FCRN Food Climate Research Network

fondation daniel & nina carasso
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FCRN foodsource

A free and evolving resource to empower informed discussion on sustainable food systems

Chapter 4.

How can we reduce food-related greenhouse gas emissions?

Foodsource is supported by: Fondation Daniel & Nina Carasso — Esmée Fairbairn Foundation — The Oxford Martin programme on the Future of Food — The Oxford Martin School —Jam Today — University of Manchester Sustainable Consumption Institute — The Wellcome Trust — WRAP

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Why should you read this chapter?

It is an internationally agreed objective to cut human-caused greenhouse gas emissions to zero this century, to avoid the worst impacts of climate change. Given the major contribution of food system activities to total human-caused emissions, reducing these emissions is of great importance. But how and by how much can emissions be reduced, while also feeding a growing population?

There are different perspectives on how food systems emissions can be reduced and it is helpful to explore these since these differences also underpin many other debates around food system sustainability. Understanding these perspectives helps to put specific proposals for reducing food system emissions into a wider food systems context.

This chapter, therefore, provides an overview of the following:

- What greenhouse gas reductions are needed across all sectors (i.e. not just food), in order to meet globally agreed climate change targets?
- What are current trends in food production and consumption and what impact might these have on future food-related greenhouse gas emissions?
- What are the three major perspectives on how food systems emissions should be reduced, and what combination of these approaches might be required?
- How does the need to reduce agricultural emissions relate to wider discussions on what food systems are preferable?

Key points

- Limiting climate change to below 2-degrees C is projected to require 40-70% reductions in GHG emissions by 2050; 70-95% for the more aspirational 1.5-degree limit.
- Food-related GHG emissions (up to 30% of all human-caused GHG emissions) currently account for all allowable emissions in 2050. Significant reductions in food-related GHG emission will, therefore, be necessary.
- This challenge is made harder by growing global aggregate and per capita demand for food in general, and for animal products (typically the most GHG intensive foods) in particular.
- Different stakeholders in the food system tend to prioritise different perspectives on how GHG emissions from food systems should best be mitigated (although many accept that a combination of approaches may be needed). Generally speaking, and to simplify somewhat, these perspectives fall into 3 archetypes:
- Production-side: produce more food for less impact and increase efficiency throughout the food supply chain. This perspective tends to prioritise efficiency improvements via new technologies (e.g. plant breeding) and a faith in globalisation, to spatially optimise food production, and so minimise environmental impacts.
- Consumption-side: reducing consumption of GHG-intensive foods, while meeting health and other sustainability goals. This perspective tends to prioritise socio-economic and political interventions to change the consumption practices of organisations and individuals.
- System transformation: reduce emissions and environmental impacts as a natural outcome of rebalancing inequalities in power, wealth, and access to food. This perspective tends to prioritise reforming institutions and governance (e.g. trade), and promotes localised and more agro-ecological food systems.
- However, each of these perspectives as outlined above, has important limitations. These are discussed in detail within the chapter.
- To most observers it is clear that some combination of all three approaches will be required: we need to produce differently, consume differently and seek to restructure food systems through changing the balance of power and wealth. Reducing waste at all stages in the food chain will also be important.

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4.1 What would be a safe upper limit to GHG emissions and where might reductions come from?

4.1.1 Significant global GHG emissions reductions are required across all sectors

IPCC reports identify likely outcomes for different global temperature increases resulting from current GHG emission trajectories. A common assumption is that an acceptable global warming limit is a 2°C rise in average global temperature above pre-industrial levels, although this is subject to debate and uncertainty.

The 2015 climate summit (COP21) in Paris resulted in reaffirmation by nations that the goal of 2°C remains, but with a strong signal of intent to limit the temperature increase to 1.5°C in response to calls by vulnerable states (specifically low-lying island nations).

The recent IPCC report calculates that GHG emissions reductions of between 40% and 70%, by 2050, will be needed for the 2°C scenario to likely be achieved. Reducing emissions to net zero well before 2100 is likely needed to maintain temperatures within this limit.

The IPCC report calculates that in order to likely stay within the 1.5°C limit, GHG emissions will need to be reduced by 70-95% by 2050.

Reductions of 70–95% in global GHG emissions across all sectors of human activity could be needed by 2050

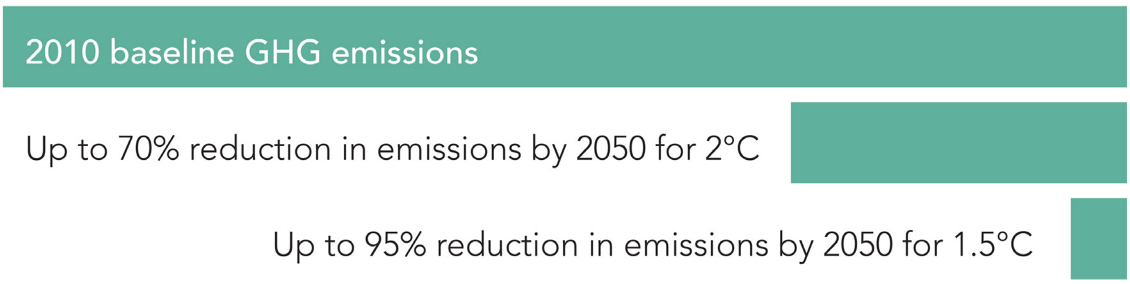

Figure 1: Comparison of annual global greenhouse gas emissions in 2010, with amounts consistent with a 2˚C and 1.5˚C target in 2050.

Source: FCRN. (2016).

This is considered to be a significant technical and socio-economic challenge.

4.1.2 The food system needs to play its part

Food-related GHG emissions are estimated to contribute around 20-30% of total global emissions (see Chapter 3). Under the 2°C scenario (entailing emissions reductions of at least 40-70%), current food-related emissions could potentially make up 100% of the total 'allowable' budget for emissions.

IPCC

The Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science related to climate change. It is administered by the United Nations with participation and decision making from 195 member states. The assessments that it produces provide the basis for government at all levels to create climate related policies.

Under the 1.5°C scenario (entailing emissions reductions of at least 70-95%), current food-related emissions would far exceed the total budget for emissions.

These ambitious reduction targets mean that food systems cannot be excluded from emissions reduction strategies

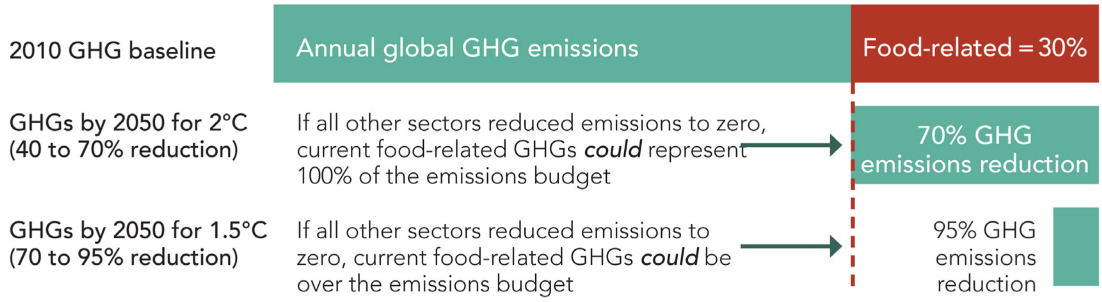

Figure 2: Comparison of annual global greenhouse gas emissions from the food system in 2010, with total global emissions amounts consistent with a 2˚C and 1.5˚C target in 2050.

Source: Vermeulen, Campbell and Ingram (2012).

While there is high uncertainty concerning actual safe limits, these figures do make it clear that GHG emissions from food systems need to be addressed. The level of absolute reductions required from the food sector is difficult to quantify, however, because the answer also depends on emission reductions in other sectors; the more that can be done to reduce emissions from the transport or built environment sectors (for example) the less needs to be done in the food sector, and vice versa. However, major reductions in all sectors will almost certainly be needed. It is also unclear what the best approaches for reductions in food-related emissions are (see later in this chapter), but the message is clear: food systems need to be part of the solution.

4.1.3 But food-related GHG emissions are likely to increase

Projections suggest that demand for food will continue to grow

Figure 3 Demand for food is projected to rise by 60% by 2050. But these are based on current trajectories, and are not definite outcomes.

Source: FCRN. (2016).

As Chapter 1 shows, demand for food is anticipated to increase by 60% by 2050. This is based on assumptions that:

- The global population will continue to rise by another 2 billion people.
- Poorer countries are expected to move out of poverty, leading to rising incomes in these countries.
- Higher incomes lead to increased spending on resource-intensive foods, including animal products.
- Increased demand for meat will result in an increased demand for arable crops as feed inputs.

However, these are projections based on the above assumptions, historical trends and current trajectories. The extent to which they come true will depend on global economic development, the actions of governments, citizens, and industry stakeholders.

Issues around changes in eating habits and sustainable eating diets are discussed in Chapter 9 and Chapter 10.

4.2 Trends in food consumption – past and future

4.2.1 Historical trends in total food consumption

Historical trends in total food consumption

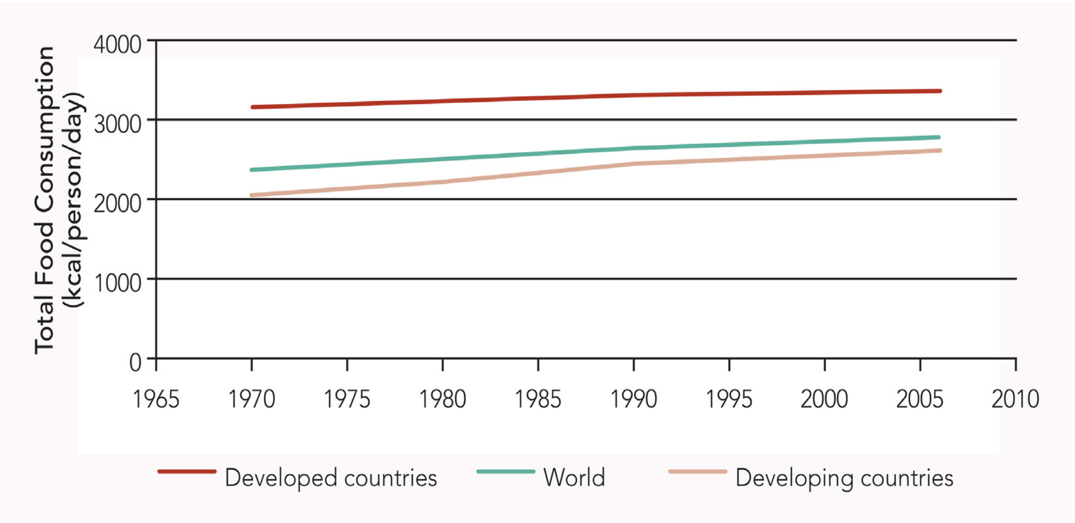

Figure 4: Total food consumption in kcal per person per day over a 35 year period, broken down into world, developed countries and developing countries.

Source: FCRN. (2016).

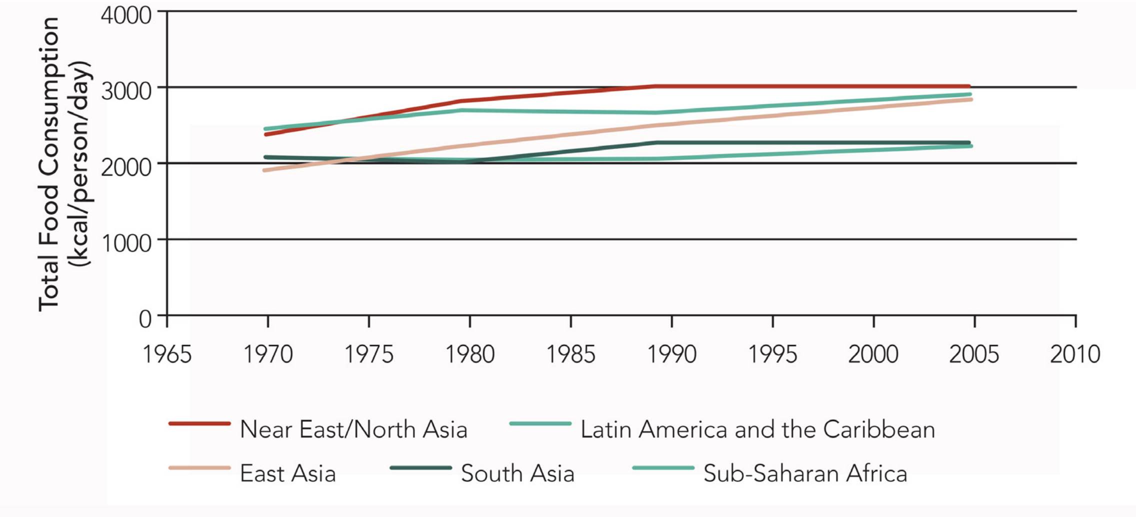

Figure 5: Total food consumption in kcal per person per day over a 35 year period, by developing region.

Source: FCRN. (2016).

Over the approximate 35 year historical period of Alexandratos and Bruinsma's analysis, average world energy intakes increased from 2370 kcal/person/day to 2770 kcal/person/day, accompanied by large shifts in dietary composition (increased consumption of livestock products and vegetable oils and a reduced dependence on roots and tubers as staples). As with many dietary trends, China is a significant contributor to the increased energy intake in developing countries, owing to its rapid economic development and increasing urbanisation in recent decades.

4.2.2 Historical trends in animal product consumption

Historical trends in animal product consumption

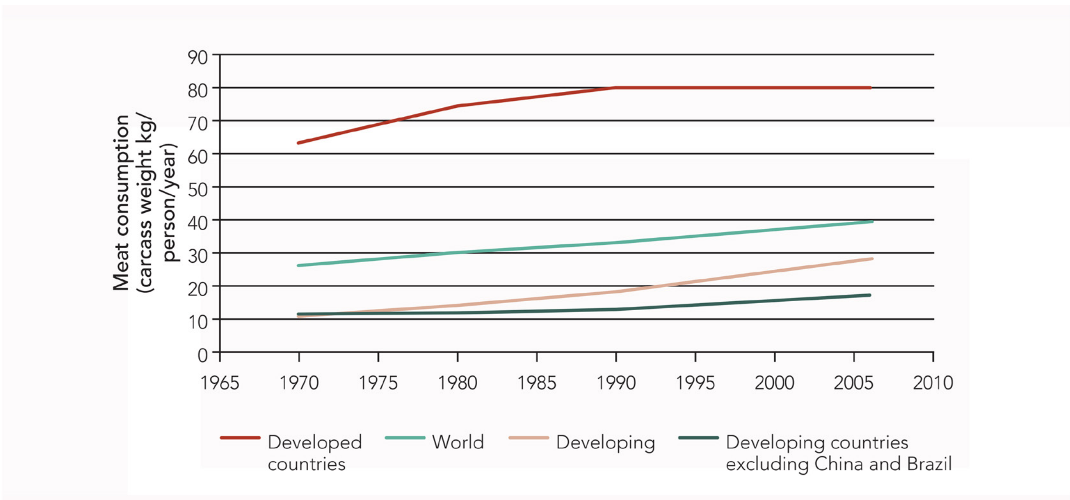

Figure 6: Meat consumption in kg per person per year over a 35 year period, broken down into world, developed countries, developing countries and developing countries excluding China and Brazil.

Source: FCRN. (2016).

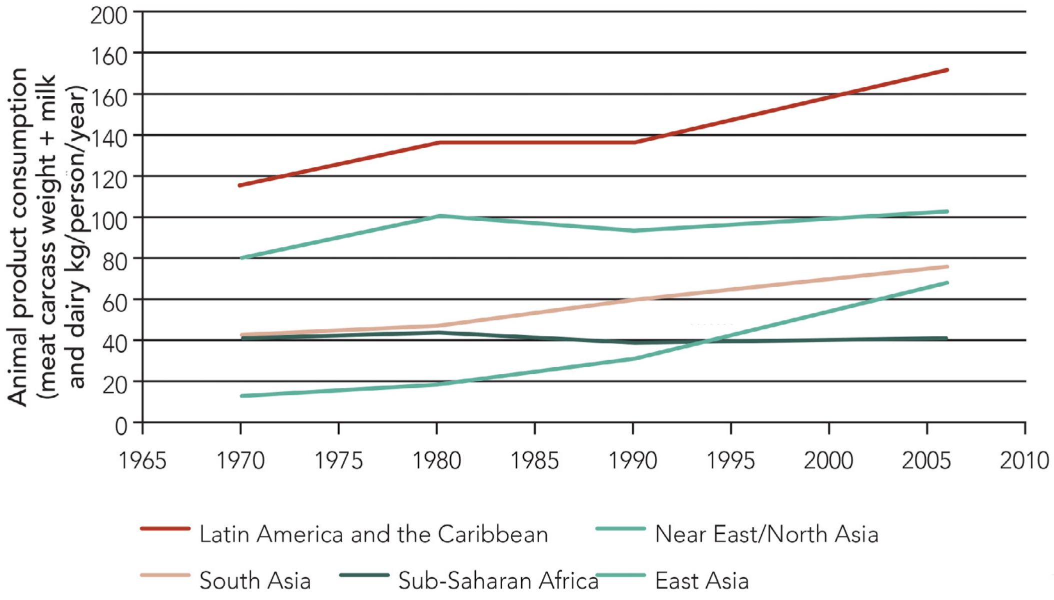

Figure 7: Animal product (meat and dairy) consumption in kg per person per year over a 35 year period, by developing region.

Source: FCRN. (2016).

Global meat consumption has grown at 2.6% a year since 1981, but the aggregate picture masks strong regional variations.

Consumption of meat has been growing at 4.9% annually in developing countries since 1981, with the per capita average increasing from 14 to 28 kg per year. But the annual growth rate is only 3.3% if China and Brazil are excluded from the developing country totals. Currently Brazil and China account for 56% of developing country meat consumption, but constitute only 28% of the developing country population.

Consumption of animal products in Sub Saharan Africa has stagnated and in some countries has actually fallen. Consumption in developed countries has risen very little, since per capita intakes are already high.

4.2.3 Causes of variation in food consumption trends

Trends to date show an overall strong correlation between per capita incomes and meat consumption – but with outliers

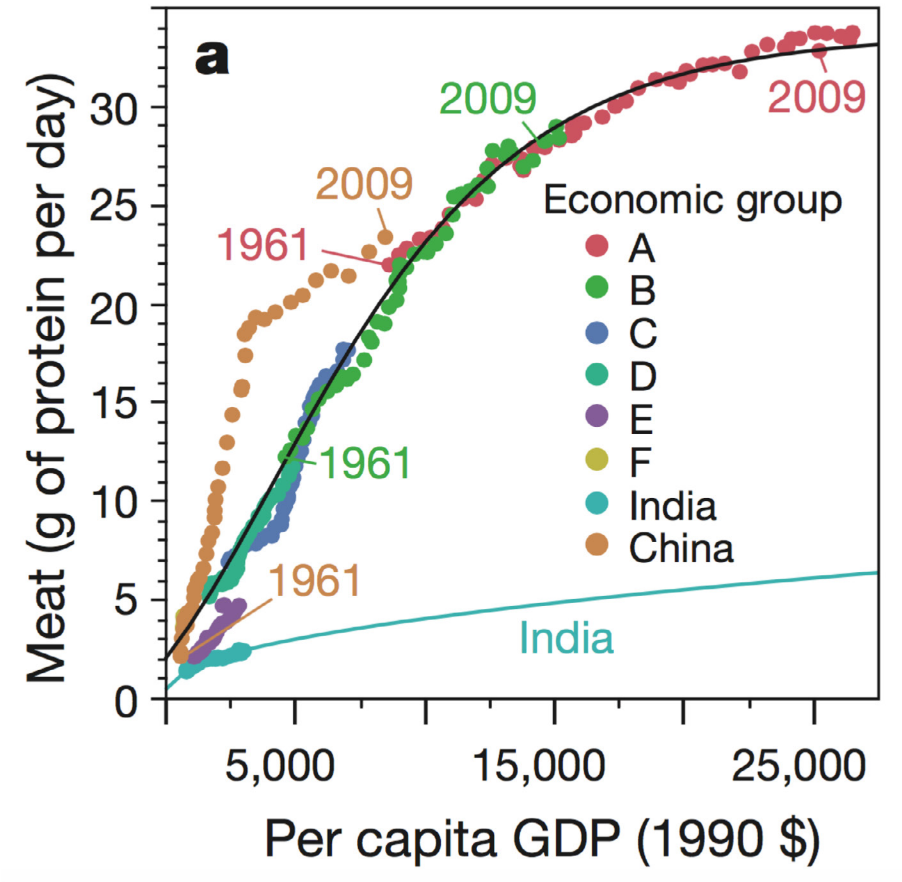

Figure 8: The relationship between meat consumption and gross domestic product per capita, according to national economic grouping.

Source: Tilman and Clark (2014).

A (if not the) major contributor to growing per capita meat consumption in most of the world is increasing per capita incomes, which have been shown to correlate closely and positively with meat consumption.

However, sometimes cultural and other factors mediate this trend. For example, it can be seen from this graph that China has higher than expected meat intakes at given per capita incomes, while India – with its longstanding religious tradition of vegetarianism – has lower than expected meat intakes.

4.2.4 Future trends in food consumption

Future trends in food consumption

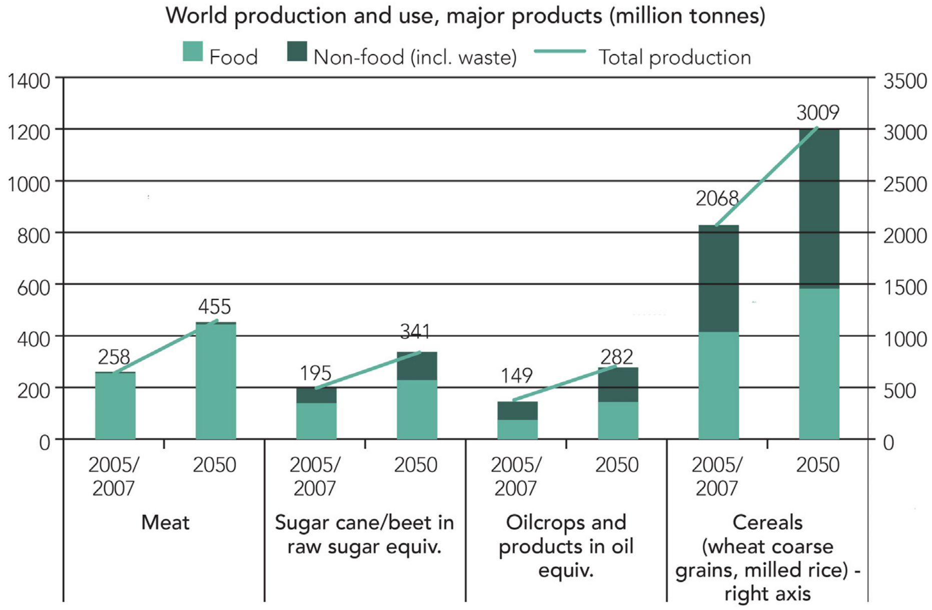

Figure 9: World production and use (million tonnes).

Source: FCRN. (2016).

Based on current trajectories – with rising incomes in developing countries, increases in food consumption per capita and absolute population growth – total food consumption is projected to rise significantly.

Absolute demand for food (and especially animal products) is expected to increase especially steeply in developing countries. However, in some regions, notably Sub-Saharan Africa, this increase in total demand can be attributed more to population growth than to major increases in per capita intakes

4.2.5 Future trends in animal product consumption

Future trends in animal product consumption

Globally, per capita consumption of animal products (meat and dairy) is projected to rise moderately, while total meat consumption is expected to nearly double. To meet this demand, an additional 200 million tonnes of meat would need to be produced annually by 2050, compared with production in 2005/07.

In developed countries, aggregate meat consumption is not expected to rise much further, if at all (since population growth is likely to be negligible and even negative in some countries, while per capita intakes also level off). In some countries, such as the United States, meat consumption has even started to decrease. This may be due to increasing health concerns and awareness, and to the weakened economy since the recession in 2008. Other developed countries showing decreased per capita meat consumption since 2008, include Canada and the UK.

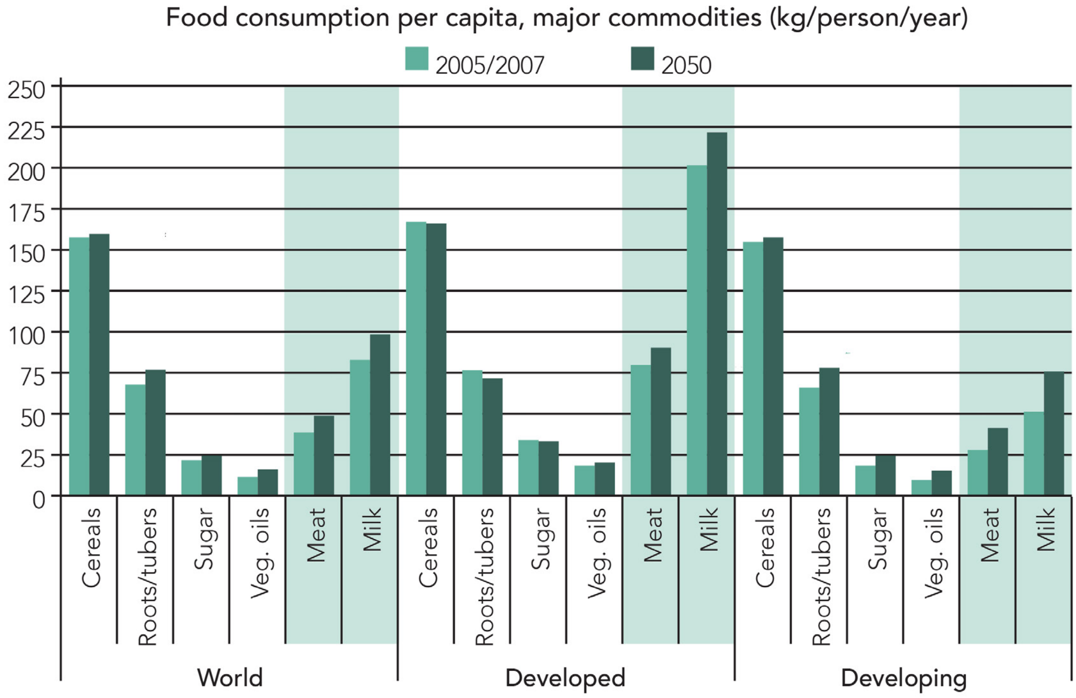

Figure 10: Food consumption levels per capita for major commodities in 2005/2007 and projected in 2050.

Source: Graphs produced by FCRN from data in Alexandratos and Bruinisma (2012).

Demand in China and Brazil is also expected to level off eventually as saturation point is reached.

The majority of the increase is therefore projected to occur in developing countries, where significant income rises and population growth are expected. Population size in Sub-Saharan Africa is projected to nearly double, from 730 million in 2006 to 1.68 billion in 2050. This growth in population numbers accounts for most of the overall growth in expected total animal product consumption – per capita intakes are not anticipated to rise substantially because poverty is likely to persist (per capita intakes of fish are, in fact, likely to decline). Rapid growth in demand is also expected in South Asia (although meat demand in India starts from a very low per capita baseline) and in the middle East/North Africa.

Meat and dairy products are highly resource- and GHG-intensive foods (see Chapter 3 for a review of this topic).

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4.3 How can we tackle GHG emissions in the food system?

4.3.1 What are the possible options?

There are three main pathways available for reducing GHG emissions from the food system.

Produce differently

Produce food with less impact

Associated with concepts such as sustainable intensification, 'closing the yield gap' and climate smart agriculture

Consume differently

Consume less GHG-intensive food

Waste less food

Encourage sustainable healthy diets

Rebalance the system

Reduce system inequity

Improve food access and availability for all

Figure 11: Three pathways for reducing emissions from the food system.

Source: FCRN. (2016).

Different interest groups and stakeholders place greater or lesser emphasis on these approaches.

The challenge can be described as follows: food-related GHG emissions need to be reduced; at the same time we need to produce enough food to feed a growing population, whose demand for GHG emission-intensive foods (such as meat) is expected to rise.

Based on this brief summary of the situation, three 3 broad approaches to mitigating food-related GHG emissions can be identified:

- Production-side mitigation, focusing on producing more food for less environmental impact, increasing farming efficiency, and minimising emissions throughout the food chain.
- Consumption-side mitigation, focusing on consuming less GHG-intensive foods, whilst at the same time seeking to align health and environmental sustainability objectives.
- System transformation, focusing on addressing system inequity and increasing affordability and accessibility of food for those currently food insecure.

Different stakeholders, actors and interest groups place emphasis to greater and lesser extents on these approaches, and within each approach there are differing degrees of consensus and disagreement. Each of these approaches is discussed in more detail later in this chapter.

Stakeholders:

- Livestock & food industry.
- Civil society organisations (including environmental, animal rights/welfare groups, public health campaigners etc.).
- Consumers and citizens (meat-eaters, vegetarians, vegans, etc.).
- People with specific dietary interests (e.g. religious, ethical, health-conscious, etc.).
- Vets.
- Ethicists.
- International development community.
- CGIAR (Consultative Group for International Agricultural Research).
- UN organisations (e.g. FAO, WHO, UNEP).

4.3.2 Who are the stakeholders involved?

Who are the stakeholders

There are many different stakeholders from within the mainstream food industry, alternative food movement, NGOs, ethicists, health groups, research communities and policy makers, all of whom have an interest in the food system's future evolution. Among these stakeholders, interest groups will place importance on different aspects of the three general approaches mentioned. For example, vegans might be more likely to emphasise consuming less meat as a GHG mitigation approach, whereas the livestock industry may be more supportive of production-side efficiencies. Evidently institutions and individuals may not stick rigidly to these categories and may adopt elements from the three different perspectives. Nevertheless, disagreements persist throughout the topics discussed in this chapter.

4.4 How far could changes in production practices reduce GHG emissions?

4.4.1 What production-side mitigation options exist?

Snapshot of production-side mitigation – the argument for this route

Focus of the argument: We need to produce more food for less environmental impact.

How: Change how food is produced and agriculture is practiced.

Example stakeholders: mainstream food industry.

Example activities:

- Store carbon in soils & plant matter – removing atmospheric CO2.
- Improve production efficiency and optimise input use (sustainable intensification).
- Breed for higher yields.
- Avoid land use change & biodiversity loss.
- Manage outputs: e.g. manure and biomass.
- Improve the efficiency and reduce the carbon intensity of transport and distribution.
- Adapt to climate change.

Some stakeholders believe that the fundamental problem is one of food supply – that we need to provide more food for a growing population, with less environmental impact.

Production-side GHG mitigation is based on the premise that our demand for food will inevitably increase (and little can or should be done to moderate it) and as such, will require an increase in food supply.

To produce more food with minimum environmental cost we need to maximise the capacity of agricultural land to store carbon, improve production efficiencies, close yield gaps, and avoid additional land-use change and biodiversity loss (for example through deforestation).

There is further discussion on sustainable intensification later in this chapter.

Yield gap

The yield gap is defined as the difference between the potential yield for a specific crop type when grown under ideal conditions for grop growth, and the actual observed yield from land in a specific location. It provides an indication of the degree to which yield could be increased, following change in management of the land through the use of irrigation or nutrient inputs, changes sowing dates, or other factors.

Agriculture and land-use mitigation options summarised by IPCC 2007

		Mitigative effects[a]		
Measure	**Examples**	**CO_2**	**CH_4**	**N_2O**
Cropland management	Agronomy	+		+/-
	Nutrient management	+		+
	Tillage/residue management	+		+/-
	Water management (irrigation, drainage)	+/-		+
	Rice management	+/-	+	+/-
	Agro-forestry	+		+/-
	Set-aside, land-use change	+	+	+
Grazing land management/ pasture improvement	Grazing intensity	+/-	+/-	+/-
	Increased productivity (e.g., fertilization)	+		+/-
	Nutrient management	+		+/-
	Fire management	+	+	+/-
	Species introduction (including legumes)	+		+/-
Management of organic soils	Avoid drainage of wetlands	+	-	+/-
Restoration of degraded lands	Erosion control, organic amendments, nutrient amendments	+		+/-
Livestock management	Improved feeding practices		+	+
	Specific agents and dietary additives		+	
	Longer term structural and management changes and animal breeding		+	+
Manure/biosolid management	Improved storage and handling		+	+/-
	Anaerobic digestion		+	+/-
	More efficient use as nutrient source	+		+
Bio-energy	Energy crops, solid, liquid, biogas, residues	+	+/-	+/-

+ denotes reduced GHG emissions
- denotes increased GHG emissions
CH_4 = methane N_2O = nitrous oxide

Figure 12: Mitigation options in the agriculture and land use sectors by greenhouse gas.

Source: Smith *et al.* (2007).

Climate change reports from the IPCC specify cropland management, grazing land management, management of soil organic content, restoration of degraded land, and management of livestock and manure as the most promising mitigation options.

This list does not include mitigation benefits from protecting forestry or through afforestation, although that is a key mitigation option (see below).

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4.4.2 How much production-side mitigation might be possible?

How much production-side mitigation potential might be possible?

The 'answer' depends on:

- The pace of technological change – i.e. the extent to which carbon intensity and yields can be decoupled.
- How far land use change can be halted (or reversed).
- Political and economic will (policies to promote mitigation, the development of a functioning carbon market and the price of carbon) and practical implementation (farmer knowledge and translation of knowledge into action).

The 'answer' also depends on how far GHG mitigation is prioritised over other environmental and societal concerns.

IPCC estimates

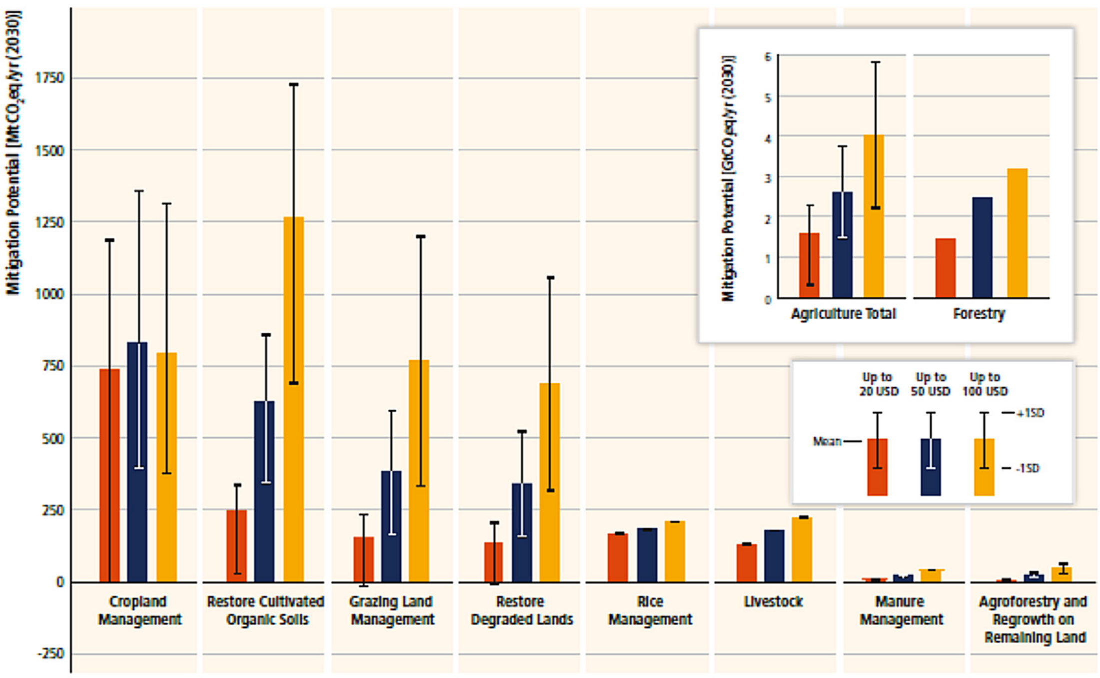

Figure 13: Estimated mitigation potential of measures in agriculture and land use at different costs per ton mitigated.

Source: Smith *et al.* (2007).

Figure 13 shows that the greater the price of carbon, the greater the mitigation potential, as currently un-economic technologies start to become more cost-efficient, and so attractive. A carbon price is a price that must be paid (e.g. through taxation) for the emission of one tonne of CO_2 equivalent into the atmosphere (source).

Carbon dioxide equivalent

Carbon dioxide equivalent (CO2.eq) is a measure used to compare and combine the warming effect of emissions from different greenhouse gases, using single measure of impact. This is done on the basis of a conversion factor known as the Global Warming Potential (GWP), which is the ratio of the total energy trapped by a unit of greenhouse gas (e.g. a tonne of methane) over a specific period of time (normally 100 years), to that trapped by carbon dioxide over the same time period.

However, the magnitude of the error bars indicates major uncertainty with all these estimates. There are not just technical but also practical economic, political and logistical limitations to how far measures to reduce emissions can actually be implemented.

Additionally, while approaches aimed at reducing GHG emissions may yield other social or environmental benefits (e.g. reductions in nitrogen pollution) there may also be trade offs (e.g. increased irrigation water use to increase productivity, thereby sparing land). The balance of positives and negatives is likely to be very locality and context specific.

IPCC estimates – mitigation potential by region

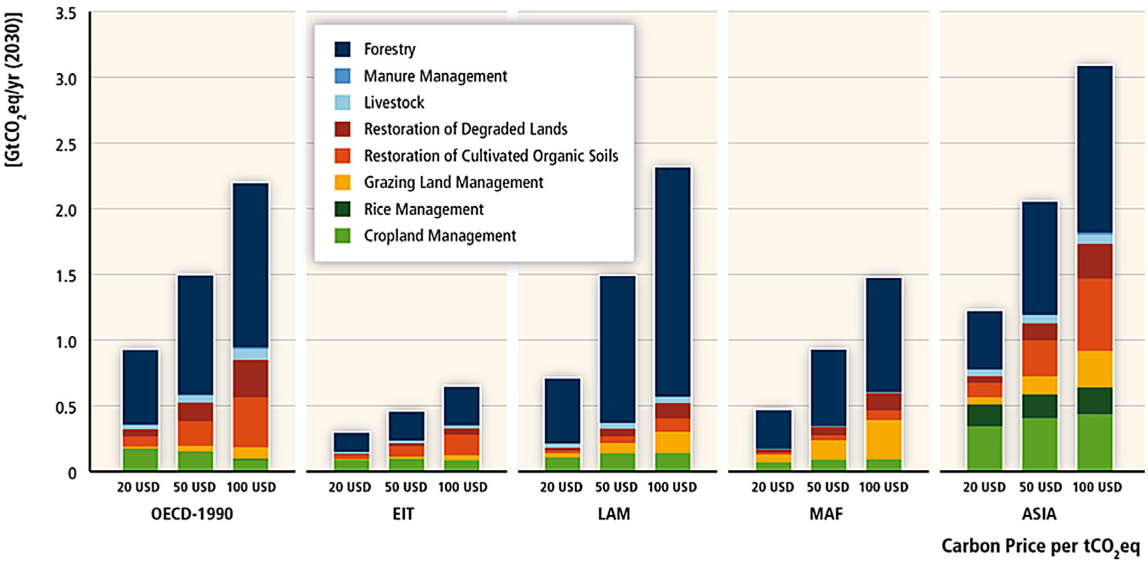

Figure 14: Estimated mitigation potential in the agriculture and land use sectors by region at different costs per tonne mitigated.

Global economic mitigation potentials in agriculture in 2050 are estimated to be 0.5 – 10.6 $GtCO_2eq/yr$.

Reducing food losses & waste: GHG emission savings of 0.6 – 6.0 $GtCO_2eq/yr$.

Forestry mitigation options are estimated to contribute 0.2 – 13.8 $GtCO_2eq/yr$.

Acronyms used in graph: EIT – Economies in Transition; LAM – Latin America; MAF – Middle East and Africa.

Source: Smith *et al.* (2007).

This graph shows the economically viable mitigation opportunities in AFOLU (Agriculture, Forestry and Other Land Use – see Chapter 3) in 2030, by region, and by type of mitigation option, at carbon prices of up to 20, 50, and 100 USD / tCO_2eq. This assumes the introduction of a carbon price, as an incentive for mitigation actions.

The attractiveness of different mitigation options varies greatly with the carbon price, with low cost options such as cropland management being favoured at low carbon prices, but higher cost options such as restoration of cultivated organic soils being more cost-effective at higher prices.

At all carbon prices, key mitigation options are for better management of agricultural land (including cropland, grazing), restoration of degraded land and protection of forestry.

Across all options, Asia has the largest mitigation potential, with the largest mitigation in both forestry and agriculture.

Current rates of 'decoupling' of production from emissions can achieve substantial reductions without any additional mitigation effort

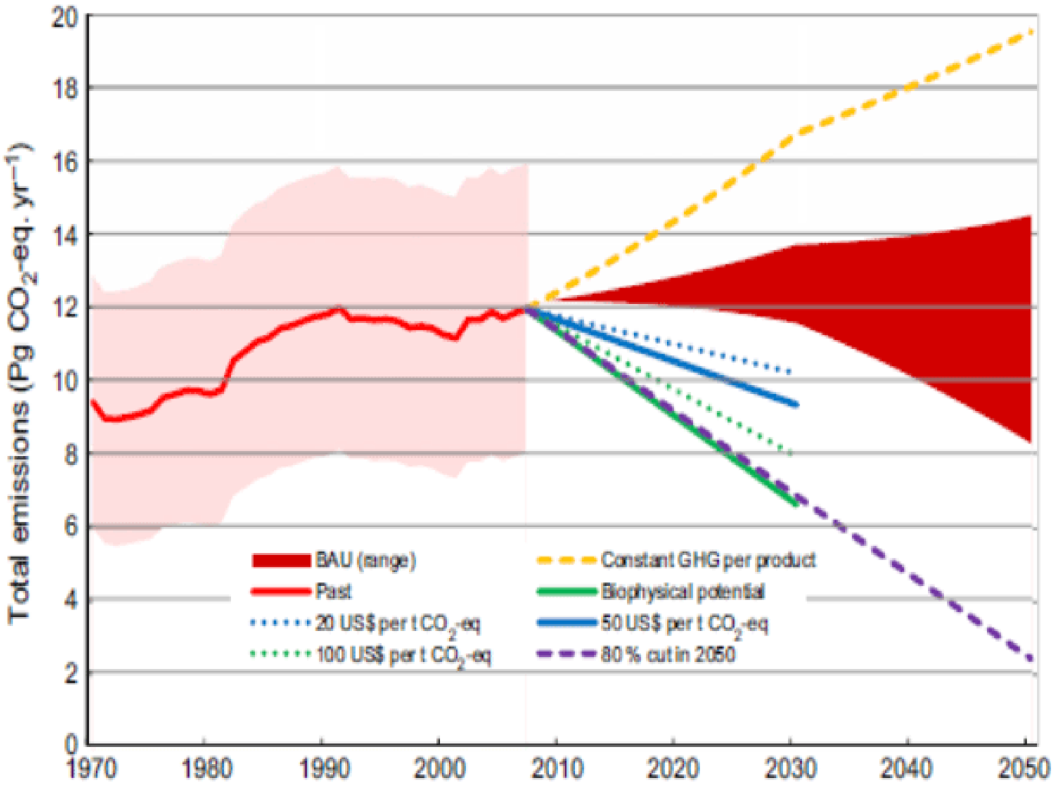

Figure 15: Future emissions scenarios up to year 2050 and potential mitigation by 2030 by cost per ton CO_2eq mitigated.

Source: Bennetzen, Smith and Porter (2016).

But efficiency improvements will not get us to an 80% reduction in emissions. In the above figure, the red solid shading shows the 'envelope of possibility' – i.e. the range in quantity of reductions achievable if improvements in emission intensity continue in a linear fashion (upper limit) or an exponential fashion (not just improvements in emission intensity but an increase in the rate of improvements). However, it also shows that technological innovation will not lead to cuts in emissions as low as 80%, which is arguably what may be needed if agriculture is to make a contribution – proportional to other sectors – to keeping the global temperature increase to below 1.5–2°C.

Some analyses suggest that production-side approaches may not be enough

- Ray *et al.* (2013): yield increases insufficient to meet food demand – alternatives are expanding cropland (deforestation) or addressing diets & waste.
- Smith *et al.* (2014): "while supply-side mitigation measures, such as changes in land management, might either enhance or negatively impact food security, demand-side ...measures, such as reduced waste or demand for livestock products, should benefit both food security and greenhouse gas mitigation. Demand-side measures offer a greater potential ..."
- Gerber *et al.* (2013) – on livestock: On a global scale, it is unlikely that the emission intensity gains, based on the deployment of current technology, will entirely offset the inflation of emissions related to the sector's growth. However ...it is possible that technological breakthroughs will allow mitigation above and beyond current estimates.

Possible reductions in emissions from production can lead to significant GHG mitigation. However, the evidence suggests that rising food demand, especially for animal products, will offset any production emission reductions.

What this really means is that production efficiencies are necessary, but, according to growing evidence, will not on their own be sufficient.

There will be a need for both production-side mitigation and changes in consumption and levels of waste (sometimes called demand-side mitigation).

Additionally, there is uncertainty about the impacts production-side mitigation will have on food security, since increases in food supply do not necessarily lead to increases in consumption among those who are food insecure. Additionally, the quality of food (rather than just quantity) needs to be considered.

Some have argued that measures to moderate demand for meat and to reduce waste, could have positive effects on both GHG emissions and food security. However, the implications for the very food insecure need to be considered – there is no one size fits all solution.

The next section (section 4.5) explores in more detail how changes in consumption might lead to reductions in food-related GHG emissions.

The range in estimates of the mitigation potential is enormous – and this uncertainty indicates that a production-only approach is risky

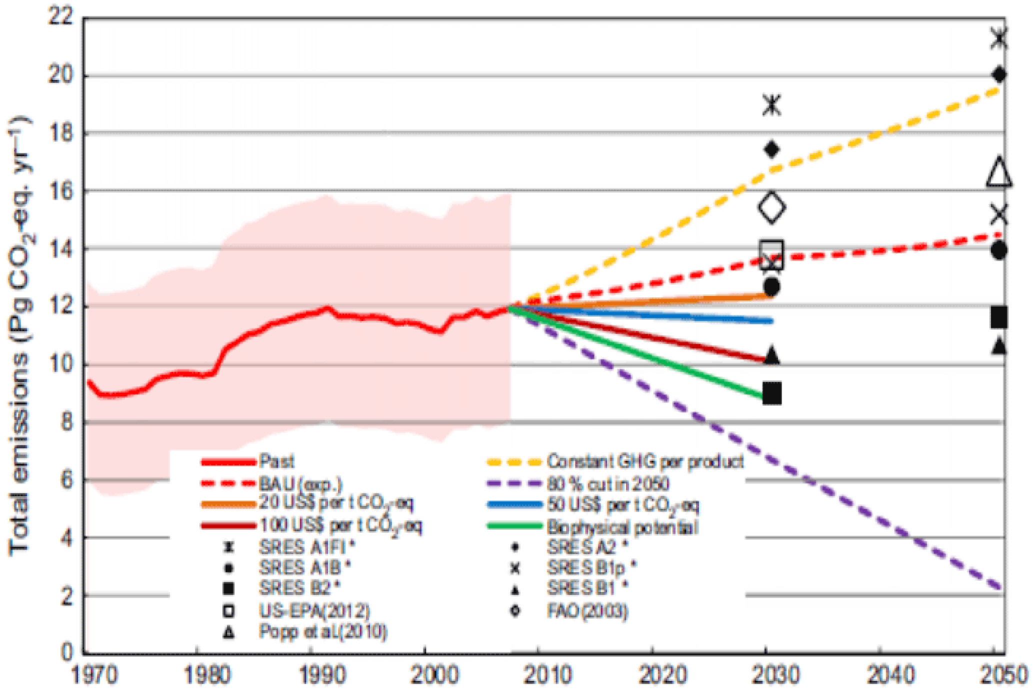

Figure 16: Future emissions scenarios up to year 2050 in comparison with other estimates, and potential mitigation by 2030 by cost per ton CO_2eq mitigated.

Source: Bennetzen, Smith and Porter (2016).

Estimates as to future agricultural emissions (including those arising from agriculturally induced land use change) range from very pessimistic (yellow dashed line – assuming no improvements in technological efficiency and ongoing land use change) to very optimistic (the IPCC's estimate of the technical potential achievable through measures to sequester carbon in soils). The purple dashed line shows how the reduction trajectory needed if agricultural emissions were to fall by 80% – this would be in keeping with the global requirement to keep the global rise in temperatures to below 1.5-2°C.

4.4.3 How does GHG mitigation fit into the wider discussion concerning agricultural progress?

Which farming systems are best suited to achieving mitigation in the context of other environmental and societal concerns?

There are a number of production-side approaches for reducing GHG emissions and/ or adapting to the impacts of climate change.

One approach advocated by many agricultural and natural scientists and accepted by policy makers has been termed "sustainable intensification". Sustainable

intensification is defined as production wherein "yields are increased without adverse environmental impact and without the cultivation of more land".

'Agroecological' approaches are often presented as an alternative, and in opposition to sustainable intensification. Agroecology has been defined as "the application of ecological concepts and principles to the design and management of sustainable agricultural ecosystems. This approach is based on enhancing the habitat both above ground and in the soil to produce strong and healthy plants by promoting beneficial organisms, while adversely affecting crop pests". However, it can also been seen as a "scientific discipline, as a movement, and as a practice" – sometimes all three – and the way it is used varies by context.

Other concepts and terms used include organic agriculture, permaculture, climate smart agriculture, eco-intensification and more.

What is the rationale for sustainable intensification?

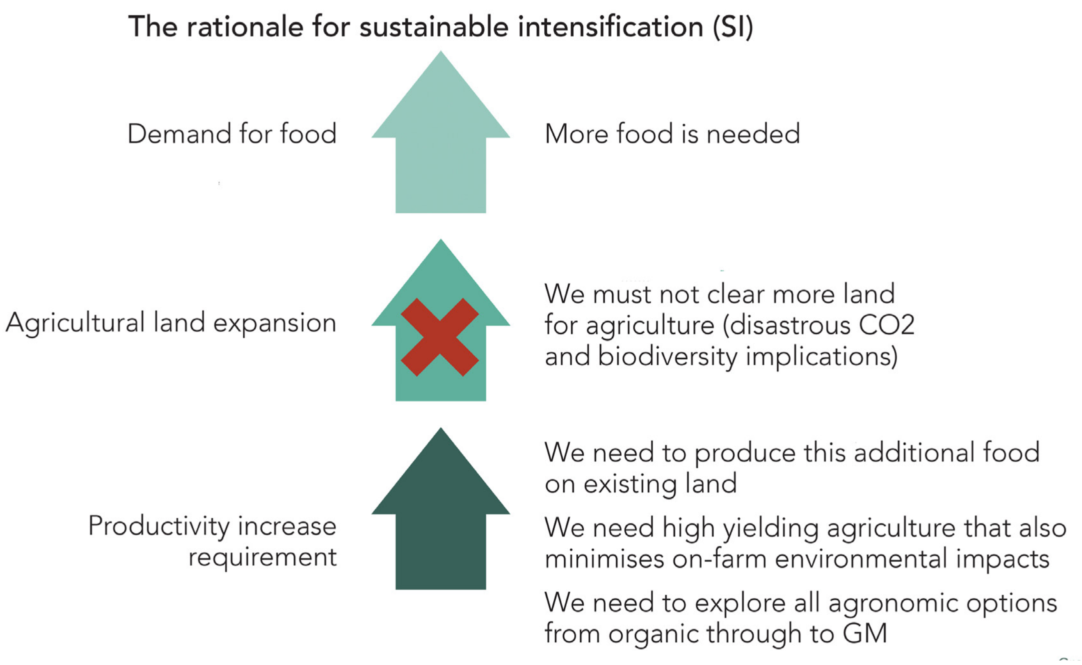

Figure 17: The rational for sustainable intensification.

Source: FCRN. (2016).

The premise for sustainable intensification is that we will need to produce more food in the future, at the same time as reducing environmental impacts. In order to do this, expansion of agricultural land (clearing more forests or other uncultivated land for agricultural purposes) is clearly a bad option (see Chapter 3 and Chapter 5 for more on deforestation, biodiversity and GHG emissions). Therefore, we need an agricultural system that is capable of increased productivity, but where higher yields go hand in hand with a reduction in negative environmental impacts.

Sustainable intensification is a contested issue. It has been interpreted by some as a 'green-washed' version of industrial agriculture. Others, however, argue that this is a misinterpretation – that the 'sustainable' part of the phrase is just as important as the 'intensive'. It denotes an approach to producing food founded on the principle that we must not cause more environmental damage, now or in the future. In this sense, SI shares much in common with, for example agroecology, which is often seen as its direct opposite. Criticisms of sustainable intensification have much in common with criticisms of the term 'efficiency' as applied to the environment.

What is the rationale for agroecology? Is SI in conflict with agroecology?

Not necessarily:

"Food outputs by sustainable intensification have been multiplicative – by which yields per hectare have increased by combining the use of new and improved varieties and new agronomic–agroecological management ...and additive – by which diversification has resulted in the emergence of a range of new crops, livestock or fish."

But SI is nevertheless contested:

"an ideology that adheres to a productivist view of feeding the world...fails to take into account power, profit, politics and participation in the food system....business as usual intensive farming with slight modifications to try and tackle the growing environmental crises caused by industrial agriculture."

And the rebound effect is a risk

"More efficient agriculture is likely to be more profitable and could lead to an expansion of the cultivated area". The magnitude of this direct rebound effect depends on the price elasticity — the ratio of the percentage change in resource demand to percentage change in resource price. If demand for a good is relatively elastic, the price decline expected from more efficient technologies will stimulate more demand. If demand is inelastic, a rebound effect can still take place through product

As shown above, there is an ongoing debate regarding the best farming approaches to deliver different GHG mitigation options.

Much of the debate stems from different ways in which people view sustainability itself. Is SI in conflict with other farming practices? In practice, there are a wide-range of approaches common to SI, agroecology, and for example, climate-smart-farming, that have a role to play in different contexts.

Price elasticity

Price elasticity refers to how much the demand for a good is affected by a change in its price. A good is said to be price inelastic if a change in price means that there is little change in demand. An example might be medication or addictive substances, like tobacco. A good is said to be price elastic if a change in price greatly changes the demand for the good.

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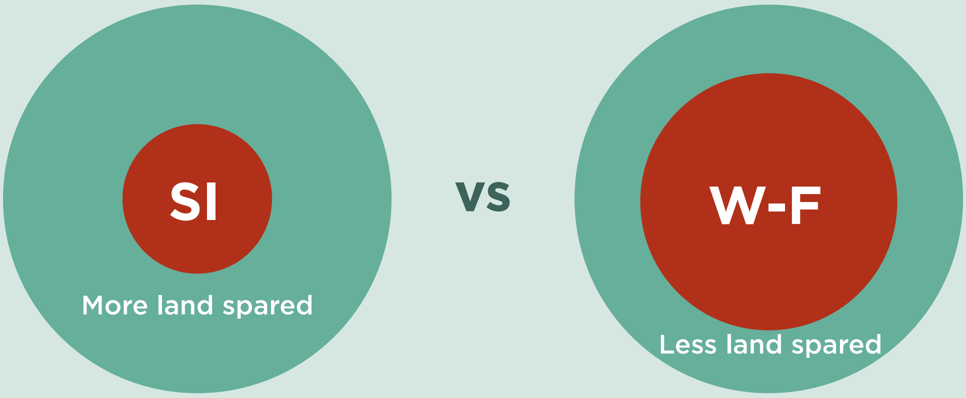
What about land use? The land-sparing (SI) vs. land-sharing ("wildlife-friendly" W-F) debate

Since land use change is such a major cause of carbon dioxide emissions and biodiversity loss, further agricultural encroachment onto uncultivated land must be limited.

One approach (land sparing) argues for intensifying production on existing land in order to 'spare' as much land as possible. Land sparing is central to the rationale for SI.

In contrast, more wildlife-friendly farming practices (more in line with agroecological approaches) often enable higher on-farm biodiversity, but are lower yielding. This approach is known as land-sharing. For a given amount of production, more land may be needed; alternatively consumption needs to be modified.



Some research supports land-sparing as a more promising strategy for minimizing farming's negative impacts on biodiversity – although this conclusion is highly context dependent. Some farming systems have had an important role in shaping biodiversity and landscapes of particular regions.

On-farm biodiversity is important too. However on-farm biodiversity may be more closely related to yield than to differences in farming practices (e.g. organic versus non organic).

Strong governance & assurances are needed so that land-sparing is a real outcome of SI – otherwise higher yields may simply drive increases in demand.

One important contribution that production-side practices can contribute to GHG emission reductions, is by preventing further deforestation and land-use change (see the information on the IPCC mitigation options above). The SI rationale is that increasing crop yields on existing agricultural land will protect the world's remaining natural habitats (land-sparing), thereby preserving biodiversity and carbon stocks in species-rich non-cultivated land (such as forests and grasslands).

This is sometimes seen to be in conflict with “wildlife friendly” approaches, for example organic farming, which emphasise higher levels of on-farm biodiversity but have potentially larger total agricultural land-use requirements. In this sense farmland is shared more with wildlife, hence the term land-sharing.

Some research finds in favour of land-sparing, protecting the natural habitats outside of farmland. This is disputed by some interest groups, for example advocates of organic farming, who point to the on-farm biodiversity benefits (land-sharing) of wildlife-friendly approaches. However, research has also shown that on-farm biodiversity is influenced more by crop yield than farming practices (such as conventional vs. organic), further complicating matters.

This illustrates the disagreements that exist between different stakeholders and interest groups with regard to which farming approaches offer the greatest potential for GHG mitigation. The contention is not so much around what mitigation options are relevant, but what approaches are needed to do deliver the reductions.

Of critical importance is what actually happens to the ‘spared’ land. Is it really spared, or do higher profits arising from higher yielding farming simply enable further land clearance for more agriculture? Governance has an important part to play in ensuring that, where possible, land really is spared.

In addition, it is essential to consider what is being produced. And When thinking about productivity, what type of foods are being grown, with what implications for human nutrition? What about jobs and livelihoods? Should a good environment (clean water, biodiversity, etc.) be seen as an ‘output’ of the system in its own right, of equal importance to wheat or maize?

Organic farming: implications for wildlife?

Organic yields (at least of cereals from the Gabriel study on the next page) are usually about half those of non-organic (“conventional”) farms, and the lower yields in any farming system are usually positively associated with many measures of biodiversity (the Gabriel study focuses on weeds). However, when measures are taken to increase yields in organic fields, biodiversity decreases, so when yields of organic and conventional farming are similar, so is the biodiversity. High yielding organic agriculture can impact on ecology (wildlife and the wider environment) to a similar extent as conventional farming. In other words, a large part of the “wildlife-friendliness” associated with organic farming is simply because it is usually less intensive.

Current high-input ‘industrial’ agriculture production has caused damage to:

- The environment – through overuse of chemical inputs and reliance on a few varieties of seeds
- People – through concentration of power in the agri-food system and displacement of farming communities
- Farm animals – as a result of confinement and breeding-feeding strategies that undermine their welfare.
- ‘More food’ is not the answer to food security.

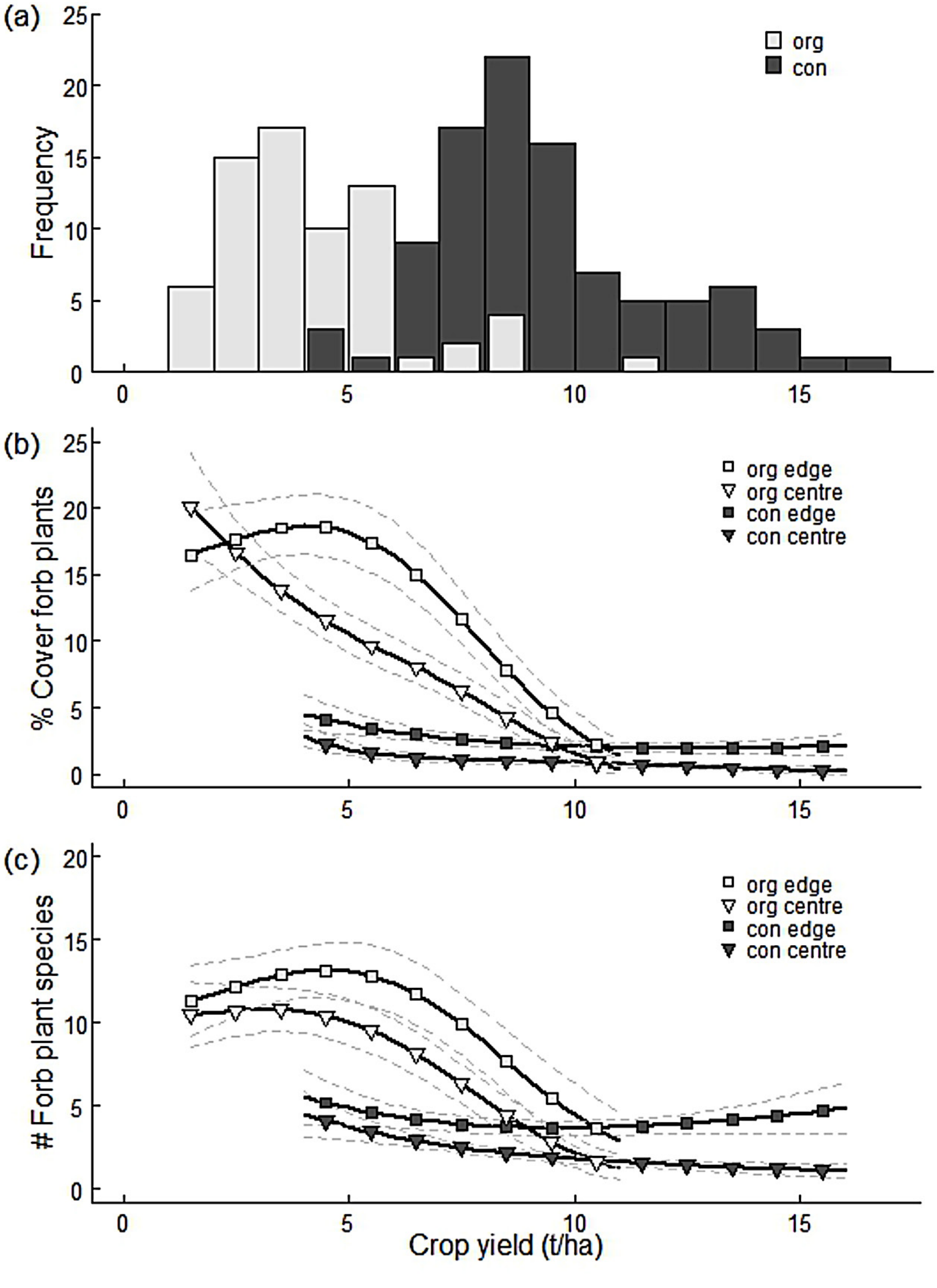


Figure 18: The relationship between crop yield on conventional and organic farms and wild plant biodiveristy.

Source: Gabriel *et al.* (2013).

TOP CHART showing that conventional farms (dark shading) tend to be higher yielding than organic farms (light shading)
Mean organic yield: 4.3 ± 0.24 t ha-1.
Mean conventional yield: 9.3 ± 0.25 t ha-1.

Middle Graph showing that as crop yield increases, the percentage of wild plant cover in organic farms decreases rapidly to similar levels as found on conventional farms.

Bottom Graph showing that as crop yield increases, the wild plant species density in organic farms decreases rapidly to similar levels as found on conventional farms.

- There is a need for more diverse systems delivering multiple outputs (including diverse foods and livelihoods).
- Such systems may not be as 'productive' as industrialised defined in terms of a single output but the narrow focus on 'more food' is misguided.
- Agricultural systems that mimic nature and draw upon traditional knowledge are more likely to be sustainable and resilient in the long term for people and the environment.

4.5 How far could changes in consumption reduce GHG emissions?

4.5.1 What is the rationale behind consumption-side measures?

Snapshot of consumption-side mitigation approaches

Many within the environmental NGO and animal welfare communities (mainly in high income countries) emphasise that demand for resource intensive food products, in effect, drives food production practices.

Focus of the argument: Production-side approaches cannot sufficiently address the mitigation challenge we face, nor do they take account of growing health problems associated with overconsumption of food. We need to eat less of the food that has high environmental impacts and tackle overconsumption too.

How: Change drivers influencing what and how much is produced.

Example stakeholders: environmental NGOs, animal welfare groups.

Example activities:

- Manage demand for GHG-intensive meat and dairy products.
- Reduce demand for GHG-intensive food in rich countries.
- Manage sustainable demand growth in developing countries.
- Reduce food losses and waste (see Chapter 5 for more on food waste).

Consumption-side GHG mitigation is based on the premise that the main drivers of unsustainable food systems are high levels of resource and greenhouse gas-intensive meat and dairy consumption, and that this needs to be managed. Production-side measures alone will not suffice.

Meat consumption is higher in rich countries and among affluent individuals, and this would need to be reduced, while developing countries would need to manage their demand increases in a sustainable manner (as people move out of poverty their consumption of meat normally rises).

Food security is not just a production issue

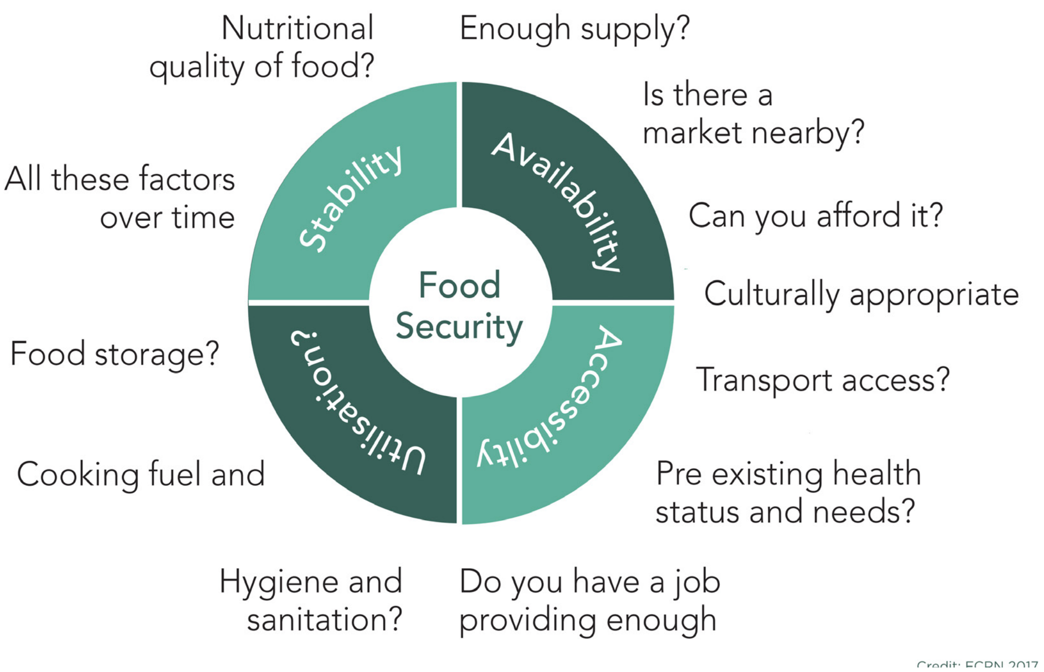


Figure 19: The four components of food security and associated questions.

Source: FCRN. (2016).

The previous section outlined production-side mitigation options for achieving food security and reducing GHG emissions, but suggested that production efficiencies alone, might not be enough. While it is accepted that we will need to produce more food to feed a growing population and that new ways of producing food are needed to manage environmental impacts, an increase in food supply itself does not guarantee food security.

A sufficient supply of food is one necessary factor for food security, but cannot guarantee food security by itself. Food needs to be accessible (physically but also economically) and it needs to be utilised appropriately and safely. For example, the tools and knowledge for appropriate preparation and cooking is necessary. Non-nutritional considerations (e.g. prevalence of illnesses such as diarrhoea) also influence the extent to which the body can absorb and use the nutrients in the food. All these factors need to be stable over time.

There are many groups who suggest that the real problem is one of consumption (rich countries eating resource-intensive and emissions-intensive food) and access (unfair food systems contributing to over-consumption in developed countries and under-consumption in poorer countries), and who, therefore, favour so-called demand-side and redistribution-oriented mitigation options.

This section looks further at the potential for GHG mitigation from changes in eating habits. Chapter 10 discusses how consumption patterns could be shifted.

Both production-side and consumption-side measures have potential to reduce emissions

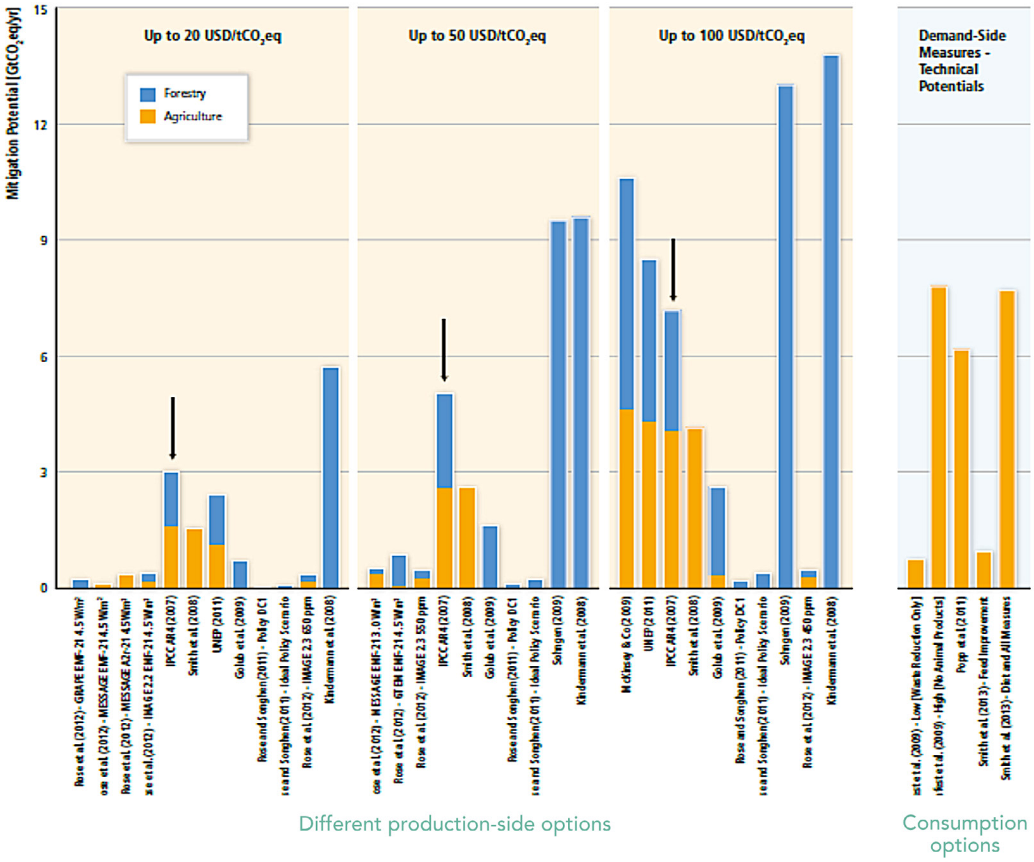


Figure 20: Estimates of mitigation potential in agriculture and forestry according to the cost of mitigation per tonne, compared with technical potential of demand side measures.

Source: Smith *et al.* (2014).

Graph showing the mitigation potential of different production- and demand-side measures (larger bars representing greater mitigation potential). Demand-side measures such as dietary change and waste reduction have large, but uncertain, mitigation. See Chapter 9 and Chapter 10 for more diets.

The IPCC AR5 report in 2014, reviewed a number of potentially important consumption-side mitigation options. The rationale is that changes in demand will (albeit with a time-lag) influence production and distribution.

It considered the potential achievable through the following approaches (orange columns on right hand side from left to right): 1. waste reduction, 2. eating no animal products, 3. eating fewer animal products 4. livestock feed efficiency (somewhat misleadingly included in this category) and 5. a study showing a combination of approaches that include some dietary change.

Changes in animal product consumption are shown to have an important impact on emissions, due to the relative high GHG emissions from livestock farming. See Chapter 3 for a review of the GHG-emissions attributed to different products, including livestock.

According to the IPCC report, reducing waste (and thereby reducing total demand for and associated production of food) has a relatively low mitigation potential, whereas eating no animal products has been shown to have the greatest potential. However, total veganism is not a realistic proposition in the immediate future, and would almost certainly have negative consequences for people living in poorer countries, where serious problems of under-nutrition and malnutrition exist.

Approaches that combine some reduction in animal product consumption and waste reductions (together with production-side approaches) offer higher mitigation potential and are more realistic in practical terms, although all approaches will be difficult to implement.

Eating less resource-intensive food and wasting less could also offer potential benefits for food supply.

Among high consumers, reduced animal product intakes can also be associated with health benefits although the issues are complicated (see Chapter 7 and Chapter 8 for more on this).

4.5.2 How can we reduce demand for resource-intensive foods?

Is it possible to specify a sustainable level of meat consumption?

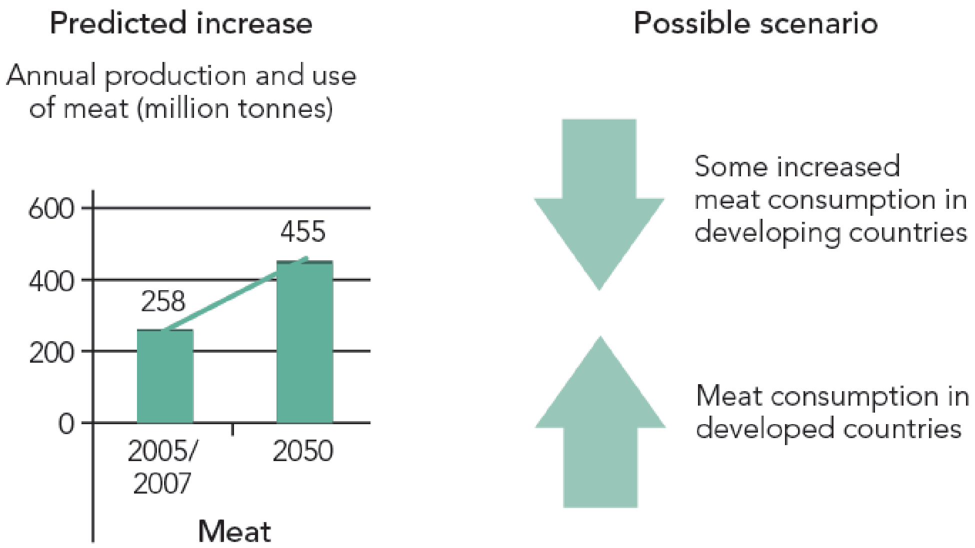


Figure 21: Illustrative scenario for achieving a sustainable level of meat consumption.

Source: Adapted from Alexandratos and Bruinsma (2012).

As discussed at the start of this chapter, demand for all food is expected to increase due to population growth and per capita income rises. Most of this increase will occur in developing countries where problems of under-nutrition persist.

Some increases in meat consumption among under- and malnourished populations in low income countries are likely needed.

In order to offset this, a reduction in meat consumption would be required in wealthier countries, and among high consuming individuals in middle income countries, where per capita meat intake is arguably higher than nutritional requirements. This can be seen as a "contraction and convergence" approach – contraction of meat consumption by rich people, and some increases by the poor, with ultimate convergence; the two meet in the middle.

What level of meat consumption in both high income and low income countries might be considered sustainable has not yet been defined. Much depends on actual population growth rates, how incomes change over time, what successful production-side mitigations are implemented and, of course, what else is or is not consumed. The 'need' for meat depends on the overall nutritional make up of the diet and is thus influenced by overall dietary patterns.

How far might we get with a "Contraction and Convergence" approach?

One proposed framework for reducing emissions to within sustainable limits in a fair and logical way is "Contraction and Convergence" (C&C). "Contraction" refers to the overall reduction in emissions, while "convergence" refers to the mechanism by which this happens, namely that all countries converge on approximately equal per capita emissions. Achieving this requires drastic reductions in emissions by high emitters, while still allowing for some increase in emissions from the very poorest and lowest emitters, so that their socio-economic development is not hindered.

Applying this C&C principle in relation to meat: what if developing country intakes were to increase as projected, but developed country intakes were to fall to that same level?

How might contraction and convergence mitigate GHG emissions and to what extent?

Based on FAO predictions for global meat and dairy consumption in 2050 (see images in side-panel; tables derived from data in Alexandratos and Bruinsma, 2012), developing countries' per capita meat and milk consumption is predicted to rise to 40 kg and 80 kg per year respectively. If developed countries were to reduce per capita meat and milk consumption to the same level (from 90 kg meat and 220 kg milk) then a 14.3% reduction in total meat demand and a 23.2% reduction in total milk demand would be possible. Meat consumption would be reduced from 448 million tonnes per year to 384; milk from 906 million tonnes to 695.

However against a 2005/2007 baseline, this will still result in an overall increase from 257 million tonnes of meat per year and from 547 million tonnes of milk.

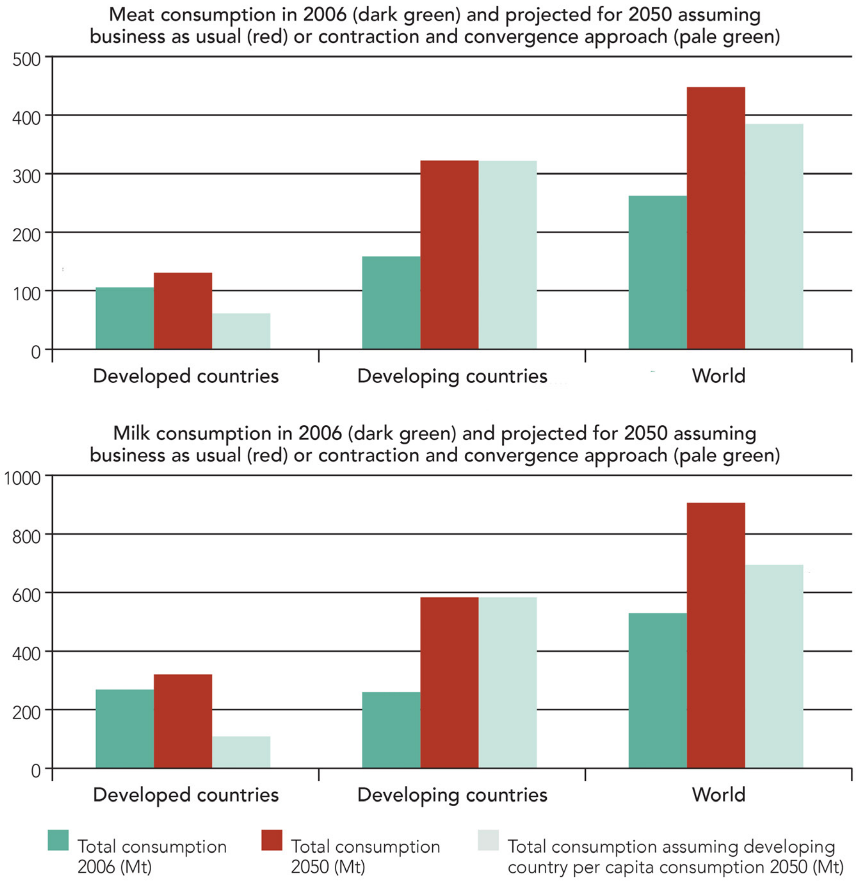


Figure 22: Potential mitigation from contraction and convergence – can reduce projected future consumption but not even to current consumption levels.

Source: Graphs produced by FCRN from data in Alexandratos and Bruinsma (2012).

So in reality, contraction and convergence will mitigate somewhat against future increases, but not reduce total meat and dairy consumption absolutely compared with current levels.

This also shows that reductions by people in developed countries, while necessary, may not be sufficient to curb the global growth in meat and milk demand, as most of the growth in absolute and per capita terms is taking place in developing countries. It is also worth noting that the term "developing countries" is an amorphous one, as there are very high and low consumers of meat and milk within both developed and developing countries – it could be argued that high consumers need to reduce their intake, regardless of whether they are in a developing or developed country.

4.5.3 Does the evidence support consumption-side measures?

What does the evidence suggest for consumption-side mitigation?

- We need to reduce demand in high income countries, but this alone will not get emissions down (see below).
- We need to substantially moderate rapid demand growth in developing countries.
- We need optimise accessibility of sustainable and nutritious food in poorer countries.
- There is a strong moral argument for contraction and convergence – but whether it is realistically achievable or sufficient is unclear.
- It is hard to define what a sustainable and healthy per capita level of meat consumption might be because there are so many dietary and other variables.
- Shifting consumption patterns is difficult – see Chapter 10 for more on this.

As illustrated in the previous sub-section, just reducing meat consumption in developed countries may not be sufficient – we also need to moderate the increase in meat consumption in developing countries. Optimal pathways are needed to ensure that nutritious food is accessible, without over-reliance on GHG-intensive sources such as animal products.

The picture is emerging of a composite approach, that includes production-side mitigation, sustainable development of eating habits in poorer countries, and less emission-intensive consumption from wealthier regions. At its heart, this could be seen as a moral question about rights to nutritious food, balanced against environmental damage (see Chapter 1 for discussions on "safe operating spaces" and doughnut economics).

One fact, though, remains largely uncontested: that there is a need for change in order to increase food security (see earlier in the chapter) defined as sufficient and stable access and availability of nutritious food. There is, however, less consensus on how to achieve that within the context of sustainable food systems and GHG mitigation.

Some of these disagreements are discussed in the next section, which looks at how rebalancing the food system might contribute to food-related GHG mitigation.

4.6 How far could socio-economic change reduce GHG emissions?

4.6.1 What is the rationale behind system change?

Rationale for system change

- There is general consensus that measures to improve food access and address system inequity are needed.
- But there are different views on how to do this.
- Some interest groups focus on reforming current institutions and processes (e.g. trade agreements, pricing strategies).
- Others advocate more radical alternative approaches based on the principles of food sovereignty and food justice, and may oppose global trade.
- They may argue for a shift towards agroecological practices and a greater role for smallholder production and traditional agriculture, and be critical of sustainable intensification.
- We focus here on these 'alternative' perspectives.

Snapshot of mitigation through system rebalance: an 'alternative' approach

Focus of the argument: This is an socio-economic and ethical problem, not a supply problem.

How: Change the **governance** of food.

Example stakeholders: alternative food movement groups.

Example activities:

- Address inequities in access, price volatilities, and terms of trade.
- Limit waste & losses at all stages.
- Empower smallholder farmers, encourage and support local production, processing and marketing.
- Often advocate organic farming and agroecological practices.

Whilst there is general consensus that global food security and environmental sustainability are challenges we need to address, there is less agreement about how this can be achieved.

Various groups point out that major drivers of unsustainable food systems are inequities within the system, such as unfair terms of trade, lack of access to food and volatile global food prices. Some groups posit that these can be resolved by a shift to locally-owned smallholder agriculture, that relies more on low-input traditional and/or organic farming approaches, and a more self-sufficient "food sovereignty" approach.

This approach is often in conflict with the shift towards more globalised food systems and large-scale agriculture. Advocates of agro-ecology, at times, oppose sustainable intensification on the basis that SI is really a by-word for industrial agriculture (see previously in this chapter for discussions on sustainable intensification).

4.6.2 What are the questions to consider?

Advocates of system changes focus on the problems caused by unfair markets that create food insecurity. They argue that globalised supply chains are unnecessarily energy-intensive, and industrial agriculture is a root cause of food-related environmental impacts – of which GHG emissions are just one.

Preferences within these approaches are for locally owned food systems, smaller-scale agriculture more oriented towards organic farming techniques, and a strong emphasis on positive environmental impacts as a central outcome of equitable food systems.

Understanding what this looks like in reality, and how distinct it is from topics discussed earlier in this chapter is, in fact, quite difficult.

The system change perspective focuses on rebalancing the system. But there are important questions to consider.

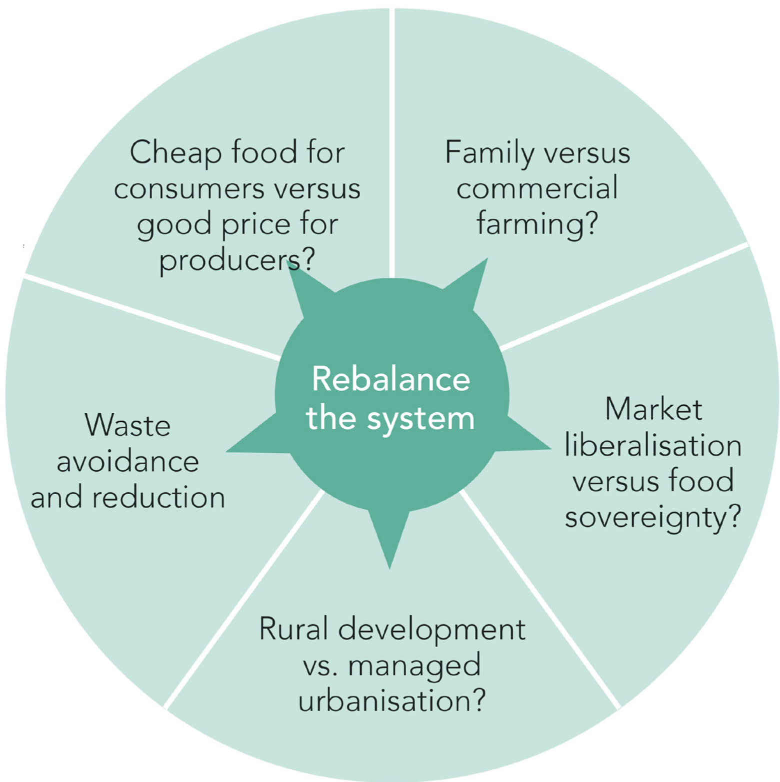


Figure 23: Questions that arise when deciding how to rebalance the food system.

Source: FCRN. (2016).

A more equitable food system might have much in common with the "contraction and convergence" demand-side approach discussed earlier in this chapter, in the sense that high income countries overconsume, and poorer countries do not have access to or cannot afford food security.

Similarly, there are overlaps between "sustainable intensification" described earlier in this chapter and elements of agroecology and organic farming.

A key differential can be the ownership of production and supply – locally produced and owned vs. non-locally owned and globally traded.

Different perspectives, few conclusions

Family farming is important.
FAO (2014)

But there is a lack of evidence that smaller, family owned farms cause less environmental damage than larger, more intensive farms.
van Vliet, *et al.* (2015)

Could organic farming yields match conventional yields with sufficient funding?
Holt-Giménez, *et al.* (2012)

But will this result in less environmental impact for the required production levels?
Gabriel, *et al.* (2013).

The goal should be to assist transition to sustainable farming practices in all shapes and forms.

It is often claimed that small, traditional, and family owned farms are more sustainable than large industrial farms, although evidence for this in reality can be thin on the ground.

Most of the world's farms are still family owned, and there is no strong evidence that the ownership model affects food-related GHG emissions and other environmental impacts.

However, some groups stress the social benefits of smallholder farms in poorer countries, and there are strong arguments for investment in assisting them to produce food in more sustainable ways. Which systems of production (from conventional through to organic) should be promoted, is the topic of much debate

As regards the localness of food systems, food transport makes an important but not dominant contribution to food-related GHG emissions – see Chapter 3 for more on this. However, localism is often advocated for a range of social, economic and ethical reasons, and not just in relation to GHG mitigation.

4.7 What combination of solutions is probably needed?

Conclusions

- Should we focus on producing more food, and how?
- Or on consuming more sustainably, and how?
- Or should we address inequity and improve access to food for poorer groups, and how?

Evidence suggests it is too simplistic – and the problem is too urgent – to rely on one approach alone. A composite approach that encompasses elements of production, consumption and systemic approaches is probably needed. Significant knowledge gaps and trade-offs exist.

How we solve these challenges has been, and still is, the subject of much debate. Some argue that we need to invest in greater technological solutions to produce more on existing land; others argue that we already produce enough but we need to reduce demand for resource intensive food and reduce food waste; others argue that the root causes of sustainable food systems are power, distribution and access.

The evidence suggests that all three approaches generate a mix of risks and benefits, and in practice all three approaches will likely need to be implemented if the necessary deep cuts in emissions are to be achieved. How we do this is, as shown throughout this chapter, is the subject of further debate. One factor missing from these different perspectives is whether the population increases that form the basis for much of the projected rise in demand for food, are indeed inevitable.

Chapter 7 looks in more detail at trends in food consumption over time, and how these are connected to nutrition and health.

4.8 Conclusions

Significant global GHG reduction targets are required across all sectors, including the food system.

Some stakeholders emphasise production-side measures for mitigating food-related GHG emissions – among those who hold this viewpoint, there is disagreement as to the best method, e.g. land-sharing vs. land-sparing.

Others emphasise demand-side measures, focussed on reducing excessive consumption of resource-intensive food and waste.

Still others emphasise the need to rebalance the system by reducing system imbalances at a social and political scale.

It is evident that these approaches are not mutually exclusive and may perhaps be most effective in combination.

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