WWF

REPORT

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WORKING TO PROMOTE SUSTAINABLE FOOD

ADAS

Conservation | Climate Change | Sustainability

A 2020 vision for the global food system

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For over 50 years, ADAS has been providing leading research into food production, providing a science-based understanding of the issues in order to protect the needs of producers, the food supply chain, consumers and the environment. Multi-disciplinary teams of ADAS experts in both food and non-food crops, provide research, consultancy and knowledge transfer services to governments and industry.

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Acknowledgements:

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WWF is the world's largest conservation organisation, and has been working to protect the natural world for over 50 years. Since its founding in 1961, it has developed from working to protect charismatic animals like pandas, to protecting the ecosystems that sustain nature, to tackling the major threats to the natural world such as climate change. Part of this is investigating the drivers of these threats, such as unsustainable consumption, which has led to WWF-UK prioritising food.

WWF-UK takes a whole value chain approach from production to plate. This includes looking at commodities such as palm oil and sugar, and the direct and indirect impacts of production, including land-use change. It also covers the increase in demand for meat and the need for more land to feed livestock, and the rapid changes in our eating habits which have led to us eating more processed foods, meat and dairy than ever before. The current food system is unsustainable in the long term: "business as usual" is no longer an option or desirable.

FOREWORD

WWF-UK's One Planet Food programme aims to reduce the environmental and social impacts of UK food production and consumption.

Duncan Williamson,
senior policy adviser (food),
WWF-UK

70%
OF WATER USE IS LINKED TO FOOD PRODUCTION

38%
OF THE EARTH'S ICE-FREE LAND SURFACE IS USED FOR AGRICULTURE

30%
OF HUMAN-INDUCED BIODIVERSITY LOSS IS ATTRIBUTABLE TO LIVESTOCK PRODUCTION

The project aims to reduce key environmental impacts across the food value chain, taking a holistic approach. Our aim is to move towards a sustainable, fair and equitable food system, based on planetary limits. We focus on three key strategic objectives:

- By 2050, global greenhouse gas emissions resulting from the production and consumption of food consumed in the UK are reduced by at least 70% based on 1990 levels.
- By 2050, water usage in the production and consumption of food consumed in the
- UK has no unacceptable socio-economic or environmental impacts.
- By 2050, the major adverse socio-economic and environmental impacts of production and consumption of food consumed in the UK is eliminated within key global ecosystems.

Food is a complicated, divisive issue, with many views on what a good, sustainable food system should look like and where the focus should be. What we do know is something is wrong with the current food system. Over a billion people are hungry, while 1.5 billion are overweight or obese. There is famine in Africa, food prices are rising, edible grains are being converted to fuel and fish stocks are running dry.

Food is a significant contributor towards global greenhouse gas emissions (30% including land-use change) and some 70% of water use is linked to food production. Agriculture dominates land-use globally, and accounts for some 38% of the Earth's ice-free land surface. It is the single most important driver of habitat loss, and with some two-thirds of ecosystems severely damaged or in a state of decline it is at the heart of many of the key environmental challenges that we confront today. Within the food sector livestock has the largest impacts, both in terms of carbon and biodiversity loss: the United Nations Food and Agriculture Organization (FAO) estimates that 30% of human-induced biodiversity loss is attributable to livestock production.

There are many questions we need to answer associated with food. Is industrialisation or organic the answer? Will we be able to feed the world through improved production techniques alone or must we look at what we eat? Do we really need to produce 70% more food by 2050? Will the rest of the world really adopt the Western style diet? What about waste?

Although we cannot answer all these questions this report takes a global perspective and looks at the available evidence to assess whether different scenarios will be low carbon and feasible in the future. These scenarios are:

1. Business as usual
2. An aspiration system that is 100% organic, with the highest welfare standards
3. A mixture of production, technology and consumption changes
4. As 3, while including other environmental considerations.

As this report makes clear, if we want to have a low-carbon food system and retain biodiversity we have to stop working in our silos and look at the whole food chain.

There is no silver bullet and there will be some very difficult choices ahead as we decide what food future we want. We welcome this report and will continue to identify how to reduce the impacts associated with agriculture and food, while looking at new ways to work with the food sector to reduce the environmental footprint of food, via both production efficiencies and the ability of business to influence consumer behaviour.

EXECUTIVE SUMMARY

WWF-UK's One Planet Food programme aims to reduce the environmental impacts inherent in the food system. The current food system is one of the main drivers in habitat loss, land-use change, greenhouse gas (GHG) emissions and freshwater use.

A lot of current studies look towards 2050, making predictions around the amount of food needed to feed a population of nine billion or more. The oft-quoted figure is the need to produce 70% more food. This is based on the assumption that the rest of the world will start consuming a more Western diet – high in meat and dairy and processed food and low in fresh fruit and vegetables. This assumption is unproven and may not be possible in a resource-constrained world, with oil becoming a rare, expensive commodity that can no longer be the backbone of agricultural production, climate change reducing many regions' ability to produce large amounts of food and water becoming scarcer. This is the "perfect storm" of water, energy and food insecurity outlined by John Beddington, the government's chief scientific adviser.

This work is looking to the medium term: a food system that can feed over seven billion people by 2020 with a climate-positive impact. ADAS and Sheffield Hallam University Centre for Food Innovation have been commissioned to deliver a research study into what this food system could look like.

This study aims is to identify what the global food system could look like in 2020 and beyond, and how it will need to change to be sustainable and contribute to global GHG reduction targets.

In Section 1 we present information from a literature review, and this information helps to inform later parts of the project.

In Section 2 we present the results from analysis of four scenarios provided to the project team. These scenarios were assessed to determine whether they can produce a low-carbon and sustainable global food system by 2020.

The scenarios were:

1. Continue on existing path – a baseline scenario where demand patterns do not change and more people move towards a Western-style diet.

2. Aspire to have organic and high animal welfare production – reflecting demand for aspirational production systems such as high animal welfare standards and organic production.

3. Improve production efficiency and reduce meat and dairy consumption – taking into account changes in production, technology and consumption, including GM and biotechnology, aquaculture, predicted production efficiencies and changes in meat and dairy consumption.

4. Take account of environmental impacts which may not decrease GHG emissions – also looks at reducing other environmental impacts associated with the food system, such as water scarcity and biodiversity loss, which may not result in low-carbon food.

A 2020 vision for the global food system

SUMMARY OF SCENARIOS

Scenarios (2020)		Changed consumption pattern	Technology to maximise production	Positive environmental impact		
No	Description			GHG emissons	Water	Biodiversity
1	Continue on existing path					
2	Aspire to have organic and high animal welfare production	✓				✓
3	Improve production efficiency and reduce meat and dairy consumption	✓	✓	✓		
4	Take account of environmental impacts which may not decrease greenhouse gas emissions	✓	✓	✓	✓	✓

The four scenarios are described, and then used to analyse how the world food system may change by 2020 and 2030. Changes by 2020 were then used to predict changes in diet by 2020, to guide Part 2 of this project, in which a road map for sustainable food was developed.

We follow a simple approach based on data from the FAO Food Balance Sheets, where food available for human consumption is divided by population. This data is used as a baseline, with consumption projections for 2020 and 2030 obtained by interpolation from Kearney (2010) (supplementary data). Analysis of change under each scenario used evidence from published literature and the expert knowledge of the project team.

Guidance for sustainable and healthy changes in diets was taken from the WWF-UK Livewell report (Macdiarmid et al., 2011). The report looks at a UK diet and UK consumption habits, but the nutritional element is global and defines what the average person should eat to be healthy, irrespective of geography. Livewell works very much from a Western perspective environmentally, and is relevant internationally. In October 2011, WWF started a three-year project under European LIFE+ funding that will enable WWF to trial Livewell in Europe, using it as a policy tool and trialling the diets in France, Sweden and Spain, incorporating local traditions and ingredients.

Summaries of the scenarios are outlined below and the preferred scenario is identified for a low-carbon and sustainable global food system by 2020.

SCENARIO 1

Continue on existing path

In this scenario global demand patterns continue on the current path towards increasing food consumption. There is also a shift in developing countries towards a Western-style diet, which is high in fat and non-extrinsic milk sugars and low in fish, fruit and vegetables.

The dual impact of consuming more food and shifting towards a Western-style diet creates health problems but also results in a large increase in GHG emissions from producing more calories per individual for an increased world population, and from increased consumption of high-impact foods. The scenario includes an increase in meat and dairy consumption, both of which have high GHG emissions at production. Another negative environmental trade-off is that the increase in land required for food production will have a negative impact on biodiversity. In terms of health, an increase in average world calorie intake per person will exacerbate obesity and related illnesses such as heart disease and diabetes. Continuing on the existing path will not deliver a low-carbon and sustainable food range.

SCENARIO 2

Aspire to have organic and high animal welfare production

This scenario outlines a change in demand which encapsulates aspirational production systems, specifically organic and high animal welfare. Products for which demand is predicted to significantly decrease in this scenario are potatoes, milk and dairy, and meat.

The increase in organic and animal welfare standards required to meet this scenario in only eight years, starting from a very low baseline, is exceedingly challenging on a world scale. Even within the EU, agreeing and implementing such regulation would be challenging. New legislation requiring a change to production systems in a short space of time would present a number of issues, one of the most important from the farmers' perspective being the cost. For example, replacing conventional cages in the UK egg industry would cost in the region of £400 million. Another consideration in implementing such legislation would be in preventing the sale of imports not produced to the same high-welfare standards.

There is no doubt we should be striving to make gains in animal welfare, to reduce our use of inputs, to manage soils better and to farm more efficiently. Scenario 2 is, however, not an effective way to achieve this because it is production led, and the necessary changes in consumption are unlikely.

SCENARIO 3

Improve production efficiency and reduce meat and dairy consumption

This scenario describes a food system which incorporates changes in production, technology and consumption – including all technological changes, aquaculture, predicted production efficiencies, and changes in dairy and meat consumption. This is the first of the scenarios to address the need to change consumption as well as production, and uses the Livewell diet as a template for a sustainable and healthy diet.

From a production and carbon emissions perspective, this scenario maximises resource efficiency through adopting best production technologies. The scenario assumes that there is no increase in farmed area, but the effect of urbanisation on farmed area is unclear. Use of technology could include genetically modified (GM) crops. In Europe, GM technology is a controversial topic but use of such technology seems to be accepted in some other parts of the world. It is possible that attitudes of consumers could change in the future as GM technology may prove to be part of the solution to feeding a burgeoning world population effectively.

The main weakness of Scenario 3 is that it does not take into account the impact of food production on local water scarcity and biodiversity. It will deliver a low-carbon food range – but not a sustainable one.

SCENARIO 4

Take account of environmental impacts which may not decrease greenhouse gas emissions

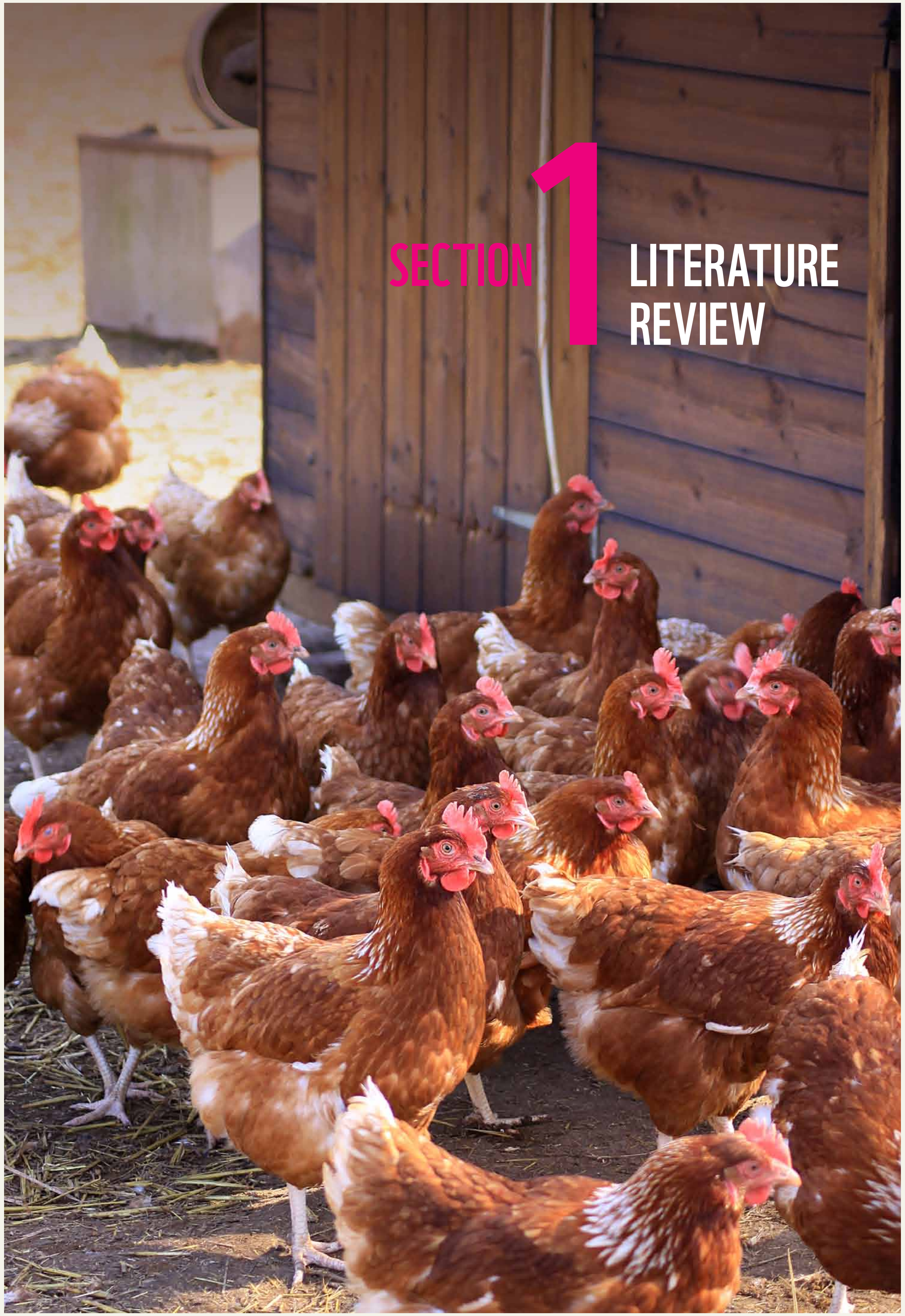
Scenario 4 is similar to Scenario 3 (above), but it addresses the main deficit of Scenario 3, namely the issue of unsustainable water use and impacts on biodiversity at a local scale. It is our view that Scenario 4 could be further enhanced by adding a requirement for enhanced animal welfare standards.

Scenario 4 is the preferred option as it will deliver a low-carbon and sustainable food system. It minimises adverse impacts of food production on the environment at a local scale, particularly in regards to biodiversity and water. Improvement in animal welfare standards could be achieved under this scenario and should be implemented alongside the food range guidelines that this scenario leads to.

CONTENTS

ABBREVIATIONS

CAFRE	Centre for Agricultural, Food and Resource Economics
DRV	Dietary Reference Value
EAR	Estimated Average Requirement
FAO	Food and Agriculture Organization
GDA	Guideline Daily Amount
GHG	Greenhouse Gas
IFOAM	International Federation of Organic Agriculture Movements
IFPRI	International Food Policy Research Institute
IUoFST	International Union of Food Science and Technology
IGD	Institute of Grocery Distribution
MEA	Millennium Ecosystems Assessment
LRNI	Lower Reference Nutrient Intake
OECD	Organisation for Economic Cooperation and Development
PAF	Population average figures
RNI	Reference Nutrient Intake
WHO	World Health Organization



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1. PURPOSE AND SCOPE

This literature review has been undertaken to provide guidance for the analysis of food system changes under each scenario in Section 2 of this report.

The reviewed literature includes academic papers and reports of research projects.

The major areas for investigation were:

- Demand patterns (current, and associated with aspirational production systems)
- Diet specifications and trends (Western-style diets and others; how much is eaten typically and trends were used to help predict consumption in 2020 and 2030)
- Dietary requirements, recommended nutrition amounts
- Production system specifications (for inclusion in scenarios)
- Population trends
- Trends in availability of agricultural land for food production (role of biofuel production in availability of land for food production)
- Trends in crop yields
- Potential for technological changes to change production systems
- Environmental impacts of production systems and how these can be mitigated.

2. DEMAND PATTERNS

Key Points:

- Demand is increasing in response to population growth, income growth and urbanisation.
- Major shifts in dietary patterns are occurring that have considerable health consequences.
- Over the last four decades fish consumption has been rising in line with the general trends of increased world food consumption.
- Aquaculture constitutes about 40% of aquatic animal food for human consumption and is expected to grow further in the future.
- Growth of aquaculture would include expansion in new environments, greater intensification and efficiency gains.

Throughout the world, major shifts in dietary patterns are occurring including a move from basic staples to more diversified diets (Kearney, 2010). Drivers of the change include:

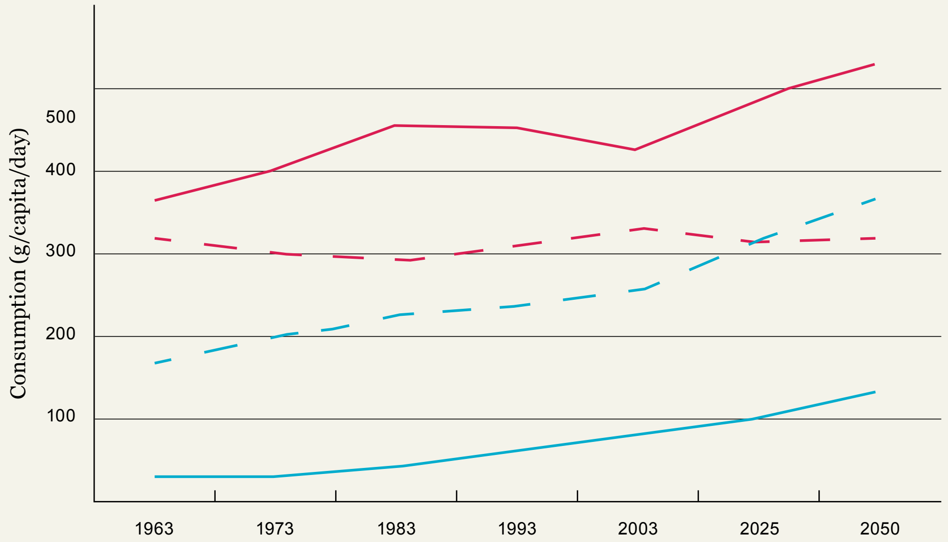
- Urbanisation
- Increasing incomes
- Market liberalisation
- Trade policies

In terms of cereals, consumption of rice has been comparatively static whereas wheat consumption has increased at a faster rate than for all other cereals, driven by demand from developing countries. Consumption of meat is growing rapidly and is expected to do so in both developing and industrialised countries. The change in consumption patterns to 2050 for cereals and meat is shown in Figure 1 and shows the projected increase per capita for both food groups clearly.

40%

AQUACULTURE CONSTITUTES ABOUT 40% OF AQUATIC ANIMAL FOOD FOR HUMAN CONSUMPTION

Figure 1:
Global consumption patterns of cereals and meat for developing countries (DC) and industrialised countries (IC). (Source: Kearney, 2010)



Key
- Meat DC
- Meat IC
- Cereals DC
- Cereals IC

GLOBAL FOOD PRICES ARE STILL HIGH RELATIVE TO RECENT HISTORICAL LEVELS AND ARE EXPECTED TO STAY HIGH, AT LEAST OVER THE MEDIUM TERM

Increase in global food prices

Despite global food prices declining from their peak levels of 2008, as well as the recent economic recession, global food prices are still high relative to recent historical levels and are expected to stay high, at least over the medium term (Nelson et al., 2010). Most observers agree that in the short to medium term, prices for feed and food will remain higher than in the recent past (IFPRI, 2008; OECD-FAO, 2008; World Bank, 2008). Potential factors responsible for the agricultural commodity price spike of 2007/08 include the rapid economic growth seen in developing countries, as well as loose monetary conditions such as money supply growth, financial laxity and depreciation of the US dollar (OECD-FAO, 2010). The Organisation for Economic Co-operation and Development (OECD) and the Food and Agricultural Organization of the United Nations (FAO) expect food commodity prices to remain at current levels or to increase in the medium term, thus continuing to exceed the real-term price levels prior to the 2007-08 price hikes (FAO, 2009d). Nelson et al. (2010) predict that real agricultural prices will increase over the period 2010-2030.

The role of speculation in financial markets sparks vigorous debate, with some analysts arguing that low returns in other markets attracted non-commercial investors into agricultural and other commodity markets, fuelling higher prices (OECD-FAO, 2010). Developing economies generally fared better than Western economies during the financial turmoil following the banking crisis, and are further along the road to recovery, led by resurgence in Asia (OECD-FAO, 2010). This is expected to continue into the future with an average annual GDP growth rate of 5.2% for developing countries and 1.6% for high-income countries over the period 2005-2050 (FAO, 2009a).

Increase in calories

Nelson et al. (2010) predict that per capita income will rise faster than agricultural price increases, with the difference resulting in higher average calorie consumption and lower child malnutrition. Certainly at the global scale, demand for food is traditionally linked to increases in the economic prosperity of populations (Audsley et al., 2010). Dietary energy in terms of calories per capita per day has been rising steadily on a worldwide basis as shown in Table 1. However, presenting averages does mask areas of scarcity. The recent Foresight report by the British Government Office for Science highlighted the inequalities of the global food system: nearly one billion are hungry and another billion suffer from hidden hunger, while one billion are over-consuming.

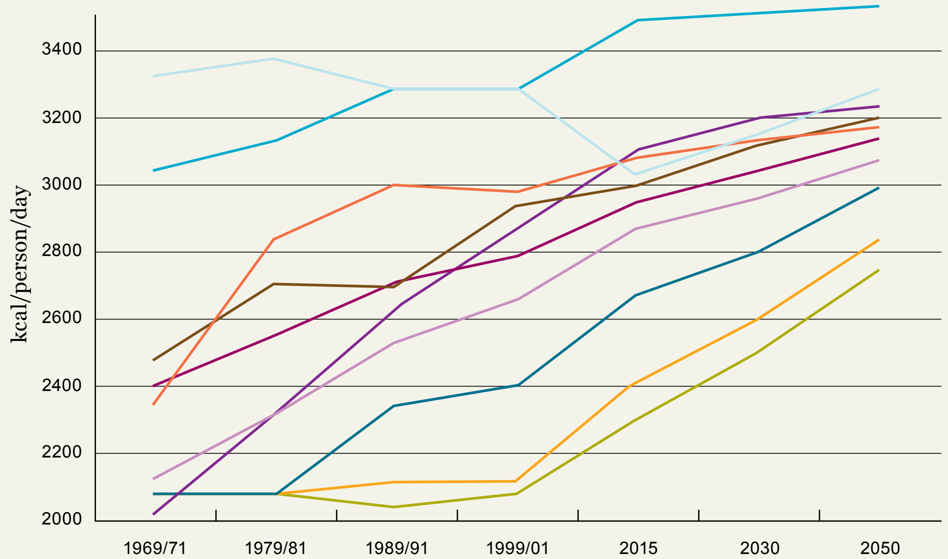
Table 1:
Per capita food consumption (kcal/person/day). Source: Alexandratos, 2006.

	1969-1971	1979-81	1989-91	1999-01	2003-05
World	2,411	2,549	2,704	2,725	2,771
High-income countries	3,046	3,133	3,292	3,429	3,462
Transition countries[1]	3,323	3,389	3,280	2,884	3,045
Low-income countries	2,111	2,549	2,704	2,725	2,771

Consequently, future growth in food demand will be dependent upon the combined effect of slowing population growth and continuing strong income growth and urbanisation (FAO, 2009a).

Figure 2:
Projections of per capita food consumption to 2050. Source: Alexandratos, 2006.

Key
- World
- Developing countries
- Sub Saharan Africa
- Excluding Nigeria
- Near East/North Africa
- Latin America and Caribbean
- South Asia
- East Asia
- Industrial countries
- Transition countries



The baseline projection of the global food system to 2050 has been widely cited and is based on using "business as usual" assumptions with no major policy changes. This projection suggests that, by 2050, the world's average daily kilocalorie availability could rise to 3,130. This is an 11% increase over the 2003 level, but would still leave some 4% of the population in low-income countries chronically undernourished. The projection assumes that agricultural production (excluding food used for biofuels) would have to increase by 70% compared with 2005/2007 to cope with a 40% increase in world consumption.

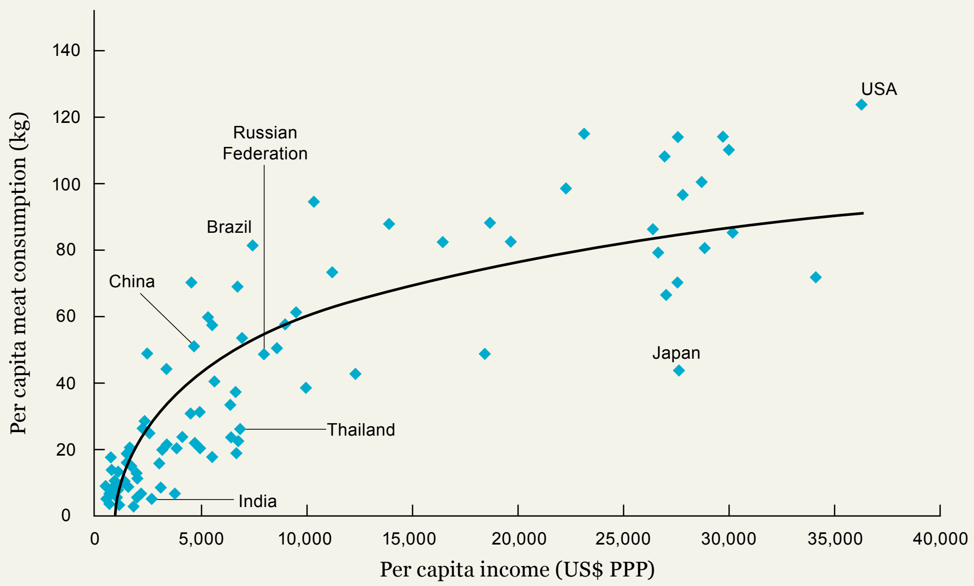
Overall developing countries will provide the majority of global growth in agricultural production, consumption and trade. Demand from developing countries is being driven by rising per capita incomes and urbanisation, reinforced by population growth, which remains nearly twice that of the OECD area (OECD-FAO, 2010).

[1] Decline in consumption in Transition Countries is based on the collapse on the Soviet Union and consequent loss of agricultural productivity (Leifert, 2002)

2.1 LIVESTOCK

Growth in the consumption of livestock products on a per capita basis has markedly exceeded growth in the consumption of other major food commodity groups (FAO, 2009d) with the most substantial growth occurring in East and Southeast Asia. In contrast developed countries have seen much more modest growth in per capita consumption of livestock products albeit from a higher base than developing countries (FAO, 2009d). Urbanisation was found to have a significant effect on the consumption of animal products, independent of income levels (Rae, 1998). For the majority of people in the world, particularly in developing countries, livestock products remain a desired food not only for taste but for nutritional value, as they provide not only high value protein but also a wide range of essential micronutrients. Figure 3 clearly shows that as countries become more economically developed the level of meat consumed increases, though at a declining rate.

Figure 3:
The relationship between meat consumption and per capita income, 2002 (national per capita income based on purchasing power parity (PPP)). Source: Steinfeld et al., 2006.



However, there are significant environmental effects arising from the growth in the livestock sector which from a local to global scale contributes to issues such as land degradation, climate change, water pollution, biodiversity loss and air pollution.

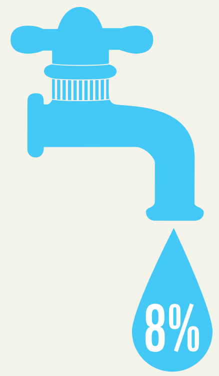
70% OF PREVIOUSLY FORESTED LAND IN THE AMAZON HAS BEEN CONVERTED TO PASTURE

Deforestation
Expansion of livestock production systems is a major cause of deforestation. Approximately 70% of previously forested land in the Amazon has been converted to pasture (Steinfeld et al., 2006), with feed crops covering most of the remainder. The world's natural pastures and rangelands have also suffered degradation from overgrazing – up to 73% of rangelands in dry areas (Steinfeld et al., 2006). Potential measures to reduce the impact of overgrazing include grazing fees, maintaining open access to common lands, soil conservation measures, silvopastures (combining forestry and grazing), restricting pasture burning and the exclusion of grazing on sensitive areas.

Structural changes in the livestock sector are altering the kinds of environmental issues that occur. For example, extensive grazing is being replaced with intensive systems, replacing land degradation issues with other problems such as potential point source pollution of water by animal manures and slurries (Steinfeld et al., 2006).

Climate change and air pollution
Globally, livestock contributes approximately 18% of all GHGs. Globally, 37% of anthropogenic methane emissions and 65% of nitrous oxide emissions are attributable to livestock systems, while livestock also produces two-thirds of anthropogenic ammonia which contributes significantly to acid rain (Steinfeld et al., 2006).

Intensification of livestock systems can reduce GHGs from deforestation and pasture degradation[2]. Conservation and silvopasture measures can also aid climate change mitigation by sequestering up to 1.3 tonnes of carbon per hectare per annum (Steinfeld et al, 2006). The reduction of enteric fermentation (through improved diets, along with improved manure management such as anaerobic digestion) can also help reduce methane and nitrous oxide emissions.



LIVESTOCK PRODUCTION ADDS TO THE STRESS ON WATER RESOURCES, ACCOUNTING FOR 8% OF GLOBAL HUMAN WATER USE EITHER DIRECTLY OR INDIRECTLY

Water
Livestock production adds to the stress on water resources, accounting for 8% of global human water (Steinfeld et al, 2006) use either directly or indirectly.

Livestock manures also contribute significantly to water pollution, which in turn can lead to eutrophication and the killing of coral reefs. Additionally, antibiotics, hormones, chemicals, fertilisers, pesticides and sediments may leach into water bodies from livestock systems and associated pastures, causing various pollution issues within the food chain and natural environment (Steinfeld et al, 2006). The environmental, human health and economic externalities of water use associated with livestock could be reduced by policy intervention, "full cost" pricing systems and taxation. The EU Water Framework Directive offers an example of one such policy mechanism.

Biodiversity
As a major driver of deforestation, livestock and the production of feedstuffs such as soya contribute significantly to biodiversity loss. Overall livestock is thought to threaten 306 of the 825 terrestrial ecoregions (Steinfeld et al, 2006). Livestock systems are also a driver of overfishing (as fish by-products are a major constituent of animal feeds) and therefore cause further biodiversity loss within aquatic systems. However, well-managed grazing systems can enhance biodiversity: in many pasture lands in Europe, the cessation of grazing would actually threaten their biodiversity value. In addition to protecting biodiversity from the effects of livestock systems by ensuring clean air, clean water and non-degradation of land, the establishment of lawful property rights, buffer zones and taxation systems can directly help preserve, restore and enhance the biodiversity of natural habitats such as forests.

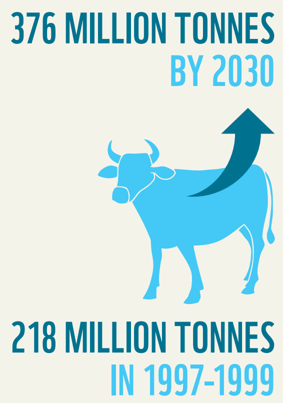
With these many potential negative environmental impacts, livestock systems should be one of the foremost concerns for environmental policy (Steinfeld et al., 2006). It is only by correct management, with the right kind of interventions and systems development, that livestock systems can also be part of the solution to these issues.

[2] Pasture degradation is caused by livestock overgrazing and is generally related to a mismatch between livestock density and the capacity of the pasture to be grazed and trampled (Steinfeld et al, 2006)

A 2020 vision for the global food system

Livestock trends

Looking into the future, all indications are for a continuation of recent trends with global growth in the demand for livestock products, particularly in developing countries (FAO, 2009d). Global annual meat consumption is expected to increase from 218 million tonnes in 1997-1999 to 376 million tonnes by 2030 (WHO, 2003). Indeed, as mentioned, there is a positive relationship between income levels and the consumption of animal protein, with the consumption of meat, milk and eggs displacing staple foods (WHO, 2003). This trend is reaffirmed by Trostle (2008) who expects milk and dairy consumption to rise 1% per annum through to 2019.



Figures 4 and 5 illustrate the trend in nominal and real prices in the last decade for livestock products and price expectations for the current decade (OECD-FAO, 2010). Average global dairy prices are expected to increase by 16-45% in 2010-19 relative to 1997-2006 (OECD-FAO, 2010). For instance, nominal prices for beef and pork are envisaged to increase by 21% and 17% to reach US$3,562/t dry weight and US$1,681/t dry weight respectively by 2019 compared to the base period 2007-09 (OECD-FAO, 2010). While livestock may not directly take food from those currently hungry, it contributes to increasing overall demand and thus prices (OECD-FAO, 2010). Demand for coarse grains for animal feed is projected to increase over the period 2000-2050 by 553Mt (OECD-FAO, 2010).

World meat prices nominal terms remain above historical levels

Nominal versus real meat prices

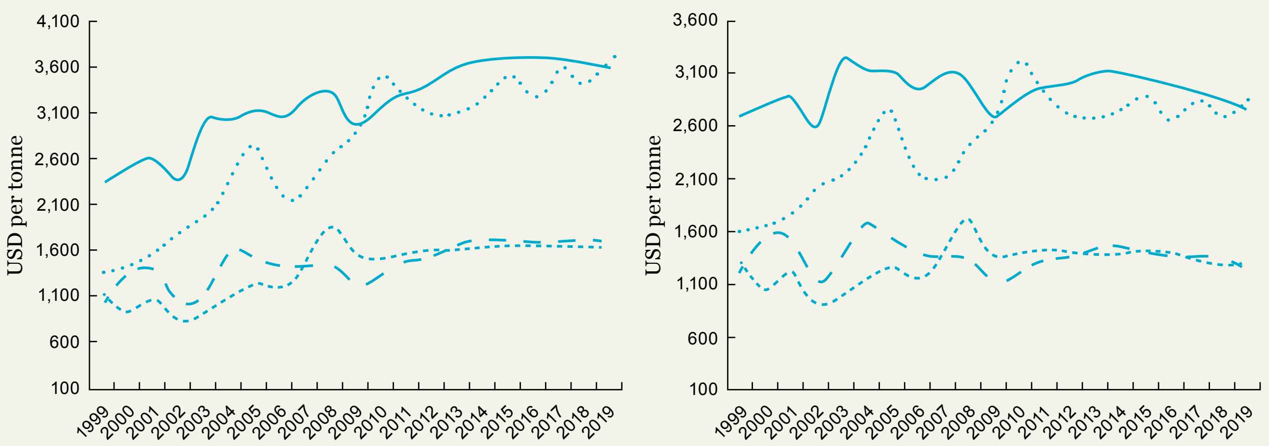
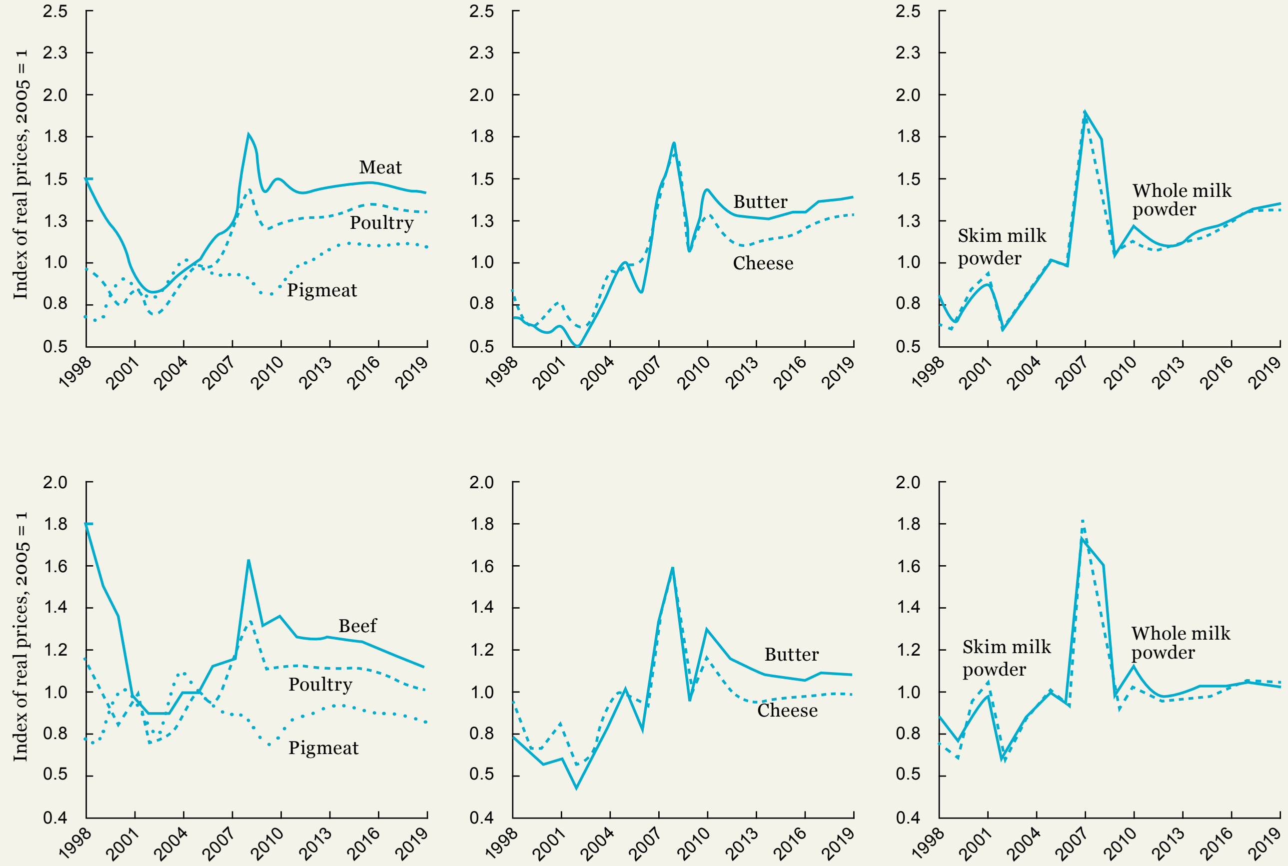


Figure 4:
Source: OECD-FAO, 2010.

Key
- Beef[a]
- Pork[b]
- Poultry[c]
- Lamb[d]

a) Choice steers, Nebraska, US dressed weight
b) Barrows and gifts, No. 1-3, lows/ South Minnesota, US dressed weight.
c) Meat of poultry export price, HS0207, Brazil product weight.
d) Lamb schedule price, all grade average, New Zealand dressed weight.
Source: OECD and FAO Secretariats.

The outlook for world livestock prices to 2019



Source: OECD and FAO Secretariats.

Figure 5:
Source: OECD-FAO, 2010.

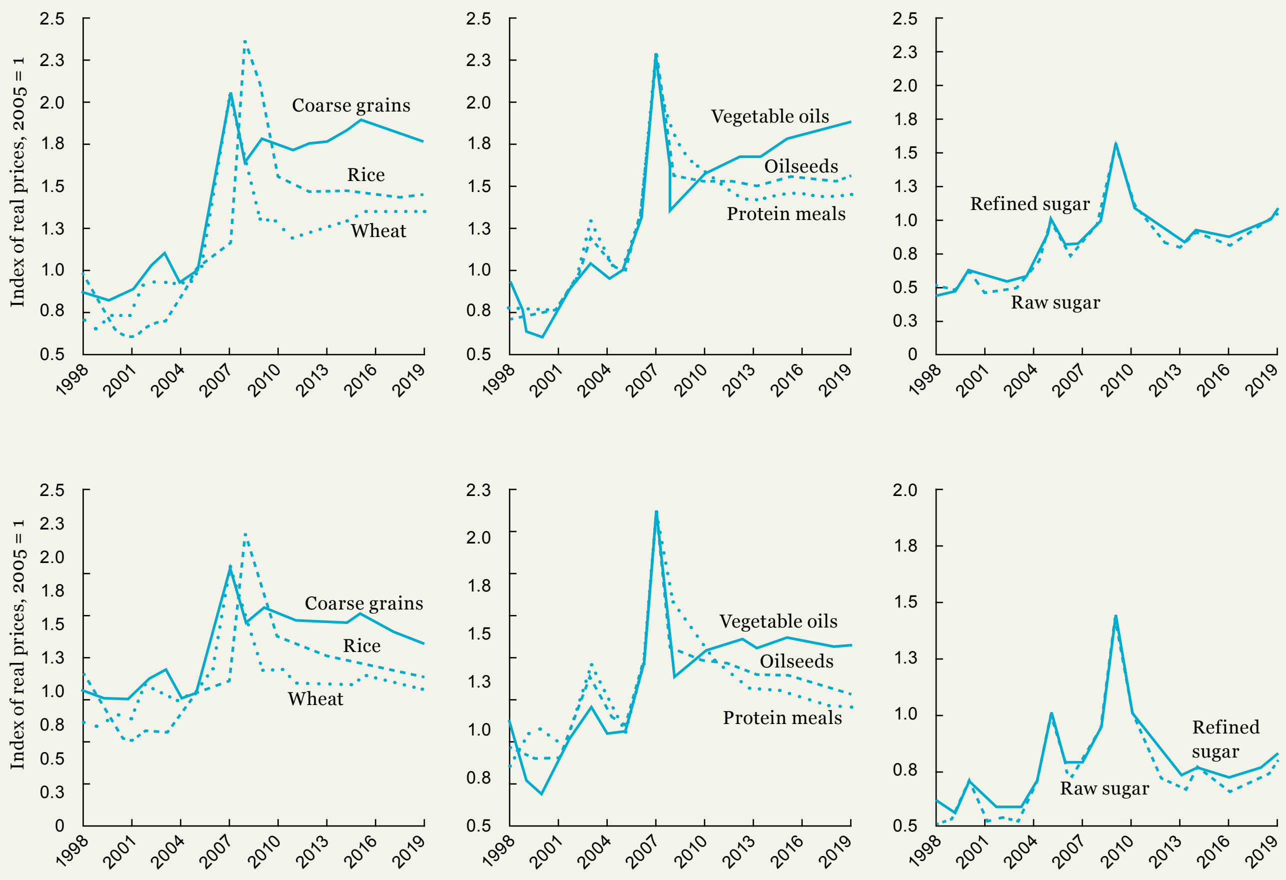
2.2 CROPS

THE REAL PRICE OF VEGETABLE OILS IS EXPECTED TO BE OVER 40% HIGHER

As incomes in developing countries have risen, the share of staples such as cereals, roots and tubers has declined, while that of meat, dairy products and oil crops has risen (Johnell, 1997). Figure 6 illustrates recent price trends for a variety of crops, as well as price forecasts for the rest of this decade (OECD-FAO, 2010).

Expectations are for average wheat and coarse grain prices to be roughly 15-40% higher in real terms relative to 1997-2006, while the real price of vegetable oils is expected to be over 40% higher. World sugar prices to 2019 are expected to be above the average of the previous decade although somewhat below the 29-year highs seen at the end of 2009.

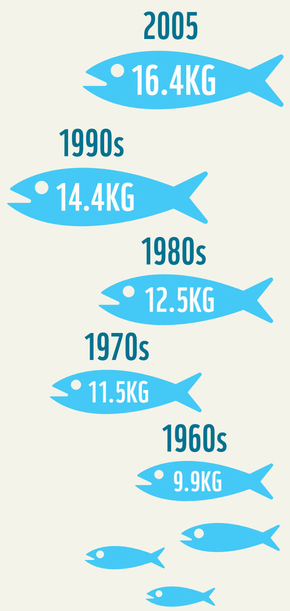
The outlook for world crop prices to 2019



Source: OECD and FAO Secretariats.

Figure 6:
Source: OECD-FAO, 2010.

2.3 FISHERIES AND AQUACULTURE



GLOBALLY, PER CAPITA FISH CONSUMPTION HAS BEEN INCREASING STEADILY

Fishery resources are an important source of nutrients, providing 1.5 billion people, particularly in low-income populations in rural areas, with almost 20% of their average per capita intake of animal protein. However, the productivity of marine capture fisheries is already highly stressed by fishing pressure, organic pollution, toxic contamination, coastal degradation and climate change. Fish landings increased almost 40-fold during the 20th century and it has been calculated that the century's total landings exceeded the entire catch of all previous centuries combined (McNeill, 2000). Production is now close to maximum ecosystem productivity; it cannot be increased substantially in future and may decline if not properly managed (Garcia and Rosenberg, 2010). WWF's *Living Planet Report* (WWF, 2010) has also stressed this issue and outlined five main factors driving this stress in capacity:

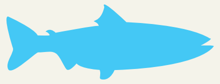
- High demand
- Trends in growth, fish consumption has been rising in line with the general trends of increased world food consumption over the last four decades
- Inefficient fishing technology
- Overcapacity in global fishing fleets
- Poor fisheries management.

Globally, per capita fish consumption has been increasing steadily, from an average of 9.9kg in the 1960s to 11.5kg in the 1970s, 12.5kg in the 1980s, 14.4kg in the 1990s and reaching 16.4kg in 2005. However, as is the case for other food products, this increase has not been uniform across all regions. In the last three decades, per capita fish supply has remained almost static in Sub-Saharan Africa. In contrast, it has risen dramatically in East Asia (mainly in China) and in the Near East/North Africa region. China has accounted for most of the world growth; its estimated share of world fish production increased from 21% in 1994 to 35 % in 2005, when Chinese per capita fish supply was about 26.1kg. Consumption in Southeast Asia is expected to increase in the near term, following the pattern observed in China (Delgado et al., 2003).

The demand for fish in the UK is increasingly being met by aquaculture, particularly salmon production, reflecting the UK consumers' preference for North Atlantic species such as Atlantic salmon (Audsley et al., 2010). With an annual global growth rate of 9% in the last two decades, aquaculture is currently growing faster than all other food-producing sectors (OECD-FAO, 2010). Aquaculture is perceived as the main source of production growth to meet growing demand in the developing world (Delgado et al., 2003). However, aquaculture is not insulated from concerns about global fish stocks. Recommending increases in fish consumption is an area where the feasibility of dietary recommendations has to be balanced against sustainability issues associated with marine stocks (WHO, 2003).

Over the last two decades there has been increasing public concern over the sustainability of fishing. Key issues described by FAO (2008a) include:

- The negative impacts of fisheries and overfishing on marine ecosystems and fish stocks
- Habitat modification resulting from destructive fishing practices
- Incidental capture (bycatch) of endangered species
- Amount of fuel/energy consumed to capture the target species.



3-5KG ESTIMATED QUANTITY OF WILD FISH NEEDED TO PRODUCE EACH KILOGRAM OF FARMED FISH

Growth in aquaculture

Aquaculture has boomed in response to demand for fish; in 2007 aquaculture contributed 43% of the total aquatic animal food for humans and this percentage is expected to increase (Bostock et al., 2010). One driver of past growth in aquaculture has been its ability to make relatively scarce, seasonal wild fish species available year-round in controlled quantities at lower prices than wild-caught equivalents: the increase in salmon consumption across Europe that followed the introduction of salmon farming exemplifies this (Guillotreau and LeGrel, 2001).

There are different forms of aquaculture for different target fish types:

Carnivorous (strictly, pescivorous) finfish. The main species concerned are salmon, trout, bass and bream; considerable effort has been invested in cod farming, but production remains small-scale. Tuna farming is also practised, but this is more akin to the finishing stage of beef-cattle farming and uses wild-caught juvenile fish rather than captive broodstock. Aquaculture for this group of species is heavily dependent on wild-capture fisheries to provide feed, although this is normally supplied in compound form. Estimates of the quantity of wild fish needed to produce each kilogram of farmed fish vary between 3 and 5kg. Some substitution of plant-derived materials for the fish components of compound feed is possible, but availability of "industrial" fish is a critical factor limiting sustainable growth.

Shrimps and prawns (warm water). There are some similarities between these activities and those in the previous group, but with some key differences:

- Shrimp and prawn farms occupy land at the sea's edge, rather than being in open water. They range from extensive operations occupying considerable space that is relatively unchanged from its natural state to intensive, more compact but more highly engineered facilities.
- The intensity of feed inputs is lower than for finfish farms: extensive operations may provide no food beyond what is available "naturally", while intensive installations feed a compound which is closer to one-third fish-derived than the two-thirds prevalent in salmon farms.
- Juveniles are commonly obtained from the wild, rather than from captive stock.

For shrimp and prawn farming, the critical challenges to growth are sourcing juveniles sustainably and establishing a resource-use model that does not involve aquaculture developments occurring at the cost of important ecosystem services provided by the area they occupy.

Herbivorous species. A report in The Economist (2003) noted that "80% of the fish produced by aquaculture are herbivorous or omnivorous, mostly produced in low-intensity systems for local consumption." The very nature of these operations means that they are, for the large part, outside the commercial food system. The practice has continued for hundreds, even thousands, of years. It has some of the desirable traits of integrated multitrophic aquaculture, in which species from different trophic/nutritional levels are incorporated in the same farming system. This may contain both plants and fish, so that solid and soluble nutrients contained in waste from harvestable or fed organisms are recycled. Intensification in this branch of aquaculture is reported to be taking place using facilities akin to those for shrimp farming.

Aquaculture and the environment

While some critical barriers to the sustainable growth of aquaculture were noted, finfish and intensive shrimp/prawn aquaculture systems cause environmental damage through several mechanisms:

- The pollution of water by chemical and nutrient leaching – this leads to eutrophication, to human health risks and risks to non-farmed organisms where pesticides used to control parasites are intensively used.
- The accumulation of solid wastes from fish farms on coastal land and on the seabed – this causes the degradation and contamination of soils surrounding inland fish farms and of the seabed and seabed ecosystems under inshore open-water farms.

The significance of impacts from these two mechanisms is exacerbated by the fact that fish farms are often located – for good practical reasons – in relatively calm inshore waters or in intertidal or shallow waters that tend to be of high biodiversity value.

- Escapes of farmed fish – these introduce diseases to wild populations, place additional pressure on the resource base used by wild populations (feed, breeding sites) and may reduce the fitness of wild populations if interbreeding changes the genetic make-up of the wild fish. Escapes of non-native farmed fish species introduce entirely new pressures into ecosystems. It has been argued (Fernández-Armesto, 2001) that, in the long term, these escapes will have the greatest consequences for the environment because they will lead to the extinction of wild species just as the domestication of cattle led to the extinction of their wild cousins in the past.
- Energy and water use – the production of compound feed used in shrimp, prawn and finfish farming requires a certain amount of energy since it is a dried product. Intensive shrimp farms often and juvenile salmon farms always require considerable volumes of fresh water.

Organic aquaculture is seen to be more environmentally sustainable. Arguments for organic aquaculture include reduction of overall exposure to toxic chemicals from pesticides that can accumulate in the ground, air, water and food supply, thereby lessening health risks for consumers.

It is unclear whether the reputation that carp and tilapia farming now have for sustainability would survive scale-up and absorption into global food supply chains. The FAO fisheries report (FAO 2008a) certainly proposes wider adoption of integrated multitrophic aquaculture.

Various models of open-ocean finfish farms or totally contained fish farms have been proposed. Some salmon farms have been moved further offshore to mitigate local environmental impacts. All "solutions" to the environmental impacts of fish farming have higher associated financial costs than the current operating models (if for no other reason than because they require active management of wastes now disposed of at no financial cost). So it is uncertain how these solutions will be accepted and implemented by the global fishing community.

3. POPULATION TRENDS

Key points:
•While there is some uncertainty in projections due to unknown future fertility and mortality trends, an increase by at least one billion is almost certain by 2050.

•Most projections for the 2050 population are between 8 and 10 billion.

•Almost all the increase will happen in the developing world.

2050 POPULATION PROJECTION IS BETWEEN 8 AND 10 BILLION

Population growth rates for the previous and current decades across selected regions are represented in Figure 7 (OECD-FAO, 2010). By 2050 the world's population is expected to increase by 34% over today's level to reach 9.1 billion, with nearly all of this increase occurring in developing countries (FAO, 2009a). Feeding a world population of some 9.1 billion people with higher consumption levels in 2050 would require raising overall food production by some 70% between 2005/07 and 2050 (FAO, 2009c). The baseline scenario has just over 9 billion people in 2050; while other scenarios range from 7.9 billion to 10.4 billion (Nelson et al., 2010). Trends towards urbanisation are considered unstoppable (FAO, 2009d), consequently increasing the need for longer food supply chains.

Figure 7:
Source: OECD-FAO, 2010.

Slowdown in population growth

Annual percentage growth

	Population	
	2000-09	**2010-19**
World	1.22	1.06
Africa	2.35	2.22
Latin America & Caribbean	1.22	0.93
North America	0.99	0.87
Europe	0.27	0.06
Asia and Pacific	1.19	0.98
China	0.67	0.57
India	1.54	1.20
Oceania developed	1.15	0.94

Note: Average annual growth is the least-squares growth rate (see glossary).
Source: UN World Population Prospects (2008 Revision)

4. DIET SPECIFICATIONS AND REQUIREMENTS

Key points
•There has been recognition that food has to be healthy but also sustainable.

•The WWF Livewell diet 2020 has been produced for aspirational future consumption.

•The main recommendations are increasing consumption of fruit and vegetables, and decreasing meat and sugary foods.

4.1 HEALTH

The nutritional value of food discussed in this section is an important consideration. Delivering the recommendation of a high average intake of fruit and vegetables requires attention to crucial matters such as where the large quantities needed would be produced and how the infrastructure can be developed to permit trade in these perishable products (WHO, 2003). Vegetarian diets[3] with a 66% reduction in livestock product consumption and the adoption of technology to reduce nitrous oxide emissions from soils and methane from ruminants could reduce direct supply chain emissions by 15-20% in the UK. Modifying consumption has a particularly important role to play. However, the nutritional properties of animal products compared with non-animal alternatives may mean that vitamin supplementation is required in the human diet (Audsley et al., 2009).

4.2 GUIDELINE DAILY AMOUNTS FOR THE UK

Guideline Daily Amounts (GDAs) communicate UK nutrient intake recommendations and are incorporated into the nutrition information on food labels. GDAs were developed by the Institute of Grocery Distribution (IGD) in collaboration with retailers, manufacturers, consumer organisations, government and other interested parties. In 2005, GDAs were extended and reviewed, resulting in a consistent "back-of-pack" GDA scheme for adult males and females and children in four age groups.

93 LEADING UK COMPANIES HAVE ADOPTED THE GDA LABELLING SCHEME

Currently, 93 leading UK companies have adopted the GDA labelling scheme. This translates to around 50% of all UK retail food and drink packs featuring GDA icons. There is increasing evidence to suggest consumers respond positively to GDA labelling. One of the UK's largest retailers reported fewer sales of less healthy products and increased sales of healthier options following inclusion of GDA labelling on its own-brand sandwiches[4].

GDAs combine Dietary Reference Values (DRVs) with other UK dietary guidelines (for example, a maximum of 6g of salt per day). Most products provide information on five key nutrients, calories, sugars, fats, saturates and salt, although information on nutrients such as protein, carbohydrates and fibre may also be included. The guidelines for adults are intended for those who are healthy, over 18 and of normal weight. While GDAs for nutrients are recommended amounts, not targets, the GDAs for sugars, fat, saturates and salt are upper limits.

[3] Including the consumption of dairy and eggs.

It is expected that 30% of the GDA for energy and nutrients comes from each meal (breakfast, lunch and dinner); the remaining 10% is normally consumed in the form of snacks and drinks. Any single menu item containing more than 30% of the GDA has "high" levels of energy or nutrients. Adult GDAs are based on an average, healthy woman with a normal level of activity and children's GDAs are based on an average, healthy child aged 5-10 with a normal level of activity.

Table 2:
Guideline Daily Amounts for adults. Source: UK Food and Drink Federation.

Nutrient	Women	Men	Adults
Calories (kcal)	2000	2500	2000
Fat (g)	70	95	70
Saturates (g)	20	30	20
Carbohydrate (g)	230	300	230
Total sugars (g)	90	120	90
Non-milk extrinsic sugars (NMES) (g)	50	65	50
Protein (g)	45	55	45
Dietary fibre AOAC (g)	24	24	24
Dietary fibre NSP (g)	18	18	18
Sodium (g)	2.4	2.4	2.4
Salt (g)	6	6	6

[4] Based on Tesco Clubcard data, January 2006: Weekly sales 8 weeks before and 8 weeks after GDA signposts added (www.gdalabel.org.uk/gda/references.aspx)

4.3 DIETARY REQUIREMENTS

Every individual uses a certain amount of each nutrient daily, so we need enough nutrients from either the daily diet or from body stores. The amount of each nutrient used daily is called the physiological requirement. This is the amount of a nutrient required to prevent signs of deficiency and varies within and between individuals. Inter-person factors which affect nutrient requirements include gender, age, height and weight. Intra-person factors affecting nutrient requirement include age, height, weight, illness and trauma, pregnancy and lactation, growth, physical activity levels, heart rate and climate.

There is a basis of strong evidence to suggest that unhealthy diets and physical inactivity are major risk factors for chronic diseases. In 2004, WHO published a responsive document entitled Global Strategy on Diet, Physical Activity and Health, which suggests guidelines for populations and individuals should:

- Achieve energy balance and a healthy weight
- Limit energy intake from total fats and shift fat consumption away from saturated fats to unsaturated fats and towards the elimination of trans-fatty acids
- Increase consumption of fruits and vegetables, and legumes, whole grains and nuts
- Limit the intake of free sugars
- Limit salt (sodium) consumption from all sources and ensure that salt is iodised.

4.4 EATWELL AND LIVEWELL DIETS

Each government tries to help its population to eat healthily. In the UK, health professionals attempt to quantify nutritional requirements for groups of people with similar characteristics. Dietary recommendations set the standard for an adequate intake for each essential nutrient and the recommendations are underpinned by objective science-based evidence which has not been superseded. The Eatwell plate has been developed by the Food Standards Agency as a health education tool designed to illustrate the proportion in which food should be eaten to make up a healthy diet.

However, increasingly there has been a recognition of the need for a diet that is both healthy and sustainable. Consequently WWF developed the Livewell 2020 diet which used the Eatwell model as its basis but also focussed on sustainability. Comparing the Livewell 2020 with the UK diet shows that to achieve the dietary and GHG targets there will need to be an overall reduction in the amount of protein consumed, with a smaller proportion coming from meat and a higher proportion coming from non-meat and non-dairy sources, as shown by Figure 8.

Livewell 2020

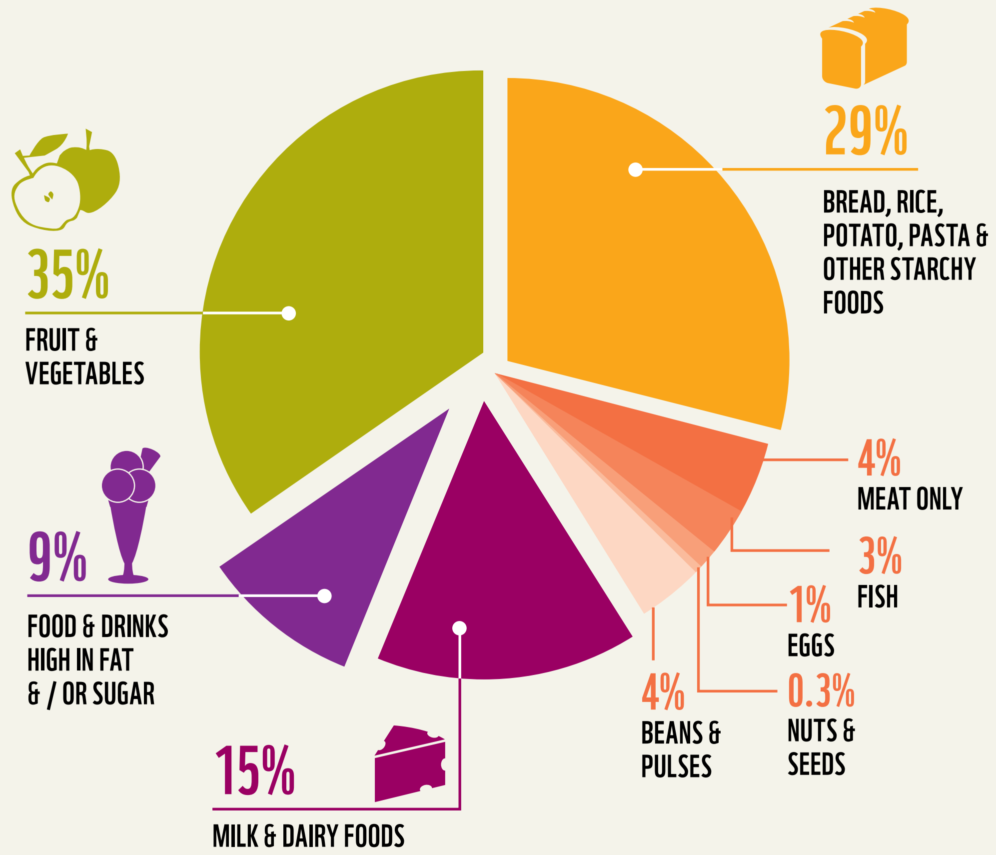
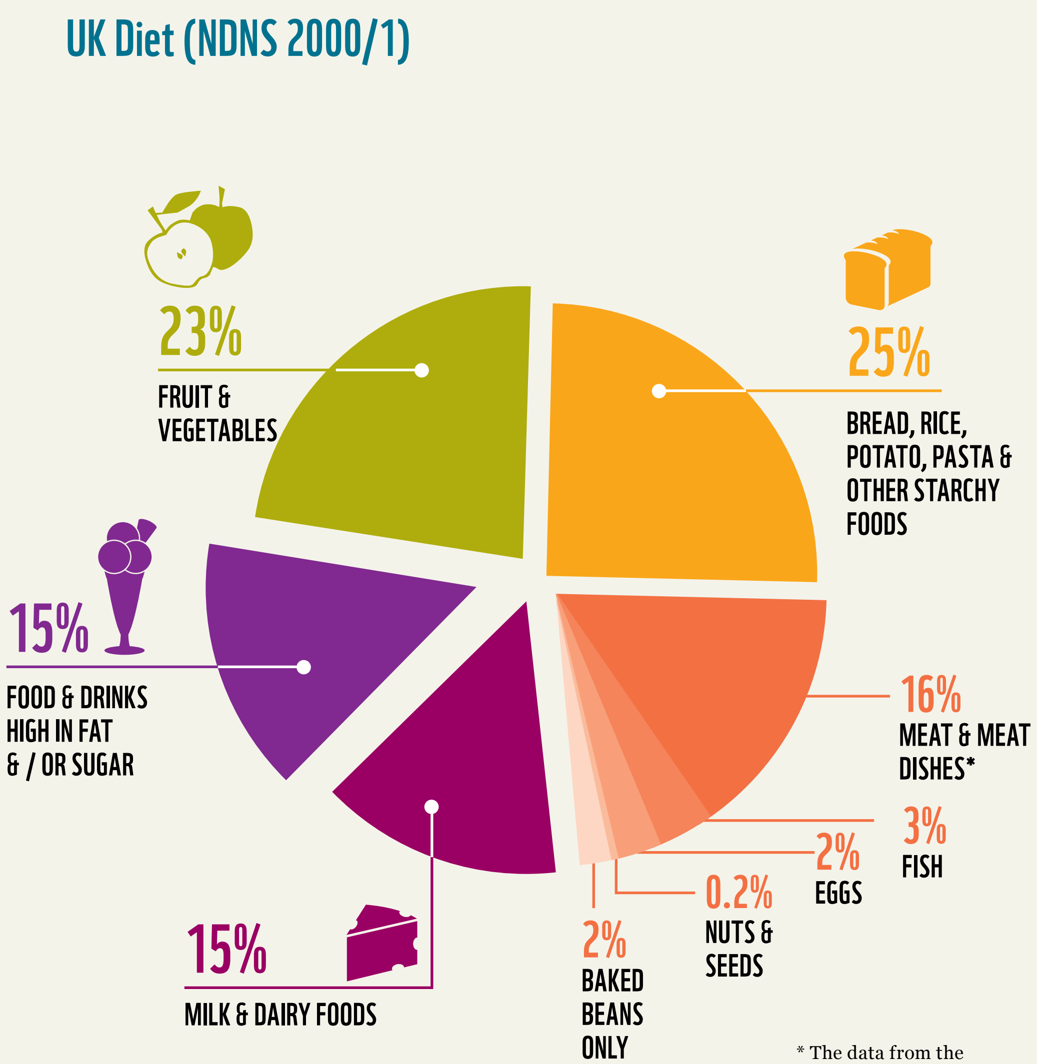


Figure 8:
Eatwell and Livewell diet recommendations. Source: Macdiarmid et al., 2011.



* The data from the NDNS (UK diet) for the meat content of the diet included meat dishes.

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Major shifts in dietary patterns are occurring, including a move from basic staples to more diversified diets. Drivers include urbanisation, increasing incomes, market liberalisation and trade policies.

5. ASPIRATIONAL PRODUCTION SYSTEMS

Key points:

•Aspirational production systems mean different things to different people.

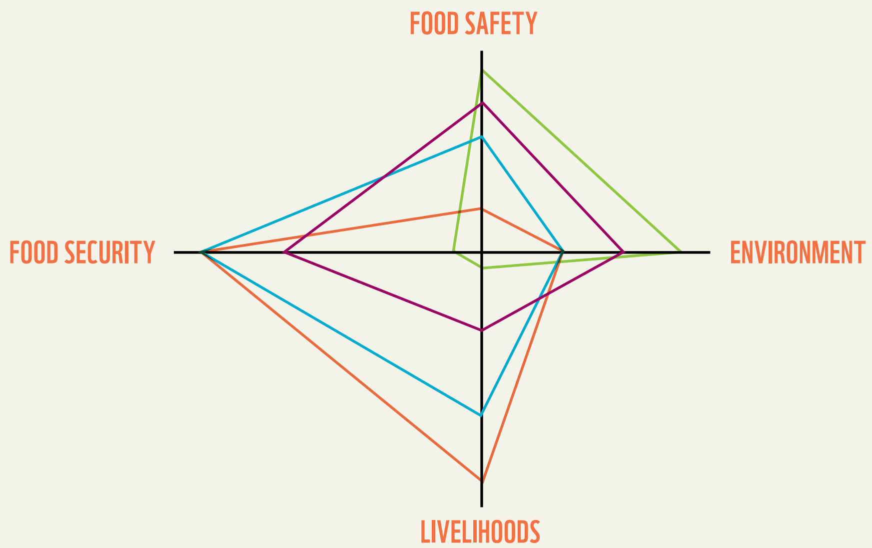
•Food security and livelihoods are the key priorities for low-income developing countries while food safety and the environment are key concerns for a post-industrial society

•Key elements for an aspirational production system to consider are animal welfare, nutritional value, geographical origin of food and type of agriculture practised.

5.1 PRODUCTION SYSTEMS

Aspirational production systems are not always well defined. For statistical purposes farm types are defined but they do not describe the many ways that, for example, production on a cereal farm could be configured. Further, different people will aspire to different things – the move toward a Western-style diet might be considered aspirational by many. Figure 9 illustrates how the process of economic development and industrialisation change food priorities by shifting concern away from food security and livelihoods, towards concern for food safety and the environment.

Figure 9:
Balancing policy objectives. Source: FAO, 2009d.



Key

- Low development, many small holders
- Rapid Industrialization
- Slow Industrialization
- Post-Industrial

5.2 ANIMAL WELFARE

Animal welfare is now a significant issue at European level and welfare standards are safeguarded by a wide range of EU Regulations and Directives. In the UK, voluntary welfare Codes of Recommendations are also in place for many livestock species.

A number of different systems have been developed to assess on-farm animal welfare. The 'Five Freedoms'[5] remain an internationally-recognised animal welfare framework, describing the provisions that should be made in order to avoid unnecessary suffering and to promote good welfare of farm animals.

Welfare has traditionally been assessed on the basis of the housing and resources that have been provided (resource-based measures), however in recent years the focus has shifted to animal-based measures (e.g. lameness) as valid indicators, since welfare is a characteristic of the individual animal, not just the system in which animals are farmed (Butterworth, 2009).

The Farm Animal Welfare Council recently reviewed progress in animal welfare in the UK and presented a new concept of 'quality of life for a farm animal'. This concept describes three states of an animal's life, namely 'a good life', 'a life worth living', and 'a life not worth living'.

In addition to legislation and Codes, voluntary quality assurance schemes for livestock production also set out animal welfare-related requirements. These have been widely adopted in a number of different countries, particularly for housed livestock (such as poultry and pigs) and in response to particular welfare concerns. Such schemes have been established by a range of different bodies, including industry groups, retail and other buyers and specialist animal welfare bodies, such as the RSPCA.

5.3 ORGANIC

The International Federation of Organic Agriculture Movements (IFOAM) defines organic agriculture as "... a whole system approach based upon a set of processes resulting in a sustainable ecosystem, safe food, good nutrition, animal welfare and social justice. Organic production therefore is more than a system of production that includes or excludes certain inputs" (IFOAM). Organic farming is generally envisaged to have a positive impact on biodiversity and is also associated with lower levels of pesticide pollution relative to conventional farming (Defra, 2007), so is viewed as an aspirational production system.

Research by Shepherd et al. (2003) has shown that crop yields are generally less in organic systems. However, organic yields can be very variable. Table 3 shows average crop yields from organic and conventional farming, and stocking rates for poultry and pigs are shown in Table 4.

Table 3:
Yields of organic and conventional crops, based on standard values. Source: Shepherd et al., 2003.

Crop	Organic	Conventional	Crop	Organic	Conventional
Wheat (winter)	4.0	7.7 to 8.5	Potatoes[1]	25	42.5
Wheat (spring)	3.2	5.8	Cabbage	25 to 35	30
Barley (winter)	3.7	6.4	Carrots	36	45
Barley (spring)	3.2	5.8	Onions	20	35
Oats (winter)	4.0	6.8	Apples	10.4	13
Oats (spring)	3.5	5.5	[1]main crop		

[5] Freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury and disease, freedom to express normal behaviour and freedom from fear and distress (Butterworth, 2009)

Table 4:
Stocking rates for organic and conventional intensive pig and poultry housing units. Source: Shepherd et al., 2003.

	Max. house size (livestock numbers)		Max. stocking density	
Enterprise	Conventional	Organic[a]	Conventional	Organic[a]
Poultry (eggs)	No limit[b]	3,000	22 birds/m^2 [c e]	6 birds/m^2 [d]
Poultry (meat)	No limit[b]	4,800	33kg/m^2 (15 birds) or 39kg/m^2 (18 birds) [2c h]	21kg/m^2 (10 birds)[d]
Pigs for fattening	No limit[g]	n/a[f]	1-6 pigs/m^2 depending on size	0.75-1.25 pigs/m^2 depending on size

[a] UKROFS – Individual Certification Bodies may have smaller limits.
[b] Typically, house size 40,000 to >100,000 birds.
[c] No outdoor access required.
[d] Outdoor access required.
[e] There may be several tiers of cages.
[f] Pigs must have access to an outdoor area.
[g] Typically, house size >2000 fattening pigs under organic regulations (apart from the final fattening stage – maximum 20% of lifetime).
[h] Updated figure from CIWF, 2007, 39kg/m^2 is allowed if additional requirements are met.

Audsley et al. (2009) found that there is little scope for reductions in GHG emissions through the widespread adoption of organic farming in the UK, with reductions in supply chain GHG emissions of about 5% (Audsley et al., 2009). The impact of organic farming on soil quality is somewhat mixed. For instance, organic farmers pay special attention to their soils as operating a sound rotational system to feed the soil is a fundamental part of organic farming – although organic matter may also be added directly to the soil in conventional farming (Defra, 2007). To date there has been no direct evidence of differences occurring in the rate of phosphorus leaching between organic and conventional farming methods (Defra, 2007).

5.4 LOCAL FOOD

A desire for renewed “connectedness” between people and food has increased interest in local foods, encouraging farmers’ markets and farm shops, which provide opportunities for high value agricultural produce (Audsley et al., 2010). Food security can be improved as a result of local food, as it decreases reliance on imports and reduces fossil fuel transportation. Local food boosts local economies and creates jobs whilst also providing a route to market for new, micro, small and medium sized businesses (CPRE, 2012). An example is Totnes, which has developed a thriving local food economy worth £4-8 million a year supporting local jobs (CPRE, 2011).. Local food is generally associated with seasonality and food at its natural best, and with reduced need for energy and associated pollution from heat, light and transport as well as being linked with careful management of habitats for wildlife (CPRE, 2012). Local food is also associated with higher animal welfare, for example, a shorter transport distance to abattoirs minimises animal stress during transport. Given the perceived economic, environmental and social benefits of local food, increasing the proportion of local food is often considered key in aspirational food production systems.

6. TRENDS IN THE AVAILABILITY OF AGRICULTURAL LAND FOR FOOD PRODUCTION

Key points:
- Availability is affected by policies that affect the primary drivers of competition for land – population growth, dietary preference, protected areas, forestry policy.
- Technology for increasing per area productivity are necessary.
- There is considerable uncertainty in drivers, pressures, data and models.
- Policy responses need to reflect conflicting demands on land use and provide a guide to land-use intensity.

6.1 DRIVERS OF PRODUCTION

Future policy decisions in the areas of agriculture, forestry, energy and conservation are likely to impose different demands for land to supply multiple ecosystem services. Agricultural land for growing food and feed crops for livestock and for pasture occupies about 5,000 million hectares, or 38% of the total global land area, with almost 13% of the total global land area being used for crops (Government Office for Science, 2011). Smith et al (2010) show that competition for land is not a driver affecting food and farming in the future but is an emergent property of other drivers and pressures.

In addition, there is considerable uncertainty over the intensity of future competition for land and its regional distribution. Smith et al. (2010) conclude that it is clear that per area agricultural productivity needs to be maintained where it is already close to optimal or increased in the large areas of the world where it is sub-optimal. To do so without damaging the environment is not easy. However, McVittie et al. (2011) show that investment in agricultural knowledge, science and technology can yield significant cost-benefit advantages when biodiversity damage is avoided, with this positive ratio increasing significantly when carbon benefits are accounted for.

International trade flows provide an important balancing mechanism for world agricultural markets (Nelson et al., 2010). Trade flows can partially offset local climate change productivity effects and the increased likelihood of extreme weather events, allowing regions of the world with positive (or less negative) effects to supply those with more negative effects. The price spikes of 2008 and 2010 both had important weather components, and during each of these periods, trade flows offset some of the locally severe potential effects (Nelson et al., 2010). On the import side, lower trade barriers reduce domestic food prices, increase the purchasing power of consumers and afford them a greater variety of food products (WHO, 2003). The remedial role of trade will therefore be increasingly critical in the future (Nelson et al., 2010).

In developing countries, demand is predicted to grow faster than production, resulting in a growing trade deficit (WHO, 2003). Restrictions on international trade could therefore jeopardise prospects for regional food security (Nelson et al., 2010). The recent spike in agricultural prices was further aggravated by policies such as export restrictions or bans, through which various countries tried to keep their domestic prices low in favour of their own consumers (FAO, 2009a). Ensuring an adequate supply of food at the aggregate level, globally or nationally, does not guarantee that all people have enough to eat (FAO, 2009a).

6.2 BIOFUELS

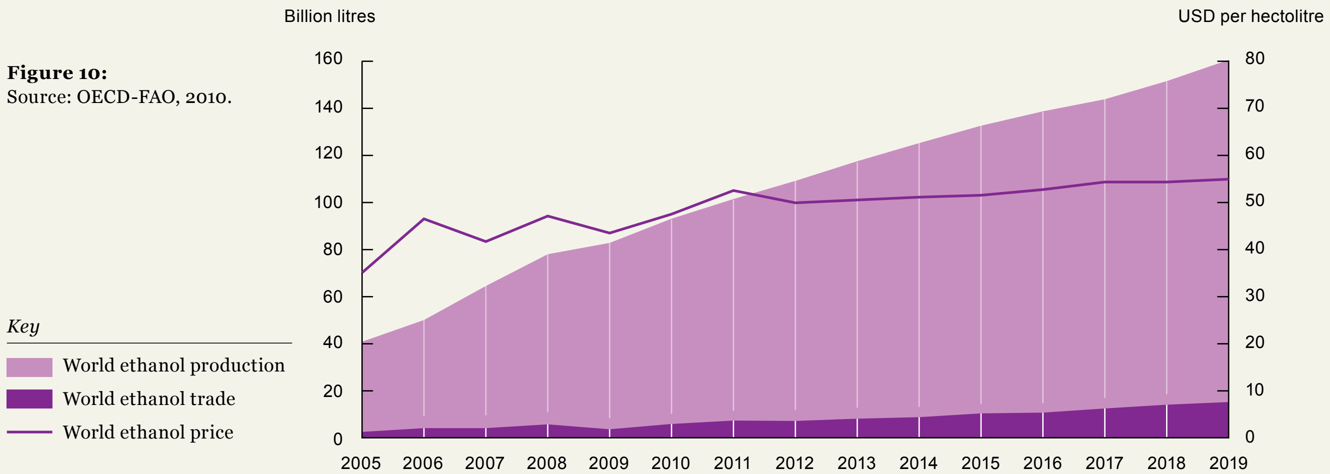
BIOFUEL PRODUCTION ACCOUNTS FOR ABOUT 7% GLOBAL COARSE GRAIN USE 9% VEGETABLE OIL USE 2% GLOBAL CROPLAND

Biofuels are the largest source of new demand for agricultural commodities, with production more than tripling over the period 2000-2008. Biofuel production accounts for about 7% of global coarse grain use (rising to 12% by 2018), 9% of global vegetable oil use (rising to 20% by 2018) and 2% of global cropland (rising to 4% by 2030) (FAO, 2009b). Recent growth in biofuel production is represented in Figures 10 (ethanol) and 11 (biodiesel), with such increases envisaged to continue well into the current decade.

Countries have adopted policies to stimulate biofuel production and consumption for one or more of the following reasons: to reduce dependence on fossil fuels (energy security), to reduce GHG emissions in the transport sector (climate change mitigation) and to create demand for surplus agricultural crops (farm income support) (Fonseca et al., 2010). In the short term, the benefits have gone primarily to farmers in developed countries (FAO, 2009b).

Global ethanol production to grow by more than 110%

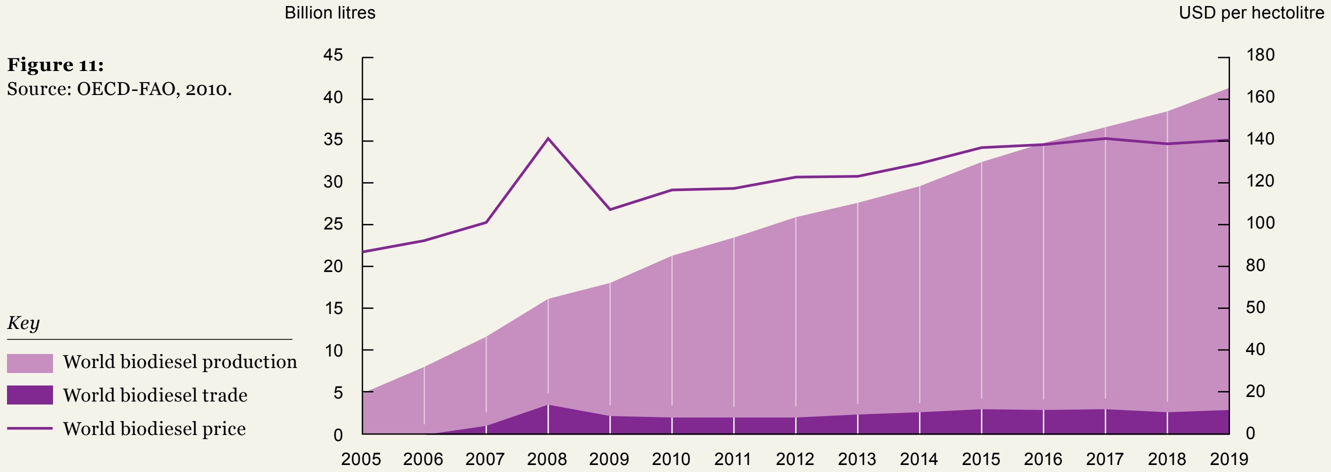
Figure 10:
Source: OECD-FAO, 2010.



Source: OECD and FAO Secretariats

Global biodiesel markets to continue to expand

Figure 11:
Source: OECD-FAO, 2010.



Source: OECD and FAO Secretariats

Most studies conclude that rapid growth in biofuel demand contributed to food price increases over the period 2000-2007 (Fonseca et al., 2010), although there is some ambiguity. For instance Fonseca et al. (2010) conclude that the rise of biofuels was not the dominant driving force behind food price increases, while Mitchell (2008) estimates that biofuels are responsible for more than 70% of these increases. Prices are expected to remain higher in the future than they would be in the absence of increased biofuel production

The majority of EU biofuel consumption has been met through reusing recently abandoned agricultural land, or through slowing down the rate of land abandonment in the EU (Fonseca et al., 2010). First-generation biofuels based on sugar and starch crops (ethanol) and oilseed crops (biodiesel) compete directly with demand for these crops as food or feed (Fonseca et al., 2010). At the same time, some of the resources previously available to livestock at a low cost are becoming increasingly costly, because of growing competition for these resources from other economic sectors and activities such as biofuel production (FAO, 2009d). The most obvious consequence of large-scale liquid biofuel production for the livestock industry is higher crop prices, which raise feed costs. Biofuel production also increases returns on cropland, which encourages conversion of pastureland to cropland (FAO, 2009d). One silver lining is that biofuel production also produces outputs which are useful in other areas of agriculture. One such output is rapemeal, a high-protein feed produced when the oil is extracted from rapeseed. Quantities of rapemeal have increased in recent years as more rape oil has been produced for use as biodiesel (Audsley et al., 2010).

As energy markets are large compared with agricultural markets, energy prices will tend to drive the prices of biofuels and their agricultural feedstocks (FAO, 2008b). This will translate into high input prices for chemicals and fertilisers as well as high transportation costs (FAO, 2009d). The emergence of the biofuels sector has now forged a closer link to crude oil markets, particularly for grains, oilseeds and sugar (OECD-FAO, 2010). The sharp increases in prices of key food commodities such as maize, wheat, rice and soybeans in 2007/2008 mirrored the increase in prices of energy products and strengthened recognition of the closer link between energy and agricultural markets (FAO, 2009a).

Figure 12 illustrates the recent and projected price of crude oil, with modest growth expected in the real price of oil for the remainder of this decade. Accordingly, the demand for agricultural feedstocks (sugar, maize, oilseeds) for liquid biofuels is expected to continue its growth over the next decade and perhaps beyond, putting upward pressure on food prices (FAO, 2009a). Should ethanol become competitive with fossil fuels, a large share of the growth in maize demand will become associated with growth in ethanol production, and the link between crude oil price and maize price will be strong (Tyner and Taheripour, 2008). It is estimated that by 2030, 44-53 million hectares of EU land could be used for growing biofuel crops; this compares with the current arable land area of approximately 82 million hectares (Fisher et al., 2010). As a result of increasing biofuel and food demand, the international price of all the UK's major agricultural products is predicted to remain about 25-30% higher by 2017 compared to 2003-2006 (OECD-FAO, 2008). High energy-price fluctuations are increasingly translated into high food-price fluctuations (IUFoST, 2010).

Oil price resumes upward trend

Figure 12:
Source: OECD-FAO, 2010.

Source: OECD Economic Outlook No. 86 (December 2009)

Conversely, second-generation biofuels, which are not currently commercially available, use biomass from non-food sources, including lignocellulosic (wood) biomass, waste matter from food crops or residues from other non-food processes (Fonseca et al., 2010). Second-generation biofuels promise to deliver higher yields. Dedicated cellulosic energy crops (such as reed canary grass) can produce more biofuel per hectare because the entire crop is used as fuel feedstock. These crops, like food crops, require land, although some may be grown on poor land that would normally not be used for food production (Fonseca et al., 2010). Certain biofuel crops can grow on degraded land, exhibit drought-resistance and might also have the potential to improve soil properties. Two frequently quoted examples are Jatropha curcas and Pongamia pinnata (IUFoST, 2010). The apparent ability of some second-generation biofuel crops to flourish on marginal land that is unsuitable for food crop production may well reduce competition between food and biomass (Fonseca et al., 2010).

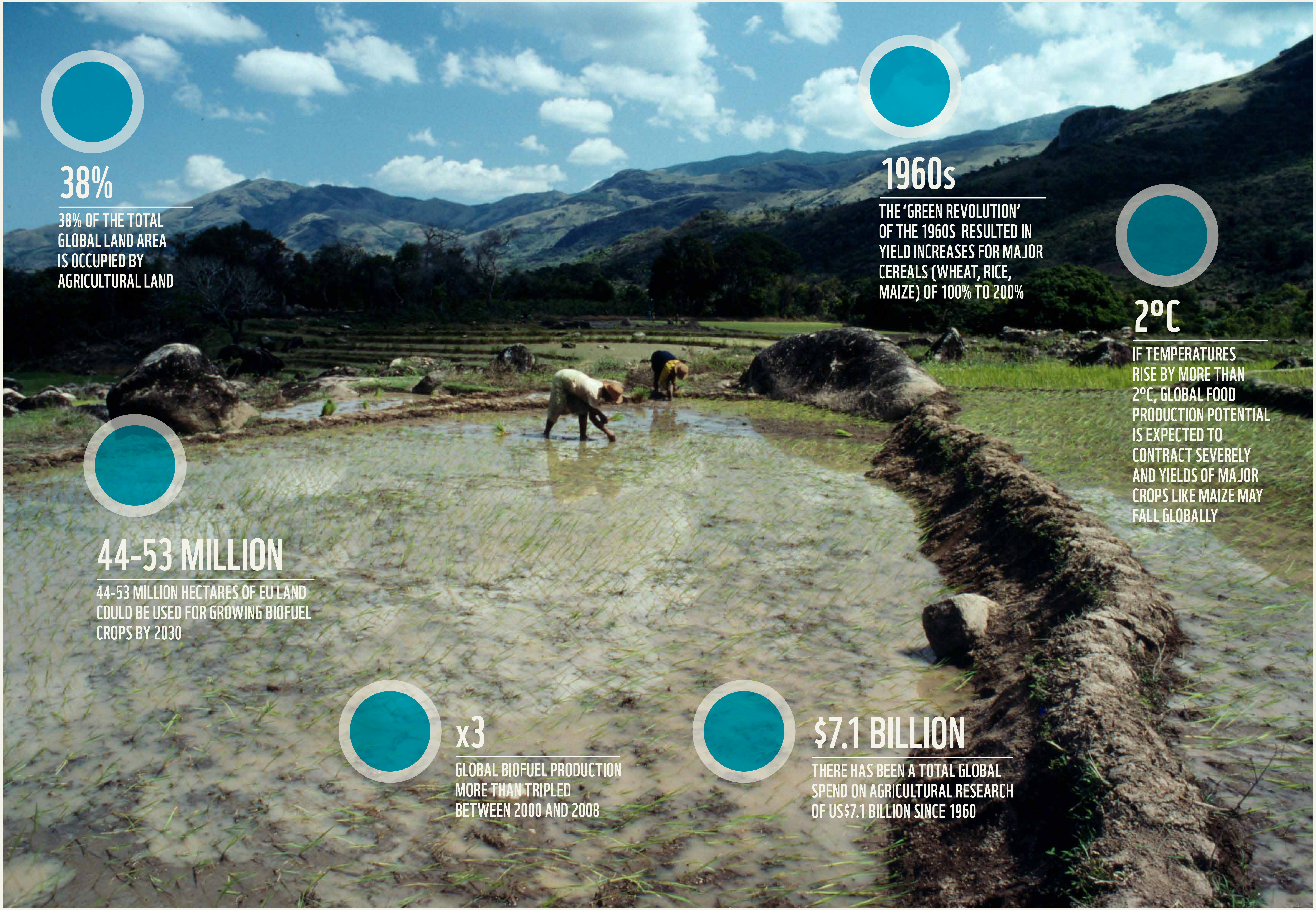
6.3 OTHER DRIVERS OF LAND USE

Land has competing uses and the changing mosaic of land use involves trade-offs between a number of sectoral interests, with agricultural production competing with industry, transport, energy, mining and forestry. The European environment – state and outlook 2010 (SOER, EEA, 2010) states that non-food-related drivers of land use in Europe are:

- Settlement and infrastructure patterns influenced by the demand for increased living space per person
- The link between economic activity and transport demand and the resulting growth in transport infrastructure.

Policy decisions can heavily influence land use. Much debate in Europe (and beyond) is centred on the multiple objectives of agriculture. Mariann Fischer Boel, EU Agricultural Commissioner 2004-2010, stated that agricultural land must be capable of maintaining the countryside, conserving nature, making a key contribution to the vitality of rural life, and responding to consumer concerns and demands regarding food quality and safety, environmental protection and animal welfare. These multiple and sometimes conflicting objectives place strains on the financial viability of the farming sector.

The SOER (2010) thematic assessment of land use suggests that policy responses need to help resolve conflicting land-use demands and to guide land-use intensity to support environmental land management.



38%
38% OF THE TOTAL GLOBAL LAND AREA IS OCCUPIED BY AGRICULTURAL LAND
1960s
THE 'GREEN REVOLUTION' OF THE 1960S RESULTED IN YIELD INCREASES FOR MAJOR CEREALS (WHEAT, RICE, MAIZE) OF 100% TO 200%
2ºC
IF TEMPERATURES RISE BY MORE THAN 2ºC, GLOBAL FOOD PRODUCTION POTENTIAL IS EXPECTED TO CONTRACT SEVERELY AND YIELDS OF MAJOR CROPS LIKE MAIZE MAY FALL GLOBALLY
44-53 MILLION
44-53 MILLION HECTARES OF EU LAND COULD BE USED FOR GROWING BIOFUEL CROPS BY 2030
x3
GLOBAL BIOFUEL PRODUCTION MORE THAN TRIPLED BETWEEN 2000 AND 2008
$7.1 BILLION
THERE HAS BEEN A TOTAL GLOBAL SPEND ON AGRICULTURAL RESEARCH OF US$7.1 BILLION SINCE 1960

7. TRENDS IN AGRICULTURAL YIELDS

Key points:

- Agricultural output has kept pace with rapid rises in global food demand over the past 50 years – but will this be the case over the next 50 years?
- There is a good prospect of achieving approximately 50% increase in crop production without the need for extra land (assuming no land is taken to produce bioenergy).
- Socio-economic factors are a key component of the food production system and government needs to adopt a holistic policy.
- Breeding should allow large increases in crop yields in an environment with increased CO2 levels with most airborne pests and disease remaining controllable, assuming crop protection chemicals remain available.
- The gap between potential and actual yield needs to be reduced.

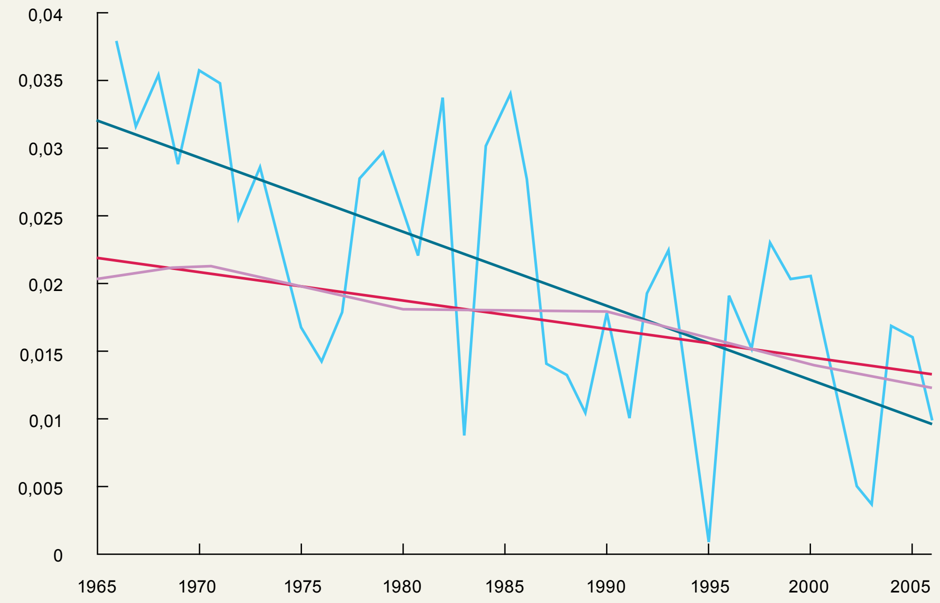
7.1 TRENDS IN CROP YIELDS

The green revolution
Over the last 50 years, agricultural output has kept pace with the rapid rises in global food demand. This has largely been achieved through increases in yield rather than area (Audsley et al., 2009). The introduction of hybrids in the 1950s saw significant rises in sorghum and maize yields in the USA (Edgerton, 2009), while the 'green revolution' of the 1960s marked the introduction of high-yielding varieties of wheat and rice, resulting in yield increases for major cereals (wheat, rice, maize) of 100% to 200% (Nelson et al., 2010; FAO, 2009a). However, yield growth rates were unequally distributed across crops and regions; despite the successes in cereal crops, yield growth for millet, sorghum and pulses (which are major staples for resource-poor farmers and rural households) was slow (FAO, 2009e).

Since the advancement of the green revolution, the relative growth in yield increase has declined steadily and has now fallen below the rate of population growth (Figure 13); growth rates of cereal yields dropped from 3% per year in 1965 to 1.5% in 2000 (Figure 14).

Growth in yields relative to population growth

Figure 13:
Source: Audsley et al., 2009.



Key
Population
Cereal Yields
Linear (Population)
Linear (Cereal Yields)

y = -0.0005x + 0.0327
R2 = 0.4608

Growth rates of yields for major cereals, 1960-2000

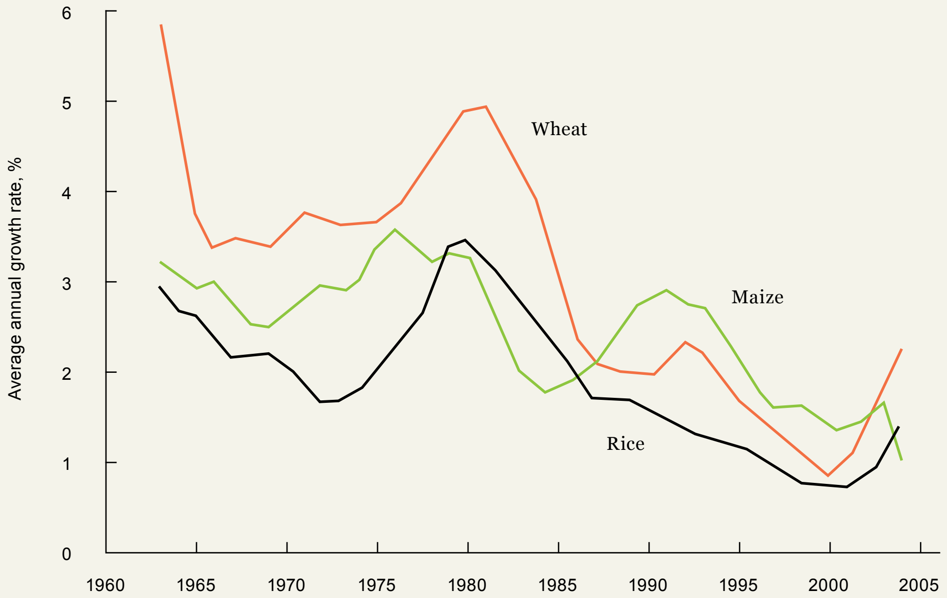


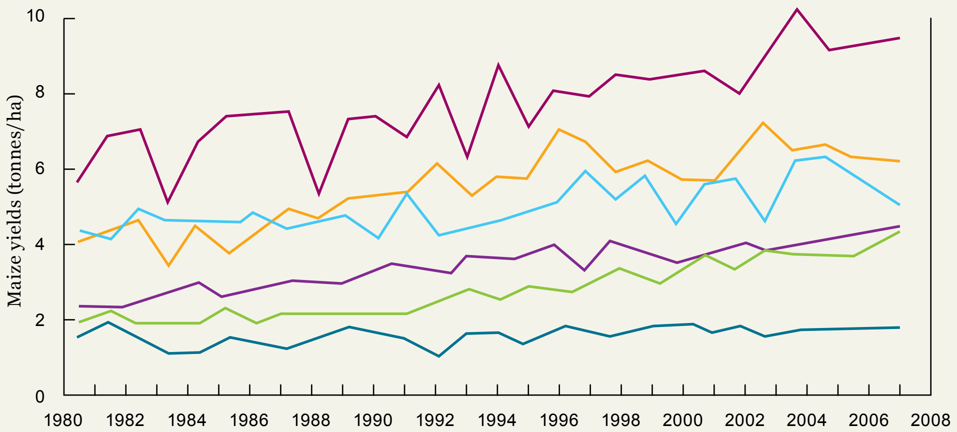
Figure 14:
Source: FAO, 2009a.

7.2 TEMPORAL VARIATIONS IN YIELD TRENDS

While the levelling off or reduced rates of improvement in cereal crop yields is common throughout the world, the timing and reasons for such turning points differ according to region. Despite the adoption of similar farming practices in most of the major grain producing countries, yields are still very variable (Edgerton, 2009). For example, cereal yields in Africa have shown little growth and are still at around 1.2 tonnes per hectare, compared to an average yield of some 3 tonnes per hectare in the developing world as a whole. The Foresight report (Government Office for Science, 2011) states that yields in the Russian Federation are estimated to be less than half their current potential, while in Sub-Saharan Africa yields are at only a third of their potential. The temporal and spatial variations for maize in different global regions are shown in Figure 15.

Variant progress in maize yields, 1980-2007

Figure 15:
Source: FAO, 2009.



Key

- Africa
- Asia
- North America
- Europe
- South America
- Oceania

Lywood et al. (2009) discuss how, for most of the world's main food crops, yields have grown significantly faster during periods of higher demand growth. They assert that these variations reflect the range of measures available to growers to enhance yields of each crop, which are typically not fully deployed during periods of low demand growth and low relative price. Furthermore, their observations show that the relationship between crop yield, area and price changes are not independent; and that area changes and yield changes in response to market signals are different for different crops and regions.

Peltonen-Sainio et al. (2008) also observe temporal changes in the interaction of yield-influencing factors. In the early phases of modern agriculture (characterised by large-scale mechanisation of crop production) actual expressed yield resulted from interaction between growing conditions, genetic gains, growing conditions and crop. Since then, the equation has gradually broadened to include additional interacting elements, market effects and environmental motives. Examples include economic incentives for farmers who aim to improve sustainability, and the adjustment of input use for cereal production according to changes in cereal pricing on global and regional markets.

7.3 SPATIAL VARIATIONS IN YIELD TRENDS

Socio-economic, technological and environmental factors all affect the spatial variation in crop yields. While agro-environmental factors such as soil type and rainfall impose varying limits to productivity for the different regions of the world, evidence suggests that socio-economic factors have a greater influence on the spatial trends in yield. For example, in low-income countries farmers do not have sufficient economic incentive to adopt yield-enhancing seeds or cropping techniques. Numerous factors compound this issue (GoScience, 2011b):

- Lack of access to credit
- Poorly defined property rights
- Lack of insurance
- Paucity of weather forecasts
- Inefficient tax and subsidy regimes
- Lack of regulation
- Lack of specific agriculture policy expenditure and investment

With regard to spatial variations in yield for maize (Figure 15), the continued use of less robust agronomic practices such as open-pollinated corn varieties instead of hybrids, low input rates or poor soil management magnify the effects of unfavourable weather in countries such as South Africa and Romania, reducing crop productivity (Edgerton, 2009). Similarly, particularly marked yield gaps can also be seen between North America and Africa (Figure 15: FAO, 2009a). In contrast to the lower-yielding countries, the USA has sustained steady increases in maize yield through fertiliser management, more efficient farm machinery and breeding hybrids with improved stress tolerance (Edgerton, 2009).

Within Europe, Peltonen-Sainio et al. (2008) recognise two major contributors to changes in yield trends: genetic improvements and changes to crop management practices. The success of management practices determines the extent to which increases in genetically controlled yield potential can be realised. Both of these factors depend upon the growing conditions of the area. In more marginal production areas, the environment poses increased challenges to production. For example in northern European conditions, the major constraints to cereal production are harsh winters, short growing seasons, risk of night frosts during early and late growth periods and uneven precipitation, with possibilities of early summer drought and heavy rain close to harvest.

IN MORE MARGINAL PRODUCTION AREAS, THE ENVIRONMENT POSES INCREASED CHALLENGES TO PRODUCTION

7.4 OPTIONS FOR CLOSING GAP BETWEEN SUPPLY AND DEMAND IN YIELD

Peltonen-Sainio et al. (2009) suggest that solutions to closing the gaps in yield between various global regions lie with public sector investments in infrastructure and institutions, and sound policies to stimulate adoption of technologies that reduce costs as well as improving productivity, thus leading to an increase in agricultural incomes. Plant breeding plays an important role in closing yield gaps by adapting varieties to local conditions and by making them more resilient to biotic (e.g. insects, diseases, viruses) and abiotic stresses (e.g. droughts, floods). Studies examined by the FAO estimated that the global yield loss due to biotic stresses averages over 23% of the estimated attainable yield across major cereals (FAO, 2009a).

Changes in crop management techniques can also help close yield gaps. As described in section 7.3 the regions which have been most successful in increasing and maintaining yields are those which have adopted improved agronomic techniques and associated technologies. In order for such improvements to be rolled out to lower-yielding regions there will need to be improvements to the underlying socio-economic drivers such as market price, infrastructure and support services so as to provide sufficient incentives for farmers to adopt improved practices.

Increasing the socio-economic incentives for improved crop production in low-yielding countries could be very significant in helping avoid future food shortages. For example, Edgerton (2009) proposes that raising corn yields in the 10 largest below average corn-producing countries to the world average would result in an additional 100 million tonnes of corn, or about 80% of the projected growth in demand by 2017 (Edgerton, 2009).

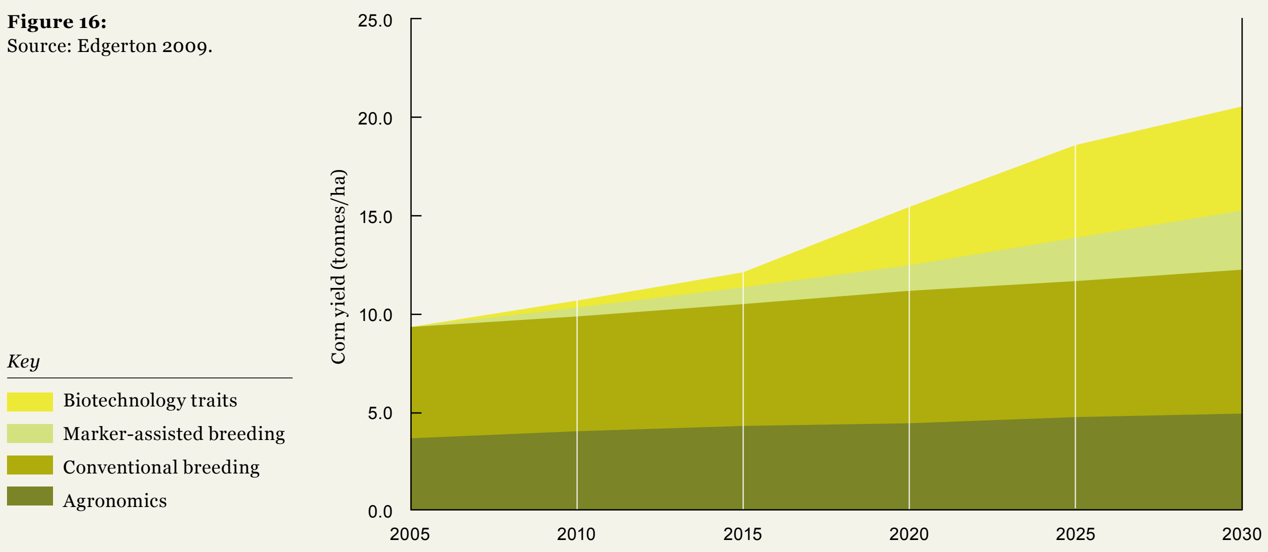
7.5 FUTURE TRENDS IN CROP YIELDS

Technology
Technological developments, particularly in genetically modified crops, are likely to become more significant in helping to increase yield potential again. With reference to maize yields in the USA, Edgerton (2009) states that the combination of marker-assisted breeding, biotechnology traits and continued advances in agronomic practices has the potential to double corn yields in the United States over the next two decades (Figure 16). Doubling US average yields would raise US average yields to approximately 20 tonnes/ha, values now rarely seen in non-irrigated corn.

Improving yields in corn and other crops on a global basis would allow farmers to meet global demand for feed, fuel and food while minimising the need to bring large amounts of new land into crop production. However, this would require significant improvements in stress tolerance, water-use efficiency and broad dissemination of excellent agronomic practices.

Anticipated impact of improvements in agronomics, breeding and biotechnology on average corn yields in the United States

Figure 16:
Source: Edgerton 2009.



Climate change
Yield improvements are driven by a combination of factors including increased mechanisation and other capital investments, agronomic improvement, increased inputs, growing conditions and socio-economic factors such as market prices, policies and financial incentives. These factors will continue to influence yield trends in the future. However, it is expected that climate change will have a greater, yet uncertain impact on yield potential (Nelson et al., 2010; FAO, 2009a).

A study by the International Food Policy Research Institute (Nelson et al., 2010) affirms that agricultural productivity is strongly determined by both temperature and precipitation. Uncertainties related to temperature were found to cause a greater contribution to climate change impact uncertainty than those related to precipitation for most crops and regions; in particular, the sensitivity of crop yields to temperature was a critical source of uncertainty.

Nelson et al. (2010) use economic modelling to provide detailed analysis of global agricultural prospects, incorporating quantitative scenarios of economic and demographic futures and the threats that climate change poses. This provides insight into potential future crop trends. One of the report outputs is the combined effects of the intrinsic productivity growth rates, climate change[6] and the economic and demographic drivers of yields for the major crops in irrigated and rain-fed systems. This shows that for irrigated crops, the yield growth rates range from a low of about 0.2% per year (0.22% per year for maize in developed countries, under an optimistic scenario[7]) to a high of over 1.5% per year (1.53% for irrigated soya in developed countries, with perfect mitigation[8] and the baseline scenario).

Yields in low-income developing countries are generally lower than in middle-income developing or developed countries, both in 2010 and 2050. For some crops (cassava, potato, sorghum and wheat), both rain-fed and irrigated yields grow faster in the low-income developing countries than in the middle-income developing countries.

However, for the important irrigated crops, low-income developing country growth rates remain low. For rain-fed systems, yields and yield growth rates are somewhat lower than for irrigated systems. Yield growth rates range from a low of 0.25% per year (developed country maize with assumed climate change[9] and the optimistic scenario) to a high of 1.88% per year (wheat in low-income developing countries with perfect mitigation and the pessimistic scenario).

According to the Intergovernmental Panel on Climate Change (IPCC), if temperatures rise by more than 2°C, global food production potential is expected to contract severely and yields of major crops like maize may fall globally. The declines will be particularly pronounced in lower-latitude regions. In Africa, Asia and Latin America, for instance, yields could decline by 20-40% if no effective adaptation measures are taken. In addition, extreme weather events such as droughts and floods are becoming more frequent, causing greater crop and livestock losses (FAO, 2009e).

Disease

An increase in both agricultural crop and livestock yields will also be affected by an increase in pathogens. Indeed Cutler et al. (2010) consider that "in the next two decades, climate change will be the most serious issue that dominates re-emergence of pathogens into new regions" – and this includes zoonotic diseases (diseases that can be transmitted from animals to humans). Climate change will affect the evolution of pathogens and disease vectors and changing circumstances and pathogen diversity will lead to diseases with altered pathogenic potential.

Availability of fertiliser

Agricultural yields could be affected in the future by the availability of fertiliser, in particular phosphorus. Phosphorus (P) is a key artificial fertiliser, along with nitrogen (N) and potassium (K). Nitrogen can be obtained from the air and supplies of potassium remain plentiful, but the "peak" in the supply of mined phosphate rock could be as soon as 2033. After this point, the non-renewable resource will be both scarce and expensive. Dwindling stocks of phosphorus could have an effect on agricultural yields and food security. The Soil Association estimates that without fertilisation from phosphorus wheat yields could fall from nine tonnes a hectare in 2000 to four tonnes a hectare in 2100. The location of the remaining rock phosphorus causes additional problems, as 87% of known reserves are found in a handful of countries. The biggest reserves are in Western Sahara and Morocco (35%) followed by China (23%), Jordan (9%), South Africa (9%) and the USA (7%). This means that other countries are dependent on imports and the entire market is open to price volatility.

However, there are possibilities of reducing our dependency on phosphorus by changing the way we farm, eat and dispose of waste such as human excreta. There are methods for increasing the availability of naturally occurring phosphorus in soils. According to the Soil Association, "the ability of the soil to maintain a pool of phosphorus in a soluble form that is available to plants can be encouraged in a number of ways and steps can be taken to use crops that make the most efficient use of available phosphorus". Methods they suggest include the use of organic farming. However, methods such as these, while providing significant benefits, will not secure the high yield levels required globally for a growing population.

[6] The climate change scenario is based on the mean of four potential climate change scenarios which consider temperature and precipitation.

[7] Scenario is optimistic in terms of income and population growth assumptions.

[8] Within the report, perfect mitigation is defined as an extremely unlikely scenario, whereby the climate of the early 2000s continues through to 2050.

[9] The climate change scenario is based on the mean of four potential climate change scenarios which consider temperature and precipitation.

Soil erosion/loss

Increase in land available for agriculture is relatively low in comparison with global crop yield increases; according to the Foresight report, global crop yields grew by 115% between 1967 and 2007, with the area of land in agriculture increasing by only 8%.

Soil erosion means that, quite simply, less land is available to grow crops, which could threaten food security. The International Soil Reference and Information Centre (2009) estimates that around a quarter (24%) of vegetated land on Earth has undergone human-induced soil degradation, particularly through erosion, creating an additional degree of uncertainty for the future of global crop yields.

7.6 FUTURE TRENDS IN LIVESTOCK PRODUCTION

Livestock yields have also been the subject of increasing scrutiny with the growth in demand for livestock products set to increase significantly. There is debate about the increase in livestock production systems that is required and the potential available.

Thornton et al. (2010) have produced a provisional forecast using data from 1980–2015 adapted from Steinfeld et al. (2006) and for 2030–2050 from FAO (2006) as shown in Table 5. Both developing and developed countries show an increase in consumption of meat and milk, but the rate of increase in developing countries is very high – a more than 100% increase in total consumption of both meat and milk. It should be pointed out that this rapid increase in demand is only one possibility and, as the authors note, this situation will require a drastic improvement in existing science and technology to be achievable.

Table 5: Past and projected trends in consumption of meat and milk in developing and developed countries. Source: Thornton et al., 2010.

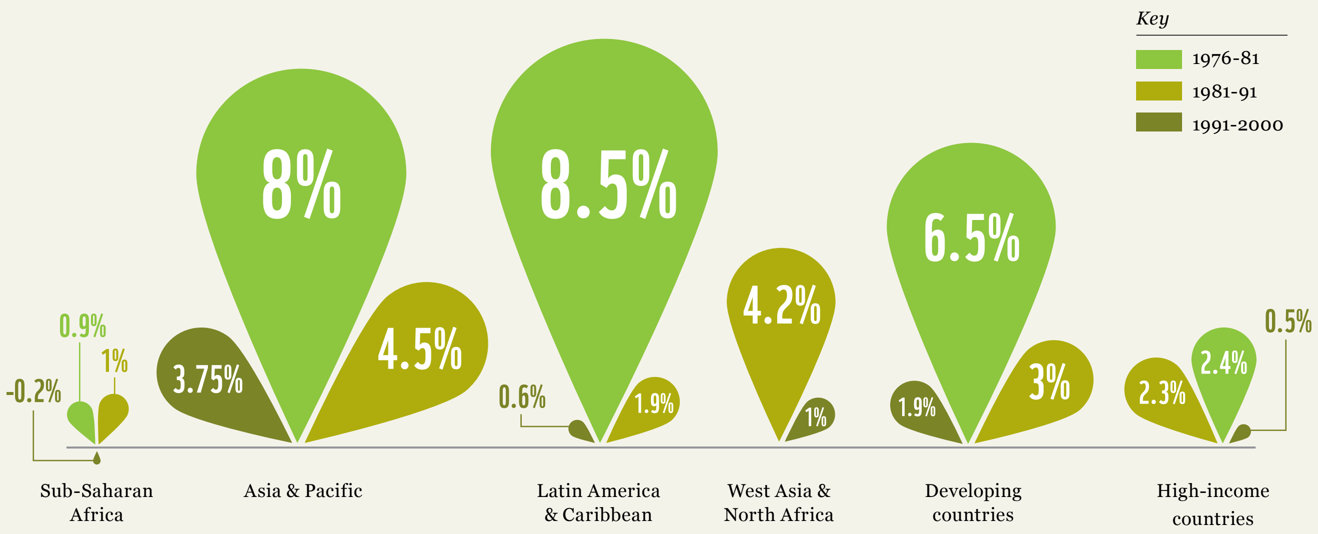
	Year	Annual per capita consumption		Total consumption	
		Meat (kg)	Milk (kg)	Meat (Mt)	Milk (Mt)
Developing	1980	14	34	47	114
	1990	18	38	73	152
	2002	28	44	137	222
	2015	32	55	184	323
	2030	38	67	252	452
	2050	44	78	326	585
Developed	1980	73	195	86	228
	1990	80	200	100	251
	2002	78	202	102	265
	2015	83	203	112	273
	2030	89	209	121	284
	2050	94	216	126	295

7.7 THE CHALLENGE AHEAD

Technological advancement is viewed as the bridge to reversing the gap between yield supply and demand (FAO, 2009e) but as Figure 17 shows there has been a considerable decline in agricultural research and development (R&D). The economic rates of return on investment in agricultural R&D are high – around 40% in both high-income and low-income countries. Research by the Consultative Group on International Agricultural Research (CGIAR) shows total agricultural research expenditure of US$7.1 billion since 1960 but the benefits from this research measured since 1989 range from nearly US$14 billion to more than US$120 billion. Even the most conservative estimates far outweigh the total investment. It would seem clear that additional investment in agriculture research is required to meet future food demands.

Annual growth rates in agricultural R&D by geographic area.

Figure 17:
Source: FAO, 2009a.



8. POTENTIAL FOR TECHNOLOGICAL CHANGES TO IMPROVE PRODUCTION SYSTEMS

Key points:
- Most of the potential technological changes are focussed on conventional production systems, particularly:
- Increasing input efficiencies
- Improving efficiency by breeding higher-yield and more robust plants and animals
- Using water more efficiently
- Increasing resilience to abiotic and biotic stresses.

Addressing the production gaps
Addressing production gaps will require the deployment of new technologies, but also the dissemination of existing technologies so small farmers in developing countries can access them. Key areas for technological intervention to improve production output include water scarcity and post-production losses (FAO, 2009e).

Although much yield improvement has already been achieved by variety development, there is substantial scope for further technology development before theoretical limits are reached for wheat (Sylvester-Bradley and Wiseman, 2005) and maize (Edgerton, 2009). There is even greater opportunity for other crops including minor cereals such as sorghum and millets, roots and tubers such as cassava and yams, which have received less attention so far, and which are very important for food security, particularly in sub-Saharan Africa (Government Office for Science, 2011).

New variety development by seed companies and adoption by growers are both long-term activities driven by price and therefore by growth in demand. Increased mechanisation increases yield by enhancing soil structure, improving the speed and consistency of planting, increasing the scope for additional inputs during crop growth, and increasing the speed and effectiveness of harvesting operations. Other capital investments such as in drainage and irrigation can reduce the adverse impact of external agronomic factors such as waterlogging or drought. Capital investment is dependent on historic crop price and demand, both as a source of cash for the investment, and as a determinant of expected returns from this investment. Consequently, the widespread adoption of such measures is also driven by price and demand growth. Varying inputs such as fertilisers, water, pesticides and herbicides can offer the most immediate change in crop yield in response to price signals, but the types and costs of inputs, as well as their yield-enhancing potential, varies significantly between crops and regions (Lywood et al., 2009).

The technology challenge also extends beyond the agricultural sector. In particular, in developing countries there is a need for research and extension services to support the appropriate development of technologies and enable them to be disseminated where needed (FAO, 2009a).

8.1 INCREASING INPUT-USE EFFICIENCIES

Increasing input-use efficiencies in agricultural production will be essential as natural resources become more scarce, with prices of non-renewable resources like fossil fuels and phosphorus expected to increase over the next decades. Conservation farming using zero tillage offers a major opportunity to reduce fuel use in agriculture by an average of 66% to 75% as well as sequestering soil carbon. Precision agriculture and integrated pest management systems provide new tools for further improving efficiency and reducing pesticide inputs (FAO, 2009e).

An increase to the area of irrigated land may be necessary to achieve yield increases in future. Technology will be required to ensure water management and use is efficient and sustainable, for example through water "harvesting" techniques and conservation of soil moisture.

8.2 INCREASING EFFICIENCIES THROUGH BREEDING

Modern biotechnology has the potential to speed up the development of improved crops, which may increase yields, decrease crop losses and reduce environmental impact. For example:

- Tissue culture techniques allow the rapid multiplication of disease free planting materials of vegetatively propagated species[10] for distribution to farmers.
- Genetic engineering can help to transfer desired traits between plants more quickly and accurately than is possible with conventional plant breeding.
- Genetic engineering for biotic stress and herbicide resistance has been shown to be successful in some cases.
- Engineered herbicide tolerance in soybeans, maize and canola has facilitated conservation tillage and permitted timelier planting with modest benefits for yields.

50%
AN AMBITIOUS PROGRAMME AIMS TO INCREASE YIELDS OF RICE AND WHEAT BY UP TO 50%

Marker-assisted breeding and biotechnology traits are relatively new technologies for productivity improvements but their use is likely to increase, so as to improve future yields. The biotechnology traits currently used in commercial production in the US increase average yields by around 5% a year by protecting corn from the stress of competing pests and weeds (Edgerton 2009).

More drought-tolerant plants have also been mooted. An ambitious programme aims to increase yields of rice and wheat by up to 50% and markedly increase water-use efficiency, though this will require genetic manipulation beyond what has been achieved to date, but it is a possibility for the future (Government Office for Science 2011).

In livestock breeding, the success of the Australian breeding programme "Droughtmaster" shows what can be achieved when heat and environmental tolerance are goals of selection. Better understanding of the physiology and genetics of animal responses to stress, coupled with genomic approaches to selection, are likely to be important in adaptation to climate change (Government Office for Science 2011).

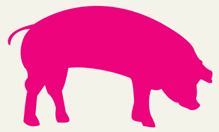
It is predicted that by 2050 genetically modified technologies (GMTs) will be cheaper and more widely available (FAO, 2009a) and therefore used much more in the production of food crops, particularly to increase yields while not increasing inputs. However, it is also acknowledged that genetically modified crops, and particularly transgenic modification, carry risks and arouse widespread public concerns in many

[10] Vegetatively propagated plants produce new individuals without seeds or spores e.g. potatoes, pineapples

countries (FAO, 2009e). The consequences of their spreading to non-modified flora and fauna are unknown, and there is concern around corporate ownership and the lack of transparency in the industry. Therefore, the effective implementation of technological advancements will require improved governance and openness as well as investments in agricultural R&D and effective dissemination mechanisms. GMTs may be part of the solution but are by no means the main part and a precautionary approach to using them must be taken.

8.3 LIVESTOCK

If livestock housing, nutrition, health and management are optimised the yield potential of animal species is determined by their genetic potential. However, there is considerable variation in output depending on the extent to which production systems are controlled through some or all of these factors. Sylvester-Bradley and Wiseman (2005) concluded that there is still potential for improving traits associated with yield and it is very difficult to quantify the genetic limit due to the uncertain nature of mutation.



HIGHER-YIELDING ANIMALS PRODUCE LESS POLLUTION PER UNIT OF PRODUCE

Sylvester-Bradley and Wiseman's estimates assume that crops will be able to use almost all of the annual rainfall. If potential crop yields for animal feeds could be achieved then the crop area required to produce each unit of livestock would decrease by between two and four fold.

Constraints for achieving potential yield can be split into:

- the development of new technology for increasing yield
- uptake of existing and new technology by practitioners.

On balance it appears that technology uptake will be the most important constraint. Increasing environmental regulation to reduce pollution and increase biodiversity, social concerns about technologies such as genetic modification, and refocusing market requirements towards free-range animal produce and quality will also restrict the uptake of technologies for maximising yields. Some of these objectives are compatible with high yields: for example, higher-yielding animals produce less pollution per unit of produce, and waste management and pollution is easier to control for housed livestock.

To an extent, the development of new technologies is less constrained than its uptake. Some innovation takes place outside agriculture, global companies are buffered against fluctuating regional demands for their products, and research institutes and universities are often centrally funded and less influenced by market forces (at least in the short to medium term). Animal (and plant) breeders have consistently increased yields for several decades, but several factors now pose a threat. In particular, as yields approach species' potentials, breeders will increasingly encounter and need to overcome traits that have negative associations with yields (poor reproductive performance, metabolic stress, reduced immunity to disease and functional fitness), while political pressures for greater sustainability will demand greater resource-use efficiency.

9. ENVIRONMENTAL IMPACT OF PRODUCTION SYSTEMS

Key points:

- There are trade-offs between agricultural output and ecosystem services. Increasing yield often comes with an environmental consequence.
- There are trade-offs between different ecosystem services. Modern land-use planning is increasingly considering multi-functional landscapes.
- Biodiversity is an increasingly important environmental indicator and should not be ignored.

Environmental effects of agriculture can be direct or indirect. Direct effects or impacts are those that are linked directly to the production process, such as emissions from making fertiliser and field machinery use. Indirect impacts are consequential and more difficult to identify, such as emissions from indirect land-use change: this might occur, for example, when decreased crop yields lead to increases in production area elsewhere.

During recent decades the environmental effects of agriculture, particularly crop management, have been increasingly taken into account. For example, cereal production is directed towards greater sustainability, often through policy measures, including economic incentives for those farmers who aim to improve sustainability (Peltonen-Sainio et al., 2009).

The need to increase agricultural productivity in the future will have environmental consequences. Edgerton (2009) is optimistic that the positive consequences will outweigh the negative. For example, while intensification of land use can lead to a degradation of water quality and increase nitrous oxide emissions, it is also possible to implement conservation tillage and transgenic insect control which will decrease environmental impact.

Nitrogen presents an interesting case. The use of so-called active nitrogen in agriculture is connected to both water pollution (nitrate run-off, ammonia volatilisation and subsequent deposition) and climate change (nitrous oxide emissions). Converting inert atmospheric nitrogen into its active forms via chemical processes also requires high energy inputs and causes its own pollution. Improving the efficiency of nitrogen utilisation therefore has the potential to address several environmental impacts associated with food systems. Section 8 noted the potential for breeding to contribute to this, but the careful management of inputs by the farmer has considerable potential also. For example there is scope for much wider uptake of best practice in nutrient management in developed-world farming as well as in the developing world. Although these practices can improve profitability for farmers, there are barriers to overcome because implementation often requires knowledge, skills, time and financial resources that many smaller farmers do not have.

Besides global warming potential, environmental impacts of food production include abiotic resource depletion, acidification, ecotoxicity and others (Tucker, Foster and Wiltshire, 2010). Loss of biodiversity is another impact linked with food production. Water use is not in itself an environmental impact, but has many environmental, social and economic impacts associated with it. Of these impacts, mitigation of impacts associated with water use and biodiversity loss are likely to have the greatest effect on food production within the timescales considered in this project (up to 2020 and 2030). These are also the environmental impacts associated with the food system

for which mitigation strategies are least likely to align with GHG mitigation. These impacts are (to a greater or lesser extent) local, whereas many other environmental impacts are global (e.g. global warming potential, stratospheric ozone depletion, abiotic resource depletion).

As referred to earlier, McVittie et al (2011) consider the value of increasing agricultural knowledge, science and technology investment in its ability to close the yield gap. They assess the global impact on biodiversity and carbon against a counterfactual position where increasing food demand results in degradation as more land is brought into production. This is reduced by closing the yield gap through increased investment. The cost-benefit ratio of the investment is positive for the biodiversity improvements alone.

We focus on impacts of biodiversity loss and water use, for further consideration.

9.1 WATER CONSTRAINTS

Water plays a key role in agriculture. The FAO (2009a) estimates that irrigated agriculture covers 20% of arable land but contributes to nearly 50% of crop production.

To produce increasing output from agriculture for a growing world population in the future will require an increase in water use, or greater efficiency. Strzepek and Boehlert (2010) found that by 2050 there would be a reduction of 18% of availability of water for agriculture due to the increased demand from municipal and industrial water users, environmental flow requirements and changing water supplies as a result of climate change.

This is not a uniform decrease, but the decrease is predicted to affect current water-scarce areas. Strzepek and Boehlert forecast an increase in demand for water of up to 200% in developing countries by 2050. At the moment, 1.4 billion people live in areas with sinking groundwater levels, particularly in the Near East/North Africa and South Asia regions (FAO 2009a) and this water scarcity is set to get worse.

IRRIGATED AGRICULTURE COVERS 20% OF ARABLE LAND BUT CONTRIBUTES TO NEARLY 50% OF CROP PRODUCTION

Jaggard et al. (2010) have modelled future crop yields in 2050, under 550ppm CO2e and a rise of 2°C in world average temperature. They predict that with a warmer and drier climate, water consumption of all crops will become more variable. Greater efficiency gains are needed and in severely water-scarce regions, the effort should focus on getting more "crop per drop" (FAO, 2009e).

Water used in meat production

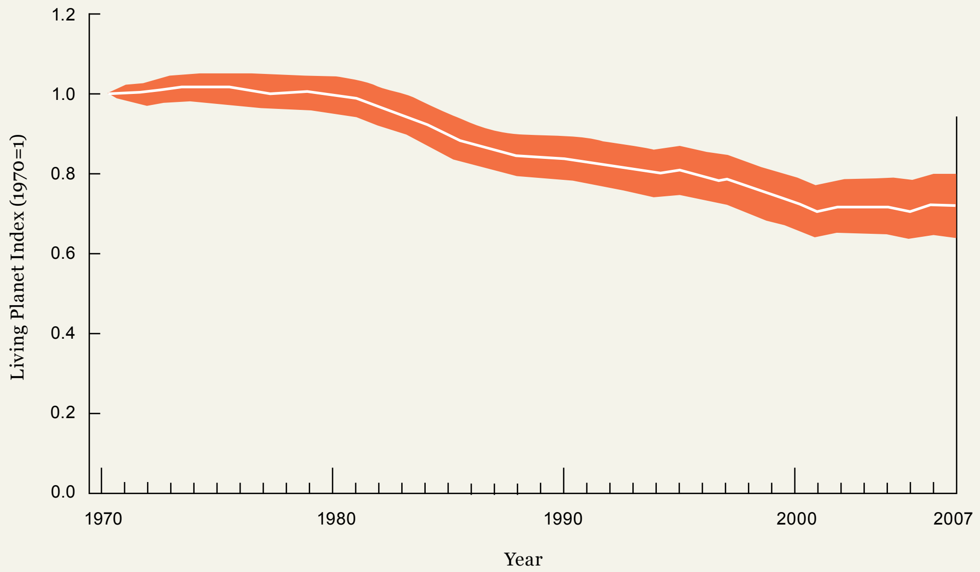
Water is an essential part of livestock farming, which is a significant consumer of water. Globally, the livestock sector uses 8% of the globally available water supply; 7% is used in feed production (Steinfeld et al., 2006). Peden et al. (2007) have also shown the disparity in water production systems: one cubic metre of water can produce anything from 0.5kg of dry animal feed in North American grasslands to around 5kg in some tropical systems. Better management of livestock can conserve water resources, but there is still a strong argument that a reduction in meat consumption could allow water to be used in high-yield agricultural crops.

9.2 BIODIVERSITY CONSTRAINTS

Biodiversity is a major consideration in future agricultural growth. The updated global Living Planet Index (LPI) declined by 30% between 1970 and 2008 (WWF et al 2012). Given the complex nature of biodiversity it is hard to measure. The LPI shows that globaly populations were a 1/3 smaller in 2008 than in 1970, based on 9,014 populations of 2,688 of amphibians, birds, fish, reptiles and mammal species.

Global Living Planet Index (1970-2007)

Figure 18:
Source: WWF et al., 2012.

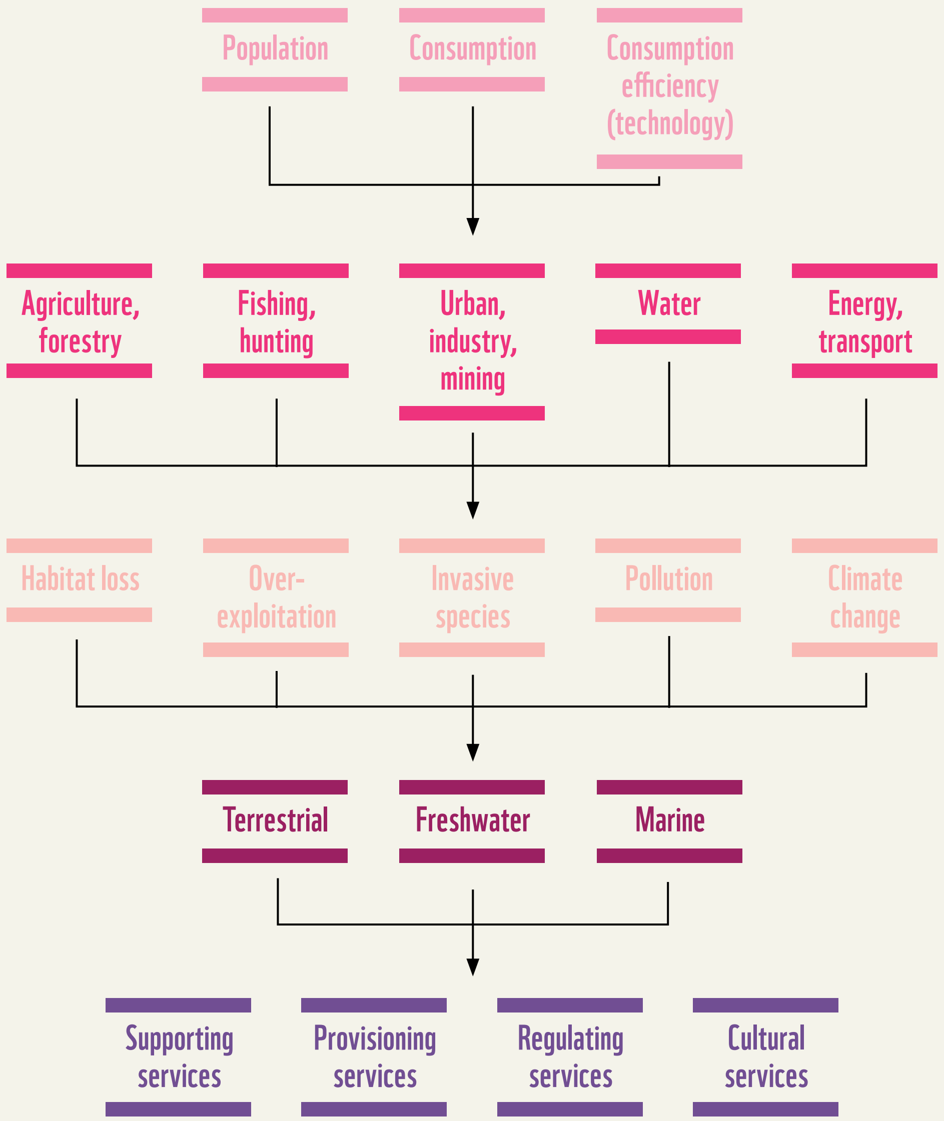


Key
Global Living Planet Index
Confidence limits

Ecosystems services
Agroecosystems are both providers and consumers of ecosystem services (Figure 19). They are often highly managed ecosystems principally designed to provide food, forage, fibre, bioenergy and pharmaceuticals. In turn, agroecosystems depend strongly on ecosystem services provided by natural, unmanaged ecosystems. These underpinning services include genetic biodiversity for use in breeding crops and livestock, soil formation and structure, soil fertility, nutrient cycling and the provision of water. Regulating services may be provided to agriculture by pollinators and natural predators of pests that move into agroecosystems from natural vegetation. Natural ecosystems may also purify water and regulate its flow into agricultural systems, providing sufficient quantities at the appropriate time for plant growth (Power, 2010).

Interconnections between people, biodiversity, ecosystem health and provision of ecosystem services

Figure 19:
Source: WWF, 2010.

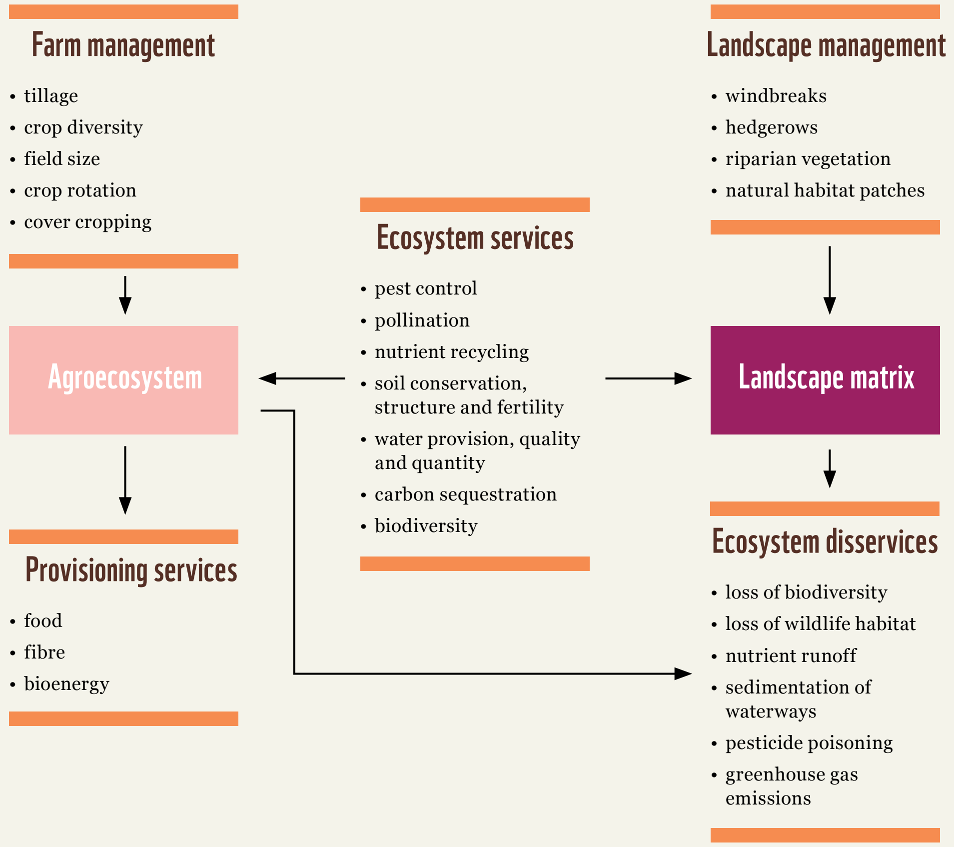


Key
Casual factors
Indirect drivers/ footprint sectors
Pressures on biodiversity
State of global biodiversity
Impacts on ecological services

Agriculture is a key direct driver of change to ecosystem services as shown by Figure 20. The services provided are counterbalanced to a degree by a range of negative externalities – invasive species, pollution of land, air and water, as well as loss of cultural services. Frequently there are trade-offs between competing resource uses. For example, an aquaculture farmer may gain from management practices that increase soil salinisation, but this may reduce rice yields and threaten food security for nearby subsistence farmers (Sarukhán and Whyte, 2005).

Impact of farm management and landscape management on the flow of ecosystem services and disservices to and from agroecoystems

Figure 20:
Source: Power, 2010.



Protected areas
Protected areas can protect biodiversity. Sinclair et al. (2002) have illustrated the success of such schemes. In the Serengeti, abundance of species found in agricultural areas was only 28% of that of the same species in adjacent protected areas of native savannah (Sinclair et al., 2002).

Future constraints
It is very probable that rising food security concerns will place biodiversity and protected areas under increasing pressure. Maintaining ecosystem services in these circumstances will require an economic and policy climate that favours diversification in land uses and diversity among land users (Swift et al., 2004) across the globe.

9.3 MEAT PRODUCTION

Consumption of meat and meat-based diets are increasing globally. There is an argument that crops should not be grown to be fed to livestock for animal protein consumption, due to the inefficiencies in converting feed to meat. A study by Pimentel and Pimentel (2003) has shown that for every 1kg of high-quality animal protein produced, livestock are fed about 6kg of plant protein. Encouraging diets with lower meat consumption could lower uncertainty in global food security, as less energy would be wasted in producing animal protein. For grain protein to be converted to animal protein there are two principal inputs or costs: first, the direct costs of production of the harvest animal, including its feed; and second, the indirect costs for maintaining the breeding herds.

Pimentel and Pimentel (2003) studied the fossil energy input for a variety of animal protein production systems, including beef, pork, lamb, eggs and broilers. They found that the average fossil energy input for those systems studied was 25kcal fossil energy input per 1kcal of protein produced. This energy input is more than 11 times greater than that for grain protein production, which amounts to about 2.2kcal of fossil energy input per 1kcal of plant protein produced.

10. FOOD WASTE

Key points:

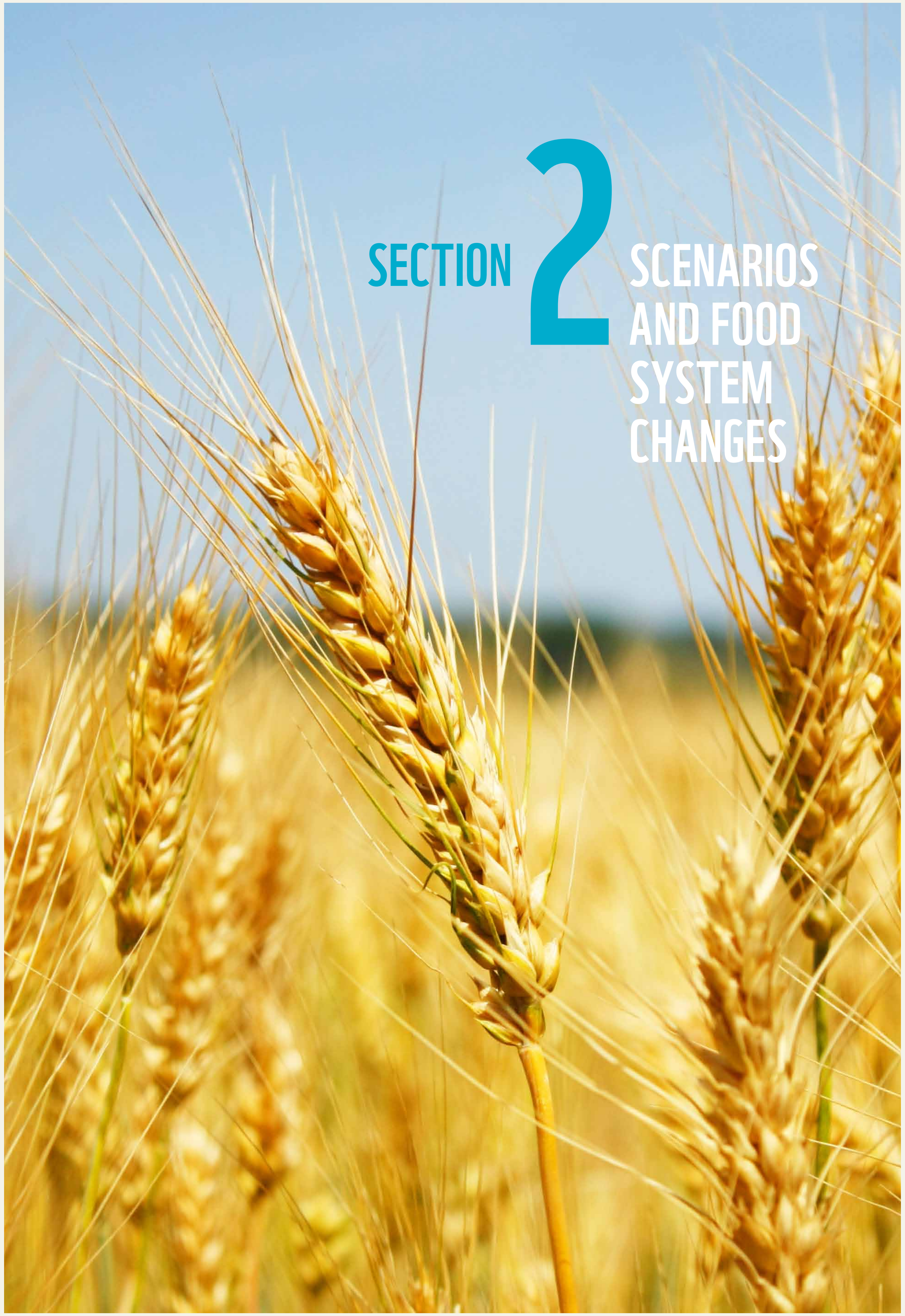
- Food waste lost across the supply chain (post-harvest losses) is the dominant form of waste in developing countries. However, household waste could also become a more prominent problem as incomes rise.
- Household waste dominates in industrialised countries. Supply chains can often be quite efficient in these countries.

Authors of studies in this area generally agree that there is significant scope for reducing supply chain losses. A study carried out in the ASEAN region found that 10% of the losses during handling, storage and processing of grains could be avoided (Groulleaud, 2002). Another study by Lundqvist et al. (2008) found that a 50% reduction in post-harvest losses, including consumer losses, was a realistic goal. It is of paramount importance that technologies are developed that can ensure food waste is limited to reduce the environmental impact of this waste and increase the overall availability of food. Reducing waste will ease unnecessary pressure on natural and financial resources by reducing overproduction (Goletti, 2003).

50% REDUCTION IN POST-HARVEST LOSSES, INCLUDING CONSUMER LOSSES, WAS A REALISTIC GOAL

Household waste could be reduced with a variety of measures, but the impact of these measures remains unknown. A study by Nellemann et al. (2009) recognised the scope for increasing food system efficiency by 30-50% through reducing and recycling food waste. A suggestion was that food waste could be used as a substitute for animal feed; however, feed safety regulations create limitations. Bender calculates that "A reduction in food waste from 50% of [consumed food products] to 35% would directly result in a minimum of a 10% decrease in global food supply requirements" (Bender, 1994).

Other areas that could be improved to prevent high levels of household waste include improved knowledge on food safety and quality issues (Sibrián et al. 2006), improved labelling and the understanding of labelling by consumers, as well as improved packaging technology (Garnett, 2008; Parfitt et al., 2010). A UK study by WRAP (2008) found that better housekeeping and planning and clearer labelling could significantly reduce consumer waste.



SECTION 2 SCENARIOS AND FOOD SYSTEM CHANGES

11. INTRODUCTION

Four scenarios were provided to the project team and these were assessed to determine whether they can produce a low-carbon and sustainable global food system by 2020. The scenarios were:

1. CONTINUE ON EXISTING PATH

a baseline scenario where demand patterns do not change and more people move towards a Western-style diet.

2. ASPIRE TO HAVE ORGANIC AND HIGH ANIMAL WELFARE PRODUCTION

reflecting demand for aspirational production systems such as high animal welfare standards and organic production.

3. IMPROVE PRODUCTION EFFICIENCY AND REDUCE MEAT AND DAIRY CONSUMPTION

taking into account changes in production, technology and consumption, including GM and biotechnology, aquaculture, predicted production efficiencies and changes in meat and dairy consumption.

4. TAKE ACCOUNT OF ENVIRONMENTAL IMPACTS WHICH MAY NOT DECREASE GHG EMISSIONS

also looks at reducing other environmental impacts associated with the food system, such as water scarcity and biodiversity loss, which may not result in low-carbon food.

Table 6:
Summary of scenarios

Scenarios (2020)		Changed consumption pattern	Technology to maximise production	Positive environmental impact		
No	Description			GHG emissons	Water	Biodiversity
1	Continue on existing path					
2	Aspire to have organic and high animal welfare production	✓				✓
3	Improve production efficiency and reduce meat and dairy consumption	✓	✓	✓		
4	Take account of environmental impacts which may not decrease greenhouse gas emissions	✓	✓	✓	✓	✓

The four scenarios are described, and then used to analyse how the world food system may change by 2020 and 2030. Changes by 2020 were then used to predict changes in diet by 2020, to guide Part 2 of this project, in which a road map for sustainable food was developed.

We follow a simple approach based on data from the United Nations Food and Agriculture Organization (FAO) Food Balance Sheets, where food available for human consumption is divided by population. This data is used as a baseline, with consumption projections for 2020 and 2030 obtained by interpolation from Kearney (2010) (supplementary data). Analysis of change under each scenario used evidence from published literature and the expert knowledge of the project team. Guidance for sustainable and healthy changes in diets was taken from the WWF-UK Livewell report (Macdiarmid et al., 2011).

12. SCENARIO 1

12.1 DEFINITION

Demand patterns do not change and more people move towards a Western-style diet.

12.2 DESCRIPTION

Because of the variation in diets between and within Western countries, it is not realistic to define a common Western diet.

Broadly, the Western diet is characterised by high fat, high saturated fat, high salt and high non-extrinsic milk sugars. It is low in fish and fruit and vegetables (compared to recommendations). Protein tends to come from high-fat meat rather than low-fat, high-fibre plants.

The food system for the world is described by the data in Appendix 1, which shows world consumption per capita, and how food categories contribute to this total. Data for the UK is also shown in Appendix 1, illustrating an example Western diet.

Data from Kearney (2010) (supplementary data), based on the FAO Food Balance Sheets, shows the predicted change in diets as world population grows and more people move towards a Western diet by 2020 and 2030. We use this data, together with estimated population data for 2010, 2020 and 2030 (Lutz and Samir, 2010; based on IIASA's World Population Programme[11]), to show the extent of change in the food system by 2020 and 2030 (Table 7).

Table 7: Percentage change in aggregate global consumption by 2020 and 2030

Food categories	2020	2030
Cereals – total	15.4%	29.0%
Wheat	17.7%	33.9%
Rice	17.8%	34.4%
Millet	-0.3%	-9.2%
Maize	16.0%	31.8%
Meat – total	16.3%	34.2%
Beef	-1.0%	-0.1%
Lamb/goat	10.6%	19.6%
Pork	30.2%	57.2%
Poultry	31.6%	63.0%
Eggs	31.8%	59.8%
Milk (whole)	5.9%	10.0%
Butter, ghee	10.6%	19.6%
Cheese	5.4%	11.2%
Fish – seafood	22.6%	44.5%
Fish – demersal	20.1%	34.9%
Fish – freshwater	33.7%	67.2%
Fish – marine	10.6%	19.6%
Fish – pelagic	37.6%	65.1%
Vegetables	16.9%	36.1%
Roots and tubers	3.8%	4.3%
Potatoes	-0.3%	0.8%
Sweet potatoes	-15.6%	-30.7%
Pulses	-0.2%	-5.3%
Fruits	20.3%	40.2%
Refined sugars	8.1%	18.6%
Animal fats	10.6%	19.6%
Vegetable oils	20.7%	43.6%

[11] Vegetatively propagated plants produce new individuals without seeds or spores e.g. potatoes, pineapples

World population growth combined with increased consumption per capita will mean that the food system will need to produce more food to meet this demand. However, the change in diets means that the burden of increased food production will not be equally spread across food types. Production of some food types will need to increase more than others. Generally increasing production will require additional land and inputs, contributing to increased greenhouse gas emissions. The food system has consistently adapted over time to the need for more food and therefore the change required within this scenario is not a major shift. However, due to the increased greenhouse gas emissions associated with this scenario, a food range that supports the development of this trend could not be considered low carbon.

A 2020 vision for the global food system

12.3 IMPLICATIONS FOR FOOD RANGE DESIGN

Data from the FAO Food Balance Sheets for the range of available food categories was translated to the Livewell food categories (Table 8).

Table 8:
Allocation of food categories used in the FAO Food Balance Sheets (2009), to Livewell food categories.

Livewell categories	FAO categories
Fruit and vegetables	Vegetables
	Fruits
Bread, rice, potato, pasta, other starchy food	Cereals – total
	Wheat
	Rice
	Millet
	Maize
	Roots and tubers
	Potatoes
	Sweet potatoes
Meat, fish, eggs, beans, other non-dairy protein	Meat – total
	Beef
	Lamb/goat
	Pork
	Poultry
	Eggs
	Fish – seafood
	Fish – demersal
	Fish – freshwater
	Fish – marine
	Fish – pelagic
	Pulses
Milk and dairy	Milk (whole)
	Butter, ghee
	Cheese
Food and drink high in fat and/or sugar	Refined sugars
	Animal fats
	Vegetable oils

FAO predictions for consumption per capita were used to calculate the changes in diet (world average) per capita for 2020 and 2030, for each food category, and overall for the five Livewell categories. There was some disaggregation, especially for livestock and fish. These predicted changes for 2020 are given below, rounded to the nearest 5%, to provide headline guidance for illustrative case studies to show how food products could change by 2020 under this scenario. The values given below are percentage changes from the current world average dietary composition.

Headline guidance for illustrative case studies, as percentage change in diet by 2020:

- 5-10% increase in fruit and vegetables
- 5% increase in cereals
- 10% decrease in potatoes
- 5% increase in meat (beef -10%, lamb no change, pork/poultry +15-20%)
- 20% increase in eggs
- 15% increase in fish
- 10% decrease in pulses
- 5% decrease in milk and dairy
- 0-5% increase in high fat and/or sugar content food.

6.3% INCREASE IN THE WORLD AVERAGE FRUIT AND VEGETABLES DIET

For comparison, consumption data (in kcal per person per day) from Kearney (2010; supplementary data), with interpolated projections for 2020 and 2030, were used together with population projections (Lutz and Samir, 2010; based on IIASA's World Population Programme, www.iiasa.ac.at/Research/POP), to indicate the total increase in food production required by 2020 and 2030. This calculation gave an increase in food consumption of 13.5% by 2020, which, although calculated in energy units rather than mass, is not in conflict with the values given above for various food types. The value for 2030 was 24.5%.

To provide context for these headlines, the following summaries for each Livewell food category show how the predicted diets change from 2010 to 2020 (% change in g/capita/day), for the world, UK, China and India.

1.4% INCREASE IN CONSUMPTION OF STARCHY FOOD AT A GLOBAL LEVEL

Fruit and vegetables
Fruit and vegetables increase in the world average diet (6.3% increase per person), and for the UK (4%), China (9%) and India (7.3%).

Bread, rice, potato, pasta, other starchy food
There is a small increase in consumption of starchy food at a global level (1.4%), with larger increases in non-Western diets (China 4.9%; India 6.7%) and a decrease in the UK diet (0.9%).

Within this Livewell food category there are larger fluctuations for individual commodities, with a world increase in cereal consumption per head (4.3%) and a decrease in potato consumption per head (-9.9%), mainly because of decreases in Europe, although not in the UK (see Table 9 for more detail).

Food category	World	UK	China	India
Bread, rice, potato, pasta, other starchy food – change in grams per day per person	1.4%	-0.9%	4.9%	6.7%
Cereals – total	4.3%	-4.8%	13.2%	3.5%
Wheat	6.4%	-6.1%	24.9%	11.9%
Rice	6.5%	8.2%	11.3%	1.6%
Maize	4.8%	-23.5%	-0.4%	17.1%
Potatoes	-9.9%	1.7%	3.0%	12.9%

Table 9: Predicted changes in consumption of starchy foods, from 2010 to 2020 (% change in g/capita/day), for the world, UK, China and India.

Meat, fish, eggs, beans, other non-dairy protein
Protein-providing foods increase overall (11.7%), with increases in pork, poultry, eggs and fish, but decreases in beef and pulses, and no change for lamb/goat meat (see Table 10 for more detail).

Food category	World	UK	China	India
Meat, fish, eggs, beans, other non-dairy protein	11.7%	0.6%	12.4%	-11.5%
Meat total	5.1%	-1.7%	14.8%	22.4%
Beef	-10.5%	-24.7%	29.6%	0.0%
Lamb/goat	0.0%	-7.9%	45.3%	0.0%
Pork	17.6%	-7.1%	14.4%	0.0%
Poultry	18.9%	14.9%	3.4%	-66.7%
Eggs	19.2%	-0.2%	14.1%	-63.5%
Fish	13.6%	1.0%	8.5%	12.4%
Pulses	-9.8%	35.2%	-66.7%	-22.7%

Table 10: Predicted changes in consumption of protein-rich foods (non-dairy), from 2010 to 2020 (% change in g/capita/day), for the world, UK, China and India.

Milk and dairy
Milk and dairy decrease in the world average diet (-4.2%), and for the UK (-10.3%). However, there are increases in China (5.4%) and India (17.6%).

Food and drink high in fat and/or sugar
High fat and sugar foods increase overall in the world average diet (1.9%), with a much larger increase in China (23.1%). There are decreases in the UK (-5.8%) and India (-10.2%).

13. SCENARIO 2

13.1 DEFINITION

A demand pattern that encapsulates aspirational production systems.

13.2 DESCRIPTION

37%
UPTAKE IN THE FALKLANDS FOR ORGANIC PRODUCTION SYSTEMS

We use two aspirational production systems, with aspirational levels of uptake, to use in further analyses. These are organic and high animal welfare (e.g. RSPCA Freedom Food) production systems. Other production systems are more difficult to define. Some aspects of production practice, such as drip irrigation, can be incorporated into any production system; we have excluded specific production practices in this scenario.

For organic production systems, currently the highest national uptake by area is 37% in the Falklands and 30% in Liechtenstein. The UK comes in at 4.57% and of European countries only Austria gets close to 20% at 17%. We propose an aspirational target of 20% organic by 2020 and 25% by 2030; this is challenging in the context of current uptake, and in excess of what wealthy European countries have achieved to date. Table 11 shows the countries with the 20 largest areas of organic production and the additional area required to hit these aspirational targets.

	Organic area 2008		Increase in area (ha) for
Country	Area (ha)	%	20% organic
Australia	12,023,135	2.9	71,434,465
Argentina	4,007,026	3.0	22,562,974
USA	1,948,949	0.6	62,512,352
China	1,853,000	0.3	108,747,000
Brazil	1,765,793	0.7	51,134,207
Spain	1,129,844	4.5	3,848,660
India	1,018,470	0.6	34,961,530
Italy	1,002,414	7.9	1,546,426
Uruguay	930,965	6.3	2,005,635
Germany	907,786	5.4	2,483,080
UK	737,631	4.6	2,488,467

Table 11: Area of organic production by country (top 20) and increase required to get to 20% target. Source: FiBL & IFOAM: Global organic agriculture statistics (www.organic-world.net/statistics.html)

Country	Organic area 2008 Area (ha)	%	Increase in area (ha) for 20% organic
Canada	628,556	0.9	12,891,444
France	580,956	2.1	4,910,026
Austria	491,825	17.4	72,186
Falklands	414,474	36.9	NA
Czech Republic	341,632	8.0	508,204
Sweden	336,439	10.8	287,161
Mexico	332,485	2.4	2,419,262
Greece	317,824	3.8	1,338,176
Poland	313,944	2.0	2,781,494
Total	**35,225,259**	**0.8**	**829,595,836**

For high-welfare farming, Table 12 shows the level of uptake in the UK in 2007. There has been rapid growth in some sectors and very little uptake in others. The rapid growth in high-welfare eggs (Table 12) suggests that rapid uptake of high-welfare farming in other sectors of animal production is possible, so for animal production systems we propose a bold aspirational target of 50% uptake by 2020 and 75% uptake by 2030.

Table 12: Percentage market penetration of Freedom Food in the UK (RSPCA)

	2004	2005	2006	2007
Beef	0.5	0.4	0.6	0.5
Chickens	1.2	2.7	3.1	5.5
Dairy cattle	N/A	1.3	1.4	1
Eggs	45	47.2	50.4	52.1
Pigs	16.6	17	16.2	14.5
Sheep	0.6	0.5	0.5	0.5

Demand patterns are assumed to change in line with the uptake of aspirational production systems, based on the ideal production patterns of those systems (e.g. mix of livestock and crop production in an organic system to optimise fertility).

As with Scenario 1, world population growth combined with increased consumption per capita will mean that the food system will need to change by producing more food. On top of this, Scenario 2 requires increased organic and high animal welfare production. The change required within the food system to adopt this scenario is significant and would require a rapid increase in organic conversion and adoption of high animal welfare standards. Without change in the proportions of food types consumed, and/or large decreases in food waste, this scenario would require more land to provide sufficient food.

13.3 IMPLICATIONS FOR FOOD-RANGE DESIGN

Changes in diet (world average) per capita for 2020 and 2030 for each Livewell category were predicted by taking the predictions for Scenario 1 and calculating adjustments based on anticipated changes in production through increased organic production and increased high-welfare farming. The changes in production were informed by the literature review, and by knowledge of the project expert group (Table 12). As for Scenario 1, there was some disaggregation, especially for livestock and fish. Estimates of changes in production under organic management vary widely between commodities, and are also confounded by other factors, such as restrictions on stocking rate of grazing animals and Nitrogen Vulnerable Zones.

Table 13: Estimated changes in production in organic and high-welfare systems, as percentages of production in current conventional systems.

Food type	Production level for aspirational systems (percentage of current)
Fruit and vegetables	100
Bread, rice, potatoes, pasta, other starchy food	60
Meat, fish, eggs, beans, other non-dairy protein	84
Meat	82
Beef	100
Lamb	100
Pig and poultry	80
Eggs	80
Fish	80
Other	125
Milk and dairy	80
Food and drink high in fat and/or sugar	100

The predicted changes in consumption for 2020 are given below, rounded to the nearest 5%, to provide headline guidance for illustrative case studies to show how food products could change by 2020 under this scenario. Values given below are percentage changes from the current world average dietary composition.

Headline guidance for illustrative case studies, as percentage change in diet by 2020:

- **5-10% increase in fruit and vegetables**

  (No change from Scenario 1, because organic production of fruit and vegetables is expected to be similar to that of conventional systems, taking account of yield changes and change in the proportion of land used for fruit and vegetables.)

- **0-5% decrease in cereals**

  (Shepherd et al. (2003) report large yield reductions in cereals (c. 41%, averaged across wheat, barley and oats) based on review of literature, and supported by yield estimates taken before and after conversion under Defra's Organic Farming Scheme (CRER, 2002))

- **15% decrease in potatoes**

  (Assumptions are for an increase in organic area to 20%, of which yield will be 60% of that in conventional systems, but there is large uncertainty about area change. We have taken a conservative view of the extent of production decline.)

- **0-5% decrease in meat (beef -10%, lamb no change, pork/poultry no change)**

  (Beef and lamb production are as for Scenario 1, as these can be largely grass or forage fed. Pork and poultry are most affected by stocking density following change to high-welfare or organic systems, therefore production decreases in countries with developed agriculture.)

- **10% increase in eggs**

  (Decreased stocking density, higher feed consumption per egg, but some increase in number of producers to partly compensate.)

- **5% increase in fish**

  (Reduced from 15% increase as we expect fish stock concerns to influence availability of fish from wild sources, and availability of feed for farmed fish.)

- **5% decrease in pulses**

  (Greater area in organic systems because pulses are used as fertility-building crops, so smaller decrease than in Scenario 1.)

- **10% decrease in milk and dairy**

  (20% decrease when there is conversion to organic, due to lower yielding organic feed crops requiring more land)

- **0-5% increase in high fat and/or sugar content food**

  (No change from Scenario 1 as production changes do not influence the extent to which food commodities are used to manufacture foods high in fat and/or sugar.)

In the UK the three biggest categories of organic food sales are dairy products, fresh produce (fruit and vegetables) and fresh meat. This indicates an aspect of consumer preference, which should be a consideration in providing guidance for future food-range design.

A 2020 vision for the global food system

14. SCENARIO 3

14.1 DEFINITION

A food system which incorporates changes in production, technology and consumption – including all technological changes, aquaculture, predicted production efficiencies and changes in meat and dairy consumption.

14.2 DESCRIPTION

Increasing yields reflect the integration, on farms, of plant and animal breeding, better husbandry systems, and chemical protection and nutrition. We used yield to integrate effects of better technologies. The literature review and expert knowledge of the project team informed the possible level of yield increase by food type.

Alongside this we use the Livewell 2020 diet (Macdiarmid et al., 2011) to specify how meat and dairy consumption will change, assuming that this is achieved worldwide by 2020 and maintained to 2030 (with further population growth). The Livewell 2020 diet would meet the 2020 GHG reduction target of 25% and recommendations for a healthy diet.

A significant shift in behaviour is required from the consumer because the scenario assumes a change in the pattern of consumption, towards the Livewell 2020 diet. A major shift in attitudes to new technologies, especially genetic modification, will also be required for some of the progress towards higher yields.

The uptake of technology on the production side is less of a shift as the food system has always adopted new technology. The speed of adoption will require increased investment in R&D as well as on-farm investment.

Food waste

Using technology and increased innovation for better farming techniques, storage and distribution can greatly reduce in food waste. It is counter-intuitive to ignore this issue if we are trying to increase food production; focusing only on production would lead to wasted effort. Increased investment in technology in this area, as well as influencing behaviour from the farmer to the consumer, and across the supply chain, would put less pressure on producing higher yields and allow for increased equality in food distribution worldwide. This subject needs to be tackled from two inter-linked perspectives.

Household waste could also become a more prominent problem as incomes rise

Food waste lost across the supply chain (post-harvest losses) is the dominant form of waste in developing countries, though household waste could also become a more prominent problem as incomes rise. At present, post-harvest loss levels are estimated at 20-50%, and there is little evidence to suggest that policy measures have significant effect on reduction. However, authors of studies in this area generally agree that there is significant scope for reducing supply chain losses. A study carried out in the ASEAN region found that 10% of the losses during handling, storage and processing of grains could be avoided (Groulleaud, 2002).

Another study by Lundqvist et al. (2008) found that a 50% reduction in post-harvest losses, including consumer losses, was a realistic goal. It is of paramount importance that technologies are developed to limit food waste, to address both food security and environmental and sustainability issues; reducing waste will ease unnecessary pressure on natural and financial resources by reducing overproduction (Goletti, 2003).

Household waste dominates in industrialised countries, where supply chains can often be quite efficient. It is clear that household waste could be reduced with a variety of measures, but the impact of these measures remains unknown. A study by Nellemann et al. (2009) recognised the scope for increasing food-system efficiency by 30-50% through reducing and recycling food waste.

14.3 IMPLICATIONS FOR FOOD-RANGE DESIGN

The required production change by 2020, for global consumption of the Livewell 2020 diet, was calculated based on projected consumption increases (Kearney 2010, supplementary data) and population projections (Lutz and Samir, 2010). The results for total production and production increases needed by 2020 are shown in Table 13. This shows a wide range of production change values, from -40% for meat, to +81% for other forms of non-dairy protein, which in our calculations is represented by pulses.

Table 14: Livewell 2020 diet composition, production and production increases needed by 2020.

Food type	Livewell 2020 diet (% composition)	Total production by 2020 for Livewell 2020 diet (Mt/yr)	Production change needed by 2020 (%)
Fruit and vegetables	35	1,737	-13
Bread, rice, potatoes, pasta, other starchy food	29	1,439	3
Meat, fish, eggs, beans, other non-dairy protein	12	595	4
Meat	4	198	-40
Eggs	1	50	-28
Fish	3	149	-33
Other	4	198	81
Milk and dairy	15	744	56
Food and drink high in fat and/or sugar	9	447	48

Potential yield increases for a wide range of farmed species are given by Sylvester-Bradley et al. (2005) (Table 14). This data shows very large potential yields, by adopting best technologies. Compared with current yields the increases are around 140% for wheat, 132% for peas and 359% for milk and dairy. A key finding of this report was that when UK yields were expressed as a proportion of the unirrigated potential the farm species were ranked as follows: eggs (0.82), poultry meat (0.81), potatoes (0.66), pigs (0.56), beef (0.53), peas (0.45), wheat (0.44), oilseed rape (0.38), sheep (0.27), grass (0.27), milk (0.22). Generally, UK agriculture is efficient and has high yields compared with agriculture in developing countries and many countries where agriculture is more extensive (e.g. Canada and Australia), so it may be expected that average world yields would be lower proportions of the potential yields.

Table 15: Potential yields of farmed species (from Sylvester-Bradley, Berry and Wiseman (2005)).

Species or food	Units	Irrigated	Rain-fed (range)
Wheat	t/ha/yr	19.2	14–18.3
OSR	t/ha/yr	7.93	4.02–7.93
Peas	t/ha/yr	8.36	5.5–8.08
Potatoes	t/ha/yr	144	61.6–72.5
Grass	t/ha/yr	30	20.2–22.3
Beef	kg LW/head/yr	694	
Milk	l/cow/year	30,000	
Sheep	kg LW/head/yr	158	
Pigs	kg LW/head/yr	3,600	
Poultry	kg LW/head/yr	23.6	
Eggs	eggs/bird/yr	365	

LW = live weight

By comparison, Jaggard et al (2010) predict that crop production will increase by approximately 50% or more by 2050 without extra land. This implies an increase of 12.5% by 2020, assuming a constant rate of increase. However, this study covered arable crops and did not take account of a shift towards a lower-meat diet such as the Livewell 2020 diet.

Our analysis shows that, on a world scale, changes in yields are possible that would allow the Livewell 2020 diet to be achieved in 2020. Since there is no advantage in producing more food than is required, we used the percentages for food categories within the Livewell 2020 diet (i.e. these are not percentage changes of the world average total food intake by weight, as for scenarios 1 and 2, but indicate the diet composition in 2020) for headline guidance.

Headline guidance for illustrative case studies, as diet composition by 2020:

Livewell 2020 diet:

1. Fruit and vegetables – 35%
2. Bread, rice, potatoes, pasta, other starchy food – 29%
3. Meat, fish, eggs, beans, other non-dairy protein – 12%
   - Meat – 4%
   - Eggs – 1%
   - Fish – 3%
   - Other – 4%
4. Milk and dairy – 15%
5. Food and drink high in fat and/or sugar – 9%

15. SCENARIO 4

15.1 DEFINITION

A system which takes into account reducing other environmental impacts associated with the food system, such as water scarcity and biodiversity loss, which may not result in low-carbon food but are key to a sustainable food future.

15.2 DESCRIPTION

Overview
The definition above implies consideration of the effects of environmental impacts on food production, excluding global warming potential (i.e. emissions of greenhouse gases, measured in units of carbon dioxide equivalent, CO2e) as one of those impacts.

This scenario is considered in a more descriptive and less quantitative way than the first three scenarios, by commenting on the implications for food-range design of mitigating the impacts of water use and biodiversity loss.

Besides global warming potential, environmental impacts of food production include abiotic resource depletion, acidification, ecotoxicity and others (Tucker, Foster and Wiltshire, 2010). Loss of biodiversity is another impact linked with food production. Water use is not in itself an environmental impact, but has many environmental, social and economic impacts associated with it. Of these impacts, mitigation of impacts associated with water use and biodiversity loss are likely to have the greatest effect on food production within the timescales considered in this project (up to 2020 and 2030). These are also the environmental impacts associated with the food system for which mitigation strategies are least likely to align with GHG mitigation. These impacts are (to a greater or lesser extent) local, whereas many other environmental impacts are global (e.g. global warming potential, stratospheric ozone depletion, abiotic resource depletion).

Conservation of biodiversity can benefit food production, but also limit the area of land available for food production

Constraints of biodiversity conservation
Mitigation of biodiversity loss could influence food production in many ways. Biodiversity supports agriculture; for example, soil microflora and predatory insects can have immediate benefits, and genetic diversity of wild plant species related to crop species can have a longer-term benefit by providing materials for breeding programmes. There is, however, also competition for land between agriculture and biodiversity conservation. Biodiversity can be conserved to some extent on farmed land – but also by protecting land, such as tropical forest, from conversion to agriculture. Thus, conservation of biodiversity can benefit food production, but also limit the area of land available for food production.

Despite its importance, both the size and direction of the effect of biodiversity conservation on food production by 2020 and 2030 are very uncertain. On farmed land some measures to conserve biodiversity could limit yield (for example, decreased chemical crop protection), but also could benefit yield (for example, through greater population of predatory insects). Similarly, expansion of land use for farming can increase production, but in the longer term may limit yield through loss of ecosystem services.

In developing this scenario we have chosen to assume that biodiversity conservation will prevent further expansion of land used for food production. As the estimates of food-system change under Scenario 3 did not assume any change in the production area, this does not modify the Scenario 3 guidance for food-range design.

Constraints of water availability
Sylvester-Bradley, Berry and Wiseman (2005) suggest that the most serious environmental effect of much-increased crop yields would be on water resources, by greatly reducing drainage into water courses. Climate change will tend to accentuate this problem.

Taking a broad view, FAO (2009a) estimated that irrigated agriculture covers 20% of cropland but contributes nearly 50% of crop production, while Strzepek and Boehlert (2010) found that by 2050 there would be 18% less water available for agriculture. Using these values we estimate that water availability could have a negative effect on production, modifying the trends given in Scenario 3 by -2% (2020) and -4% (2030).

A significant shift in the food system would be needed and this would involve changes in the location of production for some goods, and changes in the availability of some goods.

15.3 IMPLICATIONS FOR FOOD-RANGE DESIGN

Predictions of yield potentials of farmed species, even at the lower end of the ranges, suggest that a loss of yield potential of 2% by 2020 would not prevent the achievement of the Livewell 2020 diet. However, water constraints to production are likely to lead to large changes in the world food system, by changing the locations of production for many food goods, and the balance of production between food commodities. For example, some foods requiring high irrigation inputs may become more scarce.

The implications for the food-range design are, therefore, broadly as Scenario 3, but it is suggested that consumption of foods requiring high irrigation inputs, or grown in areas of high water scarcity, should be reduced. This guidance will influence procurement policy more than food-range design *per se*.

16. CONCLUSIONS

This study has reviewed evidence relating to sustainable consumption and production and considered four possible future scenarios in the light of this evidence.

These scenario results provide information that can inform the two main aspects of a food range:

1. Food product design, including portion size and composition
2. Ingredient sourcing strategy.

Summaries of the scenarios are outlined below and the preferred scenario is identified for a low-carbon and sustainable global food system by 2020.

SCENARIO 1

Continue on existing path

In this scenario global demand patterns continue on the current path towards increasing food consumption. There is also a shift in developing countries towards a Western-style diet, which is high in fat and non-extrinsic milk sugars and low in fish, fruit and vegetables.

The dual impact of consuming more food and shifting towards a Western-style diet creates health problems but also results in a large increase in GHG emissions from producing more calories per individual for an increased world population, and from increased consumption of high-impact foods. The scenario includes an increase in meat and dairy consumption, both of which have high GHG emissions at production. Another negative environmental trade-off is that the increase in land required for food production will have a negative impact on biodiversity. In terms of health, an increase in average world calorie intake per person will exacerbate obesity and related illnesses such as heart disease and diabetes.

Verdict – continuing on the existing path will not deliver a low-carbon and sustainable food range.

SCENARIO 2

Aspire to have organic and high animal welfare production

This scenario outlines a change in demand which encapsulates aspirational production systems, specifically organic and high animal welfare. Products for which demand is predicted to significantly decrease in this scenario are potatoes, milk and dairy, and meat.

The increase in organic and animal welfare standards required to meet this scenario in only eight years, starting from a very low baseline, is exceedingly challenging on a world scale. Even within the EU, agreeing and implementing such regulation would be challenging. New legislation requiring a change to production systems in a short space of time would present a number of issues, one of the most important from the farmers' perspective being the cost. For example, replacing conventional cages in the UK egg industry would cost in the region of £400 million. Another consideration in implementing such legislation would be preventing the sale of imports not produced to the same high-welfare standards.

Food procurers may be able to put in place a supply chain that is consistent with this scenario within 10 years, but this would be challenging in terms of product availability, and cost is likely to increase.

There is no firm scientific consensus that organic production produces lower GHG emissions per product than conventional methods of production. For example, a Defra-funded study found that to produce organic eggs would result in an increase in GHG emissions of up to 40% (Williams et al., 2011). Overall, the evidence suggests that organic production systems do not have lower GHG emissions than conventional agriculture. In organic arable farming, the reduction in inputs under organic husbandry is offset by the reduction in yield. Lower yield can lead to more land-use change in another place to meet food demand, adding further impact. These potentially greater impacts of organic production may be balanced by widespread and large changes in consumption (a shift to lower meat consumption), but there is no indication that this could occur by 2020.

There is no doubt we should be striving to make gains in animal welfare, to reduce our use of inputs, to manage soils better and to farm more efficiently. Scenario 2 is, however, not an effective way to achieve this because it is production led, and the necessary changes in consumption are unlikely.

Verdict – Scenario 2 will not deliver a low-carbon and sustainable food range.

SCENARIO 3

Improve production efficiency and reduce meat and dairy consumption

This describes a food system which incorporates changes in production, technology and consumption – including all technological changes (including genetic modification and biotechnology), aquaculture, predicted production efficiencies, and changes in meat and dairy consumption.

This is the first of the scenarios to address the need to change consumption as well as production, and uses the Livewell diet as a template for a sustainable and healthy diet.

From a production and carbon emissions perspective, this scenario maximises resource efficiency through adopting best production technologies. The scenario assumes that there is no increase in farmed area, but the effect of urbanisation on farmed area is unclear. Use of technology could include genetically modified (GM) crops. In Europe, GM technology is a controversial topic but use of such technology seems to be accepted in some other parts of the world. It is possible that attitudes of consumers could change in the future as GM technology may prove to be part of the solution to feeding a burgeoning world population effectively. Future adoption of GM and other emerging technologies should be carefully reviewed.

The main weakness of Scenario 3 is that it does not take into account the impact of food production on local water scarcity and biodiversity. It will deliver a low-carbon food range – but not a sustainable one.

Verdict – Scenario 3 will deliver a low-carbon food range but not a sustainable food range because local biodiversity and water availability are not protected.

SCENARIO 4

Take account of environmental impacts which may not decrease greenhouse gas emissions

Scenario 4 is similar to Scenario 3 (above), but it addresses the main deficit of Scenario 3, namely the issue of unsustainable water use and impacts on biodiversity at a local scale. It is our view that Scenario 4 could be further enhanced by adding a requirement for enhanced animal welfare standards.

Verdict – Scenario 4 is the preferred option, as it will deliver a low-carbon and sustainable food system. It minimises adverse impacts of food production on the environment at a local scale, particularly in regards to biodiversity and water. Improvement in animal welfare standards could be achieved under this scenario and should be implemented alongside the food-range guidelines that this scenario leads to.

Paul Kariuki Kamondo picks snow peas. Kamondo belongs to PELIS – Plantation Establishment for Livelihood Improvement Scheme – and now grows snow peas as an export crop and keeps bees. He is part of a community that works with WWF and the Kenya Forest Service to replant government forestry land in exchange for livelihood inputs.

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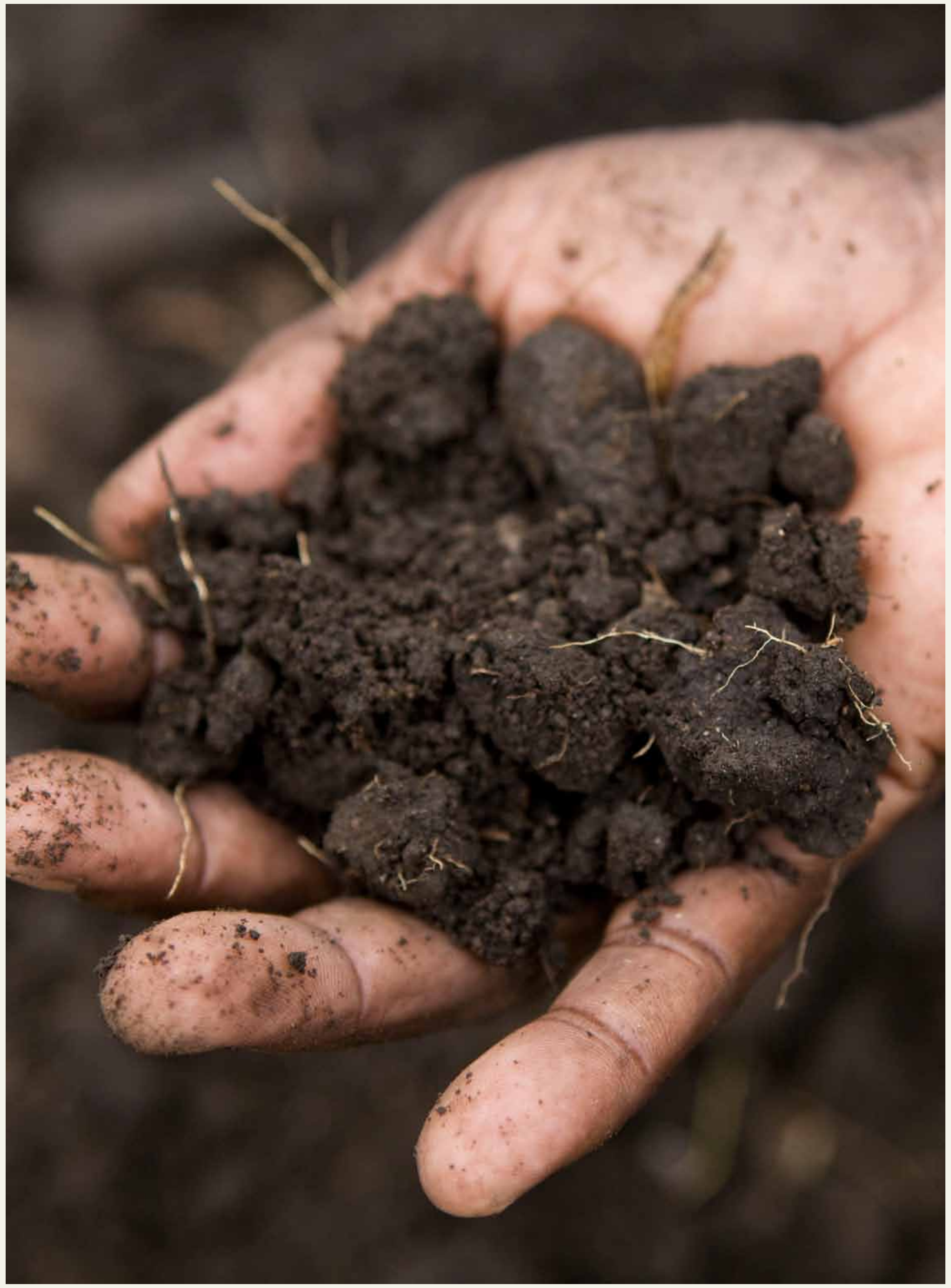

Over the last 50 years, agricultural output has kept pace with the rapid rises in global food demand. This has largely been achieved through increases in yield rather than area. But what do the next 50 years hold?

Appendix 1:
Food consumption and the percentage contribution to this total by food categories, for the world, UK, China and India.

		World			UK			China			India		
		2010	**2020**	**2030**	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
	Total (grams/person/day)	**1784.8**	**1864.9**	**1961.0**	**2304.2**	**2284.8**	**2292.6**	**2740.3**	**2977.0**	**3301.9**	**1221.7**	**1299.7**	**1385.0**
Fruit and vegetables	**Total**	44%	45%	46%	32%	34%	35%	60%	60%	60%	39%	39%	39%
	Vegetables	34%	34%	35%	18%	19%	20%	54%	54%	55%	30%	30%	30%
	Fruits	10%	11%	11%	14%	15%	16%	5%	6%	6%	9%	9%	9%
Bread, rice, potato, pasta, other starchy food	**Total**	31%	30%	29%	30%	30%	30%	25%	24%	23%	40%	41%	40%
	Cereals - total	24%	24%	23%	13%	13%	13%	17%	18%	18%	36%	35%	34%
	Wheat	11%	11%	11%	12%	12%	11%	7%	8%	9%	15%	16%	17%
	Rice	9%	9%	9%	1%	1%	1%	8%	9%	8%	16%	15%	15%
	Millet	1%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2%	2%
	Maize	3%	3%	3%	0%	0%	0%	1%	1%	1%	1%	1%	1%
	Roots and tubers	2%	2%	2%	3%	3%	3%	2%	1%	1%	1%	1%	1%
	Potatoes	5%	4%	4%	14%	15%	15%	4%	3%	3%	4%	4%	5%
	Sweet potatoes	1%	1%	1%	0%	0%	0%	3%	1%	0%	0%	0%	0%
Meat, fish, eggs, beans, other non-dairy protein	**Total**	13%	14%	14%	16%	16%	16%	12%	12%	12%	4%	4%	3%
	Meat – total	6%	6%	6%	10%	10%	10%	6%	6%	7%	1%	2%	2%
	Beef	1%	1%	1%	2%	2%	1%	1%	1%	1%	0%	0%	0%
	Lamb/goat	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%
	Pork	3%	3%	3%	3%	3%	3%	4%	4%	4%	0%	0%	0%
	Poultry	2%	2%	2%	4%	4%	5%	1%	1%	1%	0%	0%	0%
	Eggs	1%	2%	2%	1%	1%	1%	2%	2%	2%	0%	0%	0%
	Fish – total	4%	5%	5%	5%	5%	5%	4%	4%	4%	1%	2%	2%
	Fish – seafood	3%	3%	3%	3%	3%	3%	3%	3%	3%	1%	1%	1%
	Fish – demersal	0%	0%	0%	1%	1%	1%	0%	0%	0%	0%	0%	0%
	Fish – freshwater	1%	1%	1%	0%	1%	1%	1%	1%	1%	1%	1%	1%
	Fish – marine	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Fish – pelagic	1%	1%	1%	0%	1%	1%	0%	0%	0%	0%	0%	0%
	Pulses	1%	1%	1%	1%	1%	1%	0%	0%	0%	2%	2%	1%
Milk and dairy	**Total**	7%	7%	6%	15%	14%	12%	1%	1%	1%	11%	12%	13%
	Milk (whole)	7%	6%	6%	14%	12%	11%	1%	1%	1%	10%	11%	12%
	Butter, ghee	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%
	Cheese	0%	0%	0%	1%	1%	2%	0%	0%	0%	0%	0%	0%
Food and drink high in fat and/or sugar	**Total**	5%	5%	5%	7%	6%	6%	2%	3%	3%	6%	5%	4%
	Refined sugars	3%	3%	3%	4%	3%	3%	1%	1%	1%	3%	2%	1%
	Animal fats	0%	0%	0%	1%	1%	1%	0%	0%	0%	1%	1%	1%
	Vegetable oils	2%	2%	2%	2%	2%	3%	1%	1%	1%	2%	2%	2%

Global food in numbers

20%

Irrigated agriculture covers 20% arable land but contributes to 50% of crop production

ZERO

If we embrace a dietary shift, zero net deforestation is possible by 2020

© NASA

2020

It is possible to feed the world sustainably by 2020 if we change how we produce and consume food

50%

A 50% reduction in post-harvest losses is a realistic goal