

# EATING THE PLANET?

How we can feed the world without trashing it

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**Friends of  
the Earth**

**COMPASSION**  
in world farming 

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This briefing paper was produced by Compassion in World Farming and Friends of the Earth. It summarises an original study undertaken by researchers at The Institute of Social Ecology, Alpen Adria Universität Klagenfurt, Vienna, Austria, and Potsdam Institute for Climate Impact Research, Potsdam, Germany, and draws out implications and recommendations arising from the research findings. The authors of the full research report are: Karl-Heinz Erb, Helmut Haberl, Fridolin Krausmann, Christian Lauk, Christoph Plutzer, Julia K. Steinberger, Christoph Müller, Alberte Bondeau, Katharina Waha, Gudrun Pollack. The full research report can be found at:

[www.foe.co.uk/eatingtheplanet/fullreport](http://www.foe.co.uk/eatingtheplanet/fullreport)

[www.ciwf.org/eatingtheplanet](http://www.ciwf.org/eatingtheplanet)

# THE CHALLENGE

**The escalating demands of a growing and increasingly affluent world population are putting the natural world under mounting pressure. Human use of land, along with climate change, is undermining the Earth's ability to deliver vital life-support services.**

While "Green Revolution" technologies such as progress in plant breeding, fertiliser production, pesticide use and mechanisation have resulted in increases in yields and efficiencies, they have also had major widespread negative environmental and social impacts. These include the degradation of soils and ecosystems around the world, excessive use of water and loss of crop and species diversity. Biodiversity is being lost up to 1,000 times as quickly as it would naturally (Millennium Ecosystem Assessment, 2005). Farming around the world is both affected by, and a contributor to, climate change, with 22 per cent of emissions generated by agriculture of which 80 per cent comes from livestock production (McMichael *et al.*, 2007).

Intensive animal production has boosted production yields but these developments come at a severe price – these systems include production methods that cause significant and widespread animal suffering, such as the selection of animals for rapid growth, leading to lameness and other physiological disorders, and the use of cages and crates which severely restrict animal behaviour.

The world population is expected to increase significantly in the coming decades, with current predictions indicating that it will reach 9.16 billion by 2050. The number of hungry people in the world is increasing and is now over one billion (FAO, 2009). At the same time, around the same number of people are defined as obese – overweight to a level which endangers their health - highlighting how damaging the global food system is.

Whilst the food crisis is not new, recent fluctuations in commodity prices have brought political attention to the challenge of feeding a growing world population. Agribusiness has been quick to promote

further intensification of crops and livestock farming, including genetically modified crops. However, a major international assessment of agriculture (IAASTD, 2008) suggested a different approach, highlighting the huge environmental and social costs of intensive agriculture. The UN-sponsored assessment was produced over four years and involved a multi-disciplinary team of 400 scientists. Its findings have been endorsed by 58 governments, including the UK. Professor Bob Watson, (now the Chief Scientific Advisor for the UK Department of Environment, Food and Rural Affairs), who chaired the process, concluded at the launch that "business as usual is not an option". Instead the assessment recommended that researchers should urgently work with farmers' and communities' traditional knowledge to deliver agro-ecological production – farming that balances environmental sustainability, social equity and economic viability.

Feeding the world sustainably, fairly and humanely in the coming decades, under increasing pressures due to climate change, is one of the greatest challenges facing humanity. Friends of the Earth and Compassion in World Farming commissioned a study to model how the Earth can provide sufficient food and fuel for its likely population in 2050 while meeting the following objectives:

- Reducing agriculture's environmental impact
- Reducing animal suffering through humane methods of livestock farming
- Protecting areas that are critical to life on Earth such as tropical forests
- Tackling the contrast of widespread obesity in some world regions and malnourishment in others
- Investigating the potential for the use of biomass for energy provision where it can be sustainably produced and is proven to reduce greenhouse gas (GHG) emissions.

# KEY FINDINGS



Humans already use 75.5 per cent of the world's land, creating a challenge for feeding the growing population

The full research study, entitled *'Eating the Planet: Feeding and fuelling the world sustainably, fairly and humanely'* focused on land and biomass use, including cropland farming, livestock rearing, bioenergy production and conversion of primary biomass to food and fuel. It was not within the scope of the primary research to consider the social, economic and political factors which influence decisions on production, diet, land use or choice of technology. This briefing summarises the findings of the study and looks at their implications.

- Although availability of good agricultural land is limited, this study finds that feeding the world in 2050 is possible without the most intensive forms of animal and crop production or a massive expansion of agricultural land
- Humane livestock farming can be adopted and environmental objectives in crop production can be met without jeopardizing food security. Humane and sustainable farming can provide sufficient food to feed a growing world population
- Options for providing sufficient food and fuel are greatly expanded if developed countries adopt healthier, lower-meat diets and food is distributed more equally
- Sufficient food can be provided in 2050 without further deforestation, although robust policy intervention would be needed to halt current rates of deforestation
- Optimistic expectations of future bioenergy potentials should be reconsidered and lowered
- The effects of climate change on future crop yields are highly uncertain. Climate change impacts are likely to affect levels of food supply and bioenergy potentials.

For the full report and executive summary see:

[www.foe.co.uk/eatingtheplanet/fullreport](http://www.foe.co.uk/eatingtheplanet/fullreport)

[www.ciwf.org/eatingtheplanet](http://www.ciwf.org/eatingtheplanet)

# SUMMARY OF STUDY METHODS

To calculate the demand for, and availability of, food and fuel in 2050, current data on human land use was used and a set of estimates developed based on predicted population growth, future crop yields, availability of agricultural land, farming systems and diets in 2050.

The study was carried out on the level of eleven world regions<sup>1</sup> as defined by the United Nations Statistical Division (UNSD, 2006, see Figure 1). Eleven food categories were identified (cereals; roots and tubers; sugar crops; pulses; oil crops; vegetables and fruits; meat of ruminants (grazers); milk, butter and other dairy products; meat of pigs, poultry and eggs; fish; other crops). Seven food crop categories were used: cereals; oil-bearing crops; sugar crops; pulses; roots and tubers; vegetables and fruits; and others.

Current land use data shows that humans already use 75.5 per cent of the world's land area. Of the remaining 24.5 per cent that is not yet used, about half is of extremely low productivity and the remainder comprises either areas of high conservation value such as pristine forests or areas with low productivity that are very difficult or impossible to cultivate, such as alpine or Arctic tundra.

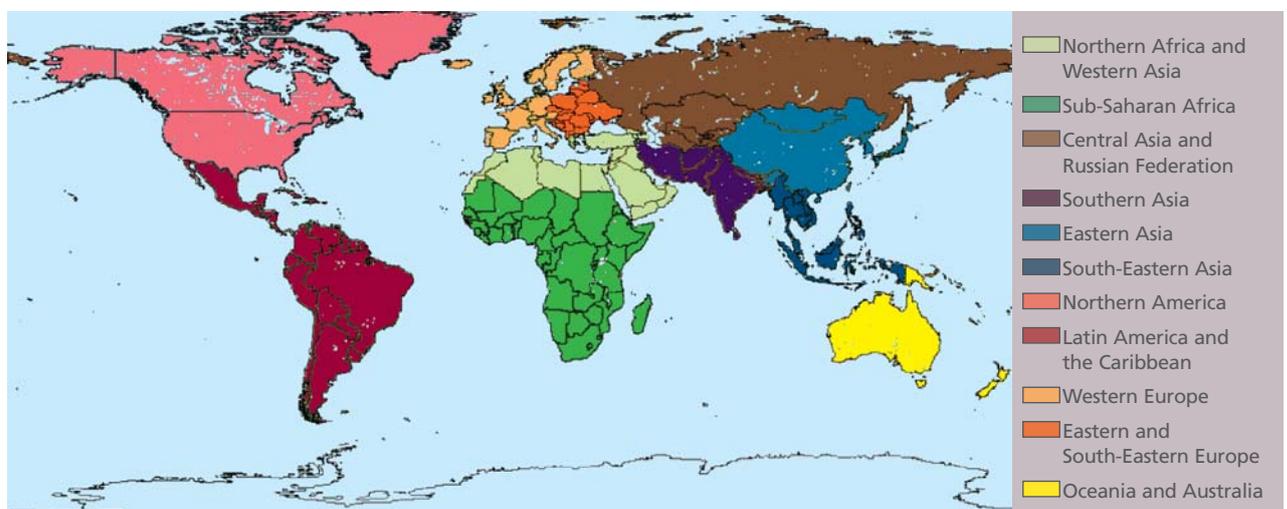
The analysis was based on combined regional data on human land use in the year 2000 (for

example, cropland, grazing areas, forestry, infrastructure), an assessment of the global human appropriation (use) of the net primary productivity of the land (HANPP) and biomass (such as food and fuel) production and consumption. HANPP is an indicator of how intensively land is being used and is defined as the difference between the net primary production (NPP) of potential vegetation and the amount of NPP remaining in ecosystems after harvest.

The likely availability of, and demand for, cropland in 2050 was calculated on the basis of different variables using the following data and estimates: forecast population size; associated growth in urban areas and rural infrastructure; crop yields as predicted by the United Nations Food and Agriculture Organisation (FAO); predicted growth in cropland area; different livestock systems and diets.

The potential for bioenergy production was calculated by assuming that 50 per cent of the residues left over from croplands after deduction of all biomass required for feeding and bedding livestock could be used for bioenergy. Any excess cropland was assumed to be available for bioenergy production.

**Figure 1. World regions used in this study**



<sup>1</sup> Region area, population density, gross domestic product (GDP), land use and other indicators are all provided in the main report annex.

## Forests

The study excluded forests both for methodological clarity and based on the central principle that their survival is critical to the future of life on Earth and that they should be protected. Any cropland expansion was expected to occur in areas currently used as grazing land. In reality, current rates of deforestation in South America, Africa and South East Asia are high and agricultural expansion is one of the key drivers. If current trends continue, a further 100 million hectares of pasture could be converted for cropland, including for soy for animal feed, in Brazil alone, forcing cattle ranchers further into forests (Rabobank, 2008). Without robust and urgent policy intervention, deforestation will certainly continue. This study adopted a zero-deforestation starting point to assess the potential to produce enough food for a growing population without further deforestation.

### Key variables and inputs

The following inputs were used in the study to model future food production scenarios:

#### 1. Potential crop yields in 2050:

- **FAO intensive crop yield** is based on FAO predictions of an increase in crop yields of 54 per cent. This is highly optimistic and, even if biologically possible, would only be realised with extensive investment in agricultural research and development. Achieving these yields in the short term would cause further severe biophysical challenges such as soil erosion and may be limited by other factors

such as climate change and water availability (IAASTD, 2008).

- **Wholly organic crop yield** refers to 100 per cent organic cropland agriculture.
- **Intermediate crop yield** is the numerical mean between the FAO intensive and wholly organic yields. It could be interpreted as 50 per cent organic, 50 per cent intensive cropping or reflect the use of more environmentally sustainable farming methods across the board, achieving average yields in between the FAO intensive and wholly organic forecasts.

- 2. The amount and distribution of land suitable for agriculture:** The expected growth in urban and infrastructure areas was calculated on the basis of forecast population growth. The area of currently unused land and land under forestry was held constant. Areas of currently unused land with particularly high productivity (including pristine forests) were excluded from the study. Cropland is instead expected to expand into areas currently used as grazing land. Two cropland expansion scenarios were considered:

- **'Business as usual' land use change:** This estimate was based on FAO predictions for cropland expansion. It assumes that global cropland areas grow by 9 per cent, thereby replacing grazing areas.
- **'Massive' land use change:** In this case global cropland grows by 19 per cent, again replacing land currently used as grazing land.



*Forests are critical for the Earth's survival*

**3. Three livestock systems:** Currently around 60 billion animals (poultry and mammals) are used to produce food annually, and according to the FAO, this number could double by 2050. The majority of this increase in production is forecast to come from intensive, indoor livestock systems (FAO, 2009b). A global move to more humane free-range systems would vastly improve farm animal welfare. In this study, all three livestock scenarios involve a mixture of subsistence systems, extensive market-integrated systems and commercially-oriented modern animal production systems.

- **Intensive livestock system:** The number of animals reared intensively in indoor systems increases to 45 per cent, replacing many subsistence farms (which are decreased by 50 per cent). The proportion of organic and humane farms is very low.
- **Humane livestock system:** Free-range systems (similar to typical UK and European Union standards) replace all intensive, indoor-housed systems and some subsistence systems.
- **Organic livestock system:** organic livestock rearing which adheres to the International Federation of Organic Agriculture Movements (IFOAM) standards replaces all intensive systems, and some subsistence systems.

**4. Four diets were defined, based on different calorie counts and varying proportions of animal products.** Countries with high gross domestic product (GDP) per capita on average consume more food and have a higher proportion of animal products in the diet than countries with low GDP. For example, the average North American consumes twice as much protein as an average Sub-Saharan African, with almost two-thirds of protein coming from animal products, compared to just one-fifth in the case of an average Sub-Saharan African.



*Sow stalls in an intensive pig farm, Denmark*

- **Western high meat:** Economic growth and consumption patterns accelerate in the coming decades, leading to global adoption of western style diets with relatively very high meat and dairy consumption. Average calorie intake increases and reaches at least 3,000 kcal per person per day in all regions. On average, 44 per cent of protein intake is assumed to come from animal products.
- **Current trend:** Over time, meat consumption increases in line with GDP. This diet scenario projects this trend into the future. By 2050, every region attains the diet of the country with the richest diet in that region. Calorie intake ranges between 2,700 kcal per person per day in the poorest regions and 3,600 kcal per person per day in the wealthiest regions, with a world average of 3,000 kcal per person per day.

- **Less meat:** This diet is based on satisfying growing food and nutrition demands with a lower meat diet. It has the same level of dietary energy - 3,000 kcal per person per day on average - as the 'current trend' diet but with 30 per cent of protein from animal products. The proportion of animal products in the diet decreases in wealthy regions such as North America, Oceania and Western Europe and increases in Sub-Saharan Africa and Southern Asia.
- **Fair less meat:** This diet assumes a fair and equal distribution of 2,800 kcal per person, per day. The proportion of animal protein in the diet is maintained at 20 per cent for everyone, marking an increase in meat and dairy consumption in the poorest regions and a decrease in wealthy regions. This diet is sufficient in terms of both quantity and quality on an average per person basis. It is consistent with healthy diet recommendations of consumption of around 90 g of meat per day (McMichael *et al.*, 2007). In terms of calorie intake, this diet is in line with average diet levels in the year 2000. However this diet model ensures the global population receives this level of calorie intake equally, so regional calorie intakes in developed countries would reduce and, conversely, increase in some developing regions.

**Table 1. Basic characteristics of the four diets**

Diet	Global increase in dietary energy	Global increase in animal protein consumption	'Business-as-usual' evolution of diet	Global protein from animal products (%)	Average calorie intake (Kcal person/day)	Globally equitable distribution of food
Western high meat	✓	✓	✓	44%	3170	
Current trend	✓	✓	✓	38%	2990	
Less meat	✓			30%	2990	
Fair less meat				20%	2800	✓

# STUDY RESULTS

## Feasibility of diet and farming scenarios

The variable crop yields, livestock systems, land use changes and diets were combined within the model, resulting in a combination of the 72 scenarios. Each one was assessed for feasibility in terms of land use to provide sufficient food for the world population in 2050. The results are presented in Table 2. The feasibility of each scenario was determined as:

- Probably feasible (yellow +/-): demand for cropland and availability differ by less than 5 per cent
- Feasible (green +): cropland availability exceeds demand by more than 5 per cent
- Highly feasible (blue ++): cropland availability exceeds demand by more than 20 per cent
- Not feasible (blank -): cropland demand exceeds cropland availability by more than 5 per cent

**Table 2.** Feasibility analysis of all 72 scenarios

	CROP YIELDS	FAO intensive	FAO intensive	Inter-mediate	Inter-mediate	Wholly Organic	Wholly Organic
	LAND USE CHANGE	Massive	Business as Usual (BAU)	Massive	BAU	Massive	BAU
DIET	LIVESTOCK SYSTEM						
Western high meat	Intensive	+/-	-	-	-	-	-
Western high meat	Humane	-	-	-	-	-	-
Western high meat	Organic	-	-	-	-	-	-
Current trend	Intensive	+	+	+	+/-	-	-
Current trend	Humane	+	+	+	+/-	-	-
Current trend	Organic	+	+/-	+/-	+/-	-	-
Less meat	Intensive	+	+	+	+	+/-	-
Less meat	Humane	+	+	+	+	+/-	-
Less meat	Organic	+	+	+	+	-	-
Fair less meat	Intensive	++	+	++	+	+/-	+/-
Fair less meat	Humane	++	+	++	+	+/-	+/-
Fair less meat	Organic	++	+	++	+	+/-	-

Scenarios may be unfeasible, or undesirable, for reasons other than cropland availability. For example, even if it were possible to attain the FAO's high yield forecast, achieving these high levels could itself undermine future food production capacity through use of inappropriate agricultural technologies, the deterioration of soils due to unsustainable cropping practices or salinization resulting from poor irrigation techniques. Determining the feasibility of scenarios for such reasons was outside the scope of the primary research, but is discussed later.

### **Land availability**

There was sufficient grazing area in all scenarios, even those that involved massive cropland area change. Deforestation was not included in the modelling and the results of the study show that forests do not need to be cleared to feed a growing world population.

The 'western high meat' diet required massive land use change in order to be at all feasible. All other diet and animal production scenarios could be adopted without requiring massive land use change, with intermediate yields.

### **Feasibility by diet**

#### **The 'western high meat' diet: Expansion of diets based on high levels of meat and dairy products is not an option**

Global adoption of the 'western high meat' diet is only probably feasible with massive land use change. This would mean that an additional three million km<sup>2</sup> of land would be needed for agricultural production, expanding into grazing land, with potential for serious detrimental environmental consequences. It would rely on a highly optimistic 54 per cent increase in crop yields in line with the highest possible FAO forecasts. This approach would also rely on confining the vast majority of farm animals in inhumane intensive production systems.

#### **'Current trend' diet: trade-offs between massive land use change and intensification**

Results show that achieving current diet trends in 2050 is possible in a number of different scenarios, but to be feasible would

require a trade-off between massive land use change and further intensification of crops or livestock production systems. This diet would probably be feasible without massive land use change and with humane livestock production and intermediate yields (between organic and intensive). However, alongside the environmental implications of this diet outlined below, uncertainties over the effects of climate change highlight the need to urgently reconsider food systems that involve such high levels of animal consumption.

#### **The 'less meat' diet: Saving natural resources and promoting global food security**

The study showed that reducing meat consumption would result in lower use of the world's natural resources and would open up more options for less intensive farming. Under the 'less meat' diet it is possible to feed the world whilst adopting lower input-output crop and livestock farming systems that have significant benefits for the environment and animal welfare, i.e. humane or organic livestock systems combined with intermediate crop yields, whilst avoiding massive land use change.

#### **The 'fair less meat' diet: Fair global food supplies providing environmental benefits**

The aim of the 'fair less meat' diet was to assess whether it would be feasible to feed the world on a highly resource-efficient diet, made available equally to the world's population. This diet had the lowest meat consumption of the four models and easily provided sufficient food to feed the global population. Under this diet, even wholly organic crop systems could probably be adopted globally, together with humane livestock systems, to produce enough food without massive land use change. The adoption of intermediate yields would even guarantee sufficient food under all livestock systems, including organic.

#### **Humane and sustainable farming can feed the world**

It has previously been presumed that feeding the world's growing demands would require significant agricultural intensification and maximisation of yield of both crops and

livestock systems, with the potential for disastrous environmental and animal welfare impacts. This study shows that even under the current trends diet, it would probably be feasible to feed the world under humane animal rearing systems and intermediate crop yields, without the need for massive land use change. If diets change to 'less meat', it would even be feasible to produce enough food under organic livestock systems with

intermediate crop yields whilst avoiding massive land use change.

This suggests that, in order to feed the world in 2050, a potentially detrimental rush to further intensification is unnecessary. Humane and sustainable farming systems, which can protect both the environment and farm animal welfare, can be considered as a mainstream agricultural strategy.

## WIDER IMPLICATIONS OF STUDY RESULTS

### Environmental and health impacts of increasing meat consumption

**Continuing along the existing global trajectory of increasing meat and dairy consumption is likely to lead to further agricultural intensification of both crop yields and farm animal production systems plus, in the case of the 'western high meat' diet, massive land use change. This could lead to significant further pressure on available resources and is incompatible with a fair global food supply.**

Both the 'western high meat' and 'current trend' diet scenarios are likely to have an enormous impact on the environment and accelerate climate change. Globally, livestock production already contributes 18 per cent to global greenhouse gas emissions, more than the emissions from all transport (Steinfeld *et al.*, 2006). Currently around 60 billion animals (poultry and mammals) are used to produce food annually (FAO, 2009b). This number would be likely to double under the 'current trend' diet, and would be further increased in the 'western high meat' diet. An expansion of animal production by 2050 is likely to lead to a massive rise in greenhouse gas emissions, increasing the likelihood that the world will fail to prevent dangerous climate change. Doubling livestock production will put pressure on other resources, such as water, the use of which in agriculture is already predicted to increase by 70 - 90 per cent in the coming decades as a result of increased demand for food (IAASTD, 2008).

The demand for land for feed production under both the 'current trend' and 'western high meat' diet scenarios will increase pressure toward crop intensification and opening up of new croplands, potentially resulting in further biodiversity loss. Intensification could impact on both crop and grazing lands, which include a large variety of ecosystems. Grazing land, for example, comprises intensively-cultivated meadows as well as semi-natural landscapes and it is often of very high ecological and biodiversity value. Biodiversity is already being lost up to 1,000 times faster than natural rates of species loss (Millennium Ecosystem Assessment, 2005). Agricultural intensification and expansion is a major factor as it drives habitat loss. Populations of 45 per cent of Europe's common bird species declined across 20 countries between 1980 and 2005, with farmland birds particularly affected, driven by agricultural intensification and the resulting deterioration of farmland habitats (Donald *et al.*, 2001).

Areas likely to be affected under these scenarios include the Cerrado of Brazil, one of the largest and most biodiverse savannah areas in the world covering an area the size of Western Europe. The Cerrado comprises large stretches of grassland, scrub and areas of woodland which run alongside river banks. It is internationally recognized as a biodiversity hotspot and is home to 40 per cent of Brazil's mammals, over 900 species of birds and 10,000 species of plants. More than half of the Brazilian Cerrado has been

replaced by crops and pasture in the last 35 years and it is now one of the world's main regions of soya and beef production (Marris, 2005). Further loss of areas such as the Cerrado could occur under a scenario of massive agricultural expansion.

### **Reducing meat consumption: benefits for animals, people and the planet**

**Maximising yields or expanding cropland at all costs, irrespective of the environmental, social or animal welfare impacts involved, is not necessary to feed the world's expanding population. Furthermore, less intensive humane and sustainable farming can easily feed the world in 2050 if the developed world reduces its meat consumption. Lower-meat diets should be pursued for their benefits not only in reducing GHG emissions and benefiting biodiversity, but also for human health.**

The 'less meat' diet would decrease consumption of animal products in North America, Western Europe and Oceania. Meat intake would increase in Northern Africa, Western Asia and in Sub-Saharan Africa for nutritional reasons as current consumption of animal products is relatively very low. On average, the proportion of animal protein in the diet would decrease to 30 per cent, from a global average of 38 per cent in 2000. This scenario would have significant environmental and human health benefits, would be feasible under realistic intermediate crop yield forecasts and would not require massive land use change. It would also have significant farm animal welfare benefits as animals would not need to be kept in intensive close-confinement livestock production systems.

There is huge potential to feed the planet using organic agriculture. Adoption of the 'fair less meat' diet would make organic crop farming a feasible way to feed the world. While wholly organic crop yields would only be probably feasible with massive land use change, a mixture of organic and conventional crop yields (as shown in the intermediate crop yield scenario) is feasible without major land use change. This means that it would be possible to provide everyone with a sufficient diet on a mixed conventional/organic crop

production system, or on a wholly organic system with improvement in organic yields.

The findings of this research support previous studies demonstrating that a reduction in the consumption of animal products would reduce human pressure on the environment. Switching to a lower meat diet would reduce pressure on land as, under these diet scenarios, feeding the world will be possible without massive land use change. This is consistent with previous studies, which showed that reducing global meat consumption could free up one million square kilometres of cropland and 27 million square kilometres of pasture that could be used to store large amounts of carbon as the vegetation regrows (Stehfest *et al.*, 2009).

A switch to organic farming or a greater proportion of organic agriculture would have a number of environmental benefits, including increasing organic matter in soils and better soil structure (Mäder *et al.*, 2002, Marriott and Wander, 2006, Fließbach *et al.*, 2007); reduced soil erosion (Reganold *et al.*, 1987, Siegrist *et al.*, 1998), greater biodiversity compared to conventional agriculture (Bengtsson *et al.*, 2005, Hole *et al.*, 2005) and lower GHG emissions, in particular due to the lack of synthetic nitrogen fertiliser use which is prevalent in intensive crop agriculture.

Lower meat consumption would result in lower greenhouse gas emissions. In 2001, the Intergovernmental Panel on Climate Change (IPCC) noted that *"a shift from meat towards plant production for human food purposes, where feasible, could increase energy efficiency and decrease greenhouse gas GHG emissions"* (IPCC, 2001). The lower land use change possible under these diet scenarios would also reduce the carbon emissions from soils and allow for more soil carbon sequestration.

Human health would benefit under 'contraction and convergence' of diets: western countries would cut back on their meat and dairy consumption, while those in developing countries increase their consumption according to their dietary needs (McMichael *et al.*, 2007). Reducing meat consumption in developed countries would reduce the risk of obesity, heart disease and some cancers (Costello, 2009). According to Lord Jay and Professor Marmott,

writing in *The Lancet*, improving health and tackling climate change through a reduction in meat consumption should be seen “as an opportunity rather than a cost” (Jay and Marmott, 2009).

### The effects of climate change

The impacts of climate change on crop yields through changes in temperature, precipitation and carbon dioxide (CO<sub>2</sub>) fertilisation are highly uncertain. Plants take up atmospheric CO<sub>2</sub> for photosynthesis. Higher CO<sub>2</sub> levels can therefore, under certain circumstances (predominantly sufficient nutrient supply), boost plant growth and alleviate water stress – this is known as the CO<sub>2</sub> fertilisation effect. However, while detectable under controlled conditions, the magnitude of this effect under real world conditions is highly uncertain. The study finds that impacts of climate change on yields would be negative if only changes in precipitation and temperature were taken into consideration and the CO<sub>2</sub> fertilisation effect did not occur, whereas it can be strongly positive if it is assumed to be fully effective (Table 3).

The effect of these yield changes has a significant impact on the feasibility of the 72 scenarios: If the CO<sub>2</sub> fertilisation effect is not taken into account, only 34 of the 72



scenarios would be at least ‘probably feasible’. If it is assumed that the full CO<sub>2</sub> fertilisation effect takes place, 62 of the 72 scenarios would be at least probably feasible.

It was not possible to model the relationship between factors such as nutrient and water availability and climate change, even though it is clear that such feedbacks will be very important. In particular water availability is likely to be a limiting factor in achieving crop yields; decreasing precipitation would lead to water stress and crop failures. Whether or not farmers will be able to attain increased crop yields under elevated CO<sub>2</sub> concentrations is also highly uncertain.

**Table 3. Modelled climate impact on cropland yields in 2050 with and without CO<sub>2</sub> fertilisation.**

	Mean crop yield change under climate change 2050	
	with CO <sub>2</sub> fertilisation	without CO <sub>2</sub> fertilisation
Northern Africa and Western Asia	+ 4.44 %	- 8.65 %
Sub-Saharan Africa	+ 8.46 %	- 6.17 %
Central Asia and Russian Federation	+ 24.91 %	+ 5.12 %
Eastern Asia	+ 11.96 %	- 3.90 %
Southern Asia	+ 18.45 %	- 15.61 %
South-Eastern Asia	+ 28.22 %	- 15.83 %
Northern America	+ 12.45 %	- 6.25 %
Latin America & the Caribbean	+ 12.39 %	- 7.02 %
Western Europe	+ 16.42 %	+ 2.04 %
Eastern & South-Eastern Europe	+ 19.08 %	- 0.66 %
Oceania and Australia	+ 0.74 %	- 16.02 %

## Fuelling the world in 2050 – possible bioenergy scenarios

The study finds that the realistic future bioenergy potential is considerably lower than many studies have put forward – a maximum of 70-100 EJ/yr under realistic combinations of assumptions by 2050 (with a maximum of 160 EJ/yr under unlikely scenarios) - and that will depend on future diets, livestock systems, yields and land use.

The bioenergy potential that this calculation represents is a maximum estimate, based on the most efficient way of converting biomass to energy, for example, combined heat and power plants that are able to utilise primary solid biomass without significant conversion losses. In reality only a small fraction of biomass is converted in this way. When converting biomass into liquid biofuels for transport use, a large part of the available energy is lost.

The potential of bioenergy to meet future energy needs cannot be considered in isolation: diets, agricultural production technology and other factors will determine how much of the Earth's biomass will be available for energy use.

A wealth of studies from international organisations - the FAO, the World Bank, the OECD and the Royal Society amongst others - have warned that exploiting the world's theoretical bioenergy potential will have dramatic negative social and ecological impacts, such as further pressure on small farmers and communities that depend on the land, upward pressure on food prices and land rights conflicts. It could also trigger indirect land use change such as deforestation in South East Asia and Latin America. In the worst cases this would result in net increases in greenhouse gas emissions.



*Large-scale production of biofuels will lead to an increase in food scarcity and rising prices*

# CONCLUSIONS

**Maximising yields and expanding cropland at all costs, irrespective of the impact on the animals, people and the planet, is not necessary to feed the world now and in the future. Abandoning environmentally-damaging intensive farming will not jeopardize future world food supplies, especially if people in developed countries adopt healthier, lower-meat diets.**

Contrary to current thinking, it is possible to feed the world using solely humane (free-range) farm animal production systems. Humane animal production can feed the world without massive land use change. It has considerable benefits for animal welfare but could also provide environmental benefits such as promoting biodiversity and reducing environmental pollution (CIWF, 2009).

Reducing meat consumption in the developed world increases the resource-efficiency of diets. This research provides a new line of evidence supporting the scientifically-established correlation between the proportion of animal products in human diets and their environmental impact (e.g., Stehfest *et al.*, 2009). With a billion people in the world malnourished, and the same number of people obese – overweight to a level which endangers their health – adjusting diets globally will benefit rich countries as well as developing ones.

There is room for better farming, with no need to destroy forests. At the moment we are cutting down forests at a rate of 13 million hectares per year, mainly to grow animal feed and make space for cattle ranching (FAO, 2005).

2008 saw the release of the most comprehensive international agriculture assessment ever conducted (IAASTD, 2008). It concluded that continuing with an intensive model of agriculture was not an option because of its huge environmental and social costs. This new research demonstrates how feasible and viable

sustainable farming options are, and adds weight to claims that researchers should be working with farmers' and communities' traditional knowledge to deliver farming that balances environmental sustainability, social equity and economic viability.

The impact of climate change on future food production is uncertain but even if climate change has a negative impact on crop yields, a global lower-meat diet will still allow for the world to be fed. Climate change should not be used as a justification for further intensification that will worsen the vicious circle of environmental degradation and greater greenhouse gas emissions.

Globally, total GHG emissions must be reduced by at least 80 per cent by 2050. Given the significant contribution of agriculture to climate change, it is vital that policy and research focus on reducing emissions. Intensive crop yields are currently associated with energy intensive inputs, such as nitrogen fertilisers. Taking account of the need to mitigate and adapt to climate impacts, an intermediate system of crop yields with 'fair less meat' diets should be pursued.

Expectations for the potential of bioenergy as a future fuel should be lowered to more realistic levels and should not be viewed in isolation from world food supplies. Any land given over to bioenergy should be used in the most energy and land-efficient way for heat and electricity production only. Targets for transport biofuels should be abandoned.

Organic farming can play a significant role in feeding a world population of 9.2 billion in 2050, while enhancing farmland biodiversity and maintaining ecosystem services. With the adoption of healthy and fair diets, organic farming can no longer be dismissed as a luxury that the world cannot afford. In fact, a mixture of organic and free-range farming can deliver a range of sustainable diet options for the world's 2050 population.

# POLICY RECOMMENDATIONS

**Farming policy** Governments should assess how policies, research priorities and development programmes need to change to ensure that the 22 key findings of the International Assessment of Agricultural Knowledge, Science and Technology for development (IAASTD) are implemented so that future food production takes place in a way that benefits farmers, poor people and the environment (see box below).

In the light of the meat and dairy industry's significant contribution to climate change and global biodiversity loss, the UK Government should bring forward a legislative commitment to measure the role of UK consumption and production of animal products and a strategy to reduce their impact. Public money spent on farming subsidies should be shifted from supporting intensive and factory farming to agriculture with proven environmental benefits such as organic and other extensive methods of production.

**Diets** Action should be taken by governments and the food industry in developed countries to reduce consumption of animal products. Any reductions would be beneficial in terms of climate and other environmental impacts, animal welfare and biodiversity. This could include public awareness-raising campaigns aimed at enabling people to adopt lower-meat diets and reducing demand for intensively-reared meat, with the aim of achieving specific dietary changes which

incorporate less but better meat ('better' meaning reduced global environmental impact and improved animal welfare).

**Organic agriculture** Given the recognised environmental and animal welfare benefits, support should be increased for research and development into organic and other environmentally and socially sustainable agricultural practices, for both crops and animal production. There would be clear benefits if it were possible to sustainably improve organic efficiencies and yields. Redirecting "mainstream" agricultural research and development in a more environmentally sustainable direction would be a valuable goal for the benefit of people, animals and the planet.

**Humane farming** Governmental and intergovernmental targets and incentives are needed for both farmers and consumers to support the transition to lower-input, extensive livestock production. A government-supported meat reduction strategy would further enable farmers to reduce animal stocking densities and move from intensive to more extensive methods.

**Bioenergy** Optimistic expectations of future bioenergy potentials should be reconsidered and lowered in the light of this study. Any consideration of the expansion of bioenergy production must be preceded by careful consideration of the direct and indirect impacts on climate emissions, biodiversity and food supply. An integrated view of food

## The IAASTD:

Recognised the complexities of the problems facing world agriculture in delivering wholesome safe and affordable food without causing long-term harm to local communities and the environment in the face of climate change.

Acknowledged the failure of past technological innovations and trade to benefit poor people and to cause harm to the environment.

Emphasised the multi-functionality of agriculture in providing more than food, fibre, raw materials and biomass, for

instance providing ecosystem services and functions, maintaining landscapes and cultures and protecting animal welfare.

Acknowledged the key role that the local knowledge of farmers, particularly women, and other small-scale food producers should play in the future in developing appropriate technologies and knowledge systems.

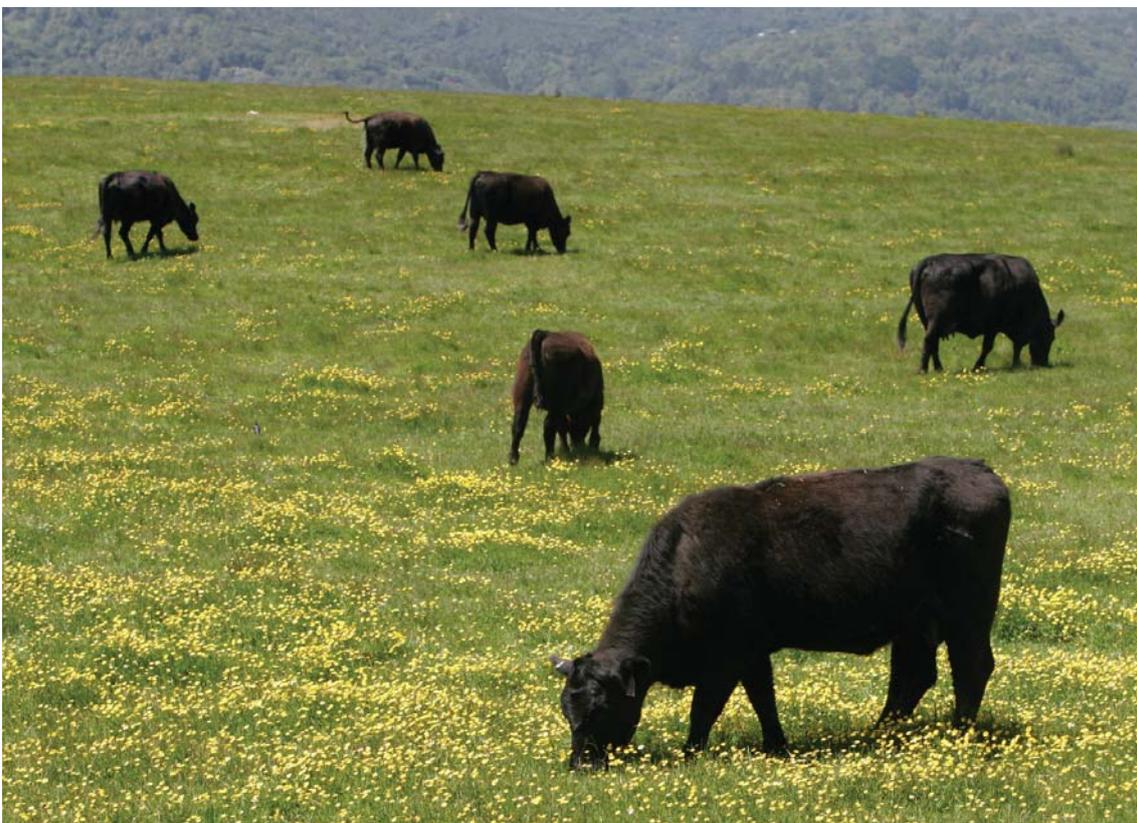
Recommended the need to focus knowledge, science and technology on agroecology in order to produce sufficient food whilst benefiting the environment and communities.

and energy needs and potential must be adopted when designing future bioenergy policies and incentives. Any land given over to bioenergy should be used in the most energy and land-efficient way for heat and electricity production only. Targets for transport biofuels should be abandoned.

**Climate change** Further research needs to focus on the impact of climate change on agriculture, as well as on reducing the impacts of agriculture on climate change. This should include developing the potential of alternatives to high resource input production methods, such as humane and sustainable farming. Taking a precautionary approach (e.g. assuming that any CO<sub>2</sub> fertilisation benefits are cancelled out by changes in rainfall and more erratic or extreme weather), global policy should encourage a move towards food systems

which can ensure enough food can be produced in future, such as the 'fair and less meat' diet under intermediate yields.

**Forests** It is clear from this research that deforestation is not required to feed the world, yet deforestation continues. Protecting forests – essential if we are to prevent runaway climate change, irreversible biodiversity loss and damage to ecosystem services – requires a strong and fair global agreement on forest protection as well as a concerted effort to support countries in implementing and enforcing national policies. Action at national and international level should recognise the rights of forest-dependent communities and avoid measures that would commoditise forest resources.



*We can feed the world using humane and sustainable farming*

# NOTES

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