scarcity and the use of water that has less impact on hydrology. More recently, the concept of 'blue' and 'green' water embodied in agricultural products has been developed (Aldaya, Hoekstra and Allan, 2008). Virtual green water is the water embodied in rain-fed crops, while blue water is water abstracted from rivers and aquifers etc. delivered to crops through irrigation. Aldaya et al. (2008) suggest that trade in crop commodities can be analysed in terms of green and blue water and that trade in virtual green water could contribute to the mitigation of water scarcity in deficit regions. In other words, trade in food can be used to move virtual green water to regions where water is scarce and food production is dependent on blue water. This means displacing 'blue water' agriculture with agriculture based on green water – a controversial issue in food exporting countries using 'blue water'.

3.9 BIODIVERSITY

Change in biodiversity is the end-point of environmental burdens and impacts. A full account of all biodiversity impacts of UK food consumption is not provided here. Impacts arising in WWF Priority Places and the north-east Atlantic are covered elsewhere in this report. Here, a note on the impact on biodiversity of crop and forage production in Europe is provided comprising a summary of an excellent review by Boatman et al. (1999). The focus is the effect of changes in European agriculture supplying the majority of UK food supplies.

Farming in Europe since 1970 has seen the simplification of cropping systems, increased fertiliser and pesticide use, and the introduction of irrigation and drainage. Simplification of cropping systems results in reduced crop diversity and loss of non-crop habitats such as grassland, field boundaries, water-courses and trees, all of which can form an integral component of farm ecosystems. These, and the loss of livestock from arable systems, have contributed to a decline in biodiversity.

Birds provide an indicator of environmental change. Percentage declines over 25 years up to 2000 in UK populations are grey partridge (86%), lapwing (55%), turtle dove (69%), skylark (62%), yellow wagtail (74%), song thrush (56%), tree sparrow (95%), reed bunting (60%) and corn bunting (80%). Similar declines in farmland species have been experienced across Europe, with 42% of declining species being affected by agricultural intensification. Such severe declines are not occurring for species associated with other habitats.

Of all European farmland species, specific causes are best exemplified by the fate of grey partridge in Britain. For this species, reduced availability of invertebrates which form a key component of chick diet, has been identified as pivotal in population declines. Nestling survival of corn buntings, another severely declining species, has also been shown to be strongly related to invertebrate abundance which occur at highest densities in relatively low-input arable systems incorporating under-sown leys. This species is also strongly associated with low input arable systems in Portugal.

Through out Europe, high crop diversity benefits many species. For example, brown hares graze different crops at different times of year, while skylarks move breeding territories from one crop to another through the breeding season, and yellowhammers switch foraging from one crop to another during the breeding season. Lapwings require cereals in which to nest and adjacent pasture on which to feed newly hatched young while little bustard males and females have different habitat requirements during the breeding season.

In Britain, geographical polarisation of arable and livestock farming has reduced the number of farms with high crop diversity. Pastures grazed by livestock are associated with large numbers of invertebrates which provide food for birds and other animals, and livestock feed sites in winter provide a source of food for seed-eating birds. The loss of livestock from farms in eastern Britain has removed these components from the arable landscape. For example, the grassland area in Leicestershire declined from 44% to 32% between 1969 and 1993, with arable grass leys declining from 13% to 9% over the same period. Intensification of grassland management and conversion of grass to arable cultivation resulted in a 92% decline in the area of ‘unimproved’ grassland in the UK between the 1930s and 1980s, with a consequent decline in biodiversity, of plants and invertebrates associated with semi-natural grasslands. The timing of agricultural activity is also important. In Ireland, the corncrake is now extinct in most areas due to earlier harvesting of grass for silage. In the Netherlands, plants and invertebrates (especially dragonflies and butterflies) associated with semi-natural grassland and forest edges also declined and drainage of grasslands has resulted in declines of wading birds.

Large areas of grassland in northern Europe have been drained for conversion to arable crop production since the 1940s, but remaining wet grassland habitats have also been severely affected by drainage of adjacent arable land. As a result there have been substantial declines in abundance and diversity of birds, plants and invertebrates associated with wet grassland habitats. In the Netherlands about 60% of the lowering of water tables is caused by draining of adjacent arable fields. Most agricultural land in the Netherlands is drained to a depth of at least 0.5 metre so that plants requiring a high water table have become rare and replaced by more common species. In southern Europe the area of irrigated crops has increased considerably since the 1960s, taking the form of pivot irrigation in formerly dry areas, and flooded rice in low-lying areas. Pivot irrigation of crops such as maize is associated with increased fertiliser and pesticide applications and the environmental impacts of irrigation are therefore largely those of these inputs, including the loss of fallows in crop rotations. The intensification of activity and inputs that are part of irrigated farming play a part in the elimination of such species from irrigated arable systems. Drainage for irrigation has resulted directly in the local extinction of arable plants and subsequent use of herbicides and fertilisers have a wider impact on the arable flora.

Agriculture can have positive effects. The biodiversity characteristic of much of north Europe depends on the cultural landscape developed for agriculture over centuries. Intensification in the last 50 years has reduced biodiversity in these managed ecosystems, however there is scope for reconciling modern production practice with furthering biodiversity associated with farming. The SAFFIE Project in the UK (http://www.saffie.info) showed that considerable progress in the restoration of biodiversity can be made in landscapes dominated by arable farming with minimal impacts on production. Grassland too can be managed to increase the habitat value of farmed ecosystems (Tallowin et al., 2006) but with considerable reduction in production potential. In southern Europe, water management can have positive effects. For example, rice growing can increase the local diversity of birds and the aquatic invertebrates on which they feed.

4 Direct impacts of food production for UK food consumption on WWF Priority Places and the north-east Atlantic

The data on food imports to the UK, (principally from the FAOSTAT) were examined for evidence of sourcing from WWF's 35 Global Priority Places. There is a direct and traceable link between UK food consumption and the following Priority Places:

- The Atlantic Forest (Brazil, Paraguay and Argentina) – beef, soy, citrus, coffee.
- The Cerrado-Pantanal of Brazil and neighbouring countries – beef and soy.
- Choco-Darien (Columbia, Panama and Ecuador) – palm oil
- Fynbos (South Africa) – citrus and wine
- Mediterranean basin and sea – fruit, vegetables and olive oil
- New Guinea and its off-shore islands – palm oil
- Borneo – palm oil
- Sumatra – palm oil, coffee, black pepper.

There are indirect links with:

- The Amazon and Guineas – global trends shifting production to these areas
- The Northern Great Plains – global trends in cereals

In addition, the UK food economy is very strongly connected to the north-east Atlantic ecoregion through the consumption of fish, both home produced and imported.

4.1 THE AMAZON

Beef and soy are the two commodities that strongly link the Amazon biome with the UK food economy. Brazil is responsible for more than 60% of the Amazon rainforest biome, a land area in Brazil which has lost 20% of forest cover since 1970. The impact of the UK food economy on the Amazon is largely due to the trade between the UK and Brazil.

4.1.1. Beef production in the Amazon biome

Brazil produced just under 8 million tonnes of beef in 2004, of which 12% was exported. There are uncertainties in the statistics and they vary due to data on weights of boned and trimmed cuts, processed meat and carcase meat. However, no matter how one examines the Brazilian beef industry, the statistics are staggering. The USDA (2008) predicts that Brazilian beef production will reach 10 million tonnes in 2008, with 2.6 million tonnes exported. Brazil is now the world's biggest exporter of beef. Until about 1990, Brazil was not present in a significant way on the world beef market. By 2001, Brazil accounted for 16% of international trade. By 2006, this had risen to 35% (Steiger, 2006). Studies indicate that exports grew to about 400,000 tonnes by 2001 and have since grown four fold to 1.6 million tonnes carcase equivalent in 2006 (e.g. Lundström, 2007) Although the UK market represents only about 1% of Brazilian production, and about 8% of exports, it has grown in line with Brazilian exports as a whole. Looking to the future, the Brazilian beef industry as a whole now has a commercial momentum in export driven activity. Three Brazilian meatpackers alone raised $1.5 billion public share issues in the first half of 2007.

Figure 13: Map showing the Amazon biome (from WWF-UK)

Livestock census data (FAOSTAT 2005) shows that the Brazilian beef industry was located primarily in the Cerrado biome in 2002. At that time, Brazil had 2.6 million sq km of agricultural land of which 2.0 million sq km was pasture (77%). This compares with a total clearance of rainforest in the Brazilian part of the Amazon biome of 0.7 million sq km up until that time, most of which had become pasture. Thus from production statistics for Brazil, pasture arising recently from cleared rainforest is not the main land resource used by the Brazilian beef industry as a whole. However, the key issue for links with consumption is the role of exports in the growth of the Brazilian beef sector. Kaimowitz et al (2005) examine the trends in the size and location of the Brazilian cattle herd and correlated deforestation with the growth of beef industry, particularly in States such as Mato Grosso that straddle the boundary between the Amazon and Cerrado biomes. Brazilian domestic beef consumption is static but the beef herd and production continues to grow driven by exports. In addition to its growth, the beef sector as a whole is tending to move north into the Amazon basin. This movement is driven by the conversion of older pasture land on the Cerrado savannah to arable cropping - soy, maize and sugar cane. Kaimowitz et al. (2006) conclude that 80% of the growth in Brazil's cattle population between 1990 and 2002 was in the Amazon. By 2004, 75% of the cleared land in Amazonia was occupied by cattle ranching and that this economic activity is economically sustainable (Margulis, 2004). The greatest increases in cattle numbers were in those states with the greatest rates of deforestation. Simon and Garagorry (2005) set out the growth of Brazilian and Amazonian agriculture between 1976 and 2002 and document the huge growth in the herd in the Amazon biome. Pasture for cattle accounted for 8% of the biome in Brazil in 2001, compared with less that 1% for cropping. They conclude that livestock is the most important vector of deforestation probably because of the high profitability of beef production in Amazon compared with land uses.

Kaimowitz et al. (2006) base their conclusions on correlations between cattle numbers and deforestation. Correlation is not causation. It remains unclear from statistics on deforestation and agricultural activity if the growth in beef production is directly *causing* deforestation. The Brazilian beef industry (ABIEC) states plainly that there is no beef production for export on deforested Amazon land. It argues that productive land elsewhere is supporting the expansion. The ABIEC state that critics are confusing the Amazon biome with the larger Legal Amazon which is an administrative region that includes part of the Cerrado, especially where beef production has grown the most. It is clear though that there is a growing beef industry in the Amazon biome – a significant proportion of the Brazilian slaughter capacity for export is located within or close to its boundaries. The industry acknowledges that cattle graze on deforested land but point out that this is not for export production and the purpose is to stake out territory. ABIEC's denial of links between exported beef and deforestation overlooks the nature of commodity trading, especially in developing economies with large domestic markets. Exported Brazilian beef may be regarded as coming from a pool of beef supplies. Supplies to one side allow exports from another. Exports are largely based on supplies from outside the Amazon, particularly the Cerrado and Atlantic Forest, enabled by the use of recently deforested areas in the Amazon to supply domestic markets.

In a multi-disciplinary and academic meta-analysis, Geist and Lambin (2001) emphasise the complexity of factors driving deforestation. Only rarely can one cause, or even a group of causes such as that encapsulated under the term 'agricultural expansion', be identified. Deforestation is driven by several direct and indirect forces in each case, and these often work together or in tandem. Having reviewed the evidence of causes of deforestation in the tropics, they refer to a tandem of forces working in a way exclusive to the lowland humid forests of South America (e.g. the Amazon). In 75% of cases studies, expansion of agriculture was the leading driver of deforestation, linked in nearly every case to logging and/or road building.

Bolivia, Colombia, Ecuador, Peru, Venezuela, Suriname, Guyana and French Guyana are the other countries with land in the Amazon. Bolivia, Colombia and Peru have significant cattle herds, but only Bolivia with a herd of about 5 million has a significant proportion (73%) in the Amazon. Otherwise, these beef industries are based on savannah regions. None of these countries have significant beef exports.

4.1.2. Soy production in the Amazon biome.

Brazilian soy production is estimated to be about 57 million tonnes having doubled since 1995 (USDA 2008). The soy industry accounts for about 6% of Brazilian GDP and is at the core of the Brazilian economy representing about 35% of exports. The EU imports about 34 million tonnes soybean equivalent as soy meal. Brazil and Argentina produce nearly 90% of this – each about 15 million tonnes. Brazil is the source of 80% of soybean supplies to the UK.

The growth of the global demand for soy is well documented and recent surges in the demand from Brazil have been linked to the concurrent EU consumer concerns about GM crops, Brazilian fiscal and monetary policy (the devaluation of the Brazilian Real), the ban on feeding animal derived proteins combined with growth in Chinese meat consumption (Morton et al., 2006). Simon and Garagorry (2005) show the dramatic growth of supplies of soy from the Amazon biome in Brazil, from zero to about 2% of Brazilian production (i.e. 800,000 tonnes) in 2003. The period from 2002 to 2004 was marked by historically high deforestation rates that seem to have just resumed after a respite between 2004 and 2006. This surge of deforestation was, unlike previous deforestation, characterised by large scale mechanised clearance indicative of highly capitalised soy production (Simon and Garagorry, 2005).

Soy expansion into the Amazon began in the late 1990s stimulated by the development of new varieties adapted to the equatorial climate. The development of these varieties and the associated production practices for the Amazon coincided with a global shortage of plant protein for animal feed. This combined with road and waterway development stimulated soy production in the region (Nepstad, Stickler and Almeida, 2006). The EU is seen as the most important export market in the expansion of the Amazon soy industry. The higher prices for soy have driven up the price of suitable land right across Brazil leading to both direct and indirect pressure on forests. The indirect pressure is due to the conversion of previously cleared pasture land across Brazil to soy cropping stimulating the cattle industry to relocate northwards to the Amazon. Many cattle ranchers who had land in the Cerrado suitable for soy have sold off their holdings following a 4- to 10-fold increase in land value and have used these capital gains to expand beef production in the Amazon. Until recently, this cattle to soy chain was dominant. In recent years the direct and highly mechanised conversion of forest to soy production has become evident as a dominant force working at a large scale (Morton et al., 2006).

Although soy yields are high in the Amazon biome, production in such a humid climate is technically challenging. In addition, lack of transport infrastructure and crop handling facilities is a major factor holding back development and increasing costs. The Brazilian Soy Producers Association (ABIOVE) states that in 2005 soy occupied only 0.3% of the land in the Amazon biome. Thus, its regards the direct impact of soy on the Amazon biome as insignificant.

However, statistics on land use in the region indicate pressure from soy production in the wider Amazon region, especially in the transition zone between the Cerrado and the Amazon biomes with growing pressure on the margins of the Amazon biome. There has been a surge in the development of vital infrastructure in the region which means that while the Amazon biome may not be widely planted, it is now very vulnerable to development. In 2005 soy accounted for 1.4% of the wider legal Amazon region. Thus, soy occupied 7.7% of the land in the wider legal Amazon which is not in the biome compared with 5.4% for Brazilian land outside the Amazon biome as a whole. One can say from this that soy is now a crop concentrating on the Amazon frontier.

4.1.3. Palm oil in the Amazon

Nepstad et al (2008) provide a map of the suitability of the Amazon for oil palm production. It shows that virtually the whole of the Amazon is highly suitable.

Oil palm production has grown dramatically in the Amazon from a low base. Palm oil exports from Brazil and Colombia in 2005 were 45,000 tonnes and 225,000 tonnes respectively. Exports to the UK have been the export mainstays of these emerging South American palm oil economies. The UK stands out in how it draws in South American palm oil for about one fifth of its supplies indicating that UK manufacturers are sensitive to concerns about oil palm in South-east Asia.

Even though exports to the UK dominate, plantations remain a minor land user. Colombian plantations extended to about 250,000 ha in 2003, and Brazilian plantations extended over 75,000 ha in 2006 with the expectation of trebling production over the next five years.

The literature indicates that this is an infant industry in South America developed so far largely to meet growing local demand for fats and oils for food. While this remains a minor land user, the significance for the future lies in the fact that the technology and production know-how has now been established in the Amazon. From a production standpoint, the Amazon is well placed to supply expanding markets driven by a global biofuels industry.

4.1.4. UK consumption and the Amazon rainforest

Olmos (2008) calls for consumers to act to protect the Amazon. He says that “the major drive for destroying the forest is the hunger of foreign markets for the cheap Brazilian beef and grains, especially soy. He adds that Brazil will behave in a responsible way regarding environmental issues only if strong economic pressure is applied by markets which are paying for the Amazon to be destroyed.

In considering such calls, the issue for UK consumers is the causal link between their consumption and Amazon deforestation, and the potential for consumers to influence land use change. Deforestation is associated with expansion in agriculture, but it remains unclear if this agricultural expansion onto cleared land is a consequence or a cause of forest clearance. In an analysis of land use change in the biome, Simon and Garagorry (2005) conclude that agriculture in the biome grew faster than that of Brazil as a whole and that agriculture production has moved north into the region. Thus they conclude that the region is a new frontier for Brazilian agriculture and that trends in commodity prices imply an increase in forest clearing.

Even though the use of cleared land for soy is closely connected with the use of land for beef production, there appears to be differences in the response of these industries to market signals, and thus consumer actions. The costs of producing beef in Brazil are lower than any other country at about $2 dollars per kg carcass weight. This compares with about $6 dollars for Ireland and the UK. Brazilian producer prices are thus determined by the domestic market and by tariff barriers.

The situation with soy is different. Tariff barriers play a smaller role and recent market developments indicate that the growth in the production of soy in Brazil is strongly influenced by world market prices, which have risen steeply due to demand from the livestock producing countries such as the UK, Germany and the Netherlands. The literature suggests that the marginal expansion of production in the Amazon biome and in the transition zone is heavily dependent on the recent surge in global demand for food and the boom in commodity prices. The soy industry in the Amazon biome appears particularly sensitive to global demand and prices – it is at the margins in the agricultural and economic sense. The evidence presented by Jaccoud et al. (2003) suggests that the influence of the final consumer on the production chain is strong, especially with respect to expansion in the transitional lands and in the Amazon biome. The cost of production in Brazil is higher than in Argentina but lower than the US. Machinery and pesticide costs are relatively high in Brazil while land costs are low compared with the US, particularly in the Amazon. There is evidence that direct transport costs for soy from frontier and Amazon regions combined with capital cost of developing infrastructure and the technical difficulty of producing soy in a humid climate mean that economic soy production in the Amazon biome depends on high global prices. This in turn depends on high consumer demand for livestock products.

The Brazilian Soy Producers Association (ABIOVE) and its member companies pledged on July 24, 2006 not to trade soy originating from land cleared in the Amazon biome for two years after that date. This was extended for a further year in June 2008. This 'moratorium' is a valuable first step in collectively addressing the threats to forests but its success depends of much wider measures, including measures in the beef sector. A moratorium should not be regarded by consumers as a signal that the risks to the forest arising from the consumption pattern they cause are being adequately addressed. Given the dependence of soy expansion on high world market prices, it is vital that the moratorium complements rather than displaces consumer driven moderation in demand and in global prices. Napstad, Stickler and Almeida (2006) emphasis the importance of consumer driven market mechanisms to complement top-down regulation of land use change. They argue that successful negotiation of social and environmental performance criteria and an associated system of certification that enhances returns to agriculture on land that does not threaten sensitive habitats is a potentially powerful instrument. This instrument is reinforced by access to international markets and in the longer term by wider appreciation of the role of the forest in the protection of regional hydrological cycles that support agriculture in Brazil as a whole. Jaccoud et al. (2005) support this and add that efforts to encourage efficient production in suitable agro-ecological zones could lead to a scenario where greater market access combined with effective and enforceable policies to manage expanded production brings mutual reinforcement of economic, environmental and social benefits.

Evidence of a link between deforestation and rising commodity prices has been supported by recent developments. In January 2008, the Brazilian Government acknowledged that after a brief respite since about 2004, there are signs of accelerations in the rate of deforestation, especially in the state of Mato Grosso which has a strong agricultural sector and which straddles the boundary between the Cerrado and Amazon biomes. Clearance rates reached unprecedented levels for the time of year in the last five months of 2007. The Brazilian Environment Minister was reported to have said that the "economic reality of these states indicating that these activities impact, without a shadow of a doubt, on the forest" (BBC website, 24 January 2008. Chomitz (2007) sets out a model of the agricultural frontier which identifies the rent from agricultural land as affected by proximity to food markets as the key driver behind deforestation. Road building, perhaps initially for logging, makes forest land more proximate to food markets and thus extends the frontier into the forest. Assuming such a model puts commodity prices and access to market at the centre of any analysis of forces driving deforestation.

Considering all the evidence reviewed, it is concluded that the economics of land use change as manifest in land values is a critical issue. Individuals clearing the forest seek to gain through an increase in the private market value of that land at the point of clearance and later. There may be a speculative element to this as land prices in the Cerrado rose dramatically in recent years. Nepstad et al (2008) present convincing evidence relating to the value of agricultural land. The net present value of Amazon land for cattle is about $500 per hectare throughout much of the Amazon. This rises to about $1000 per hectare in Foot and Mouth disease fee states where there is access to export markets. Thus, in addition to the general land value, this is compelling evidence that beef export markets are influencing land prices and thus directly linked to deforestation even though exports represent only about 12% of production. These net present land values seem to be reflected in the real land market – Butler 2007 reports John Cain Carter citing land values of around $1200 per hectare with values rising rapidly.

Most of the Amazon is not (yet) suitable for soy production but where it is, net present land values can exceed $10,000 per hectare. For a combination of infrastructural, soil and climate reasons, these values can only be achieved in less than 10% of the forested areas of the Amazon. Thus, soy production is a very potent potential driver of land use change via land prices in suitable areas.

Nepstad et al. (2008) do not quote net present values for standing forest, but low values are implicit in their report. Chomitz (2007) also quotes low values for standing forest in the Amazon. He concludes people clear and log forests because they gain from doing so. In addition to the gain in land value on conversion, the conversion process yields one-off returns for timber.

It is argued here that deforestation is the outcome of individuals' rational response to the present and expected future land values under different uses. In policy terms, this arises from an acute market failure arising from the public nature of much of the forest (as public land) and its public benefits (greenhouse gas mitigation, hydrological benefits, biodiversity) in contrast to the private goods generated by deforestation (private land title, timber, and food commodities). Approaches from a UK consumption perspective could be built around the economic reality of land prices and could seek to increase the economic value of forested land and established agricultural land whilst simultaneously reducing the value of newly or illegally cleared land. This may appear ambitious, but land values in the region already reflect access to international markets for beef as affected by Foot and Mouth Disease status. So the basis for market interventions affecting land values exists.

Even though sufficient to drive widespread deforestation in the Amazon, land values in the Amazon are generally low because most of the land can only sustain beef production. These values amount to a reward for forest clearance that could be relatively easily countered.

However, Margulis (2004) reports that deforestation followed by even low yielding beef production raises income in the communities but that the private benefits are rather exclusive adding to social and economic inequalities. Tipping the balance towards retention of the forest might be achieved by awarding an economic return for the ecosystem services, for instance through REDD or the Clean Development Mechanism, provided by the standing forest, by higher prices for selectively harvested (sustainable logged) timber, and/or market discrimination against food commodities delivered from newly or illegally cleared forest. Mechanisms to deliver these are developing and could be applied concurrently to deliver synergistic effects and to avoid unintended consequences associated with the transfer of agriculture to other forest frontiers. The Soy Moratorium mechanism not only affects the value of existing agricultural land, such mechanisms can influence the forward price of land ear-marked by individuals for clearance, thus providing an immediate brake on deforestation. A moratorium could be introduced for beef (Butler, 2007) sending a strong land price signal right across the Brazilian Amazon. If sustained, these moratoria reduce the market value of newly or illegally cleared land in the long term. Various trading mechanisms can complement this by rewarding the ecosystem services provided by the retained native forests, through for example carbon trading and off-setting. From the consumer perspective, produce certification schemes enable consumers to provide farmers with vital preferential access to markets. These mechanisms are powerful on the ground because they harness peer-to-peer pressure amongst farmers (Nepstad et al., 2006; Butler, 2007). Moratoria on their own have the potential disadvantage of displacing production from one agricultural frontier (e.g. the Amazon or Pantanal) to another. So produce certification schemes have a vital complementary role in actively increasing the value of commodities produced under certified conditions thus leading to increased productivity on such lands. Such approaches apply to all situations where agriculture is driving land use change. A global approach right across climate zones is plausible.

4.2 THE CERRADO – THE BRAZILIAN SAVANNAH

Figure 14: A map location of the Cerrado (Brazilian savannah) as delineated by WWF. National boundaries are shown in black

This ecologically heterogeneous region covering ca 2 million sq km is dominated by savannahs, but also contains several types of forests and dry-land plant communities that often form mosaics with the savannahs. Its high biodiversity is seriously threatened by conversion to agriculture and a lack of protected representative areas. Despite extensive conversion of wild vegetation to agriculture, it is still the most rapidly changing biome in Brazil. The development of this savannah since 1950 represents the world's single largest increase in farmland since the settlement of the mid-west of the US. In the last 35 years, more than half has been transformed into pasture and land planted with cash crops. Conservation efforts have been modest: only 2.2% of its area is under legal protection.

4.2.1. Land use in the Cerrado

There are inconsistencies in published data on land use in the Cerrado. The Cerrado has an area of 207 million hectares, of which 139 million hectares have agricultural potential, according to the Embrapa. From only 200,000 ha under cultivation in 1955, the Cerrado had well over 40 million ha under cultivation by 2005 (The World Food Prize Fact Sheet). By then, this area produced 54% of Brazil's soy, 28% of Brazil's maize grain, and 59% of its coffee. It also produced rice, cotton, cassava and sugar. In addition to the cultivated area, it is estimated that the Cerrado includes more than 60 million ha of pasture of which about 80% is degraded. This supports 55% of Brazil's beef industry. The scientific and technical breakthroughs that drove this expansion in agricultural development are seen as a milestone in global agricultural development. WWF Brazil sources indicate that only 30% of the Cerrado remains not used for agriculture and this is relatively unprotected and thus vulnerable to development.

Water is a key resource in tropical savannahs and is a mediator of wider impacts of land use change. Irrigation is used in the dry season impacting directly on ground and surface waters. In addition, the huge areas of rain-fed crops and pastures have wider implications for hydrological cycles with impacts extending beyond the farmed area and into other biomes such as the Pantanal. The native vegetation is exceptionally deep rooted and this supports canopy transpiration into the dry season (Oliveira et al., 2005) drawing on soil water from 8 meters and deeper. This transfer of water from deep soil layers to the atmosphere supports local rainfall vital to the shallow rooted grasses and annual plants. In addition, the dry season depletion of deep soil reserves by these trees and shrubs vacates a large storage capacity which is available for recharge in the wet season. Thus, the native vegetation of the savannah is crucial to the hydrology of the whole region and to rain-fed crops grown in it. Without it, the climate in the region would become drier, make agriculture less viable, and ultimately threatens other biomes, particularly the Amazon rainforest (Oliveira et al., 2005).

The clearance of savannah is not as well documented as it is for the Amazon. It is evident that agricultural expansion into the savannah is easier both technically and from a legal viewpoint. Scrub rather than high forest is widespread and trees are felled for charcoal as well as for timber. The remaining vegetation can be removed on a large scale using chains dragged by dozers sweeping 100 m wide swaths. A delegation from the Irish Farmers Association studied beef production in Brazil by travelling through the Cerrado in 2006 and 2007. They report on-going deforestation, typically following the traditional pattern of logging followed by burning and removal of stumps, followed by a succession of arable crops that benefit from the fertile soil left by the forest (Kevin Kinsella, Irish Farmers Association, Personal Communication, February 2008).

4.2.2. UK consumption and the Cerrado savannah

The links between UK consumption and Brazilian agricultural expansion are clearer for the Cerrado than for the Amazon. The Cerrado is central to Brazilian agricultural development. Even crops traditionally associated with areas outside the Cerrado such as citrus in Sao Paulo and coffee from the Atlantic coast have moved into the Cerrado driving Brazilian exports. The UK is a major importer of these mainstays of Cerrado agriculture – soy, beef, coffee, and citrus fruit, and thus directly connected to Cerrado agriculture. Even where the UK is not importing directly from Brazil, for example in the case of coffee in some years, Brazilian production on this scale feeding global commodity markets is indirectly connected to UK consumption.

The central (rather than marginal) role of the Cerrado in Brazilian agriculture, and especially in exports, has implications for UK consumer based habitat change mitigation measures. The following are points relevant to such mitigation:

- The Cerrado is one of the world's lowest cost producers of key commodities – soy, maize, sugar, coffee and citrus. To a great extent, Brazil influences the price in these global commodity markets. Brazilian producers' access to the world commodity markets, rather than the level of consumer demand or price in individual national markets, drives producer prices. Changes in consumption levels in the UK or even across the EU would have little direct effect on agricultural activity in the Cerrado.

- The Cerrado's crops are productive. Soy and maize yields are as high or are higher than in the US. As exemplified by the rapid development of zero-tillage systems, Cerrado farmers are innovative and interact effectively with the public Brazilian agricultural research effort, a science and technology resource of global significance. This provides opportunities for reinforcing eco-efficient approaches addressing global concerns.

- Cerrado farmers are now developing more complex resource conserving systems with well designed crop rotations. Of particular significance is the development of livestock production systems embedded in the cropping areas that close nutrient cycles and facilitate more complex and resource conserving rotations. The production of livestock integrated into the production of the crops they eat is preferable from a resource viewpoint to the export of feedstuffs for intensive livestock production concentrated in north-western Europe. It addresses the consequences of the separation of livestock and crop production and is a contribution to the development of a more sustainable global agricultural system (Galloway et al. 2007).

- There is uncertainty in statistics on cattle numbers, total beef output and the pasture area in Brazil. However, using FAO (FAOSTAT) and USDA statistics, a beef yield of about 50 kg carcase weight per hectare is estimated for Brazil as a whole based over a total pasture area of 200 million ha with 90% used for beef production. This would be representative of the Cerrado. This compares with 260 kg per hectare per year (including land-use embodied in imported feedstuffs) for UK suckler beef (Williams et al, 2006). UK suckler beef production includes extensive land management practices so this difference illustrates the potential for raising the productivity of Brazilian beef production and thus reducing the pressure on clearing new land.

- It is expected that drivers behind deforestation are similar to those in the Amazon but the returns to conversion are generally much higher (Chomitz, 2007) due to the suitability for a wider range of agricultural activities. Production is more directly connected to global markets so the market mechanisms outlined in relation to the Amazon could be applied. In addition, in the Cerrado the remaining natural vegetation provides ecosystem services through local and regional hydrological cycles that are crucial to the performance of agriculture in the region.

4.3 THE ATLANTIC FOREST

The Atlantic Forest originally covered about 1.2 million sq km of which about 100,000 sq km remains intact. It stretched along the entire southern coast of Brazil, extending into Argentina and Paraguay. The Atlantic Forest Biome is the focus of conservation attention because of the level of endemism and threat. The high level of endemism is due in part to the fact that the Atlantic Forest is isolated from the Amazon by the savannas and woodlands of the Cerrado region. Vegetation cover provides soil stability, especially on steep slopes. More than 60% of the Brazilian population lives in the Atlantic Forest region. Seventy percent of Brazil's GDP may be traced to the resources of this forest.

Figure 15: The Atlantic Forest Global Ecoregion (Conservation International)

The Atlantic Forest region is the cradle of Brazilian agriculture which is now a world leading exporter of coffee, citrus fruit, cacao, cane sugar and beef. In addition, the expansion of large cities such as Sao Paolo is a major cause of deforestation in this region. Even though the colonisation process began in the 16th century, the loss of forest cover has been most rapid and severe in the past two decades reflecting the recent enormous growth in Brazil as an agricultural exporter. The remaining forested areas are highly fragmented. In southern Brazil, only 1% of the original forest remains, mostly in upland sites

Although recent legislation has restricted the clearing of the remaining primary forests for plantations, enforcement is difficult and logging is still gradually destroying the remaining fragments of the forests that once covered the entire region. Despite these pressures, the remaining forest is benefiting from a degree of protection. Agricultural interests have recognised the role of the forest in regulating local climate. In addition, the Atlantic Forest region is familiar to the Brazilian NGO community and thus the focus of attention. The Atlantic Forest is also the focus of recent regulatory measures from the government in Paraguay. These measures have been very successful and show the effectiveness of concerted centralised government action in controlling deforestation.

The Atlantic Forest area is a source of beef, soy and coffee exports and is most closely connected to the UK through orange juice consumption. Brazil is the world's largest producer of oranges with 25% of the world's crop. Oranges account for about 1 million ha in Brazil, the great majority in this biome. Evan though this is only 1% of the land area, it represents a force for land use change locally. A similar situation pertains for coffee and cocoa. Locally, coffee is a major source of income, and plantations represent a serious local threat to the forest.

4.4 CHOCO-DARIEN MOIST FORESTS

The Choco-Darien Moist Forests cover a 187,000 sq km coastal zone running from south-east Panama to north-west Ecuador. It includes all the coastal territory of Colombia. Up to about a third of this area has been altered in some way, with about 20% deforested. 30% of the area in Panama is protected but this protected area amounts to only about 2% of the entire ecoregion complex. The extent of protection in Colombia is low – only a further 2.5% is protected there despite the large proportion of the ecoregion complex in Colombia territory. Despite this low level of official protection, the Moist Forests remain relatively intact in Colombia and Panama (according to Conservation International) but are under extreme pressure in Ecuador.

Panama has no direct agricultural trade with the UK. UK imports from Ecuador are insignificant, but it is noteworthy that Ecuador is a major exporter of bananas worldwide so is indirectly affected by UK consumption via global commodity markets. Colombia and Ecuador export bananas and palm oil in significant quantities, and these crops are grown predominantly in the Moist Forest ecoregion complex. Coffee is a major export product but largely produced at higher elevations between 900 and 2000 m (Vera, 2006b).

The clearance of forestland making way for agricultural expansion in Colombia and Ecuador amounts to about 245,000 ha per year, or 0.1 and 1.7% of the remaining forest areas of Colombia and Ecuador respectively.

Oil palm is the main Colombian export to the UK. It is widely distributed outside the Amazon biome in lowland Colombia, so the Moist Forest ecoregion complex is used for its production. However, it remains a relatively minor land user across Colombia extending to 210,000 ha in 2003 (Fedepalma statistics). This is about 0.2% of the Colombian territory. Colombia exported a total of 260,000 tonnes of palm oil products in 2005, 40% of this was exported to the UK accounting for about 14% of UK supplies.

About 8 million ha of Ecuador's 28 million ha land area is in the coastal Pacific zone (Wunder, 2000), covering Ecuador's part of the Moist Forest ecoregion complex. 3.3 million ha forest remained in 1999 reflecting the clearance of the area for agriculture, especially oil palm and bananas. Deforestation rates at 1.7% across Ecuador between 2000 and 2005 are amongst the highest in the world indicating that the ecoregion complex is especially threatened here. The links to the UK food economy are indirect, largely through the global trade in bananas.

4.5 THE PANTANAL

The Pantanal wetland biome is an immense inland delta on the Paraguay River which floods in the wet season. It comprises up to about 200,000 sq km during the wet season which is one third of the Upper Paraguay River Basin, the other two-thirds being 'Planalto' or highlands in Paraguay, Bolivia and Brazil. 60% of the 600,000 sq km Pantanal basin is in Brazil. The lowland flood plain of the basin is extremely flat sloping as little as 1 cm per km from north to south. It accounts for about 3% of the world's wetlands.

The Pantanal flood plain is not densely populated and agriculture is constrained by seasonal flooding. There are about 8 million cattle in the Pantanal on about 2500 holdings, making it a substantial producer of beef. Traditional cattle ranching has played a long standing role in the development and maintenance of the landscape in the basin with cattle occupying elevated land in the wet season. So the impact of farming in the Pantanal itself is reported to be minimal and the Pantanal flood plain and waters remain in relatively good condition.

Figure 16: A map location of the Pantanal wetland biome as delineated by WWF

However, agricultural development in the elevated lands of the wider basin has increased dramatically since the 1970s, particularly in Brazil. By 2005, 45% of the vegetation in the basin had altered, including 17% subject to deforestation (Conservation International, 2006). Large areas of Cerrado vegetation in the basin have been cleared for agriculture. This has resulted in extensive sedimentation build-up in the waterways of the lowland areas. In addition, the liming of soil has increased the pH level of several important Pantanal waterways, and extensive phosphorus fertilisation of soils is expected to have increased nutrient loads in water and sediments.

The United Nations University Institute for Advanced Studies (UNU-IAS, 2004) emphasises the ecological and parallel policy inter-linkages affecting the Pantanal. The Pantanal is directly and profoundly affected by land-use in the basin around it, which in turn is affected by markets for agricultural products and land outside the basin, particularly in the wider Cerrado. The expansion of agriculture in the basin around the Pantanal flood plain is affecting both water quality and the pattern of flooding within it. Low and high water levels have become more pronounced which is circumstantial evidence that deforestation in the wider basis is altering hydrology as described for the Cerrado.

Direct links between UK consumption and the Pantanal are limited – the main link is that mediated by the wider Brazilian Cerrado in relation to Brazil's role in the delivery of food commodities imported by the UK, particularly beef and soy. Recent developments add biofuel from sugar cane to the list of commodities affecting agricultural development in the basin.

To a large extent, the threats to the Pantanal linked to UK consumers spill over from the Cerrado. Despite the indirect nature of links with European consumers, initiatives to enable consumers recognise sustainable production are emerging from the Pantanal region. Conservation International reports a programme to certify organic beef produced on 160,000 ha in the Pantanal.

4.6 THE FYNBOS

The Fynbos (meaning fine bush) Biome of South Africa is the richest Mediterranean plant community in the world. The biome covers 7.8 million ha. In addition to the Fynbos biome vegetation, the Cape region as a whole includes Forest, Nama Karoo, Succulent Karoo and

Thicket Biomes. The Cape Floral Kingdom of which the Fynbos biome is key compares with some of the richest floras worldwide.

Within the Fynbos biome, there are two main subdivisions - Fynbos and Renosterveld. While the Fynbos is richer in plant species, the soils are poorer than those of the Renosterveld. The Renosterveld is typified by fine-grained fertile soils that are now used for agriculture, particularly cereal crops such wheat.

The high fertility of the Renosterveld has led to the widespread conversion to agriculture. Less than 5% of West Coast Renosterveld remains. Agricultural expansion has reduced lowland habitats such as the Sandplain Fynbos and Coast Renosterveld by 83 percent and 48 percent of their original extent, respectively. Much of what remains exists in isolated fragments in a landscape dominated by agriculture.

The biome's link with the UK food economy is through fruit, much exported as wine. The Western Cape region is responsible for 90% of South African wine production, ca 100,000 ha. About 40% of South Africa wine exports go to the UK. So the UK wine market is the major driver behind the expansion of wine growing in the Cape region.

Conservationists and wine producers are working together to integrate biodiversity protection into agriculture. The Biodiversity and Wine Initiative was formed by the South African wine industry and Western Cape and international conservation bodies. It aims to prevent the destruction of the province's threatened lowland Fynbos and Renosterveld by the proliferation of vineyards in ecologically sensitive areas. Biodiversity guidelines have been incorporated into the industry's Integrated Production of Wine guidelines. Wines produced by environmentally sensitive estates are also increasingly attractive in foreign markets which give wine producers a financial incentive to run environmentally sensitive businesses. LEAF UK certifies the environmental performance of South African farms in collaboration with WWF-UK.

4.7 THE MEDITERRANEAN BASIN

4.7.1 The Mediterranean basin, rivers and forests.

The Mediterranean Basin comprising the land draining into the Mediterranean Sea has an area of 2 million sq km, of which only about 100,000 sq km remains undisturbed. It includes 22 ecoregions and some of the most intensively farmed land in the world such as the Rhone valley in France, the valley of the River Po in Italy, and the Nile Valley that supplies vegetables to the UK. It includes much of the Spanish fruit and vegetable production areas, and the Middle East, including Israel. The UK is a major and growing consumer of the relevant crops – vegetables, fruit, wine and olives.

Water is the key constraint to production, and the most striking feature of Mediterranean agriculture is the relationship between output value and irrigation. Water demand in the Mediterranean countries doubled between 1950 and 2000, and irrigated agriculture accounts for 65% of water consumed (Nostrum 2006). The irrigated area doubled between 1960 and 2000 to 20.5 million ha with the biggest increases in absolute terms in Spain and Turkey. The food exporters to the UK are Spain, Italy, Greece and Turkey. Morocco is in more recent years the focus of significant investment in intensive agricultural production, including for the UK market. This has caused extensive and irreversible environmental degradation.

Spain exemplifies the consequences of expansion of Mediterranean agriculture most. Spain is a world leader in the export of fresh horticultural produce and together with France and Germany, the UK is one of Spain's largest market for many products, for example strawberries and tomatoes. To service north European demand, Spain has invested heavily in all aspects of water exploitation: dams, boreholes, irrigation infrastructure, and desalination. Spain has the largest desalination capacity in the world (Dickie, 2007) and about 22% of the desalinated water is used for agriculture, for example for horticulture in Almeria. Irrigated intensive agriculture is frequently associated with practices that remove vegetation cover leading to soil erosion. There has been widespread conversion of extensive farming with high landscape and biodiversity value to intensive olive and fruit plantations.

Consumer oriented debate about water use in the Mediterranean is usually focused on the well known irrigated crops – soft fruit and vegetables. These crops drove the expansion of irrigation in the 1980s. Less well known is the increase in the use of irrigation to support what was previously the domain of dryland agriculture, particularly olives, with serious consequences for the environment (Beaufoy, 2001). Crops such as wheat, maize and sugar beet also draw on significant quantities of irrigation water in the Mediterranean, for example in the Ebro Basin. Wheat is responsible for nearly a third of irrigation in Turkey.

The Mediterranean Basin provides a particularly complex challenge to the development of consumer oriented food policy. The following points are relevant:

1. The Mediterranean Basin has been used for agriculture for thousands of years and even with recent intensification, agriculture occupies less land in Mediterranean countries than in most north European countries. Therefore, land occupation *per se* and land use change is not the major concern.

2. The causes of the major impacts on the environment, particularly irrigation, are driven by a mix of market and institutional forces. Consumer demand is clearly behind the increases in the production of fresh fruit and vegetables. However, EU policy is, or at least has been, a factor behind the production of olives and tomatoes. CAP reform has increase the influence of consumption as a driver behind production opening up opportunities for consumers to exert more influence. In broad terms, this is a consequence of the decoupling of support from production and the partial nationalisation of support through national commodity ‘envelopes’.

3. Quite a significant proportion of the irrigated crop area is accounted for by crops not special to the Mediterranean such as wheat and maize. It is suggested here that trade liberalisation and water pricing would result in market forces that reduce these water demands.

4. Supply chains to the UK are vertically integrated and some are owned by UK based businesses. This gives UK consumers influence over production practices. This influence operates at different levels: from market signals affecting individual producers through to signals influencing national policies on how national payments support growers, for example the olive support regime.

5. Imports to the UK from the Mediterranean are dominated by fruit and vegetables, components of a healthy diet low in animal products. Debate about environmental burdens arising from such consumption needs to consider that these products come from a relatively small land area and they support diets that are generally low impact for the environment.

6. Production efficiency can be improved. The literature refers frequently to possibilities to increase water and fertiliser use efficiency.

7. Many health and nutritional characteristics of Mediterranean products are also provided by other products, for example rapeseed oil as an alternative to olive oil.

4.7.2 The Mediterranean Sea.

The European Environment Agency and the UNEP have twice reported on the condition of the Mediterranean Sea in the last decade (UNEP/EEA 1999 and UNEP/EEA 2006). In summary, despite the extent of intensive agriculture in these river basins, the Mediterranean Sea remains relatively unaffected by environmental burdens arising from agriculture. In general terms, Mediterranean agriculture serving UK consumers is not a major cause of environmental degradation of the Mediterranean Sea.

The major burden arising from agriculture is nutrients – nitrogen and phosphorus. In contrast to the Atlantic Ocean, phosphorus (not nitrogen) is the limiting nutrient. The Mediterranean Sea receives a significant input of phosphorus but this is largely from none agricultural sources. The Mediterranean Sea is generally unaffected by eutrophication because the sea is very low in nutrients compared with the Atlantic and thus these emissions have generally little impact. Soil erosion also results in burden, often related to phosphorus emissions from soil.

Even though these burdens are small compared with non-agricultural sources, they can contribute to some significant local enrichment and impacts. In this context, it is noteworthy that high soil and phosphorus losses relative to cultivated and drainage area are reported for Italy, Greece and Turkey. Loses from France and Israel are relatively low.

Aquaculture has grown in the Mediterranean. This includes shellfish, tuna and sea bass. Sea bass production is particularly relevant to the UK consumer as the UK is becoming a significant importer of sea bass farmed in the Mediterranean. Sea bass are raised in cages that have local environmental impacts and can affect local ecosystems. Overall though, and despite the lack of strong tidal currents, impacts are highly localised and reversible (Karakassis, I., Institute of Marine Biology of Crete, Greece).

4.8 BORNEO AND SUMATRA

Much of WWF's work considers the islands of Borneo and Sumatra together and so they are treated as one Priority Place in this report. They are also closely linked from a UK consumption viewpoint. Sumatra and more than half of Borneo is in Indonesia. The northern part of Borneo comprises the State of Brunei and part of Malaysia.

The island of Borneo and Sumatra comprise 0.74 and 0.47 million sq km respectively (a total of 121 million ha). They represent about 54% of the land areas of Indonesia and Malaysia. They are frontiers of a rapidly growing agriculture and plantation cropping sector. Land use change leading to cash cropping is particularly strong in Indonesia.

Indonesia and Malaysia are linked to the UK food economy principally through palm oil, coffee and black pepper. Indonesia also produces other spices such as clove and cinnamon, and these crops are reported as contributing to the degradation of important sites on Sumatra (WWF, 2007). Both islands have been subject to very rapid deforestation, currently amongst the highest in the world.

Figure 17: WWF's Priority Place areas on Borneo and Sumatra (from WWF Indonesia website)

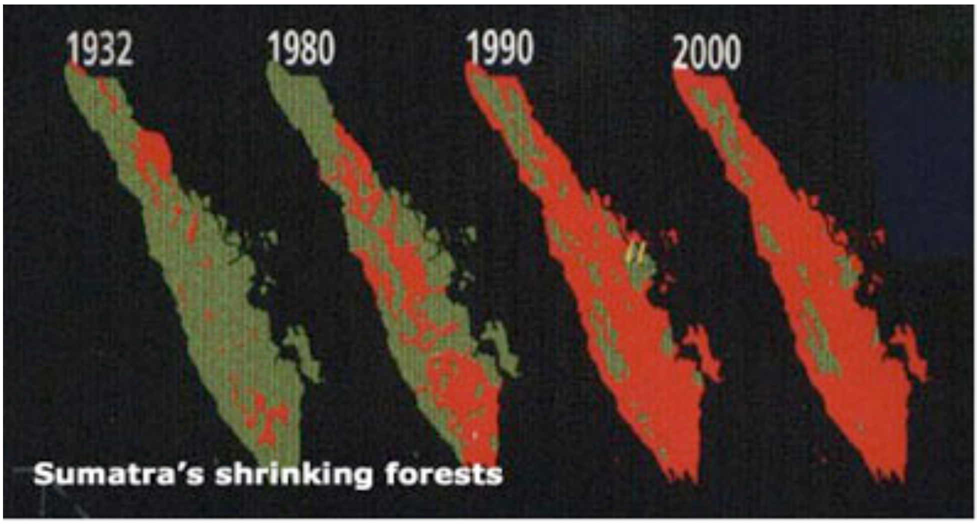

Figure 18: Changes in forest cover since 1932 in Sumatra (WWF Indonesia)

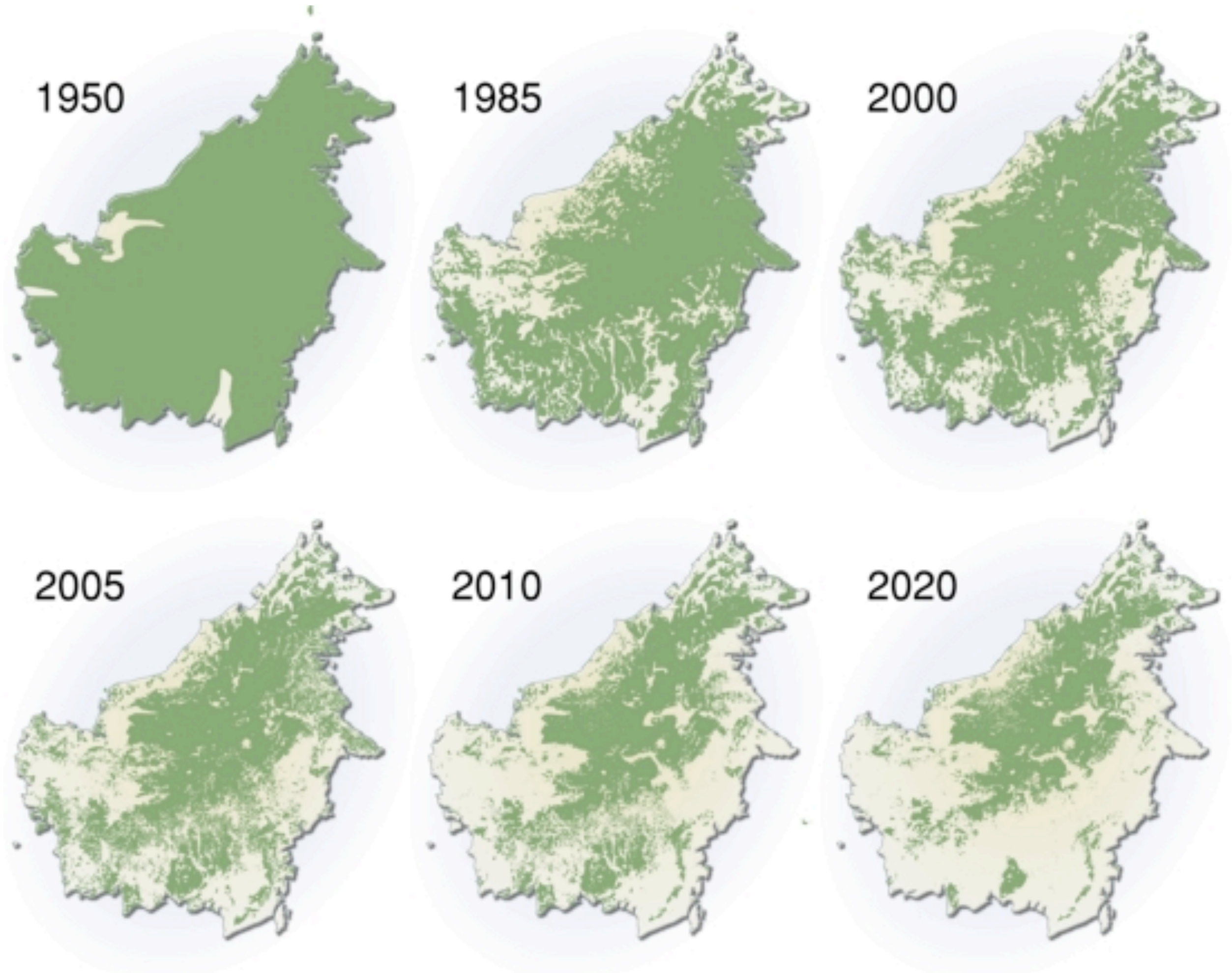

Figure 19: Changes in forest cover in Borneo since 1950 with predictions to 2020. Source: Hugo Ahlenius, UNEP/GRID-Arendal

4.8.1. Coffee

Indonesia accounts for about 17% of coffee (ca 20,000 tonnes) consumed in the UK. About 70% of this is produced in Sumatra. Assuming a yield of 1 t ha (WWF, 2007), this accounts for 20,000 ha of coffee plantations in Indonesia. Indonesia exports nearly 0.5 million tonnes of coffee each year, so UK consumption accounts for about 4% of the export crop. FAO statistics report that 1.4 million ha of coffee were harvested in Indonesia in 2004. WWF has reported that coffee production is a significant driver behind forest degradation in Indonesia, particularly Sumatra.

4.8.2. Palm oil

Indonesia, Malaysia, Columbia and Papua New Guinea are central to the international palm oil trade and oil palm is the dominant agricultural crop in South-east Asia. Malaysia was the biggest producer in 2004 with 13 million tonnes from about 4 million ha and Indonesia produced 10 million tonnes (Malaysian Palm Oil Association). Indonesian production in particular has growing rapidly over the last decade and Indonesian plantations now stand at 7.3 million ha, producing 18 million tonnes of palm oil (USDA, 2007). So Indonesia has just over-taken Malaysia as the world's top producer and exporter. Oil palm accounted for 12% of Malaysian land cover in 2004, i.e. 24% of land not covered by native forest. About half of Indonesia is not covered by native forest (100 million ha) 7% of which is now occupied by oil palm. There is a total of 2.5 million ha of oil palm on Borneo (3.4% of Borneo) and 4 million ha on Sumatra (8.5% of Sumatra). Borneo in particular offers scope for expansion of the crop. The Indonesian Government plans to expand oil palm plantations to about 25 million ha by 2020, representing a ten-fold increase in 25 years. Both islands, particularly Borneo, would be affected. The social costs of this plantation expansion are huge (Serge, 2008).

Market developments over the last decade indicate that investment in plantations has until now been sensitive to demand and price in food markets. However, the industry is now focused on the potentially huge market for biodiesel and sees biodiesel as essential to growth. Expansion in Indonesia in particular is focused on biodiesel, but other suppliers, including Columbia, are investing in biodiesel manufacturing facilities. The current world price of palm oil at about $1,100 per tonne (June 2008) equates to about $1 per litre for diesel. A mineral oil price of about $140 dollars per barrel is equal to $0.9 per litre suggesting that the price of palm oil is linked to the price of crude oil as suggested by Lewis (2008). Consideration of the impacts of UK biofuel consumption and policy is outside the scope of this report, but it is noted that if current trends continue, growth will be driven by biofuels. This has major implications for the role of food markets in influencing the fate of the rainforests of south-east Asia.

The following features of land use and agriculture in Borneo and Sumatra are relevant to consideration of the role of UK consumers in habitat protection:

1. UK palm oil consumption for food accounts for only 0.9% of current production in Malaysia and Indonesia. The UK food sector is characterised by vertical integration and concentration at the retail and manufactured levels. Retailers and manufacturers are sophisticated in relation to supply chains. This gives consumers some influence in the development of certification schemes and in the governance of supply chains. The UK is in a strong position to lead the way in developing the environmental and social certification of palm oil building on the work of the Roundtable on Sustainable Palm Oil.

2. Compared with other European countries and the US, the UK has been relatively cautious in the support of transport biofuels such as biodiesel, and has consistently sought to align public financial support to environmental benefits. NGO interactions with consumers could acknowledge and encourage endorsement of this policy position.

3. Palm oil is now comparable in price with mineral oil. Even if the EU and even the US were to block the use of palm oil in their biofuels, palm oil is competitive with mineral oil in wider fuel markets. In other words, as long as world crude oil prices remain high, the palm oil industry in Indonesia and Malaysia may not need access to markets in the EU created by blending mandates (e.g. the Renewable Transport Fuel Obligation (RTFO)) to justify further expansion.

4. There is a lack of clear data on land use and land use change in Indonesia and Malaysia. Despite all that has been written about the link between deforestation and oil palm plantation expansion, much of the evidence is unclear with respect to what drives deforestation at the point of conversion. This lack of evidence seems to have hindered the development of the Roundtable for Sustainable Palm Oil (RSPO). Land use data indicates that palm oil plantations still occupy no more than about 10% of land not forested in Indonesia and Malaysia in 2005 (FAOSTAT, 2007). The expansion of oil palm is reflected in an increase in permanent crops of 7 million ha across Indonesia and Malaysia against a background of 112 million ha of un-forested land. FAO data on land use in Malaysia and Indonesia fail to account for more than half of the land not forested. These data gaps undermine the arguments that oil palm is necessarily driving deforestation on a wide scale.

5. In Indonesia in particular, there are real issues about governance, law enforcement, and land use policy. Chomitz (2007) identifies how elites gain advantage at the expense of the wider community. In other words, the regulation of land use change is undermined by corruption and even by the use of violence in suppressing local opposition. The literature points to high social costs.

6. Linked to corrupt practices, mechanisms to recognise the social, environmental and economic value of standing forests are virtually non-existent in Indonesia. Companies can gain legal control over forested land or are at least allowed to log without paying a price that reflects the utility of that land as forest for its current (traditional) users.
7. The literature indicates that logging is the major driver behind degradation of the forest in the first instance. However, with an oil product value of more than $1,000 per tonne, the net present value of land under oil palm is high. Therefore, it is concluded that the palm oil market alone could drive the clearance of forest. Linked to this is the potential social benefit of this type of land use, particularly in densely populated areas. Palm oil production is revenue and labour intensive, providing the economic foundation for combating poverty if development is just.
8. The land use situation in Borneo and Sumatra is particularly worrying. Unless there is a radical change in policy and law enforcement, the current expansion plans have the potential to drive wide-scale deforestation, fragmenting the remaining forest to the point where its biodiversity value is seriously compromised. With the development of biodiesel, the scope for food consumers, especially UK food consumers, to directly influence land use change in Malaysia and especially Indonesia is limited. The role of the UK supply chain is thus one of providing an example to the wider international business and political community.

4.9 NEW GUINEA FOREST

The island of New Guinea is dominated by 50 million ha of rainforest. Even though it is one of the most intact large scale rainforest areas of the world, deforestation rates are high at around 1% per year. Subsistence agriculture supports a very large proportion of the population, and about half the cleared land is converted to agriculture. WWF indicates that the forest is at risk from widespread deforestation.

Production statistics are scarce and older than those of most other countries. Subsistence agriculture is combined with cash cropping. Agricultural exports from Papua New Guinea in 2000 comprised 331,000 tonnes palm oil, 65,000 tonnes coffee, 37,000 tonnes cocoa, 66,000 tonnes copra, 48,000 tonnes copra oil and 8,000 tonnes tea. The link with the UK food economy is through palm oil.

The UK imported 161,000 tonnes of palm oil from Papua New Guinea in 2005, making it a very significant consumer. Palm oil from Papua New Guinea accounted for 24% of UK supplies in 2005. The UK has thus been a major driver behind the development of the palm oil industry on the island.

Koczberski, Curry and Gibson (2001) describe the palm oil industry in Papua New Guinea. At least until 2001, the industry was characterised by small-holder involvement. Small-holders supply mills operated by nucleus estate companies. More recently, external investment, some raised on the London Stock Exchange, is focused on the island driven by the emerging biodiesel market.

4.10 NEW NORTHERN GREAT PLAINS

Northern Great Plains covers 72 million hectares of North America that originally was dominated by grassland. It is now dominated by agriculture and only 1.5% of the area is protected. Despite having been subject to widespread conversion to the staples of American agriculture – wheat, maize and soy – conversion (‘sod-busting’) of remaining original grassland continues.

The link with UK consumers is indirect. The Great Plains of North America comprise one of the bread baskets of the world. The ecoregion is now under renewed pressure from the rising world market prices for agricultural commodities, especially wheat, maize and soy. In some respects, the Plains agriculture mediates between the market for food and biofuels and transmits the impact of the boom in bioethanol onto world markets for cereals.

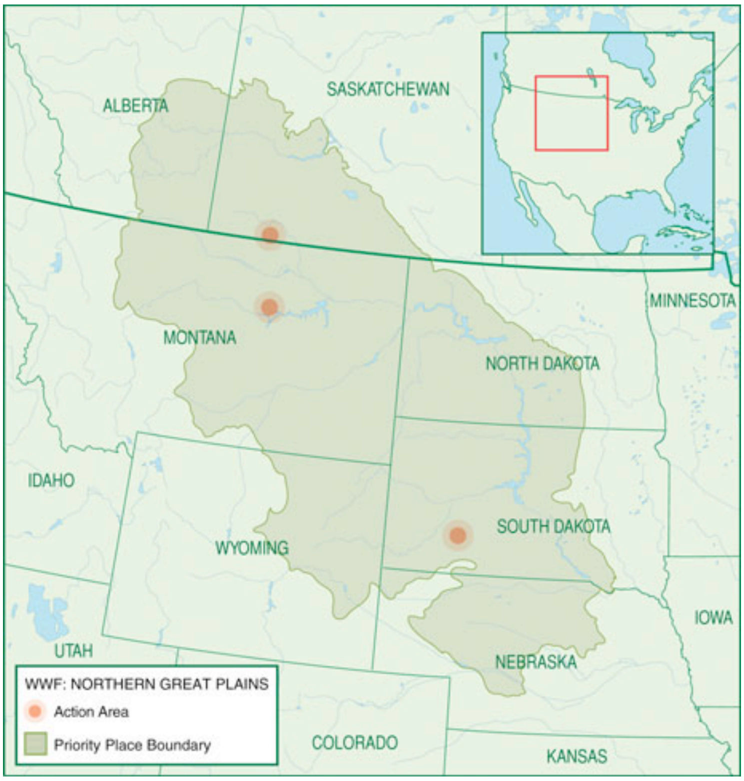

Figure 20: The Northern Great Plains as mapped by WWF

4.11 THE NORTH-EAST ATLANTIC AND IMPACTS OF FISH CONSUMPTION

4.11.1. UK fish consumption and the condition of the north-east Atlantic Shelf

WWF-Germany provides a comprehensive account of this ecoregion and pressures on it (WWF 2004), the summary of which is presented here. The north-east Atlantic Shelf ecoregion covers a sea area of about 1.38 million sq km (Figure 21). It is one of the most diverse marine regions in the world, with a wide variety of coastal and offshore habitats and ecosystems. The influence of nutrient-rich North Atlantic water coupled with the naturally high productivity of the continental shelf sustains a rich biodiversity of marine plants and animals. Primary production from phytoplankton, seaweeds, etc, is substantial. In the ecoregion's natural state, these crops of plants support large stocks of zooplankton, pelagic and demersal roundfish, flatfish, benthic animals such as shellfish, seabirds and shorebirds, and seals and whales. This productivity makes the ecoregion one of the world's great fishery resources. These resources have had a great influence on UK consumers' preferences for seafood – for the most part species native to the north-east Atlantic are what most UK consumers prefer as seafood.

The commercial fisheries currently land about 4 million tonnes of fish and shellfish annually. All are intensively exploited and the majority of the fish stocks used for human consumption are overexploited. Many human activities in the region, on land and at sea, pose serious threats and result in substantial impacts on biodiversity.

Public awareness of the impact of the UK food economy on the north-east Atlantic is probably deeply affected by what Daniel Pauly termed 'shifting baselines' (Pauly 1994). There is nobody alive today with experience of north-east Atlantic fisheries close to their natural state. In these circumstances, the term 'shifting baselines' is particularly appropriate. It refers to a loss of perception of change that occurs when each generation redefines what is 'natural'. This extends to fisheries scientists failing to identify the correct 'baseline' population size (e.g. how abundant a fish species population was *before* human exploitation). Areas that once swarmed with a particular species hundreds of years ago may have experienced long-term decline, but just previous decades are considered the appropriate reference point for current populations. In this way large declines in ecosystems or species over long periods of time go unnoticed.

The impact of the UK food economy on the north-east Atlantic Shelf is both direct and indirect. The direct impacts arise from fishing based in the UK and in nearby countries to supply fish and fish products to the UK. Indirect impacts range from the effects of nutrients derived from agriculture on water quality through to climate change which is causing a shift in populations towards those adapted to warmer waters. Statistics on the role of the UK in consuming the 4-million-tonne fish harvest of the ecoregion are not available but the various data on production, imports and exports suggests that the UK alone accounts for the consumption of about one third of the north-east Atlantic fish harvest. Icelandic waters are outside the ecoregion but fishing there affects migratory species across the North Atlantic. So it is noteworthy that the UK is Iceland's biggest export market. Increases in some classes of production, particularly the harvest of smaller pelagic fish for industrial purposes has occurred, and some of this increase is linked to the reductions in predation by larger piscivorous fish (e.g. cod).

A hidden aspect of fishing is the physical damage to the seabed and structures important to marine habitats. This is particularly relevant to the UK food economy which is characterised by a preference for demersal fish (e.g. cod and plaice). Fishing for such species usually involves bottom trawling. Bottom trawling expanded in the late 19th century with the introduction of steam power to the fishing fleet. Most areas of the North Sea seabed were trawled regularly by 1890, many areas more than once a year (Roberts and Mason, 2008). Undisturbed by bottom trawling, the North Sea seabed supported a far greater biomass of invertebrates than it does now. These creatures depended on and contributed to complex physical structures built up over centuries which trawling destroyed and reduced to mobile sand and mud. The extent of trawling is now such that there are virtually no untrawled areas in the North Sea left. Left undisturbed, this seabed would recover most of its ecosystem functionality in a decade.

There are indirect impacts from the UK food economy. The ecoregion basin includes a large proportion of Europe's agricultural land and thus the main destination of much of European agriculture's emissions of nutrients to water. While phosphorus is the limiting nutrient in freshwaters and drives eutrophication of rivers and lakes, nitrate is limiting in marine environments. Nitrate emissions to water impact particularly on shallow marine ecosystems. For example, run-off from agriculture accounts for half of total inputs of nutrients to the Baltic Sea (WWF Baltic Sea Scorecard). The UK food economy is linked to these emissions. About 95% of the UK's meat and dairy supplies comes from the north-east Atlantic basin and this production is associated with phosphorus and nitrogen enrichment of marine waters, particularly in the Baltic and North Sea.

The Atlantic salmon deserves special mention. It is one of the 42 WWF priority species or taxa and this ecoregion represents a major proportion of its North Atlantic habitat and is the marine home to most salmon migrating European rivers. The Atlantic salmon is in serious decline and in danger of extinction in the wild. The UK food economy has multiple impacts on the salmon's complex life-cycle. Fishing for salmon at sea is now widely banned since the Irish government closed the last drift-net fisheries in 2006 (*Irish Times*, 2006). However, it is believed that young salmon are caught as by-catch in the very extensive pelagic fisheries of the North Atlantic – many ironically supporting fishmeal production for salmon aquaculture (European Angler Alliance, 2003). Industrial fishing also draws on the wild salmon's food base. The salmon is very sensitive to water pollution. Diffuse pollution from agriculture throughout Europe is a major barrier to the recovery of salmon rivers. In particular, as the chemical and biological quality of rivers improves, particle ('silt') run-off from farmed land becomes an increasingly important constraint on the salmon. Siltation of gravel beds is detrimental to the survival of salmon eggs and fry. Because of the biology of the salmon, where fish return to their river of origin to mate and spawn, each river system has a unique population. This means that the species is susceptible to genetic disruption from fish escaping from farms.

4.11.2. UK fish consumption and global fish stocks

The north-east Atlantic is over-exploited with respect to most popular food species. In addition, species that are currently relatively plentiful have suffered crashes and local extinctions in the past. Reflecting this, UK seafood production is declining and imports are increasing. This pattern is reflected across the EU, with EU fish production declining and imports from other countries increasing. The raises the question of the knock-on effects of UK and EU consumption for world fisheries.

There is great uncertainty in data about the production and consumption of fish worldwide. However, it is clear that production has grown greatly since 1950. FAO statistics indicate that per capita consumption has risen seven-fold since 1950, with particularly large increases for the US, India and China. Watson and Pauly (2001) drew attention to uncertainties in FAO production data and they conclude that world catch fishery production has declined since the 1980s at a rate of about 360,000 tonnes per year due to stock depletion. This leads to the conclusion that if present fishing pressures continue, many of the world's commercial fisheries will be wiped out within two to three decades. Already about 75% of fisheries are fished either at or above capacity or are in some other way over-exploited. This mean that there is little scope for expanding catch fishery output and that conservation of stock and a reduction in fishing pressure is part of a strategy to increase fishery output in the longer term.

As exemplified by the loss of the cod fishery off the east coast of North America, the loss of fisheries causes the loss of thousands of jobs. Social justice is particularly compromised in fisheries through the 'arms-race' nature of fisheries technologies. Stock decline is caused by efficient fishing technologies. The largest fishers arm themselves further to chase the remnants of the stocks they have already depleted while smaller operators using more sustainable practices are over-proportionally affected by stock depletion. The loss of piscivorous fish such as cod also leads fishers to hunt further down the food chain turning to newly discovered resources such as blue whiting for industrial fishmeal production, for example. This sets up a vicious cycle which alters and simplifies ecosystem structure, reducing biodiversity. Industrial fishing removes large quantities of plankton-eating pelagic fish and by-catch of other species such as salmon and cod to support aquaculture which in turn is making up for the loss of wild fisheries. The excessive harvesting of pelagic biomass such as blue whiting for aquaculture extends the impact of fisheries down the marine food chain putting pressure on the food resources of the remaining piscivorous fish.

At present, more than 41 million people worldwide are directly engaged in fishing or aquaculture (FAO 2006). Fishing and aquaculture support a global fish intake equal to 14kg per capita (excluding China). So there are also implications for global food security. Fish provide 16% of the animal protein consumed by people worldwide. In many developing countries, the percentage is higher. In Asia, for example, fish represent 26% of the continent's animal protein intake. In addition to quantity, marine fish in particular are a very good source of essential fatty acids.

4.11.3. Fishing and greenhouse gas emissions

In contrast to most forms of agricultural production, fishing is an energy-intensive activity and CO_2 is the main greenhouse gas emission arising. Tyedmers, Watson and Pauly (2005) estimate that, on average, fishing consumes 620 litres of diesel per tonne of marine fish caught.

This equates to about 1.8 tonnes of CO_2 per tonne of fish caught. This fuel use amounts to 1.2% of mineral oil use in the world. Despite the high energy inputs, the resulting greenhouse gas emissions are low compared with meats from agriculture.

Behind this average fuel consumption lies a huge range of fuel intensities ranging from about 20 litres per tonne for the most efficient small pelagic fisheries (e.g. anchovy) to over 3,000 litres per tonne for invertebrates. Demersal fisheries are also energy-intensive due to the power required for bottom trawling and the low yields from depleted stocks. A key feature of fishing is the increase in fuel use as stocks decline. Energy consumption increases as boats range further to hunt down depleted stocks. In most natural hunter–prey systems, the increased cost of predation reduces the intensity of predation allowing prey stocks to recover. In fisheries, however, stock depletion leads to higher fish prices, propped up by consumer preferences (e.g. for cod) sending a signal to hunters (i.e. fishers) to intensify hunting further. The overall effect of this is increased investment by fishers in power and fuel as stocks decline. The other side of this phenomenon is the expected benefits of the recovery of depleted stocks. The recovery of depleted stocks represents a rebuilding of the capital base of the system, the sustainable fish yield of which represents the interest earned. A reduction in fishing will allow stocks to recover to the point where a much reduced fishing effort will be sufficient to harvest the sustainable catch, thus generating multiple benefits. This reduced effort may comprise more operations with wider multifunctional social benefits such as inshore fishing.

Tyedmers (2008) reviewed a wide range of life-cycle studies and concluded that like meat production, primary production (fishing) is the main source of emissions in the fish production chain. Although transport distances can be very long with for example fish being transported to the Far-east for hand filleting or hand shelling, modern transport in container ships carrying up to 14,000 containers is very energy efficient.

4.11.4. UK fish consumption and fishery policy

UK fish consumption is modest by European and US standards, but is about 50% higher than the global average excluding China. The UK Food Standards Agency says Britons do not eat enough fish and advises two 140g portions of fish per week which with current processing yields equates to an average per capita consumption of up to about 40kg per year.

There seems to be a reluctance to examine the current dietary advice in the light of current sustainable development challenges with causal links in mind. The current advice seems to reflect the mindset of the post World War II era (protein consumption) and the concerns of the 1970-2000 period around saturated fats. It seems to be a public health approach that bundles direct and indirect effects to give a public health benefit. It is not determined by causal links. As a result it combines benefits associated with what fish bring to the diet (beneficial fatty acids) with benefits arising from what fish displace in typical diets (saturated fat). The result is a policy to encourage consumption perhaps beyond that required to sustain the causal link between the benefits fish (essential fatty acids) and the benefits associated the displacement effect of fish consumption. The latter in particular seems to be the driver behind the recommendation on white fish consumption – precisely the consumption that is doing most damage to our most vulnerable sea fisheries.

There may be scope for reducing the UK food economy’s demands on fishery resources through altering the pattern of fish consumed. UK consumers’ preference is conditioned by a plentiful supply of piscivorous fish from the north-east Atlantic over past centuries. This is manifest in the resilient demand for demersal white fish, salmon and tuna today (about 64% of consumption). In ecological terms, UK consumers are top predators and this has implications for the impact of consumption on marine ecosystems. Moreover, the demand for demersal fish is met largely by bottom trawling in the north-east Atlantic, and the 'top-predator' consumption includes 100,000 tonnes of tuna.

The effect of the UK preference for piscivorous fish is manifest most clearly in the fact 45% of the fish consumed by the UK food economy is used for aquaculture. The ecosystem impact of this industrial fishing is poorly understood. Particularly for sandeel, which is food for a wide range of marine animals including fish for wild fisheries such as cod, it remains unclear if current industrial fishing is having significant ecosystem effects (Huntington et al., 2004). However, there is reasonable consensus that blue whiting stocks are already over-exploited. From ecological principles it is reasonable to speculate that reduced take of industrial fish would benefit the other fisheries. This is particularly relevant given the large quantities of by-catch in most forms of industrial fishing.

The production of one kilo of salmon requires 2-3kg of industrial fish for fishmeal which is included in fish food at a rate of about 45%. Eating plant eating fish would be a more sustainable option – i.e. eating down the food chain. This can be achieved in a number of ways. Consumption could switch from farmed fish to direct consumption of the fish fed to salmon. The Norwegian fishing industry is already looking at harvesting blue whiting for direct human consumption thereby gaining a premium over blue whiting for fishmeal production. Such a shift would enable reductions in salmon production.

The most effective form of 'eating lower down the food chain' would be a switch to omnivorous farmed fish such as tilapia. Tilipia is a herbivorous freshwater fish produced in warmer climates. Inclusion of fishmeal in tilapia diets is less than 1% and the fish has gained a significant market share in some countries, notably the US.

Another approach is to make current farmed species such as salmon more herbivorous, reducing the inclusion of fishmeal and increasing the proportion of cereals, soy and oilseed meal etc in the diet. There are currently constraints to this because of the role of marine algae in delivering essential omega 3 fatty acids to the marine food chains through the pelagic fish in fishmeal. Salmon need these fatty acids. Moreover, a significant part of the value of farmed salmon in the human diet arises from the link with marine algae that the pelagic fishmeal provides. Recent research is seeking to transfer the genes in marine algae responsible for the omega 3 fatty acids in seafood to oilseed crops such as linseed thereby opening up the opportunity of reducing the inclusion of fishmeal (Personal communication, Johnathan Napier at Rothamsted).

There is a good deal of consensus in the literature that providing incentives for sustainable production is likely to more beneficial than product boycotts. Providing incentives for such production has a double effect – the demand for the undesired product is reduced and the demand for alternatives is increased, setting up differentials in markets. WWF and Unilever established the Marine Stewardship Council in 1997 to certify sustainable fisheries and their products. The MSC now certifies 26 fisheries worldwide, ranging from the tiny inshore fishery at Hastings in England to fisheries yielding more than 1 million tonnes per year. Certified fisheries represent about 7% of the global catch, excluding China. The role of MSC-certified fish in branded seafood businesses and even in the provision of seafood by discount retailers such as Lidl is testament to the potential of food product certification more widely.

Product certification has the potential to play a key role complementing conventional fisheries management approaches. It is a direct reward to fishers for sustainable management of fisheries and an ecosystems approach to fishery conservation. The key for consumer-orientated conservation action is that certification can facilitate the switch from the vicious cycle of throwing more fishing capacity, fuel and technology at a declining fish stock to the much less intensive fishing of a larger sustainable stock with the result that the fish yield increases with reduced fishing effort. Certification provides the basis for fishers to participate in the conservation effort harnessing peer-to-peer regulatory forces.

Certification has the merit of complementing conventional regulatory measures, particularly ecosystem approaches to fisheries management. Such measures focus on managing the ecosystem with particular emphasis on trophic interactions. FAO 2002 cites Cortner et al. (1994) in describing an ecosystems approach to fisheries as “a management philosophy which focuses on desired states rather than system outputs and which recognises the need to protect or restore critical ecological components, functions and structures in order to sustain resources in perpetuity”. Product certification is well placed to allow consumers and the fish processing sector to support an ecosystems approach to fisheries management.

Fisheries management in European water remains dominated by conventional management approached focused on fisheries outputs. These include Total Allowable Catches, regulation of fishing capacity and time at sea, etc. Enforcement is complex, with undesirable side effects such as discards of by-catch. In addition to exercising direct influence on fisheries through certification, consumers, retailers and processers can support complementary measures such as the establishment of marine reserves as described for the North Sea by Roberts and Mason (2008). It is also clear that certain technologies enabled the destruction of marine ecosystems. So there is also a case for banning technologies and breaking the vicious cycle and ‘arms-race’ described above. This is not without precedent. Drift netting for salmon is banned, and this ban was introduced with financial compensation for operators. In agriculture, the UK government’s stance on genetically modified herbicide tolerant crops represents a form of technology choice editing based on the expected ecosystem impacts of widespread adoption.

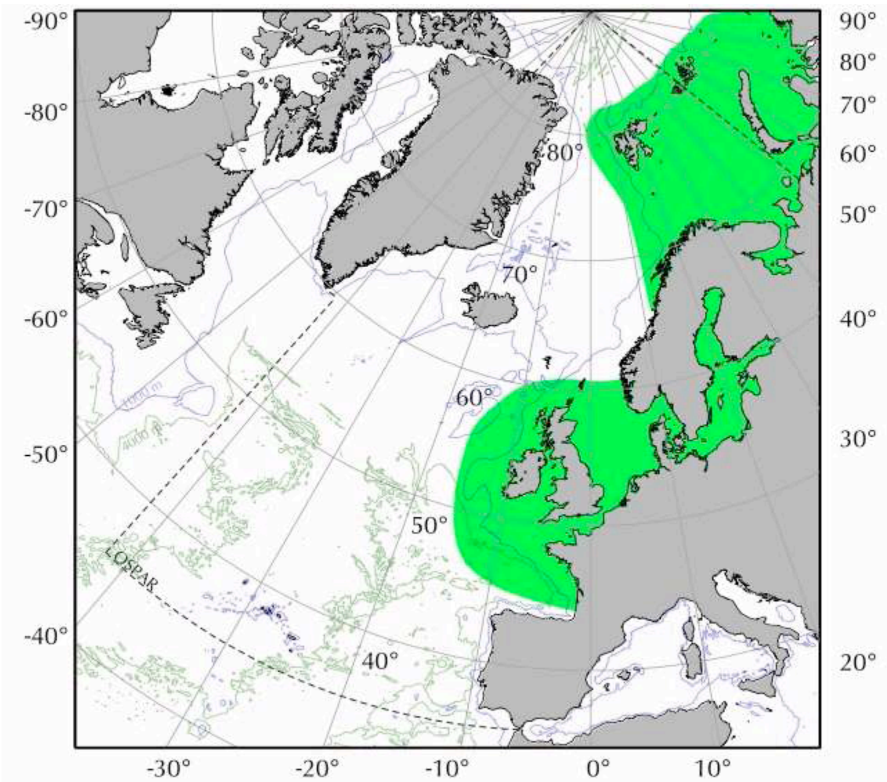

Figure 21: WWF Global 200 Ecoregions in the north-east Atlantic and Barents Sea

5 Discussion and policy conclusions

There has been an explosion in public interest in food matters in the UK, especially in the last year. Food policy is now under the spotlight, prompted by celebrities, input from NGOs, and contributions from public bodies such as Defra. Primary production and some aspects of the distribution and retail supply chain directly related to food, such as refrigeration are the important targets for policy attention. Until recently, public debate in the UK has focused on aspects of food production and distribution to an extent not justified by their impacts on the environment. Debate has sometimes been dominated by 'emblematic' conflicts characterised by focus on the use of certain plant breeding tools such a 'genetic modification' (GM) and issues such as 'food miles', 'local food', 'organic', 'industrial farming' chemical farming' and so on. This has distracted attention away from effective efforts to improve the environmental performance of the food system. Emblematic conflict around these issues has also compromised the development of effective policy and technical progress relating to what really matters to the environment. What really matters is fostering sustainable consumption patterns, increasing the resource use efficiency of food production, improving farmland as a habitat, and reducing land-use change. This report identifies some guiding principles that may help – these principles relate in particular to land-use change and carbon sequestration, the intervention in the nitrogen and hydrological cycles, and effects of diversity in vegetation cover in the landscape.

5.1 THE ENVIRONMENTAL IMPACTS FROM THE PRODUCTION OF FOOD FOR THE UK

Even without allocating any of the emissions from deforestation to the UK food economy, the production, processing, distribution and retailing of food for the UK directly drives a greenhouse gas emission equivalent to 32 million tonnes carbon, an emission equal to 17% of the greenhouse gas emission attributed to the UK. Garnett (2008) estimates that on a life-cycle basis, UK food consumption is responsible for a GHG emission equivalent to 38 million tonnes of carbon, or 17% of the emissions embedded in UK consumption. About half of this environmental burden arises from primary production, ie the growing of the crops and raising animals. These burdens and impacts from primary production are intrinsic to the food economy while those associated with food manufacture, transport and retailing are influenced by the wider economy – how electricity is generated, transport infrastructure etc.

The major burdens are: carbon dioxide emissions from land-use change (e.g. deforestation); nitrous oxide emissions from the nitrogen cycle; methane emissions from livestock and rice production; increased water abstraction from water bodies and altered absorption of water from soils by plants; nitrate, phosphorus and particulate pollution of water; and reduced habitat quality on farmed land. Broadly speaking, the major impacts of these processes are the contribution to global warming, the reduction in habitat arising due to the increase in land occupied by agriculture, the degradation of farmland and aquatic eco-systems as habitat due to intensive cropping, crop protection measures and water pollution, and impacts on aquatic habitats due to reduced water flows and eutrophication from nitrates and phosphates.

Globally, food production is the major driver behind about a third of anthropogenic greenhouse gas emissions. When emissions from deforestation are considered (to which the UK food economy is clearly linked), it can be argued that the role of UK food in greenhouse gas emission from UK consumption is broadly similar in the region of 30%. It's not possible to be more precise than this, but it is certain that the food-chain is a large item on a personal consumption based greenhouse gas account.

Globally, greenhouse gas emissions driven by food production are dominated by the release of carbon dioxide from deforestation (18%), nitrous oxide emissions from the nitrogen cycle in agricultural soils (8%), methane from animals and rice (ca 6%), direct energy use in agriculture (ca 1.5%) and fertiliser manufacture (about 1.2%). In contrast to other sectors, energy use is a relatively minor cause of emissions and has been reducing steadily on a unit output basis since the 1970s. Thus, efforts to mitigate greenhouse gas emissions from the food economy focus on reducing deforestation, reversing the associated depletion of soil carbon, reducing man's impact on the nitrogen cycle, and reducing methane from cattle, sheep and rice production. Although not classified as an 'agricultural' emission, the reduction of deforestation for agriculture is the most important target for the mitigation of greenhouse gas emissions driven by food production.

Man's impact on the nitrogen cycle is second to man's impact on the carbon cycle in terms of the scale of intervention in geochemical cycles and consequences for the global environment. The intensification of the nitrogen cycle is intrinsic to agriculture in all its forms. This starts with both biological (by legumes) and synthetic (fertiliser) nitrogen fixation. This fixation initiates a cascade of transformations, each associated with greenhouse gas emissions to the atmosphere and emissions of ammonia to air and nitrate to water causing eutrophication of ecosystems. Raising the efficiency of nitrogen use in agriculture is central to reducing greenhouse gas emissions from the food production. Even though there has been a decline in UK nitrogen fertiliser consumption, linked to measures to addresses nitrate in water, a strategic approach to reducing intervention in the nitrogen cycles as a whole has not been used. The nitrogen balance of UK agriculture is poorly understood and the effect of reactive nitrogen as a whole is not the focus of policy action. Unlike in some other EU countries, there is little attention paid in UK agriculture to farm level nitrogen balances. The consequences for this at the product level are now becoming evident in life-cycle assessments. For example Dalgaarrd, Halberg and Hermansen (2007) concluded that the environmental profile of Danish pork is better than that of UK produced pork most production technologies are similar. This difference is due to higher nitrogen use efficiency throughout the production cycle driven by nitrogen balancing. The consumption of soy driven by increases in the consumption of livestock products is a particular concern. Danish pigs consume 40% less soy compared with UK pigs as a result of this holistic approach to the nitrogen cycle.

In considering the impact of the UK food economy, the environmental impact of agriculture in the UK and near neighbouring countries is important but often overlooked in debate about imports. There is a trade-off between impacts arising in exporting countries serving the UK and impacts from home-grown production, some of international significance. As the user of about 70% of UK land, agriculture dominates many emissions to water, air and soil in north-western Europe so it would be wrong to assume that home-production is preferable to imports. Some impacts of UK production are overlooked simply because we have grown accustomed to them. River systems and their flows are dominated by drainage going back centuries, wetlands have been removed, soil as a pollutant of water is overlooked, and crop management and protection is a major force on biodiversity through profound effects on food webs.

5.2 UK CONSUMPTION

In terms of the weight of commodity used in the food system, UK food consumption increased by 15% between 1990 and 2005 while UK self-sufficiency in food fell from 70 to 60%. Imports increased by 51% in terms of weight. Global food markets are connected over long distances through trade in key food commodities, for example soy. Waste is a significant factor in the growth of UK commodity consumption. Consensus is emerging that up to 30% of the food grown for the UK food economy ends up in products that are not eaten. The growth in consumption (which includes waste) at the commodity level means the UK food economy is now sending out stronger signals to other countries, drawing on more global resources, adding to environmental burdens in exporting countries, and contributing more to forces driving land use change.

In addition to the increase in the quantity of food commodity drawn on, the pattern of food consumption has changed. The increases are particularly large in poultry, fruit and vegetables. There has been an increase in meat commodity consumption of about 18% due almost entirely to a doubling in the consumption of poultry meat. The pattern of demand over the last 15 years shows that the UK food economy is increasing poultry meat consumption in addition to, rather than instead of, other meats. The increase in pig and poultry consumption has increased the consumption of soy adding to forces driving land-use change, particularly in the Cerrado and indirectly in the Amazon. Life-cycle assessment is effective in evaluating greenhouse gas and other environmental burdens arising from products. Assessments consistently show that beef and lamb give rise to more burdens than pig and poultry meat. However, life-cycle assessments are not always effective in capturing impacts on biodiversity and carbon stocks due to land-use change.

There has also been a shift in consumption from indigenous and in-season fruit and vegetables to fruit and vegetables from other climates. The consumption of Mediterranean fruit, vegetables and olive oil in particular has grown faster than the food economy as a whole. Much of this is due to the increase in fruit juices and wine. The shift in the pattern of consumption is generally speaking, from relatively resource efficient indigenous fruit and vegetables to more diverse and resource demanding products. The increase in olive oil consumption is associated with significant environmental effects as it is facilitated by a switch from extensive rain-fed olive trees to intensive and irrigated plantations.

The UK food economy has a very profound effect on the north-east Atlantic. UK fish consumption is moderate by European standards but still represents 2% of world fisheries production and has significant consequences for sensitive fish stocks and the wider environment. The key consumption issue is UK consumers' preference for demersal whitefish species such as cod native to UK waters but which are now over-exploited. In addition to depleting stocks, bottom trawling of the north-east Atlantic causes huge physical damage to the marine environment. The preference for piscivorous fish such as salmon, cod and tuna means that UK fish consumption is particularly resource demanding or has potentially large impacts on stocks.

Relatively minor changes in consumption can have large marginal effects. The world's food economy is growing and this growth is manifest most in forces acting on the frontiers between farmed and unfarmed land, especially forest and wetland. The large effect at these frontiers of relatively small changes in consumption in importing countries is well illustrated by the example of beef. UK beef consumption was 1,041,000 tonnes in 2005 compared with 1,032,000 tonnes in 1990, and increase of only 0.1%. Due to declining UK production, the import content of UK consumed beef increased from 9 to 26%. Brazilian exports direct to the UK increased 30 fold from 2,000 tonnes to 66,000 tonnes in 2005 according to FAOSTAT data on Brazilian exports. Other statistical sources confirm this growth in Brazilian beef in the UK. Thus, a relatively small change in consumption/production relationships in the UK was associated with a 30 fold increase in imports from Brazil. It is reasonable to conclude that UK consumption drew on about 1% of Brazilian beef production in 2005. This may appear insignificant, however due to the role of exports driving the increase in Brazilian beef output, exports to the UK accounted for about 10% of the expansion of the Brazilian beef herd. A resource swop within Brazil means that expansion is occurring in the Amazon for domestic consumption releasing other beef resources for export. The combination of the export of soy and beef from Brazil is driving a pattern of land use change through Brazil that amplifies the effect of exports on the Amazon rainforest. Brazil is expanding exports through a cascade of resource exchanges within Brazil that ends up drawing largely on land resources in the Amazon. The UK consumer is contributing to the market forces driving this.

UK consumers have increased fruit and vegetable consumption and shifted consumption away from robust in-season produce towards more perishable products, out-of-season produce, citrus fruit, and exotic produce generally. This includes out-of-season produce such as strawberries produced in the UK using new production techniques to extend seasons. Traditional UK vegetables are also resource efficient in terms of energy (Defra 2000). Drawing on the results of Lillywhite et al (2007) it is concluded here that in-season production of traditional UK fruit and vegetable species is relatively eco-efficient. A reversal of the trend away from the in-season consumption of the staples of the British horticultural sector would reduce pressure on resources in the Mediterranean basin in particular, particularly scarce irrigation water.

The distance food has travelled ('food-miles') is not a reliable indicator of environmental burdens of food. Long distant bulk transport by sea and by rail is efficient. Modern logistical operations in the UK are also efficient. As a result, apart from air-freighted food, transport usually has little effect on the life-cycle environmental burdens of imported foods and the difference between home-grown and imported foods depends largely on how the food is produced.

5.3 UK PRODUCTION

The decline in the role of UK agriculture is largely due to global trade liberalisation and competition. Rising imports do not necessarily mean rising environmental impacts. However, the decline in UK production against a background of increasing domestic demand raises questions from a global environmental viewpoint. There are also global social consequences of increasing UK reliance on global markets given the tightening world food supplies. The resulting increasing imports often have over-proportional marginal impacts (as illustrated by beef above) particularly when several globally traded commodities are acting together on land use change (for example beef and soy in the Cerrado of Brazil). However, in considering the effects of imports, it should be remembered that there is an environmental trade-off between production in exporting countries and production in the UK. There is also a social trade-off between drawing on global food resources and supporting export markets in developing agricultural economies.

There may be a case for addressing the decline in UK field crop horticultural production in particular to reverse the trend away from the robust staples of UK field horticulture. The UK horticultural sector is not growing in line with the increase in UK fruit and vegetable consumption. There is a question of cause and effect here (is increasing exports a consequence or a cause of decline), but the end result is greater reliance on more perishable products and on imports of fruit and vegetables into the UK food economy.

From a global resource viewpoint, UK pig and poultry production is part of a wider North-west European pig and poultry industry characterised by dependence on feed from outside Europe. Dietary energy input into livestock production comes largely from maize, barley and wheat produced in Europe. For the protein component, European pig and poultry production is very heavily dependant on South American soy, particularly from the Cerrado of Brazil. Europeans' high level of pig and poultry consumption based on European production sets up a chain of resource exchanges through international trade that drive expansion of agriculture in South America. A kg of UK pigmeat embodies the consumption of about 700 g of soy meal. A kg of poultry meat embodies about 500 g of soy meal. The yield of the meal fraction of soy is about 2 tonne per ha in Brazil. Every tonne of pig and poultry meat (as carcass) consumed in the UK accounts for about one third and one quarter respectively of a hectare over a year in Brazil and Argentina. A systematic approach to reducing nitrogen inputs across the whole UK agricultural system would generate consistent downward pressure on oilseed meal imports (especially soy) and fertiliser use, and encourage the efficient recycling of organic manures. In contrast to the intensive livestock production areas of the Netherlands, Germany and Ireland, the UK farming industry which has a large proportion of pig and poultry production located in crop producing areas well placed to improve the recycling of nutrients. As advocated by Galloway et al. (2007), improving the nitrogen balance of UK agriculture would encourage reductions in soy imports and fertiliser application while maintaining or increasing production through improved recycling of organic nutrients and improved utilisation in crops and animals. This would have benefits in terms of biodiversity, resource protection and pollution.

5.4 WWF'S PRIORITY PLACES AND THE NORTH-EAST ATLANTIC

The UK food economy interacts directly through significant direct trade with the following Priority Places:

- The Atlantic Forest (Brazil, Paraguay and Argentina)
- Borneo
- The Cerrado-Pantanal of Brazil and neighbouring countries
- Choco-Darien (Columbia, Panama and Ecuador)
- Fynbos (South Africa)
- Mediterranean sea, forests and Balkan rivers and streams
- New Guinea and its offshore islands
- Sumatra

These direct interactions are due to imports of beef from Brazil; soy from Brazil; palm oil from Borneo, Sumatra, Colombia (Choco-Darien) and New Guinea; fruit, vegetables and olive oil from the Mediterranean and Brazil; and coffee from Sumatra.

The UK food economy has significant indirect interactions with the following Priority Places:

- The Amazon and Guineas
- The Northern Great Plains

The indirect interactions are due to global trade in beef, soy and cereals, and are very significant in the case of the Amazon. Beef and soy imports from the Cerrado of Brazil have raised the value of Cerrado land causing the production of beef for Brazilian consumption to move northwards to the Amazon. The Northern Great Plains is under threat from a broad range of forces caused by the global increase in cereal and soy prices. The UK has profound impacts on the north-east Atlantic through fishing.

The effect of UK food imports on these Places could be dwarfed by biofuel imports if a significant market for biofuels developed. Biofuels pose significant threats to the Cerrado, the Northern Great Plains, and to all Priority Places where oil palm is grown. The market for biofuels is potentially so large that it is difficult to envisage a significant contribution to transport from biofuels without large effects on land-use change and biodiversity in Priority Places.

5.5 IMPLICATIONS FOR POLICY

5.5.1 Sustainable consumption

Government policy even in the most environmental aware European countries does not go as far as to suggest that consumption in the economy should be reduced. Food production, particularly livestock production, causes emissions and impacts that cannot be avoided. These arise from the natural processes in the soil and in digestion no matter what production system is used. Therefore, in the case of food consumption in the UK, a policy of reducing commodity consumption overall, and shifting the pattern of consumption towards a range of foods with lower impacts, is worthy of serious consideration. Foremost is generating less waste and consuming less meat and milk, and shifting fish consumption away from demersal white fish, tuna and salmon. Given the resource efficiency of UK vegetable production, it is reasonable to expect that restoring the consumption of the staples of UK field based horticulture would be a positive step forward provided areas at risk to water scarcity are avoided.

Some of the waste in the UK food system is a consequence of the interaction between the consumers, UK's multiple retailers and suppliers, and the growth in food services at the expense of home cooking. Supermarkets have a particularly influential role in the UK food economy. They have condition consumers to expect a full range of perfect fresh products available in all supermarkets all the time. Defra research has identified that the constant provision of a full range of fresh produce can only be achieved through significant over-provision and thus waste. There may be scope for significant reductions in waste in fresh produce supply chains if consumers ceased to expect a full range of fresh produce all the time. All consumers, including the food service industry, could better align consumption to availability. This means accepting variation in supply and purchasing fresh food more in response to availability, particularly seasonal availability.

A policy on livestock products has potentially significant social implications. In addition to being the means of 'harvesting' pasture covering 26% of the ice-free land surface, livestock also consume about one third of the cereal harvest (ca 670 million tonnes) and the meal from in excess of 200 million tonnes of soybeans. So the increasing demand for livestock products is the main driver behind the increasing demand for food. Moderating the consumption of livestock products is potentially a cornerstone of any policy on global food prices and food security for the poor. While it is important that the developed economies moderate the consumption of livestock products, the important positive role of livestock in food production and diets world wide must be recognised. The development of the UK poultry sector illustrates how efficient production leads to affordable high quality food raising the living standards of low income households. So social justice means extending benefits of the livestock sector to the poor, and this would be very difficult to achieve if the current level of consumption in developed economies is not reduced. Cattle, sheep and goats 'harvest' pasture, much of it on land not suitable for crop production. They are also a source of income for 1.3 billion people, including 1 billion of the world's poor. The challenge in the developed economies has a complexity which demands more than just a position on vegetarianism. It is about fostering a pattern of consumption and production that harnesses the eco-efficiency of livestock delivering the benefits moderate consumption of livestock bring to most diets to as many people as possible.

Minor changes in consumption of livestock products in Europe can have significant effects on European farm businesses in the short term. We have seen this recently in Europe where a small increase in milk supply combined with a small contraction in demand has led to a significant reduction in farm-gate milk prices in Germany. Similar short term price effects affect pig and poultry producers. However, this may be a short term social price that must be paid and the European livestock industry may need to adapt to public policies that do not endorse high livestock consumption and which may tackle intensive production based on imported feed in particular.

Reducing the consumption of livestock products corresponds to moving lower down the food chain in the ecological sense. This in line with the principle that species located lower down the food chain depend on less primary production and resources. The same principle can be applied to fish consumption. A move away from piscivorous fish such as salmon, cod and tuna towards plankton eating fish and herbivorous farmed fish (e.g. carp and tilapia) would bring environmental benefits. UK consumers in particular should be encouraged to draw on a wider range of seafoods reducing the pressure on over-exploited demersal white fish stocks.

5.5.2. Sustainable production.

The UK food economy is part of a global food economy increasingly relying on emerging agricultural super-powers such as Brazil. To meet demand sustainably, global crop production needs to increase substantially by 2050 without further destruction of natural resources. Without an increase in production efficiency and yields per hectare, expansion in demand will drive further conversion of land to agriculture. This means that supporting knowledge intensive farming, innovation and technical change is central to creating the conditions in which agricultural expansion into valuable wild habitats and intensification in semi-natural habitats can be minimised or halted. As we have seen since 1990 in the UK, a reduction in food production or an increase in consumption will result in increasing reliance on global food markets. This applies to Europe as a whole. Directly or indirectly, increased consumption and/or reduced production in Europe will draw on increased agricultural expansion in emerging agricultural economies. As illustrated by the example of the effects of imports of beef from Brazil, changes in UK demand seem small relative to total supplies but the effects at the margins can be significant. From a global food supply and environmental viewpoint, it is valid to argue that Europe is morally obliged to farm its resilient productive soils well using all the knowledge based approaches available. Associated with the need to promote efficient production in Europe, the reality of emerging agricultural super-powers such as Brazil needs acceptance and these new agricultural regions need support in developing eco-efficient and socially just production practices. Raising the efficiency of agricultural production in areas in South America away from key habitats will reduce pressure on land-use change, especially if accompanied by product certification. This will contribute directly to global food security addressing the social consequences of high food prices. Attention to production efficiency needs to work across all scales of production – from the large scale mechanised production in the Cerrado through to the small holders on the forest edge in the Amazon and in Africa. There is also a case for focusing on the restoration of production capacity in countries such as Russia that have experienced declines in agriculture. Raising eco-efficiency will require full consideration of the benefits of all of the technologies available combined with the development and deployment of these technologies in support of environmentally and socially just productive agriculture. Pitting recognisable or branded farming systems against each other is not a positive contribution. An overarching theme for all systems and scales of production will be the harnessing and enhancement of biological cycles and the conservation of key resources such as soil carbon, reactive nitrogen, phosphorus and water.

In the wake of the realisation of the consequences for the poor of high commodity prices, a consensus has emerged around the world and across various sections of society that raising the productivity of crops and animals world wide is central to reducing environmental impacts, particularly greenhouse gas emissions, associated with agricultural expansion. Increased agricultural productivity reduces, or could reduce, consumption related environmental burdens in a number of ways and is now key to combating greenhouse gas emissions and global poverty:

(a) By opening up opportunities to reduce land-use change (e.g. deforestation).
(b) By increasing the inputs of carbon to soils increasing carbon sequestration from the increased biomass productivity.
(c) By reducing emissions related to livestock numbers, particularly methane.
(d) By opening up opportunities for re-wilding, integration of conservation measures into production, and reforestation of land.
(e) By increasing the efficiency of nitrogen capture by crops and retention in the soil-crop-animal system thus reducing emissions, especially on a unit output basis.

Cattle pasture is the main crop at the frontier between agriculture and forest in Amazonia. There are about 200 million ha of pasture for cattle grazing in Brazil alone, an area more than 10 times that of UK agricultural land. There are uncertainties in production data, but it seems that productivity of pasture used for beef production is one fifth to one tenth that of Western Europe at about 50 kg carcass beef per hectare per year. Brazil can continue to increase agricultural production and exports without deforestation. To be effective in reducing land-use change, policies that increase yields need to be combined with policies that reduce the market value of produce from inappropriately cleared land. Otherwise, as we have seen from the breeding of soy adapted to tropical climates, increased agricultural productivity through technical change can increase the value of agricultural land generally, and thus drive land-use change further.

The disconnection between livestock production and the production of livestock feed is a cause of inefficient use of resources. Nutrients such as phosphorus are transferred from deficient crop producing areas causing to places where there is often already excess causing resource depletion and pollution at the same time. Across the world, 72% of poultry and 55% of pigs are raised in intensive systems sustained by feed from other regions (Galloway et al, 2007). There is a global transfer of nutrients from the Americas to Europe and Asia. Reconnecting crop and livestock production and conserving reactive nitrogen and phosphorus within the soil/plant/ animal system is central to the development of a more eco-efficient agriculture. From a sustainable consumption viewpoint, such reconnection strategies extend to active encouragement of livestock production integrated with crop production in crop exporting countries such as the Cerrado region of Brazil. This is already happening and the application of advanced nitrogen conserving approaches in these systems could have significant benefits. Current European tariffs on crop commodities and livestock products supports continued disconnection by favouring the import of feedstuffs to convert to meat in concentrated intensive animal production in North-west Europe.

While more efficient production technology can improve the environmental performance of agriculture, the opposite is usually the case in wild fisheries. As stocks deplete, fisheries production drops and intensified fishing is maintained by increasing prices, often at the expense of those fishers who are using more sustainable practices. The destruction of the marine environment in the north-east Atlantic, particularly the North Sea, through bottom trawling for demersal fish is an example of a vicious cycle based on a ‘fishing technology arms race’. The brief investigation conducted for this study of the dynamics of fish stocks leads to the conclusion that current policy based on rationing the fishing effort and limiting the landing of fish is just tinkering at the edges of the problem. Right from the invention of trawling, technology has driven the increasing pressure on fishery resources and now drives a vicious circle of fewer fishers using more fuel and technology to intensify the hunting of depleted stocks. This raises the question of restricting certain fishing technologies and banning access to fishing grounds through the establishment of marine reserves. If successful such a policy would result in the rebuilding of stocks to the point that fishery production with much less intensive fishing would increase.

5.5.3 Harnessing markets

The challenges to the environment presented by global agriculture and fisheries are often portrayed as the consequence of recklessness on the part of producers and the communities concerned. For example, it is sometimes implied that a careless and an even ignorant mentality which mistakenly undervalues forest causes deforestation. With some notable exceptions, for example studies done by the World Bank (Margulis, 2004; Chomitz 2007) and others such as Nepstad et al. (2006), the conservation literature and the policy discussions that flow from it only rarely present land-use change as a consequence of legitimate rational economic behaviour, including that driven by rural poverty. From examining the range of reports available, it is concluded that deforestation is a rational response to differences in economic value of forested and agricultural land as determined by the market value of their products. A greater understanding and acceptance of the rationality of economic behaviour driving change would help the more prompt formulation of effective policy. It is essential to understand the private interests causing land-use change at the point and place of change and further policies that address the underlying economic forces. This would lead to the more prompt advocacy of economic instruments and the effective harnessing of markets by consumers to protect natural resources and the environment.

Even though often seen as a negative development, the ‘corporatization’ of production, trade, processing and retailing, especially UK retailing, offers significant opportunities to harness market forces. The shift from open commodity trading to dedicated supply chains and private product concentrates power with some negative social consequences but also puts influence and power in the hands of consumers. The UK food industry is characterised by vertically integrated supply chains and the retail sector is dominated by a small number of very sophisticated retailers that are renowned for the influence they have over suppliers and production practice. This puts a solid lever in the hands of UK consumers with which markets affecting natural resource use and biodiversity can be influenced.

Changing consumer preferences in relation to commodities from particular countries, for example in relation to 'beef from Brazil' or 'palm oil from Indonesia' is a blunt instrument, especially against the background of the production in these countries driven by domestic consumption and global spot markets. Policies could be designed around influencing land values. Consumer orientated initiatives designed around influencing the value of land according to the environmental sustainability of its conversion and use might lead to the development of more effective and better targeted change in consumer preferences. This can be particularly effective where risk adversity is a characteristic of the actors concerned, as is the case of Amazonian beef producers. This means continued trade that rewards effective land use for agriculture where this makes environmental sense combined with market measures designed to reduce the market value of produce from inappropriately changed or used land.

5.5.4. Product certification

Product certification that is visible to and understood by consumers is the key to harnessing markets to create differences in land values. The prize for compliant producers is preferential market access. Certification that does not reward compliant producers sufficiently to influence land values will be relatively ineffective. There have already been notable successes, especially in the UK. Even the UK's largest retailers are individually small players in the global food commodity market and alone have little influence on production, particularly when production for export is not directly connected with its land use change consequences. An approach that goes beyond individual retailers and supply chains and which adopts an ecosystem services component could be adopted. The Marine Stewardship Council exemplifies such an approach and how the market can create powerful incentives for sustainable production, working with the grain of rational economic behaviour. For WWF interests in the UK food economy, the foundations of success in key products are already there. In the case of beef, the effect of Foot and Mouth Disease Status in Brazil on local land values shows that export market access has a big effect even though 80-90% of Brazilian beef is for domestic consumption. The focus of UK palm oil buyers on less controversial producer countries, for example Papua New Guinea and Colombia, is indicative of the influence of concerns within the UK food economy being transmitted to producers. Product certification depends on effective custody of the supply chain and monitoring of production, backed by land-use governance and effective public regulation. Complementing the markets for produce, we now have markets emerging for regulatory ecosystem services such as for Reduced Deforestation and Degradation (REDD) and the Clean Development Mechanism. As suggested by Ebeling and Yasue (2008), if brought together these complementary forces acting on the differences in land values at the point of deforestation could be significant.

5.5.5. Land-use governance and production regulation

The emphasis above on harnessing markets does not deny the effectiveness of central government policy. The example of Paraguay shows that a clear central government policy on land-use change is effective. A comprehensive ban or control of land-use change is difficult to undermine with such a highly visible activity as deforestation. A full analysis of the opportunities presented by the recognition of Reduced Emissions from Deforestation and Degradation (REDD) is outside the scope of this study. However, such a mechanism provides a potentially powerful incentive to governments to enforce clear laws on forest clearance and degradation. For the conservation community, a focus on the differential between the value of forested and un-forested land provides a framework to focus interventions in policy making and markets.

It is easy for Europeans to be critical of failing public policy and regulation in developing economies, forgetting that enforcement of agri-environmental regulations in Europe is not easy. Combining local regulation with international market incentives could be effective – in effect a partnership between 'top-down regulators and 'bottom-up' market instruments. The reward of market access for compliant producers endorsed by international monitoring underpins peer-to-peer acceptance in producer communities which in turn is supportive of effective public enforcement.

Even where forces that subvert the enforcement of public policy are addressed, the regulation of land use by public authorities over such large and inaccessible areas remains a challenge. Highly visible land-use change is the key issue in many critical regions so recent advances in earth observation provide the private sector, particularly the NGO community, with the possibility to complement enforcement efforts and to use the certification of products and market to translate the results of monitoring into changes in asset values. The facilitation of public access to the evidence of land-use change would help to create an atmosphere in which abuse is less tolerated within the affected communities and particularly within their markets.

5.5.6. Avoiding un-intended social consequences

The dynamics of land-use change have a strong local social dimension that need to be understood in detail if un-intended social consequences are to be avoided. In particular, measures affecting the market value of agricultural assets need to be progressed hand-in-hand with measures to address rural and land poverty as a driver behind land-use change. Land clearance and conversion in the tropics depends on a plentiful supply of very cheap labour, ie it depends on rural poverty. Measures that bring economic development to these areas provide an alternative deforestation as a source of income for the poor (Chomitz, 2007).

5.6 PUBLIC POLICY

5.6.1. Public information

Addressing gaps in the provision of good quality information to the public is one of the key roles of government in a market based democracy. This is particularly important in the food economy where market function can be compromised by the development of vertically integrated supply chains and private standards. The NGO community can support this information function and draw attention to key information gaps that need to be filled to inform the most sustainable consumption patterns. Public information needs to be evidence based, not evidence backed advocacy of previously fixed positions.

Some of the changes in the UK food economy are linked to public health policy, in particular the consumption of fish, fruit and vegetables. There is scope for delivering such public health policy linked to policy on the environment. There is also a need to ensure food policy in relation to health is mindful of the environmental consequences of consumption exceeding the minimum required for optimal health – for example the consequences of high or poorly balanced fish consumption. The elements of the 'Mediterranean diet' for example that deliver health benefits could be identified so as to identify the wider range of foods that deliver these benefits reducing the unsustainable demands on key foods commonly associated with such diets, e.g. olive oil and fish.

5.6.2. Reform of the Common Agricultural Policy

The UK government is committed to further reform of the Common Agricultural Policy. The UK Treasury and Defra set out a vision of reform up to 2020 (A vision for the Common Agricultural Policy, HM Treasury and Defra 2005). Even though this is a vision rather than a plan of action, the policy direction the UK will seek is clear. This includes reduced subsidy for European production, active coupling of support to the delivery of public goods, and a liberalised global market providing for example South American and African farmers with more access to the EU. The vision sees benefits for the European environment through de-intensification, and economic benefits for exporting countries, particularly in the short term, where WWF has significant interests – Brazil, Latin America in general, Indonesia and South Africa.

5.6.3. Research and development

Despite the reductions in UK public investment in research over the last 15 years, the UK public research base is still a science and technology resource of global significance. It traditionally has had an outward looking perspective and a history of supporting global agriculture with knowledge and technology. Public science policy could provide greater rewards for researchers who establish partnerships with developing agricultural economies and who address research questions of practical significance to food production in environmentally sensitive regions of the world.

5.6.4. Working with public policy in the UK

UK policy makers have had significant success in recent years in driving forward beneficial change at an international level – particularly the reform of the CAP in 2003. The UK is now at the forefront of policy making in the sustainable consumption area, particularly in relation to food and agriculture. UK policy-makers have also advocated a precautionary approach to the development of biofuels and biogas avoiding the environmental down-sides of biofuel and biogas development experienced in other European countries and the US. NGO recognition of these successes would further positive and fruitful engagement with policy makers and legislators.

The literature includes a great deal of material claiming damaging land-use change and production practices connected to production for export to the EU. Proof, or even convincing evidence, of a causal link between the commodity markets as affected by consumers decisions and the damage claimed is often rare. It is suspected that this lack of causal evidence or gaps in land-use data is slowing the development of market alliances, for example Round Tables for commodities. A greater emphasis on causal links may accelerate the development of effective market mechanisms. Even though politicians may note the impact of campaigns in their constituencies, clear evidence of causation is crucial to the effective engagement of policy makers who are charged with turning political vision into change in the real world. Given how Defra has followed WWF's lead already, there is scope for further partnership with the UK government in advancing public and private policy to improve the environmental performance of the UK food economy.

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TABLE 5: VEGETABLE OIL EXPORTS TO THE UK (TONNES)

2005	Castor	Groundnut	Maize	Misc. Oilseeds	Olive	Rapeseed (seed)	Rapeseed oil	Sunflower oil	Sunflower seed
Argentina					1			4321	1568
Austria				66	1	0		538	
Belgium	1	3009	3785	16	2364	85	18227	22124	36
Bulgaria									1670
Canada				24			0		771
Chile								0	23
China		19		339	3			1	11206
Czech Republic					29				53
Denmark			38	3		8340	154		68
Egypt				4		61			1184
Ethiopia				960					
Finland					23		13765		
France	0	1128	168	215	1675	3651	30995	32136	5191
Germany	247	3	110	59	941	20216	1474	17930	468
Greece				50	3031				1
India	8642			620			45		703
Iran				10					3
Italy	2	31	144	11	20314			183	110
Latvia						3150			
Netherlands	807	314	114	361	242	89	10905	34957	18752
New Zealand				109	3	161			
Poland					1	2704	1	0	9
Portugal					334				
Russian Federation				2954					
Senegal		503							
Spain	23	23	78	1	24332		25	27	13
Sweden	0				27	6	314		
Ukraine								8477	
USA	3	0	10	114	0		10	73	4407

TABLE 6: DIRECT PALM OIL EXPORTS TO THE UK IN TONNES (EXPORTS TO UK AS % OF TOTAL EXPORTS)

	1990	2005
Brazil	-	37267 (84)
Cameroon	2000 (4)	2979 (9)
Colombia	-	105433 (46)
Côte d'Ivoire	3604	5099 (17)
Ecador	-	4320 (4)
Indonesia	99411 (9)	135028 (1)
Malaysia	78721 (1)	118297 (1)
Papua New Guinea	80781(1)	161480 (42)

TABLE 7: SOURCES OF DIRECT SOY MEAL EXPORTS TO THE UK

	1990	2005
Argentina	23883	165269
Belgium	81414	11797
Belize	2472	1526
Brazil	282375	950867
British Virgin Islands		41283
France	1802	25
Germany		17100
Netherlands	679673	361327
USA	40487	60448
Uruguay	993	9626

TABLE 8: SOURCES OF IMPORTS OF TROPICAL AND SUB-TROPICAL FRUIT (TONNES) IN 2005 (EXPORTS TO UK AS % OF TOTAL EXPORTS)

2005	Bananas	Mangoes etc	Papayas	Fresh pineapples	Plantains
Belize	65834 (87%)			16 (1%)	
Brazil	35634 (16%)	8441	5159	50 (50%)	
Burkina Faso		135			
Cameroon	157823 (64%)		1	120 (3%)	
Colombia	99925 (7%)		51	5 (1%)	6467
Costa Rica	137428 (9%)	1972		49218 (44%)	2708
Côte d'Ivoire	28049 (14%)	473	333	4502 (-)	
Dominica	12814 (98%)	25			123
Dominican Republic	113829 (72%)	446	85	21 (-)	
Ecuador	340 (1%)	289			1231
Egypt		32	295		
Gambia		608	28		
Ghana	2178 (40%)	48	111	4632 (13%)	1
Guatemala	279 (1%)	355	7	1440 (3%)	
India		1438	1047	6 (50%)	
Israel		2360	1		
Jamaica	11654 (100%)	193	28	102 (1%)	
Pakistan		9676	1152		
Panama	27710 (8%)			1661 (8%)	
Peru		4320	1		
Saint Lucia	28243 (-)	9	12		1
Saint Vincent/Grenadines	15893 (84%)				2
Senegal		415			
South Africa		902	1	2718 (2%)	

TABLE 9: SOURCES OF IMPORTS OF NON-CITRUS MEDITERRANEAN FRUIT (TONNES) IN 2005 (EXPORTS TO UK AS % OF TOTAL EXPORTS)

	Apricots	Avocados	Cantaloupes and other melons	Grapes	Kiwi fruit	Peaches and nectarines	Watermelons	Grapes (incl. wine)
Argentina	3	187	54	948		712	69	23221
Australia	15			78		229		222613
Austria	56						115	246
Belgium	159	1154	371	1735	2025	373	10	541
Brazil		51	53347 (34%)	10223			7727 (39%)	15
Bulgaria								5066
Chile	3	5943	3	50717	7678 (6%)	3595 (2%)		78906
Costa Rica			24871 (11%)				2610	
Cyprus			28	31			814	1201
Egypt	1		670	12459		355	71	
France	3916 (50%)	21784	5059	3756	485	5474	537	266411
Germany	307	1862	2484	12061	746	3837	1698	102337
Greece	58	31	136	23646	535	1146	3757 (4%)	881
Honduras			1159					
Hungary			77				469	3320
India				9759				17
Israel	264	1166	347	1759	108	328	3	139
Italy	256	4	1329	7556	17818 (8%)	41951 (9%)	414	238263
Kenya		633	4					
Mexico	4	215	20	6307		382		37
Morocco			49	3849		156		22
Namibia				3512				
Netherlands	226	2195	5809	7984	1558	1073	1360	3338
New Zealand	191	8			6170 (3%)			22586
Portugal	42		199			505	124	17594
South Africa	1090 (10%)	12977 (24%)	712	51317	3	2703 (10%)		111225
Spain	1369 (4%)	5392(23%)	51929 (18%)	25806	436	33372 (7%)	19256 (6%)	99363
USA	102	61		8905		1165	4	114221

TABLE 10: SOURCES OF IMPORTS OF CITRUS FRUIT (TONNE) IN 2005 (EXPORTS TO UK AS % OF TOTAL EXPORTS)

	Citrus fruit juices	Citrus fruit	Grape-fruit (incl. pomelo)	Grape-fruit juice	Grapefruit juice, conc.	Lemon juice	Lemons and limes	Orange juice	Orange juice, conc.	Oranges
Argentina	391	56	829		40		10046	178		20911
Belgium	1840	54	891	7	462	0	398	14328	49481	529
Belize			187		200		32			6908
Brazil		19			10		6157	47885		1907
Cuba			293							5939
Cyprus		779	5715		1		967	14		6128
Egypt							471			38244
France	1	10	2786	0	2906	36	1491	1167	2603	8841
Germany	136	200	383	2770	1332	5	1626	47318	42839	4243
Ireland	371	18	46	597	2238	39	77	32243	7881	667
Israel	62	32	13088	58	475		743	1738		14411
Italy	650	356	71			2348	399	200	290	2396
Jamaica		72		10					429	441
Morocco							2			29252
Netherlands	100	145	2187	3874	1739	9	5920	109300	10483	6148
Pakistan							1	7		100
South Africa	0	36	19775				14576		4	72753
Spain	791	458	768		2546	11	34912	4615	54613	75459
Sri Lanka	2								5	
Swaziland			2664							2686
Sweden		2				1		77	17	5
Switzerland										32
Turkey			4662			4	8197	4128	8	14090
USA		0	2740		172	5	90	1595	2	715
Uruguay	19		235				2319			18662

TABLE 11: SOURCES OF IMPORTS OF TEMPERATE FRUIT (TONNES) IN 2005

	Apple juice	Apple juice, concentrated	Apples	Cherries	Plums	Plums, dry	Raspberries	Strawberries
Argentina			1836	561	955	165		2
Australia			2136	48	562			26
Austria	668	1138	4913	78				
Belgium	504	188	9054	185	375	1	273	5888
Brazil	3	71	15110					
Canada	2		5557	228		11		
Chile		43	29774	788	9684	1998	97	2
China	22	6359	6434			24		
France	108	560	157674	1612	5426	2892	152	1161
Germany	8914	67216	29187	167	1511	36	5	834
Greece		0	100	404	158	0		8
Ireland	2510	6144	774	74	17	3		25
Israel	8	62		1	253			759
Italy	14	1583	34237	1069	11629	75	6	36
Morocco								1778
Netherlands	1477	5963	14230	563	1483	2	376	11117
New Zealand			63806	22	20			1
Poland	6	7297	52				1	25
Portugal		1682	3642		2874		268	2073
South Africa	35		95743	4	10659		84	14
Spain	284	10395	5995	5443	25699	1	3084	20775
Turkey	1319	1091		5683	21	17		
USA	34	21	33438	2584	417	2050	960	1394

TABLE 12: ESTIMATED FEEDSTUFF INPUTS INTO UK CONSUMED LIVESTOCK PRODUCTS (KTONNES)

	Product consumption	Product net Import	Production	Quantity of concentrate feedstuffs per unit product	Total concentrate feedstuff consumption	Concentrate feedstuffs embedded in UK production	Concentrate feedstuffs embedded in net imports
Eggs	559	76	615	4.00	2234	2461	303
Beef	1041	260	762	4.50	4685	3429	1172
Chicken meat	1598	317	1360	3.30	5272	4487	1046
Milk	14442	2013	14577	0.27	3899	3936	544
Pig meat	1228	554	706	4.60	5648	3248	2549
Turkey meat	207	-17	211	4.00	828	845	-68
Total	69539	30637	61187		22567	18405	5545

WWF-UK
Panda House, Weyside Park
Godalming, Surrey GU7 1XR
tel: +44 (0)1483 426444
fax: +44 (0)1483 426409

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