Ecological Livestock

Options for reducing livestock production and consumption to fit within ecological limits, with a focus on Europe

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GREENPEACE

Image Piglet in the Tierpark Arche Warder in Germany. The park is a registered charity, and specialises in rare and endangered breeds, housing over 800 animals of more than 70 species.

Contents

For more information contact:
pressdesk.int@greenpeace.org

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Art Direction and Design by:
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Ottho Heldringstraat 5
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greenpeace.org

Note to the reader

This documents describes Greenpeace's vision for ecological livestock, outlining the main impacts of the current destructive industrial livestock system, and the basis for a shift to global sustainable animal production. This is not a policy document, but describes the options for a sustainable global livestock system, focusing on Europe as a point of departure.

Greenpeace definitions of "Ecological Farming" and "Ecological Livestock"

Ecological farming ensures healthy farming and healthy food for today and tomorrow, by protecting soil, water and climate, promotes biodiversity, and does not contaminate the environment with chemical inputs or genetically modified organisms.

Ecological livestock integrates farm animals as essential elements in the agriculture system; they help optimise the use and cycling of nutrients and, in many regions, provide necessary farm working force. Ecological livestock relies on grasslands, pasture and residues for feed, minimising use of arable land and competition with land for direct human food production, and protecting natural ecosystems within a globally equitable food system.

Image Holstein-Friesian cows at an intensive dairy farm in Somerset, UK. Most of the cows here are housed all year round with no break for pasture. The all-female herd is kept in a constant state of pregnancy in order to produce an endless stream of milk.

#1

Main impacts of livestock

Human pressure on the planet is reaching a scale that could compromise the stability of the Earth's systems. A group of influential scientists have recently identified nine planetary boundaries related to Earth-system processes and their associated thresholds, which, if crossed, could destabilise our living environment (Rockstrom et al 2009b, Rockstrom et al 2009a).

The main impacts of livestock production are key components in four of those boundaries – biodiversity loss, nitrogen and phosphorus cycles, land use change, and climate change – including the three already beyond acceptable levels (see Figure 1). As of 2000, the livestock sector has already occupied a large fraction of the safe operating space[1] of the planet's resources (Pelletier & Tyedmers 2010):

- 72% of safe operating space available for the productivity[2] of all vegetation on Earth, thus affecting biodiversity loss and land use at large;
- 117% of the safe operating space for reactive nitrogen mobilisation; and
- 52% of the safe operating space for human-induced climate change gases.

We focus on these three boundaries to frame the three main impacts of livestock on the planet.

Nine planetary boundaries

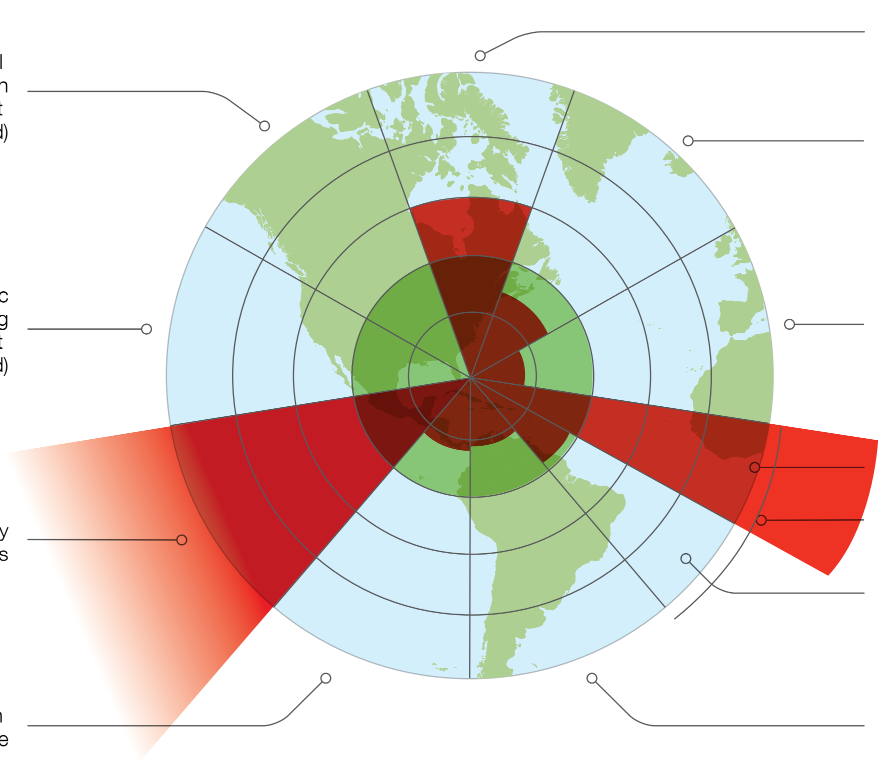


Figure 1 Nine planetary boundaries and their safe operating space as proposed by Rockstrom et al 2009b. "The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded." The largest impacts of livestock production are key components in four of those boundaries (biodiversity loss, nitrogen and phosphorus cycles, land use change and climate change). Adapted by permission from Macmillan Publishers Ltd: Nature. Rockstrom J, Steffen W, Noone K, Persson A, Chapin FS, Lambin EF, Lenton T, Scheffer M, Folke C, Schnellhuber HJ, Nykvist B, De Wit CA, Hughes T, Van der Leeuw S, Rodhe H, Sorlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Febry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P & Foley J (2009). A safe operating space for humanity. Nature, 461: 472-475, copyright (2009).

1.1

Biodiversity loss and change in land use

Biodiversity loss represents the planetary boundary where humans have exerted the major overshooting of the safe operating space (Figure 1). Changes in land use exert the most significant effect on biodiversity loss (Rockstrom et al 2009b). Thus, we are combining these two planetary boundaries, biodiversity loss and land use change, as they are both massively affected by livestock systems globally (but acknowledging other livestock impacts also affect biodiversity loss to variable degrees).

> Our biosphere, and each of the ecosystems within it, has limits. We can extract from it only so much, and spew into it only so much before we exceed those limits, with consequences irrevocable and uncertain. All of these limits – impending shortages of food, water, energy, waste repositories, space – have a common thread; all are tied, in one way or another, to our use of 'land'. […] And we cannot think about use of our lands without examining the place of livestock thereon.
>
> – Janzen 2011

Human pressure has accelerated current biodiversity loss to place it as the sixth major extinction event in the history of life on Earth. The other five were induced by natural events; this one is human-induced (Rockstrom et al 2009a). Certainly, biodiversity loss is 1,000 times above background levels (MA 2005).

Changes in land use constitute the most significant cause of biodiversity loss due to human activities (Rockstrom et al 2009a). Although there are many agents of deforestation, **expansion of livestock production is one major cause of land use change, driving conversion of natural ecosystems to both grazing and arable land for feed.** For example, recent statistical analysis shows that deforestation in the Brazilian Amazon is strongly related to soya expansion in nearby settled agriculture areas due to indirect pressure from cattle expansion (Arima et al 2011).

> Livestock remains the world's largest user of land, but its use has shifted steadily from grazing to the consumption of feed crops. Unfortunately, environmental and resource costs of feed-crop and industrial-livestock systems — often separated in space from each other and from the consumer base — remain largely unaccounted for in the growth process.
>
> – Naylor et al 2005

Humans appropriate plant biomass for many uses – food, feed, and materials, to name a few examples. However, only about 12% of the global plant biomass appropriated by humans is directly used as food, while 58% of this biomass is used to feed livestock (Krausmann et al 2008).

"*An astonishing 75% of the world's agriculture land*" is devoted to raising animals, including both the land used to grow crops for animal feed and pasture and grazing lands (Foley et al 2011).

Land use change is induced by competition for land arising from (among others):

- increasing demand for food and animal feed as the world population grows and shifts to diets richer in animal products,
- increasing demand for bioenergy crops as strong national policies subsidise the mainstream use of bioenergy,
- increasing demand for biomaterials as the world moves to a bioeconomy (bioplastics, natural fibres),
- increasing urbanisation and demand for infrastructure and industrial uses of land.

In addition to the increasing demand for all the uses humans extract from land, there is also a simultaneous loss of productive land due to its unsustainable agricultural use, for example soil degradation, salinisation, erosion and desertification (Guo et al 2010). When the soil is damaged, and thus less productive, new land will need to be brought into cultivation. These interacting forces often result in the expansion of agriculture land at the cost of natural ecosystems and biodiversity.

Globally, livestock production is increasing and projected to continue to grow in the future (IAASTD 2009). This global trend also affects crop patterns and the competition for croplands to grow feed or food. For example, in India the rapid growth in poultry demand and production (15-20% growth a year[3]) is greatly increasing the demand for maize feed (Mehta et al 2008). Poultry farms consume about 90% of the domestic maize production[4]. Consequently, farmers are shifting from growing food crops to growing maize as feed, which displaces other traditional staple crops like millets, and will likely impact nutrition security, food availability and food prices.

Competing uses of biomass in the shifts to a global bio-economy

Humans already appropriate about one third of all the biomass produced by the planet (Vitousek et al 1986) and globally croplands and pastures occupy about 35% of ice-free land surface (Haberl et al 2007). Further, there are regions, such as locations in Asia and Africa, where between 60% and 100% of biomass is already appropriated by humans, and other regions, for example, where all crop production is for international exports (Haberl et al 2007). Thus one initial question on biomass is "*how much of the biosphere's productivity can we appropriate before planetary systems start to break down?*" or even if we have already crossed that threshold (Foley et al 2007, Rockstrom et al 2009b).

Thus, it is clear that productive land and biomass are limited and should be shared between human uses and ecosystem services. At the same time more human uses are coming into competition. For example, the upcoming shift towards more biomaterials creates increasing demand for cropland and plant productivity (for fibres, chemicals, pharmaceutical feedstock). The rising trend of growing biomass for energy uses puts further pressure on land. The example of EU policies is explored below.

Effect of EU biofuel policies on livestock production and feed supply

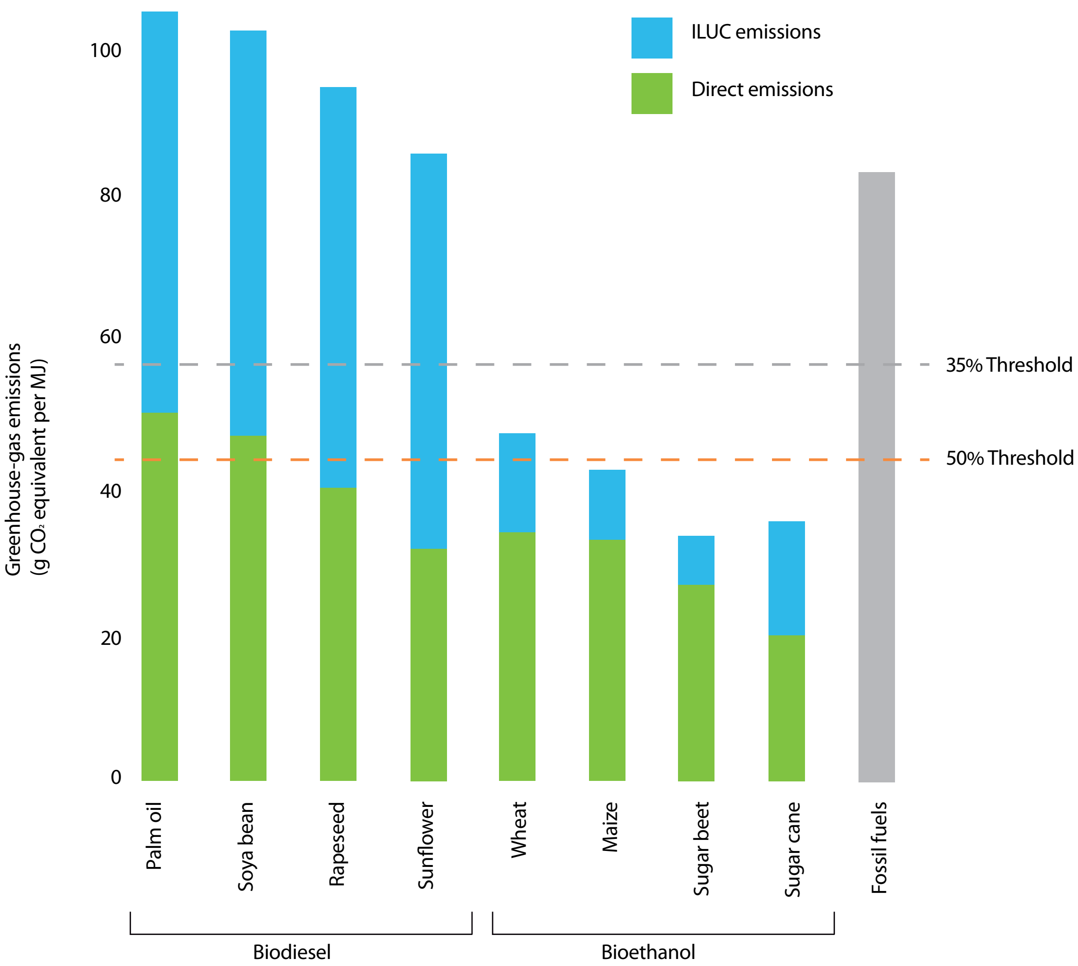
The bioenergy and livestock sectors are experiencing some degree of inter-linkage, and this is affecting to some extent livestock production, feed supply, and land use change within and outside Europe. This inter-linkage comes from various factors, as the bioenergy sector produces co-products for the livestock sector with its own high economic return and demand[5]. For example, in the US maize kernels are used for ethanol production and the rest of the plant is used for animal feed, while in Germany the whole maize plant is fed into biogas plants for bioenergy production. Besides, because the commodity price of food, feed and bioenergy are now linked to a great extent, their impacts, including indirect land use change, are also interconnected (Renssen 2011, Gibbs et al 2010, Gibbs 2009, Naylor et al 2007). Indirect land use effects of biofuel policies tend to be stronger in regions far away from Europe.

There are strong concerns among the scientific community[6] about the negative effects of the EU biofuel policy (and those of other countries, such as the US, Brazil) especially on agricultural land expansion and food prices outside Europe (Nellemann et al 2009, Renssen 2011). With regards to indirect land use change occurring somewhere else outside Europe due to European policies on bioenergy, modelling scenarios of EU policies on bioethanol and biodiesel from the European Commission show that most projections attribute the largest shares of indirect land use changes as occurring outside the EU (Edwards et al 2010). Many current biodiesel and bioethanol crops show uncertain GHG emissions savings when compared to fossil fuels, in large part due to indirect land use change (Renssen 2011, Figure 2).

EU biofuel policies also stimulate changes in EU agricultural land use, cropland and livestock production. For example, within Europe, increased demand for grain used for bioenergy will increase demand for cereals, which will cause some decline in grassland area, converted to arable land to grow cereals (Blanco-Fonseca et al 2010). According to available modelling that considers bioenergy co-products used as animal feed, dry distillers grain (DDG) production as a co-product in the processing of coarse grains and wheat will be nearly 6 million tonnes higher due to biofuel policies. This will have an impact on the EU animal feed market; the total amount of feed consumed will increase marginally but feed use of coarse grains will decline by 4.1% (due to some replacement by co-products). Bioenergy co-products will replace some of the animal feed as coarse grains, but due to higher cereal prices, animal feed in general will be more expensive (due to increased demand).

Figure 2 Greenhouse-gas emissions from direct and indirect land-use change for different energy crops. Interesting with regard to livestock since there is certain degree of inter-linkage between bioenergy crops and livestock production through feed supply and land use changes. Figure taken from Renssen 2011. "The orange and grey dashed lines across the bars show the threshold for a 50% and 35% emission saving, respectively, compared with fossil fuels. Initially biofuels will have to deliver a 35% saving under EU law, but this will rise to 50% in 2017. Indeed, when policymakers talk about raising the threshold in the context of the ILUC debate, they are reportedly talking about raising it to 50% — this graphic shows that according to what we know about the scale of ILUC, this policy approach wouldn't solve the problem. ILUC data is from a draft report of the International Food Policy Research Institute; direct emissions data is from the EU's Renewable Energy Directive." Reprinted by permission from Macmillan Publishers Ltd: Nature Climate Change. Renssen S (2011). Policy watch: A biofuel conundrum. Nature Climate Change, 1: 389-390, copyright (2011).

Greenhouse-gas emissions from direct and indirect land-use change for different energy crops




P

Image Maize harvest in northern Germany. A harvester cuts the maize plants and processes the grain, which is then loaded onto trucks. The maize will be used for bio-fuel, bio-gas, and animal feed.

1.2
Global nitrogen and phosphorus cycles.

Eutrophication, "*the syndrome of excessive nutrients, noxious algae, foul water, and dead zones*" is already a familiar and widespread problem faced by millions of people dependent on water passing through agricultural and livestock-producing regions (Carpenter 2008). Moreover, **nitrogen and phosphorus pollution is a major threat to stability of Earth's systems, disturbing local and regional functioning of water cycles, soils and global climate patterns. Agriculture, and in particular livestock, is the most significant contributor to nitrogen and phosphorus pollution worldwide** (Sutton et al 2011b, Pelletier & Tyedmers 2010). The livestock contribution arises from the massive use of grain feed (like soya from tropical lands, and maize or wheat from temperate regions) and large over-application of chemical fertilisers to industrial agriculture and livestock systems, often creating problems of depletion of nutrients where animal feed is grown and problems of pollution from manure where livestock is produced, often in far way places (FAO 2009, MacDonald et al 2011).

Nitrogen

In Europe "*80% of the nitrogen in crops feeds livestock, not people*" (Mark Sutton[7])

According to Rockstrom (et al 2009a, 2009b), the **safe planetary boundary for nitrogen has been greatly exceeded, and humans should drastically reduce nitrogen discharges to a mere 25% of current values.** This highlights the massive planetary damage of current nitrogen pollution on Earth, and the necessity to dramatically reduce the flow of nitrogen.

The livestock sector is the single largest contributor to reactive[8] nitrogen mobilisation on the planet (Pelletier 2010). Synthetic nitrogen is used as fertilisers to grow crops for animal feed. Some of this nitrogen is lost to the environment, mostly as nitrates polluting water systems and as the greenhouse gas nitrous oxide, which has 296 times the global warming potential of CO_2.

> For example for Europe: "*Amazingly, livestock consume around 85% of the 14 million tonnes of nitrogen in crops harvested or imported into the EU; only 15% is used to feed humans directly. European nitrogen use is therefore not primarily an issue of food security, but one of luxury consumption.*"
>
> – Sutton et al 2011b

Some impacts of nitrogen pollution within Europe have been outlined (Sutton et al 2011a):

- At least 10 million people in Europe are potentially exposed to drinking water with nitrate concentrations above recommended levels.
- Nitrates cause toxic algal blooms and dead zones in the sea, especially in the North, Adriatic and Baltic seas and along the coast of Brittany.
- Nitrogen-based air pollution from agriculture, industry and traffic in urban areas contributes to air pollution by particulate matter, which is reducing life expectancy by several months across much of central Europe.
- In the forests, nitrogen pollution through atmospheric deposition[9] (nitrogen travelling by air) has caused at least 10% loss of plant diversity across two-thirds of Europe.

Phosphorus

Recent analysis shows that, along with nitrogen, the planetary boundary for phosphorus has also been exceeded (Carpenter and Bennett 2011). Phosphorus is added to farm soils as a synthetic fertiliser, but a great part of it is washed off with the soil into streams and lakes, causing major environmental damage to global freshwater systems. At the same time, overuse of phosphorus – which is finite and is mined – in farming has led to depletion of phosphate rock reserves, with shortage looming in the future (Cordell et al 2011, Cordell et al, 2009). See Tirado and Allsop (2012) for a detailed assessment on phosphorus sustainability issues within the agriculture system.

1.3
Climate change

Agriculture contributes to climate change with between 17% and 32% of greenhouse gas (GHG) emissions, the latter when including land use change (mostly deforestation), and a large proportion of these emissions come directly or indirectly from livestock production (Pelletier & Tyedmers 2010, Bellarby et al 2008, IPCC 2007). The Food and Agriculture Organisation of the UN (FAO) estimates that livestock alone accounts for about 18% of global GHG emissions, including land use change, but this number is under review.

In EU27, the contribution of livestock to GHG emissions accounts for between 12% and 17 % of the region's GHG emissions (Bellarby et al 2012).

A large proportion of emissions from livestock production comes from land use and land use change. In particular, the production of animal feed is largely associated with changes in land use, including deforestation in tropical regions. For example, it has been estimated that emissions from land use and land use change contribute to between 14% and 38% of the GHG emissions from the production of beef and dairy in EU27, mostly due to reliance on imported concentrated feed (Bellarby et al 2012). Estimates for land use and land use change are uncertain, which is reflected in the wide range of relative contribution given in the example above depending on whether these emissions are attributed to land use change (forest) or agriculture, which in turn depends on the context and system boundaries.

Image Soya that is grown in the Brazilian region is mainly used to feed animals in European countries.

Image Sheep grazing on the "Pieperpad" in the Netherlands. The Pieperpad ('the Spud Trail') is a marked 1000km bicycle route through organic farms in the Netherlands, from Friesland in the north to Zeeland in the south.

#2

Future trends on impacts from livestock production

Demand for livestock products is projected to increase faster than demand for other foods, due to trends in changing diets and lifestyles worldwide (IAASTD 2009). The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) projected livestock production to increase by 117% from 2000 to 2050, along with a doubling in grazing intensity in pasturelands and massive growth in cattle numbers (from 1.5 billion animals in 2000 to 2.6 billion in 2050) (IAASTD 2009).

The rapid growth in meat and milk production and consumption will put increasing pressure on grains for feed. "*Globally, cereal demand as feed will increase by 553 million tonnes during 2000-2050, a staggering 42% of total cereal demand increase*" (IAASTD 2009).

Most projections of future livestock scenarios assume there will be no more expansion of livestock on pastureland, including grasslands, due to land scarcity and competition with other uses (Lambin and Meyfroidt 2011). It is assumed that all further expansion will be through intensification of livestock production systems. However, this intensification will increase the already unacceptable burden of livestock on the planet's safe operating space.

It is often suggested that gains in livestock production efficiency, for example by technological advances, will compensate for growth in livestock numbers, and thus ameliorate its impacts. However, given projected livestock expansion by 2050 and current impacts on safe operating space of the planetary boundaries for biomass and biodiversity, nitrogen and greenhouse gases, the magnitude of efficiency gains would have to be disproportionate to be sufficient. For example, Pelletier calculated that efficiency gains would have to be between 136% and 433% to maintain livestock impacts within acceptable impacts level (Pelletier 2010). The magnitude of these efficiency gains makes them very unrealistic within the next 50 years.

Moreover, advances in nutrient cycling efficiency, both in crop and livestock production, will not be sufficient to ameliorate increasing rates of nutrient losses and pollution. In spite of some efforts to increase nutrient recovery from agriculture, projections to 2050 show dramatic increases in nutrient losses from agriculture (+23% surpluses for nitrogen and +54% surpluses for phosphorus). This is driven by increases in livestock production, with its inherent low efficiencies in nutrient use (Bouwman et al 2011). A growing livestock sector makes the whole agriculture system more inefficient in nutrient cycling. In addition, a significant share of nutrients in animal manures (globally about 20% for nitrogen and 15% for phosphorus) ends up outside the agriculture system, for example in storage lagoons or when used as energy. However, model projections show that a system with higher recycling of manures and better integration of livestock in farming systems can lead to reductions in chemical fertilisers use by 22% and reductions in losses from nitrogen and phosphorus by 9% and 13% respectively (Bouwman et al 2011).

In conclusion, the livestock sector will effectively double in number in the next decades, and its impacts will also multiply. Technological advances and gains in efficiency will not be sufficient to limit unacceptable damage to our planet's resources. A drastic reduction in livestock numbers plus a better integration of animals within mixed farming systems will be necessary.

Image Inside the chicken pen of Agricoltura Nuova, an organic farm on the outskirts of Rome.

#3

Our vision: Elements of ecological livestock

Ecological livestock, and more widely ecological farming, relies on the principle of **ecological optimisation.** Ecological optimisation works with potentials and constraints of the system in terms of what effects it has on resources and its waste assimilation capacity.

The way to operationalise this principle is to develop "*'regenerative' agricultural systems that continuously recreate the resources they use and achieve higher productivity and profitability of the system (not necessarily of individual products) with minimal external inputs (including energy)*" (Hoffman 2011).

This means acknowledging and optimising all the ecosystem services that a landscape provides – not only agricultural production, but also water filtration, nutrient cycling, carbon sequestration and other functions.

Agriculture intensification and land sharing vs. land sparing

Ecologically optimising agriculture systems will ultimately lead to achieving global food security while ensuring protection of ecosystem services. In some regions, this will mean increasing food production ("*recognising that agricultural yields are not always equivalent to food*" (Foley et al 2011)). Any increase in yields will have to go hand in hand with ecological farming practices working with nature, combining farming with maintaining the provisioning of ecosystem services to improve the resilience and sustainability of land (see Foley et al 2005).

Figure 3 below represents the different options for optimising ecosystems services and food production, in a gradient from higher in ecosystem services (*land sharing*) to higher in food production (*land sparing*). Ecological farming and livestock systems provide a balanced approach between the two extremes. Greenpeace is not against intensification of yields; increasing food production is good for farmers, good for food security and good for the planet, but only if it goes hand in hand with ecological practices. Ecological farming is about intensifying ecosystem services and food production from the *same* piece of land.

Conceptual Framework for comparing land use and trade-offs of ecosystem services

Natural ecosystem | Cropland with restored ecosystem services | Intensive cropland

1. food/biomass production
2. forest production
3. preserving habitats and biodiversity
4. water flow regulation
5. water quality regulation
6. carbon sequestration
7. regional climate and air quality regulation
8. infectious disease mediation

Natural ecosystem

Cropland with restored ecosystem services

Intensive cropland

© FRED DOTT / GREENPEACE

Source: Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice IC, Ramankutty N & Snyder PK (2005). Global consequences of land use. Science, 309: 570-574. Reprinted with permission from AAAS.

Figure 3 Conceptual framework for comparing land use and trade-offs of ecosystem services, with an hypothetical gradient from nature conservation to land sharing, or "nature-friendly farming", and land sparing. The provisioning of multiple ecosystem services from the same piece of land under different land-use regimes can be illustrated with these simple "plant" diagrams, in which the functioning of each ecosystem service is indicated by the size of the leaf; the bigger the leaf, the more effective the ecosystem service (this is a qualitative illustration, the size of the leaf is not normalised with common units.) For purposes of illustration, we proposed three hypothetical landscapes in a gradient from nature conservation (left) to an intensively managed cropland where crop production is maximised but other services are compromised (right), and a cropland with restored ecosystem services (middle). The natural ecosystems are able to most effectively support many ecosystem services (e.g. nature conservation), but not food production. The intensively managed cropland, however, is able to produce food in abundance (at least in the short run), at the cost of diminishing other ecosystem services (land sparing). However, a middle ground—a cropland that is explicitly managed to maintain other ecosystem services—may be able to support a broader portfolio of ecosystem services (land sharing) including food production.

Land sharing or "wildlife-friendly" farming aims at integrating food production and conservation on the same land. It involves measures to maintain or enhance populations of wild species within areas of food production by modifying or restraining agricultural practice. Extensive grazing of cattle or sheep on permanent grassland can be considered a specific type of land sharing between livestock production and biodiversity conservation within an agricultural landscape.

A contrasting theory of land use is *land sparing*, which believes that intensive agriculture will lead to more land available elsewhere for conservation and biodiversity, for example forest protection. This approach is debated, as farmers farm to make profit, not to feed themselves, and there is, in theory, no limit to demand for traded agriculture goods. If the profit per hectare will increase, this can result in an increased incentive for agricultural expansion at the cost of deforestation and biodiversity loss. If profit per hectare reduces, this can also be an incentive for deforestation, as more land is needed to make up the lost profit.

Greenpeace believes that the only way that land sparing for conservation could ever work is if there is adequate protection for forests that is legally enforced, i.e. so there can be no further deforestation. Without forest protection, agricultural intensification runs the risk of being a perverse incentive encouraging deforestation given the reality of unlimited demand (for feed, bioenergy, fibre).

The main elements of the Greenpeace vision for **ecological livestock** are:

- Land use: ecological livestock farming **minimises use of arable (crop) land, works within a comprehensive eco-regional conservation and land use plan that protects and restores natural ecosystems**, while optimising use of grasslands and pastures not required for crop production (in the land use plan) either for food production, nature conservation, or both.
- Soil fertility: Ecological livestock is key to **agro-ecological soil fertility that works towards closed nutrient cycles by re-coupling land-based livestock production with soil fertility**. [No synthetic fertilisers and efficient use of all fertilisers, minimising losses].
- Biodiversity: ecological livestock **protects biodiversity** of wild species and maintains a diversity of farm animal breeds and plant varieties. It supports a comprehensive network of protected ecosystems that maintains and restores natural biodiversity in the landscape. Integrating biodiversity and biodiversity protection in agriculture practices enhances the resilience of the agriculture system (see Tirado & Cotter 2010).
- Climate change. Ecological livestock **reduces the impact of livestock on greenhouse gas emissions**, mostly by reducing the number of animals kept worldwide and protecting grasslands that can be rich carbon sinks.
- Ecological livestock is **part of a non-polluting ecological farming system**, where pest management is achieved **without chemical pesticides** and there is **no use of genetically modified organisms (GMOs)**; no GMOs in feed for livestock, and no GMO animals.
- Meat consumption: Ecological livestock within the framework of a "default" livestock system will mean a **drastic cut in the consumption of animal protein in high income countries and a moderate increase of consumption in low and middle income countries**, following the shrink-and-share principle.

3.1
"Default" use of land

Ecological livestock are *default* land users[10], i.e. they don't monopolise land that is required for other intrinsic elements of the agriculture system and they do not compete with humans for prime arable land. Their role is to exploit the use of biomass not accessible to humans and to make efficient use of agriculture wastes, surpluses and marginal biomass. A "*default*" livestock diet is one "*that provides meat, dairy and other animal products which arise as the integral co-product of an agricultural system dedicated to the provision of sustainable vegetable nourishment*" (Fairlie 2010).

The idea in a "*default*" land user strategy is similar to that of "*ecological leftovers*"[11]: an ecological farming system in which animals are a secondary output that help obtain maximum benefit of plant biomass not suitable for human food (grass, food processing residues, and so on). Maintaining livestock under the "default" strategy, as by-products or co-products of the farming system, also means minimising its environmental impact. When the system is not "overridden" with the need to produce too much animal protein, environmental impacts are also kept to a minimum. This is illustrated by the "hockey stick" graph proposed by Simon Fairlie and supplied by Elferink et al (2008) (Figure 4 below): when animal product consumption is kept low (under level B in the Figure), then environmental impacts are also kept low. Otherwise, as more feed is needed to supply a growing demand for animal products, so the environmental impacts become much greater.

Environmental impact of animal product consumption

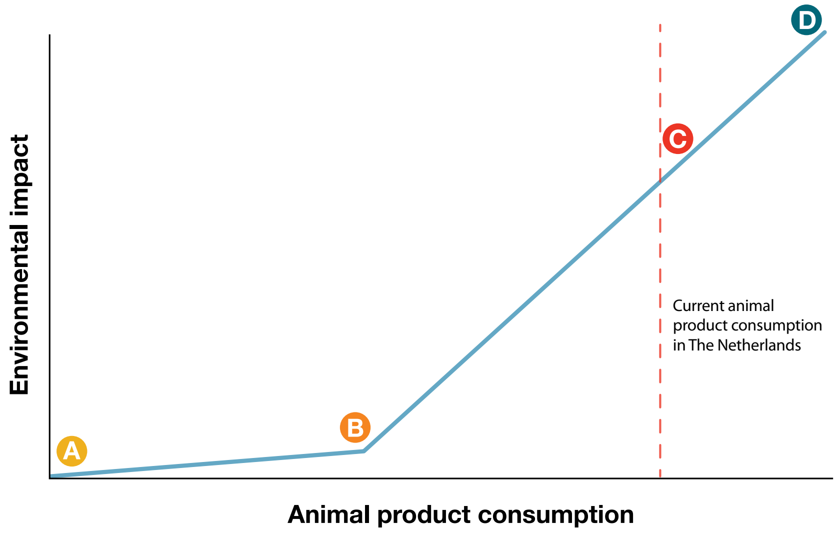


Figure 4
The environmental impact of animal product consumption. In section A-B food residue is fed to livestock. In section B-D feeding crops are required as feed. The dotted line represents the current animal product consumption in the Netherlands.

Adapted from Elferink EV, Nonhebel S & Moll HC (2008). Feeding livestock food residue and the consequences for the environmental impact of meat. Journal of Cleaner Production, 16: 1227-1233.

When animal production is kept low (under level B in the graph), it can provide other ecosystem services and socioeconomic benefits without the burden of excessive environmental impacts. **In order to keep impacts within acceptable levels, production of animal products should not be driven by demand but by ecological optimisation of the available resources and available waste assimilation capacity of the planet.**

Ruminants and other animals that can obtain energy from plant fibre provide a means of converting otherwise inedible biomass like grass and crop processing co-products into a human-edible food source. In this respect, cattle raised on pastureland can provide a way of capturing food energy otherwise unavailable to humans. It has been calculated that the amount of human food energy produced relative to the amount of human food energy consumed by cattle can vary from as little as 5% for beef when cattle is grown in feedlots to 70% when cattle is raised on pasture[12] (Pelletier et al 2010). This difference underscores the benefits of producing animal products on land not suitable for agricultural crops, for example on rough grazing lands that cannot be exploited for other uses or where this does not interfere with other conservation of biodiversity objectives. We acknowledge an ecological livestock system based on "default" uses of land will mean a (large) unknown level of reduction in livestock production and consumption, dependent on how much adequate pastureland can be utilised sustainably at global and regional scales.

In trying to optimise the use of resources, we believe the amount of livestock production should be proportionate to the amount of available feed from by-products, pasture and grasslands not required for other agricultural purposes, and it should not displace conservation of natural ecosystems. For example within Europe there are areas of farmland with high nature value (HNV) that are being preserved by legislation. Some of these HNV farmlands are pasturelands that support some livestock production and some indeed need livestock for their ecological integrity. They are an example of ecological uses of land by "default", where food from animals can be produced without competing with direct human food production and while protecting biodiversity (Paracchini et al 2008). It is estimated that only 4% of dairy production and around 20% of beef production comes from high nature value grasslands in Europe (Westhoek et al 2011).

Our vision of land use under an ecological livestock system includes the following principles that ensure livestock minimises competition with direct human food production or with conservation of natural ecosystems:

- Livestock should not drive conversion of natural ecosystems, directly for cattle rearing or indirectly for feed production or by displacement of other crops (for example, much deforestation in the Amazon driven by soya expansion into nearby agricultural areas (Arima et al 2011).
- Livestock should be reared on grassland not required for other agriculture purposes (pasture lands, permanent grasslands or rotated grasslands that are part of an ecological farming system), thus minimising competition between livestock and humans for prime arable land. However, biodiversity conservation needs to be taken into consideration as well.
- Feeding grains and other human foods to livestock must be kept to a minimum, in an attempt to maximise direct human food production from arable land. For cows, this means feeding cows mostly with grass, hay and roughage. For pigs and poultry, this means making maximum use of agriculture residues and other wastes suitable for animal feed (by-products and co-products, concentrates from food industry wastes, for example). This is feasible and it is still the "default" process in many developing countries. For example, it has been estimated the food residues generated by every Dutch person a year, if fed to pigs, will produce 81g of pork for each person each day (which is a significant portion of the recommended daily protein intake) (Elferink et al 2008).
- Land used for livestock must be kept with high plant biodiversity, avoiding monocultures. Ecological farming does not determine specific limits to the size of a farm, but ecological principles put natural limits to the size of the farm as any number of animals will need a minimum area for sustainable nutrient cycling, feed provision, efficient use of pastures, avoiding overgrazing and animal welfare considerations. The principle of ecological optimisation can help in deciding what is the sustainable number of animals to be kept on a land area, taking into account that maximising potential productivity (intensification) must also consider limits in waste assimilation capacity of the land and its surroundings (nutrient loading).
- Livestock grazing must be kept in balance with the productive capacity of the land, avoiding overgrazing that degrades natural vegetation and erodes soils, leading sometimes to extreme land degradation and desertification in water-limited environments. Recent analysis shows that 38% of land on earth is in danger of desertification (Nuñez et al 2010). However, if managed under the principles of ecological balance and optimisation of land use, livestock can help restore organic carbon in the soil, improve water retention and increase biodiversity and productivity. For example, in Africa a long-term initiative shows how managing cattle to increase carbon storage in the soil and increase soil fertility, while also minimising fires, can turn degraded marginal lands into very productive grazing lands[13].

3.2
Agro-ecological soil fertility

In ecological farming, nutrient recycling and nitrogen fixation can provide soil fertility without synthetic fertilisers. The use of organic fertilisers, generally cheap and locally available, makes ecological farming more secure and less vulnerable to the accessibility of external inputs and price fluctuations.

Ecological farming makes the best possible use of inputs, aiming to build up natural soil fertility and improve efficiency. Organic fertilisers can also be overused; ecological farming aims at optimising any type of input.

In ecological livestock systems, livestock provide the service of moving nutrients around and concentrating them to bring them back to the soil (auto-mobile manure spreaders taking nutrients from inaccessible areas and depositing as manure where needed).

Ecological livestock systems efficiently recycle manure and wastes, reintegrating livestock and arable farming. Ecological livestock sees manure not as a waste but as a valuable input that needs to be returned to soils. A significant amount of manure ends up outside the agriculture system (about 20% of nitrogen and 15% of phosphorus present in manure) and inefficient use of it within the agriculture systems means that, for example, only about half of the phosphorus in manure used on agricultural lands is recovered in the crop (Cordell et al 2011, Bouwman et al 2011).

The four guiding principles of agro-ecological soil fertility on livestock farms are:

1 No use of synthetic fertilisers. There are many proven agro-ecological practices to provide soil nutrition without the need for chemical fertilisers (Badgley et al 2007, Yaduvanshi 2003, Mäder et al 2002). However, under certain exceptional circumstances, mineral phosphorus or potassium may be needed to restore soil fertility of degraded lands in the short term.

Image Workers building a new biogas unit in Kammavaripalli, Bagepalli taluk, India.

2 Increase efficiency in fertiliser use to minimise losses of nitrogen and phosphorus (from any chemical or organic source). An ecological farming and livestock system should aim at the best possible and more efficient use of resources, for example in the case of crop residue use after harvest. Priority should be given to the use of resources that first enhance food availability and maintain soil fertility over energy security. Crop residues form an important ingredient for improving soil nutrients and soil organic matter.

Crop residues (used as feed, fuel or for soil improvement) can also be used in sequence (cascading), thus minimising competition between the various potential functions. For example, in India crop residues in the form of rice straw after harvest are used to feed cows in a mixed farming system. The manure produced by cows is then used in small-scale biogas plants to supply energy to the farm household. The nutrient-rich residue from the biogas plant is later put back to the soil to enhance soil fertility. Some crop residues should also be returned to the soil to enhance soil organic matter. This type of cascading of nutrients and energy can build efficient and resilient food systems.

3 Ensure a balanced return of nutrients to productive croplands and pastures, by recycling manure and other wastes. Avoid imbalances between imports/exports of nutrients from remote regions, by limiting or avoiding the use of concentrate feed and synthetic fertilisers.

4 Maintain or increase soil organic matter in agriculture soils, as a crucial step in maintaining or improving soil fertility and enhancing water use and resistance to drought stress.

Nitrogen

Growing legumes, adding compost, animal dung, and green manures are some ways to increase organic matter and fertility of the soil. Natural nutrient cycling and nitrogen fixation by legumes can provide fertility without synthetic fertilisers, and at the same time save farmers the cost of artificial inputs and provide a healthier soil, rich in organic matter, better able to hold water and less prone to erosion. Sequestration of carbon in farming soils can also significantly contribute to climate change mitigation.

With regard to nitrogen, a recent meta-analysis of data from 77 published studies suggest that nitrogen-fixing legumes used as green manures can provide enough biologically fixed nitrogen to replace the entire amount of synthetic nitrogen fertiliser currently in use globally, without reducing food production (Badgley et al 2007).

For example, in dairy pastures in the UK the use of the legume white clover in mixed grasslands results in similar productivity, less pollution, at less expense to farmers than the application of chemical nitrogen fertilisers (Andrews et al 2007).

Phosphorus

Ensuring phosphorus remains available for food production by future generations and preventing pollution of water systems with phosphorus requires actions in two main areas: reducing phosphorus losses, especially from agriculture lands, and increasing phosphorus recovery and reuse on agriculture lands. To close the broken phosphorus cycle, major actions are needed both in arable land and livestock systems. Actions required include:

- Minimising the amount of manure that is wasted and not used as fertiliser, maximising the return of manure to the land from where the feed originates.
- Stopping overuse of phosphorus fertiliser on arable land: minimise mineral phosphorus use and optimise land use (optimising the trade off between yield and ecological services)[14].
- Avoiding phosphorus losses from cropland soils: avoid erosion by improving soil management (cover crops, buffer strips) and improve soil quality. This is important in relation to livestock in avoiding overgrazing that exposes soil and might increase erosion.
- Adjusting livestock diets to minimise phosphorus losses, for example avoiding mineral phosphorus supplementation to animal diets.

3.3
High biodiversity

Historically, farmland is land converted from natural ecosystems. Some of it, especially in temperate regions, may be from historical (pre-1600) deforestation. Nevertheless, biodiversity within agriculture systems varies widely and livestock production systems, if managed carefully, can have considerable biodiversity value, even aiding the conservation of native species, especially farmland species.

Ecological livestock protects biodiversity of native species and maintains biodiversity of farm animal breeds and plant varieties. In spite of the damage to biodiversity that most current livestock systems cause, there are also many examples of livestock production that are ecological and protect biodiversity within agriculture systems. For instance it is recognised by scientists that

> low-input extensive livestock systems have historically created and maintained the ecological diversity of unimproved grasslands in Europe, and the restoration of such systems appears to be central to any attempts to restore grassland biodiversity.
>
> – Vickery et al 2001

In Britain, extensive mixed sheep and cattle grazing farms show much higher diversity of birds than livestock of a single species at higher stocking rate (Evans et al 2006).

Furthermore, livestock is considered as an essential element for conservation of certain natural areas, for example grasslands, steppes and semi-open landscapes. For example, in certain areas of Central Europe, cattle can simulate the management tools needed to maintain natural semi-open landscapes that were historically maintained by large herbivores now extinct in the region (Plachter and Hampicke 2010).

3.4
Ecological livestock for reducing emissions of greenhouse gases

An ecological livestock system would reduce the contribution of animal products to greenhouse gas emissions mostly by reducing global production and consumption of animal products and by minimising food waste (for more detailed analysis in EU27 see Bellarby et al 2012).

In addition, significant GHG emission savings can be made by minimising reliance on feed grains (thus minimising land use change due to expansion of croplands to grow animal feed) and optimising use of pasturelands, including managing soils for improved carbon storage (Bellarby et al 2012).

For example, current scientific evidence assessing the full life cycle of beef and dairy products, including land use and land use change related to feed production, concludes that less-intensive animal production in Europe, relying mostly on grasslands and with low chemical fertiliser inputs, emits less greenhouse gases per kilo of product than intensive production systems, especially for dairy (Bellarby et al 2012). This is mostly due to the high GHG emissions associated with imported feed production in croplands (i.e. land use and land use change) compared to animals relying on pasturelands, where there is also some soil carbon sequestration taking place (Bellarby et al 2012). Grasslands can sequester carbon, especially in well-managed extensive grazing lands, if application of synthetic nitrogen fertiliser is avoided[15]. But there is still uncertainty as to how much and for how long the stored carbon can be sequestered in the soils.

3.5
No synthetic pesticides or genetically modified organisms

No use of pesticides or genetically modified (genetically engineered) seeds should be used in crops used to feed livestock.

3.6
Reducing the consumption of meat and dairy, particularly in high-income societies

The impact of current livestock production is already unacceptable in terms of land use change and attendant loss of biodiversity, disruption of nitrogen and phosphorus cycles and climate change. Nevertheless, livestock production is forecast to double in the next decades, if we do not reverse the driving forces behind this trajectory soon. Technological advances, gains in efficiency and reduction in food waste (both post-harvest and at the consumer level) are all necessary, but they will not be sufficient to limit unacceptable damage to our planet's resources – there is no easy fix.

In the EU the dairy sector is the largest user of agricultural land. Meat and dairy consumption is very unequally distributed across global regions (Table 1). The high consumption of dairy in developed countries, considered harmful for human health, is as high as 75% over World Health Organisation (WHO) recommendations (Lloyd-Williams et al 2008, Westhoek et al 2011), while dairy intake among the poorer regions of the world is low.

If we are to effectively limit the damage of the growing industrial livestock sector, the only real option is to reduce the amount of animal products we produce and consume.

Reducing meat consumption has been the resounding recommendation from many scientists and global institutions in recent years, from UN institutions, to economist Pachauri (head of the Intergovernmental Panel on Climate Change (IPCC)) and Lord Stern[16] or the UK's Sustainable Development Commission and the WHO[17]. Besides helping protect our planet, eating less meat and dairy promotes a fairer world and improves human health.

Table 1 Current and future meat and dairy consumption.

	Population (bn)	Meat (kg/person/year)		Milk (kg/person/year)	
	2050	**2007**	**2050**	**2007**	**2050**
World	8.9	40	51	79	99
Developed	1.0	78	103	202	227
Transition	0.3		68		193
Developing	7.5	28	44	42	78
N. America		121		251	
W. Europe		87		266	
Brazil		81		125	
China		53		29	
India		3		71	

Projection of meat and dairy consumption show significant increases in all regions, with steeper growth in developing countries. However, in spite of this rise, inequality in consumption of animal products will prevail under current trends.

On a planet with 9 billion people in 2050, 7.5 billion of those living in the poorer regions, significant cuts in consumption will have to be implemented in order to reduce environmental impacts and increase equality. Many options have been presented in terms of specific levels of meat consumption that will help reduce impacts by 2050: from a business-as-usual (BAU) scenario that will double livestock production globally, to a "default land user strategy" for the livestock sector that will see impacts minimised but will require drastic cuts in animal production worldwide (Table 2). Table 2 summarises some options for per capita meat and milk consumption by 2050, and their estimated positive (or negative) impacts on the planet's resources.

What is clear is that drastic cuts in consumption will be required in the richer regions of the world, even under a BAU scenario, in order to reach equality in global food distribution (global meat consumption ~50 kg meat/cap/yr, about half of what we consume today in rich societies). However, if we are serious about protecting the planet, cuts will have to be much more drastic. For example, in order to maintain livestock production (and its impacts) to levels of 2000, average world meat consumption will have to be 25kg meat/cap/yr, or one quarter of what we eat today in rich societies. However, even these cuts will not reduce the unacceptable levels of environmental damage we see today. And even in developing regions, estimated growth trends will have to be slowed down in order to keep livestock impacts under control. **A shrink-and-share approach is needed, understanding that achieving a balanced amount of animal protein among the poorer peoples in the world will inevitably require drastic cuts in the richer sections of societies, even in developing countries.**

The more positive message from this analysis is that even if we were to reduce livestock impacts to a minimum, aiming for a purely ecological livestock system based mostly on available grasslands and residues which does not compete with human food, we will always be able to enrich our diets with some animal products (12kg meat/cap/yr, about 250g of meat and half a litre of milk per week). This will obviously mean large cuts in wealthy societies, and a drastic lifestyle change in our consumption habits. Livestock production when kept within ecological levels has many benefits both for human and the planet's health. **Our recommendation is not about avoiding meat and dairy products altogether, but about eating much lower levels that are good for human and our planet's health. This recommendation is especially relevant for people in high-income societies, where our nutritional needs can easily be satisfied mostly with plant food, as they currently are in much of the developing world.**

These estimates are rough projections, without regard to potential changes in technology and practices that will improve our chances of maintaining higher levels of meat and dairy consumption while still protecting our planet. However, even very optimistic levels of efficiency gains (+35%) will mean cuts in consumption to about one third of what we eat today in rich societies (35 kg/cap/yr in Table 2, Pelletier 2010).

Reduction in waste is another option that is not included in our estimates in Table 2: if we reduce the amount of meat and dairy we waste, that will enable us to compensate some higher level of meat consumption (but nevertheless cuts will still be required). It has been recently estimated that consumers in rich societies waste an average 20% of the food bought within households (WRAP 2010). In Europe and the US, about half of the animal product losses and waste occur at the consumer level (Gustavson et al 2011). In developing countries, levels of post-consumer animal product waste are much lower, but there are relatively higher losses at animal production level (Gustavson et al 2011).

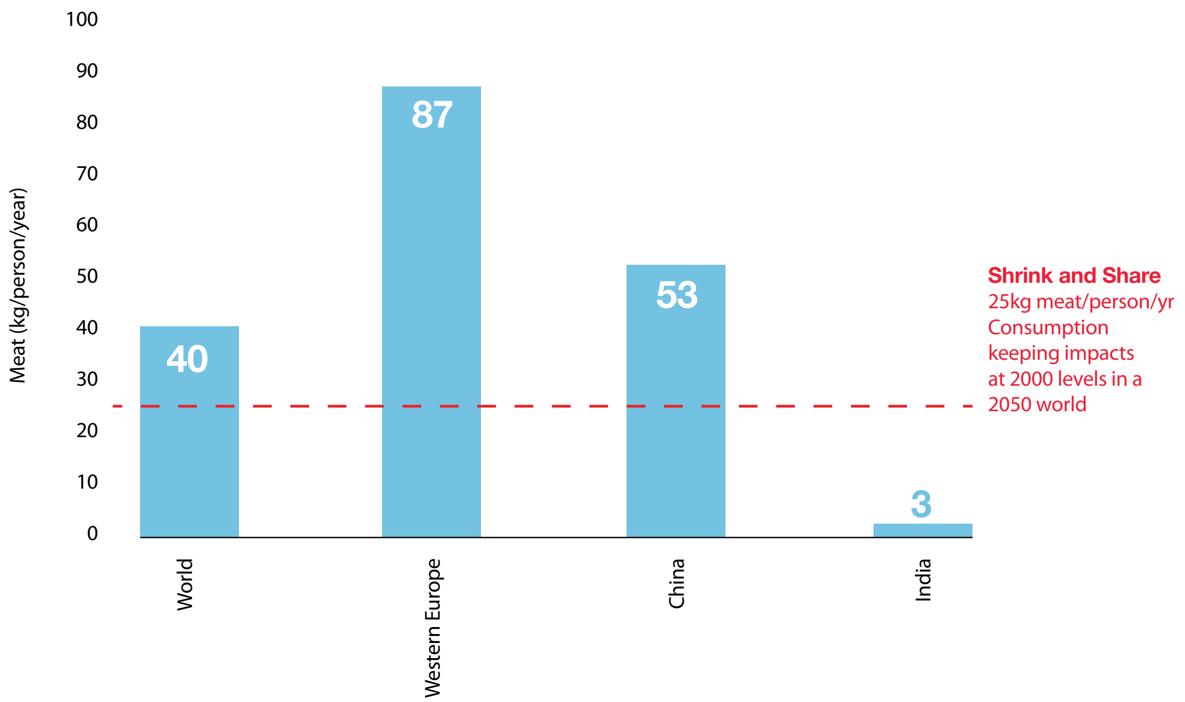
Each person's willingness to limit our damage to the planet by reducing meat and dairy consumption will decide our consumption levels in 2050, but from the estimations science gives us so far, we know those cuts to consumption will have to be drastic (particularly knowing that current damage to the planet is clearly unacceptable with 2 billion less people around than the anticipated 9 billion for 2050). Figure 5 summarises the extent of the required cuts in meat and dairy consumption relative to consumption levels in year 2007, assuming a shrink and share approach to diet shifts towards 2050.

Table 2 Options for reducing meat and dairy consumption towards 2050 and estimated benefits for the environment. Some are rough estimates shown here to illustrate the levels of consumption that the planet can sustain compared to current levels. (BAU: Business As Usual scenario).

Options for consumption of meat and dairy	Meat 2050 (kg/ person/ yr)	Milk 2050 (kg/ person/ yr)	Effect on the planet*	Impacts
Western Europe today (FAOSTAT)	90	270	☹☹☹	More than tripling current livestock production. Massive environmental damage, compromising stability of life earth's systems (Rockstrom et al 2009; Pelletier 2010).
BAU 2050 production, shared equitably (Garnett 2009)	51	99	☹☹	Doubling current livestock production. Dangerous effects on nitrogen pollution (~2 times more than the estimated safe sustainability limits for the planet), biomass appropriation (~90% of the total planet acceptable limits), and GHG (~70% of the total planet acceptable limits) (Pelletier & Tyedmers 2010).
All consume as projected in developing countries for 2050 (Garnett 2009)	44	78	☹	Large increases of livestock production, only 15 % reduction compared to BAU 2050 (Garnett 2009).
Healthy diet (Stehfest 2009) (Harvard Medical School and Dutch guidelines)	37		☺	Large increase of livestock production, although a 27% reduction compared to BAU 2050. 20% reduction in GHG gases and 33% reduction in land-related GHG emissions. Direct mitigation costs are reduced by 54% compared to reference (cumulative reductions 2010-2050) (Stehfest et al 2009).
Increase efficiency in meat production by 35% and cut consumption by 35% to meet safe planetary levels (Pelletier & Tyedmers 2010)	35		☺	Decrease in livestock production assuming 35% increase in efficiency and 35% cuts in consumption to meet safe planetary limits: 19% reduction in GHG, 42% reduction in biomass appropriation, 21% cut in nitrogen reactive relative to BAU 2050 (Pelletier & Tyedmers 2010).
World Cancer Research Fund's recommendation for health (for meat excluding poultry and eggs)	30		☺	Decrease in livestock production relative to BAU 2050. Environmental impacts within safe planetary limits.
All livestock produced in 2000 shared equitably in 2050 (no growth). (Garnett 2009)	25	63	☺☺	Livestock production kept at 2000 levels, results in about 50% reductions in GHG compared to BAU 2050 (Garnett 2009, Greenpeace Climate Vision 2009). See Figure 5 for comparison with current consumption levels.
Global default livestock system (zero land competition with human food production, minimum impacts) (Fairlie 2010)	12	26	☺☺☺	Livestock production results from efficient use of grasslands and wastes and cropland not required for human food. Requires about 60-70% reduction in meat and dairy consumption (Fairlie 2010, Bellarby & Smith 2012 in press).

* Effect on the planet: negative symbols ☹ indicates increase in livestock production, and thus its impacts, relative to 2000 levels; positive symbols ☺ indicate reduction in livestock production relative to 2050 projections. The number of symbols try to summarise extent of livestock production and consumption changes and related impacts, with ☺☺☺ maximum positive change under an ecological system and ☹☹☹ maximum negative impacts under BAU for 2050. (These values are illustrative only and have not been normalized or quantified).

Meat consumption averages in 2007



Dairy consumption averages in 2007

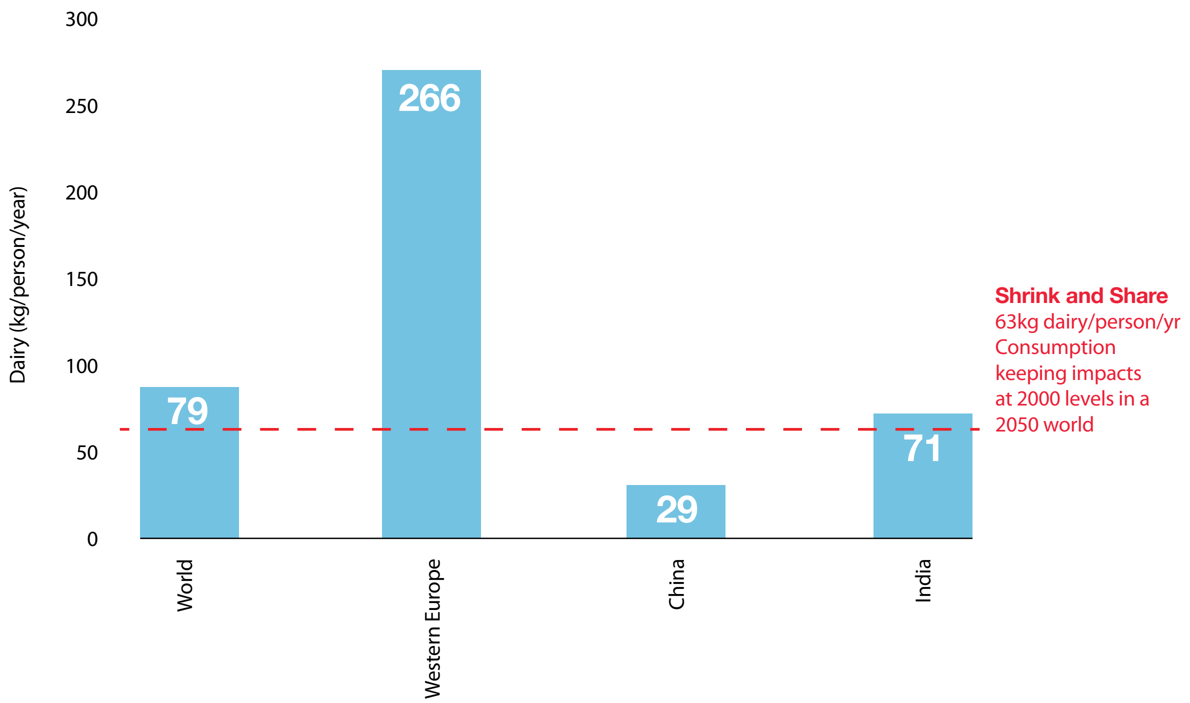


Figure 5 Meat and dairy consumption averages for the world, Western Europe, China and India in year 2007 and (*red line*) proposed levels to keep livestock production and its impacts at year 2000 levels towards 2050. Please note that low per capita consumption levels in India and China mask the much higher apportion of global livestock demand because of their larger populations: almost 30% of all meat demand and 25% of all dairy demand comes from both countries combined. Data source is FAOSTAT 2011 and Garnett 2009.

Reducing meat and dairy consumption and impacts on health

Changes towards a low meat and dairy diet in societies with high consumption of animal products will not only have very positive effects on the planet's biodiversity, nutrient cycles and climate, but it will also have very positive consequences for human health (Table 3). In Europe, protein consumption is about 70% higher than recommended by the WHO (Westhoek et al 2011), and much higher than recommended levels for reducing cancer, type 2 diabetes and heart disease risks, plus maintaining a healthy body weight (Table 3). The World Cancer Research Fund, Dutch and Swedish government dietary guidelines[18] plus multiple health professionals and academics from different regions, all recommend a low meat diet for better human health and increased life expectancy (Table 3).

For example, a recent international analysis shows that a 30% reduction in intake of animal products in high-consuming populations (for example, the UK and the Brazilian city of Sao Paulo), besides reducing growth in GHG emissions, will substantially decrease by about 17% deaths and disability caused by ischaemic heart disease in those populations (Friel et al 2009).

Moreover, a low-meat diet in Europe and other rich societies would lower demand for feed and land, which eventually could result in increased food availability, perhaps also in less developed countries (Westhoek et al 2011). This is particularly important in light of new factors adding to the competition for farming land, as the growing demand for bioenergy from crops has been demonstrated in recent food price crisis (Nellemann et al 2009). There is potential to increase global food security from a move towards low-meat diets.

Growing calories in plants is much more efficient in terms of energy, land, water, labour, nutrients and climate-change gases (Table 4), than growing calories in meat or animal products (Galloway et al 2007, McAlpine et al 2009). The average fossil fuel energy needed to produce calories in meat is about 10 times higher than the energy needed to produce calories in plants (Pimentel & Pimentel 2003, Bellarby et al 2008). A plant-based diet is better for our health, for our climate, for our forests, for our rivers and oceans, and for global food security, and it also helps keep food prices low (Nellemann et al 2009).

Table 3 Summary of main health benefits of a low-meat diet

Health benefits of eating less meat in rich societies	
Reduce colorectal and other types of cancer	(Chan et al 2011, WCRF 2010)
Reduce death and disability from heart disease	(Friel et al 2009)
Reduce type 2 diabetes risk	(Pan et al 2011)
Help weight loss and maintaining a healthy weight	(Vergnaud et al 2010)

Table 4 Global warming potential of the main meat categories, as well as milk and selected plant products for comparison

Product	**Global warming potential (kg CO_2 -e per kg of product)**
Sheep	17.4
Beef	13.0
Pork	6.3
Poultry	4.6
Milk	1.3
Wheat bread	0.8
Potato	0.2

(kg CO_2 equivalents on a 100 year time scale per kg product). Source: Bellarby et al 2008, calculations based on UK data (Foster et al 2006)

Summary table

Table 5 This table summarises how ecological livestock can help fight the main environmental problems associated with our current destructive system of livestock production.

Parameter	Problems of industrial livestock systems	Solutions from an ecological livestock system
1 Land use	**1** Livestock is one of the main drivers of land use change and deforestation, and associated biodiversity loss, globally. **2** Land used to grow feed for livestock competes with land used to grow food for humans threatening food security.	**1** Cattle on grass: main feed for cows, sheep and goats is forage. Grass is unfit as human food and should be grown on land not required for arable cropping. **2** Higher use of agriculture waste: growing animals more efficiently with human food waste, especially applicable for pork and poultry (with safety precautions). **3** Reductions in animal numbers will free up pressure on productive land for cropping and conservation.
2 Nutrient cycles	**1** Agriculture, and in particular livestock, is the most significant contributor to N and P pollution worldwide. **2** Nitrogen and phosphorus pollution is destroying water bodies worldwide. **3** Nitrogen and phosphorus out of balance due to delinking livestock and arable farming, and the overuse and inefficient use of nitrogen and phosphorus on arable lands to produce feed. Industrial livestock farming is causing inefficiencies and losses of nitrogen and phosphorus.	**1** Keep nitrogen and phosphorus use and losses from livestock farms to minimum, via agro-ecology: - no use of chemical fertilisers - efficient use of all fertilisers - returning of nutrients (e.g. in manure and composted residues, including human waste) to productive land - best practices in manure and slurry management within livestock farms.
3 Biodiversity	**1** Land use change and nutrient pollution major causes of biodiversity loss due to livestock farming.	**1** Grasslands with cattle as high nature value (HNV) habitats in Europe. **2** Biodiversity-rich farming: multi-functionality of ecosystem services, no chemicals, high diversity of breeds and plant varieties and high efficiency in natural resource use.
4 Climate	**1** Livestock is, directly or indirectly, a major emitter of greenhouse gases worldwide.	**1** Grasslands can sequester carbon, especially in well-managed extensive grazing lands. But there is still uncertainty as to how much and for how long the stored carbon can be sequestered in the soils. **2** Ecological practices can reduce livestock GHG emissions mostly by reducing the number of animals kept. This can be done by reducing waste of meat and dairy products and by reducing consumption of animal products in high-income societies.

Are ecological livestock products better for your health?

Meat and dairy are good sources of proteins and nutrients, but nowadays in Europe and other rich societies we are eating too much meat, milk and dairy products, which can also create health problems. We can get higher health benefits by reducing the amount of meat and dairy we consume in rich societies and increasing the amount of fresh vegetables and fruits in our diet.

In terms of health claims for meat and dairy from grass-fed vs. from grain-fed cows, if "we are what we eat", that seems to work for cows too. Meat and dairy from ecological grass-fed cows are better when produced from cows that don't come into contact with the chemicals, pesticides and other pharma-drugs that are usually applied in conventional agriculture. The best well-known health benefit of ecological, organic or grass-fed meat and dairy is the absence of bad things: no residues from agrochemicals or other drugs. This is also much better for the environment, which indirectly is also better for our health and the health of farmers and rural communities.

More research on the specific nutritional benefits of grass-fed milk is needed, but some scientific evidence suggests milk from pasture-raised cows has a healthier balance of some fats (higher levels of some omega 3 over omega 6 essential fatty acids) and higher levels of conjugated linoleic acid (CLA) (Elgersma et al 2006, Clancy 2006). However, the science is still not 100% certain on this one (sometimes it happens, sometimes, like in winter when cows are eating less fresh grass, the effect might be small). In any case, milk from grass-fed cows is better if it comes from a chemical-free cow. The best advice, however, is still to eat less quantity but better quality organic or grass-fed dairy products.

Image Holstein - Friesian cattle, at Brue Valley Farm in Baltonsborough, Somerset.

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Endnotes

1 Safe operating space for humanity refers to the limits below the planetary boundaries where there is less risk of "irreversible and abrupt environmental change" that could make Earth less habitable.

2 Net Primary Productivity (NPP) determines the amount of energy available for transfer from plants to other levels in the food webs in ecosystems. Human appropriation of NPP not only reduces the amount of energy available to other species, it also influences biodiversity, water flows, carbon flows between vegetation and atmosphere, energy flows within food webs, and the provision of ecosystem services (Haberl et al 2007).

3 http://www.commodityonline.com/news/Indian-poultry-industry-growth-to-drive-corn-prices-higher-43040-3-1.html

4 http://www.allaboutfeed.net/news/indian-poultry-sector-wants-maize-futures-banned-108.html

5 For example, the Chairman of Australian Ethanol Ltd stated that: "The future of ethanol in Australia is in grain alcohol adopting the US model where the fuel ethanol revenue pays the bills and the profit comes from the distillers' grain by-product. With a strong cattle industry and continuous demand for Australian red meat; fuel ethanol from grain is the future".

6 International Scientists and Economists Statement on Biofuels and Land Use. A letter to the European Commission. http://www.ucsusa.org/assets/documents/global_warming/International-Scientists-and-Economists-Statement-on-Biofuels-and-Land-Use.pdf

7 http://www.bbc.co.uk/news/science-environment-13025304

8 Reactive nitrogen is the type of nitrogen that is active in the environment, biologically or chemically. It includes ammonia, urea, the greenhouse gas nitrous oxide, and other forms. Non-reactive nitrogen is in contrast inert: like the N_2 gas, which forms the ~80% of volume of the Earth's atmosphere.

9 Nitrogen deposition usually changes plant community composition and can also affect individual species, making them more susceptible to pests and diseases, or via soil acidification, for example.

10 Default land users in the sense defined by Fairlie S (2010). Meat. A benign extravagance. Permanent Publications, Hampshire, UK. "A default is the natural outcome of a system when it is not overridden for any specific purpose" (Fairlie, 2010).

11 From Garnett 2010 as in Fairlie 2010.

12 Note that this is still lower than 100% for pasture-grown cattle since the cow/calf phase consumed a small amount of grain feed.

13 http://challenge.bfi.org/winner_2010
http://www.guardian.co.uk/environment/2011/jul/22/cows-climate-change

14 Also, phosphorus-solubilising bacteria and mycorrhizas are worthy of study in relation to the development of inoculants for use as a mechanism to increase phosphorus availability in pastures from reserves in the soil and/or applied rock phosphate.

15 "Increased carbon sequestration by a management practice may increase other GHG emissions and, as such, decrease or even negate the sequestered CO_2 in the soil. The application of synthetic fertilizer, for example, was considered to result in net GHG emissions when considering emissions from fertilizer production and nitrous oxide emissions after application (Powlson et al 2011)". From Bellarby et al 2012.

16 http://www.guardian.co.uk/environment/2008/sep/07/food.foodanddrink

17 Lloyd-Williams F, O'Flaherty M et al (2008). Estimating the cardiovascular mortality burden attributable to the European Common Agricultural Policy on dietary saturated fats. Bulletin of the World Health Organization 86: 535-541A.

18 http://www.wcrf.org/cancer_research/expert_report/recommendations.php
http://www.gezondheidsraad.nl/en/publications/richtlijnen-goede-voeding-ecologisch-belicht
http://www.slv.se/upload/dokument/miljo/environmentally_effective_food_choices_proposal_eu_2009.pdf

Greenpeace International
Ottho Heldringstraat 5
1066 AZ Amsterdam
The Netherlands

greenpeace.org